MANAGEMENT OF KIKUYU (*PENNISETUM CLANDESTINUM*) FOR IMPROVED DAIRY PRODUCTION

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DECLARATION

This thesis is the result of the author's original work except where acknowledged or specifically stated to the contrary in the text. It has not been submitted for any degree or examination at any other university or academic institution.

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"Grassland could be managed. And with the right management it would award the farmer with as beautiful a harvest as the finest wheat land. This was a crop to be nurtured, a resource to be husbanded. It was a key component in the great agrarian cycle which sustained civilisation."

Graham Harvey, The Forgiveness of Nature.

Abstract

South African dairy farmers have generally used kikuyu pasture to tide them over from one ryegrass season to the next, and as a result of its resilient nature, have assumed careful management of it to be unnecessary. This has resulted in its mismanagement which is unaffordable in current times where the profitability of dairy farming is increasingly dependent on low input, pasture-based systems. Kikuyu pasture may play a larger role in supplying nutrients to dairy cattle over the summer months in future as the alternative home produced feed sources such as silage and perennial ryegrass become increasingly unaffordable. Improving animal production from kikuyu is difficult as there is little information relating kikuyu pasture management to dairy cow performance. Efficient utilization and quality of temperate pasture have been more comprehensibly researched. The relations discovered between the chemical compounds in temperate grass species have been applied to tropical pastures such as kikuyu with limited success and often confusing results. For example, crude fibre in kikuyu was found to be positively related to digestibility. In South Africa, much research has been done on the use of kikuyu in beef production systems. This information has been applied to dairy farming systems with limited success, owing to the higher metabolic demands of dairy animals. Pasture farming needs to become more precise to improve pasture quality and hence milk yields as research trials focussing on stocking rate and grazing system comparisons have yielded results that are too general with little application at the farming level. A need for integrated and flexible management of animals and pastures has been recognised. The grazing interval is a key aspect in improving pasture and animal performance and fixed rotation lengths and stocking rates have been identified as being detrimental to performance. The relation between growth stage and pasture quality has lead researchers to identify plant growth characteristics, such as pasture height and leaf stage, as signs of grazing readiness. At the four and a half leaves per tiller stage of regrowth, the chemical composition of the kikuyu plant is more in line with the requirements of the dairy cow, with the leaf to stem ratio at its highest. The primary limitation of kikuyu pasture is a lack of energy, particularly readily fermentable carbohydrate, which makes the fermentation of structural carbohydrates difficult and dry matter intakes are reduced. Other limitations to animal performance include high cell wall constituents, low calcium, magnesium and sodium content and antinutritional factors such as nitrate and insoluble oxalate. These deficiencies and antinutritional factors are in some cases unique to

kikuyu pasture, meaning that kikuyu specific supplementation may be the key to improving performance from dairy cattle grazing kikuyu pasture. The objectives are to evaluate current kikuyu management systems in South Africa and their impact on dairy cow performance and to evaluate the use of pasture height and burning as quality control tools.

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Introduction

Improving kikuyu pasture management in South Africa has major macro and micro economical benefits as well as environmental advantages with regards to water management. Marco economically, South African dairy farmers have to become more globally competitive, as have New Zealand dairy farmers (Parker, 1999), with their loss of protection from outside competition. This has come with the political change and trade agreements made in this country (Broom, 1999). Competing with world prices is made even more difficult with a fluctuating currency that creates input cost instability. Over the last two decades, the South African Dairy industry has changed considerably. Statutory bodies such as the Minister of Agriculture and the Dairy Board used to determine milk prices on a cost of production plus basis and farmers were almost totally protected from outside competition. This led to the establishment of inefficient production systems based on high costs and high performance per cow with much over capitalization and small margins (Broom, 1999). Now there is a high degree of international competition that the dairy industry faces in supplying the food and beverage markets. The marketing strategy in the past has been use of low prices with the assistance of government subsidies and tariff protection, which are no longer (Parker, 1999). The system that has typically developed as a result of economic protection and fresh milk market is year round calving for consistent milk production and much use of annual pastures and fodder crops. Farmers that have achieved high milk yields per hectare have done so using excessive concentrates and nitrogen. The focus of management systems has been on concentrate feeding and not on optimal pasture utilisation (Every, 1999), which is now having devastating effects on the profitability of dairy farming. Dairy farming systems have not changed quickly enough to cope with market changes as is evident from reports such as this one in the Natal Witness, dated the 24th of February 2002, which stated that an estimated 20% of dairy farmers in South Africa could be out of business by July 2002 despite increases in the milk price. The maize price was largely to blame, as it increased from R800/ton at the beginning of 2001 to R1400/ton at the beginning of 2002. The milk price has been low and input costs have become volatile. Another report on www.news24.com dated the 12th of March 2002 entitled 'SA milk crisis the worst ever', stated that many farmers were slaughtering their dairy cows because of the beef price being more favourable than the milk price. There has been little change in the total amount of milk produced per year over the past decade. The number of dairy farmers has declined and the size of the herds has increased. The domestic market has not grown over the past decade and there are many reasons for that, particularly competition form other food and beverages. This means that expansion may have to be beyond our borders meaning that dairy farmers will have to compete on a global scale. Alternatively expansion of the local market will mean competing against other cheaper food sources (Bredin, 2005).

On a more micro economic scale or farm level, the low cost, efficient production systems that must be employed include the production of bigger volumes of higher quality milk from more productive cows and use of fewer replacement heifers, meaning that cows must have good longevity in addition to good reproduction and production traits (Broom 1999). Dairy farmers in KwaZulu-Natal are currently trying to expand their herds and are using all available replacement heifers. As a result, attaining the reproductively and productively efficient cow is a long term goal. Farmers have to become more efficient by reducing costs. The major cost reducing opportunity lies in feed. Feed costs account for as much as 70% of total production costs. Labour saving technology is recommended as a means of lowering costs (Parker, 1999), but its high costs make it unavailable to most farmers. An immediate economic benefit can be attained by fully utilising farm produced feed. More precise management is needed with the use of higher stocking rates, and accurate measurement of pasture quality and quantity, and it is in this field that the research trials in this thesis are done. According to Broom (1999) important issues in reducing costs are the use of legumes to reduce the amount of fertiliser applied, using less concentrate supplementation and employing simple systems and minimising debt. Alternatives to concentrate supplementation on kikuyu pasture, such as making silage, or introducing irrigated pastures, are also expensive and often the extra income from any extra milk produced does not offset the additional costs. Certain improvements in commercial concentrate supplements could be made to improve yields.

The environmental benefit from kikuyu pasture is in a reduction of water use. Most pastures require irrigation, but many farmers do not have access to irrigated land. According to Dugmore (1999) only 20% of the average KwaZulu-Natal farm is arable, although according to Booysen (undated cited by Bransby, 1983) 70% of KwaZulu-Natal is suited to cultivated pastures. Most farmers have expanded to the limit of their irrigation potential and irrigation is becoming more and more difficult with new levies and increased costs, resulting from environmental concerns and water availability in general. Further expansion is only possible with improved irrigable land utilization or on dryland pastures such as kikuyu. Kikuyu has the potential to improve the economics of dairy production, as it is a resilient and highly productive pasture that thrives on nitrogen fertilization (Miles *et al.,* 2000). Once established, the only major expense is nitrogen fertilizer, unlike other pastures such as ryegrass that require replanting and irrigation in addition to fertilization. With the increase in fuel and machinery costs in South Africa, it is possible that the profitability of producing milk off pastures such as ryegrass could be declining despite the potentially higher milk yields obtained. There is also the likelihood of stricter legislation regarding water use in the near future (Motram, 2002). Kikuyu could not only reduce costs for the commercial farmer, but make dairy production viable for small scale and emerging farmers who generally have limited access to capital and hence irrigation. A common misconception among farmers is that kikuyu is capable of looking after itself. However, it is essential that kikuyu is grazed at its correct stage of regrowth, nitrogen fertilizer is judiciously applied and rejected pasture is removed for optimal production to be achieved (Fulkerson, 1999a). The problems resulting from the mistreatment of kikuyu are hard to rectify because minimal research has been done on kikuyu for dairy production systems in South Africa and the few management practices that have been recommended have not been quantified and are therefore of little use to dairy farmers. Farmers have traditionally used Kikuyu in South Africa as a pasture to carry cattle from one ryegrass season to the next. Farmers have accepted lower milk yields from kikuyu without any knowledge of management practices that may potentially improve dairy cattle performance.

The quality of kikuyu, rather than the quantity, is important in obtaining reasonable milk yields (Reeves & Fulkerson, 1996a) and South African dairy farmers have focused more on quantity despite the decrease in quality of kikuyu over the season. There is an accumulation of residual herbage during the summer, which increases the stem to leaf ratio (Dugmore, 1998). Less energy is available to the animal, so feed intake and production drop. The non-protein nitrogen content of kikuyu increases as the season progresses. This raises the potentially toxic nitrate content of the pasture and has a negative effect on the digestibility of fibre (Van de Merwe, 1998) leading to a decline in milk butterfat levels. Milk yield per cow is low on kikuyu pasture because of a shortage of readily fermentable carbohydrates. This results in a high protein to energy ratio in the rumen. Nitrogen is not captured by rumen microbes and is instead wasted, which leads to financial losses. Kikuyu has mineral deficiencies and contains antinutritional factors that render certain minerals unavailable to the animal. It is low in sodium, calcium and magnesium and it often has excessive nitrogen and potassium. This can lead to metabolic disorders, which also have to be prevented for efficient dairy production.

Mineral supplements are essential for dairy production off kikuyu pasture. Commercial concentrates, and in particular maize, have been relied upon to make up for the energy deficit. The high costs involved in commercial concentrate supplementation have led many farmers to cut down on the amount of feed offered to each cow. Cows are not obtaining their full requirement of nutrients, as this is dependent on the correct quantity of supplement being fed to each cow according to the nutrient density of the ration.

Commercial concentrates are formulated according to a broad range of dairy cow needs in order to cater for different dairy production systems. There are rations suitable for cattle on high protein diets, such as pastures, and other rations suitable for animals on low protein base, total mixed ration (TMR) diets. The ration labelling stipulates maximum fibre, minimum protein, minimum phosphate, maximum calcium and minimum fat according to Act 36, 1947. Concentrates are not formulated according to the protein, energy and mineral imbalances of kikuyu, which are different to other pasture species. It is likely that dairy cattle grazing kikuyu in South Africa are producing milk off a diet that is not balanced, especially since only the concentrations of the minerals required by the animal are inspected, not the relation between the supplemented minerals and those already present in kikuyu, and as a result, optimal production is not being achieved. Dairy farmers require information on how best to manage kikuyu in order to make profits. The ability of kikuyu to meet the dairy cow's requirements for milk production needs to be established. The imbalances and deficiencies identified in kikuyu pasture need to be corrected through the development of more affordable and kikuyu-specific supplementation. Management of kikuyu pasture for improved dairy cow performance cannot maximise pasture and animal production, but must be an optimal combination so that the profitability of the dairy industry can be improved.

The aim of this dissertation is to consolidate available literature on kikuyu pasture; identify how dairy farmers in KwaZulu-Natal and the Eastern Cape are managing their kikuyu and to determine what management techniques are working; to identify whether pasture height is a suitable means of determining grazing readiness and pasture availability within a flexible management system; Burning kikuyu pasture as a cheaper means of maintaining pasture quality through the removal of old material.

Part 1: Literature Review

1.1 The best dairy cow type and size to use in dairy production systems

Although the focus of this research lies primarily with the management of kikuyu pasture as a means of reducing costs, it is crucial that the correct cow is used in the system for it to be viable. Expecting an animal bred for a total mixed ration (TMR) system to survive on a kikuyu based system may not be possible as will be discussed.

In creating a sustainable dairy production system it is essential that the most suitable animal for the production system is used. Milk production, cow type and size are important factors to be considered in optimising production per cow or production per hectare from cultivated pastures (Bartholomew, 1985). The most suitable cow is dependent on the type of management system and the economics of producing milk. For example, American and New Zealand dairy production systems are vastly different. Cow size is important because it is positively correlated to feed conversion efficiency (FCE) and the ability of the cow to turn feed into milk is a key issue in reducing the high feed costs. Selecting animals for FCE, as such, is difficult. Instead, FCE is selected for indirectly by selecting for cow size. Feed costs, although high, are not the only costs incurred by farmers. The right animal for the system should cost the least over her lifetime (Mahoney, *et al.*, 1986). If low cost production systems are characterised by a larger output of milk of greater quality from more productive cows and use of fewer replacements (Broom, 1999), then longevity is important in addition to FCE.

There is an optimal cow size regardless of the management system employed. Research has shown that FCE is maximised at a certain size beyond which, milk yields decrease with each kilogram increase in body size. According to Jones & Stewart (1996), the average difference between a 500 and a 501 kg cow is 9.3 kg of milk in 300 days. The difference between a 700 kg cow and a 701 kg cow is 1.5 kg for the same period. Yields start to fall, as cows get bigger than 671 kg. The difference between an 800 kg cow and an 801 kg cow is a loss of 7 kg of milk (Jones & Stewart, 1996). It appears that larger cows are better than smaller cows if the maximum cow size in the groups for comparison is 671 kg, and smaller cows are better than larger cows if the minimum weight in the group is 671 kg.

Cow size plays an important role in selection programs, and for years, Holsteins in North America have been selected for large body size. Cows of today are substantially bigger than they were in the 1960's, yet have no functional or economical advantage over small cows within a breed (Hansen, *et al.* 1999) and there is little reasonable justification for their selection (Mahoney, *et al.* 1986). American farmers have selected larger cows because they believe that larger cows can eat more and produce more milk. This is important in TMR systems where maximum potential intake of cattle is 10 to 20% greater than under grazing (Holmes, undated). Scores by the Holstein association of the USA and Canada place more favourable ratings on large cows and some farmers try to compensate for poor heifer size, resulting from poor heifer management, by selecting for increased potential for large mature size (Hansen, *et al.* 1999). At any level of production, the larger cow needs less energy per kilogram body weight to produce a given amount of milk and bigger cows can produce more milk on a diet of a certain quality (Jones and Stewart, 1994) (presumably if they weigh less than 671 kg). According to Morris and Wilton (1976), the ability of large cows to produce more milk may not only be because they are large, but because they are used in systems that maximise production per cow. Smaller cows are usually used in pasture management systems that are more concerned with maximising pasture utilization and production per hectare. Large cows produce heavier calves, which is an advantage in veal production (Hansen *et al.*, 1999). They do yield a higher salvage value when culled (Collard, 1999), but according to Holmes (1999), the higher maintenance costs of large cows are not offset by the extra salvage value of the meat when they are culled in New Zealand. Larger cows have the advantage in that fewer of them are needed to fulfil a quota, with fewer demands on management and lower overheads, but the loss of one large cow has a serious effect on production. The capability of large cows to eat more roughage is lost in early lactation when the demand for energy is highest (Collard, 1999). Not all large cows produce more milk than all smaller cows and increases in size have not always come about as a correlated response to increased productivity (Hansen *et al.*, 1999).

Large cows have many disadvantages, which can be detrimental in pasture based dairy production systems. These include a larger maintenance requirement and less efficiency at producing a given amount of milk (Jones and Stewart, 1992). New Zealand dairy production systems are characterised by high land and concentrate feeding costs, unlike American dairy production systems where land and concentrates are relatively inexpensive (Holmes, 1999). The profitability of the New Zealand system is dependant on the production of milk that is high in solids (protein and butterfat) off pasture because 90% (Holmes, 1999) of the unsubsidised dairy products, such as butter and cheese, are exported. The market for fresh milk is very small in New Zealand. Land is expensive and most feed is produced directly off it, meaning that little feed is purchased. Efficiency is therefore measured in litres per hectare instead of litres per cow as is done in America (Holmes, 1999). FCE per cow is not as important in milk production per hectare and milk solid yield per hectare is a more accurate means of determining economic efficiency. The New Zealand genetic improvement program has become highly successful since the inclusion of body weight in the index. Body weight is given a negative weighting because of the extra feed required to maintain heavy cows (Holmes, 1999) and large cows continue to grow after first calving, despite already achieving a satisfactory size. This continued growth is not economically desirable (Mahoney *et al.*, 1986). The DM intake of dairy cows on good quality pasture ranges from 3.5 % body weight for large cows to 4% body weight for small cows (Holmes, undated). As a result, the average genetic merit of New Zealand dairy herds has improved by about 35% and milk fat yield per cow has improved by 50% since 1950. This is despite an increase in stocking density from 1.4 to 2.4 cows per hectare (Holmes, 1999). From this evidence it seems that smaller cows are capable of yielding more milk fat and are more suited to intensive grazing systems than large cows. Smaller cows generally produce higher milk fat yields (Sieber *et al.*, 1988). But, according to Jones and Stewart (1998), there is no relation between production of milk fat or protein and Holstein size. The observed genetic improvement in milk fat yield per cow may not be negatively correlated to body size.

The increase in stocking rates in New Zealand since 1950 has been necessary for efficient harvesting of the pasture, but this causes the cows to be low yielding and to have reduced FCE. This apparent disadvantage is offset by a positive relationship between FCE, milk yield and infrequency of health problems (Mahoney, *et. al.*, 1986). Cows have better productive performance with improved FCE and milking ease, but have poorer reproductive performance, as it is difficult to get cows to conceive soon after calving. This is a major challenge in seasonal dairy production systems of New Zealand that rely on the rapid pasture growth in spring for milk production. It is economically essential that all cows calve in the 60-day period from July to September in order to maintain the seasonal production cycle (Hansen *et al.*, 1999). Cows must become pregnant as quickly as possible during the period from October to December. Breeding efficiency is vital because cow numbers have to be maintained. If some cows have to be sold because they are not conceiving within 60 days, others have to be bought in which is not economically efficient or characteristic of low cost dairy production systems. As a result, traits of more concern than FCE include health and fertility. An important advantage of the small Holstein-Friesland is that fewer services per conception are required in the first lactation (Hansen *et al.*, 1999) and there is no difference in calving ease between large and small Holstein-Frieslands (Jones and Stewart, 1998).

Small cows are less prone to lameness as they have shorter, stronger legs that are under less stress. Large cows have a higher centre of gravity than small cows and are more likely to slip and fall (Hansen *et al.*, 1999). This is important in pasture based systems where cows have to walk to obtain sufficient food, but this advantage falls away in American systems where cows are housed in sheds and are allowed little room for movement. Large cows are also more predisposed to disease and have higher incidences of metabolic problems such as ketosis, dystocia and milk fever (Badinga, 1985). Larger Holsteins have shorter lives than smaller Holsteins, meaning that there is a greater need for replacement females (Hansen *et al.*, 1999). Small Holsteins suffer from more udder related problems apparently because shorter legs make their udders closer to the ground and more likely to become infected or damaged (Hansen *et al.*, 1999).

The breed differences are largely related to size. Holsteins produce more milk than Jerseys, but Jerseys require fewer open days (Badinga *et al.*, 1985). The Jersey may be able to maintain better reproductive performance because it is better able to lose heat. This may explain the antagonistic relationship between milk yield and reproductive performance (Badinga *et al.*, 1985). The high milk yields of the Holstein breed is associated with increased metabolic heat production, which may affect their thermal balance.

The Jersey has been crossed with the Holstein-Friesland under New Zealand type production systems in South Africa because they perform well under intensive grazing conditions. They are less prone to disease and their hard black feet make them less prone to lameness. Some people believe that they utilize pasture more efficiently for producing milk. Their milk has more solids, which is essential in successful New Zealand farming. A possible explanation for the efficient pasture utilisation by Jerseys is that they are cows which have a smaller heart girth measurement and larger paunch girth and this cow shape allows for significantly higher milk yields compared to cows with the opposite circumference (Sieber *et al.*, 1988). This and the New Zealand influence are the reasoning behind the presently contentious issue of crossbreeding. The Jersey with its bigger paunch is believed to be able to consume more grass relative to its size, than the Holstein (Sieber *et al.*, 1988). The Jerseys larger milk solids yield, better fertility and health, and the potential for hybrid vigour, has resulted in many farmers putting their Holstein-Friesland cows to Jersey bulls.

New Zealand farmers use small cows because they believe that they are economically more efficient. Unlike New Zealand, South Africa has a large fresh milk market, which is why more emphasis has been placed on liquid milk as apposed to milk solids. Yield has therefore been measured in terms of ℓ/cow, and large cows have, up until now, been given preference. Large cows produce more milk than small cows, but the increase in size debatably brings with it a reduction in efficiency. The dairy cow type should match the environment and resources available to the South African farmer in the pasture based dairy production system so that business objectives may be achieved.

1.2 Temperate and Tropical Pastures for meeting the nutritional requirements of the dairy cow

Pastures that are used by South African dairy farmers are either of temperate or tropical origin, with kikuyu being a tropical pasture. Most dairy farmers use temperate pasture species as the primary source of winter feed if they have irrigation and tropical grasses are used to maintain production over the summer months when there is little or no temperate grass available. On farms without irrigation tropical grasses are the primary feed source throughout the year (Teitzel *et al*, 1991). There are certain limitations of pastures in general in meeting the nutritional requirements of the dairy cow, but there are inherent differences in quality and quantity between temperate and tropical pastures which affect cow performance. Milk production is dependent on pasture quality so long as quantity is not limiting (Stobbs, 1975).

The major advantage of tropical pastures is that they can produce large amounts of herbage over a relatively short period of time (Stobbs, 1972) and are generally more persistent. Temperate grasses, being cool season grasses are different to tropical grasses, which are warm season grasses (Marais & Figenschou, 1990). Tropical and temperate grasses have different carbon pathways for photosynthesis. Tropical grasses have a lower rate of photorespiration, a higher maximum level of photosynthesis and possibly a lower level of transpiration. Tropical grasses use less water per gram of dry matter (DM) production during growth and have a different leaf anatomy particularly in the development and distribution of vascular bundles (Marais & Figenschou, 1990). Tropical grasses have different soluble carbohydrates or non-structural carbohydrates (NSC). NSC consist of water soluble carbohydrates (WSC) and starch. Tropical grasses have starch or sucrose as the main NSC although the main storage carbohydrate is species specific. Temperate pastures have a higher total NSC content and have fructosan, raffinose and stachyose as the main NSC (Marais & Figenschou, 1990).

It is difficult to make comparisons between tropical and temperate pastures, as their true feeding value cannot be determined with any certainty using chemical analyses (Moore & Mott, 1973).

Instead feeding values must be determined in terms of animal performance under grazing conditions, with output per animal giving the best indication of forage quality, as long as animal potential and grass supply are not limiting (Moore & Mott, 1973). The quantity of pasture eaten is dependent on the availability of herbage, its physical and chemical composition and the nutritional requirements of the animal. There are many pasture and animal factors that influence production, including the genetic potential of the animal to produce, voluntary intake, pasture digestibility, rumen conditions, plant structural components, pasture management and availability, selection by the animal and environmental conditions (Stobbs, 1975). Because intake is controlled by so many unrelated factors, in addition to quality and availability, it can rarely be predicted accurately form laboratory analyses. This is a major challenge as effects on intake must be taken into account before animal performance can be used as a measure of quality (Bransby, 1983).

A brief comparison between temperate and tropical pastures, keeping in mind the difficulties in making assumptions based on chemical analyses, reveals that tropical grasses have a much higher cell wall constituents (CWC) component as values less than 55% have seldom been observed but values in excess of 65% are common at early stages of growth (Marais & Figenschou, 1990). At advanced stages of growth CWC may be 75 to 80%. Growth is stimulated and senescence accelerated by the high temperatures and rainfall, under which tropical pastures grow. This results in reduced digestibility and intake because of the increased CWC. Senescence occurs quicker in summer than in spring or autumn (Blaser, 1981). The CWC component in tropical grasses is important as it forms the biggest part of the digestible organic matter (DOM), but higher CWC and lower NSC places greater demands on the microbial and mechanical processes of digestion in the reticulo-rumen (Marais & Figenschou, 1990). Tropical grasses have higher contents of crude fibre (CF), acid detergent fibre (ADF) and lignin and their mean digestibility was found to be 12.8 units lower than temperate forages (Minson & Mcleod, 1970) (cited by Moore & Mott, 1973).

The grazing behaviour of cattle differs according to whether they are consuming tropical or temperate pastures. The composition of the pasture can affect selection by grazing animals. The location of higher quality components (i.e. leaf) in the canopy structure of the tropical pasture sward influences ease of selection (Stobbs, 1975). Effective utilisation of pastures and the ability of cows to consume enough DM depend on bite size and number of bites per unit time (Holmes, undated). It is easy to work out temperate pasture allocations because the temperate grass sward is more or less homogenous in quality. Tropical pastures vary considerably in yield, density and height, depending on the species and stage of maturity (Hutton, 1960 cited by Stobbs, 1973). Cattle graze tropical pastures more selectively because of the heterogeneous nature of the sward. Grazing time on tropical pastures, particularly tall stemmy species is excessively long because cattle have more difficulty meeting their nutritional demands (Stobbs, 1975). This occurs even when the quantity of pasture is not limiting (Stobbs, 1973). At low grazing pressure cattle grazing tropical pastures can compensate for its poorer quality by selecting the more nutritious parts. Cattle may not be able to fully compensate for reduced DM intake by extending the grazing time as, according to Holmes (undated), pasture intake is limited by the ability to graze the pasture. Tropical pastures have a lower leaf bulk density in the upper sward, making it difficult for animals to get large mouthfuls. Generally intake and digestibility decrease with advancing maturity but this decline is greater for tropical grasses (Stobbs, 1975). Intake is limited by similar factors for both temperate and tropical pastures, but for a given digestibility, temperate pasture has the potential for higher intake (Moore & Mott, 1973). Cattle consume more young temperate grass than young tropical grass because of a higher proportion of cell wall constituents (CWC) in tropical grass. Cattle can compensate to some extent for poor quality grazing, but a point is quickly reached when quality affects production (Stobbs, 1972).

Production can only occur when feed intake exceeds maintenance requirements and small improvements in pasture quality can result in relatively large increases in milk production. Intake of herbage increases with digestibility and an improvement in digestibility of 4% should lead to an increase of 8% in voluntary feed intake and a 20% increase in DE consumption. Fifty percent or more of the digestible nutrients are used in maintenance, so an increase of 4% for digestibility should lead to a 40% improvement in production (Moore & Mott, 1973), therefore small changes in management to improve tropical pasture quality could have large beneficial effects. The dry matter intake of cattle on temperate and tropical pastures is different. This is largely explained by quality and differences in growth habit. Intake is not perfectly correlated to digestibility and is affected by physical factors such as structural components of plants and the rumen environment, which can alter rate and extent of forage degradation by microbes. There is a relation between intake and digestibility and lignification and digestibility. Lignin is considered the primary structural inhibitor of quality in tropical pastures. This is because tropical grasses have lignified sheath cells surrounding the vascular bundles, which are not degraded in the rumen (Moore & Mott, 1973). Given the poor relation between intake and digestibility and the limitations of chemical analyses as a means of predicting animal performance, it is necessary to examine the physical structure of the grass as well as the rate of passage through the digestive system.

Pasture quality as a means of explaining differences in performance of cattle on tropical and temperate pastures cannot be primarily attributed to protein. Protein should not be the first limiting nutrient in tropical pastures (Butterworth, 1963 cited by Moore & Mott 1973) although it can be deficient in mid summer in under grazed, lightly fertilized improved pastures (Moore, *et al.*, 1969 cited by Moore & Mott, 1973). The nitrogen (N) status of the animal can greatly influence intake, digestibility and hence production and a low N status will cause production to drop. The minimum level of crude protein (CP) below which N becomes the first limiting nutrient in tropical pastures is 7% on a DM basis (Minson & Milford 1967, cited by Moore & Mott, 1973) as at CP levels higher than 7%, energy or other nutrients will be first limiting.

Tropical species cannot support levels of production that temperate pastures can in general, because of their inherent lower quality, although quality can be quite variable (Moore & Mott, 1973). Milk production per cow from unsupplemented tropical pastures is lower than from temperate species at a similar stage of regrowth (Stobbs, 1972). Many authors have come to the conclusion that tropical grasses are inherently of low quality compared to temperate grasses because of their high fibre content (Moore & Mott, 1973). Cows grazing tropical pastures can produce quite high levels of milk in excess of expected production from chemical composition estimates. This was attributed to the ability of the cow to draw on body reserves and being able to select a more nutritious diet while grazing (Stobbs, 1972).

Trials to evaluate DM digestibility have been done using beef cattle, which are far less sensitive to pasture quality than lactating animals, which may account for some of the confusion when comparing tropical and temperate pasture quality in terms of DM or OM digestibility (Moore &

Mott, 1973). Stewart (1998) found live weight gains of Holstein heifers to be much lower than Hereford heifers on kikuyu pasture. A digestibility of DM, OM or energy of 65% in a grass should indicate good nutritive value and permit adequate intake of DE, except in lactating animals (Hamilton *et al.*, 1970 cited by Marais & Figenschou, 1990). Unlike beef cattle, a much clearer distinction exists in milk production from cattle grazing temperate or tropical pastures. Dairy cows have much higher nutrient requirements and are more sensitive to slight changes in diet quality than beef cows. As a result, they usually perform worse on tropical pastures (Moore & Mott, 1973). Animals only produce 8 to 9kg of milk per cow per day at low grazing pressure on tropical pastures (Stobbs 1971 cited by Marais & Figenschou, 1990) compared to 16kg per cow/day for cows grazing temperate pastures in Scotland (Greenhalgh, 1970 cited by Marais & Figenschou, 1990). The lower production per cow on tropical grasses may be because of a lower maximum intake and digestibility (Moore & Mott, 1973). This may be due to high CWC in the tropical grasses at comparable stage of growth (Moore & Mott, 1973) or lower protein content of the forage (Marais & Figenschou, 1990). Digestibility of CWC and OM are highly correlated in tropical pastures and it is important that rate and extent of digestion of CWC is measured (Moore & Mott, 1973). The prediction of CWC digestibility is not accomplished by chemical analysis, except by lignin analysis within certain species as they mature, as lignin is the primary structural inhibitor of quality in tropical grasses (Moore & Mott, 1973).

Poor quality tropical pastures not only affect milk quantity but can also affect milk quality (Stobbs, 1972). High producing dairy cows grazing these pastures are usually undernourished in the first few months of lactation and are in a negative energy balance. The draw on body reserves characteristic at this time is greater than normal (Stobbs, 1972). When milk yield is depressed because of lower intakes of DE the percent butterfat increases and protein decreases. This is not favourable in terms of meeting the market demands, as the market prefers milk lower in fat and higher in protein (Stobbs, 1972). The composition of milk fat also changes from mainly short chain fatty acids to long chain fatty acids, which are less soluble. Short chain fatty acids are synthesised in the udder from acids absorbed from the rumen. Long chain fatty acids are derived from body fats (Stobbs, 1972). Cattle on restricted diets catabolize body fat for milk production. The ability of the cow to lay down and milk off fat should be used to the best economical advantage. Another important consideration in milk production from tropical pastures is that some pastures can alter the flavour of milk (Stobbs, 1972).

Tropical pastures are often deficient in sodium, sulphur, copper and cobalt. Tropical pastures that are deficient in phosphorus are usually also deficient in energy and protein (Gartner *et al.*, 1980). The ability of tropical panicoid grasses belonging to *Cenchrus, Setaria* and *Pennisetum* (all closely related genera, with kikuyu belonging to *Pennisetum*) to accumulate oxalate (Marais, 1990) further reduces the quality of some tropical grass species. Most oxalate in *Cenchrus* and *Setaria* is in the soluble form, but most in *Pennisetum* is in the insoluble calcium oxalate form. Rumen microbes can adapt to high levels of soluble oxalate in the diet and destroy it in the rumen. Insoluble oxalate passes through unchanged, rendering calcium unavailable to the animal (Marais, 1990) and making supplementation essential for animals grazing these pastures.

The quality of tropical pastures could be greatly improved through a number of different approaches such as improved management and utilization of existing pasture resources, introduction of new pastures or oversowing existing pastures with introduced species (Whiteman, 1980). Better tropical grass species have already been introduced in an attempt to improve yield and quality of tropical grasses (Moore & Mott, 1973). Careful management is needed because most tropical pastures experience seasonal productivity with the alternating wet and dry seasons (Whyte, 1962 cited by Moore & Mott, 1973). In order to improve pasture systems pasture yield, persistence, ability to associate with other pasture species and ease of propagation must all be considered (Whiteman, 1980). There are several improved tropical pastures that are palatable and nutritious when properly managed and their composition and digestibility is comparable to temperate species (Vincente-Chandler *et al.*, 1964 cited by Moore & Mott, 1973). High pasture yield is sought because yield is linearly related to milk production (adjusted for supplement intake) up to 3000 ℓ/cow per lactation and grass yield is positively related to N and moisture supply (Teitzel *et al.*, 1991). Better quality species, better knowledge of their management and strategic use of concentrate should enable good production per hectare to be achieved from tropical pastures (Stobbs, 1972). Tropical pastures form an important part of fodder flow on dairy farms in South Africa and are an economical source of food if properly managed.

1.3 Measuring temperate and tropical pastures with the pasture disc metre

Much research in the eighties was aimed at relating herbage availability to animal performance. This research has generally not been successful because of inaccurate ways of measuring herbage availability such as clipping quadrats and visual observation (Bransby, 1983). The development of the disc metre improved the ability to understand the relations between herbage availability and stocking rate and average daily gains (Bransby, 1983). A more practical reason for the development of the pasture disc metre was because of a need for a quick, easy and non destructive way to estimate pasture mass on the farm so that appropriate grazing management practices could be adopted and feed budgeting could be more accurately assessed (Fulkerson & Slack, 1993). In subtropical and tropical regions assessment of pasture mass is generally done by observation (Fulkerson & Slack, 1993). The Ellinbank rising plate meter (RPM1) (Earle & McGowan, 1979) has been commonly used to estimate pasture mass and is better than using pasture height as density is also taken into account (Fulkerson & Slack, 1993). The automated rising plate metre was constructed for measuring DM present in a pasture consisting mainly of green perennial ryegrass. The coefficient of variation for readings taken on a particular day by a particular operator is 13%, but this rises to 18% when readings taken from different days are pooled (Earle & McGowan, 1979), probably due to variations in walking pace, measuring style and sward structure from day to day. There is considerable variability between operators. The advantages of the RPM1 are that it is simple and quick to use and is as accurate as the electronic capacitance metre (Earle & McGowan, 1979). The Ellinbank rising plate metre can be used to estimate the intakes of a herd, but not of individual animals (Reeves *et al.*, 1996c). It is difficult to measure kikuyu pasture mass using the plate metre because of the high proportion of stem compared to green forage (Reeves *et al.*, 1996c).

Ryegrass white clover swards are frequently measured but measurement of tropical pastures poses some problems (Fulkerson & Slack, 1993). Bartholomew (1985) calibrated his falling plate disc metre by cutting the grass under the disc meter to ground level with a pair of sheep shears. This was done before and after the fifth paddock in each grazing cycle was grazed. There was no significant relation between disc height and pasture yield in recently grazed and grown out pasture, indicating that bulk density of the pasture was the same before and after utilization, which would seem unlikely. Reasons for this result may have been that that the pasture was infrequently grazed, which resulted in a more open sward, trampling of the grass by cattle produced uncharacteristically low readings, dung patches produced uncharacteristically high readings, and an inability to harvest all the material in recently grazed pasture compared to ungrazed pasture, which would make calibrations less accurate. The problem could, in theory, be largely overcome with the Ellinbank rising plate meter (RPM1) (Earle & McGowan, 1979) as density of the pasture is also taken into account (Fulkerson & Slack, 1993). Factors that contribute to the inaccuracies of measuring pasture with a disc metre include the ability of pasture to erect itself after trampling, which can be misinterpreted as growth, and trampled pasture could be considered consumed (Bartholomew, 1985). When measuring growth rates of pasture it is important that the height of the pasture is taken into account as taller pasture grows faster, having more leaves and therefore higher root carbohydrate reserves to initiate growth, therefore making the pasture under low stocking rates appear to grow at a faster rate.

There must be differentiation between dead and green material because of the rapid rates of growth and senescence associated with tropical pastures. Animal performance is related to green leaf supply and not total DM on offer (Murtagh *et al.*, 1986 cited by Fulkerson & Slack, 1993). The assessment of tropical pasture mass is less accurate than temperate grasses because of the lower stocking rates and greater total herbage mass. A heavier plate could be used to more accurately assess the mass of tropical pastures (Fulkerson & Slack, 1993). Pasture metres have been used to estimate mass of kikuyu and *Paspalum dilatatum* with reasonable precision (Fulkerson & Slack, 1993). In a trial done on the North coast of New South Wales it was found that the use of green stem and leaf DM (what the cow most likely would have grazed) rather than total DM to calibrate the pasture metre reduced the variation in results of tropical pasture mass for kikuyu and setaria (Fulkerson & Slack, 1993). The regression equations obtained describing the DM differed significantly for metre readings in early season and late season. Accuracy of predicting pasture mass declined from early to late season and this was attributed to the build-up of stoloniferous material. Calibration curves have been pooled for estimating the mass of ryegrass-white clover pastures grown in the subtropical areas using the standard Ellinbank rising plate metre. These pooled regressions are precise because of sward uniformity and are confidently used. Calibrating the metre using total DM of tropical pastures (i.e.

clipping pasture to soil level) gave unacceptably low accuracy even in well-managed and highly utilized swards. Calibrations using shoot, or green DM greatly improved the mass estimates (Fulkerson & Slack, 1993).

Removing the stubble component is sensible as cattle are unlikely to graze this material (Fulkerson & Slack, 1993). There is a need to develop two sets of regression equations based on early (Nov-Feb) and late (March to May) seasons for tropical grasses because of the build-up of material beyond the specified calibration height of 5cm (Fulkerson & Slack, 1993). Deciding when early season ends and late season begins is a problem. If feed available on offer is taken to be total DM for ryegrass-white clover pasture and DM greater than 5cm stubble height for kikuyu, then the variation as a percentage of the feed available on offer is 1.6% for ryegrass and 5% for kikuyu. Intake of ryegrass-white clover pasture can be estimated with an error of 10% with the Ellinbank rising plate meter. The calibration equation can be applied to pasture widely varying in composition, age and season. Accuracy of determining intake of tropical pastures is probably less than half that of temperate pastures because of the higher DM on offer and lower proportion removed at each grazing (Fulkerson & Slack 1993).

For accurate estimation of kikuyu pasture DM with a disc meter it is essential that the pasture is well utilised. If the residual material is minimised at each grazing, then there will be no need for accounting for the accumulation of residual material over the season. The same operator should measure the pastures to account for variability between operators.

1.4 Irrigating pastures

Many pastures in South Africa require irrigation in order to be productive, particularly the temperate pastures, as rainfall is insufficient to meet the moisture requirements. Bransby (1983) stated that irrigation has limited potential in South Africa in terms of water supply. Irrigating kikuyu pasture has the benefit of allowing for increased stocking rates and guaranteed yields, provided that the water source for irrigation is sustainable. Another advantage is that irrigated kikuyu can be oversown with a winter grass such as Italian ryegrass (Roos 1975). The benefits of irrigation can only be reaped with an initial large capital outlay followed by continuous and careful management. There is little room for error as a 3% drop in yield is experienced for every day that the pasture is stressed and if the number of consecutive stress days exceeds four, as much as 50% of the yield can be lost (Mottram 2002). Kikuyu under irrigation requires more N fertilizer, in excess of 300kg N/ha/annum (Roos 1975) although yields are higher.

The costs of irrigation are highly variable and depend on the type of system employed and level of management required. The two major systems are the dragline and centre pivot. The dragline system costs between R7500 and R8500 per hectare and the centre pivot between R9000 and R11500 per hectare (Mottram 2002). According to Twiddy (2002), the cost of a centre pivot is R8500 per hectare and the costs per annum include interest at 15%, which equates to R1275 and depreciation over 10 years at R850. The advantage of the dragline system is that it can fit any shape or sized land on any slope. The disadvantages are that it is labour intensive with one labourer required for every 25 hectares, and is not compatible with fertigation (Mottram 2002). The disadvantages of the centre pivot system, other than the high cost of the system, is that it is limited to a circular or part of a circular configuration and can only withstand 8 or 9% slope in one direction. The advantages of this system are that it has a minimal labour requirement, is compatible with fertigation, which cuts down on tractor and diesel costs, and higher pasture yields of up to 20% over the drag line system can be obtained with good management (Mottram 2002). Under dry land conditions it is possible for one hectare of kikuyu to support between three and six cows (Williams 1980) and with more moisture, or irrigation, the carrying capacity can be increased to eight cows/ha for almost eight months a year (Williams 1980).

Despite these potential advantages of irrigation, it is likely that irrigation will become increasingly expensive in South Africa with tighter control on water use. Efficient irrigation management will be essential and will have to be carefully scheduled to fit the grazing cycle to be cost effective. Accurate scheduling of irrigation is difficult without the assistance of expensive or unavailable instruments such as neutron probes, capacitance probes, evaporation pans or a nearby weather station (Mottram 2002). Costs can be reduced by irrigating during electricity off peak times. The new levies that have been introduced on water use are likely to increase soon, which will affect farmers in the Umgeni River catchment area, in particular. Theft of irrigation draglines and centre pivot cables on many KwaZulu-Natal dairy farms poses further problems.

The costs of maintaining perennial ryegrass pasture are greater than kikuyu pasture. The cost of the centre pivot alone is R2125 per hectare per year. Systems can be quite variable depending on the irrigation scheme and whether it is supplementary or not, but for comparative purposes, a breakdown of the cost of maintaining two extremely different pasture systems, a perennial ryegrass-clover pasture per hectare under centre pivot and a dry land kikuyu pasture over a season is given in Table 1. These systems are compared because they both provide pasture over the summer months. Kikuyu can grow without irrigation, but the perennial ryegrass-clover pasture will need irrigation in order to survive in most parts of KZN.

Table 1 A cost comparison of maintaining a ryegrass-clover pasture and a kikuyu pasture (Twiddy, 2002)

Item		Perennial Ryegrass-clover		Kikuyu	
	Cost $R.kg^{-1}$ / $R.mm^{-1}$*	Amount $Kg.ha^{-1}$ / $mm.ha^{-1}$*	Cost R/ha	Amount Kg/ha	Cost R/ha
Seed	20	27	540		
Nitrogen	3.9	400	1560	300	1170
Phosphorus	12.5	20	250	20	250
Potassium	5	50	250	50	250
Sprays			150		150
Lime	0.24	500	120		
Planting costs (contractor)			400		
Diesel			300		
Electricity	R1*	600*	600		
Repairs & Maintenance			260		260
Centre Pivot			2125		
Total			6555		2080

*Refers to / $R.mm^{-1}$ or $mm.ha^{-1}$ in the relevant columns.

The cost of seed ranges from R10 to R30 a kg and is sown at 27kg/ha. It costs 70c, 53c, 42c and

35c/kg DM to produce 9, 12, 15 and 18t DM of ryegrass-clover respectively. It costs 23c, 17c and 14c/kg DM to produce 9, 12 and 15 tons DM of kikuyu pasture respectively, without taking the reduced N inputs associated with lower yields into account. The costs of maintaining kikuyu pasture are also very variable, particularly with regard to the nutrient status of the soil, and whether it is mown or mulched, but once it is established, it is permanent. The spraying costs of both kikuyu and ryegrass are variable as sometimes lawn caterpillars, which chew off the tillers, strike in February-March (Twiddy, 2002).

1.5 Kikuyu pasture

1.5.1 The origin and adaptability of kikuyu pasture

Kikuyu is a tropical pasture, or summer perennial grass, that comes from the Kikuyu region of East Africa (Williams, 1980). It is named after the Kikuyu people of Kenya who traditionally lived where the grass thrives in the Aberdare Mountains (Mears, 1970). Kikuyu has been introduced to tropical, sub tropical and many temperate regions of the world because people were impressed by its vigour. Despite its introduction to many countries, it has not been welcome in areas such as North Island of New Zealand, Jamaica, and Fiji and in New Guinea and is considered a weed in California. It has been a useful introduction in areas of Angola, Cameroon, Morocco, Swaziland, Zimbabwe, St Helena, Mauritius, Madagascar, Madras, Ceylon, Taiwan, Norfolk Island, Hawaii, Brazil, Paraguay, Costa Rica, Panama, Colombia, New South Wales, Queensland and South Africa (Mears, 1970). Kikuyu was introduced to SA in 1908 (Mears, 1970) and has been extensively cultivated since 1911 (Roos, 1975). In many countries where kikuyu occurs naturally its potential productivity was overlooked until the 1960's because of the high cost of nitrogen fertilizer, lack of seed and the risk of it becoming a weed. Kikuyu rapidly invades cleared areas in the first stage of succession (Mears, 1970). It is an important pasture species in South Africa because it is potentially high yielding, resilient under poor management and has a favourable response to N fertilizer (Miles *et al.*, 1997). It is well adapted to the Mist belt of the KwaZulu-Natal Midlands (van Ryssen *et al.*, 1976) covering 30000ha of the province (Marais & Figenschou, 1990). It forms an important part of fodder flow, producing a large amount of dry matter (Dugmore & du Toit, 1988) and yielding up to 18 tons /ha/ season. It is also used in the Lowveld, Vaal triangle and the coastal regions of Eastern Cape (Marais

& Figenschou, 1990) as well as the Eastern Highveld. It is popular for lawns, parks and sportsfields, but more importantly it is an outstanding grass for animal production and has much to offer in intensive dairy systems (Roos, 1975).

Naturally kikuyu exists on forest margins in east and central Africa at an altitude of 1950 to 2700m in areas with an average rainfall of 1000 to1600mm and minimum and maximum temperatures from 2 to 8 °C and 16 to 22 °C respectively (Mears, 1970). The first factor limiting kikuyu growth is temperature, with high temperatures being preferred although it tolerates lower temps (Roos, 1975). Although fertile soil is essential for successful growth (Mears, 1970), soil is not considered to be a limiting factor with judicious fertilization (Roos, 1975). Although well drained and aerated soils are recommended, heavy clay soils are also suitable (Roos, 1975; Williams, 1980) and the grass can sometimes even grow in vlei areas (Roos, 1975), but will not withstand long periods of water logging (Williams, 1980). It should not be established on sandy soils of poor fertility because the high demand for fertilizer will make the pasture unprofitable through leaching out of nutrients. On soils with low fertility production will be disappointing regardless of rainfall. The performance of kikuyu improves as rainfall increases above 700mm (Roos, 1975), but the grass can still be grown successfully at rainfalls lower than 700mm if the soils have a high water holding capacity (Williams, 1980). Kikuyu is able to utilize moisture at depth during dry periods because of its root system (Mears, 1970).

Over 50 varieties exist with three ecotypes, *Mol*, *Kabete* and *Rongai* having been recognised by Edwards in 1937 (Mears, 1970). In California, where kikuyu is classified as one of the worst weeds, 12 different genotypes were identified (Wilen *et al*., 1995). Kikuyu reproduces asexually, via rhizomes and stolons, and also by seed that it is able to produce regardless of the growing conditions. In open areas kikuyu spreads by seeds, as there is less competition from existing plants. If kikuyu is physically destroyed, it can continue to survive through the germination of seeds in the soil. Kikuyu seed can spread via animals as it can remain viable after passing through the digestive system. Rethman (1989) found that about half of the viable kikuyu seed fed to sheep remained viable after it had passed through the digestive tract, and that 82% of the viable seed was excreted within 28 hours of ingestion. However, kikuyu primarily spreads vegetatively (Wilen *et al*., 1995). There has been much interest in the seeding variety of kikuyu, Whittet, but this was not found to be better than the non-seeding ecotype in production potential in KwaZulu-Natal (Cross, 1979a). Kikuyu grass spreads by stolons and rhizomes to form a dense sward (Williams, 1980), making it well adapted to heavy grazing (Roos, 1975). It has a more horizontal growth habit in the cooler highveld, and a more upright growth habit in hotter areas such as Ukulinga (Pienaar *et al.* 1993). Its high DM yield and protein content give it a potentially high carrying capacity. Its growing season is longer than most veld grasses, because of its frost resistance, (Roos, 1975) beginning earlier in spring than many established summer grasses and continuing into the late autumn (Williams, 1980). Although kikuyu will not survive sustained frosts, it survives light frostings and winter frosts that occur at night in many areas of South Africa. Light frostings cause the exposed herbage to become desiccated therefore improving the DM content and hence DM intakes (Mears, 1970). Kikuyu recovers early and quickly after a severe winter and has high resistance to dry periods (Roos, 1975). Palatability and acceptability to the animal are usually good (Roos, 1975). It is a grazing grass and not suited for hay production (Williams, 1980) because of its high moisture content. Surplus growth in the summer can be conserved for foggage purposes and used in winter (Williams, 1980). It has a good winter-feeding value with a CP content of 8 to 10% in Mpumalanga sourveld area (Roos, 1975).

1.5.2 Establishment of kikuyu pasture

Kikuyu can be established either with seed or with vegetative material (Roos, 1975). Most attention up until the 1970's was given to vegetative propagation because there was no machinery capable of harvesting the seed which prevented seed production on a commercial scale for many years (Mears, 1970). Mears (1970) identified that the high seed yields of 252 - 445kg/ha could suggest that commercial seed production would be feasible.

Planting vegetatively was done by means of hand planting, but was time consuming, labour intensive and it was often difficult to find sufficient quantities of rhizomes. Alternatively, pasture sods were lifted with a rotavator, which was a quicker method, and the rhizomes were collected (Roos, 1975). Hand planting was done by digging furrows one metre apart with a plough and placing the rhizomes (10 to 15 cm in length) 30 cm apart within each furrow. The rhizomes are lightly covered and compacted mechanically or by hand (Roos, 1975). Mechanical planting involves chopping the rhizomes into 2 to 8 cm long segments, spreading them over the land, which is then disked and rolled. This method can only be used in high rainfall areas or under irrigation as planting must be done in moist soil and then compacted. Vegetative plantings have an advantage in that even land is not necessary (Roos, 1975).

Seed established pastures require more management than those established vegetatively (Cross, 1979a). Kikuyu can be established from seed provided the cultivar used is suited to the climate (Cross, 1979a). Whittet is one of the best seeding strains, but starts growing later in the season, peaks higher and declines more rapidly than common non-seeding varieties. This is because the Whittet cultivar has been bred for hotter conditions along the coastal region of Australia. Whittet is not so tolerant of winter conditions and is recommended for warmer areas of the country (Cross, 1979a). Seed can be broadcast or drilled in. Direct drilling involves placing the small seeds just below the soil surface using narrow, inverted T-shaped tines, which can be attached to most conventional seeding machinery (Cransberg, 1995). Alternatively, seed can be mixed with fertilizer and planted using a maize planter (Williams, 1980). Seed establishment requires evenly cultivated land and 1.5 to 2 kg/ha clean seed (Roos 1975) or 2 to 3 kg/ha (Cross, 1979a) is needed with row spacing of 1 to 1.5m (Roos, 1975). Planting is done in early summer after reasonable rains, which ensures a good stand of strong plants before the first frost (Roos, 1975). Establishing later means fewer weeds but increased likelihood of frost damage. The end of January is the latest time for planting in Gauteng. Seeds begin to germinate from the fifth day and germination is 60 to 80% successful under controlled conditions (Roos, 1975). Seedlings are very vulnerable to adverse conditions such as drought, weed competition and heat until they reach the age when they produce stolons and rhizomes some six to eight weeks after germination (Cross, 1979a). Although broadcasting seed is possible, it is made difficult by the small amount of seed used and controlling weeds is not easily done (Roos, 1975). Row establishment simplifies mechanical weed control. Seed can be included in chaff, which is removed from areas that flowered well. The chaff is collected after the first frost has killed the unnecessary leaf and stem material and can be done as late as September (Roos, 1975). The chaff is spread over a fine seed bed in early summer, lightly worked and rolled, but the amount of chaff needed/ha is unknown and varies with amount of seed bearing chaff (Roos, 1975).

In the first year after establishment, kikuyu can be grazed if sufficient material is available and if the roots are sufficiently developed so that seedlings will not be pulled out. Grazing as well as slashing kikuyu in the presence of weeds promotes spreading (Roos, 1975). The grazing potential of kikuyu develops slowly because of its slow growth after establishment, especially if it is by seed, and is dependant on soil fertility. Under average conditions the production potential is thirty percent by year one, sixty percent by year two, ninety percent by year three and one hundred percent only by year four. In the first winter after establishment it is common for the runners to die back to the mother plant. Cutting the runners off from the mother plant can prevent this. If fertility is built up before sowing, full production potential can be reached in 2 years (Roos, 1975).

1.5.3 Fertilization requirements in terms of dry matter yields.

Fertilization strongly affects DM production and protein content of kikuyu. The DM production of kikuyu varies among regions of South Africa and according to rainfall, but a rough guide in tons per hectare under dryland conditions is given in Table 2. Dry matter production over the growing season ranges from 7280 to 11200 kg/ha (Mears, 1970) or from 10 to12 tons/ha with 15 being possible (Roos, 1975). The protein content varies from 20% in summer to 8 or 10 % in winter (Roos, 1975). The approach to fertilizing pasture has changed slightly from basing fertilizer applications purely on soil analytical data, with information from papers serving as a guide (Roos, 1975), to basing fertilization on replacing the nutrients that are removed and not just following recommendations based purely on soil fertility (Doonan & Irvine, 2002). If a farm is producing 350kg milk solids per hectare and 200 to 300kg milk fat per hectare then the levels of nutrients removed are 14 to 20kg/ha P and 40 to 65kg/ha K. Replacing what is removed will maintain pasture at that level of fertility with extra fertilizer required to improve soil fertility (Doonan & Irvine, 2002). The nutrients supplied to the pasture are not independent of each other. The efficient use of N fertilizer depends on adequate basal elements P, K and Mg being available (Cross, 1979a). High producing pastures require 150ppm K, 20ppm P and 60ppm Mg (Cross, 1979a). Fertilizer programs should focus on N and P. Little K is removed from the land by grazing and should only be applied if it is too low (Roos, 1975). Despite the recommendations, response to fertilization is variable even when the uneven distribution of the excreta is taken into account (Bransby, 1990). Efficient animal production on kikuyu requires sound N fertilization practices. Phosphorus and K are strongly held on clay particles, unlike N, which is lost by several routes (Manson *et al.*, 2000).

Table 2 Dry matter production of kikuyu for each month over the growing season (Roos, 1975)

Month	October	November	December	January	February	March	April
DM (t/ha)	0.8	1.4	2.0	1.8	1.6	1.2	1.0

A strict fertilization program should be followed prior to planting. Very acidic soils should be limed. Twenty to 40 kg/ha P should be disked into soils with a P content less than 10ppm, with larger amounts needed if roots are broadcast and disked in. About 150 to 200 kg KCl per ha should be applied if soil levels are low to ensure winter survival. Manure can be incorporated into OM deficient soil by feeding animals during the winter prior to establishment on the land (Roos, 1975). Once the seedlings are established, and begin to make runners, the grass is topdressed with 600 kg limestone ammonium nitrate (LAN) divided in two dressings, one in November and the other, no later than February. It is not necessary to apply P in the first few years if a good application was given before establishment. To quickly achieve the maximum potential of kikuyu pasture, a strict fertilization program is needed for the next three to four years (Roos, 1975). Once established, production is then determined by fertiliser applications, particularly N.

Kikuyu is often highly efficient in its response to N fertilizer which improves its competitive ability and extends its growing season (Mears, 1970). Lower N applications cause kikuyu to peak earlier. Herbage production can be maximised from 170 kg N /ha and upwards. It was found that applications of 90kg N/ha over the growing season caused production to peak one month earlier at Cedara (Cross, 1979a). Nitrogen fertilizer controls yield potential when rainfall is above 650mm during the growing season and basal fertilizer requirements are met (Cross, 1979a). Much research has been done on the response of kikuyu to N fertilizer under mowing in small plot experiments. Use of this information under grazing is inaccurate because the required amount of N can be less, with much of the N eaten being returned to the pasture in excreta (Bransby, 1990). Approximately 75 to 85% of the N in forage consumed by dairy cows is excreted (Miles, 2002). With DM production of 10t/ha, no significant difference was found between mown plots fertilised with 200kg N/ha/annum and grazed pastures fertilised with 141kg N/ha/annum indicating that an equivalent of 59 kg N/ha was being recycled (Cross, 1979a). It is estimated that, under grazing, a reduction of 30% can be made on N fertilizer recommendations established from cutting trials to achieve the same DM production, but only after the third year of pasture establishment. Similarly, a reduction of 40% can be made for P (Cross, 1979a). It is necessary to build up the desired level of N before any reliance can be placed on recycled nutrients (Cross, 1979a, Roos, 1975). Recycling of nutrients makes a larger contribution when cattle are eating high protein concentrate (Cross, 1979a).

Higher N applications generally improve animal gains and allow for higher stocking rates, but in some trials high N applications reduce average daily gains, possibly because of toxic compounds such as nitrates present in highly fertilized pastures (Bransby, 1990). This will be discussed in more detail in Part 3. Miles (1997) criticised experiments that set out to evaluate N effects on animal performance in their failure to include a zero N treatment, such as the trial by Bransby (1990). The contribution of N from the soil is not taken into account and extrapolation is unreliable (Miles, 1997). Plants can obtain N from mineralization of soil N, returned N in excreta and fertilizer application. The amount of N mineralized depends on the soil temperature and pH, which must favour microbial action, as well as the soil OM content and is at a maximum in late summer. N mineralization depends on the carbon to nitrogen ratio, which must be below 30:1 (Miles, 2002). The plant available N in the soil is limited. Unfertilized, previously productive pastures yielded 6 to 9 tons per hectare in the first year and 0 to 2 tons in the second year which is as low as pasture that had not been productive and not fertilized (Miles, 1997). At two-week cutting intervals soil N made no contribution, but did at 10-week cutting intervals with a contribution of 0.09 to 0.31 kg N/ha/day because of more extensive root activity and a more open sward at 10 weeks (Whitney, 1974).

It is recommended that 250 to 300 kg/ha/ N be applied per season, but more can be applied if climatic conditions are favourable or on sandy soils with rainfalls exceeding 800mm (Roos, 1975). Low DM yields of 5 to 8 tons/ha can be achieved with 60 to 150 kg N/ha, medium DM yields of 9 to 13 tons/ha can be achieved with 175 to 250 kg N/ha and high DM yields of 14 to 16 tons/ha can be achieved with 275 to 375 kg N/ha/annum (Manson *et al.*, 2000). The highest yields are only attainable under favourable climatic conditions and good management (Manson *et al.*, 2000). In the KwaZulu-Natal Mistbelt and Highland sourveld the efficiency of response to N fertilizer is 30kg DM/kg N over an application range of 0 to 250kg N per hectare. At low rainfalls the efficiency is much lower (Miles, 1997). Pasture yields per unit of N fertiliser increase with increasing cutting interval, up to a 10 week cutting cycle (Whitney, 1974). If larger amounts of N are applied, there is little response as efficiency declines sharply with the law of diminishing returns. If N is applied in excess of requirement accompanied by a low efficiency of response, then the return on investment of N decreases. The protein content increases and upsets the protein to energy ratio in the diet causing milk production to decrease. Excess N is a major cause of soil acidification, which increases long-term lime expenditure (Miles, 2002). Ammonium sulphate nitrate (ASN) has the highest and LAN the lowest acidifying capacity (Roos, 1975). Urea is 15 to 20% less efficient than ASN and LAN on kikuyu, but there is little difference between the fertilisers on Italian ryegrass (Manson *et al.*, 2000). According to Roos (1975) N should be applied in three split dressings over the grazing season in order to ensure a good distribution of protein during the summer and minimises losses of N due to drought. The amount applied should decrease gradually as the season progresses. Miles (1997) recommended that six dressings be applied as apposed to three as this improves the efficiency by 3.5kg DM per kg N and further minimises N losses through leaching, denitrification and volatilisation. Infrequent heavy dressings increase CP and nitrate content of kikuyu (Manson *et al.*, 2000). Nitrogen is available to the plant for two to eight weeks after fertilisation (Whitney, 1974). According to Manson *et al.* (2000), the amount of fertilizer to apply should correspond to the immediate production required and the interval before the next N application. Dressings of 40 to 75 kg N/ha on established kikuyu should give maximum yields, depending on frequency of application and soil quality. Nitrogen should be used strategically. It should not be applied in mid summer when feed is not limiting (Manson *et al.*, 2000).

Up until the 1970's, little investigation had been done on the P requirement of kikuyu (Mears, 1970). Mears (1970) found that responses to P were limited to P deficient soils. The uneven distribution of excreta can make soil analyses inaccurate, as soil samples pooled over a whole paddock will yield results indicating sufficient quantities of P and K, when there are areas where they are deficient. Areas around trees and drinking troughs have very high concentrations of P and K (Twiddy personal communication, 2002). Grass is able to maintain a high P content ranging from 0.2 to 0.42% (Mears, 1970). Miles (1997) found little or no response to P. The response to P and K is heavily dependent on there being sufficient N. At high levels of N, increasing P and K increases the yields (Cross, 1979b). Similarly, for kikuyu to respond well to N, the requirements for P and K must be met (Cross, 1979b). Cross (1979a) observed an additive effect of P and N on production when an increase in DM yield of 4111 kg/ha was obtained with increased applications of N and P from 195 and 66kg/ha/season to 390 and 88 kg/ha/season respectively. Miles (1997) found no evidence of a P-N interaction. Roos (1975) recommended, that under heavy grazing conditions and if sufficient P was applied at establishment, annual applications of only 16 to 25 kg/ha (Roos, 1975).

Potassium deficiency is unlikely to occur in kikuyu (Mears, 1970) because it is recycled through the animal (Cross, 1979a). Roos (1975) still recommended an annual application of about 100kg KCl/ha/annum despite the recycling of nutrients and that the amount should be increased according to soil sample results. According to Roos (1975), large amounts of K are removed from the soil by kikuyu. Kikuyu has K levels of 0.64 to 1% (Mears, 1969 cited by Mears, 1970). Kikuyu has been known to respond to sulphur application on krasnozen soil in Queensland, but usually superphosphate can correct any marginal sulphur deficiency (Mears, 1970). If superphosphate is not being used then there can be sulphur deficiencies.

1.5.4 Kikuyu pasture compared with ryegrass pasture

It is difficult to compare pastures and animal performance because there are few reports where kikuyu has been compared with other species under similar climatic and soil conditions (Mears, 1970). This must be borne in mind in this discussion. Although under the traditional dairy farming system in South Africa, the two pastures are considered to have different roles, there is much use of perennial ryegrass pastures as the preferred pasture over the summer months. Kikuyu and ryegrass are commonly used pastures for dairy production in South Africa. Differences between kikuyu and ryegrass often relate to inherent differences between the tropical and temperate pastures as discussed in Part 1.2, but more species specific differences do exist. Kikuyu is generally regarded as an outstanding grass for animal production, comparing favourably with other tropical grasses in terms of digestibility and chemical analysis and is comparable with lucern (Davie & Pienaar, undated). The traditional dairy production system in KwaZulu-Natal uses kikuyu pasture in the summer months and annual ryegrass in winter. Extending the grazing season on annual ryegrass has been the focus of much research for plant breeders, because of its superior quality, but maintaining ryegrass pastures is expensive. Kikuyu has positive attributes including high DM yields, ability to respond to fertilizer, a high retention of minerals, a long period of vegetative growth, a high digestibility and intake of DM, ability to withstand heavy grazing and tolerance of cold, but is not very compatible with legumes (Ross, 1975). It is not as palatable as temperate species, but is still considered to be a sweet grass and maintains palatability into late summer and even early winter (Roos, 1975). Temperate species are generally less persistent with a growing season that is shorter, but are more compatible with legumes. Perennial ryegrass will eventually require replanting after two to five years depending on the soil type and grazing management. Kikuyu has a growing season that is longer than most veld grasses because of its frost resistance and is persistent because of its rhizomes and stolons. Temperate pastures are more vulnerable to dry conditions and require irrigation. Although kikuyu requires less moisture than temperate pastures other grasses such as *Eragrostis curvula* and *Cenchrus ciliaris* perform better at rainfall lower than 700mm. *Eragrostis curvula* is a better pasture grass in the early season as dryland kikuyu has insufficient DM at this time to satisfy animal requirements. Kikuyu peak production is only reached at the end of December (Roos, 1975).

Chemical composition of plants depends on soil nutrient level and the physiological age with older plants being of poorer quality (Roos, 1975). Chemical analyses of samples of kikuyu pasture taken throughout the growing season indicate that it is similar in composition to Italian ryegrass (*Lolium multiflorum*) (Dugmore & du Toit, 1988), but milk production from kikuyu pasture is generally low, despite its composition and high total DM yields (Reeves *et al.*, 1996b). This is atypical of animal performance on tropical grasses, which usually exceeds expectations from chemical analyses through selection of diet by the cow and her ability to milk off her back (Stobbs, 1972). This once again highlights the danger of predicting animal performance from chemical analyses as discussed in Part 1.2. Milk production from cows on kikuyu alone is 11ℓ in early summer, 9ℓ in mid summer and 6.8ℓ for late summer compared to ryegrass which can supply sufficient nutrients for maintenance and production of 16ℓ of milk (Warren, 1972 cited by Dugmore & du Toit, 1988). Well-managed kikuyu in New South Wales offered to Friesians of average genetic merit will yield 13 to 16ℓ/cow/day of milk (Reeves *et al.*, 1996b). Production on perennial ryegrass pasture (*Lolium perenne*) is from 22 to 24ℓ under the same conditions (Reeves *et al.*, 1996b).

Table 3 Mean nutrient concentrations (%DM) of well-managed kikuyu and ryegrass (Reeves *et al.*, 1996b).

Nutrient	Kikuyu	Ryegrass
CP	20.75a	25.23b
DOM	73.4a	84.21b
ADF	23.1a	17.74b
NDF	60.3a	39.5b
Ca	0.305a	0.592b
P	0.308	0.333
K	3.07	3.44
Na	0.015a	0.37b
Mg	0.24	0.24
Oxalic acid	0.68a	0.12b
WSC	1.93a	9.10b
Starch	3.44a	6.60b
Nitrate	0.026	0.046
Amino acids (g/kg CP)	713	918
NPN (g/kg CP)	221	245

Within row means with different letters are significantly different (P=0.05)
CP crude protein, OMD organic matter digestibility, ADF acid detergent fibre, NDF neutral detergent fibre, Ca calcium, P phosphorus, K potassium, Na sodium, Mg magnesium, WSC water soluble carbohydrate, NPN non-protein nitrogen.

The primary reason for less milk produced from kikuyu is believed to be a shortage of readily fermentable carbohydrate (WSC and starch). The importance of NSC in the diet of the dairy cow is further discussed in Part 3. NSC of kikuyu compares favourably with other subtropical grasses, but is far lower than temperate species such as ryegrass (Marais & Figenschou, 1990). According to Marais & Figenschou, (1990) the type of NSC present in kikuyu is primarily sucrose and starch could not be detected. This is contradictory to work by Reeves *et al.* (1996b) where starch was detected (Table 3). The total carbohydrate in ryegrass is 157g/kg DM compared to 53.7g/kg DM in kikuyu (Reeves *et al.*, 1996b). The levels of WSC in kikuyu over the season are given in Table 4. WSC in kikuyu increases in the leaf and stem during the morning and reaches a maximum at mid afternoon (Reeves *et al.*, 1996b; Marais & Figeschou, 1990). The stem has a greater capacity to accumulate NSC. In the afternoon, NSC levels out; this indicates equilibrium between photosynthesis, translocation and utilisation. When regrowth is six weeks old, kikuyu has a lower concentration of NSC which may be due to higher fibre content (Marais & Figenschou, 1990). There is a large overnight drop in NSC because the sucrose content fluctuates, which could affect the nutritional value of kikuyu. *Lolium perenne* herbage loses very little NSC because it contains mainly fructosan instead of starch (Marais & Figenschou, 1990). The NSC content of *Lolium multiflorum* is 250g/kg DM of which 170g/kg consists of fructosan (Waite & Boyd, 1953 cited by Dugmore & du Toit, 1988). The NSC content of kikuyu is only 30 to 50% of that in Italian Ryegrass (Marais, 1998). The WSC content determined at 9 am was 0.36 in ryegrass and 0.09 in kikuyu (Reeves *et al.*, 1996b). In winter, perennial ryegrass has a high NSC content because clear skies and high solar radiation maximise photosynthesis and minimise loss through respiration. Lower night temperatures contribute more to higher NSC content by minimising losses than clear skies do by increasing photosynthesis (Fulkerson *et al.*, 1998). Fluctuations in WSC have important implications in milk production as farmers use kikuyu as night pasture when annual ryegrass is available. At this time the WSC content of kikuyu is at its lowest. This also poses problems for farmers with cattle on kikuyu for 24 hours a day in mid summer as high temperatures can lead to dairy cattle consuming most of their daily DM intake at night.

From Table 3 it can be seen that ryegrass has significantly higher concentrations of crude protein (CP), non protein nitrogen (NPN), DOM, WSC, starch, Ca and Na (Reeves *et al.*, 1996b). Kikuyu has significantly higher concentrations of ADF, neutral detergent fibre (NDF) and total oxalates (Reeves *et al.*, 1996b). Kikuyu and ryegrass both have high levels of NPN, being 220 and 240 g/kg NPN respectively, and therefore relatively low levels of true protein. The NPN content of perennial ryegrass-white clover and kikuyu pasture is the same at 26% CP (Fulkerson *et al.*, 1998). These high levels of NPN and relatively low levels of true protein may result in the overestimation of the protein value to animals (Reeves *et al.*, 1996b). There are differences in protein quality as in kikuyu, 71% of the total N content comprises amino acids compared to 92% in ryegrass (Reeves *et al.*, 1996b). Levels of each amino acid in kikuyu do not change significantly with season and are not significantly different from ryegrass with the exception of cysteine and methionine which were lower. Methionine is one of the two most limiting amino acids in ruminants grazing pasture, the other amino acid being lysine (Reeves *et al.*, 1996b). Sodium is much higher in ryegrass, a natrophil, than kikuyu which is a natrophobe (Miles *et al.*, 1995). The Na content of kikuyu remains much the same over the growing season, but is much lower than recommended and supplementation is essential (Reeves *et al.*, 1996b). The Na content of perennial ryegrass increases with regrowth time (Fulkerson *et al.*, 1998). The P, Mg and K contents of kikuyu and ryegrass were not significantly different in Table 3. Potassium levels in kikuyu are high at leaf emergence and gradually decline to a level at or below those found in ryegrass at full elongation (Reeves *et al.*, 1996b). The ratio of N to K should be less than 20 to avoid lengthening the intercalving period (Berringer, 1988 cited by Fulkerson *et al.*, 1998). The ratio is below 12 for temperate grasses, but the mean value for kikuyu is 30 (Fulkerson, 1998). The ADF content in ryegrass is lower than recommended 19-21% to prevent milk fat depression but levels in kikuyu are adequate (Reeves *et al.*, 1996b). The ratio of Ca to P in perennial ryegrass leaf is 2.2 at the three leaves per tiller stage; with Ca content increasing and P content decreasing with regrowth time (Fulkerson *et al.*, 1998). The Ca and P contents of kikuyu over the season are given in Table 4. It can be seen that kikuyu follows the opposite trend with the lowest ratio of Ca to P at the time of maximum growth in summer of 0.76 to a high in autumn of 1.26. The Ca to P ratio varies from 0.9 to 2.5. In both perennial ryegrass-white clover and biennial ryegrass pastures, the P content barely meets the maintenance requirement of the dairy cow. Zinc and Cu are marginal in ryegrass and Zn is low in kikuyu (Fulkerson *et al.*, 1998).

Table 4 Variation in the chemical composition of kikuyu over the seasons (Fulkerson *et al.*, 1999)

Season	WSC (%)	Starch (%)	NDF (%)	ME (MJ/kg)	N (%)	Ca (%)	P (%)
summer	4.2	5.9	56	8.2	2.85	0.25	0.33
autumn	3.7	4.1	52	9.3	2.83	0.34	0.27
spring	5.7		43	9.1	2.32	0.26	0.26

WSC water soluble carbohydrate, NDF neutral detergent fibre, ME metabolisable energy, N nitrogen, Ca calcium, P phosphorus.

Pasture experiences a drop in quality as its growth slows down, meaning that dairy cattle grazing any pasture species require supplementation. The drop in kikuyu quality is seen in the reduced WSC and starch levels in autumn shown in Table 4. Kikuyu and ryegrass both have unfavourable protein to energy ratios, which limit milk production (Fulkerson *et al.*, 1998). Despite the higher WSC content of ryegrass, it still has an unfavourable WSC to protein ratio of 0.36 (Reeves *et al.*, 1996b). In kikuyu and ryegrass, NSC is negatively correlated to N (Marais & Figenschou, 1990). This is seen in kikuyu pasture in Table 4 in spring where WSC was highest and N lowest. Unfortunately the starch content of kikuyu in spring in Table 4 is not available. The ratio of CP to WSC in perennial ryegrass ranges from 3.5:1 to 1.2:1 depending on the season, but remains constant for biennial ryegrass at 2.3:1 (Fulkerson *et al.*, 1998). The WSC to CP ratio of perennial ryegrass-white clover pasture was 3:1 in early autumn and 2.7:1 in late spring (Fulkerson *et al.*, 1998). There is a decline in NSC levels in kikuyu leaves from the 1.5 leaf per tiller stage to the 3.5 leaves per tiller stage of regrowth, after which it remains constant. Protein levels stay relatively constant so the ratio of protein to NSC in kikuyu stays around 2.8:1 from the 3.5 to the 4.5 leaves per tiller stage of regrowth (Fulkerson *et al.*, 1998). Ryegrass regrowth samples taken at the three leaves per tiller stage had a CP to NSC ratio of 2.5:1 (Fulkerson *et al.*, 1998). Kikuyu pasture has lower metabolisable energy (ME) content than temperate pastures. The ME content of biennial ryegrass ranges from above11.5 MJ/kg DM to below 10 MJ/kg DM in late spring when nearly all tillers became reproductive (Fulkerson *et al.*, 1998). The ME values of perennial ryegrass-white clover pasture ranges from above 11MJ/kg DM in May to 9MJ/kg DM in summer following stem elongation and seed set. The mean ME value for kikuyu varies over the growing season (Table 4), but on average is 8.5 MJ/kg DM (Fulkerson *et al.*, 1998).

Kikuyu and ryegrass both have inflated K levels, Mg deficiencies and similar nitrate contents. The major disadvantages of kikuyu in relation to ryegrass include deficiencies in Na, Mg, Ca and energy and higher levels of oxalic acid. The kikuyu compared in Table 3 is well managed, therefore comparing more favourably with ryegrass than may be expected.

Well-managed kikuyu pasture is a cheaper pasture to maintain than perennial ryegrass as was discussed in Part 1.4. More use of this cheaper pasture could be made through seasonal calving, matching pasture supply and animal demand.

1.5.5 Kikuyu grazing management practices

Home grown forage is the cheapest source of feed and in order to increase production, limiting factors have to be identified. The most profitable option for dairy farmers is to utilize as much pasture as possible as the main feed source. Pasture or pasture-based supplements should make up 85 to 95% of the diet on a dry matter basis because a direct relation has been identified between pasture utilization per hectare and gross margin per hectare (Doonan & Irvine, 2002). In order to achieve maximum production pasture quality and quantity should be considered as they both directly affect animal performance and are affected by management and environmental factors (Doonan & Irvine, 2002). Cross (1979b) considered the importance of pasture quality in addition to quantity in trials using dairy cattle. Poor grazing management accounts for low milk production from cows grazing kikuyu, especially in late summer and early autumn, as feed intake and herbage quality are negatively affected. For reasonable milk yields, special attention must be paid to grazing management (Cross, 1979b), namely pasture quality, utilization (grazing duration and intensity), and regrowth potential (Reeves & Fulkerson, 1996b). Little research has been done on these aspects of pasture management, which are becoming increasingly important as farmers begin to view the cow as no longer the centre of milk production, but as a means of converting grass into milk. There is a need to evaluate management systems more from a grass point of view, in terms of grazing dynamics rather than on animal factors and set stocking rates, as farmers cannot begin to meet animal dietary requirements if pasture management is not sound. Kikuyu is a high producing, relatively inexpensive source of feed, considering the possible returns, but can become expensive if not properly utilized (Roos, 1975). With correct grazing management over the summer of nearly seven months, milk yields of about 9000 ℓ/ha without supplementation and 13000ℓ/ha with an energy supplement can be obtained (Cross, 1979b).

The utilization of pasture should be the focus of improving returns on dairy farms because if pasture is well utilized, quality should, theoretically, be maximized by the prevention of the build up of residual material. The best method of utilizing pasture has been the focus of research over the last few decades, but the methods of quantifying pasture use have produced unclear results, which are often of little practical use to the farmer. Bransby (1983) and Bartholomew (1985) considered quantity of pasture to be the most important factor determining animal performance and little attention was paid to pasture quality. Bransby (1983) and Bartholomew (1985) tried to maximise pasture utilization by focussing on the animal numbers required to harvest the pasture, hence stocking rate was considered to have the largest influence on the performance of animals and pasture. In fact most research in South Africa has been carried out to evaluate performance of pastures and animals at set stocking rates. Stocking rate and grazing intensity are not very useful terms as they are defined as the number of animals per unit area of land and the number of animals per unit of available forage respectively (Mott, 1960 cited by Greenhalgh *et al.*, 1966). Grazing intensity is the more useful term of the two, but is difficult for nutritionists to use as they see food needed per animal as being more appropriate. Herbage allowance, or herbage allowed per animal over a period of time, is therefore used (Greenhalgh *et al.*, 1966). Bransby (1983) linked the importance of stocking rate to herbage availability. He studied the effect of pasture availability on animal performance by attempting to keep the pasture height constant and adjusting animal numbers using the put and take system. This system was a move away from set stocking rates, but did not take changes in pasture quality into account as pasture of a particular height can have considerable variation in quality depending on growth stage. Kikuyu quality deteriorates at almost the same rate over the season regardless of height (Bransby, 1980). The quality of herbage consumed can be affected by the herbage allowance as a large allowance allows for selective grazing. The optimal allowance varies according to the nature of the herbage as more mature pasture may require a higher allowance than younger pasture (Greenhalgh *et al.*, 1966). Stocking rate was found to have no significant effect on seasonal DM production with rainfall having a far larger effect (Bartholomew 1985).

Results of comparisons between rotational and continuous grazing systems have generally shown no significant difference; perhaps because of the use of beef weaners that are not nearly as sensitive to changes in pasture quality as dairy cattle. Theoretically average daily gains should be lowest for continuous grazing treatments and highest for the rotational grazing treatment with the stocking rate that has the most optimal combination of pasture availability, rate of intake, utilization and quality. Bartholomew (1985) found that the CF fraction was lowest for the grass under the highest stocking rate, which should indicate superior quality grass and should improve average daily gains. A possible reason for the little difference seen in animal performance under continuous and rotational grazing is that animal performance can be high on any grazing system as long as energy intake is sufficient, meaning that there must be enough leafy, digestible pasture available (Blaser, 1981). Animal performance on most tropical pastures is not improved under rotational grazing compared to continuous grazing, unlike temperate grasses where production per hectare is higher on highly stocked, rotationally grazed pasture. The rotational grazing system employed is a set number of days grazing and rest. According to Blaser (1981), rotational grazing results in the build-up of mature herbage that prevents selective grazing. The comparison of grazing systems fails to take the most important measurement, being pasture allowance, into account. According to Mears (1970), frequency of defoliation effects chemical composition. Cattle under continuous grazing may graze for longer and make up for a lower rate of intake, which can be successful provided that availability is not limiting (Pattinson *et al.*, 1981). Cattle under the rotational grazing system may be grazing poorer quality herbage. Milk production fluctuates on fixed rotational grazing systems as the level of nutrition changes. The potentially higher output per hectare or per animal on grass species that respond to rotational grazing can be cancelled out by rigid rotation systems based on fixed dates, or by constant stocking rates. These effects cause poor plant performance and can destroy pastures, resulting in poor animal performance. Under rigid rotational grazing, the nutritional requirements of animals and the management of pastures for quality and high yields are ignored (Blaser, 1981).

Booysen (undated, cited by Bransby, 1983) stated that pasture should be characterised under continuous grazing initially so that the results would be free of any variation brought about with rotational grazing systems. But, animal performance is more dependent on pasture availability than the grazing system employed (Bransby 1983; Blaser 1981). Both continuous and rotational grazing systems can optimise animal performance. It is set stocking rates that are detrimental to grazing systems as they fail to take the nutritional requirements of ruminants and the management requirements of the pasture into account and cause extreme variability in the quality and quantity of pasture available over the year (Blaser, 1981). Blaser (1981) went on to say that the stocking rate experiments could not allow for suitable analysis and advances in understanding (Blaser, 1981). Under set stocking rates, growth of the pasture exceeds utilization in summer and the pasture becomes low in leaf density and high in stem, reducing DM intake (Brown *et al.*, 1968 cited by Blaser, 1981). Animals and pasture should be managed together in order to achieve desirable yields and maintain a good quality sward, especially with tropical pastures (Blaser, 1981). It is important that research results are of use to the farmer. Set stocking rates do not help the farmer fine tune his pasture management for dairy production, which is dependent on a variety of continuously changing and often site specific environmental and management factors. Stocking rates should be variable so that pasture can be allocated to stock in terms of their requirements.

According to Blaser (1981), "managed rather than set variables can improve the efficiency of animal production". Rotational grazing should be replaced by systems that are more flexible. Conserving herbage improves pasture availability and quality. Constant stocking rate experiments should be replaced with variable stocking rate experiments to overcome the problems of low production and FCE and high costs of having several stocking rates (Blaser, 1981). Pastures need to be quantified in terms of management practices, rather than grazing systems and although the management strategies for optimising milk production are likely to be different from farm to farm, major trends must be identified. It is important that there are sufficient cows to harvest the available pasture than to stick to a particular stocking rate. Stocking rate, in addition to N fertiliser application, as discussed in Part 1.5.3, should continuously change through the season as pasture growth rate changes so that supply meets demand. Pasture management that maximises quality and quantity must be based on measures that are applicable to all farms so that it is useful to all farmers.

1.5.5.1 The Grazing Interval

Grazing interval has a major affect on pasture quality and growth (Reeves & Fulkerson, 1996) and must be based on plant growth characteristics (Fulkerson *et al.*, 1993) so that the quantity and quality of the pasture available is optimised (Reeves & Fulkerson, 1996a). Dairy farmers in South Africa generally determine the grazing interval according to a set period of time and variations in pasture growth over the season are not taken into account. When the grazing interval on a ryegrass white clover pasture was based on growth characteristics as apposed to a fixed time period of two weeks, the seasonal yield was 32% greater (Fulkerson *et al.*, 1993). Basing grazing interval on plant growth should improve yield, quality and hence milk production. Mears (1970) identified that successful management of kikuyu pasture requires knowledge of the interaction of the frequency and severity of defoliation with N application. New growth in adequately fertilised kikuyu is palatable and must be properly utilized to prevent the grass from becoming rank and developing a mat formation (Cross, 1979b). Karnezos *et al.* (1988) found even steer performance to be dependent on the stage of regrowth of the pasture, despite the lower sensitivity of beef animals to diet quality compared to dairy animals. In South Africa, management of kikuyu pasture has not been quantified in terms of pasture yields. Recommendations can be made, but they are not backed up with figures, which are crucial in convincing farmers, who are generally resistant to change, to adopt new technologies. Quantifying kikuyu management is difficult as kikuyu quality varies even when planted in the same area (Cross, 1979b).

Over the years, there have been many debates as how best to graze kikuyu pasture. In addition to arguments over whether continuous or rotational grazing is better, the length of the grazing cycle in a rotational grazing system has been debated. Flexible management systems were not really considered to be an option. If grazing interval is based on plant growth characteristics, continuous grazing and rigid rotational grazing systems become impossible to implement. Williams (1980) thought that rotational grazing would be more efficient. In 1970, Mears suggested that research be done to prove the assumption correct that rotational grazing results in more efficient use of N and improves animal performance. Mears (1970) suggested that maximum production would be obtained on kikuyu that is frequently hard grazed and fertilized with N, but no figures were given. Turner (2002) found that grazing kikuyu in quick rotation resulted in pasture high in NPN and lower in fibre that reduced milk solids and cow condition. Consequently, he uses longer rotations of 24 to 30 days. Roos (1975) identified that the productivity of kikuyu could be increased if grazing management was based on a system of short duration grazing as better utilization could be achieved on a rapid rotational system. Large numbers of paddocks would be needed for short periods of grazing and would be rested until their turn comes around for grazing again (Roos, 1975). According to Williams (1980), many farmers have 8, 10 or even 20 paddock rotational grazing systems with rest periods of approximately 20 days, but he made no mention of how this 20 day rotational system should vary in length over the season to accommodate the growth rate of the pasture or how period of stay would affect pasture growth. There was recognition that the grazing periods should be shortest when the grass was growing the fastest. Roos (1975) gave vague guidelines stating that in a 16-paddock system the grazing period would fluctuate from one to four days, which would mean a rest period of from 15 to 60 days.

Henning *et al.* (1995) studied the effects of the period of time a pasture was grazed and the period of time a pasture was rested on the performance of dairy cattle. Pasture was stocked at two Friesian cows per hectare and grazed for one, two or four day periods of a 15, 30 or 60 day rotation cycle respectively from December to May. Unfortunately he did not compare various periods of stay against one period of rest and vice versa. A 30-day rotation cycle gave the best results with milk yields, fat corrected milk, lactose and solids not fat being highest. This confirms that high quality kikuyu pasture can be achieved if the period of rest between grazing periods in a rotation does not exceed four weeks (Cross, 1979b) and that cycles that are too short cause reduced milk yields (Turner, 2002). It also disproves Mears (1970) theory that production is maximised by quick grazing rotations. Neither butterfat nor protein was affected by rotation cycle (Henning *et al.*, 1995), which contradicts Turner (2002) who observed a reduction in milk solids when the grazing rotation was short. Cows on the 15 day cycle grazed longer each day to try and compensate for the lack of DM availability, grazing 8.1 hours compared to 6.3 hours on 30 day cycle and 5.7 hours on 60 day cycle (Henning *et al.*, 1995). Milk yields showed a marked autumn slump on the 15-day cycle and the other two cycles showed a steady decline in milk yields from 13.5kg in December to 8.4 kg in May. OM intake and OMD *in vitro* did not differ between cycles, but OMD decreased for all cycles from 67.6% in December to 44.7% in May. Pasture availability was identified as being the most important in determining the volume of output per unit area and little mention was made about pasture quality (Henning *et al.*, 1995). The average canopy heights over the season were 85, 150 and 300mm for 15, 30 and 60 day rotation cycles respectively. In spring (November and December) the 60-day rotation cycle produced the highest milk yields and then the 30-day cycle produced the highest yields from December to March. The 15-day cycle out yielded the others from April to May

(Henning *et al.*, 1995). This highlights the importance of basing the grazing rotation on pasture growth characteristics.

To successfully use plant growth characteristics in determining the grazing interval, a plant growth characteristic has to be easily measurable and consistent in indicating grazing readiness. Pasture height has been used because it is believed to have a major effect on DM intake, given that cattle use their tongues to graze (Bransby 1980). Pasture height is a better indicator of grazing readiness than time between grazing periods, but is better used for determining nutrient supply on areas of uniform fertility rather than grazing readiness (Reeves & Fulkerson 1996a). This is because pasture height is influenced by soil fertility and air temperature and is therefore not solely related to plant development (Dairylink, undated). Fulkerson (1999a) found no significant relation between pasture height and the amount of rank material, meaning that pasture height does not give an accurate assessment of quality. Pasture height may not give an indication of grazing readiness in terms of pasture quality, but it is useful in ensuring adequate DM intake. Herbage intake usually increases at a decreasing rate with increasing pasture height, up to a certain point, after which it falls (Stobbs, 1975). Pasture mass is important in addition to pasture height and cannot be easily separated from the effects of pasture height because there are confounding results as changes in height and mass is associated with a change in nutritive value (Stobbs, 1975). There is a significant relation between leaf bulk density and intake and the effects of leaf bulk density and the ratio of leaf to stem could not be separated either (Stobbs, 1975). Stobbs (1973) found that variations in pasture height have a smaller influence on intake than leaf density or the leaf to stem ratio. In order to increase dry matter intakes on tropical pastures, management should aim for increased pasture density and leaf to stem ratio .

Many researchers (Roos, 1975; Bransby, 1990) have used pasture height as an indicator of grazing readiness with the first paddock being grazed in spring after fertilization when the pasture is 10cm in height. It is not evident whether they carried out any research to determine the optimum height. Roos (1975) argued that grazing at the 10 cm pasture height would ensure that the cattle would not be placed on kikuyu pasture too early in the season when selective grazing could result in decreases in mass. Grazing should only commence when there is enough growth to ensure sufficient DM intake, which is unlikely to occur before the grass is 10 cm high (Roos, 1975). According to the results from Henning *et al.* (1995), 30cm would be the correct height to graze kikuyu in spring, although this was only compared against 8.5 and 15cm. Measuring pasture height with a disc metre does not account for losses through uprooting and contamination and is a measure of the whole paddock and not of individual tillers. The falling plate disc metre measures compressed herbage and not herbage height, which is confusing and inconsistent, therefore not being successful when applied to farming situations (Bransby, 1980). Cattle prefer grazing tillers that have not been previously grazed. Bransby (1980) suggested that the proportion of the pasture grazed might be a useful indication of when to move animals in a rotation system. When 80 to 90% of the pasture has been grazed for the first time, grazing spread is reduced considerably and animals should then be moved to avoid restricting intake (Bransby, 1980). This method does not allow for easy measurement as it focuses on animal behaviour and not on pasture growth. It would be very difficult to quantify and does not indicate grazing readiness. Using leaf stage for determining the grazing interval reduces wastage through leaf senescence and reduces the decline in pasture quality (Reeves & Fulkerson, 1996a). At the correct leaf stage plant reserves have also been replenished sufficiently (Reeves & Fulkerson, 1996a). South African farmers and researchers generally regard grazing kikuyu according to leaf stage as impractical, but this may be because it is a relatively new method of establishing grazing readiness and there is a general resistance to change.

1.5.5.2 Leaf stage

Reeves and Fulkerson have done much work at Wollongbar research station in Australia in establishing leaf appearance as a means of deciding when pasture should be grazed. The use of leaf stage as an indicator of kikuyu grazing readiness has resulted from its successful use for ryegrass pasture. Using leaf stage as an indicator of grazing readiness poses different challenges for kikuyu compared with ryegrass. Ryegrass and kikuyu are different as discussed in Part 1.5.4. They have different physiology as ryegrass consists of a series of individual tillers, each tiller regrowing after grazing until about three leaves have expanded (Dairylink, undated). This number is maintained through the replacement of dying leaves with new leaves. The growth point of ryegrass is near the soil surface, so it is hard to kill ryegrass by hard grazing. Kikuyu differs from ryegrass because it has a stem in its vegetative state, unlike ryegrass that only develops a true stem when it is in its reproductive stage of growth (Dairylink, undated). Kikuyu grazing management focuses particularly on keeping the proportion of stem and dead material as low as possible in relation to leaf and offering as much leaf to the cow as possible. This is because leaf has 9.2 MJ/kg DM ME and 21.3 % protein in comparison to the stem that contains 7.4 MJ/kg DM ME and 16.7 % protein (Reeves & Fulkerson, 1996a). The focus with ryegrass management is to keep the proportion of dead leaf material and wastage down. Figure 1 and Table 5 below give the changes in the energy value and quantity of kikuyu with regrowth time in summer and illustrate the importance of maximising kikuyu leaf to stem ratio and grazing kikuyu early.

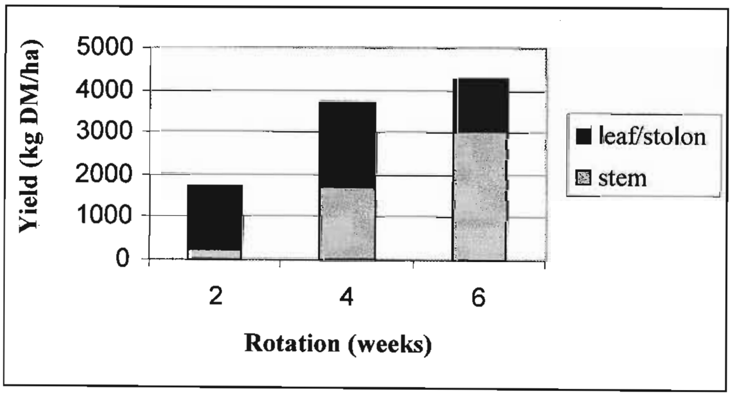


Figure 1 Yield and pasture quality of kikuyu leaf, stem and stolon in summer, during a period of rapid growth (Northland kikuyu action group KAG, 2002).

Table 5 Energy (MJ ME/kg DM) values of kikuyu leaf, stem and stolon in summer, during a period of rapid growth

	Rotation length (weeks)		
	Two	Four	Six
Leaf	10-11	9-11	9-10
Stem/stolon	9-10	8-9	7-9

Ryegrass management aims at maximising persistence, quality and utilization. Kikuyu management should aim at maximising pasture quality and utilization (Reeves & Fulkerson, 1996a) by presenting the pasture to the cow at the correct stage of regrowth, removing rejected pasture and applying the correct fertilizer (Fulkerson, 1999a). Kikuyu is inherently a poorer quality grass being less digestible than ryegrass at the same stage of development (Reeves & Fulkerson, 1996a). Its decrease in quality over the season is because farmers assume that it does not require careful management. Kikuyu is extremely resilient and can survive even under very poor management. In contrast farmers follow strict pasture management programs for ryegrass production, as this is the only way to ensure its survival.

Using leaf stage as an indicator of grazing readiness has been successfully used with ryegrass pasture because it is usually well managed and uniform in stage of growth. Using this technique on mismanaged kikuyu poses some problems because it can only be done in well grazed or well mulched pastures (Reeves & Fulkerson, 1996a). This limits the use of this technique in South Africa. Grazing based on leaf appearance intervals is the best way to determine when to graze and the duration of grazing (Fulkerson, 1999a). The growth of ryegrass and kikuyu are both dependent on temperature and the time taken for one leaf to appear is the leaf appearance interval. In well-grazed pastures, the plant relies on carbohydrate reserves to initiate growth before it has sufficient leaf to begin photosynthesis. Ryegrass can be grazed when two leaves have expanded as its carbohydrate reserves have been sufficiently replenished. This sets the minimum grazing interval. Three or three and a half leaves per tiller sets the maximum grazing interval as beyond this point senescence begins and quality declines (Fulkerson *et al.*, 1993). Grazing between two and three and a half leaves per tiller equates to about 2.4t DM/ha and the level of wastage is acceptable. At yields greater than 2.5 t DM/ha, utilization is poor. Grazing at the three leaves per tiller stage improves ryegrass survival (Fulkerson *et al.*, 1993). The harder the pasture is grazed at one grazing, the higher the pasture utilization, but if the pasture is grazed below 5 cm then production per cow decreases and the plant's reserves are removed and less leaf remains to initiate regrowth. More NSC is used to affect growth at more severe levels of defoliation (Fulkerson *et al.*, 1999), so leaving a few leaves speeds regrowth but utilization drops because of the dead material present. Defoliating at an earlier stage, such as the two and a half leaves per tiller stage, may be necessary at peak season or in times of moisture stress because growth has slowed down (Fulkerson *et al.*, 1993). Waiting till the three and a half leaves per tiller stage will result in the pasture being wasted as it becomes unpalatable.

In comparison, kikuyu should be grazed at four and a half new leaves per tiller (Reeves & Fulkerson, 1996a) or at the three to four new leaves per tiller in summer and spring and five or six leaves per tiller in autumn (Fulkerson *et al.*, 1999). In determining the optimum leaf stage, only grass above the 5cm stubble height was considered, as material below 5 cm would not be available to the cow (Reeves & Fulkerson, 1996a). Cattle should not graze kikuyu lower than 6 cm in height because below this height it is very deficient in readily fermentable carbohydrate (Fulkerson, 1999a). In a comparison of defoliation intervals two, four, and six leaves per tiller, and defoliation heights 3, 6 or 12 cm, it was found that defoliating at the two new leaves per tiller stage to 3 cm height resulted in maximum DM yield, and defoliating at the 6 new leaves per tiller stage to 12cm resulted in the lowest DM yields over a season (5225 versus 1722 kg/ha) (Fulkerson *et al.*, 1999). The only benefit of defoliating to 12 cm height is to capture extra NSC as the concentration was 8.4, 9.5 and10.6% for defoliation heights 3, 6 and 12 cm respectively (Fulkerson *et al.*, 1999). Increasing the grazing interval increases kikuyu pasture on offer at each grazing but reduces the overall amount of pasture on offer over the season. Grazing as frequently as two leaves per tiller reduces build up of fungal leaf diseases that make kikuyu unpalatable, but quality (low levels of calcium, magnesium and excessive protein) is poor and there may be insufficient pasture available for dairy cows at this time especially since dairy cows usually do not graze more than two thirds of what they are offered (Fulkerson *et al.*, 1999). From this information, it was decided that grazing could be set at the four-leaf stage or at 12-day intervals to 5 or 6cm stubble height (Fulkerson *et al.*, 1999). Kikuyu is able to withstand frequent defoliation but a compromise must be made between more quality pasture at the four and a half new leaves per tiller stage and higher quantities produced over the season at the two new leaves per tiller stage in order to satisfy animal needs (Fulkerson *et al.*, 1999).

Grazing at the four and a half leaf stage provides cows with grass of optimal quality, after which, the proportion of available leaf declines to below 80% and the stem and dead material fractions increase (Reeves & Fulkerson, 1996a, Fulkerson *et al.*, 1999). After four and a half leaves per tiller there is a fall in OM digestibility and CP concentrations (Fulkerson *et al.*, 1999). The effect of defoliation intervals of 2, 4 and 6 leaves per tiller on ME and N content of kikuyu was 9.1, 8.8 and 8.6 MJ/kg and 2.8, 2.6 and 2.1%, respectively (Fulkerson *et al.*, 1999). The time taken to reach the four and a half leaves per tiller stage varies, being dependent on temperature, from about 12 days in mid summer to about 35 days in autumn (Reeves & Fulkerson, 1996a). Henning *et al.* (1995) also identified that the best rotation length varied according to season. Grazing must occur between the minimum and maximum grazing interval. The minimum grazing interval is set by a high proportion of CP in the form of nitrate and NPN in early regrowth, which can cause digestive disorders and nitrate poisoning (Fulkerson, 1999a). The CP levels of the first and second new leaves are high after emergence and remain above 20% for a couple of weeks before rapidly declining. From the third leaf onwards, CP declines from emergence (Fulkerson & Reeves, 1996a). The mineral concentrations in kikuyu change with regrowth and are more in line with animal requirements at four and a half leaves per tiller. K falls, but is always too high for the dairy cow, Ca rises, but up to 95% of it remains unavailable as it is bound to oxalate, Mg rises, P falls and CP falls, but NPN remains too high (Fulkerson, 1999a). The decline in K allows easier absorption of Mg through the rumen wall. Young grass is therefore high in nitrates and K and low in Ca and Mg (Fulkerson, 1999a). The maximum grazing interval is set by the senescence of leaves and increased stem growth at four and a half leaves per tiller (Fulkerson, 1999a). New leaves accumulate Ca and grazing at the four and a half leaf stage allows maximum intake. Delaying grazing from two to four and a half leaves increases Ca and Mg content by 18 and 20% respectively and allows protein to fall before a decrease in OM digestibility is experienced (Fulkerson *et al.*, 1999). Delaying defoliation so that the pasture may have a mineral content more in line with dairy cow requirements may not be worthwhile because it is cheap to supplement animals with these elements (Fulkerson *et al.*, 1999). Grazing at the four and a half leaf stage of regrowth optimizes the quality of the grass available to the dairy cow and favours regrowth of the plant, but innate nutrient deficiencies in kikuyu make supplementation necessary to optimise milk production.

Results from the trial done by Fulkerson *et al.* (1999) differ from other work done as only leaf yields were considered and not total DM yields as were analysed in previous work done. These results could be considered to be more relevant as cattle would not consume stemmy pasture. According to Stobbs (1975), pasture management should focus on optimising the ease of defoliation and that more attention should be paid to leaf than total DM. This raises the point that perhaps leaf to stem ratio should not be of concern, but rather the total amount of leaf available, given the different growth habit of kikuyu compared to ryegrass. However, according to Stobbs (1975), the effects on intake of leaf density and the leaf to stem ratio cannot be separated.

1.5.6 Preventing the build-up of fibrous material

In Kenya kikuyu grass is reported to be low in fibre and high in protein (Mears, 1970), suggesting that quality could be improved either through breeding or management. The recommended management of ryegrass pasture is that it should be grazed hard and infrequently, about every four to six weeks, and then mulched or slashed to get rid of weeds (Fulkerson *et al.*, 1993). If pasture is grazed at its correct stage of regrowth then one third of the pasture leaf should be left after grazing as forcing cows to graze more than this will increase stem intake and milk production suffers. This practice and selective grazing (Bredon, 1980 cited by Eckard, 1991) leads to a build-up of fibrous material in kikuyu in the form of left over material which has no value to high producing cows in subsequent cycles so must be removed to promote regrowth (Cross, 1979b). The removal of the mat is important in lowering N fertilizer costs as the dense mat causes the response of kikuyu to N fertiliser to be poor in the early season. This is because part of the N is used by bacteria living in the organic matter of the mat. The only solution to this problem is to apply more N (Manson *et al.*, 2000). The mat may also harbour microorganisms that may negatively affect animal production and may be associated with kikuyu poisoning in cattle under intensive grazing (Bryson, 1982).

Kikuyu can be mulched or grazed down to 5cm or even as low as 3cm if there is sufficient moisture (less than six days since the last rain of 18mm) as dry conditions can lead to pasture damage if it is grazed or mulched short (Fulkerson *et al.*, 1999). Followers can also be used to remove low quality grass and let light in to stimulate new growth (Reeves & Fulkerson, 1996a). Dry cows can be given a strip of kikuyu and a mineral lick (Fulkerson, 1999a). In this way grass is not wasted. Unfortunately, there are usually insufficient dry cows available to graze the pasture down quickly enough to prevent damage to regrowth, so other methods, such as slashing, mulching or silage making, must be employed. Slashing is less favourable than mulching because the windrows left shade the kikuyu and hinder growth (Fulkerson, 1999a). Mulching is commonly carried out three to four times a season following careful instructions so as not to damage the pasture and requires expensive diesel and tractor power. The pasture is grazed, mulched or slashed down hard once in early season to top weeds, two or three times in peak season and once late in the season if the kikuyu is to be oversown (Reeves & Fulkerson, 1996b). It is interesting to note that even in 1979, Cross was advising that some paddocks could be closed off for silage and that it is important to make sure that it does not get too long or it will become rank (Cross, 1979b). He stated that at least three cuts should be taken and not just one at the end of January to maintain reasonable quality.

Most South African dairy farmers have generally always managed the grazing of their ryegrass pasture by providing cows with new strips of pasture after each milking. This increases DM intakes as cows graze harder for a given amount of DM and reduces selection and contamination of pasture (Reeves & Fulkerson, 1996b). Roos (1975) stated that contamination and loss of palatability of kikuyu pasture could be overcome by means of harrowing or slashing (Roos, 1975). Given the high costs of diesel and machinery, strip grazing could be a far more favourable option for kikuyu especially when considering the other benefits of improved intakes and utilization. Farmers try to increase ryegrass intake by offering cows more grass, but this increases the amount of residual material. This problem can be overcome by allowing the dairy cows to graze the pasture first and obtain the high protein low fibre tops and followers eat the grass higher in fibre. If the pasture is growing fast, then the duration of grazing and grazing interval should be shorter. If the regrown shoots are long enough to graze, about 8 cm, then the duration is too long and a back fence should be used to keep the cows off the regrowth (Fulkerson *et al.*, 1993). This infers that continuous grazing is harmful to kikuyu. Use of follow on cattle, mulching or slashing must be done within three days of the start of the first grazing or it will do more harm than good. According to Dugmore & du Toit (1988), the autumn slump associated with kikuyu pasture was almost completely overcome, at Cedara, with the use of electric fencing to restrict the grazing area and the use of follower animals in the early part of the season to graze the pasture down and prevent the mat formation later on in the season (Dugmore & du Toit, 1988). The autumn slump could be because of poor grazing management, which allows the grass to become rank (Dugmore & du Toit, 1988). In a trial by Henning *et al.* (1995) the autumn slump in March was greatest for a 15-day rotational grazing cycle compared to a 30 and 60 day cycle. This indicated that the autumn slump has little to do with the build up of moribund pasture, as no residual pasture was present on the 15 day grazing cycle

(Henning *et al.*, 1995).

There is potential to improve dairy cow performance through the better management of kikuyu. Under typical management practices, kikuyu pasture yields high amounts of DM but its quality is low and cows only produce 12 ℓ milk/ cow/ day without supplementation (Reeves & Fulkerson, 1996b). Research at Wollongbar has revealed that if kikuyu is correctly managed milk yields of 15 to 16 ℓ milk/cow/day are attainable without changes in body reserves provided that the minerals known to be deficient in kikuyu are provided (Ca, P, Na) (Reeves & Fulkerson, 1996b). However, the work by Australian authors, in particular, discussed in this section focuses very much on the best ways to utilize pasture and certain important aspects of dairy cow nutrition are overlooked. Although some consideration is given to animal requirements in terms of minerals and NSC, little thought is given to the fibre fractions. Fibre is generally considered to decrease the nutritional value of pasture, but according to Dugmore (2002), fibre is the most important fraction in obtaining high milk yields, although requirements for protein and readily fermentable carbohydrate must be simultaneously met. This will be further discussed in Part 3.

1.5.7 The effect of grazing management on the patch structure of kikuyu pasture

Although patch grazing is primarily observed in natural grazing systems where factors such as plant species composition, rainfall, soil and topography play a role in determining which areas are more palatable, it is also seen in swards consisting of only one pasture species. This occurs particularly when cattle graze at moderate stocking rates, causing patches varying in biomass quality and quantity to form, with more heavily utilized patches being more digestible (Cid & Brizvela, 1998). Animal performance on most tropical pastures is not improved under rotational grazing compared to continuous grazing because the rotational grazing systems adopted are rigid in terms of time and stocking rate, which cancels out any potential for higher output per hectare or per animal (Blaser, 1981). Rigid rotational grazing causes a build-up of uniform mature herbage and selective grazing is prevented. Cattle under continuously grazed pastures can perform well by grazing higher quality, heavily utilized patches as long as pasture height is not so limiting that the reduced bite size cannot be made up for by increase biting rate (Cid & Brizvela, 1998). Patch grazing is useful for explaining similar weight gains at less than critical stocking rates as long as the affects of season and grazing system are taken into account (Cid & Brizvela, 1998). Patches are indicative of overgrazing and under grazing in certain areas and defeats the object of recommended stocking rates, reduces efficiency of pasture utilization by animals (Willms *et al.*, 1988) particularly on dairy farms.

Patches are maintained and generated according to relations between animal intake and pasture growth rate (Cid & Brizvela 1998; Willms *et al.,* 1988). Grazed patches are maintained by repeated grazing of regrowth (Willms *et al.*, 1988) which eventually becomes overgrazed with the remaining pasture becoming rank as the season progresses (Ring *et al.*, 1985). The causes of patch development have been widely researched and vary according to stocking rate. Formation of patches is generally determined by the intensity and time of grazing (Willms *et al.*, 1988), but at high grazing pressure only thistles and dung determine animal selection and production and pasture condition could suffer as a result of overgrazing (Cid & Brizvela, 1998). Although the relative proportions of patches with different utilizations is affected by season, grazing system and stocking density, stocking density was found to principally affect the height of lightly utilized pastures. Grazing management at the beginning of the season plays a major role in the development of patches. If animals are offered more pasture than they can consume, only certain areas will be well utilized and will continue to be well utilized throughout the season while the remaining pasture becomes rank (Ring *et al.,* 1985). The likelihood of patch development increases with greater variability in herbage height at grazing commencement (Morris, 2002).

Several reasons for the repeated grazing of patches, which have less biomass per unit area, have been given. The patches have biomass that is more dense and higher in N (Cid & Brizvela, 1998). Willms *et al.* (1988) found that overgrazed patches had soils that were shallower and contained less organic matter. From this it was suggested that patch distribution may be related to factors affecting palatability such as dung and plant litter. Cattle refuse to graze pasture near faeces for a short period of time after which this pasture is preferred because of the increased biomass availability (Cid & Brizvela, 1998). The higher plant available P and N of overgrazed patches was thought not to be related to dung as animals avoid grazing near dung patches (Willms *et al.*, 1988; Morris, 2002) until the second or third grazing from the time of deposition (Hirata *et al.*, 1987). Livestock select forage growing on urine patches (Morris, 2002), but this may depend on the original nitrogen concentration of the pasture as on highly fertilised pastures, these areas may be avoided. According to Cid & Brizvela (1998), the higher N concentration in heavily utilized pastures may be because concentrated grazing keeps the pasture at a shorter and younger stage of regrowth with a lower ratio of C: N. Increased defoliation may also increase N uptake and allocation to leaves (Cid & Brizvela, 1998).

Although cattle can gain nutritional benefits through patch grazing at low to moderate stocking rates (Cid & Brizvela, 1998), this is not applicable to intensive dairy production systems were land is generally limited. Poor utilization at the first grazing of the season causes patches to develop with pasture supply exceeding demand (Ring *et al.*, 1985). The patch structure of the sward, in terms of pasture heights and permanence of patches, can be controlled through grazing management (Gibb & Ridout, 1986). High grazing pressure, use of high stocking densities for a short period of time (Willms *et al,*. 1988) and intensive early stocking (Morris, 2002) can reduce the patchiness of a sward. Burning can be effective at creating a more uniform pasture (Morris, 2002). This could be beneficial to dairy farmers who identify patches as signs of poor pasture utilization. As animals graze pasture less selectively when it is in short supply (Hirata, 2002), flexible grazing strategies should be adopted to ensure that pasture supply does not exceed demand. Rotational grazing is important as it allows recovery from and reduces degradation caused by patch overgrazing (Teague & Dowhower, 2003).

Dryland kikuyu pasture height is typically uneven, with patches. Using the pasture disc meter to measure pasture height, in order to estimate biomass using a regression equation, does not give an indication of sward condition. This is because of the compression of the pasture under the plate meter (Gibb & Ridout, 1986). Pasture height can be misleading with less frequently grazed pastures having greater means and standard deviations (Gibb & Ridout, 1986). It is therefore worthwhile to study patch dynamics in addition to the average pasture height of the sward for explaining differences in animal performance.

In terms of managing kikuyu pastures, patch dynamics should be taken into account in addition to pasture height and leaf stage. Areas that have not been grazed are unlikely to be grazed in the next grazing, therefore reducing the actual area available for grazing. The same pasture is continuously wasted as it is left by the cows. This pasture should be removed to maximise the grazing area and ensure high quality grass.

Part 2: Research Trials

For sustainable dairy farming in South Africa, it has been identified in Part 1 that low cost production systems need to be adopted and that kikuyu could help in achieving this if it could be properly managed to improve its quality. Research trials were done to determine whether its quality could be improved through grazing management. The first trial is an investigation into pasture height as a means of determining grazing readiness and improving the quality of kikuyu. The build up of fibrous material has been identified as posing problems for maintaining pasture quality and for accurate measurement of the pasture with a disc meter. The second trial investigates whether burning could be used to remove and slow down the build up of fibrous material. The third trial is a survey to identify current methods of managing kikuyu pasture in KZN and the Eastern Cape and to investigate if any of these methods are having a positive impact on kikuyu pastures quality and hence dairy cow performance.

2.1 The effects of rigid and flexible rotational grazing management strategies on the quality and quantity of kikuyu pasture and cattle performance.

2.1.1 Introduction

"Managed, rather than set, variables can improve the efficiency of animal production" and rotational grazing should be replaced by systems that are more flexible (Blaser, 1981). It is in light of this argument that a trial was carried out to investigate the effect of a rigid and a flexible rotational grazing system on pasture and animal performance. Researchers have measured animal and kikuyu pasture performance by controlling grazing management and varying stocking rates (Bartholomew 1985; Bransby, 1983). Research trials have focussed on comparing rotational and continuous grazing systems as a means of determining the best method of managing kikuyu pasture, and have revealed conflicting results. The rotational grazing systems employed have commonly consisted of a set number of days of grazing and rest. Continuous grazing is generally not applicable to dairy farms, where land is generally the most limiting resource and optimal pasture utilization is required. Pasture utilization efficiency is the key to improving returns on dairy farms (Doonan & Irvine, 2002) and fixed rotational and continuous grazing do not promote good pasture utilization throughout the season. There is a clear need to establish better methods of managing kikuyu pasture particularly on dairy farms.

For reasonable milk yields from cattle grazing kikuyu grass, pasture quality, utilisation by the cattle and sustainability must be considered. Grazing interval has a major affect on pasture quality and growth (Reeves & Fulkerson, 1996b) and must be based on plant growth characteristics (Fulkerson *et al.*, 1993). Usually farmers have pastures grazed and rested for a fixed number of days. Variations in pasture growth through the season are not taken into account. As a result, pasture is poorly utilized and there is a build up of stoloniferous material in the case of kikuyu pastures. A proposed better method of establishing a grazing interval is based on the quantity of pasture available (Reeves & Fulkerson, 1996b) and varying the area grazed throughout the grazing season as a means of matching supply and demand rather than varying the grazing cycle alone. Animal performance is dependent on the stage of growth of the pasture at grazing (Karnezos *et al.*, 1988). The use of plant growth characteristics on which to base the grazing interval rules out the use of continuous and fixed rotational grazing systems.

The successful use of plant growth characteristics in determining the grazing interval requires that the plant growth characteristics are easily measurable and consistent in indicating grazing readiness. Pasture height does not give an indication of grazing readiness in terms of quality as leaf quality changes with growth time. It also does not give an indication of the amount of leaf material versus stem material. Fulkerson (1999a) found no significant relation between pasture height and the amount of rank material. Height can ensure adequate DM intake under most conditions and is an easy, objective measure as long as dead material is taken into consideration. Leaf stage is only successfully used as an indication of grazing readiness on well grazed or mulched kikuyu pasture (Reeves & Fulkerson, 1996b), with a uniform, upright growth habit, which could be problematic for kikuyu in South Africa as farmers generally assume it not to require careful management.

The aim of the trial was to investigate differences between two rotational grazing systems, the first being rigid and based on set number of days of grazing and rest, and the second a flexible rotation based on pasture height and availability as a means of determining grazing readiness.

2.1.2 Materials and Methods

The trial was carried out at Broadacres, neighbouring Cedara Research Farm, situated north west of Pietermaritzburg, at an altitude of 1150m and located at 29°32'S and 30°17'E. The average rainfall for the area is 877mm. Twenty-eight Male and female Hereford and Nguni beef weaners, both having similar growth rates (Stewart, personal communication, 2002) were stratified according to body weight, blocked according to breed and sex and randomly allocated to two treatments, a rigid and a flexible rotation. Treatments were not replicated due to infrastructural constraints. Eight half-hectare kikuyu paddocks, situated in a row across a 10 to 15% east facing slope, were allocated randomly to the two treatments in such a way that alternate paddocks belonged to the same treatment. This allowed 2ha per treatment and an average-stocking rate of 3.4 AU/ha, which was considered realistic, but light enough to allow for differences between the two treatments to become evident through accumulation of rank material. The rigid rotation was 28 days in length with cattle moving to new pasture on a weekly basis, a typical kikuyu grazing system practiced in South Africa. The flexible rotation varied in length and was based on the quantifiable characteristic of pasture height as measured with a falling plate disc pasture meter. Cattle moved to new pasture once it had reached a height of 12cm or when they had grazed the current pasture down to a height of about 8cm. The height of well utilised kikuyu at Broadacres was 8cm as there was some dead material present at the start of the season. An initial grazing height of 12cm and an after grazing height of 8cm would ensure that the weaners had 1000kg of pasture per hectare available, or 500kg per half hectare paddock (Bartholomew 1985). This was estimated to be sufficient pasture for the weaners (dry matter intake of 2.5% body weight). The criterion that the pasture should be 12cm in height for grazing took preference over the end of grazing height of 8cm. Once the pasture in the first paddock of the flexible rotation treatment had been grazed, it was monitored until it reached 12cm in height again. The cattle were returned to this paddock regardless of whether they had grazed all four of the paddocks available to them. The pasture in the paddocks that had grown longer than 12 cm before the cattle were able to graze it, were grazed down by another herd of cows in as short a time as possible to remove the excess material as this pasture was considered to be suboptimal. This method was favoured over mowing of the pasture, being cheaper and an easier option at Broadacres. The animals were given free access to water and a standard dipping and inoculation program was followed.

The season was characterised by abnormally low rainfall and the trial began in the beginning of November 2002. Both herds of cattle grazed the pasture for one month before the trial began under a rigid rotation system to condition the pasture and animals. Each paddock was fertilised with 150 kg LAN in December and February.

The pasture height ahead and behind the cattle was measured every time they moved on to new pasture in the rotation, by taking 200 readings with a standard pasture disc meter (Bransby & Tainton, 1977), to the nearest centimetre. This was done to estimate pasture availability, apparent intake, and pasture regrowth following defoliation and to get an indication of the patchiness of the sward. The disc meter calibration equation $Y=749.5+242.79(\pm 10.39)d$ (Bartholomew 1985) was used to calculate pasture biomass per hectare from pasture height. Progressive pasture growth was calculated by dividing the cumulative pasture growth by the number of days in the trial.

Grab-samples of pasture ahead of the weaners were taken every time they moved paddocks and a composite sample of all the paddocks grazed was taken at every rotation. The kikuyu pasture samples were analysed at the Cedara Laboratory for crude protein, dry matter, fat, ash (organic matter), NDF, ADF, calcium, phosphorus, magnesium, sodium, potassium, zinc, copper, manganese and iron. Metabolisable energy values were calculated from the following equations:
Digestible organic matter (DOM) % = 71.6 – (0.62*CP (%)) (Dugmore, 1998)
ME = 0.83(0.193*%DOM-0.661) MJ.kgDM^{-1} (Corbett, 1978)

Both herds of weaners were weighed weekly, on the day that the herd on the rigid rotation moved. The stocking rate was light enough so that the pasture under the rigid rotation system was never very well utilized, typical kikuyu grazing management. Poor utilization of the pasture under the rigid system would help ensure that gut fill at time of weighing would not be significantly different from those cattle under flexible treatment. Empty rumens could not be guaranteed at the time of weighing due to the flexibility of the system. The weaners were compared in terms of animal units (AU). A weaner weighing x will be defined as $x^{0.75}/450^{0.75}$ animal units (Brown, 1954 cited by Tainton, 1981). Metabolic weight gains were calculated as the change in AU weight over time.

Data was analysed using Systat 10. Differences in animal performance between treatments and over time were analysed using analysis of variance (ANOVA) and general linear model (GLM). Beef weaner mass was converted to animal units (AU) upon which analyses were done.

2.1.3 Results and Discussion

Only results obtained from the 26th November 2002 onwards were considered in statistical analyses. The season was characterised by low rainfall with only 382ml over the growing season, which was 44% of the average rainfall.

2.1.3.1 Animal Performance

There was no significant difference in metabolic weight gains between the two treatments (Figure 2), but the tendency was for the cattle under flexible grazing management to gain more weight. Covariate analysis revealed no significant effect of sex ($P=0.452$) or breed ($P=0.510$) on average daily gains. Linear regression revealed significant difference in initial metabolic mass ($P<0.001$) (0.51 AU vs. 0.54 AU for rigid and flexible rotation treatments respectively). Average live weight per animal at the beginning and end of the trial for the rigid and flexible rotation treatments were 187kg and 235kg vs. 196kg and 254kg. The cattle under flexible rotation grazing management were able to attain similar liveweight gains on a smaller area of land. Except for the first rotation, where 2 ha of land were used, each rotation covered a total of 1.5ha of kikuyu compared to the rigid rotation system that used 2ha over each rotation. More animals could have been stocked on that area of land and achieved similar performance.

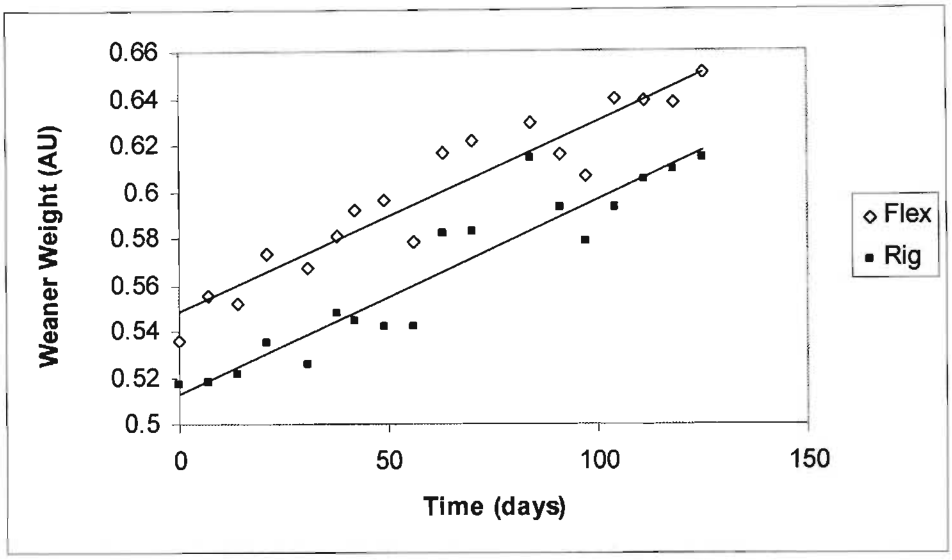
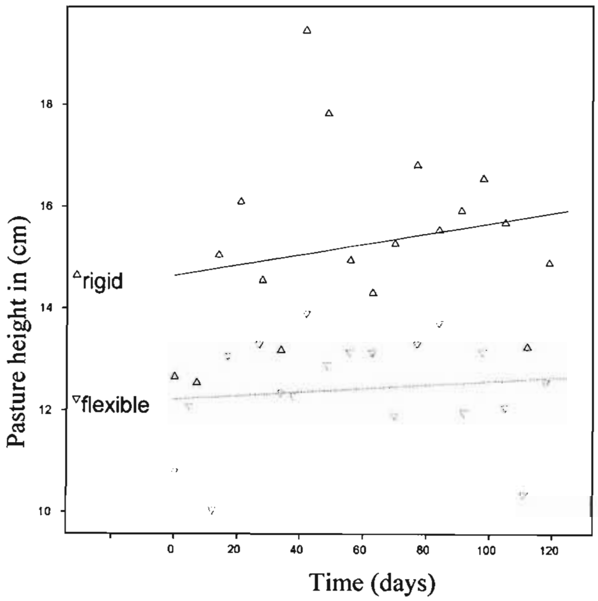


Figure 2 Metabolic weights of beef weaners under rigid and flexible rotation grazing management. $R^2 = 91$.

The 0.5ha that was not grazed by cattle on the flexible rotation was grazed down in January and again in March for a period of five days at a time by a herd of cows at a stocking density equivalent to 16 AU/ha. The average number of animal units present over the trial was 8.06, equating to a stocking rate over available land of 4.03AU/ha. The total amount of weight gained over the trial period for the flexible and rigid treatments were 99.9 and 89.1 kg/AU respectively. Average daily gains were lower than expected. A possible explanation could be in the reduced palatability of the pasture because of the low rainfall attained over the season. Slow growth causes nitrate build up (Marais *et al.*, 1987).

2.1.3.2 Pasture quantity

The pasture heights before and after grazing are given in Figure 3a and the height of the residual material following grazing is given in Figure 3b (note that the Y axis scale of pasture height is different for the two graphs). Pasture height before grazing for the flexible grazing treatment did not vary much as height was the criterion for grazing readiness. There is a gradual increase in height of pasture before grazing, although not significant, for the pasture under the rigid rotation, indicating a build up of rank, stem material, and characteristic of kikuyu under lower stocking rates. The amount of residual pasture remaining after grazing increased with time (Figure 3a and b), indicating the development of the mat of stolons and dead leaf material that is typical of kikuyu. The development of the mat was different for the two treatments. The rate of increase in residual material over the seasonal under the rigid rotation appeared greater than under the flexible rotation.



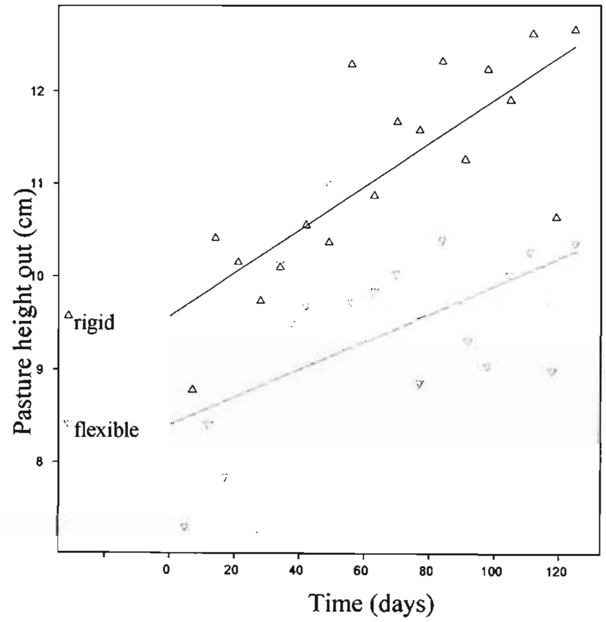
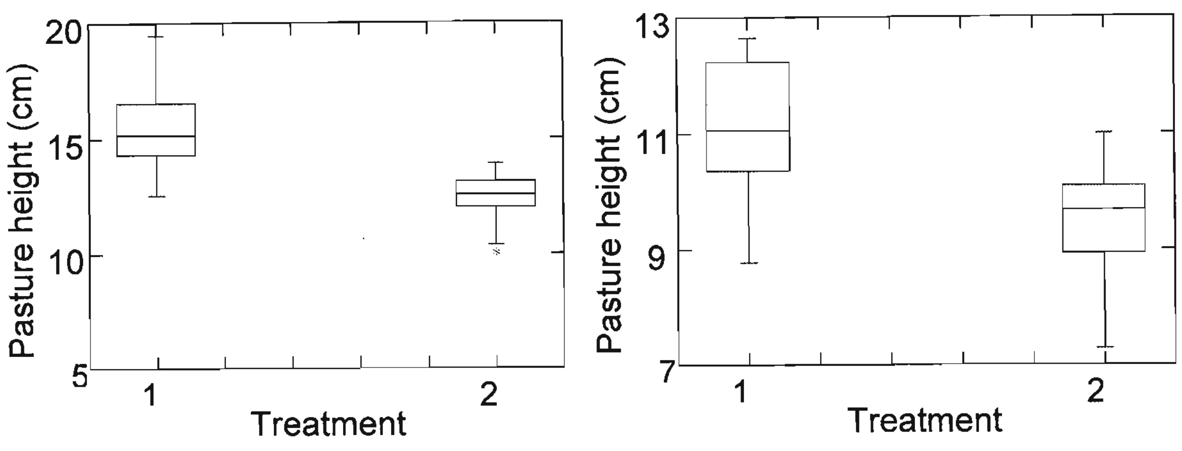


Figure 3 Pasture heights before (a) and after grazing (b) under rigid and flexible rotation management. Equations for pasture height after grazing for rigid and flexible treatments respectively: Y=9.85+0.019.day and Y=8.16+0.015.days. R^2=64.8. Equations for pasture height before grazing for rigid and flexible treatments respectively: Y=14.85+0.067.days and Y=12.04+0.0067.days. R^2=48.2 ($P<0.001$)



a) b)

Figure 4 Pasture height before grazing (a) and pasture height after grazing (b). Treatment 1=rigid rotation; treatment 2=flexible rotation.

Cattle under the rigid rotation system grazed pasture with greater variability in height than those under flexible management (Figure 4a and b). Pasture availability was less predictable, making fodder flow planning in a farming situation, potentially difficult. There were times when there would have been excessive pasture available to the animals, which would not have been consumed and instead become rank. If the animals used in the trial were dairy cows it is likely that milk yields would have fluctuated according to the changing plane of nutrition. At the end of each grazing cycle, one paddock under flexible grazing management had not been grazed except in the early part of the trial when conditions were dry. This could have provided quality grazing for other animals had it been grazed before the grass became mature. The grass in paddocks under the rigid rotation treatment was generally never well utilised. This, mostly stem material, would need to be removed by followers, mulching or mowing. The difference between rigid and flexible grazing management is in economics, achieving the same performance with less land and less wastage.

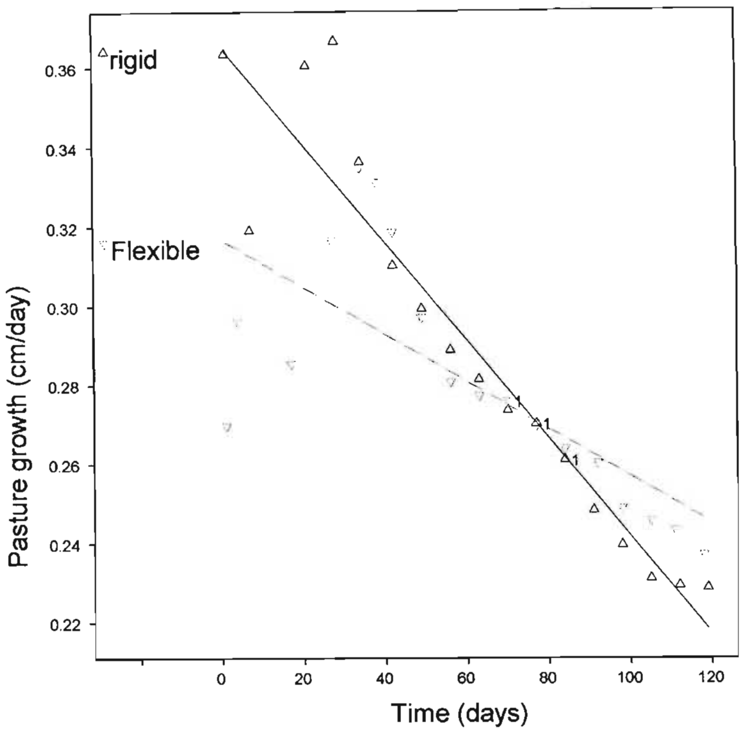


Figure 5 Growth rate of kikuyu pasture under rigid and flexible rotation grazing over the season (December to March). Equations describing growth for rigid and flexible treatments respectively were as follows: Y=0.36538-0.00124.days and Y=0.31668-0.00187.days. R^2=77.3. (P<0.001)

Pasture growth rate (Figure 5) was calculated by subtracting the previous after grazing reading from the following pasture height before grazing reading for each paddock. The number of days rest between grazing then divided this figure. Growth rates were significantly different (P<0.001). The kikuyu under rigid rotation grew faster than kikuyu under the flexible rotation at the beginning of the season, but after about day 75, the kikuyu pasture under flexible management grew faster. The difference between disc meter readings before and after grazing became less over the season, particularly for the rigid rotation pasture. Later on in the season, it became difficult to determine, with any accuracy, the amount of pasture available to the animals as pasture heights became similar for in readings and out readings. In some cases, a higher average reading was obtained for cattle after they had grazed compared to before grazing, probably due to material becoming more rank and less easily compressed by the disc metre. Stem material does not become as compressed under the falling disc plate meter as the leaf material. As a result, the loss of leaf material through grazing was not detected sometimes. At these times animals on the flexible treatment commenced grazing when the pasture had a satisfactory appearance. The pasture appeared to be a shade of green that was found to be synonymous with the 12cm pasture height obtained earlier in the season. The green shade was due to the growth of leaf material. This method is problematic in its subjectivity and illustrates the need for alternative methods of determining grazing readiness of kikuyu.

Pasture removed by the animals was calculated by subtracting the herbage remaining in each paddock after grazing from the initial quantity of pasture available, plus growth. Centimetres of pasture removed was converted to dry matter using the equation Y=749.5+242.79d (Bartholomew 1985).

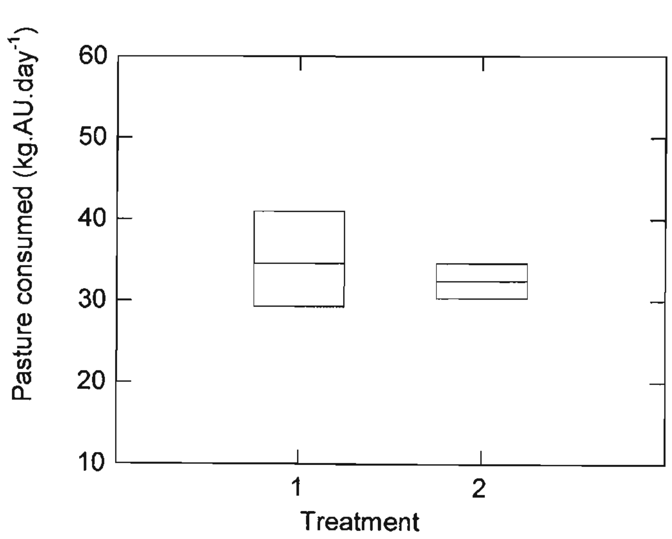


Figure 6 Animal unit consumption of kikuyu pasture per day over the trial. Treatment 1 = rigid rotation and treatment 2= flexible rotation.

Consumption of pasture DM per treatment per day was on average 35.30kg±2.09 and 30.20±1.51kg for rigid and flexible treatments respectively (P=0.04). Time of season had a significant effect on intake (P=0.06). Cattle daily feed intake varied from 22.38kg to 57.35kg under rigid rotation and from 20.19 to 47.01 under flexible rotation. It is important to bear in mind accuracy of pasture disc meter measurement and the role of trampled pasture, which would have been considered to have been consumed. The figures for daily animal unit intake of kikuyu are unrealistically high, but are useful for comparative purposes. Inflated figures for intake may be explained by the ability of trampled pasture to erect itself with time (Bartholomew, 1985), which would have been considered growth. Trampled pasture would have been considered eaten.

2.1.3.3 Pasture Quality

There was no significant difference in pasture quality between the rigid and flexible rotation treatments, explaining no significant differences in gain per animal unit. Time had a significant effect on the nutrients ash, fat, Mg, K and Mn. Fat and Mn were lowest in spring and highest in autumn. Potassium, Mg and ash were highest in spring and decreased with time. Miles *et al.*, (1995) also found Mg to be highest in spring and lowest in summer, but Mg was also high in autumn. This trial ended at the end of March, which perhaps was not late enough in the season to observe an increase in Mg levels.

Cattle under the flexible rotation treatment were able to gain at least as much weight as those under the rigid rotation treatment, but they consumed significantly less pasture. The accuracy of the disk meter in measuring pasture availability is questionable, as discussed. Chemical analyses should have accounted for similar gains on less pasture, but a possible reason for this may be explained by the uncertainty of using chemical analyses to estimate feeding values (Moore & Mott, 1973). Output per animal under grazing conditions gives the best indication of quality (Moore & Mott, 1973). Sward structure affects intakes. Lower leaf bulk density in rank pasture reduces bite size (Holmes, undated; Stobbs, 1972) and pasture under rigid rotation often became rank. Leaf material is more digestible than stem and the ratio of leaf to stem is likely to have been lower under the rigid rotation, although this was not measured. Only leaf material was sampled throughout the trial. Cattle under rigid rotation may have consumed stem, accounting for a higher intake and no difference in gain. Digestibility of cell wall constituents must be measured in determining pasture quality (Moore & Mott, 1973). Prediction of cell wall digestibility is not achieved by chemical means, except through lignin analysis. Lignin is the primary structural inhibitor of quality (Moore & Mott, 1973) and would have been higher in the stem material. Lignin was not measured in this trial and may have explained why the cattle under the flexible rotation treatment were able to gain similar weight to those on the rigid rotation treatment, despite having lower intakes.

In addition to lignin, nitrate analysis may have been useful in explaining animal performance. Poor animal performance is associated with old established pastures, which are heavily fertilized with N due to a build up of nitrates (Marais *et al.*, 1987; Bryant & Ulyatt, 1965).

An analysis of variance for average kikuyu pasture quality for the two treatments compared to animal requirements is given in Table 6. The calcium levels in kikuyu at Cedara are below marginal (0.3%). Magnesium levels are adequate. The target for daily intake of magnesium is 30g/lactating cow and 40 to 60g if K levels are high (Puls, 1994). British cattle breeds are less efficient than other cattle breeds at extracting Mg from low quality roughage; similarly beef breeds are less susceptible to Mg deficiency than dairy breeds (Puls, 1994). Mineral utilization could have differed between the Nguni and Hereford cattle. Potassium levels are high, but below the toxic level of 4%. Such high levels could cause udder oedema, reduced feed intake and weight gain (Puls, 1994). Weight gains over the trial period were low. Although Mg levels were adequate, the high K levels could have inhibited absorption. The K: Na ratio for the two treatments is 64:1. A ratio of 40: 1 and over in grass clover pastures can cause bloat (Puls, 1994). The ratio should be kept at 5:1 to promote Mg absorption (Puls, 1994). It is likely that most Mg in the kikuyu was not absorbed. Sodium levels are below requirement. Cattle can store Na in saliva for several months before deficiency symptoms become evident (Puls, 1994).

Table 6 Kikuyu pasture quality under rigid and flexible rotations in relation to beef and dairy requirements.

	Mean ± standard deviation (dry matter basis)						
	Rigid	Flexible	F ratio	Probability	Req. (beef steers)	Req. (dairy cows)*	Max Tolerance*
Ash (%)	9.435 ± 1.07	9.266 ± 0.810	0.296	0.590			
Fat (%)	2.866 ± 0.519	2.974 ± 0.632	0.325	0.573			
ADF (%)	28.636 ± 2.326	28.133 ± 2.167	0.465	0.500		21	
NDF (%)	63.264 ± 3.131	63.463 ± 2.185	0.051	0.823		27-33	
CP (%)	21.804 ± 3.195	21.675 ± 1.758	0.024	0.880	9.9-11.4	15.8	
ME (MJ/kg)	8.778 ± 0.307	8.747± 0.189	0.133	0.717			
Ca (%)	0.278 ± 0.028	0.276 ± 0.034	0.062	0.804	0.18-0.53	0.38-0.81	1.4
Mg (%)	0.329 ± 0.029	0.324 ± 0.034	0.249	0.621	0.05-0.28	0.25-0.35	4
K (%)	3.656 ± 0.469	3.695 ± 0.377	0.079	0.781	0.5-0.7	0.8-2.45	4
Na (%)	0.057 ± 0.015	0.058 ± 0.022	0.077	0.782	0.06-0.1	0.18-0.67	5
K/Ca+Mg	2.291 ± 0.286	2.356 ± 0.270	0.501	0.485	<2.2	<2.2	>2.2
P (%)	0.314 ± 0.034	0.319 ± 0.034	0.203	0.655	0.18-0.37	0.35-0.45	1
Zn (ppm)	35.729 ± 5.129	38.589 ± 8.343	1.557	0.216	20-40	50-100	5000
Cu (ppm)	8.312 ± 2.453	8.223 ± 2.413	0.012	0.912	4-10	25-100	200
Mn (ppm)	100.323 ± 19.199	103.794 ± 25.711	0.215	0.646	20-40	40-200	1000
Fe (ppm)	148.550 ± 35.406	157.054 ± 50.901	0.344	0.561	50-100	100-500	2000

*Puls, (1994)

The Cu levels in the kikuyu were adequate for the beef animals, but deficient for dairy cows (Table 6). Copper deficiency manifests itself in poor fertility, anoestrus, high somatic cell counts, poor hooves and low milk yields, particularly if the deficiency is Zn induced. Copper and Zn are antagonistic, but in this kikuyu both are present at low levels. Zinc is present at marginal levels for dairy cows, but suitable levels for beef weaners. Low zinc levels can inhibit immune response, cause foot rot, reduce conception rates and feed intake.

2.1.4 Conclusion

There was no significant difference in gains per animal unit for the rigid and flexible grazing rotations. Animals under the rigid rotation ate significantly more pasture, according to disc meter measurements. Cattle under the flexible rotation system were able to gain as much weight as those under the rigid rotation, but on less land and grass. Although there were no significant differences in pasture leaf quality, there may have been significant differences in nutrients that were not measured, such as lignin, which may have accounted for similar gains for different pasture intakes. Alternatively cattle under the rigid rotation may have consumed more of poorer quality stem material. Leaf stage is thought to be a better plant growth characteristic as an indicator of grazing readiness and has an effect on pasture quality. Basing the flexible management system on leaf stage may have produced more significant results in terms of pasture quality and animal growth.

Measurement of intake on poorly managed pastures with a disc meter is unreliable because of the build-up of unpalatable material and trampling. This highlights the importance of sound pasture management in our ability to measure accurately on farm level. The larger portion of rank pasture under the rigid grazing system may have been less palatable and digestible than the pasture under the flexible grazing system, which had less of an accumulation of rank material. Although disc meter readings may indicate high dry matter availability, this may not be palatable or be of high quality. Pasture under the flexible treatment was able to feed more cows, trial animals and followers. Alternatively, in a farming situation, this pasture could have been made into kikuyu silage and fed to animals at times if the year where there is a shortage of pasture. This pasture could also be useful as a buffer against drought conditions where a feed deficit could result. As much live weight was gained on the flexible as was on the rigid rotation treatment, but with use of less fertiliser and land. The same animal productivity was attained at a lower cost.

The use of leaf stage as an indication of grazing readiness for the flexible rotation would have been beneficial. Measuring pasture height is useful for determining dry matter available. Both height and leaf stage pose problems on mismanaged pastures, but on well managed pasture the use of the two methods together should lead to improved pasture management.

2.2 Burning as a quality control tool for kikuyu pasture

2.2.1 Introduction

Kikuyu pasture is typically poorly utilized on South African dairy farms, which results in the formation of a mat of residual material, consisting of stolons and dead material. This is because dairy cattle should not be forced to graze the pasture down sufficiently to prevent the mat formation as milk production would suffer with increased intake of stem over leaf material. The mat reduces palatability and intake and may host toxic bacteria (Bryson, 1982). It also makes management and accurate allocation of material to cattle difficult as it reduces the accuracy of predicting pasture mass (Fulkerson & Slack, 1993). The methods of controlling the development of the mat, including mulching and mowing, are generally expensive. There is usually an insufficient number of dry stock to harvest the residual pasture quickly enough to prevent damage to the pasture (Fulkerson 1999a). A cheaper and possibly effective option would be to burn the kikuyu pasture at the beginning of the season to remove the accumulated material from the last season. This method has been criticized because the pasture accumulated over the dry season, that may have a useful purpose for livestock, is wasted. Many farmers are under the impression that kikuyu cannot be burnt because it never dries out sufficiently. The lack of information on this poorly researched topic prompted research trials to be carried out at Ukulinga (29°24′E, 30°24′S), South Africa. Ukulinga has shallow Westleigh soils and an average annual rainfall of 700ml. Short midsummer droughts are common. Annual mean temperature is 18°C, reaching 40°C on midsummer days. Frosts occasionally occur in winter. The objectives of these trials were to assess the effectiveness of burning in removing the mat and the subsequent effects on pasture quality, quantity and animal performance and sward structure over the season.

2.2.2 Materials and Methods

Six blocks of kikuyu pasture, each 0.75 ha, were allocated randomly to two treatments, burn or no burn, with burnt plots adjacent to those not burnt (Figure 7). Blocks were burnt in August, 2002, when kikuyu growth was beginning, using a backfire ignited at plot borders. The back burn was favoured over the head fire, being slower, going against the wind and more likely to burn the pasture down to the ground, penetrating the mat. After burning, 10 quadrats (0.5 m^2) per plot were clipped in a row 1 m from the fence line and 10 m apart to allow for a paired t-test comparison of means for unburnt and burnt residual material for burnt and unburnt plots. At the end of September, vegetation height estimated by pasture disc meter readings was related to dry matter biomass determined by clipping (n=72). In addition, samples of leaf material were submitted to the Cedara laboratory for chemical analysis to determine forage quality.

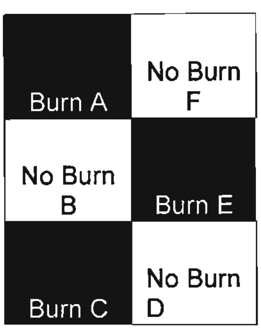


Figure 7 Layout of the burn and no burn areas with block numbers A to F

Each treatment block (burn or no burn) was divided into four paddocks (0.19ha each). Thirty beef cattle of mixed breeds were stratified according to body weight, blocked according to sex and previous treatment and randomly allocated to six herds, which were in turn randomly allocated to each block. This allowed a stocking rate of 3.3 AU/ha, which was considered light enough to allow for potential differences in pasture yield between burnt and unburnt pasture to be observable. The cattle began grazing the pasture at the end of October, 2002, and they were, for the most part, moved onto fresh pasture once a week to allow for a 28-day rotation cycle. Early summer rainfall was low, causing poor pasture growth rate. On the 22^{nd} of November 2002, all animals were removed form the trial because of a shortage of pasture. They returned to the trial ten days later.

The cattle were weighed weekly and the height of the pasture ahead and behind the cattle was measured using a standard disc meter (Bransby & Tainton, 1977), every time they moved in order to estimate the amount of available dry matter. Progressive pasture growth was calculated by dividing the cumulative pasture growth by the number of days in the trial. The cattle were compared in terms of animal units (AU). A weaner weighing x will be defined as $x^{0.75}/450^{0.75}$ animal units (Brown, 1954 cited by Tainton, 1981). Metabollic weight gains were calculated as the change in AU weight over time. Each pasture was grazed four times over the trial. Two hundred disc metre readings were taken, to the nearest centimetre, per paddock for the first and third grazing rotations and fifty for the second and fourth rotations. Grab-samples were taken of the pasture ahead of the cows for quality analysis. Samples were analysed at Cedara for for nitrogen, dry matter, ash (organic matter), NDF, ADF and some minerals including calcium, phosphorus, magnesium, sodium and potassium. Metabolisable energy was calculated using the following equations:

Digestible organic matter (DOM) % = 71.6 – (0.62*CP (%)) (Dugmore, 1998)

ME = 0.83(0.193*%DOM-0.661) $MJ.kgDM^{-1}$ (Corbett, 1978)

Table 7 Average soil nutrient status at Ukulinga

P (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Exch. Acidity (cmol/L)	Total cations (cmol/L)	Acid sat. (%)	pH (KCl)	Zn (mg/L)	Mn (mg/L)	Organic carbon (%)	Clay (%)
14	143	1510	453	0.26	11.88	2	4.93	2.7	36	3.1	40

The fertiliser recommendations for kikuyu pasture, according to Manson *et al.* (2000), depend on the level of production desired. Given the low average annual rainfall at Ukulinga of about 700ml (Bransby, 1990), medium production of about 12 tons/ha was considered attainable. Although six dressings per season are recommended to improve the efficiency of response of pasture to fertilizer, three dressings were more practical and were applied at Ukulinga. A total of 236.7 kg $N.ha^{-1}$ in the form of LAN was applied over the season. The kikuyu was top dressed in October, November and January. Soil samples taken in autumn of 2002 revealed that there was sufficient soil phosphorus and potassium for kikuyu pasture (Table 7), so they were not applied.

At the end of the trial, five quadrates (0.5 m^2) per block were clipped in a row 1 m from the fence line and 10 m apart in the paddock that would have been grazed next to determine whether there was a significant difference in biomass between burnt and unburnt pastures at the end of the grazing season.

The data were analysed using analysis of variance to see if there was a difference in performance of cattle on burnt and unburnt pasture. Animal and grass performance data were analysed using General linear model (GLM) to compare differences between treatments over time. Initial quality data collected after burning were analysed using Principle Components Analysis (PCA) to identify trends in quality differences between plots burnt and not burnt.

2.2.3 Results and Discussion

2.2.3.1 Cattle performance

One animal from each group was removed from the trial at the end of January and was excluded from the animal performance statistical analyses because pasture growth was less than expected due to low rainfall. The average stocking-rate for the trial up until the end of January was 3.66AU.ha^{-1}, after which, it was 2.79 AU.ha^{-1}. Metabolic weight gains of cattle grazing kikuyu that had been burnt were not significantly different from those grazing kikuyu that had not been burnt ($P = 0.173$), but the trend was for cattle grazing burnt kikuyu to have a higher rate of gain (Figure 8). Initial metabolic live weight was significantly different for the two treatments ($P = 0.023$). The equations describing gains for the burn and no burn treatments from Figure 6 were Y=0.632+0.0011228.day and Y=0.643+0.0011228.day (R^2=74.5) respectively. Total gain per animal unit was 141.74±10.723 kg.AU^{-1} and 118.44±17.359 kg.AU^{-1} for burn and no burn treatments respectively. Not burning kikuyu for fear of wasting the accumulated material is invalid as cattle can do as well with less grass, perhaps of a better quality as will be discussed.

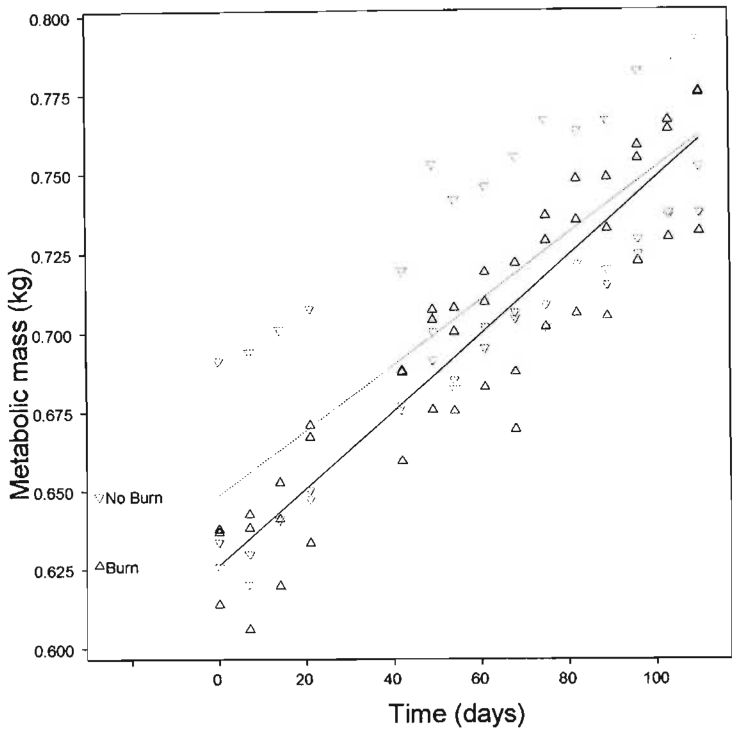


Figure 8 Live weight gains of cattle grazing kikuyu that was burnt and that which was not burnt.

2.2.3.2 Pasture Quantity

The immediate effect of burning significantly reduced the aboveground biomass of residual material from 3.54 to 1.40 $t.ha^{-1}$ ($P<0.01$), leaving some stoloniferous material (samples clipped in September 2002). Samples clipped at the end of the trial (March 2003) revealed that the effect of burning at the beginning of the season on the reduction of aboveground biomass was still evident at the end of the season (4.0$t.ha^{-1}$ vs. 5.2 $t.ha^{-1}$ $P=0.005$). Woodhead (1982 cited by Eckard, 1991) found that there was a 15% drop in DM production of kikuyu that was burnt in spring. At Ukulinga the drop in dry matter present over the season production appears to be in the order of 23%.

Progressive pasture growth rates were calculated from pasture disc meter measurements taken weekly over the trial. Pasture growth rate was significantly different for burnt and no burn pastures (Figure 9). Equations describing the growth of burn and no burn pastures were Y=0.216+0.003d and Y=0.324+0.002d respectively (R^2=0.54). There was a significant difference in pasture growth rates between the six plots, but this effect was independent of burning (P=0.001). Pasture removed at grazing was calculated by subtracting the pasture remaining after grazing from the initial amount, plus growth. Pasture removed was significantly different between treatments; 0.523±0.035cm.AU.day^{-1} and 0.628±0.023cm.AU.day^{-1} for burnt and no burn pastures respectively. Cattle grazing kikuyu that was not burnt appeared to consume more pasture.

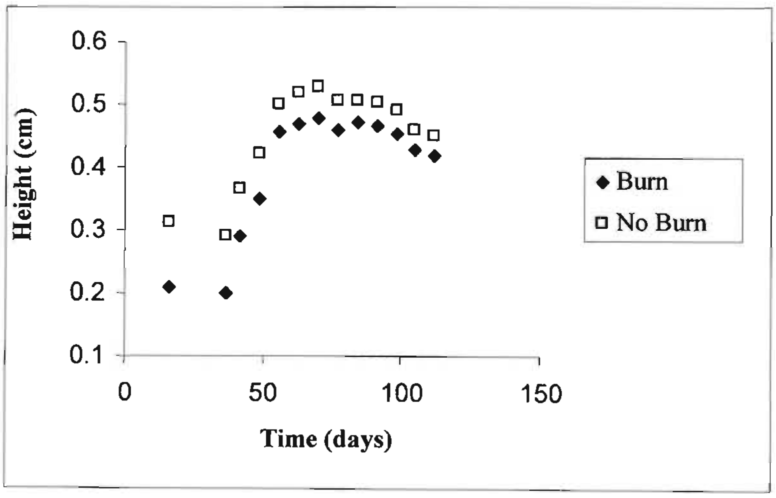


Figure 9 Pasture growth rate over the season at Ukulinga

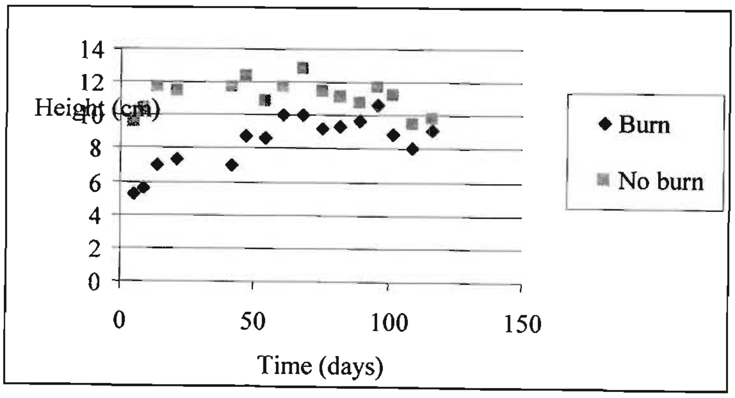


Figure 10 Pasture heights at the end of grazing for burnt and unburnt pasture.

Pasture heights before and after grazing for burnt and unburnt pasture were significantly different, being 10.924±1.133cm and 14.827±0.722cm before grazing and 8.411±0.631cm and 11.09±0.470cm after grazing, respectively (P=0.007, F-ratio 25.301 before grazing and P=0.004, F-ratio 34.778 after grazing). The pasture that was burnt was grazed shortest at the beginning of the season and gradually the pasture height after grazing increased at a decreasing rate as the season progressed. There was little change in the after grazing height for pasture that was not burnt, but there was an increase up until the middle of the season, after which the grass was grazed down shorter again. The after grazing height for burnt pasture over the trial was best described by the equation $y = -0.0007x^2 + 0.115x + 4.83$ (R^2=0.82), whereas the unburnt pasture after grazing height was best described by the equation $Y= 0.000006x^3 - 0.001x^2 + 0.089x + 9.733$ (R^2=0.60). The amount of pasture removed by the cattle, assumed to be intake but including wastage, was closely related to the amount of pasture that they were offered or the height of the pasture before grazing. Correlations between height of pasture before grazing and amount removed were 0.89 and 0.88 for burnt and unburnt pasture respectively.

2.2.3.3 Pasture Quality

The immediate effect of burning on the quality of kikuyu pasture is given in Table 8, which shows the results from clippings taken at the end of September and submitted to the Cedara laboratory for analysis. These were in turn related to beef cattle requirements.

Table 8 The nutritional value of burnt and unburnt kikuyu pasture in spring in relation to beef cattle requirements

Component	Mean (Burnt)	Mean (Unburnt)	F-Ratio	P-Value	Required dietary • values	Maximum • Tolerance
Ash (g/100g)	9.94	8.61	21.9	0.009 **		
Fat (g/100g)	3.37	2.63	29.7	0.005 **		
ADF (%)	33.7	36.6	11.2	0.029 *		
NDF (%)	67.3	74.4	64.9	0.001 **		
Protein (g/100g)	15.11	9.44	483.2	0.000 **	9.9-11.4[a]	
ME (MJ/kg DM)	8.428	9.103	355.1	0.000 **		
Calcium (g/100g)	0.33	0.31	2.0	0.230 NS	0.18-0.53	2
Magnesium (g/100g)	0.29	0.26	2.1	0.219 NS	0.05-0.25	0.4
Phosphorus (g/100g)	0.42	0.34	12.0	0.026 *	0.18-0.37	1
Potassium (g/100g)	3.14	2.22	136.0	0.000 **	0.5-0.7	3
Sodium (g/100g)	0.036	0.027	4.5	0.101 NS	0.06-0.1	10[b]
Copper (ppm)	6.75	3.33	60.0	0.001 **	4-10	115
Manganese (ppm)	124.5	118.3	0.2	0.636 NS	20-40	1000
Iron (ppm)	215.0	213.8	0.0	0.967 NS	50-100	1000
Zinc (ppm)	29.5	30.5	0.1	0.739 NS	20-40	500
K/(Ca+Mg)[c]	2.02	1.53	46.8	0.002 **		2.2

* $P \leq 0.05$, ** $P < 0.01$, NS non significant
• NRC (1984)
[a] steers weighing 200 to 250kg gaining 0.7 kg/day
[b] as sodium chloride
[c] derived on an equivalent basis

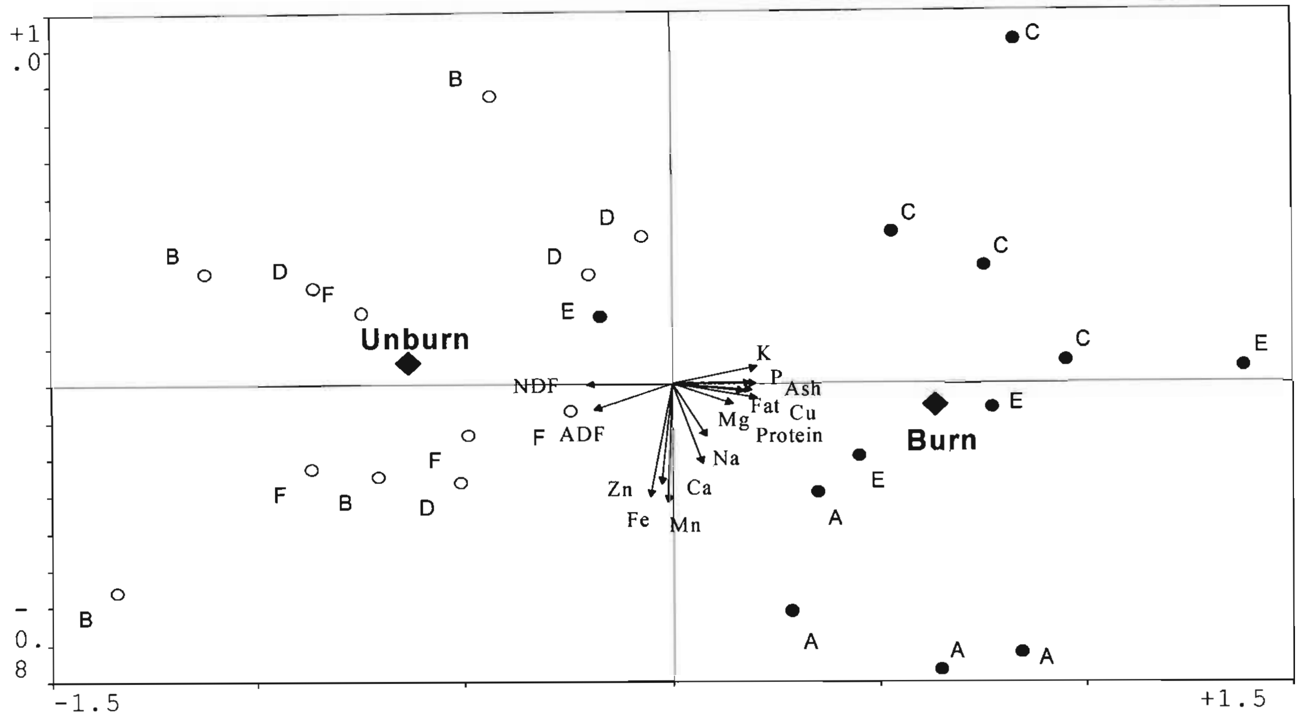


Figure 11 Principle components analysis axes one and two (eigenvalues 0.54 and 0.18 respectively) of samples taken from burnt (•) and unburnt (○) kikuyu pasture, with samples labelled according to block number (A-F) and centroids for mean burnt and unburnt plots. ADF=acid detergent fibre, NDF=neutral detergent fibre.

The effect of burning on kikuyu spring growth is given in Table 8 and Figure 11. Axis one of the PCA (Figure 11) accounted for more than twice the variation of axis two and represents a quality gradient from sites high in acid detergent fibre (ADF) and neutral detergent fibre (NDF) to sites high in potassium, ash, fat, phosphorus, magnesium and protein. This gradient largely separated burnt and unburnt plots. Axis two represented a gradient in micronutrients, unrelated to burning, but possibly due to spatial variation among plots, especially among those that were burnt. This indicates an immediate improvement in kikuyu quality with the decrease in NDF, which limits dry matter intakes at high levels. Table 8 also shows a significant immediate effect of burning on reducing NDF and ADF concentrations to levels comparable with those obtained by Dugmore (1998) of 65% and 35% respectively. Burnt kikuyu pasture levels of NDF and ADF still remain high and could still limit dry matter intakes. Chemical analyses have been reported insufficient in the prediction of kikuyu pasture digestibility as there has been no confirmation in animal production trials (Dugmore

& du Toit, 1988). Dugmore (1998) regarded a fat content of 2.8% DM to be high for roughage, which is lower than 3.37% in the burnt kikuyu (Table 8). Burning increased the protein levels of kikuyu, which could reduce the amount of early season nitrogen fertiliser required to improve the quality of kikuyu pasture. It is likely that early season nitrogen applications of the kikuyu which was not burned, would have caused little response with most of the nitrogen being used up in the decomposition of the mat of material left over from the previous season. More nitrogen may have been needed by the kikuyu that was not burnt in order to gain a growth response. Energy and protein are negatively correlated in the equations used for the calculation of kikuyu ME. The lower energy of burnt kikuyu pasture resulted from the higher protein having a negative weighting on energy content. Organic matter digestibility and protein have a negative relation (Dugmore, 1998), which also would have reduced the ME with ash levels being higher in the burnt kikuyu. Kikuyu is typically deficient in Na, Ca and Mg. Calcium and Mg levels were not significantly improved with burning, but appeared to be adequate for beef cattle (NRC 1984). The Ca levels are higher and the Mg levels slightly lower than the 0.24% and 0.30% reported by Dugmore (1998) respectively). Calcium is made unavailable to the animal through its accumulation of oxalate (Marais, 1998). Phosphorus levels were not limiting in burnt and unburnt pasture, except at higher requirement levels where burning may be beneficial. Potassium is significantly higher in the pasture that was burnt and exceeds the maximum tolerance level ($P<0.001$). High potassium levels interfere with the uptake of calcium and magnesium, making estimations of absorbed amounts difficult. The K/(Ca+Mg) ratio should be kept below 2.2 to prevent metabolic problems (Dugmore, 1998). Sodium levels in kikuyu, a natrophobe, are deficient and supplementation is essential in preventing bloat (Dugmore, 1998). Deficiencies of zinc and copper may be experienced in some cases (Table 8). Burning significantly improved copper concentrations, but they remain too low for some classes of beef cattle (NRC, 1984).

Table 9 Quality comparison of kikuyu pasture over the season under treatments burn and no burn

	Mean ± standard deviation (dry matter basis)		F-value	Probability	Cattle Requirements	Nutrient	
	Burnt	No Burn			beef steers[b]	dairy cows[a]	Max Tolerance[a]
Ash (%)	8.928±0.51	8.676±0.387	2.644	0.114			
Fat (%)	2.932±0.381	2.871±0.402	0.208	0.652			
ADF (%)	31.429±2.144	31.734±2.413	0.151	0.700		21[d]	
NDF (%)	66.222±2.005	66.478±2.904	0.090	0.766		27-33[e]	
CP (%)	18.405±2.117	17.485±2.765	1.187	0.284	9.9-11.4	15.8[f]	
Ca (%)	0.351±0.035	0.418±0.180	2.227	0.145	0.18-0.53	0.38-0.81	1.4
ME (MJ/KG)	9.093 ± 0.211	9.184 ± 0.275	1.179	0.286			
Mg (%)	0.330±0.044	0.361±0.067	2.557	0.120	0.05-0.28	0.25-0.35	4
K (%)	3.295±0.335	3.019±0.317	6.066	0.019*	0.5-0.7	0.8-2.45	4
Na (%)	0.069±0. 058	0.051±0.023	1.376	0.249	0.06-0.1	0.18-0.67	5
K/Ca+Mg[c]	1.900±0.191	1.626±0.220	15.030	0.000**	<2.2	<2.2	>2.2
P (%)	0.382±0.015	0.371±0.029	1.982	0.169	0.18-0.37	0.35-0.45	1
Zn (g/kg)	33.703±3.672	35.094±4.476	0.982	0.329	20-40	50-100	5000
Cu (g/kg)	8.258±2.413	7.358±2.300	1.239	0.274	4-10	25-100	200
Mn (g/kg)	116.148±10.625	122.768±18.593	1.799	0.190	20-40	40-200	1000
Fe (g/kg)	145.231±26.838	161.097±40.194	2.011	0.166	50-100	100-500	2000

* P≤0.05, ** P<0.01, NS non significant
[b] NRC (1984)
[a] Puls, (1994)
[c] derived on an equivalent basis
[d]Fulkerson *et al.*, 1998
[e]Kolver, 2000
[f]600kg Friesian cow producing 30ℓ milk/day (NRC 1989, cited by Miles *et al.* 2000)

Linear regression analysis of pasture quality over the season (Table 9) revealed that ash, NDF, DOM, Fat, ADF and protein no longer differed significantly. No significant difference between treatments was found for Zn, Mn, Na, P, Mg, Cu, Ca and Fe. Potassium and the K/(Ca+Mg) ratio were the only nutrients measured that differed significantly. Calcium was significantly different at the beginning of the trial, indicating that burning had a significant short lived effect on kikuyu calcium content. A comparison of all pasture samples taken over the growing season revealed that only K and the K/Ca+Mg ratio was significantly different (Table 9). The concentrations of the ADF and NDF found in the kikuyu at Ukulinga exceed the requirements of the dairy cow. The kikuyu would have supplied sufficient protein for milk yields of over 30ℓ if intake was not limited and sufficient energy was available. The Ca levels appear to be marginally deficient, but are likely to be unavailable due to the likely presence of oxalate (Marais, 1990). Similarly, Mg levels appear more than adequate, but the interference of the near toxic levels of K could prevent absorption, as with Ca. Sodium levels are typically low in kikuyu, a natrophobe (Dugmore, 1998). Although the K/Ca+Mg ratio is below the critical level of 2.2, it is likely that with the presence of oxalate, the available Ca is much less and the ratio is higher. Phosphorus levels are adequate and Zn is in over supply. Copper levels are low and supplementation would be necessary.

2.2.4 Conclusion

Burning may be a cost effective method of removing the build up of fibrous material in the spring. Burning has a significant affect on both the quantity and quality of kikuyu pasture. However, the effect of burning on quality is limited to certain nutrients and is short lived on most. Burning holds early season benefits on quality. Pasture heights became similar towards the end of the season indicating that the reestablishment of the mat of stolons and rhizomes is achievable within a season and within season control in the form of mowing or mulching is necessary. Eckard (1991) stated that burning should not be done every year as the formation of the mat takes a few years, but reestablishment of the mat was seen within a season in this trial.

The observed loss of production of around 23% of the burnt kikuyu may be outweighed by the lower costs of burning compared to other methods of removing the mat. It appears that the extra dry matter produced by not burning does not improve animal performance, given that there was no significant difference in gains. The extra DM may be useful in a drought year. The cattle were removed from the trial due to a lack of dry matter, particularly for pasture that was burnt. Eckard (1991) found no significant drop in production with spring burning compared to mowing indicating that loss of production with burning comes at a lower cost.

Kikuyu pastures and kikuyu oversown with ryegrass under no till cultivation often carry heavy pesticide burdens in the form of worms and insects which eat fresh pasture growth. A further avenue of research could be to look at burning as a means of control. Cattle were able to attain similar live weight gains despite the differences in pasture quantity consumed. Neutral detergent fibre has a major influence on dry matter intakes and the reduction with burning should have caused increased intake of kikuyu pasture. Leaf and stem behave differently under the plate meter with leaf being more easily compressed. Trampled stem material, which quickly erects after grazing, would have contributed towards the eaten pasture portion, causing inflated estimates of pasture intake of pasture not burnt. This may not have occurred for the burnt pasture treatment where less stem material, relative to leaf, was observed, although not measured.

2.3 The effect of grazing management on patch structure of kikuyu

2.3.1 Introduction

Pasture utilization and gross margin per hectare are directly related (Doonan & Irvine, 2002) as land, although not as limiting as in countries such as New Zealand, is often the most limiting resource on dairy farms. If animals are offered more pasture than they can consume, only certain areas will be well utilized and these areas will continue to be well utilized throughout the season while the remaining pasture becomes rank (Ring *et al.,* 1985). This defeats the object of recommended stocking rates and reduces the efficiency of pasture utilization (Willms *et al.,* 1988). Cid & Brizvela (1998) stated that cattle can gain nutritional benefits through patch grazing, but it is not economical on land-limited intensive dairy production systems. Grazing management, particularly at the beginning of the grazing season plays a key role in reducing sward patchiness. If pasture supply exceeds that demanded by cattle at the beginning of the season (Ring *et al.*, 1985), or if cattle are introduced to pasture with considerable variability in height (Morris, 2002), there is increased likelihood of patch development. Patch development can be limited by applying high grazing pressure or use of high stocking densities for short periods of time (Willms *et al.*, 188) and early intensive stocking (Morris 2002). Burning could be a means of reducing variability in pasture height at the beginning of the grazing season when pasture has been poorly utilized during the previous season or if there are too few cattle to harvest all the pasture (Morris, 2002). The correct grazing system must then be adopted throughout the grazing season to ensure that a uniform high quality pasture is offered to dairy cattle. The creation of a uniform poor quality pasture, through not ensuring that the grass is grazed at its correct stage of growth and that supply meets demand, is likely to be more detrimental to animal performance than a patchy sward. Flexible grazing management strategies must be adopted to ensure that pasture is well utilized. Measuring sward patchiness is useful in addition to measures of pasture height as it gives an indication of sward condition (Gibbs & Ridout, 1986). The effects of burning kikuyu at the beginning of the season on the patch dynamics of the sward over the season were investigated at Ukulinga research farm (29°24′E, 30°24′S), South Africa. The effects of a flexible and a rigid rotational grazing management strategy were compared in terms of the patch developments in the swards at Broadacres, neighbouring Cedara Research Farm, situated north west of Pietermaritzburg, at an altitude of 1150m and located at 29°32'S and

30°17'E.

2.3.2 Materials and Methods

The patch structure of recently grazed kikuyu swards at Cedara and Ukulinga were analysed. Frequency distributions of the two hundred disc metre readings taken per paddock over every rotation at Cedara and the 200 disc meter readings taken per paddock over rotations one and three at Ukulinga were analysed using Maximum Likelihood Estimation (MLE) (Derry, 1999). A significant patch structure is indicated by a bimodal distribution. A reduction of the Akaike Information Criterion (AIC) indicated an improved fit with a bimodal as apposed to a unimodal distribution. The number of paddocks best described by single and double normal distributions was compared using ANOVA. The mid point between the means of the distributions for each treatment was used to separate short (patch) and tall (non-patch) pasture. The proportion of frequency values above and below this mid point was used to calculate the size of areas under patches and non-patches.

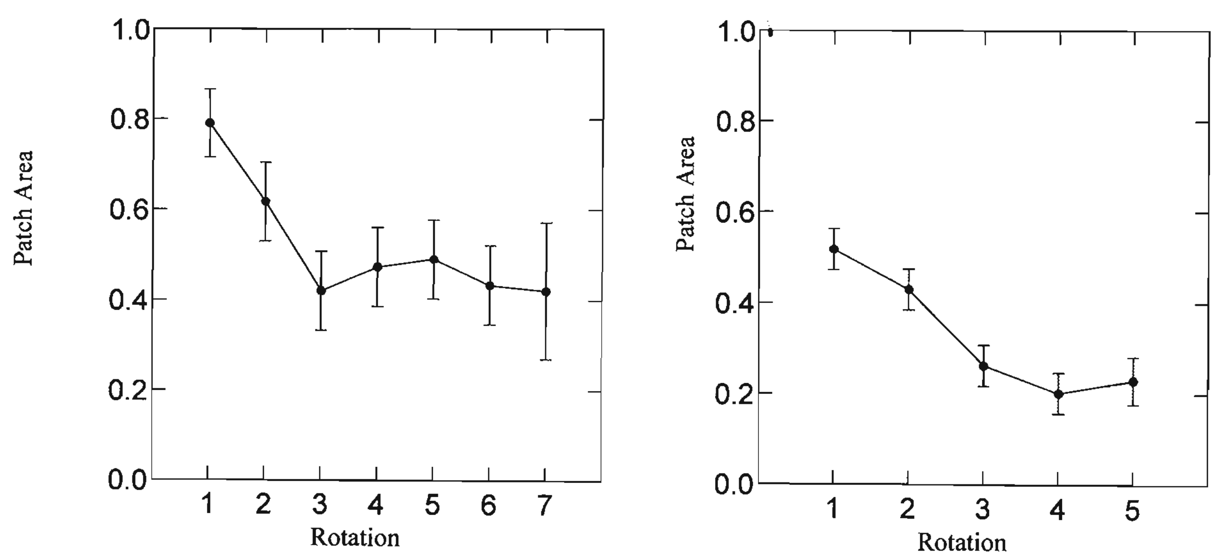
Once the trial at Ukulinga was completed, disc metre readings were taken for pattern analysis. Four paddocks were chosen, each from different blocks and at the same stage of the grazing rotation. A 50 x 30m plot was laid out in each paddock. In each plot, one disc meter reading was taken per square meter (n=1500 per plot).

2.3.3 Results

The aim of the flexible grazing management strategy at Broadacres was to try to create a pasture that was similar to that contained in well utilized patches by ensuring that it did not become rank and that it was grazed frequently. However, it is likely that cattle need to patch graze to a certain degree in order to select pasture that is high in fibre or high in nitrogen according to their requirements.

2.3.3.1 Cedara

Double normal distributions were fitted to the frequency distributions of pasture heights. Bimodal distributions described the rigid rotation data better than a single normal distribution (P=0.005), but single normal distributions described the flexible rotation data better according to the AIC. The pasture under the rigid rotational grazing systems appeared to be patchier than that under the flexible management. Areas of pasture grazed shorter than 9 cm were considered to be well utilized. The patch or well-utilized proportion of the area of kikuyu under the flexible rotation treatment ranged from 42 to 79% of the total grazing area over the grazing rotations. That under the rigid rotation treatment ranged from 19 to 50% (Figure 12a and 12b).



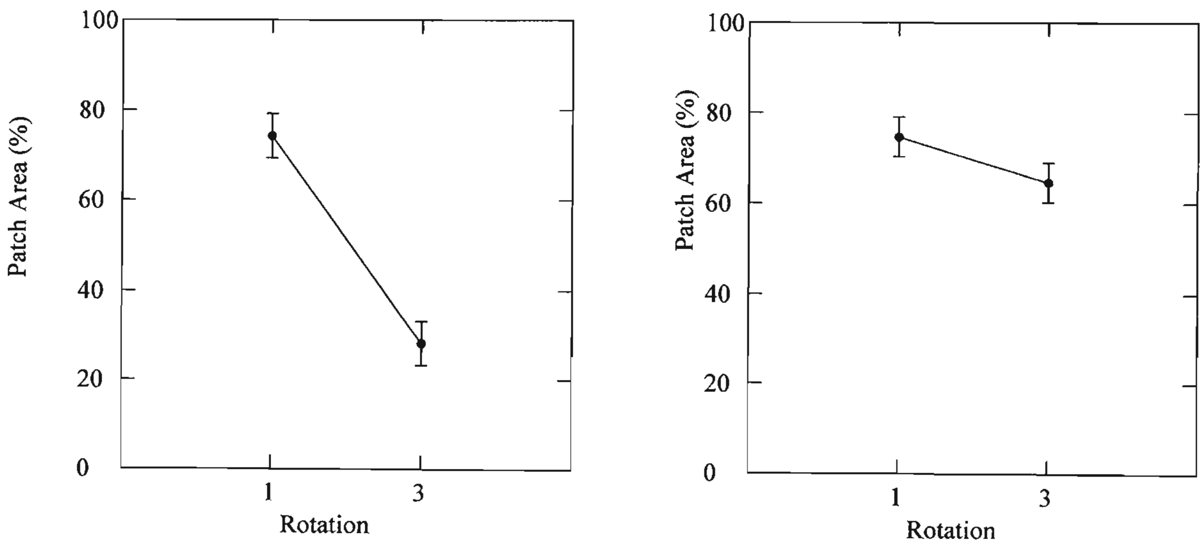
a) b)

Figure 12 Change in patch area over rotations under a) flexible and b) rigid rotational grazing.

The change in the size of patch area for the flexible and rotational grazing treatment over rotations were significant (P=0.058, F-ratio=2.783 and P=0.001, F-ratio=9.125 respectively). The difference in patch area between the flexible and rigid rotations was significant (P=0.038, F-ratio=5.742).

2.3.3.2 Ukulinga

Single and double normal distributions were fitted to the frequency distributions of pasture heights for the burn and no burn treatments. The burnt pasture data had significantly more (P=0.006) paddocks better described by a bimodal distribution than the no burn treatment. This suggests that burning kikuyu pasture subsequently results in a patchier sward. The mid point between the means of the bimodal distribution was incomparable for the burnt and unburnt pasture. The tall pasture component of the burnt pasture was shorter than the short component of the unburnt pasture. The midpoints seven and 12 were chosen for the burnt and unburnt respectively based on distributions obtained over the first rotation. From Figures 13 a and b, it is seen that the patch area had been significantly reduced from rotation one (74.2±19.5%) to three (28.2±14.3%) for the burnt pasture (P<0.001, F-ratio=43.303). By the third rotation, the area of pasture that the cattle were utilizing well had decreased. The well utilized area for the unburnt pasture was not significantly reduced from 74.7±14.7% after the first rotation to 64.6±15.7% after the third rotation (P=0.12, F-ratio=2.62).



a) **b)**

Figure 13 Change in patch area from rotation 1 to 3 for a) burnt pasture and b) unburnt pasture.

2.3.4 Discussion and conclusion

For both the grazing management and burning trials cattle gained similar weights on significantly different quantities of pasture. Although pasture quality may provide some explanation for this, there is perhaps not enough of a difference between the sward qualities under different treatments to account for the variation. The burnt kikuyu was only significantly different in quality initially and only K was significantly higher in the burnt kikuyu pasture over the entire season. Potassium levels exceeded animal requirements and could only have impacted negatively, therefore not explaining similar live weight gains with lower intakes. Pasture quality failed to account for variation between the rigid and flexible grazing rotation treatments for the trial at Cedara. Although every effort was made to make the pasture samples taken over the trials as representative as possible of what the cattle may have eaten (through avoidance of dung patches, weeds and fence lines) this could not be guaranteed. Samples were not necessarily of grazed patches and the ratio of grass from patch and non patch areas may not have been representative of intakes. This is assuming that there would have been significant differences in pasture quality between patches and non patches. Total patch area under the rigid rotation grazing management was smaller than under the flexible treatment. The stocking rate was higher under flexible management and use was made of followers to graze residual material, which would have promoted larger patches with less moribund material. Early season pasture management affects patch development over the entire season. A larger total patch area was maintained over the entire grazing season for the flexible treatment as the pasture was more heavily stocked from the second rotation onwards. Total patch area was greater under the burn treatment at Ukulinga with early season burning of the pasture, but this was maintained over the first and possibly second rotations after which the patch areas were even less than under the no burn treatment. A shortage of dry matter material and a shorter pasture height determining patch from non patch pasture compared with pasture under no burn may have explained this sudden change in patch size. Either the animals grazed the whole pasture more uniformly, or the height distinguishing patch from non patch was too short and only pasture that was very short would have been considered to be well utilised. The sward became more similar to the unburnt pasture as the season progressed.

Although early season grazing management affects patch development (Ring *et al.*, 1985), there were significant changes in patch sizes with each grazing at Cedara, indicating an ability to control patch development and size within seasons. At Ukulinga, there was already dead plant material present at the beginning of the season under the no burn treatment, which may explain the little change in patch area over the two rotations. The patchiness of the burnt sward indicated that the cattle were able to utilise a larger area of pasture well, the pasture being in shorter supply and perhaps more palatable without the rank material. The higher K levels maintained over the season may have impacted negatively on palatability later on in the season. Pasture growing n patch areas may have been of a superior quality and digestibility in particular, which could perhaps explain similar gains on either less area, at Cedara, or less dry matter at Ukulinga.

2.4 A survey of current kikuyu management practices in KwaZulu-Natal and the Eastern Cape.

2.4.1 Introduction

Kikuyu plays a vital role in fodder flow over the summer for most KwaZulu-Natal (KZN) farmers and over the whole season for many farmers in the Eastern Cape. Farmers have traditionally used Kikuyu in South Africa, and KZN in particular, as a pasture to carry cattle from one ryegrass season to the next. A common misconception among farmers is that kikuyu is capable of looking after itself. They have accepted the lower milk yields, assuming them intrinsic to kikuyu pasture. The problems resulting from the mistreatment of kikuyu are hard to rectify because minimal research has been done on kikuyu for dairy production systems in South Africa and the few management practices that have been recommended have not been quantified and are therefore of little use to farmers.

The real cost of fertiliser and dairy concentrates have increased on average by about 2% per annum relative to increase in milk price over the past 15 years (Penderis, 2003). Margins are ever decreasing meaning that low cost milk production is the only way for dairy farming to remain viable. Farmers have little influence over the milk price. Lowering the costs of feed is important as they can account for as much as 70% of total production costs (Parker, 1999). Economical feeding of dairy cows involves maximising the use of available resources, namely pasture. South African dairy farmers have to become better pasture farmers to improve profits (Every, 1999).

Kikuyu has the potential to improve the economics of dairy production, as it is a resilient and highly productive pasture that thrives on nitrogen fertilization (Miles *et al.*, 2000). Once established, the only major expense is nitrogen fertilizer unlike other pastures, such as ryegrass, that require replanting and irrigation in addition to fertilization. Many farmers do not have access to irrigated land. Ryegrass pasture is likely to become even more costly with increasing price of irrigation equipment and higher levies on water use. Temperate pasture seed is also expensive. Kikuyu could not only reduce costs for the commercial farmer, but also make dairy production viable for small scale and emerging farmers who generally have limited access capital and hence irrigation. According to Dugmore (1999) only 20% of the average KwaZulu-Natal farm is arable, although according to Booysen (undated cited by Bransby, 1983) 70% of KwaZulu-Natal is suited to cultivated pastures. The low cost production of milk needed to make dairy farming viable, necessitates that farmers either expand their herds to bring down fixed costs per unit or become more efficient. Producing sufficient irrigated pasture to feed larger herds is often proving difficult with many farmers having expanded to the limit of their irrigation potential. Further expansion is only possible with improved irrigable land utilization or on dryland pastures such as kikuyu.

Utilizing farm produced feed to its full potential requires precise management with the use of higher stocking rates, and accurate measurement of pasture quality and quantity. Concentrate supplementation is crucial for cows grazing kikuyu pasture because of the high metabolic demands placed on them. The alternatives to concentrate supplementation, such as making silage, or introducing irrigated pastures, are also expensive and often the extra income from any extra milk produced does not offset the additional costs. Commercial concentrates are formulated according to Act 36 of 1947, which caters for a broad range of dairy cow needs in different dairy production systems, and not according to the protein, energy and mineral imbalances of kikuyu. It is likely that dairy cattle grazing kikuyu in South Africa are producing milk off a diet that is not balanced. Accurate supplementation to a basal diet of kikuyu pasture is only possible once farmers have begun to manage kikuyu pasture properly. Correction of dietary imbalances and deficiencies must first be done by improving pasture management, and then through affordable kikuyu-specific supplementation.

Although it is essential that kikuyu is grazed at its correct stage of regrowth, nitrogen fertilizer be judiciously applied and rejected pasture removed for optimal production to be achieved (Fulkerson, 1999a), methods of achieving this are often difficult or expensive. Methods of determining grazing readiness and of removing rejected pasture have not been compared in terms of effectiveness or economics in South Africa. A survey was carried out on dairy farms in KwaZulu-Natal and the Eastern Cape in an attempt to compare different kikuyu management techniques in terms of animal and pasture performance and economics.

2.4.2 Materials and Methods

Twelve KwaZulu-Natal farmers and five Eastern Cape farmers were chosen for the survey. Cattle had to be grazing kikuyu pasture for 24 hours a day. This proved difficult given the sub-average rainfall this season, with most farmers relying heavily on supplementary feed and irrigable pastures. The KwaZulu-Natal farmers were visited once over the summer, in the beginning of 2003 and the Eastern Cape farmers were visited in November 2002 and May 2003. Of the farmers in the Eastern Cape, one was from East London and the other four from Alexandria. The farmers in KZN were from the Creighton, Ixopo, Highflats, Pietermaritzburg, Merrivale, Karkloof, Lidgetton and Mooi River areas. The questionnaire was sent to each farmer prior to being visited so that they could collect relevant information in advance. They were not expected to complete the questionnaire as this was done upon visitation. Supplementary feed, such as hay and silage, and grazing-ready kikuyu pasture (according to the farmer) was sampled. Soil on the Eastern Cape farms was sampled to remove discrepancies between Cedara and Eastern Cape laboratories. Commercial concentrate analyses were obtained from the farmers and feed companies.

Samples taken from farms were analysed by the Voermol Laboratory. Protein analysis was done using the Leco FP 2000 nitrogen analyzer according to the AOAC. Fibre, acid detergent fibre (ADF), neutral detergent fibre (NDF) and lignin were analysed using the Ankom fibre apparatus:
Fibre Ankom technology - 9/99
ADF Ankom Technology - 9/99
NDF Ankom Technology - 8/98
Lignin Ankom Technology - 9/99
Moisture was analysed on the Milestone microwave apparatus, the technology having been developed by Milestone in Italy and compares well with the AOAC oven method. Fats were analysed using the gold fish fat apparatus based on ether extraction given by AOAC. Ash was analysed in a Muffle Furnace at 600 degrees Celsius as recommended by the AOAC. Metabolisable energy (ME) was calculated using the following equations:
Digestible organic matter (DOM) % = 71.6 – (0.62*CP (%)) (Dugmore 1998)
ME = 0.83(0.193*%DOM-0.661) $MJ.kgDM^{-1}$ (Corbett 1978)

Data were initially analysed using regression tree analysis to identify major causes of variation between kikuyu pasture quality and dairy cow performance. Data were analysed using Canoco (4.5). Two principal components analyses (PCA) were done, one of kikuyu pasture quality in relation to farms and the other on kikuyu pasture quality, milk yield, butterfat, protein and days in milk in relation to farms. Information collected from the survey was introduced in the form of supplementary environmental variables, which were overlaid on the original PCA's to identify possible reasons for differences in pasture quality and animal performance. Data were further analysed with Regression Tree Analysis using Cart® (Steinberg & Colla, 1997) to identify factors with the biggest influence on milk yield and grass quality. Data were compared using analysis of variance with Systat 10. The total diet for each farm or herd was evaluated using CPM-dairy to identify dietary imbalances and deficiencies.

2.4.3 Results and Discussion

Interpretation of the data was made under the assumption that the pasture sampled was representative of the management conditions detailed by each farmer. Nutrients in kikuyu vary according to environment, location, management and season (Cross, 1979b) and the requirements of the dairy cow vary according to lactation number, pregnancy, lactation stage, body weight, activity and yield (Stewart *et al.*, 1995). The aim of the survey was to find out how management of kikuyu affects its quality and what the subsequent affect on milk production is. Data related to milk production and kikuyu pasture management were collected. Kikuyu management data was related to kikuyu pasture quality alone. Factors relating to the dairy cow were related to both kikuyu pasture quality and production of milk and solids. A PCA of cow performance and kikuyu quality showed how they varied together according to site.

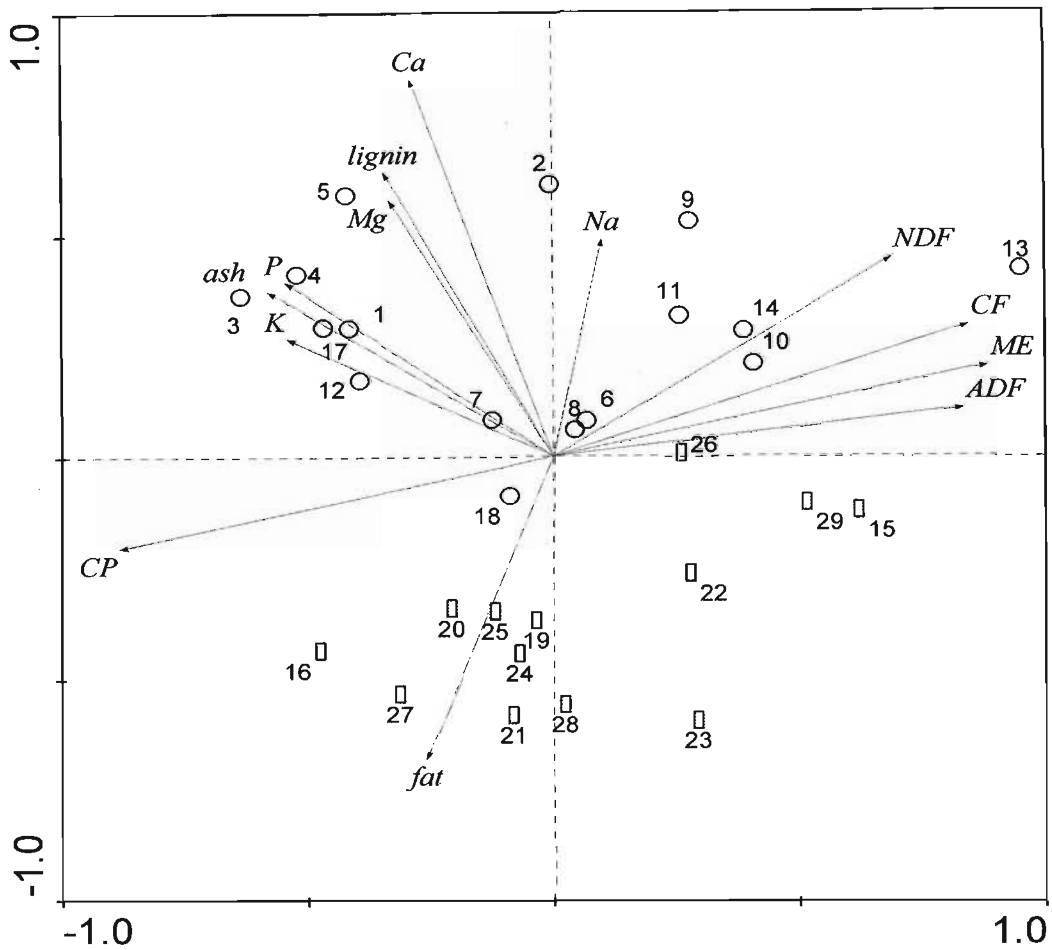


Figure 14 Principle components analysis of kikuyu quality in relation to sites. Eigenvalues for axes one and two were 0.3673 and 0.2259 accounting for 59% of total variation. Sites represented by ǃare KZN farms and ○ EC farms.

From Figure 14, the major gradients describing the distribution of plots in relation to kikuyu quality are a protein and energy (ME)-fibre gradient (Axis 2) and a fat, sodium and calcium gradient (Axis 1). Figures 15a and 15b indicate that EC and KZN farmers are separated by axis 2, the calcium fat gradient. Eastern Cape kikuyu is generally higher in Ca, Mg, Na and lignin. KwaZulu Natal kikuyu is higher in fat. This separation of farmers according to province has led to a discussion focussing on possible reasons for differences in kikuyu quality.

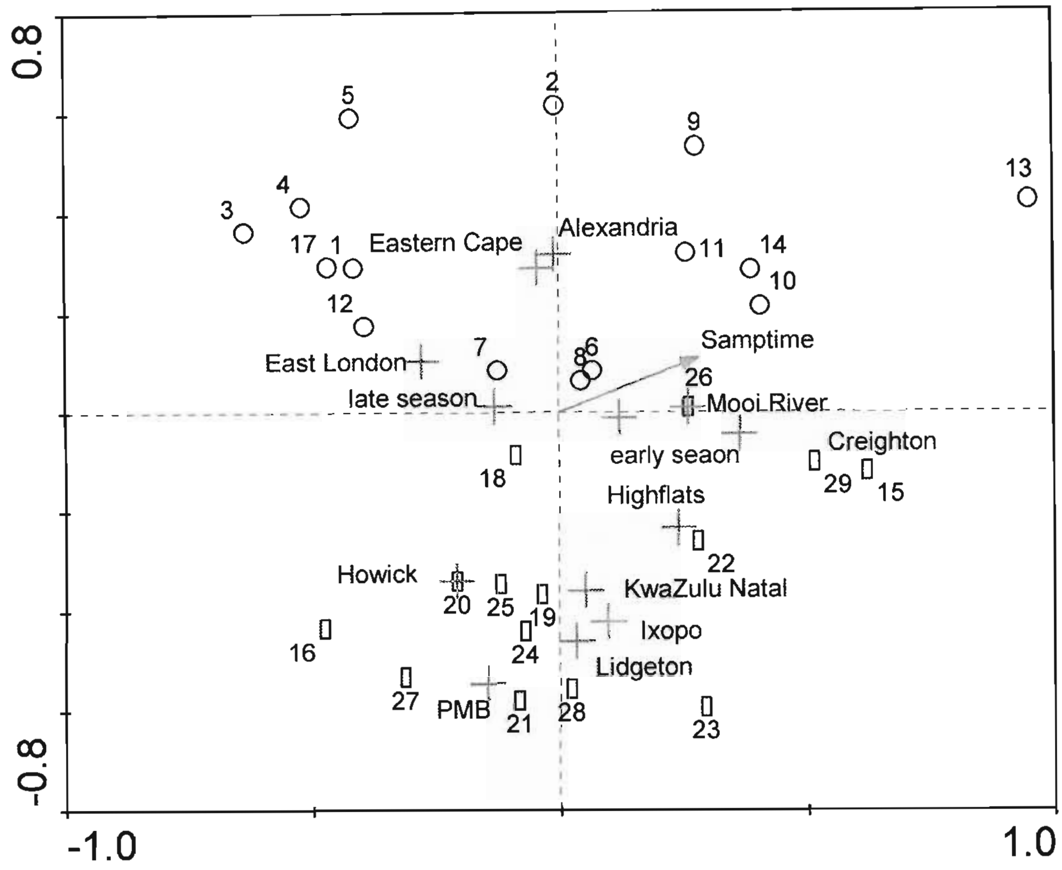


Figure 15a Principle components analysis of sites in relation to supplementary environmental variables geographical location and sampling time (samptime early or late season). Eigenvalues for axes one and two were 0.3673 and 0.2259, accounting for 59% of the variation. Sites represented by ▯are KZN farms and o EC farms.

Figure 15a and b Axis one is a time gradient with early season and late season having R^2 values of 0.33 and -0.33 respectively. Sampling time, which was time of the day that the sample was taken, had R^2 values for axes one and two of 0.28 and 0.11 respectively. Axis two is a location gradient, separating EC and KZN ($R^2 = 0.86$) farmers. Lidgetton, Ixopo and Pietermaritzburg (PMB) were all highly correlated to axis two. Most EC farmers were from Alexandria, with one from East London, which explains the high R^2 value of 0.82 for Alexandria with axis two.

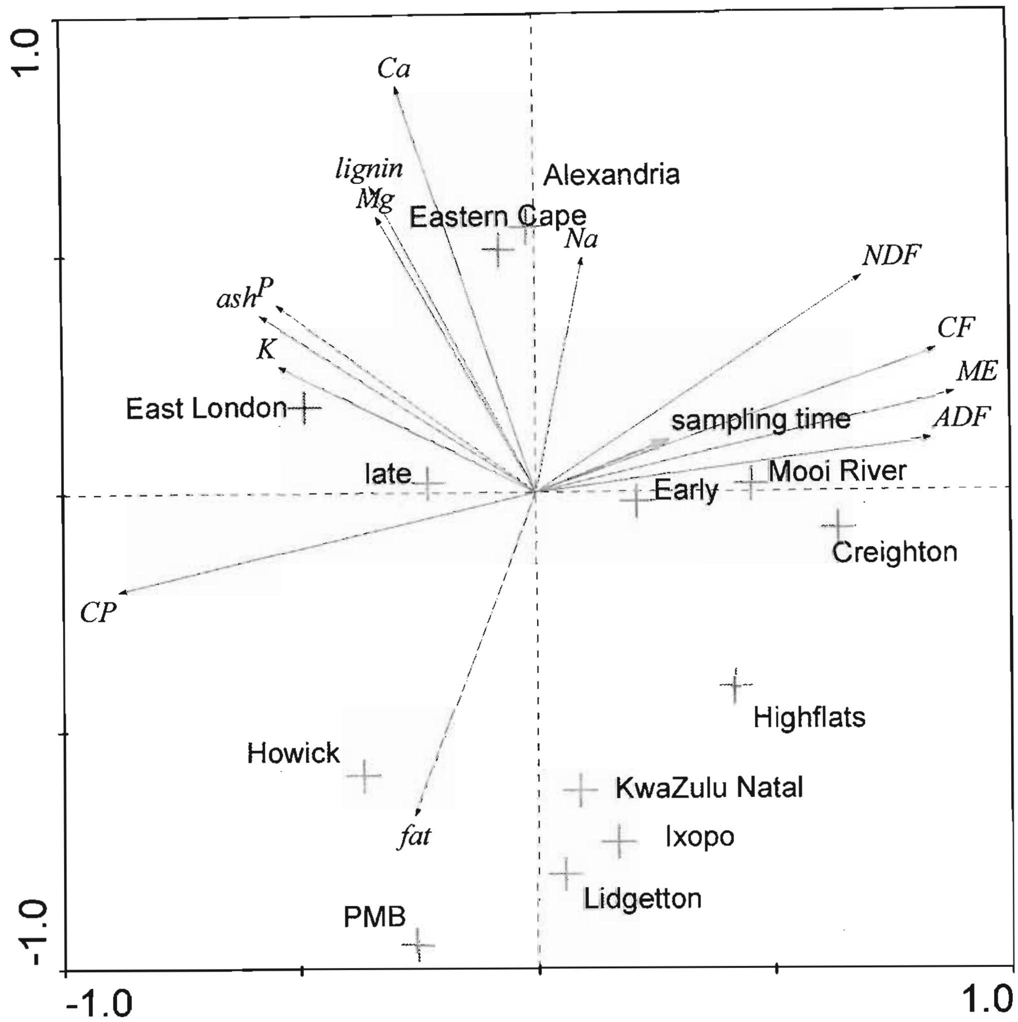


Figure 15b Principle components analysis of kikuyu quality in relation to supplementary environmental variables geographical location and sampling time (early or late season). Eigenvalues for axes one and two were 0.3673 and 0.2259, accounting for 59% of the variation.

Dugmore & du Toit (1988) found that production from kikuyu was lower than expected from chemical analysis because of the negative effects of high protein on fibre digestibility. Figure 14 shows CP and fibre content of kikuyu pasture are negatively correlated. Lignin, which is the biggest structural inhibitor of fibre digestion (Marais, 1998), is not correlated to either protein or fibre concentrations, although there is a tendency for it to be more positively correlated with protein.

Higher levels of Ca and Na in EC kikuyu agrees with work done by Miles *et al.* (2000). They found kikuyu Ca, P, K, Mg and Na levels in the EC to be 0.48%, 0.40%, 3.4%, 0.36% and 0.24% respectively.

Table 10 Kikuyu quality comparison between KwaZulu-Natal and the Eastern Cape in relation to dairy cow requirements.

Parameter	Eastern Cape (Mean ± s.d.)	KZN (Mean ± s.d.)	F-ratio	P	Cow requirement[1]
Protein	24.60±4.48	24.71±2.79	0.006	0.938 NS	
Fat	2.87±0.62	3.49±0.65	6.39	0.018*	
Ash	9.59±1.57	8.65±0.99	3.44	0.075*	
CF	20.51±1.90	20.08±1.98	0.328	0.572 NS	
NDF	58.70±3.84	56.26±4.00	2.598	0.120 NS	
Lignin	6.26±1.06	4.35±0.64	31.497	0.000**	
ADF	46.2±4.31	46.42±4.01	0.014	0.907 NS	
Ca	0.46±0.08	0.30±0.04	40.054	0.000**	0.45-0.81
P	0.44±0.08	0.40±0.06	3.042	0.093*	0.35-0.45
Na	0.19±0.13	0.07±0.12	6.391	0.018 NS	0.18-0.67
K	3.08±0.66	2.88±0.59	0.672	0.420 NS	0.8-2.45
Mg	0.43±0.05	0.34±0.08	13.629	0.001**	0.25-0.35
Ca:P	1.05:1	0.75:1			1:1-2:1
K/(Ca+Mg)	1.36	1.72			<2.2
K:Na	16:1	41:1			5:1

[1] Puls (1994)

* P≤0.05, ** P<0.01, NS non significant

Table 14 shows a significant difference in fat content between KZN and EC as to be expected from the strong gradient in Figure 14. The significant difference in ash content indicates differences in organic matter content of kikuyu pasture for the two provinces. Calcium falls just within requirements for the EC, but is deficient in KZN. Large concentrations of oxalate known to occur in kikuyu pasture could render most of the calcium unavailable to dairy cattle (Marais, 1990). According to Miles *et al.* (2000) EC kikuyu is low in oxalate. KZN kikuyu is likely to be highly deficient in Ca. Despite the potential availability of Ca in the EC, the relatively high concentrations of P found in kikuyu make the Ca: P ratio unfavourable. This imbalance can be easily rectified in the EC, being marginal, but in KZN an inverse balance is likely when taking the role of oxalate into account. It is difficult to correct imbalances below 0.5:1 without causing metabolic problems

(Bredon, 1980 cited by Miles *et al.,* 1995). Kikuyu sodium levels in EC fall just within adequate range, but are deficient in KZN. An explanation for this difference is proximity to the ocean (Miles *et al.*, 2000). Kikuyu is a natrophobe, incapable of absorbing sufficient Na to meet animal requirements (Marais, 1998). Potassium levels exceed animal requirement in both provinces. Potassium limits Mg absorption (Reeves *et al.,* 1996b). Magnesium levels are adequate and more than adequate for KZN and EC respectively. Farmers adopting short rotations are likely to have higher kikuyu K because levels are higher at leaf emergence (Reeves *et al.*, 1996b). Miles *et al.* (1995) found that the K/(Ca + Mg) ratio in KZN varies from 2.19 to 3.15. The ratio in Table 14 is more favourable due to slightly lower K levels and higher Ca than figures cited in the literature. Dugmore (1998) stated that cows need to maintain the K: Na ratio at 15: 1 in the saliva to prevent bloat. The ratio should be kept below 20: 1 to prevent lengthening of the intercalving period (Berringer, 1988, cited by Fulkerson *et al.*, 1998). Puls (1994) stated that K: Na should be 5:1 to promote Mg absorption and a K: Na ratio of over 40:1 can lead to bloat. According to Table 14, cattle in KZN are likely to have metabolic and fertility problems unless supplemented. Pasture containing a combination of K and Na greater than 3.5% should be avoided (Puls, 1994). It is important that K levels are carefully monitored on farm, especially in the EC where Na levels are higher and increases in K levels seem to be controlled more by management factors (Figure 14). Requirements for electrolytes need to be assessed according to environment as heat stress and excess dietary N increase water requirements which upset the electrolyte balance (Puls, 1994). Balancing N levels in the diet with energy is important also for mineral nutrition. This will be discussed in more detail later.

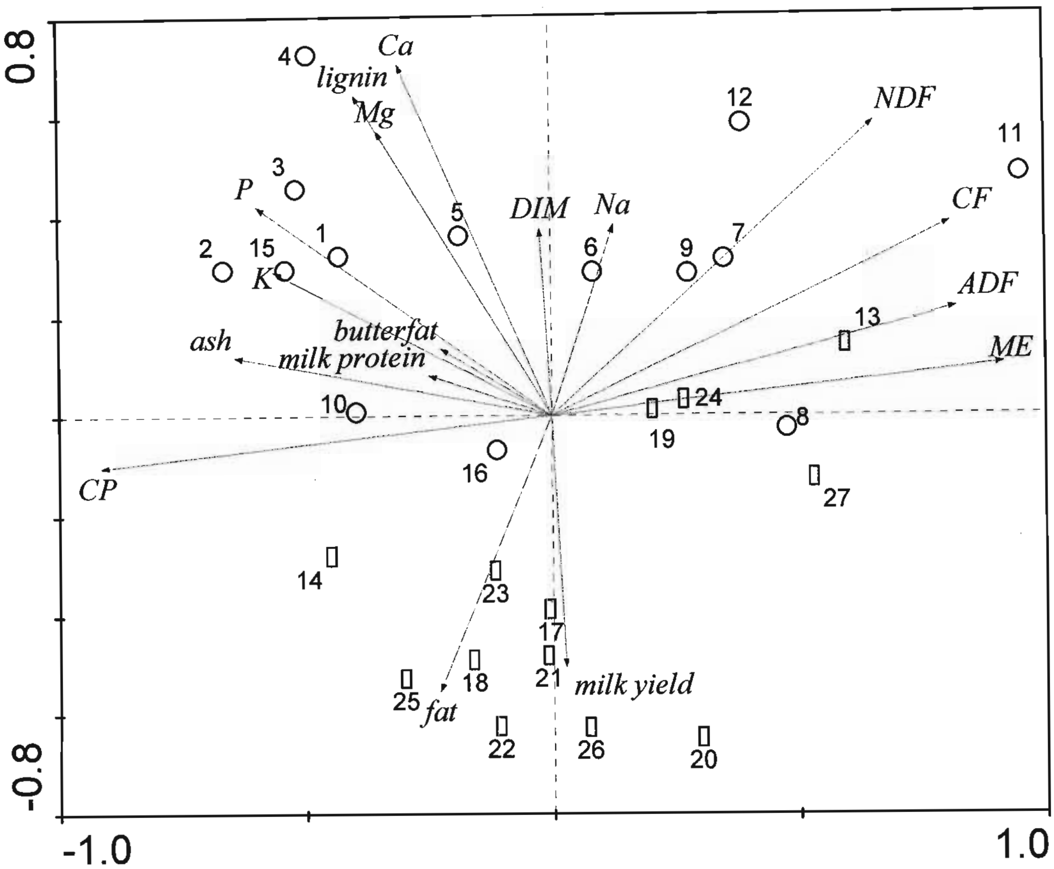


Figure 16 Principle components analysis of kikuyu quality and dairy cow production. Eigenvalues for axes one and two were 0.2989 and 0.1733 accounting for 47% of total variation. DIM=days in milk. Sites represented by ▯are KZN farms and ○ EC farms.

Figure 16 is a simple PCA ordination plot describing the relation between kikuyu quality gradients and milk, butterfat and protein yield. Days in milk were also included because some farmers only had cows long in milk on kikuyu. Butterfat and protein are not strong gradients but are related to Axis 1. Axis 2 is described by a milk yield days in milk gradient. Milk yield was highly correlated to kikuyu fat content. There is a tendency for farmers in KZN to have higher yields per cow. Butterfat and protein are negatively correlated with milk yield and tend to be higher in the late season samples. Fibre is a major driver of butterfat production, through the production of acetic acid through rumen fermentation, but milk solids are negatively correlated with increased fibre levels in kikuyu. This may be because of an energy shortage or stage of lactation.

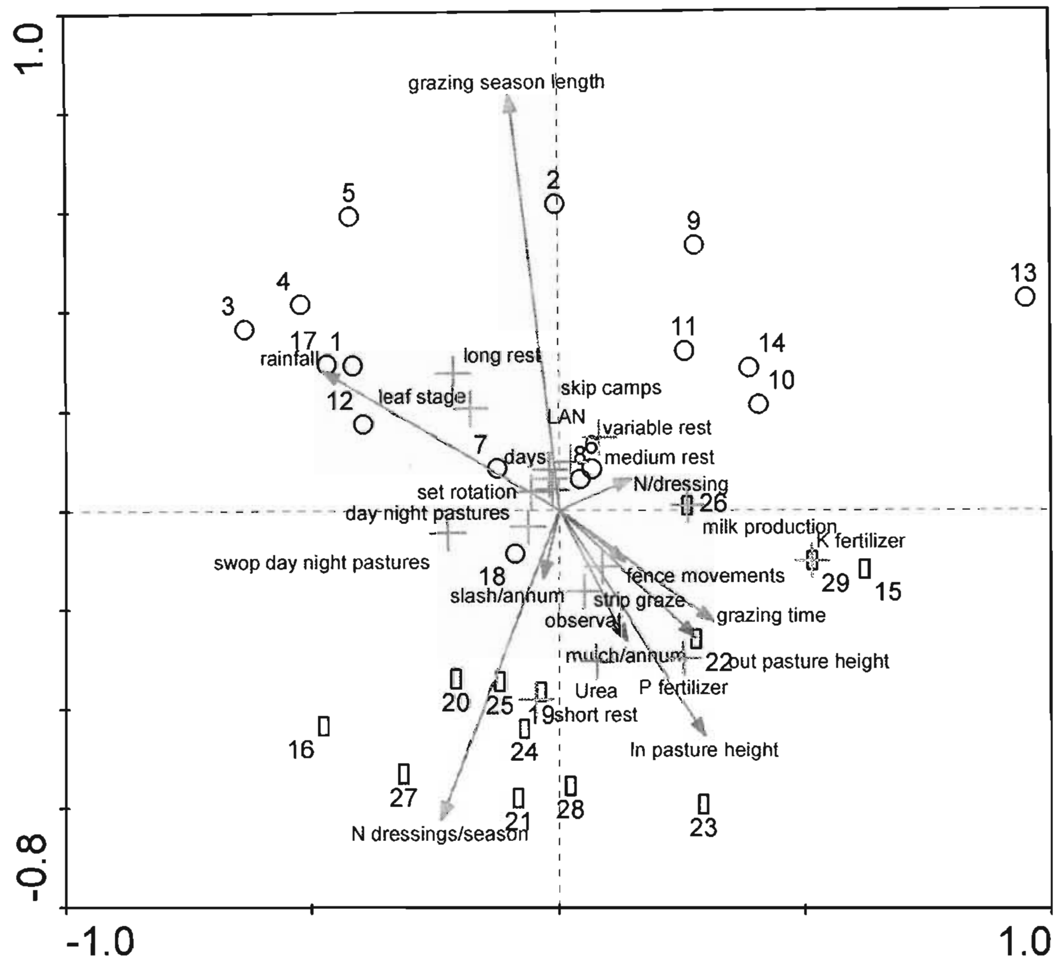


Figure 17a Principle components analysis of kikuyu quality with supplementary pasture management variables. Eigenvalues for axes one and two were 0.3673 and 0.2259 accounting for 59% of total variation. Sites represented by ▯ are KZN farms and ○ EC farms.

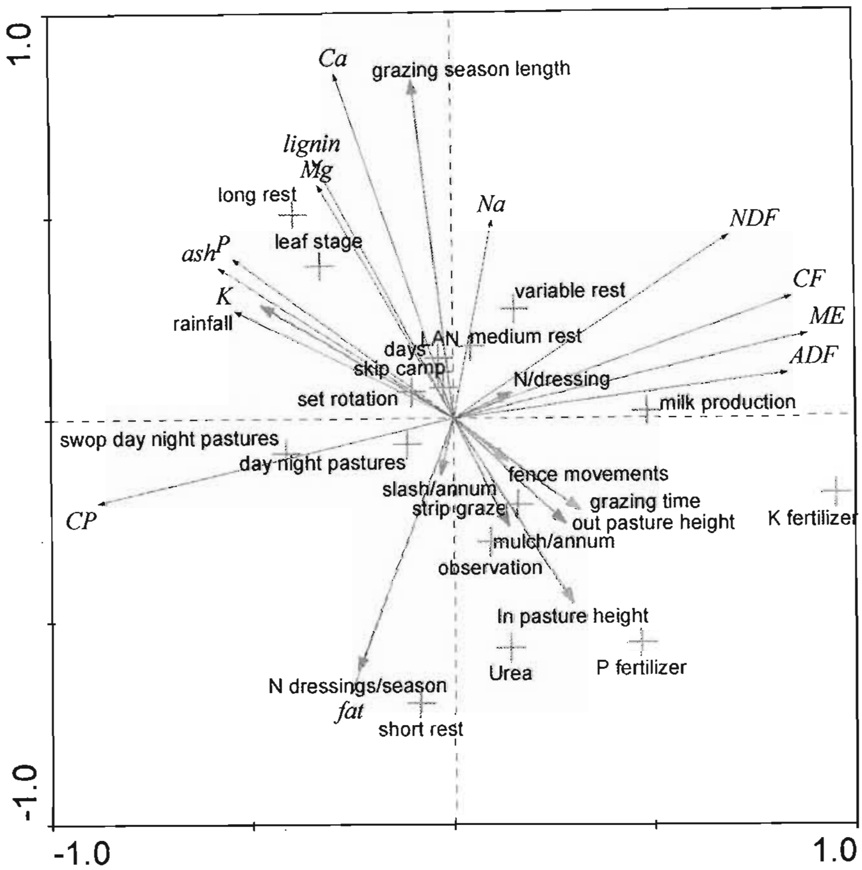


Figure 17b Principle components analysis of kikuyu quality with supplementary pasture management variables. Eigenvalues for axes one and two were 0.3673 and 0.2259 accounting for 59% of total variation.

The relation of kikuyu quality, management factors and rainfall over the season is given in Figures 17a and 17b. A protein and fibre gradient, the two being negatively correlated describe Axis 1. Axis 1 separates sampling season differences (Figure 15) between farmers in the Eastern Cape. Kikuyu sampled in autumn was higher in protein and lower in fibre than those sampled in spring. This could be explained by rainfall as spring was drier than autumn. Farmers in KZN drier areas also tended to be located on the higher fibre side of the axis. All kikuyu was dryland except for case 16, which was irrigated. Rainfall since August 2002 was taken into account. Rainfall accounted for variation among farms. Slashing and mulching of kikuyu appeared to have little influence on kikuyu pasture quality. None of the management variables described much variation on Axis 1. Axis 2 is highly correlated with grazing season length and number of N dressings. KZN farmers applied more dressings of N (mean 1.25 vs. 2.50). Grazing season length varied from an average 6.5 months in KZN to 12 months in EC. KZN kikuyu pasture is considerably taller before and after grazing than that in EC. Pasture heights before and after grazing for KZN and EC are 21.2±5.0 vs. 13.6±2.0 (P=0.00) and 9.8±4.8 vs. 5.3±2.4 (P=0.005). Pasture height before and after grazing was positively correlated.

According to Figure 17, use of leaf stage as a means of assessing grazing readiness had little correlation with quality gradients. EC farmers made use of leaf stage as a means of determining grazing readiness. Days since last grazing, set rotations and skipping paddocks may have had greater influences. Although pasture height was included as a means of assessing grazing readiness, it was not used by any farmer. KZN farmers made more use of observation, rather than measurement, in deciding when to graze pastures. One farmer used fluctuations in milk production as an indicator of when to move his cows, but this approach is problematic in that it treats a problem that should have been prevented. Many farmers, who do not base grazing on observation, use time or days since the last grazing. This was more popular among the KZN farmers. The observed sign of readiness was usually when the grass begins to fall over and has sheen. One farmer reported grazing ready kikuyu to be a foot tall and waves when the wind blows. The cows were then removed from the paddock when there is a reduction in milk production. Other rotations were based on grazing the longest pasture first, regardless of the length of the pasture, or leaf stage. Grazing pastures for more than three days is considered harmful to growth when pastures are growing quickly as root reserves are depleted. This was seen on some farms. KZN pastures were considerably taller before and after grazing.

Nitrogen per dressing is not an important gradient as there was little difference from between areas (67.69±12.35 and 72.81±21.83 for KZN and EC respectively). One KZN farmer used potassium fertiliser, while five used phosphate. EC farmers used N only. EC farmers used LAN fertiliser and KZN either urea or LAN. Kikuyu fat content and number of N dressings are highly correlated but this is explained by KZN farmers applying more dressings to their kikuyu pasture that is higher in fat. Increased N application raises kikuyu CP levels and there is a positive correlation between number on N dressings and CP content according to the graph. Amount of N per dressing is negatively correlated to CP content, indicating that distribution of N applications may be more effective than total N.

Rainfall accounted for some variation and is highly positively correlated with kikuyu K, P and ash levels. It is negatively correlated with fibre levels. Number of times kikuyu was slashed or mulched over the season failed to explain much variation in quality. These practices were minimal over the season due to low initial rainfall. Of the farmers that practiced mulching, those in KZN did so more often than EC farmers did. Weather conditions in the EC are highly variable. Some farmers were afraid to mulch because of slower regrowth afterwards and unreliability on rainfall. Grazing season length has a major influence and is strongly correlated to the second axis. Farmers in EC graze kikuyu all year round, while KZN farmers graze kikuyu only over the summer months. Rest period between grazing was divided into short, medium, long and variable. There was one case of a long rest period, being over 25 days. A 28-day cycle was adhered to all season regardless of growth. A medium rest period was 20 to 25 days and there were six EC and two KZN cases. Short rest periods of less than 20 days were used only by KZN farmers. This may be a function of faster growth rates in warmer conditions and more leaf material remaining after grazing (indicated by higher after grazing readings) to initiate regrowth. Short rest periods failed to explain much variability in quality. There were seven cases of variable rest periods in EC and three in KZN. The close proximity of the two points on the graph indicates little difference between medium and variable rest in explaining quality gradients. Many farmers make use of separate pastures for day and night, but there were only two cases where the pastures were swapped. Pastures further away from the buildings or on cooler slopes are generally used for the day. Failure to swap day and night pasture has repercussions for K build up from higher dung concentrations on night pastures. There were four EC and five KZN cases where farmers strip grazed kikuyu. Cows were given access to fresh pasture three times a day in the EC, whereas the fence was usually moved twice a day in KZN.

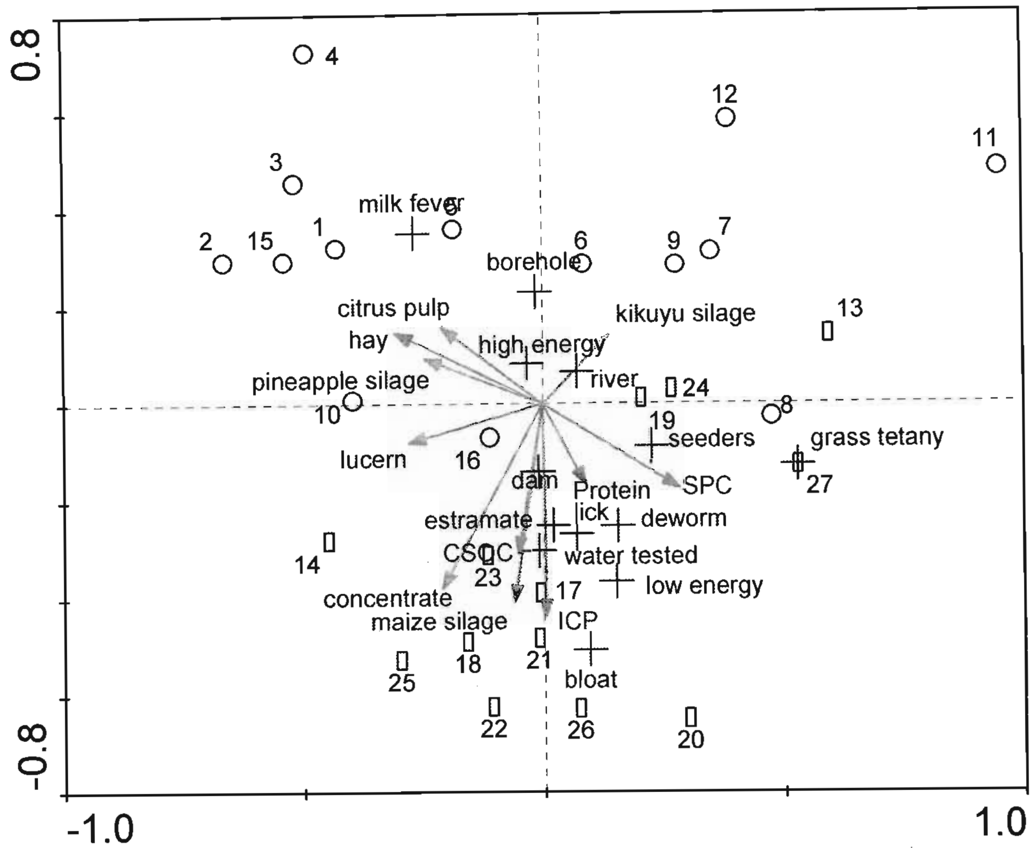


Figure 18a Principle components analysis of sites determined by kikuyu quality and milk yield and quality in relation to supplementary feeding, metabolic disorders, fertility and water quality. Eigenvalues for axes one and two were 0.2989 and 0.1733, accounting for 47% of total variation. Sites represented by ▯are KZN farms and ○ EC farms. ICP=intercalving period SPC=services per conception.

The amount of concentrate and maize silage fed account for variation along Axis 2 of Figure 18. Increased concentrate and maize silage intake were associated with higher milk yields. The tendency was for KZN farmers to feed more concentrate. Only KZN farmers fed maize silage. Eastern Cape farmers supplemented their dairy cows with pineapple silage, lucern, citrus pulp or kikuyu silage. One KZN farmer supplemented his cows with lucern and cottonseed oil cake (CSOC). All EC farmers made use of high energy concentrates with high maize inclusion rates. Some KZN farmers were feeding their cows cheaper, lower energy concentrates. There was a tendency for KZN farmers to feed higher protein concentrates to cows on kikuyu. All except for one farmer in the EC fed 12%

protein concentrates to their cows. Supplementation with maize silage necessitates the use of high protein concentrates due to low protein content of maize silage, which explains its use in some cases. Many farmers thought kikuyu to be lower in protein than ryegrass and they started using higher protein concentrates when moving from ryegrass on to kikuyu. This may have later season benefits when total protein intake may be affected by lower kikuyu intakes if poor pasture management results in accumulation of old material and dietary fibre levels increase, limiting intake. Farmers in the Alexandria area all have in parlour feeding of concentrates. The East London farmer and some KZN farmers made use of post feeders. Licks were only used by some KZN farmers, but were not used at all in EC, probably due to a perceived more favourable mineral balance of their kikuyu.

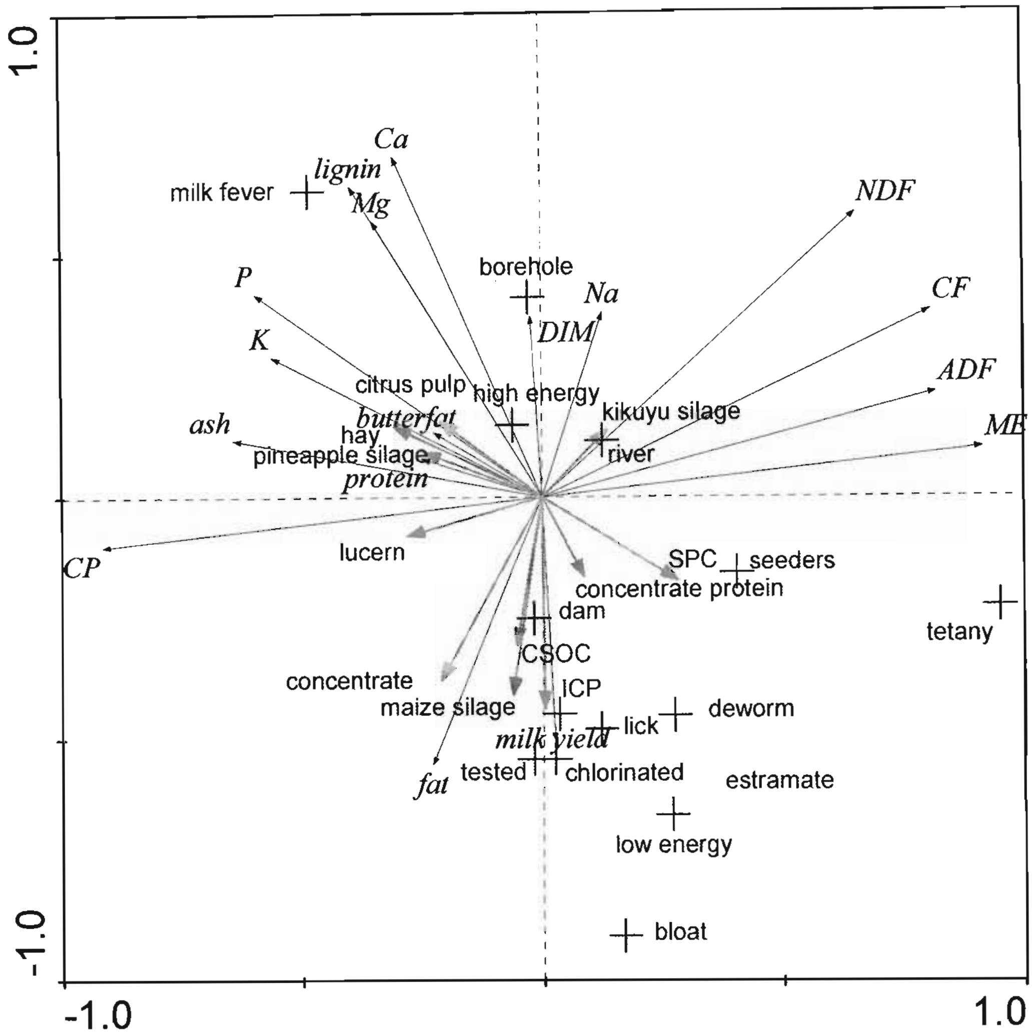


Figure 18b Principle components analysis of kikuyu quality and milk yield and quality in relation to supplementary feeding, metabolic disorders, fertility and water quality. Eigenvalues for axes one and two were 0.2989 and 0.1733, accounting for 47% of total variation. ICP=intercalving period SPC=services per conception.

Axis 1 in Figure 18b is correlated to services per conception (SPC). Intercalving period (ICP) is strongly correlated with axis 2 and milk yields. Cow fertility is lost at the expense of high milk yields. There is a tendency for the KZN farmers to produce more milk per cow and fertility suffers as a result. Prostaglandin in the form of Estramate and seeders were more commonly used by KZN farmers. There were two cases in EC where prostaglandin was used. This is interesting because some EC farmers calve seasonally and the system requires more fertile cows. Perhaps a more rigid culling regime for cows with poor fertility had been carried out in EC. There was no relation evident between kikuyu quality and grass tetany, milk fever and bloat incidences. More EC farmers had milk fever incidences, but bloat was more common in KZN. Given the Na and K levels in KZN, bloat would be likely to occur in cows grazing kikuyu as the ratio of K: Na would be high. Only one farmer reported that grass tetany had been a problem. None of the EC farmers dosed their dairy cows for internal parasites, and liver fluke in particular. Half the KZN farmers dosed their dairy cows. Water sources in KZN were usually dams, but were variable for the EC. Kikuyu quality, milk production and the average number of days in milk were analysed together using PCA.

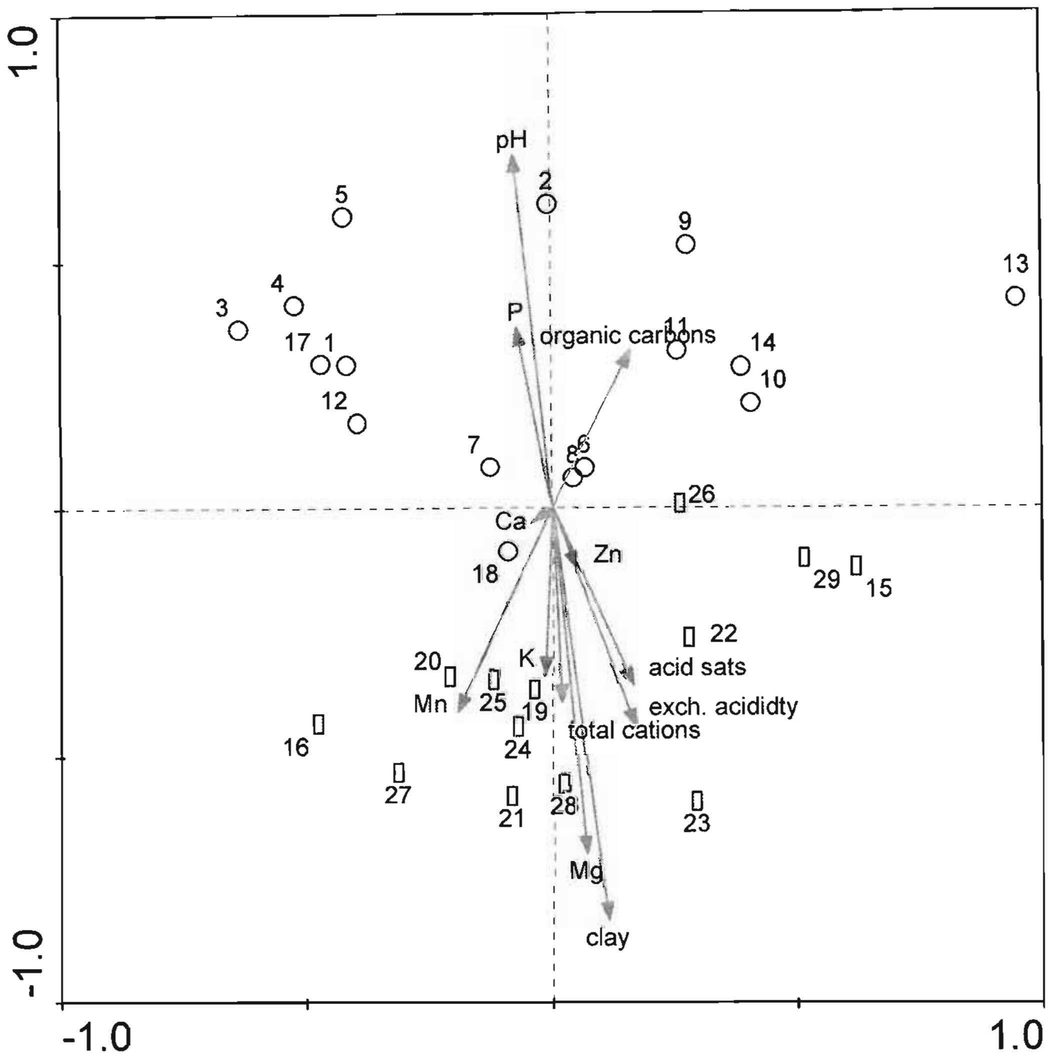


Figure 19a Principle components analysis of sites in relation to kikuyu quality with supplementary soil quality variables. Eigenvalues for axes one and two were 0.3673 and 0.2259, accounting for 59% of total variation. Sites represented by ▯ are KZN farms and ○ EC farms.

Soil quality in Figure 19a failed to explain much variation along Axis 1 but Axis 2 represents a soil acidity and clay content gradient. Soils in KZN are generally more acidic with higher clay content than soils in the EC. The trend is for EC soils to be higher in P and organic carbons. KZN soils seem higher in total cations. Soil Ca did not account for much variation. Poor correlations exist between soil and kikuyu Ca and K levels. Soil P and kikuyu P are positively correlated. There is a negative correlation between kikuyu and soil magnesium levels. Use of soil mineral content as an indicator of kikuyu mineral content is unreliable.

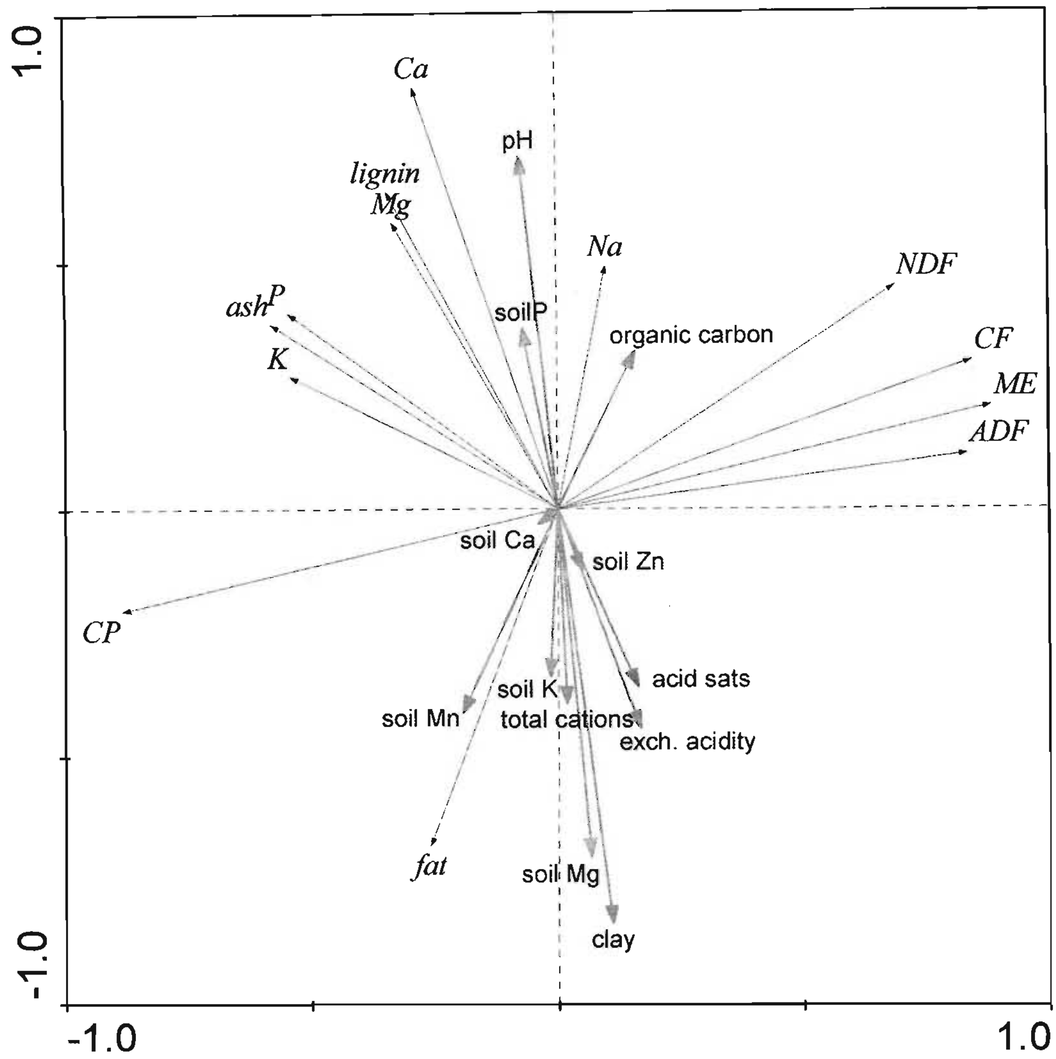


Figure 19b Principle components analysis of kikuyu quality with supplementary soil quality variables. Eigenvalues for axes one and two were 0.3673 and 0.2259, accounting for 59% of total variation.

Figures 20a and 20b give kikuyu quality and milk yield and quality with the supplementary variables of breed, cow size and condition, herd sizes and age groups and calving pasterns. Axis 2 is represented by a gradient in cow size. None of the supplementary variables accounted for much variation along axis 1. Changes along axis one appears to be related to early or late season sampling time (Figure 20a). Cows in KZN are generally larger than those in EC. The use of cross breed cows, which are smaller than Holsteins, was greater in EC. Holsteins were used in both provinces, but those in KZN tended to be of a larger type. There were more cows in milk in EC than in KZN. In the case of dairy herd dynamics, all groups are closely correlated to number of cows in milk, but the correlation is strongest for first lactation cows. It is usual for growing herds to have a higher percentage of young cows in the herd and first calvers in particular. The use of Jersey cows did not account for much variation as they were used only by one farmer. Time taken to milk the cows per day was longer in KZN than in the EC, despite the larger herds in EC. This can be attributed to more EC farmers having modern dairies. There was a tendency for KZN cows to be in better condition. EC cows walk longer distances to and from the dairy. It is this factor and poorer fertility that has led EC farmers to cross breed their cattle. Cross breeds are believed to be hardier animals. Semi seasonal calving systems rely on good fertility even more than regular calving systems and they are willing to have this even at the expense of some milk yield. Milk yield per hectare was also considered in addition to yield per cow in EC. Only one farmer in KZN was on a semi seasonal calving system compared to the EC where it is common.

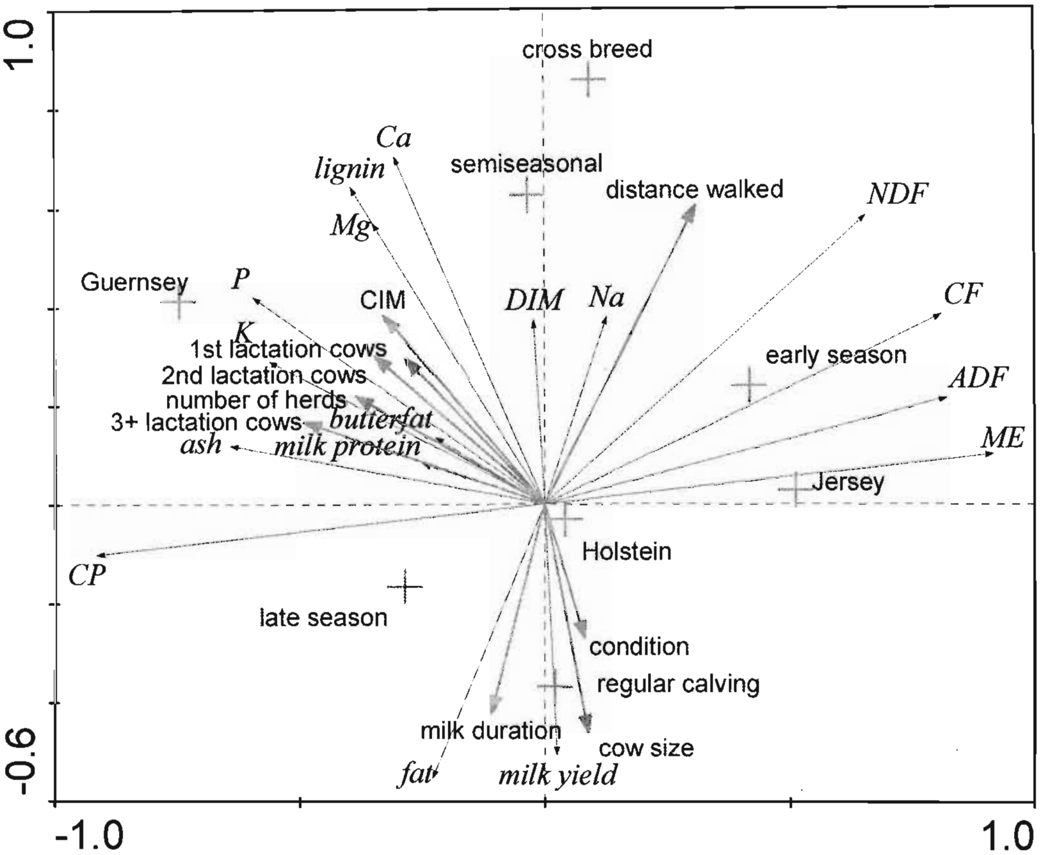


Figure 20a Principle components analysis graph of kikuyu quality with supplementary environmental variables calving pattern and herd dynamics. Eigenvalues for axes one and two were 0.2989 and 0.1733, accounting for 47% of total variation.

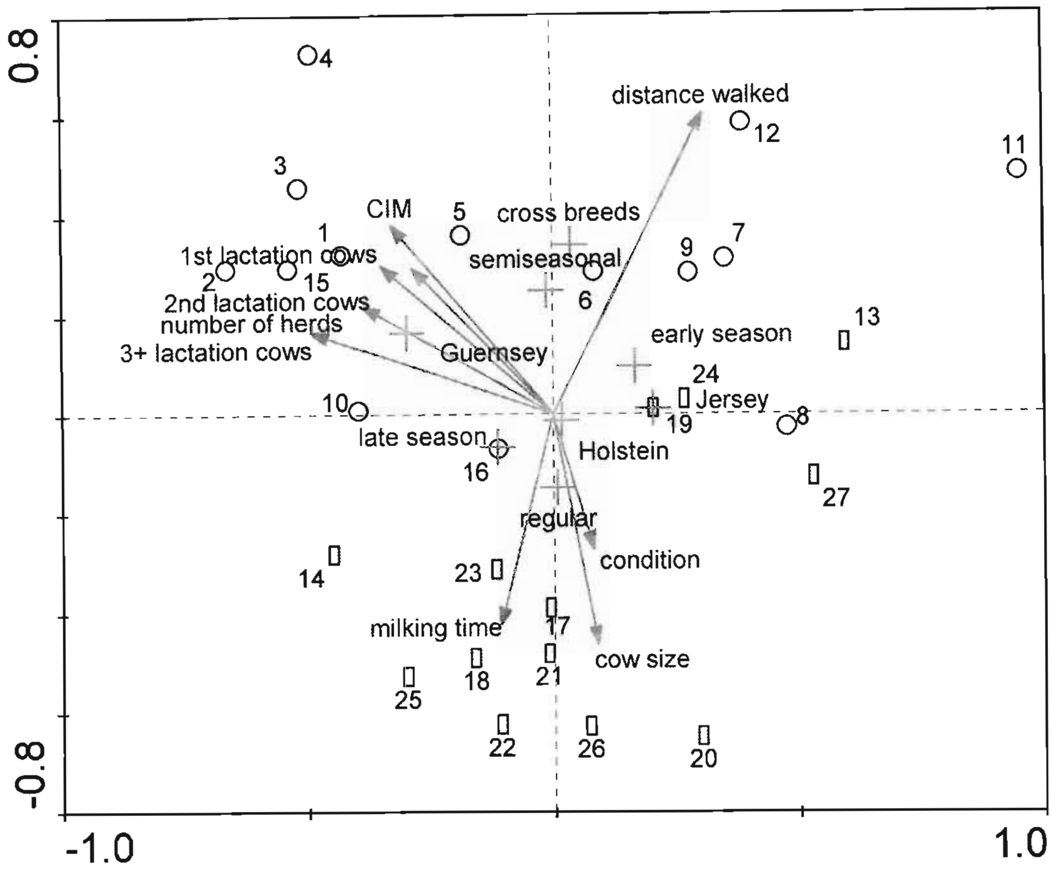


Figure 20b Principle components analysis graph of sites in relation to kikuyu quality with supplementary environmental variables calving pattern and herd dynamics. Eigenvalues for axes one and two were 0.2989 and 0.1733, accounting for 47% of total variation. Sites represented by ▯ are KZN farms and ○ EC farms.

Data were further analysed using Regression Trees to identify the factors with the largest influence on milk yields. From Figure 21a it can be concluded that days in milk has the largest influence on milk production in this small data set with two herds of early lactation cows producing significantly more milk. These were considered outliers and were removed by the analysis initially. Following that, concentrate had the biggest influence with cows supplemented with less than 4.6kg concentrate per day having significantly lower milk yields. Kikuyu quality had little influence on poor performing cows. When cows were performing better and were being supplemented, then kikuyu quality seemed to have an influence on milk production. Kikuyu fat content was significant in further dividing the farms, following that location was significant. Farms in the Lidgetton, Mooi River and Howick areas had the highest kikuyu fat concentrations.

Following the initial regression tree analysis, kikuyu fat content was considered since it was a factor separating farmers on the basis of milk production. Soil acidity is a factor determining kikuyu fat differences with more acidic soils, yielding kikuyu with a higher fat content (Figure 21b). Of the farms with more acidic soils, those with higher soil calcium contents have kikuyu with higher fat content. Regression tree analysis of kikuyu protein revealed no result, indicating that none of the factors investigated could explain differences in kikuyu protein values.

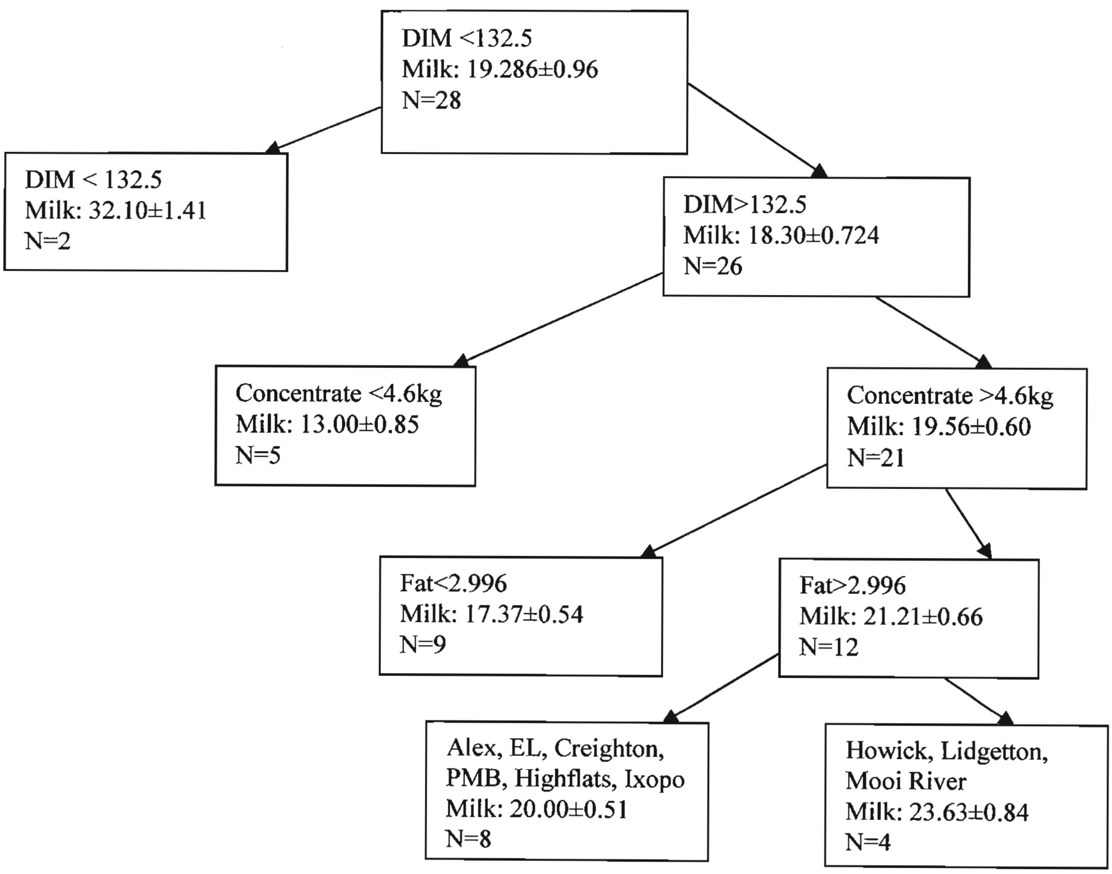


Figure 21a Regression tree of major factors affecting milk production. (DIM=days in milk)

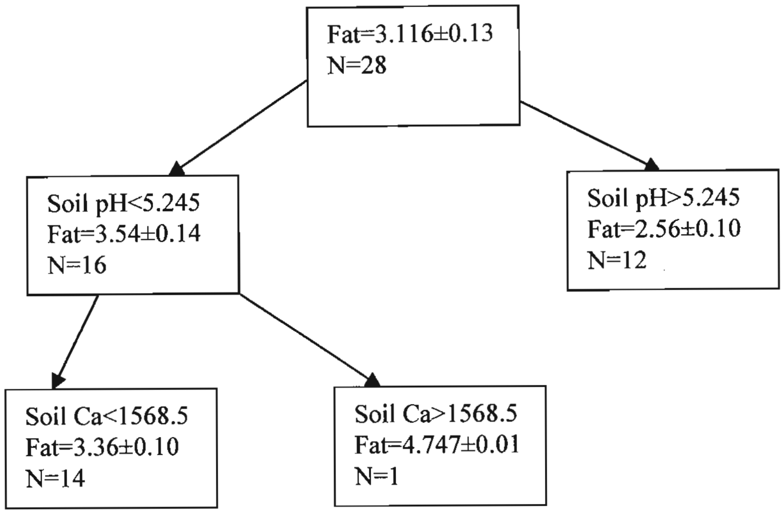


Figure 21b Regression tree of factors causing differences in kikuyu fat (% dry matter) content.

2.4.4 Evaluation of diet quality in relation to dairy cow requirements using CPM.

Data collected on farm was analysed using Cornell Penn Miner version 2.5(CPM). The data entered into the model included the following:

Cow factors: body weight and condition, milk yield, butterfat, protein, distance walked in a day, stage of lactation, days pregnant, number of lactations.

Management factors: continuous grazing system,

Environmental factors: temperature, storm exposure, humidity, mud.

Feeds: all kikuyu quality data was entered into the program along with supplement analyses. Nutrients that were not analysed were based on literature or data already present in the program and were held constant over all farms.

Costs: Concentrate and roughage costs were collected in the survey. The cost of kikuyu pasture was held constant over each farm because few farmers had figures available. The costs used are given in Table 11 below.

Table 11 Feed cost ranges entered into the CPM program

Roughage	Cost (R/ton as is)
Maize silage	230
Kikuyu	60
Pineapple silage	125
Lucern	870-1000
Hay	300-600
Kikuyu silage	230
Cotton seed oil cake	2000
Citrus pulp	100
Concentrate	1500-2100

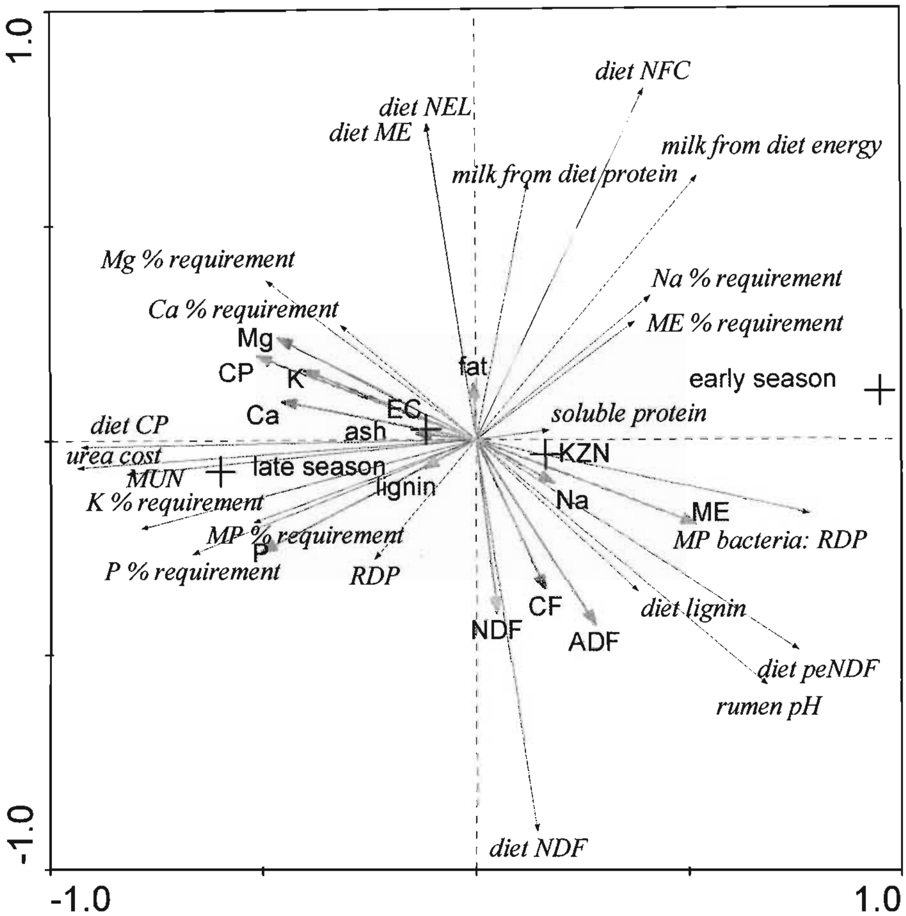


Figure 22a Principle components analysis of CPM output with kikuyu quality as supplementary environmental variables. Eigenvalues for axes one and two are 0.3087 and 0.2121, accounting for 52% of total variation. (NDF=neutral detergent fibre; NEL=net energy lactation; ME=metabolisable energy; NFC=non fibre carbohydrate; ADF=acid detergent fibre; RDP=rumen degradable protein; peNDF=effective fibre; MUN=milk urea nitrogen)

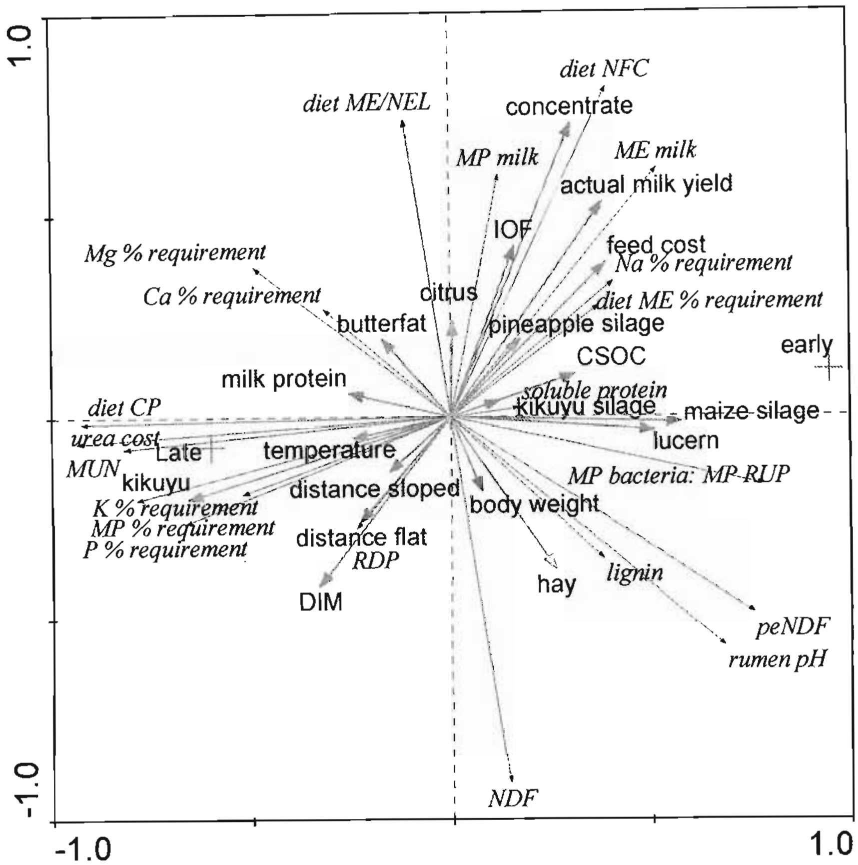


Figure 22b Principle components analysis of CPM output with CPM input variables as supplementary environmental variables. Eigenvalues for axes one and two were 0.3087 and 0.2121accounting for 52% of total variation.

Axis one of Figure 22a and 22b represents a protein gradient and axis two is a fibre-energy gradient. Kikuyu intake (kg.cow.day^{-1}) best describes variation along axis one along with kilograms maize silage and lucern fed per cow per day. Time of sampling also described some variation along axis one. Axis 2 is best described by kilograms concentrate fed per cow per day and actual milk yield per cow per day. Dietary protein, milk urea nitrogen (MUN) and urea cost were all highly positively correlated. Increasing temperature, although not a major gradient, is positively correlated with MUN and urea costs. High temperatures are known to increase MUN levels, but the mechanism is debatable (Newbold, 2004). Higher protein levels are associated with late season sampling. Increasing proportion of kikuyu in the diet resulted in increased protein, K and P as a percent of requirement. Kikuyu is generally high in these nutrients. Kikuyu Ca and Mg levels contributed to meeting total dietary Ca and Mg levels. Kikuyu Na levels had little influence on total dietary Na levels as it is easily supplemented and was in very small quantities in KZN. Increasing amount of kikuyu in the diet was also associated with increasing days in milk and distance walked by cows. This can be explained by management practices, where cows later in milk are fed less supplements and are placed in the paddocks that are further away from the dairy. Dietary NDF levels were not closely correlated with kilograms of kikuyu in the diet, but more closely related to hay in the diet. Similarly, dietary lignin was little influenced by kikuyu, but by hay. Efforts to reduce the lignin content of kikuyu through plant breeding are likely to have little impact considering the magnitude of the effect of feeding a kilogram of hay to cows. Hay did improve the effective fibre (peNDF) value of the diet and rumen pH. This has important benefits as rumen pH can fall drastically when cows are fed large amounts on N rich pasture. High MUN was associated with reduced rumen pH. Kikuyu CP levels were related to higher total dietary protein, higher MUN levels and an increased urea cost in the form of energy. Dietary protein was negatively correlated to the ratio of metabolisable protein from bacteria to rumen undegradable protein as well as soluble protein. A desirable ratio is more than one, with ratios below one indicating poor rumen microbial health and an undersupply of RDP. RDP was negatively correlated with milk production. Predicted milk yields from dietary protein and energy were positively correlated with actual milk yield. Kikuyu fat content was correlated to total dietary energy, but the kikuyu in KZN was higher in fat and these farmers tended to supplement concentrates more. Dietary energy as a proportion of requirement was positively correlated with milk yield and negatively related to dietary protein as a percentage of requirements. This could be explained by a general oversupply of protein and undersupply of energy in the diet. Feed costs and income over feed described some variation along axis two (R^2=0.38 and 0.42 respectively), and were positively correlated. It appears that increasing the costs through supplementary feed for cattle on kikuyu pasture is related to a corresponding increase in income over feed costs, due to positive responses.

2.4.5 Conclusion

This survey was greatly limited by its size and the low rainfalls of the season. Farmers supplemented their cows more than normal, particularly in spring as the rains were late. Large proportions of dairy cow diets were made up of feedstuffs other than kikuyu and a little concentrate. More useful data could be obtained from a survey of this nature of more farms over more than one season. Little differences in pasture quality could be related to management of the pasture. Many factors, such as kikuyu fat, Ca and Na content could be related to areas. Dairy farming varies considerably between those farmers visited in the EC and KZN and many differences could be attributed to different management philosophies. There was a tendency for EC farmers to focus more on cow fertility and production per hectare, while KZN farmers were generally still very much focused on production per cow. This meant that kikuyu in EC was better utilised than in KZN, with the focus being on minimising wastage of fertilised pasture. EC herds were larger with more cows needed to harvest the abundant kikuyu and buffers against shortages were present in the form of lucern and pineapple silage. There were some EC farmers that were afraid to mulch pastures for fear that there would be a mid summer drought and growth would be set back too much. Other farmers managed pastures to maximise quality in the form of more leaf and less stem. Pasture samples taken were only of leaf as this is what cows eat and the ratio of leaf to stem was not measured, which would have been useful. Kikuyu leaf seems to be innately of similar quality according to areas, and changing its quality with management is not feasible from these results. It is the quantity of leaf produced through better management that could have been a more important measure. Cows on EC farms utilised pastures better, probably allowing for better quality growth. KZN farmers generally used kikuyu as filler and supplemented their cows regardless of grass quantity available. Lower cow numbers and stocking rates meant that kikuyu was never well utilized. Mulching on some farms overcame this problem. The differences in kikuyu management could have had huge impacts on the financials of the farmers and a survey of similar nature, but including accurate pasture financial data would have allowed strong conclusions to be drawn. Unfortunately very few farmers measure their management inputs on kikuyu accurately, making the availability of this type of data unlikely.

Managing kikuyu pasture for better quality and finding alternative varieties is pointless when farmers are unaware of the impact that their supplementary feed has on the overall diet of the cow. Cows were often oversupplied with protein in the concentrate which exacerbated the already high levels in the kikuyu. Feeding hay to cows on kikuyu only made the high NDF values worse. There is little point in focusing on the right stage of growth to graze kikuyu in order to minimise high fibre, if left too late, or minimise high protein, if grazed too soon, if cows are poorly supplemented.

Part 3: Nutrients in kikuyu for meeting the requirements of the high producing dairy cow.

The management of kikuyu pasture to improve quality have been discussed in Part 1 and methods to improve quality have been investigated in Part 2. The objective of this section is to explain performance of dairy cattle on kikuyu in light of its deficiencies and antinutritional factors. Kikuyu is a relatively cheap pasture to maintain, as discussed, but there is much concern over its ability to supply dairy cows with sufficient nutrients for adequate milk yields. The profitability of the dairy industry could be greatly increased with any improvement in animal production from kikuyu (Dugmore & du Toit, 1988). Milk yields are low, particularly in late summer and early autumn. This is attributed to poor grazing management, as discussed, which reduces quality and palatability (Davie & Pienaar, undated; Cross, 1979b). Determining the nutrients available in kikuyu and matching them to the requirements of the dairy cow is difficult and inaccurate. The ability of kikuyu to meet the nutritional demands of the high producing dairy cow is questionable given the large variation in kikuyu quality with environment, location, management and season (Miles *et al.*, 2000; Cross, 1979b). The nutritional requirements of the high producing dairy cow are ever changing depending on cow size, stage of lactation, pregnancy, body condition score, milk yield, milk solids, lactation number and activity (Stewart *et al.*, 1995). According to Roos (1975), kikuyu has a high and variable potential carrying capacity in summer, capable of supplying sufficient DM for three Friesian cows per hectare for seven months, assuming a DM intake of 15kg and milk yields of 15.3ℓ each day. This agrees with Cross (1979b) who stated that daily milk yields of 45 ℓ/ha without supplementation is possible over the 195 day summer period (Cross, 1979b). In South Africa kikuyu grass is notoriously high in fibre and low in readily fermentable carbohydrate (Mears, 1970) which causes palatability and intake problems that negatively affect production (Miles *et al.*, 2000). Mineral imbalances cause metabolic disorders and infertility (Miles *et al.*, 2000).

A major difficulty in relating kikuyu nutritional quality to the requirements of the dairy cow is that results from chemical analyses of kikuyu, as well as other tropical pastures, contradict principles established through the study of temperate grasses (Dugmore *et al.,* 1986). This is because the equations used for temperate pastures have been used to derive digestibility for tropical pastures

(Dugmore *et al.,* 1986). It is obvious that intrinsic differences exist between temperate and tropical pastures. Dugmore *et al.* (1986) discovered that the least digestible fraction, CF, according to the equation, was the most digestible fraction in kikuyu and that NFE, the highest digestible fraction, had the lowest digestibility. The mean chemical composition and digestibility coefficients of kikuyu fractions are given in Table 12. These compare favourably with work by Dugmore & du Toit (1988) where the mean chemical composition and digestibility coefficients are 18.7% and 66.9% for CP, 24.4% and 70.3% for CF, 2.85% and 61% for EE, 42.3 and 68.7% for NFE and 60.7 and 68.7% for DOM respectively. Other research on tropical grasses revealed similar results (Dugmore & du Toit, 1988). CP can vary from 14 to 30% (van Ryssen *et al.*, 1976). The ether extract (EE) of 2.8% is high for roughage. The NPN content of 20 to 30% CP is not unusually high for pasture (Dugmore, 1998).

Table 12 The mean composition, digestibility coefficients, DOM and TDN value of kikuyu grass (mean±sd; n=12)

Component	Composition (%DM)	Digestibility Coefficient (%)
ADF	34.8±1.97	56.5±6.13
ADL	6.6±1.32	78.0±20.5
NFE	47.7±3.05	58.3±6.09
CF	26.0±2.31	61.9±5.53
CP	17.4±3.66	65.0±3.82
Silica	0.94±0.28	
NO3-N	0.7±0.5	
DOM		56.4±4.06
TDN		57.6±3.84

ADF acid detergent fibre, ADL acid detergent lignin, NFE nitrogen free extract, CF crude fibre, CP crude protein, NO3-N nitrate, DOM digestible organic matter, TDN total digestible nutrients.

Dugmore & du Toit (1988) found no significant relation between DOM and any chemical fraction of kikuyu. The DMD of kikuyu, which varies from 47.3 to 63.2% (van Ryssen *et al.*, 1976), compares favourably with other tropical grasses (Mears, 1970). The structural carbohydrates, cellulose and hemi cellulose, present in plant cell walls provide a source of energy for the ruminant (Marais, 1998).

According to Marais (1998) the digestibility and energy available in these components depends on the amount of lignification of the tissue and the ratio of cellulose and hemi cellulose. A small amount of lignin can render a large amount of cell wall indigestible. The ratio of the less digestible hemicellulose to cellulose in most tropical grasses ranges between 0.6 and 0.7, but kikuyu differs from the norm with a ratio of 1 (Marais, 1998). Silica level and lignin (Table 10) have a significant positive relation with DOM despite the belief that they contribute to low digestibility of grass. This may be because of the positive association of DOM and ADF rather than the direct effects of lignin and silica (Dugmore *et al.,* 1986). Pattinson (1981) found a positive relation between ADF and DOM. The digestibility of lignin in kikuyu is variable and this is believed to be because of lignin carbohydrate complexes formed in the rumen which precipitate in the abomasum (Dugmore *et al.,* 1986). The minimum NDF levels recommended for TMR rations are 27 to 33% (Kolver, 2000). NDF is important for stimulating saliva production, which in turn buffers the rumen pH (Kolver 2000). The ADF content for kikuyu is 35% and NDF, 65% (Dugmore, 1998). The ADF is above the recommended 21% for cows producing between 20 and 30 ℓ milk/day (Fulkerson *et al.*, 1998). The NDF content is a major factor limiting milk production off pasture especially for poorer quality grasses like kikuyu (Fulkerson *et al.*, 1998) as it limits intake. The Cornell Net Carbohydrate and Protein System further refines the term NDF with the term effective fibre (eNDF) (Kolver, 2000). This fibre most effectively stimulates chewing and saliva production and should be at a minimum of 20% in the diet. The rumen pH should then be prevented from dropping below 6.2, where microbial digestion of fibre slows down. Acid detergent fibre can be used to get an indication of the eNDF content (Kolver, 2000). Pasture generally contains more fibre, a minimum of 35% NDF, of a more fermentable nature than recommended, meaning that the eNDF content is lower, a minimum of 17%. Kikuyu has high levels of NDF meaning that rumen pH should not limit microbial fermentation (Kolver, 2000). Further reductions in kikuyu digestibility or increased NDF could have serious implications for milk production. The selection of ecotypes with a more favourable ratio of hemi cellulose to cellulose and screening of kikuyu for reduced lignin could improve the digestibility of kikuyu (Marais, 1998).

3.1 The digestibility of kikuyu pasture in relation to fertilizer application.

The study of kikuyu pasture has revealed some strange results other than the higher digestibility of CF over NFE and the contribution of CF to DOM. NPN reduces the digestibility of CF but there is no significant relation between total N and CF digestibility (Dugmore & du Toit, 1988). Thus, N fertilisation manipulates the digestibility of kikuyu as higher N applications increase the NPN content of kikuyu. There is a negative correlation between CP and DOM.

Fertilizer application affects the DOM content of kikuyu (Dugmore *et al.*, 1986). From three to six weeks of regrowth, pasture receiving 200 kg N/ha increased in DOM and CP remained constant, but pasture receiving 400kg N/ha declined in DOM and CP content (Dugmore *et al.*, 1986). The increase in DOM with age under 200 kg N/ha is because of the positive relation between CF and DOM. CP levels in kikuyu are negatively associated with digestibility of ADF, OM, NFE and CF, which is unusual as CP usually, raises the digestibility of NFE and CF (Dugmore *et al.*, 1986). The digestibility of kikuyu pasture limits milk production and must be improved, but this cannot be done with simultaneous increases in N fertilisation. As CP rises, CF and NFE digestibility will be reduced resulting in reduced DOM (Dugmore *et al.*, 1986). Tainton *et al.* (1982) found animal performance decreased with increasing N application. Van der Merwe (1991 cited by van der Merwe, 1998) found that the kikuyu CP content and its rumen degradability after 20, 30 and 40 days from fertilization were 29% and 74%, 25% and 55%, and 24% and 57% respectively. High applications of N just prior to grazing will yield kikuyu with a high CP degradability and low fibre degradability. This completely disrupts the protein to energy ratio, and milk production efficiency.

Eckard & Dugmore (1994) found that N fertiliser applications exceeding 50kg per ha per application in early spring and autumn can result in plant nitrate levels as high as 0.9 to 1.0%. Ammonia induced bloat can result. This is caused when hungry cows are placed on new pasture containing high N levels. Negative feedback loops operating when rumen ammonia levels become too high are activated too late. Animals favour wilted grass because of its higher fibre content, but this grass can have elevated nitrate levels. Fertilizer dressings should be limited to less than 50kg/ha at dangerous times of the year.

Poor animal performance is associated with old established pastures, which are heavily fertilized with N (Marais *et al.*, 1987). A build up of N negatively affects production, with the limit being 0.2 g nitrate /100g DM, above which possibly causing nitrate toxicity (Bryant & Ulyatt, 1965). The availability of readily fermentable carbohydrate is the most important factor determining the toxic level of nitrate (Bryant & Ulyatt, 1965). Pastures accumulate nitrate for many unclear reasons and this can lower the digestibility. Nitrate concentrations increase exponentially with increasing total N in the plant (Marais, 1998), therefore the nitrate content of 0.7, associated with pasture with a CP content of 20% (Dugmore, 1998), could be much higher as CP contents of kikuyu often exceed 20%. Nitrate is not very toxic but is readily reduced to ammonia by microbes with toxic nitrite as an intermediate (Marais, 1998). Nitrate ions are readily absorbed by the root and translocated via xylem to leaf mesophyll cells for reduction (Marais *et al.*, 1987) resulting in high leaf and stem nitrate levels. The nitrate and its reduction products are stored in metabolic pools where they are generally immobile. Nitrite formed in the reduction of nitrate does not accumulate but is reduced to ammonia in a single step. The ammonia is then incorporated into organic compounds such as amino acids and peptides (Marais, *et al.*, 1987). Nitrite negatively affects some rumen microbes and reduces digestibility (Marais, 1998). Absorbed nitrite reacts with haemoglobin to form methaemoglobin that is incapable of binding oxygen. Tissues become starved of oxygen and death, though seldom, can result. After some weeks of ruminants grazing kikuyu pasture high in nitrate, methaemoglobin declines in the blood indicating that some adaptation by microbes does occur, allowing for more efficient reduction of nitrite. Few deaths have been reported but production suffers (Marais 1998). There are few confirmed cases of nitrate poisoning because symptoms are often masked by the time post mortem is carried out. Symptoms are similar to red water. High protein levels can cause non frothy bloat and reduced appetite (Eckard & Dugmore, 1994).

The nitrate content of young leaves is low, but increases until maturity after which it decreases (Marais *et al.*, 1987). Protein N and NPN follow the opposite trend in that they decrease as the leaves mature and became senescent. The nitrate content is therefore low when kikuyu is growing fast. Nitrate levels increase when growth declines and when kikuyu is under stress as there is less demand for organic nitrogenous substances. Nitrate increases under sunny conditions, being a photosynthetic process and declines in rainy conditions. Nitrate increases with total organic N, NPN and protein N. The accumulation of nitrate is caused by excessive uptake of N or the feedback inhibition by reduced nitrogenous compounds such as amino acids. Another cause is high N fertilization and mineralisation. High N and K levels in soil and plant tissue, which are typical of old, established kikuyu pastures, facilitate N absorption, translocation and accumulation in storage pools. Nitrate levels are lower in leaves than in stems where much of the nitrate is stored. Kikuyu, unlike most pasture species, always has a true stem, which elongates continuously and is always available for grazing (Marais *et al.*, 1987). A CP content higher than 20% could potentially have dangerous nitrate levels (Dugmore *et al.,* 1986), so applying less N fertilizer, especially if recycling of excreta is occurring, could reduce the accumulation of nitrates (Marais, 1998).

3.2 Mineral content of kikuyu pasture

Low production from dairy cattle grazing kikuyu pasture is not only attributed to a lack of readily fermentable carbohydrate, but also to mineral imbalances and deficiencies (Marais *et al.*, 1990). Highly fertilized kikuyu has a high CP content that causes reduced milk production and blood mineral deficiencies (Dugmore, 2002). Dairy cows are sensitive to mineral imbalances because of the high demands of lactation and pregnancy (Miles *et al.*, 1995) and small imbalances and deficiencies can lead to production, reproduction and health problems (Grant, undated). Little attention has been paid to mineral deficiencies as they are manifested subclinically (Miles *et al.*, 1995). Trace mineral imbalances and deficiencies are problematic, being difficult to measure as they are present in such small quantities (Little, 1981). The homeostatic controlled mineral concentration in the dairy cow is vital for biological functions. Tissues cannot be maintained properly if minerals are deficient (Little, 1981). Deficiencies are difficult to diagnose because several nutrients are usually involved, the symptoms are usually non-specific, including a loss of appetite and hence production, and by the time clinical symptoms develop, the deficiency is well developed. Diagnosing deficiencies can be done by analysing animal or plant material, but this relies on testing for the right mineral (Little, 1981). Mears (1970) maintained that mineral requirements of animals could be met with kikuyu except calcium. However, Na and Mg in addition to Ca are deficient.

Large changes can occur in the chemical forms of minerals from the plant to the digesta (Little, 1981) which is important to keep in mind when matching the mineral content of kikuyu grass to the requirements of the dairy cow. The diet of the dairy cow should contain at least 17 minerals and three vitamins for optimal milk production, reproductive performance and health. The required macrominerals include calcium, phosphorus, magnesium, sodium, chlorine; potassium and sulphur and trace minerals include iodine, iron, cobalt, copper, manganese, zinc and selenium. Vitamins A, E and D are required as K and the B vitamins are synthesised in the rumen (Grant, undated). Macro or micro minerals differ in the quantities required by the animal. Macrominerals are required for structural purposes in the cases of Ca, P and S or for the maintenance of the acid base balance in the case of Na, Cl and K. Potassium, Ca and Mg are also involved in energy transfer, nerve impulse transmission and enzyme activation (Little, 1981). The trace minerals Mn and Cu are enzyme cofactors. Zn, Mb and Se contribute to the activities of enzymes, I to the functioning of hormones and Co contributes to vitamin B12 (Little, 1981). Potassium, Fe, chromium, fluorine, silicon, vanadium, tin and nickel are rarely deficient because they are usually present in the soil in sufficient quantities (Little, 1981).

In addition to being able to measure mineral quantities in kikuyu, the digestibility or availability of minerals must also be known. Biological availability determines how well a mineral is digested and used by the animal with higher quantities of the minerals with low availabilities being required (Grant, undated). Tables of mineral requirements take the average availability of minerals in feedstuffs into account (Grant, undated) and therefore relating minerals contained in kikuyu to dairy cow requirements is not very specific. For example, the availability of calcium in forages is 35% which is lower than 51% for most mineral supplements and 43% for grains. The average calcium availability is 38% which is used in tables of mineral requirements (Grant, undated). The dietary requirements are based on mineral quantities in tissues or secretions produced in the various physiological states as well as from endogenous losses from the body. This gives the physiological requirement at the tissue level, termed the net requirement (ARC, 1980 cited by Grant, undated). The net requirement is then divided by the absorption coefficient to give the actual dietary requirement expressed as percent DM based on an assumed DM intake. Diagnosing deficiencies through the analysis of blood or plasma is inaccurate for minerals such as P because much is stored in the bones, but suitable for Mg that has no significant amounts stored. Significant amounts of Na are stored in the rumen and plasma concentrations are unsuitable for Na deficiency diagnosis (Little, 1981).

The KwaZulu-Natal Midlands has acidic soils that cause kikuyu to have a low Ca content (Marais *et al.*, 1992). The deficiency has been attributed to increased solubility of aluminium in acidic soils that reduces the amount of exchangeable Ca ions (Awad & Edwards, 1977 cited by Marais *et al.*, 1992) or to the high K content of the pasture that reduces Ca uptake (Miles *et al.*, 1985). The mineral concentrations of kikuyu are highly variable in the Eastern Cape even between farms (Miles *et al.,* 2000), but particularly when comparing the Eastern Cape to Cedara in KwaZulu-Natal. From Table 13, kikuyu in the Eastern Cape has a far more favourable mineral concentration, having higher concentrations of the minerals Ca and Na, which are deficient in kikuyu. Potassium is above the highest tolerance level for dairy cows even when the levels are increased to accommodate cattle under heat stress (1.3 to 1.5% DM) (Little, 1981).

Table 13 The mineral requirements of the high-producing dairy cow and the mean mineral concentrations of kikuyu at Cedara and from Eastern Cape farms.

Element	Eastern Cape #	Cedara $	Cow Requirement*
Ca (%)	0.48	0.24	0.4-0.5
P (%)	0.4	0.33	0.3-0.4
Ca:P	1.3	0.76	1:1-2:1
K (%)	3.4	3.6	0.9
Mg (%)	0.36	0.3	0.3
Na (%)	0.24	0.03	0.12
S (%)	0.27		0.12
Zn (mg/kg)	35.6		26
Cu (mg/kg)	6		10
Mn (mg/kg)	67.5		25
K/(Ca+Mg) Φ	1.6	2.5	<2.2

* Holmes & Wilson, 1987 cited by Miles *et al.*, 2000; NRC 1989 cited by Miles *et al.*, 2000.
# Miles *et al.* 2000
$ Dugmore 1998
Φ calculated on an equivalents basis

3.2.1 Calcium content of kikuyu pasture

A Ca deficiency is not unique to kikuyu pasture as most forages contain insufficient amounts to meet animal requirements. The Ca content of tropical grasses is generally low and ranges from 3 to 4g/kg DM, but the mean Ca content of kikuyu is 2g/kg DM, the leaf containing 2.5g/kg DM and the stem 1.6g/kg DM (Marais, 1990). Calcium is lowest in midsummer compared to autumn and spring (Miles *et al.* 1995). The Ca deficiency of kikuyu is made worse by the accumulation of oxalate (Marais, 1990). Oxalic acid is an organic compound produced during normal plant growth and is usually regarded as an end product of metabolism. Oxalate's role in plants is not well understood, but its synthesis is believed to be involved in the absorption and assimilation of N and in ionic balancing in the plant. Oxalate is involved in nitrate uptake so the N content of kikuyu could affect oxalate concentration and therefore the availability of Ca. Oxalate in the plant is either in the soluble form, as K or Na salts, or in the insoluble form as Ca oxalate crystals (Marais, 1990). Soluble oxalate should not cause health problems as rumen microbes can destroy it after an adaptation period of only three to four days. Insoluble oxalate passes through the digestive system unchanged, rendering Ca unavailable to the animal. Insoluble oxalate could create serious health problems by altering the digestibility of kikuyu and causing Ca deficiencies (Marais, 1990).

Calcium controls cell wall synthesis and if deficient, changes can occur in cell wall structure, hence affecting digestibility and nutritional value (Marais *et al.*, 1992). Significantly lower DM yields are found in kikuyu low in Ca (Marais *et al.*, 1992). The specific association of the crystals in calcium oxalate with poorly digestible tissue such as phloem, xylem, cambium, mesophyll and epidermis further reduces the availability of Ca. Total oxalate in kikuyu varies considerably and factors affecting its concentration are not known. The oxalate in kikuyu could theoretically bind all calcium in kikuyu. Oxalic acid interferes with energy metabolism and precipitates as crystals in the renal tubes and in doing so, causes acute toxicity in cattle consuming pasture (Marais, 1998). The Ca deficiency created is of greater concern than the oxalate.

The total oxalate concentration of kikuyu at Cedara fertilized with 250kg N/ha applied in three equal dressings was 9g/kg DM with about equal amounts of soluble and insoluble oxalate. There is a highly significant positive relation between the insoluble leaf oxalate and the total N content of kikuyu. Leaf contained more NPN and more than three times the total oxalate present in the stem. Fertilising with Ca may improve palatability, or intake, and improve digestibility by reducing the retention time, but this is due to changes in the fibre fraction and not directly because of Ca (Marais, 1990).). Milk contains 1.25g Ca/ℓ which, according to Cross (1979b) must be taken into account in fertiliser programs, although increasing the Ca concentration of the kikuyu growth medium only increases the ratio of insoluble to soluble oxalate while total oxalate content remained the same (Marais, 1998). Dairy cows can maintain blood plasma Ca levels for a long time by mobilising bone Ca. If they are on a Ca deficient diet for a long time bones can become weak and skeletal deformities result. Calcium deficiency can also cause grass tetany and reduce the rate and amplitude of rumen contractions, which could affect digestion, reduce feed intake and rate of passage through the digestive system (Marais, 1990). Low Ca levels can lead to reduced conception rates (Dugmore, 1998).

3.2.2 Phosphorus content of kikuyu pasture and its interaction with calcium

Kikuyu has a high P content for a tropical grass, being highest after four weeks of regrowth, after which it declines (Gromide *et al.*, 1969). Phosphorus is very mobile in the plant and occurs mainly as inorganic phosphate (Little, 1981). Phosphorus follows the opposite trend in seasonal variation to Ca (Miles *et al.*, 1995). Cows require 1.7g P/L milk and 10 to 13g for maintenance (Puls, 1994). Phosphorus is adequate for dairy cows in summer, but is marginal in spring and autumn (Miles *et al.*, 1995).

Calcium and P requirements of the dairy cow change according to bodyweight, milk yield and composition and stage of pregnancy and it is important that they are balanced for the whole lactation cycle. The minerals mobilised in early lactation must be replaced later on in lactation to maintain health and performance. The Ca to P ratio should be kept between 1.4: 1 and 2.5: 1 for optimal health (Little, 1981). Cows can tolerate ratios of 4-7:1, but not less than 1:1 (Puls, 1994). The Ca and P requirements of a 600kg cow producing 23 ℓ milk/day is 0.54 and 0.34% of dietary DM respectively or a Ca to P ratio of 1.6 to1 (NRC, 1989 cited by Fulkerson *et al.*, 1998). The Ca and P contents of kikuyu in Table 13 indicate that P levels are marginally adequate and Ca is adequate in the Eastern Cape, but is severely deficient at Cedara. Although Ca is usually mostly unavailable to the animal because of oxalate, studies in the Eastern Cape indicate low oxalate concentrations (Miles *et al.*, 2000. The Ca to P ratio can sometimes be as low as 0.4: 1 in KZN. The Ca to P ratios is effectively much lower because of Ca being bound to oxalate (Marais, 1990). It is difficult to correct imbalances below 0.5:1 without causing metabolic disturbances because most supplementary feeds do not contain sufficient amounts of Ca to correct the imbalance (Bredon, 1980 cited by Miles *et al.*, 1995).

3.2.3 Potassium content of kikuyu pasture and its interaction with other minerals

Potassium levels in all pasture types are much higher than that required for dairy cattle (Fulkerson *et al.*, 1998), but kikuyu is atypical of tropical grasses as it still has a high K content after 12 weeks of regrowth (Gromide *et al.*, 1969). The K/(Ca+Mg) in Table 13 for Cedara is much higher than recommended for the dairy cow, but is favourable in the Eastern Cape. The ratio should be kept below 2.2, to prevent milk fever. Potassium, as well as Na, Cl, Fl and I, occur mainly in the ionic form and are readily available for absorption (Butler & Jones, 1973, cited by Little, 1981). Dairy cows can tolerate a maximum of 3% K in the diet (NRC 1989, cited by Miles *et al.*, 2000) which is lower than the values reported in Table 13. High K intake can lead to interference with the uptake of other cations like Ca and Mg leading to metabolic problems (Fulkerson *et al.*, 1998) such as grass tetany, milk fever and delayed expulsion of foetal membranes (Miles *et al.* 1995). High K levels cause udder oedema and reduced feed intake (Puls, 1994). It is difficult to tell how much Mg and Ca are actually absorbed by the animal because of the interference of K. According to Puls (1994), high dietary K levels inhibit Mg absorption, but enhance Ca and Na absorption. High temperature and stress increase K required by cattle.

The Na in kikuyu is less than half that of the NRC requirements (Fulkerson *et al.*, 1998). Saliva is a sensitive index of Na status because if Na is deficient, Na in the saliva will be replaced with K (Little, 1981). Kikuyu is deficient in Na because it is a natrophobe, accumulating Na in its roots and not its leaves (Dugmore, 1998). Kikuyu is incapable of absorbing sufficient Na to meet animal requirements even if soil levels are adequate, so supplementation is essential (Marais, 1998). The high Na of kikuyu in the Eastern Cape, in Table 13, is explained by the location of the farms, being 3km from the sea (Miles *et al.*, 2000). The ruminant requires enough Na to maintain the ratio of Na to K at 15 to1 in the saliva to prevent bloat (Dugmore, 1998), although Puls (1994) stated that bloat only occurs at ratios exceeding 20:1. The ratio should be kept below 20 to prevent lengthening the calving interval (Berringer, 1988 cited by Fulkerson *et al.*, 1998). The ratio should be kept at 5:1 to promote Mg absorption (Puls, 1994). This ratio does not exceed 12 for temperate pastures but the mean value for kikuyu was 30 indicating that reproductive problems could occur (Fulkerson *et al.*, 1998). Potassium levels are high at emergence and remain high for some time, but they do decline as the leaf emerges and levels out at or below those found in ryegrass at full elongation (Reeves *et al.*, 1996b). Potassium limits Mg absorption (Reeves *et al.*, 1996b). The K/(Ca+Mg) ratio varies from 2.19 to 3.15 in the KZN Midlands (Miles *et al.*, 1995).

About 50% of Mg is water soluble (Jones, 1973, cited by Little, 1981). Mg is ingested by protozoa or absorbed onto bacterial cell walls and significant quantities may be complexed in a non-ionic form by certain organic acids and lignin (Little, 1981). Magnesium present in kikuyu is largely unavailable because the high concentrations of N and K are antagonistic to its uptake (Dugmore, 1998). It declines with regrowth along with Ca and Fe (Gromide *et al.*, 1969) and follows the same trends in concentration over the season as Ca (Miles *et al.*, 1995). Although a deficiency in Mg can lead to grass tetany, this is seldom seen in cattle grazing kikuyu pasture as it affects about 1 to 3% of dairy cattle (Marais, 1998). Mg requirements range from 0.25 to 0.3% for high producing cows, but higher levels may be required in early lactation and when supplementary fat is being fed (Little, 1981). Soils that are low in Mg or that are limed with sources other than dolomitic lime will yield grass that is low in Mg. Magnesium oxide should be supplemented (Little, 1981). Magnesium improves fertility by reducing the inter-calving period and services per conception (Dugmore, 1998). Older cows have the highest incidence of grass tetany, as their labile reserves of Mg in the bone are less

(*Marais et al.,* 1992). The disease occurs mostly in spring or autumn during periods of cool weather followed by warm weather that stimulates plant growth (Marais *et al.*, 1992). Low concentrations of energy and certain organic acids reduce the availability of Mg to animals. Nitrogen and K fertilizers also increase the incidence of grass tetany. Fertilizing with Mg has been used to prevent grass tetany and has been most successful on acid, coarse textured soils. Foliar applications of MgO and adding magnesium salts to the diet of cattle have also been successful, but there is no completely satisfactory way of increasing Mg intake in grazing cattle (Marais *et al.*, 1992). Milk yields often suffer as a result of hypomagnesemia (Marais *et al.*, 1992). Low calcium, high magnesium rations prior to calving accelerates Ca transfer from the bones, reducing incidences of milk fever (Puls, 1994).

3.2.4 Sulphur content of kikuyu pasture

Puls (1994), gives requirements for sulphur as 0.21 to 0.36%, which are higher levels than the 0.12% given in Table 13. An optimum N to S ratio is 10: 1. According to Table 13, kikuyu has excessive amounts of S, which could increase the chances for Mo toxicity and interfere with Cu utilization (Little, 1981). Kikuyu generally has high levels of nitrogen. The extra S could be needed to balance the ratio of N: S. Deficiency results in reduced DM intake, rumen fermentation and increased milk fever incidences.

3.2.5 Trace mineral content of kikuyu pasture

The Zn concentration in kikuyu from the Eastern Cape (Table 13) is more than adequate, but, according to Fulkerson *et al.* (1998), kikuyu is often deficient in Zn and this may reduce milk yields, reproductive performance and resistance to disease. Excessive Zn can interfere with the utilization of other trace minerals such as Cu and Fe (Grant, undated). According to Puls (1994) adequate Zn levels range from 50 to 10ppm, which is higher than the figures given in Table 13. Supplementation with Zn on a daily basis is necessary as it is poorly stored. About 45ppm Zn is required in the diet dry matter and an additional 16ppm must be supplemented for every 0.1% increase in Ca above 0.3%. Excess Zn reduces Ca metabolism and visa versa (Puls, 1994), but considering both are present at inadequate levels in kikuyu, this is unlikely to be a problem. High Cu levels decrease Zn in the liver and can cause hoof problems (Puls, 1994), but copper also appears to be in short supply in kikuyu. Zinc deficiency can inhibit the use of vitamin A stores (Puls,, 1994), which may be a problem in cattle grazing kikuyu.

Dairy cow requirement for Mn of 25 ppm in table 6 is lower than requirement given by Puls (1994) who stated that cows need 40 to 200ppm Mn. Kikuyu in the Eastern Cape (Table 13) is adequate. It is estimated that less than 1% of dietary Mn is absorbed. Manganese in silage is less available than in hay and the availability of Mn in pasture is reduced with liming (Puls, 1994). High N contents raise the Manganese content of kikuyu (Gromide *et al.*, 1969). Deficiency causes silent heats, reduced conception rates, abortions, cystic ovaries, small calves and an increase in the percentage of male calves born (Puls, 1994). High levels reduce iron absorption. Calcium, Fe, Zn and P are antagonistic to Mn.

Dairy cows require 0.3 to 1ppm Se in dietary DM (Puls, 1994). Dry cows require 3 to 5 mg of Se per day and lactating cows require 6 to 8 mg daily when soils are deficient. Se is believed to improve reproductive efficiency, reduce the incidences of mastitis and retained placentas in dairy cattle. Excessive amounts of Se are toxic (above 2 ppm). Unfortunately, Se levels in kikuyu could not be found in the literature, and are likely to be variable depending on Se fertilization.

3.3 The protein to energy ratio

Grasses are considered primarily as a source of energy for ruminants, yet energy is the first limiting factor of milk production from N fertilized pastures (Davidson *et al.*, 1991 cited by Reeves *et al.*, 1996a) and energy is a major limiting factor of kikuyu pasture (Fulkerson, 1999a). In a trial by Joyce (1974), sheep fed chopped kikuyu grass were in a negative N balance, despite there being sufficient N present in the kikuyu to meet their requirements. This was attributed to the use of protein as an energy source because the kikuyu was lacking in ME. Protein and carbohydrates are the major nutrients required by rumen microbes, but the best sources and amounts are not yet known (Hoover & Stokes, 1991). Optimal animal production depends largely on the protein to energy ratio in feed

(Marais & Figenschou, 1990), but kikuyu has low levels of readily available energy, with a NSC content of 5% (Dugmore, 1998), and lower digestibility of structural carbohydrate with increased nitrate content when heavily fertilized with N (Marais, 1998). Digestion of carbohydrates controls the energy available for microbial growth and the proteins affect total fermentation and production of microbial DM (Hoover & Stokes, 1991). Production from kikuyu is lower than expected from its chemical analysis (Dugmore & du Toit, 1988) because of the relation between CP content and the fibre fractions. Sub clinical levels of nitrate decrease rumen digestion of kikuyu high in N (Marais *et al.*, 1990). The low ME content of kikuyu of about 9 MJ ME/kg DM, as apposed to 10 MJ ME/kg DM of ryegrass, results in a DM intake of about 15.4 kg compared to 16.4 kg for ryegrass and milk yields of 13.5 kg/day for kikuyu and 18.8 kg/day for ryegrass. Small differences in energy result in large differences in milk yields (Dugmore, 2002) and highlight the importance of trying to improve the energy content of kikuyu. Lack of readily fermentable carbohydrate, or NSC, is detrimental to the protein supply from microbes to the cow as readily fermentable carbohydrate determines the efficiency of protein metabolism in the rumen (Marais, 1998). The energy and protein content of pasture must be simultaneously assessed.

The mean ME value for kikuyu is 8.5 MJ/kg DM (Fulkerson *et al.*, 1998) or 9.3 MJ ME/kg DM in spring, 9 MJ ME/kg DM in summer and 8.8 MJ ME/kg DM in autumn (Dugmore, 1998). The extent of rumen fermentation of the diet first depends on the quantity of readily fermentable carbohydrate, especially sugars, pectins and starch, and then energy availability from the structural carbohydrates degraded (Hoover & Stokes, 1991). Most energy obtained from subtropical grasses is from structural carbohydrates, but NSC is needed to improve performance. Non structural carbohydrate is the most variable chemical component during regrowth over the season and this could play a major role in the extent of the imbalance of protein to energy that limits milk production (Fulkerson *et al.*, 1998). The optimal protein to energy ratio, more favourably expressed as digestible intake protein (DIP) to NSC ratio, for rumen microbial synthesis is two (Hoover & Stokes, 1991). The average CP to WSC ratio in kikuyu is 2.8:1 at the four and a half leaves per tiller stage (Fulkerson *et al.*, 1998), which is much higher than recommended. The low levels of NSC which generally create the poor ratio are aggravated by a drop in NSC after sunset and higher night temperatures experienced during the kikuyu growing season further reduce these reserves (Marais & Figenschou, 1990). As cattle spend many hours grazing at night in hot weather, their diet will be very low in NSC (Marais & Figenschou, 1990). The lack of NSC results in the accumulation of excessive amounts of urea derived ammonia that is excreted in the urine (Marais, 1998). Any increase in the NSC content of kikuyu would greatly improve its nutritional value. This could be achieved through selective breeding, choosing ecotypes higher in NSC or manipulation the factors controlling the NSC content (Marais & Figenschou, 1990). Timing of grazing could improve the quality of kikuyu pasture in terms of diurnal WSC fluctuations. Reeves *et al.* (1996b) recommended that supplements be fed during the day and kikuyu be grazed in the late afternoon when ambient temperatures are lower and WSC levels are more desirable. Manipulation of the NSC content by grazing in the afternoon and evening rather than at night is not very beneficial as the highest recorded NSC content is 9%, which is still far too low for balancing the protein to energy ratio (Marais *et al.*, 1990).

Although kikuyu is high in protein, it is believed that responses to protein supplementation could be obtained as not all CP is thought to be available to the animal (Reeves *et al.*, 1996a) and protein quality could be limiting. Mears (1970) stated that animal performance is unlikely to be limited by protein deficiency as a negative N balance only occurs when CP is below 8%. According to Kolver (2000) dairy cows are not limited by protein as long as levels in the pasture are 18 to 21%. Fulkerson *et al.* (1998) stated that CP levels are too high for milk production as the dietary CP requirements for a 600kg Friesian cow producing 23 ℓand 30 ℓ of milk/day are 14.5% and 15.8% respectively (NRC, 1989 cited by Fulkerson *et al.*, 1998), which can easily be met with kikuyu if it is fertilized correctly (Fulkerson *et al.*, 1998). CP only takes the N content of the grass into account and not protein degradability and quality. These could be limiting factors of protein in kikuyu, but Reeves *et al.* (1996b) found only methionine and lysine to be low. Protein is degraded in the rumen into peptides, amino acids and ammonia, which are all needed by certain microbial populations, and must all be supplied to maximise proliferation (Hoover & Stokes, 1991). The CP content of kikuyu is variable according to season, management practices and location. Stocking rate plays a major role as highly stocked animals graze the pasture down further, therefore consuming pasture of lower protein content (Bartholomew 1985). Crude protein ranges from 14 to 22% (Tainton, 1978 cited by Cross, 1979) or 18% in spring, 16.5% in summer and 16% in autumn at Cedara (Bredon *et al.*, 1987 cited by Van der Merwe, 1998). CP can be as much as 25 to 30% when N fertilizer is applied liberally or there is an accumulation in the soil through excreta (Van der Merwe, 1998) although soil accumulation of N has a limited effect. The protein levels remain high throughout growth and maturity (Van der Merwe, 1998; Dugmore *et al.*, 1986).

The amount of N fertiliser needed to optimise kikuyu pasture quantity negatively impacts on quality. A compromise has to be made as the amount of N fertilizer needed to optimise DM yields often leads to CP values of over 20%, which causes a severe imbalance of protein to energy and N is lost (Marais & Figenschou, 1990). According to Miles (1998), kikuyu grass yields are maximised at a protein content of 17.5%, and milk yields at 18 to 21% (Kolver, 2000) indicating that there is no need for kikuyu to contain CP levels in the region of 25%. Nitrogen fertilizer increases the concentration of all nitrogenous constituents (Bryant & Ulyatt, 1965). Excess rumen ammonia levels reduce milk production, because of the extra energy required to convert ammonia to urea in the liver and excrete it in the urine (Fulkerson *et al.*, 1998). After three weeks from fertilization, kikuyu has a high CP content and degradability, being 29% and 74% respectively which means that excessive ammonia would be present in the rumen (Van der Merwe, 1998). Nitrogen fertilizer can influence the proportions of volatile fatty acids in the rumen. Low levels of N fertilizer on ryegrass pasture caused less acetic acid, and more propionic and butyric acid production in the rumen of sheep at two hours after feeding, which is typical of rumen fermentation patterns (Bryant & Ulyatt, 1965). High levels of N fertilizer caused acetic acid production to increase in relation to propionic acid production with time after feeding. This may be caused by nitrate, which is an oxidising agent that favours the production of acetic acid. Increased acetic acid production may have negative effects being lower in energy than propionic acid (Bryant & Ulyatt, 1965) although acetic acid is a precursor in BF production. Whether this would also be the case on kikuyu pasture is yet to be determined. According to Kolver (2000), high CP contents in pasture fed to high producing cows do not seem to reduce the milk solid content, but rather cause the cow to lose body condition.

3.4 Milk Urea Nitrogen tests

Milk urea nitrogen (MUN) tests are a means of monitoring the utilization of protein (Van der Merwe, 1998) and were developed for cattle under feedlot conditions (Trevaskis & Fulkerson, 1999). A high

MUN content is associated with high dietary protein levels resulting in excessive rumen ammonia (Dugmore, 2002). This is caused by the rapid degradation of pasture protein in the rumen and is more likely in pastures containing CP in excess of 20%. The rate of rumen protein degradation exceeds microbial protein synthesis, which leads to large amounts of ammonia being absorbed across the rumen wall into the bloodstream. The liver converts the ammonia to urea that is released into the blood as blood urea nitrogen (BUN). This urea is mainly excreted in the urine but also in the milk and uterine fluid. It is also recycled to the rumen in the saliva (Dugmore, 2002). High levels of BUN indicate that there are nutritional problems. These problems could be either a protein imbalance with high levels of protein, excessive degradable intake protein, high or low undegradable intake protein, amino acid imbalance or excess soluble intake protein, or a combination. Protein synthesis is dependent on there being the right amino acids in the correct quantities being present at the same time. The problem could also be a shortage of readily fermentable carbohydrates to capture the ammonia or a poor rumen environment for microbial growth (Hutjens & Barmore, 1995). When cows graze kikuyu pasture they have a significantly higher level of milk urea (43mg/day) than when they graze ryegrass (35mg/day) for the rest of the year (Travaskis & Fulkerson, 1999).

The conversion of ammonia to urea is metabolically expensive in terms of energy and milk yields decline. It is estimated in New Zealand that the energetic costs of converting ammonia to urea and the low carbohydrate availability associated with high CP pasture could decrease milk yields by 11 ℓ per day when ryegrass protein content increased from 20 to 35% of herbage DM (Dugmore 2002). A negative energy balance reduces fertility and embryo development (Hutjens & Barmore, 1995). It is possible that excessive CP intake in early lactation may affect reproduction and reduce fertility by altering the uterine environment and impairing the survival of sperm, ova and embryos (Dugmore, 2002). Low levels of BUN indicate insufficient ammonia in the rumen from too little protein in the diet, which reduces milk and protein yields. Protein is an expensive nutrient and ration protein levels are increasing because of the annual increase in milk yield per cow of 2 to 3ℓ and emphasis on component pricing (Hutjens & Barmore, 1995). Cows cannot consume enough DM in early lactation so higher levels of protein are fed to provide the amino acids needed. As cows mobilize body fat as an energy source in early lactation, so increased amounts of protein are needed. The increased protein in the diet can lead to health problems. Excessive N excretion also has a negative impact on the environment. Excess protein may reduce the cows resistance to infection or ability to recover from reproductive problems as cows fed high protein diets were found to have more reproductive and health problems (Hutjens & Barmore, 1995). Travaskis & Fulkerson (1999) found no relation between high MUN and poor reproductive performance.

Measuring rumen ammonia, BUN, uterine urea nitrogen or MUN would be a useful management tool to evaluate the protein status of the cow and to prevent reproduction and production losses (Hutjens & Barmore, 1995). MUN tests are available in laboratories and in America as commercially available test strips. MUN is related to BUN but lags BUN by about 2 hours. The MUN can therefore reflect the BUN subsequent to the previous milking. MUN has been found to be between 83 and 98% of BUN. A MUN content of over 385mg milk urea/L milk indicates that there is excess CP in the diet and a shortage of rumen fermentable carbohydrates. The optimum range is 257 to 385 mg milk urea /ℓ milk. Cornell University workers suggest that MUN should lie between 12 and 16 mg per 100 ml, otherwise money and feed are being wasted in reduced milk yields and health problems (Hutjens & Barmore, 1995). According to Van der Merwe (1998), the MUN status of Holstein-Friesian cows on kikuyu for 24 hours a day and receiving 3kg of maize based concentrate twice a day was within the optimal range. It is recommended that MUN tests be done when cattle are grazing lush pasture, when protein levels and type has been changed in the diet, when conception rates are low or when milk protein tests are low (Hutjens & Barmore, 1995). The problem with MUN tests is that they are relative measures. It is recommended that the entire herd be tested initially so that a base line and means of comparison can be established. The test is highly variable and action must only be taken if the majority of the herd have high values (Hutjens & Barmore, 1995). MUN content of bulk milk is useful for assessing the ratio of N to WSC and not the MUN content of individual cows (Trevaskis & Fulkerson, 1999).

3.5 Palatability, intake and selection

Most authors contribute the poorer milk yields associated with cows grazing kikuyu pasture to lower intakes and therefore an inability of the dairy cow to meet her daily DM requirements, although, Mears (1970) stated that the intake of kikuyu grass compared favourably with other grass species. The measurement of pasture intake is difficult as most models used to predict intake use animals in confinement where selection is limited (Vazquez & Smith, 2000). Pasture intake is affected by pasture allowance and mass, supplementation and herbage digestibility (Vazquez & Smith, 2000). Grazing management practices such as frequency, duration and intensity of grazing all affect the palatability of kikuyu just as they affect its quality. Higher fertilizer applications influence the palatability of kikuyu and depress intake (Milford & Minson, 1966 cited by Mears, 1970). At peak season, cattle have high intakes of kikuyu, but there is a steady decline in quality towards the end of the season that brings with it a decline in feed intakes. This seems to occur regardless of grazing rotation as daily DM intakes dropped from 18.1kg DM/ha in December to 10.4 kg DM/ha in May for 15, 30 and 60 day grazing rotations (Henning *et al.*, 1995). This decrease in feed intake of 43% was accompanied by a decline in digestibility of 38% from December to May (Henning *et al.*, 1995). Dugmore and du Toit (1988) found that selection by beef steers did take place when they grazed kikuyu pasture and that their DM intakes were between 1.56 and 2.14%. Cattle will consume what they prefer in a kikuyu sward. To overcome the decline in intake, supplementation would be necessary from December onwards if milk yields are to be maintained (Henning *et al.*, 1995).

Kikuyu is selectively grazed because it is a tropical pasture with a heterogeneous structure (Stobbs, 1975) and stocking rate, number of days of grazing the same pasture and season do not effect selection (Dugmore *et al.*, 1991). Chemical analyses of the selected material differ from the chemical analyses of the average material on offer. It was found that beef steers select material that is higher in fibre and lower in protein in high N pasture and for high protein in low N pasture, indicating the desire for an optimum protein level, which was 14%, in the diet (Dugmore *et al.*, 1991). Usually material consumed is higher in N, P and GE but lower in fibre than the average of the material on offer (Arnold, 1985; cited by Dugmore *et al.*, 1991). This is of concern for dairy cattle, which have higher CP requirements than 14%. The N content of kikuyu reduced intakes in sheep for the entire 24 day grazing period, suggesting that two weeks of active growth following fertilisation is insufficient time for levels to decline (Pienaar *et al.*, 1993). Kikuyu maintains a high CP content throughout growth and maturity (Van der Merwe, 1998). Kikuyu with a CP content of 15%, with 30.8% of the N being soluble, has a urea equivalent content of 1.64%. Feed intake decreases as the urea equivalent exceeds 1.5% (Pienaar *et al.*, 1993). Animals select against oxalate (Pienaar *et al.*, 1993) therefore animals grazing kikuyu with a high oxalate content will utilise the pasture poorly. The high moisture content of kikuyu has also been blamed for the inability of dairy cattle to meet their DM requirements when grazing kikuyu. The DM content of kikuyu ranges from 16 to 20 % (Cross, 1979b). The moisture content can be controlled through careful management to ensure it does not exceed 80% where cattle have difficulty consuming enough to obtain nutrient requirements (Cross, 1979b). Good quality hay can also be supplied to ensure that cows can consume sufficient material to meet their DM requirements. However, feeding *Eragrostis curvula* hay showed no beneficial effect on lamb live weight gains and reduced gains in one season in a trial by van Ryssen *et al.*, (1976) because it replaced pasture intake, but had a lower energy value. The high moisture content does not explain why intakes of kikuyu are lower than ryegrass that also has high moisture content. Holmes and Lang (1963) found that the moisture content of the herbage did not affect intake, although pastures other than kikuyu were used in this experiment. High fertilizer applications increase the accumulation of nitrate that reduces cellulose digestibility and intake (Dugmore *et al.*, 1986). The excretion of excess N requires increased water intakes that can reduce DM intake (Marais, 1990). Fertilising with Ca may improve palatability, or intake, and improve digestibility by with reducing the retention time, due to changes in the fibre fraction (Marais, 1990).

Davie and Pienaar (undated) investigated the low voluntary intake of kikuyu pasture in sheep and found that a possible reason could be impaired saliva flow from inefficient rumen function. Without sufficient buffering from saliva, the pH of the rumen digesta dropped and animals reduced intakes to prevent the pH of the rumen from reaching the critical range of less than six (Davie & Pienaar, undated). The pH fluctuated from 5.78 to 6.8 (Davie & Pienaar, undated). Kolver (2000) explained that pH can fall below 5.8 and be tolerated by dairy cattle grazing pasture because volatile fatty acid production from fibre fermentation does not hinder micro organisms like acetic acid from starch fermentation does. An infusion with NaOH into the rumen increased OM intake, illustrating that reduced pH could be accountable for reduced intakes (Davie & Pienaar, undated). According to Pienaar *et al.* (1993) the rumen pH of sheep fed kikuyu pasture is around 6.5 and this facilitates absorption of ammonia from the rumen. Kikuyu has the potential for foaming, suggesting the presence of saponins (Pienaar *et al.*, 1993), which could limit intake.

The poor performance of dairy cattle grazing kikuyu can perhaps be explained by grazing behaviour of cattle grazing tropical pastures. When leaf quantity is low, animals grazing tropical pastures prefer to restrict intake rather than increase the quantity of stem in their diet (Dugmore *et al.*, 1991). This may explain why Dugmore *et al.* (1991) found the stem fraction to have no significant contribution to the equation predicting dietary selection. The selection by animals for high fibre meant that they chose more mature leaf material and were happy to select leaf material among senescent material (Dugmore *et al.,* 1991). It was found that taller kikuyu had a higher amount of leaf material on offer with higher fibre, which is more palatable. Fulkerson (1999a) advised that management should aim to optimise density of kikuyu leaf to the cows as young leaf has an ME of 9 MJ/kg DM, which equates to 14 to 15 ℓ of milk per day and the stem has an ME of only 7.5 MJ/kg DM which is equivalent to 2 to 3 ℓ milk/cow/day (Fulkerson, 1999a). But, if cows prefer not to consume stem by lowering intakes, then the leaf to stem ratio for kikuyu is not the primary concern and management should aim to maximise the amount of leaf material on offer regardless of the quantity of stem. The leaf to stem ratio is important in preventing the fibrous mat buildup and its effects cannot easily be separated from those of leaf density (Stobbs, 1975).

Dugmore *et al.* (1991) concluded that kikuyu should be fertilized at lower levels of N than recommended to keep the CP and CF levels optimal, even though yields are reduced. Alternatively, cattle should graze kikuyu at a later stage of regrowth to maintain yields and supply herbage with optimal chemical composition (Dugmore *et al.*, 1991). Grazing at the four and a half leaves per tiller stage, enables CP levels to drop.

3.6 The autumn slump

The autumn slump is the primary weakness of kikuyu in sustaining milk yields throughout the season (Henning *et al.*, 1995). The autumn slump could be because of poor grazing management, which allows the grass to become rank (Dugmore & du Toit, 1988). As discussed in Part 1, the autumn slump was almost completely overcome with the use of electric fencing to restrict the grazing area and the use of follower animals in the early part of the season to graze the pasture down to prevent the mat formation from developing later on in the season at Cedara (Dugmore & du Toit, 1988). However, according to Henning *et al.* (1995), the autumn slump is not caused by moribund pasture because it was most severe on the 15-day rotation cycle, where no residual material was present, compared to a 30 and 60 day cycle. The other two treatments had a steady decline in milk yields from December (Henning *et al.*, 1995). The autumn slump as experienced by most dairy farmers in KwaZulu-Natal occurs despite the peak in DOM found in autumn (Dugmore & du Toit, 1988). The low milk production could be because of reduced DM intake which could result from increased NPN content as there is a negative relation between NPN levels and DM intake in steers grazing kikuyu pasture (Dugmore & du Toit, 1988). The inverse Ca to P ratio and ionic imbalance (K/Ca + Mg)>2.2, which deteriorated as the season progresses, could also contribute to the autumn slump. The autumn slump therefore may not be caused by a decrease in digestibility directly (Dugmore & du Toit, 1988) or the build up of moribund pasture. Bartholomew (1985) found that there was a decrease in CP in early February and it increased again later in the month or early March. A possible explanation given was that proteins were being used by the plants for growth and respiration following defoliation. CP was therefore assumed to play a major role in the autumn slump, but the autumn slump was found to occur regardless of when N fertilizer was applied, indicating that factors other than CP are responsible for it.

3.7 Conclusion

Many of the antinutritional factors associated with kikuyu are not controllable through management, but others are. The strategic fertilising of kikuyu can control nitrate poisoning and prevent declines in milk production through not exacerbating the already high protein to energy ratio. Lowering the stem to leaf ratio could lower nitrate poisoning risks as more nitrates are stored in the stem than the leaves. Monitoring of nitrogenous compound effects on the cow through the use of MUN tests will help management. The low calcium levels, particularly in KZN could be improved through lowering soil acidity through the application of lime, dolomitic lime will boost the deficient Mg levels. The benefits of this are debatable as the ability of oxalate to bind all Ca in kikuyu is a possibility. High P concentrations could be reduced by grazing the pasture on slower rotations, allowing longer rest periods between grazings. Potassium levels, although always too high, can be controlled by limiting the amount of excreta deposited onto the kikuyu. Cows should not be wintered on frosted kikuyu paddocks to avoid an accumulation of dung. Sodium levels are innately deficient and will have to be supplemented. Trace minerals, with possibly the exception of Zn and Mn will have to be supplemented, but this is further discussed in Part 4.

Part 4: Overcoming well managed kikuyu pasture quality limitations

If kikuyu is grazed at the correct time, residual pasture removed and it is fertilized carefully to minimize harmful effects on the cow, while still maintaining pasture performance, how does the pasture manager overcome the effects of the antinutritional factors that remain? Part 4 is an investigation into how these factors can effectively be managed through supplementation and inclusion of other pasture species.

4.1 Supplementation of dairy cattle grazing kikuyu pasture

There have been many possible explanations given for the poor performance of cattle grazing kikuyu, but the low ME content has been mostly blamed (van Ryssen *et al.*, 1976). None of the anti quality factors can be eliminated through good management except nitrate levels, which means that supplementation is presently the only solution, with the selection of ecotypes with more favourable chemical compositions being a long term solution (Marais, 1998). The first step in successful pasture farming is to efficiently produce milk from grass (Kolver, 2000) as discussed previously. Once farmers are managing their pastures optimally, the only way for them to increase the profitability of their business and milk production is by expanding or intensifying the farming operation. Supplementary feeding has to be done precisely as it greatly affects the profitability of intensification (Kolver, 2000). Although in grazing based dairy systems relatively low milk yields per cow are acceptable, it is important that production per cow is improved in order to reduce the unit costs of production, particularly if the cattle are of high genetic merit. To improve production per cow concentrates are needed as nutrients contained even in good quality temperate pasture become limiting (Fulkerson *et al.*, 1998). This applies particularly to South Africa where pastures are of an inferior quality to those in New Zealand (Stewart *et al.*, 1995). Supplementary feeding allows for increased stocking rates and for making up deficits in pasture supply. In New Zealand supplementary feed is used to extend their comparatively short lactations (Kolver, 2000).

In the case of kikuyu, mineral supplements have to be provided. Ca and P need to be supplemented especially in high rainfall areas as they are usually deficient (Roos, 1975), but it could be difficult to obtain an adequate balance between Ca and other minerals using existing licks (Marais, 1990). The levels of Ca and P needed to correct the inverse Ca to P ratio are above those derived from dicalcium phosphate (Dugmore, 1998). Pasture could be better managed to lower oxalate concentrations and reduce the reliance on and hence cost of supplements as oxalate is related to N content (Marais, 1990). Sodium levels are much lower in kikuyu than recommended and supplementation with NaCl is essential (Reeves *et al.*, 1996b). Cobalt, Cu, Se, Mn and Zn are stored in a number of tissues, particularly the liver, so supplementation is only required at intervals as supply and demand are met by the reserves (Siebert & Hunter, 1981). Molybdenum and I are not stored in appreciable amounts and daily supplementation is required. They are best supplied in fertiliser or licks. Supplying minerals by topdressing pasture is more economical than the alternative methods, but does not ensure that animals are receiving what they require as effectively as through injection or dosing (Siebert & Hunter, 1981). In KwaZulu-Natal, cattle blood selenium levels are low and heifers grazing kikuyu topdressed with selenium at the beginning of the grazing season, showed signs of improved fertility (Stewart & Miles, 2003). In addition to considering the protein to energy ratio, S should also be taken into account. Protein is a source of N and S for rumen microbes (Siebert & Hunter, 1981), and as the CP content of kikuyu is largely N from N fertiliser, a sulphur deficiency could be of concern. However, according to Table 13, S is more than adequate in kikuyu. Feed availability, fibre content, protein content and the ratio of N: S provide criteria on which to judge the success or failure of a supplement of energy, protein, NPN and non-protein sulphur (Siebert & Hunter, 1981).

It is important that in ration formulation the nutrients available in the pasture and how they change according to environment and plant growth stage are taken into account in addition to the requirements of the cow (Fulkerson *et al.*, 1998). Supplementation is often expensive because of substitution of concentrates for the less expensive pasture. There are often poor responses from dairy cattle grazing pastures to supplementation because supplementation is often done without the knowledge of the nutrients contained in the pasture (Black, 1990 cited by Fulkerson *et al.*, 1998). Under the best circumstances, it is impossible to know the exact requirements of the dairy cow or how to accurately meet them (Stewart *et al.*, 1995). Response to supplementation depends on the supplementation level, stage of lactation and pasture quality and quantity (Reeves *et al.*, 1996a) as well as cow size, pregnancy, activity and milk solids yield (Stewart *et al.*, 1995). Balancing energy and protein in the diet of the cow in early lactation is even more difficult and is critical in terms of the cow's ability to get back into calf. Cows in early lactation battle to consume enough energy to meet their demands for maintenance and production. This negative energy balance created affects fertility. If more than 15% of cows in the herd have anoestrus periods exceeding 40 to 50 days, then it is likely that diet is imbalanced (Ferguson, 1996). The levels of N and energy already in the diet also affect the response to supplementation. Feeding excessive amounts of degradable intake protein (DIP) can cause irregular heat intervals and reduced fertility (Ferguson, 1996). In South Africa there are standard dairy rations formulated regardless of the pasture species that the cattle are grazing (Table 14). The rations must be formulated according to Act 36 of 1947. Concentrates are not formulated according to the protein, energy and mineral imbalances of kikuyu. Although it is not possible to analyse the pasture available on each farm to balance the nutrients, because of the costs and time involved in doing so (Fulkerson *et al.*, 1998), there is a need for more pasture specific supplementation in South Africa. The inclusion of Fe in dairy rations in KZN is unnecessary as its abundance poses antagonistic problems with other minerals. A ratio of Ca to P needs to be much higher to compensate for the lack of Ca. Phosphorous may not even be needed in many cases. Digestion of nutrients is significantly affected by season, pasture species and stage of growth of the pasture (Beever *et al.*, 1986 cited by Fulkerson *et al.*, 1998) and the region where the pasture is grown. Before kikuyu specific supplements can be formulated pasture management must improve so that there are fewer causes of variation in the quality of management-sensitive kikuyu (Cross, 1979b). Nutrients both present and actually available to the animal from pasture must be given (Fulkerson *et al.*, 1998).

Table 14 Guidelines for dairy concentrated meals (as fed g/kg) (Registrar: Act 36 of 1947).

Feed	CP	Protein (no NPN)	Moisture	Fat		CF	Ca		P
	min	max	Max	Min	max	Max	min	max	Min
Dry cow	110	35	120	25	85	120	25	8	5
Dry cow + anionic salts	120	67	120	25	85	120	30	40	8.5
Dairy meal 12	120	35	120	25	85	120		15	5
Dairy meal 15	150	35	120	25	85	120		15	5
Dairy meal 17	170	35	120	25	85	120		15	5
Dairy meal 19	190	35	120	25	85	120		15	5
Dairy meal 21	210	35	120	25	85	120		15	5
Dairy meal 23	230	35	120	25	85	120		15	5

When farming with high quality temperate pastures, the decision of when to provide supplements is based on the quantity of grass available. One theory is that supplements should be provided when intake falls below the targeted 15 to 16 kg DM/cow/day in early lactation, and 12 kg DM/cow/day in late lactation (Kolver, 2000). When cattle are grazing kikuyu, it is usually not the quantity of pasture that is of concern, but rather the quality. Once the mineral requirements have been catered for, energy must be considered as milk production is primarily related to the energy content of the feed. When kikuyu loses quality, particularly later on in the season, supplementation becomes necessary. The level of supplementation depends on the cost structure on the farm, such as labour and capital (Kolver, 2000). The type of supplement needed in turn depends on the amount of supplementary feed being fed (Kolver, 2000). A high quality energy supplement should be given if less than 30% of the diet is provided by supplementary feeding. If over 30% of the diet is taken up by supplementary feeding, then special attention should be paid to preventing metabolic disorders (Kolver, 2000). Different nutrients are first limiting at different levels of production (Kolver, 2000) and it is important that the desired level of production is considered when deciding what supplements to provide. Energy is usually first limiting up to 25 kg milk/cow/day. Milk solids will increase with increased energy, but not with increases in other nutrients. Both protein and energy are required at milk yields of over 30 kg of milk/cow/day and additional protein will be required at yields above 35 kg milk/cow/day (Kolver, 2000). Tainton (1978, cited by Cross, 1979b) stated that protein supplementation would only be needed at milk production of up to 30 ℓ/day.

Bypass protein can increase feed intake (Siebert & Hunter, 1981). Reeves *et al.* (1996a) and Allwood (1994) found undegradable protein (UDP) to be ineffective in improving performance of cattle grazing kikuyu. This is explained by Kolver (2000) who stated that recommendations for TMR are that it should contain 18% CP of which 65% is rumen degradable protein (RDP), 35% is UDP and 32% is soluble. Kikuyu has an average CP content of about 24% (Allwood, 1994) which is about 70% degradable (van der Merwe, 1993, cited by Allwood, 1994). About 30% of the CP is UDP and 70% is RDP (Allwood, 1994). Although the composition of kikuyu does not quite meet the protein recommendations, high protein pastures meet the requirements for high milk production in practice. It is estimated that pasture should contain 18% CP for 20 kg milk/cow/day and 24% CP for 30 kg milk/cow/day. Pastures can supply enough metabolisable protein to the cow as rumen microbes grow well with a highly degradable protein source. Ryegrass has a high rate of passage ensuring that significant amounts of protein bypass the rumen (Kolver, 2000). Kikuyu with its higher fibre content and slower rate of passage may not cause this degradable protein to bypass the rumen, but it does contain only slightly less UDP than the recommended 35%. Supplementation with UDP can cause increased loss of body condition for cows in early lactation (Kolver, 2000) as they will try to balance this protein by drawing on fat reserves. Protein supplements should therefore not be required (Kolver, 2000).

Reports on production potential of dairy cows on kikuyu pasture vary considerably in the literature. With energy based concentrates, yields of 18 to 19 ℓ per cow per day can be achieved with 3 kg of concentrates for cows on and 21 to 23 ℓ of milk per cow per day can be achieved by feeding 6kg of concentrates per day if buffers are also provided (Reeves & Fulkerson, 1996b). With a carrying capacity of three cows per hectare, daily milk production for a Friesland receiving no supplements is about 15.3 ℓ per day and with 1.5 kg of maize meal per day, about 22.2 ℓ of milk per day is possible. A Jersey receiving 1.6 kg of maize meal per day can produce 20.7 ℓ of milk per day. Concentrates would be needed in November for cattle producing over 15 ℓ of milk and from February to April for cattle producing over 20 ℓ of milk (Cross, 1979b). Energy is the primary limitation for milk production off pasture (Meijs 1981 cited by Fulkerson *et al.*, 1998). The energy deficiency of kikuyu is greater and more liberal concentrate feeding is recommended for dairy cows grazing kikuyu than cows grazing ryegrass for a given level of production (Bredon & Hathorn, 1974, cited by van Ryssen *et al.*, 1976).

The lack of readily fermentable carbohydrate in kikuyu should allow for substantial responses to supplementation. Unfortunately, supplementation with readily fermentable energy cannot make up for poor quality roughage (Dugmore, 2002). Roughage forms the largest portion of the dairy cow's diet and is a major determinant of the final quality of the ration. Roughage stimulates saliva production, buffering the rumen against acidosis and microbes produce acetic acid, which is a precursor for butterfat production. The higher the digestibility of the roughage, the more energy is available for milk production. Increasing the amount of concentrate fed to the dairy cow grazing kikuyu pasture to improve the protein to energy ratio reduces the butterfat content of the milk. This is because the roughage fermenting microbes that produce acetic acid are hindered by the decrease in rumen pH resulting from concentrate being fed (Dugmore, 2002). The pH of the rumen does drop with the production of volatile fatty acids from fibre fermentation, but this can be tolerated by rumen microbes of dairy cattle if no highly fermentable carbohydrates are being supplemented (Kolver, 2000). This is because starch is fermented to lactic acid, which depresses microbial growth and causes metabolic disorders. Rumen microbes favour starch fermentation over fibre, hence fibre fermentation is reduced. Hay supplementation is unnecessary on kikuyu because of its high NDF content of well over 35% in pasture. This means that rumen pH will not be limiting (Kolver, 2000).

Grazing cows will always produce less milk than cows on total mixed rations (TMR) regardless of the supplements provided. An example taken from Kolver (2000) showed that cows on TMR produced 44.1 kg milk/cow/day and grazing cows produced 26.9 kg milk/cow/day and that the difference could be described by five variables from the Cornell Net Carbohydrate and Protein System computer program. The grazing cows had a DM intake of 19 kg DM compared to the 23.4 kg DM/cow/day of those on TMR, which accounts for 9.4 kg of the difference in milk/cow/day. Energy used for grazing and walking accounted for about 3.7 kg of milk/cow/day and the process of converting excess N in the pasture to urea accounted for 1.8 kg of milk/cow/day. The rest of the difference was accounted for by milk composition and live weight (Kolver, 2000). Although increasing the DM intake of grazing cows should increase milk yields, DM intake of high quality pasture is limited to 19 to 20 kg DM/cow/day. Cows need to consume 24 kg DM/day to achieve higher levels of production, meaning that about 40% of the diet would need to be supplementary feed (Kolver, 2000), which can not be regarded as a profitable option. Pasture does allow for high production of milk solids, but supplementary feeding is needed for higher yields. Energy supplements make up for deficits in the following way: A 500kg Friesian producing 2 kg milk solids per day and losing 0.25 kg/day would require an energy intake of 186 MJ ME/day (maintenance (64 MJ ME) + milk solids (2kg milk solids per day x 65 MJ ME/kg milk solids) – live weight loss (0.25 kg LW x 32 MJ ME/kg LW loss)) (Kolver, 2000). Kikuyu pasture contains, on average, 8.5 MJ ME/kg DM, so DM intake would need to be 22 kg DM/cow/day. This is not possible, so high quality feeds must be used as a supplement to achieve higher production levels. The cheapest energy source in Rands /MJ ME should be used, but care must be taken over inclusion levels to avoid acidosis. Fats can also be used, but cannot be included at levels higher than 3% protected and 3% unprotected fat, otherwise fibre digestion can become depressed (Kolver, 2000).

Nutritional guidelines for complete rations for high producing dairy cows recommend that 34 to 38% of the diet should be readily fermentable carbohydrates and starch should account for more than 30% of the diet (Kolver, 2000). This will adequately provide energy for rumen microbes to convert ammonia into protein. High quality pastures contain between 5 and 25% readily fermentable carbohydrate (Kolver, 2000), with kikuyu being at the lower end of the scale, which is much lower than recommended levels. This again highlights the need for pasture specific supplementation as there is considerable variation in pasture energy concentrations. Milk production is highly successful on high quality pastures as fibre is easily fermented and this provides sufficient energy for the microbes (Kolver, 2000). Often, no improvement in performance or energy intake is seen with soluble carbohydrate supplementation. In trials where animals grazing kikuyu received supplements, no improved kikuyu grass intake was observed. Reeves *et al.* (1996a) did not get responses above 3kg of cereal concentrate supplementation. This may have been because of a more favourable protein to energy ratio or substitution of supplement for pasture. If the substitution rate is low, or if the supplement is given to cows that have a restricted pasture intake, milk solids production will increase as a result of improved microbial protein production (Kolver, 2000). NDF limits intake, so animals grazing higher quality pastures can consume more. There should be better responses to maize concentrate from cows grazing kikuyu than cows grazing ryegrass, for example, as the quality, or ME content, of the supplement will be far more superior to kikuyu than ryegrass. This means that there will be less energy substitution of concentrate for kikuyu than concentrate for ryegrass (Stewart *et al.*, 1995). Although the supplement for cattle grazing kikuyu need not be as high in quality as one for cattle grazing ryegrass in order to observe improved intake of energy, the concentrate needs to be of a higher nutrient density because intake of kikuyu grass is limited by its NDF content. The energy supply must become available for the microbes at the right time to allow them to synthesise microbial protein and breakdown structural carbohydrates. This can be done by feeding the concentrate at the right time or feeding a combination of fast fermenting and slow fermenting energy sources. Starch and NSC sources improve rumen fermentation in diets of fast fermenting grasses such as ryegrass. Care must be taken in supplementing with high levels of energy as normal rumen function can be disrupted by depressing rumen degradation of fibre (Doyle, 1987, cited by Reeves *et al.*, 1996a). It is important that the energy supplement is fed at the right time so that it becomes available to rumen microbes at the same time as the protein. Recent research indicates that slower fermenting grasses like kikuyu should be supplemented with slower fermenting energy sources such as rice and sorghum to increase milk production. Using the appropriate energy source to match roughage degradability has increased production by two litres per day in production trials (Dugmore, 2002). It is recommended that a combination of quickly fermenting and slower fermenting energy sources be used in the ration to overcome problems of excess ammonia (Hutjens & Barmore, 1995). Supplements such as monensin and lasolocid can improve the protein to energy ratio in the rumen by reducing the breakdown of protein (Dugmore, 2002). Buffers do not totally relieve the problem because microbial competition for nutrients in the rumen decreases fibre breakdown (Hoover 1986, cited by Reeves *et al.*, 1996a). Cereal based concentrates can increase milk production on well-managed kikuyu pasture (Reeves *et al.*, 1996a), but it is essential that the income from the improved animal performance can overcome the cost of the supplement (van Ryssen *et al.*, 1976).

Table 15 Recommended mineral levels for complete dairy feeds (as fed) (Act 36 of 1947).

Mineral	Recommended level (g/kg)	Maximum tolerable level (g/kg)
Ca	5 – 10	18
P	3 – 4.5	9
Mg	1.8 – 2.7	4.5
K	8 – 9	27
Na	1.6 – 1.8	13.5
Cl	1.8 – 2.7	22
S	1.8 – 2.3	3.5
	mg/kg	mg/kg
Fe	45	900
Mn	36	900
Cu	9	90
Co	0.1	9
Zn	36	450
Mo		4.5
Se	0.27	1.8
I	0.55	45
F		36
As		45

Supplementation should strive to improve the retention of nutrients and improve the digestibility of the grass (Marais, 1990). Supplementation reduces the amount of nutrients wasted by improving efficiencies of nutrient utilization by the animal. Preventing the wastage of N reduces costs and saves the environment from harm. Marais *et al.* (1990) found that supplemented animals excreted less urine and energy excreted in urine and faeces was significantly less than the unsupplemented animals. The wastage of N is not only expensive in terms of the N itself, but also energy as the conversion of ammonia into urea is an energy expensive process. The unsupplemented and therefore energy deficient animals lost even more energy in excreting the excess N and lost weight while supplemented animals gained (Marais *et al.*, 1990). The excretion of the N required increased water intake that reduced feed intake (Marais *et al.*, 1990). In a trial by Marais *et al.* (1990) sheep consuming kikuyu cut after four weeks regrowth with a low N content of 27g N/kg DM (16.9% CP) experienced no change in rumen ammonia levels with supplementation of maize meal. The sheep consuming kikuyu with a high N content of 36g N/kg /DM (22.5% CP) had rumen ammonia levels that were twice that of those grazing the low N grass. Supplementing sheep on the high N grass with maize meal at 20% of their expected intake decreased the ammonia levels in the rumen so that they equalled ammonia levels in the sheep fed on low N grass. The lack of an effect of maize meal supplementation on the low N grass was attributed to a more favourable protein to energy ratio in the diet (Marais *et al.*, 1990). If the OM to CP ratio tends towards 3:1, ammonia begins to increase and below this, ammonia increases rapidly. The maize meal significantly increased total daily feed intake, but not the intake of kikuyu. Supplementation with maize meal significantly increased DMD and N retention. Supplementing the sheep on the high N grass increased the DMD from 50.6% to 61.1%. The unsupplemented sheep had poor N retention and 50.4% of the consumed N was excreted in the urine compared to the 29.8% excreted by the supplemented sheep. Poor N retention is attributed to a lack of ME in high N grass (Marais *et al.*, 1990).

Energy has to be supplemented to dairy cows grazing kikuyu, but the cost of energy supplements such as maize and its byproducts are highly volatile, often unaffordable. The use of molasses as a substitute for maize could be useful because it has a more stable price structure than maize in South Africa. Molasses is not only a good energy supplement, but it also contains S (Siebert & Hunter, 1981). Van Ryssen *et al.* (1976) looked at the use of molasses compared to maize as a supplement for lambs grazing kikuyu. Treatments included molasses and maize meal, fed at approximately the same TDN level, and increased grazing pressure. The kikuyu paddocks were grazed on a rotational basis with all lambs being moved at the same time to estimate grass left in order to calculate the substitution effect of supplement for grass. Molasses significantly improved live weight gains (LWG) compared to unsupplemented animals and there was no difference observed in LWG between molasses and maize meal treatments even at higher grazing intensities (van Ryssen *et al.*, 1976). The unsupplemented animals required a larger grazing area for a given period of time, which indicated that substitution effects occurred. The grading of the carcasses was higher for the supplemented groups than those that received no supplements, which indicates more fat deposition in the supplemented groups, and the gradings were the same for the groups receiving maize and the groups receiving molasses. Less of a difference was observed between supplemented and unsupplemented animals at lower stocking rates (van Ryssen *et al.*, 1976). However, differences may be seen in dairy cattle performance on maize compared to molasses as they may be more sensitive to quality than lambs. Dairy cows require different types of carbohydrates for the different microorganisms (Hoover & Stokes, 1991). The major limitation of molasses is that it has a lower inclusion rate compared to maize. Molasses has a low recommended inclusion rate of well below 25% of the ration (Kolver, 2000) whereas maize is commonly included in dairy concentrate rations at 60%.

An added advantage of supplementation is that the pasture can be grazed down to a suitable point for proper pasture management without the risk of poor animal performance (van Ryssen *et al.*, 1976). By using supplementation as a buffer against reduced animal performance on pasture, the farmer can manage his pasture properly (Doonan & Irvine, 2002). Supplementation can make up for imbalances and deficiencies in the basal roughage diet, but do not make up for a poor roughage base (Dugmore, 2002).

4.2 Oversowing kikuyu pasture

Supplementing dairy cows on kikuyu pasture may often not fit the low cost dairy production systems, given the high costs. Oversowing kikuyu with either legumes or temperate pasture such as ryegrass may be useful in altering its quality. Well managed kikuyu serves as a useful base pasture for oversowing, particularly on sandy soils as it aids in moisture retention. It also can significantly extend the grazing season (Cransbery, 1995).

4.2.1 Oversowing kikuyu with legumes

The practice of oversowing kikuyu with a legume has come about as an attempt to overcome its seasonality and poor quality (Fulkerson & Slack, 1996) or to find an alternative to the traditional and costly system of planting annual ryegrass for winter, which is only grazed between six to nine times, requires up to 500 kg of N fertilizer for one season and has a high labour input in addition to the seed purchased (Davison *et al.*, 1997a). Kikuyu is typically grown as a monoculture in summer with 250-350 kg N/ha/year (Fulkerson & Reeves, 1996b) and because of the vigorous growth of kikuyu grass and the grazing pressure common on dairy farms, most legumes cannot coexist with kikuyu (Fulkerson & Slack, 1996). The inability of kikuyu to readily combine with legumes means that careful management is needed (Mears, 1970; Teitzel *et al.*, 1991) especially since the mineral deficiencies crucial to the survival of legumes are difficult to detect. The exact process of carefully managing the kikuyu-legume pasture is largely unknown and is hard to make use of under farming conditions (Mears, 1970). A possible reason for the little work done on oversowing kikuyu with clover, is that many studies have shown that better cattle performance on N fertilised grass pastures compared to tropical grass legume pastures. N fertilized pastures are more robust in response to different management, can support high stocking rates, are easy to establish and compete more favourably with weeds than grass-legume pastures (Teitzel *et al.*, 1991). Optimal conditions for clover growth differ from optimal conditions for kikuyu growth (Bartholomew, 1998). Bransby (1983) stated that there is limited potential for incorporating legumes into pasture in South Africa because of the high incidence of acidic soils, as clover requires a soil pH of above 5 for successful establishment (Fulkerson, 1999b). Clover requires higher P and potash levels, lower N levels and lower temperatures of 15 °C to 25 °C compared to 25°C to 35 °C or kikuyu for optimal growth (Bartholomew, 1998). Despite this, studies in Australia have shown that kikuyu and clover complement each other with white clover re-establishing itself in the autumn when the growth rate of kikuyu slows down and with kikuyu growth taking off in early summer after the clover has set seed and its growth declines. Under careful management in commercial dairy production conditions over 12t DM/ha of white clover and 8t DM/ha of good quality kikuyu have been grown annually (Fulkerson, 1999b).

Despite the apparent advantages of N fertilized kikuyu, there are certain limitations in the use of N fertilizer. N fertilizer is crucial for pasture growth in the tropics and sub tropics, which are characterised by low soil N (Teitzel *et al.*, 1991), but N fertilizer is costly, causes soil acidification and is not sustainable (Fulkerson & Slack, 1996; Tietzel *et al.*, 1991). Acidification rate varies, being higher with increasing N application, initial soil pH and use of ammonium sulfate (Teitzel *et al.*, 1991). Inclusion of white clover into kikuyu would reduce the use of N fertiliser and improve pasture quality (Fulkerson & Slack, 1996; Fulkerson & Reeves, 1996b). According to Fulkerson (1999b) the N input of kikuyu-clover pasture is half that of a kikuyu-ryegrass pasture. Although milk production response to N fertiliser is linear between 150 and 600 kg/ha N for kikuyu pastures under three years of age, near optimal performance is achieved from annual applications of 200 kg N/ha (Cowan unpublished cited by Teitzel *et al.*, 1991). Over 30% clover in a kikuyu pasture is capable of fixing 50 to 200 kg N/ha, which could be sufficient for mature pastures, but N fertilizer is still needed at certain times of the year when the N in the soil is insufficient to meet the requirements of the plants. Davison *et al.* (1997b) found that the lack of response in milk yields with additional N fertilizer on a kikuyu-clover pasture indicated that sufficient N was supplied from the clover, although cows did select for the higher quality clover as apposed to the kikuyu (Davison *et al.*, 1997b). Milk yields were not improved by applying 300 to 600 kg of N per hectare as the increase in the amount of pasture on offer forced the cows to eat more kikuyu than clover (Davison *et al.*, 1997b). White clover has the added advantage of protecting kikuyu allowing growth to continue in adverse conditions of heat and frost.

The costs of establishing clover in kikuyu pasture is of major concern, and it is important they can be offset by the higher total milk yields and the reduced N input. Management must promote clover persistence by once again focussing on the plant growth characteristics (Fulkerson & Slack, 1996) so that resowing takes place less often. Cutting to 5 cm stubble height when the lower leaves of the clover plant show signs of senescence produced the best yields and most favourable balance between kikuyu and the legumes compared to a defoliation interval based on 2 weeks (Fulkerson & Slack, 1996). Oversowing clover into kikuyu pasture is often unsuccessful because kikuyu out competes clover over the summer (Fulkerson & Reeves, 1996b) as after defoliation, kikuyu has more residual leaf than clover to initiate regrowth (Bartholomew, 1998). Most legumes have variable yields, especially under dryland conditions, because of the effects of soil pH, plant pathogens and grazing management on stolon survival and seedling recruitment (Fulkerson & Slack, 1996). Management is slightly different depending on the species of legume and whether it is dryland or irrigated. Irrigating legume based pastures extends the growing season and enhances the survival of legumes, which allows greater amounts of N to be fixed each year (Tietzel *et al.*, 1991). Clover requires irrigation and it is difficult, if not impossible, for it to be oversown in the coastal regions where kikuyu continues to grow quite vigorously into the winter (Fulkerson, 1999b).

Lack of persistence of clover is a major problem. Fulkerson and Slack (1996) discovered that two varieties of Lotus, Sharnae and Maku, and Haifa white clover (*Trifolium Repens*) can persist for two years in a kikuyu sward. Lotus (*Lotus pedunculatus)* is able to overcome two of the problems associated with kikuyu-clover pastures as it is tolerant of acidic soils and has the advantage of having lower nutrient requirements and a high level of tannins that reduce the incidence of bloat (Fulkerson & Slack, 1996). With irrigation, drainage and high level of fertility, white clover produced substantially more DM of a higher quality than the Lotus species and grows better with kikuyu (Fulkerson & Slack, 1996). Davison *et al.* (1997a) found that Haifa white clover was dominant over Safari clover (*Trifolium semipilosum*). According to Fulkerson (1999b) persistence of clover depends on the amount of clover that can be maintained in the pasture. Re-established takes place less often in pastures where clover makes up more than 50% of the pasture (Fulkerson, 1999b). Dense swards of white clover can attract plant root nematodes with a severe decrease in pasture vigour after the third year, necessitating a year with no white clover every three years (Fulkerson, 1999b). Davison *et al.* (1997a) attributed the decline in the white clover content of the pasture over three years to stocking rate and the amount of N fertilizer applied. The rate of decline was highest when cows were stocked at five cows per hectare as apposed to 3.75 and 2.5 cows per hectare, but this could be explained by the selection by cattle for white clover over kikuyu. Clover grew best under a stocking rate of 3.75 cows per hectare and receiving no fertiliser, as, under these conditions, it was able to regenerate itself each winter. At a stocking rate of five cows per hectare and 150 to 300kg of N, kikuyu production increased. It was found that clover could tolerate up to 300kg of N per hectare if the stocking rate was five cows per hectare, but it could not tolerate as little as 150 kg N per hectare if the stocking rate was only 3.75. The amount of clover in the diet need not be very much in order to observe improved milk yields. Davison *et al.* (1997b) found that the relation between proportion of clover in diet and milk yield was the strongest, even though clover made up on average only 15% of the diet. This is because clover improves the protein quality and digestibility of kikuyu (Minson 1990 cited by Davison *et al.*, 1997b).

More recently, in Australia, white clover has been used in autumn and spring and kikuyu in summer (Fulkerson & Reeves, 1996b) in order to extend the availability of good quality pasture over the grazing season. Different management strategies are used to promote the growth of the one over the other at different times of the year, depending on which has a more favourable growth at the time. The kikuyu sward must be removed by heavy grazing, harvesting or mulching after the last grazing and the mat must be allowed to decompose (Fulkerson & Reeves, 1996a; Fulkerson, 1999b). A light disc harrowing is advisable before sowing (Fulkerson, 1999b) to break the stolons. Because of the difficulty in suppressing kikuyu sufficiently to give the oversown species a chance to establish itself, there has been much interest in the use of herbicides among farmers in South Africa. Although herbicides suppress growth with variable results, they do not remove the shade provided by the kikuyu plants which retards the growth of the oversown species (Fulkerson & Reeves, 1996b). At Cedara, use of 5 ℓ of roundup per hectare or rotavation allowed for the establishment of clover in kikuyu pasture (Bartholomew, 1998). It is critical that sowing and management changes to favour white clover over kikuyu take place at the right time, usually six weeks before the first expected frost. This allows for the establishment of the clover plants that depend on warm weather and the onset of cold weather sets the kikuyu back (Fulkerson 1999b and Reeves & Fulkerson, 1996a). Haifa white clover, which is ideal in complementing kikuyu, is broadcast at 4kg/ha. Cattle can be placed in the paddock after to compact the soil around the seeds (Fulkerson, 1999b). Clover can be planted at 3kg/ha and then rolled in (Bartholomew, 1998). Alternatively, clover can be planted in strips in kikuyu pasture. Roundup can be applied to the strips of kikuyu where clover is to be established. This system allows for management that optimises both kikuyu and clover growth simultaneously, but increases the likelihood of bloat (Bartholomew, 1998). Timing of fertilization is also crucial. Fertilization with N must cease three weeks before sowing the clover and K, P and Mo fertilizer must be applied for nodulation (Fulkerson & Reeves, 1996b; Fulkerson, 1999a). The timing of P fertilization can affect legume response (Mears, 1970).

Kikuyu should be grazed when it exceeds 8cm as shading will kill clover seedlings (Fulkerson, 1999b). This frequent grazing should last for five to seven weeks until the clover dominates and then grazing should be hard and infrequent (at long intervals of about every 30 to 40 days during spring) to favour clover growth (Fulkerson, 1999b). Davison *et al.* (1997a) also found that higher grazing pressure in early summer stimulated clover growth. In late spring when kikuyu becomes more favourable than clover, management should change to favour kikuyu growth (Fulkerson & Reeves, 1996b) as the survival of clover stolons is inversely related to kikuyu grass yields (Davison *et al.* 1997a). Kikuyu growth can be stimulated by applying N fertilizer (Bartholomew, 1998; Fulkerson & Reeves 1996b), increasing frequency and decreasing severity of grazing and increasing watering interval if needed (Fulkerson & Reeves, 1996b). Light frequent grazing removes cloverleaf and favours kikuyu growth (Fulkerson, 1999b).

The sensitivity of dairy cattle to quality of diet compared to beef cattle was yet again observed by Teitzel *et al.* (1991) who stated that despite the benefits of kikuyu legume pastures, studies have shown increased beef production from grass-N pastures over grass legume pastures in Australia. Annual milk production from grass-N pastures ranges from 3000 to 4500 ℓ per cow under dryland conditions at stocking rates of two cows/ha under 800 mm rainfall and 2.6 cows/ha under 1200 mm (Teitzel *et al.*, 1991). As would be expected, milk yields per cow over a lactation decline with increasing stocking rate. In comparison, on an irrigated clover-kikuyu pasture, yields are 4649, 4115 and 3861 kg/cow for the stocking rates 2.5, 3.75 and five respectively. Milk production from irrigated annual ryegrass pasture stocked at five cows per hectare receiving 400 kg N per hectare was 4026 kg/cow (Davison *et al.*, 1997b). Although it is not sound practice to compare milk yields from different trials, it can be seen here that higher yields are attainable on irrigated pastures for a given stocking rate, but it must be seen whether the extra costs of irrigating and oversowing are covered by the extra milk yields. According to Davison *et al.* (1997b) the perennial kikuyu-clover system has the potential to produce more milk than the traditional tropical pasture system, but the costs are much higher in terms of legume seed and irrigation. The kikuyu-clover system has higher yields per cow, but lower yields per hectare than the ryegrass-clover system (Davison *et al.*, 1997b). It was advised that the stocking rate on the kikuyu-clover system be maintained at below five cows per hectare if the cattle are to maintain suitable condition to reconceive in winter (Davison *et al.*, 1997b).

It was estimated that the costs of running the kikuyu-clover system would be 30% less than the annual ryegrass system (Davison *et al.*, 1997b). However the kikuyu-clover system has an unstable cost structure as additional clover may need to be sown every three years and annual ryegrass may still be needed if milk yields are to be maintained over the winter months, especially in areas that have frost . The profitability of the system is extremely sensitive as a change in stocking rate from 2.5 to 3.75 with no N inputs changed the system from being least profitable to most profitable when a variety of stocking rates and fertilizer applications were compared. The kikuyu-clover system stocked at 2.5 cows per hectare with no N fertilizer was characterised by the highest amount of dead material, compared to the system with the least dead material that was stocked at five cows per hectare and received 150 kg of N. The least profitable system was also characterised as having the lowest milk fat yields (Davison *et al.*,1997b). Higher N applications and stocking rates increased the CP content of the pasture over the season, which caused milk protein to decline because of the energy expenditure in the excretion of the excess soluble N in the diet (Martin & Blaxter, 1965 cited by Davison *et al.*, 1997b). Combining clover with kikuyu has the beneficial effect of raising the Ca content of the pasture as the Ca content of clover is higher than ryegrass, which is higher than kikuyu (Davison *et al.*, 1997a). However, the availability of this Ca to the animal was not given. Potassium levels are highest for ryegrass, but P, Mg and S were low and similar for all grass species meaning that supplementation of dairy cattle would be needed for all systems, in late summer and autumn on the kikuyu-clover system and late winter and spring on annual ryegrass (Davison *et al.*, 1997a). Legumes are good sources of S (Little, 1981), which is important if less fertilizer is being applied to the kikuyu pasture. No difference was seen between kikuyu-clover pasture that was not fertilised and kikuyu pasture fertilised with 150 kg N/ha (Bartholomew, 1998).

The fact that dairy cattle select for clover in the kikuyu-clover pasture makes it difficult to maintain pasture of a consistent quality, which can give consistent milk yields. In the trial by Davison & Lisle (1997), dairy cattle grazed in a seven-day rotation and kikuyu leaf available declined significantly from day zero to day seven. The yield of stem did not change significantly over the week, and neither did the proportion of dead material in October, but the proportion of dead material increased in May and was greater for pastures stocked and fertilized more heavily (Davison & Lisle, 1997). In May the kikuyu leaf formed 58% and clover 5% of the diet and in October, kikuyu leaf formed 44% and clover 24% of the diet. The decline in kikuyu leaf in the diet over the seven day grazing period was 74%, 74%, 51% and 32% for days 0, 2, 5 and 7 respectively and for clover 12, 3, 4 and 2% respectively. In October the cows selected initially for clover and then kikuyu leaf which lead to an increase in the stem and dead material later on in the week. In May, kikuyu leaf made up most of the diet. The Ca content of the pasture decreased from 0.45% to 0.31% in May and from 0.81% to 0.42% in October over the grazing period. The treatment where cows were stocked at five cows per hectare and 600 kg N applied had the lowest Ca intake and those on the lowest stocking rate of 2.5 cows per hectare and no N applied had the highest Ca intake. Mg was also higher in October than May. The decrease in Ca, Mg and CP over the week indicates the difficulty in setting the rotation program. To reduce the fluctuations in diet quality and pasture on offer and to obtain a more even flow of milk, a shorter grazing rotation is needed (Davison & Lisle, 1997).

4.2.2 Oversowing kikuyu with temperate grasses

Most farms in South Africa have limited irrigable land and the ability to oversow kikuyu with annual or perennial ryegrass would have major advantages for dairy fodder production as this would allow for almost year round production of forage off the same land. Every year in winter kikuyu can be oversown with ryegrass if under irrigation, or with oats if dryland, but this requires the application of N fertilizer (Fulkerson & Reeves, 1996b) unlike oversowing with clover. The purpose is once again to improve the nutritional value of kikuyu, but is mainly to improve land utilization. Oversowing kikuyu with annual ryegrass improves the quality of pasture over the winter spring period when kikuyu would be dormant (Harris, 1998). There are many concerns surrounding the oversowing of kikuyu with ryegrass. Many people believe that it is not a desirable practice since pasture management employed is a compromise between the needs of kikuyu and the needs of ryegrass. There is also the suspicion that allelopathic effects between the two pasture species may hinder growth. However Manyawu & Madzudzo (1996) did not suspect that there were any allelopathic effects of annual ryegrass on kikuyu in their research work. Annual ryegrass requires at least 300kg N/ha/annum (De Beer *et al.*, 1985 cited by Manyawu & Madzudzo, 1996), which is the same as mature kikuyu under irrigation (Roos, 1975). There is also concern surrounding the competitive nature of kikuyu and ryegrass. According to Manyawu & Madzudzo (1996) provision of adequate moisture and nutrients minimises root competition and competition is for aerial space only. In areas where there is very little frost, kikuyu remains too competitive, making oversowing with annual ryegrass impossible (Harris, 1998). The oversowing of kikuyu with ryegrass is possible, with little loss to wet season pastures, in areas where frosts commonly occur from May to August, that have an altitude of about 1600m, temperatures that range from 11 to 23 ^{0}C and acidic soils (Manyawu & Madzudzo, 1996).

There are two methods of introducing ryegrass pasture into an established kikuyu pasture either by sod seeding or oversowing at the end of the season. Sod seeding has the advantage in that good germination is more ensured because of good contact between seed and soil (Manyawu & Madzudzo, 1996). Oversowing is the preferred method because it is simple and less expensive (Mueller & Chamblee, 1984 cited by Manyawu & Madzudzo, 1996). Ryegrass should be oversown into kikuyu when the growth of kikuyu has been retarded by artificial or natural means. At the same time it should be sown when the temperatures are optimal for germination and establishment (Manyawu & Madzudzo, 1996). In a trial by Manyawu & Madzudzo (1996), Midmar ryegrass was oversown into a kikuyu-Kenyan white clover (*Trifolium semipilosum*) pasture at 27kg/ha seed. Roos (1975) recommended Italian ryegrass be sown at 20kg seed/ha and the seed can be trampled in using animals. Harris (1998) used 30 kg seed per hectare after lightly scraping the soil surface. Rolling reduces the growth (Harris, 1998). The grass is then irrigated and top-dressed with N when the ryegrass has germinated (Roos, 1975; Manyawu & Madzudzo, 1996). Applying N fertilizer a month after sowing boosts the ryegrass in warmer areas (Harris, 1998). According to Roos (1975) kikuyu should be grazed down heavily in March and surplus material must be removed. Harris (1998) also stated that the surplus material must be removed. It is necessary that kikuyu be grazed low before slashing because too much mulch may depress seedling emergence (Manyawu & Madzudzo, 1996). The ryegrass seedlings must be able to receive sufficient light (Harris, 1998). In a comparison of seed bed preparations, it was found that there was no significant difference between slashing kikuyu and leaving trash, slashing and removing trash and slashing, removing trash and disking in terms of yield and herbage quality. Disking was found to help when kikuyu was oversown with annual ryegrass early in the season, in March, but the improvement did not offset the extra costs and risk of soil erosion and weed encroachment because of exposed soil. The cheapest and easiest seedbed preparation is to slash and leave trash (Manyawu & Madzudzo, 1996).

Time of grazing during the season and date of sowing had an effect on herbage quantity. Early sowing, in Zimbabwe, during March, resulted in higher yields as this allowed for a greater number of harvests in a season (Manyawu & Madzudzo, 1996). According to Harris (1998), time of oversowing does not affect total yields much. Reports on how soon annual ryegrass can be grazed after sowing range from eight to 15 weeks and depend on the climate and date of sowing (Manyawu & Madzudzo, 1996). Early sown plots can be grazed sooner (Harris, 1998), sometimes taking less than eight weeks from the sowing date (Manyawu & Madzudzo, 1996). According to Reeves and Fulkerson (1996) pasture can be grazed after eight weeks. Despite the benefits of early sown pasture, the establishment of annual ryegrass into kikuyu is expected to be better if delayed until the cold season (Manyawu & Madzudzo, 1996). This is because kikuyu stops active growth much later on and early sowing could only be beneficial with the use of artificial means of retarding kikuyu. The cool temperatures also retard ryegrass growth in June and July. Herbage production increased with time after sowing and ryegrass consisted of 57% of the total herbage on offer (Manyawu & Madzudzo, 1996).

The grazing management strategies for kikuyu and ryegrass were discussed at length in Part 1.5.4. Although there were many similarities between kikuyu and ryegrass in terms of grazing management, the signs indicating grazing readiness, such as new leaves per tiller, were different for the two pasture species. It is unlikely that the growth rates of the two pasture species are exactly the same, given their completely different origins, and therefore it is debatable whether they will reach grazing readiness at the same time. As a result it is likely that milk production will suffer because dairy cows will be offered herbage that will be of sub-optimal quality. This sacrifice may be well worth making for the farmer short of irrigable land. Harris (1998) stated that management should aim at minimising the competitiveness between the two grasses and that fertilization should aim at maximising the yields of the more dominant species. Shortening the grazing cycle from 28 to 21 days favours kikuyu growth in spring, but kikuyu growth is set back as a result of oversowing. Annual ryegrass yields in oversown pasture are lower than pure stands (Harris, 1998). Much research has gone into developing ryegrass cultivars that are more persistent. If ryegrass is oversown into kikuyu, it is unlikely that much use could be made from its extra persistence and it will ruin the kikuyu yield the following season as both grasses are highly competitive. Choice of ryegrass cultivar is important and Westerwolds should be favoured over Italian cultivars. Oversowing should take place every second year rather to reduce the negative effects on the pastures as well as the build up of parasites, which makes regular dosing of cows more necessary (Harris, 1998). There has been very little research regarding this matter, especially in South Africa, and any discussion on long-term effects is purely speculative.

4.3 Conclusion

Dairy cattle cannot maintain high performance on kikuyu pasture alone. Supplementation of minerals in the form of lick is a relatively easy method of overcoming their deficiencies. The supplementation of energy poses a bigger financial problem at certain times with reliance on maize. Molasses may help, but cannot fully substitute maize, having a lower recommended inclusion rate. Oversowing kikuyu with legumes or temperate pastures may help balance the diet, but could be limiting in dry areas, being more dependant on moisture than kikuyu, although kikuyu seems to aid in water retention and lowering evaporation. Recent advances in no-till equipment have made the oversowing of kikuyu with ryegrass and oats farm more successful. Oversowing with legumes has the added advantage of not only helping overcome certain mineral and energy deficiencies, but reducing N fertiliser use. Oversowing with ryegrass improves the mineral balance as ryegrass is not as deficient in the minerals Ca and Mg. the added advantage is being able to graze the same area of land all year round, which enables land limited farmers to expand their herds.

Part 5: Discussion and Conclusion

Although there has been much discussion in the preceding parts, there are certain aspects that may require further investigation. The primary aim in promoting the use of kikuyu pasture on South African dairy farms is to improve the economics of dairy farming. Kikuyu should be able to reduce the costs of feeding dairy cattle with the appropriate management as it has a minimal demand for machinery, chemical and seed input and is tolerant of poorer soils compared with ryegrass. The best way to manage kikuyu will not maximise pasture performance or animal performance, but should maximise profitability. Aspects that contribute to the profitability of dairy farming cannot all be managed to their full potential because they may negatively impact on each other. Research should aim to identify and quantify relations between the different management aspects to improve the precision of managing dairy farms. The survey carried out should lay a foundation for further research work of these relations. Farmers have generally not aimed at optimising kikuyu pasture utilization, but have used it to tide them over until the next ryegrass season. The lower milk yields associated with poorly managed kikuyu have become accepted and little effort made to try and improve them. Milk production is dependant on pasture quality as long as quantity is not limiting (Stobbs, 1972). Improving the quality of kikuyu pasture is the key to improving milk production.

The success of pasture based dairy production systems involves the choice of the correct cow. If bigger volumes of milk from more productive cows and the use of fewer replacement heifers are required to reduce costs (Broom, 1999) then more reproductively efficient and robust cattle are needed. Although high producing cows are desirable because they produce more milk, high production and FCE are inversely related to reproductive performance and health (Hansen *et al.*, 1999, Mahoney *et al.*, 1986). High yields per cow are unlikely to be achieved on farms that have highly stocked pastures with the aim of improving pasture utilization (Mahoney *et al.*, 1986), regardless of the production potential of the animal. It has been found that smaller Holstein Friesians tend to be more reproductively efficient than larger Holstein-Frieslands (Jones & Stewart, 1998). Smaller cows live longer, are more fertile and are less prone to lameness, having legs and feet more suited to walking long distances (Hansen *et al.*, 1999). Although feed contributes the most to production costs, it is important that all costs are reduced. The type of cow chosen for pasture based dairy production systems should lower production costs over her entire lifetime and not over a single lactation.

The fact that the cow is no longer regarded as the only central aspect of dairy farming, that's potential must be maximised, but as a means of converting available grass into milk has enabled the identification of pasture management as a key to improving profits. Before, the only solution considered for the problem of the autumn slump would be supplementary feeding and farmers would accept the temporary higher costs knowing they would be reduced with the oncoming ryegrass season. Production per cow and production per hectare cannot be simultaneously maximised. Many farmers choose to maximise production per cow with high input costs. Bredin (2005) attributed the ability of farmers to manage large herds well to the treatment of the animals as a herd and no longer as individuals. The most profitable option for dairy farmers is to utilize as much pasture as possible as the main feed source. Pasture or pasture-based supplements should make up 85 to 95% of the diet because a direct relation has been identified between pasture utilization per hectare and gross margin per hectare (Doonan & Irvine, 2002). Seasonal calving and the conservation of grass have resulted from attempts to utilize available pasture more fully.

The literature suggests that relations among kikuyu nutrients are not well understood in terms of their impact on overall quality. This makes matching the nutritional value of kikuyu to the requirements of the dairy cow even more difficult. The use of principles derived from the nutritional value of temperate pastures is much to blame for the confusion. Dugmore and du Toit (1988) were unable to find a chemical component that contributed significantly to DOM. It was concluded that fibre may not be related to nutritional value of tropical and subtropical pastures (Dugmore *et al.*, 1986). The poor quality of kikuyu may also be because of a poor ratio of hemicellulose to cellulose, kikuyu having a higher proportion of the less digestible hemicellulose. The lignin content determines the digestibility of these components. Small amounts of lignin in kikuyu could render a large portion of it indigestible (Marais, 1998).

Kikuyu is a high producing, relatively cheap source of feed, but can become expensive if it is not properly utilized (Roos, 1975). Small improvements in quality can result in relatively large increases in milk production (Moore & Mott 1973) and any improvement in animal performance on kikuyu could greatly increase the profitability of the dairy industry (Dugmore & du Toit 1988). Integrated systems of management (Stobbs, 1975), that will help increase profits, will be achievable once relations within and between cattle and pasture management have been quantified. The effects of pasture quality and quantity on animal performance cannot be easily separated or simultaneously maximised as, according to Fulkerson *et al.* (1999) harvesting kikuyu at the two leaves per tiller stage yielded the most DM over the season, but the pasture was of a poorer quality than that harvested at the four and a half leaves per tiller stage where quality is optimum. Increasing the grazing interval increases the amount of pasture on offer but decreases total yields over the season (Fulkerson *et al.*, 1999). Grazing at short intervals of two leaves per tiller reduced the buildup of leaf diseases that reduce palatability, but the quality was poor and there is insufficient pasture available for meeting the requirements of the dairy cow, as dairy cows should not be made to graze pasture down below 6cm (Fulkerson *et al.*, 1999). The minimum grazing interval is set by high NPN and nitrate concentrations and the maximum grazing interval is set by leaf senescence and increased stem growth (Fulkerson, 1999a). Minerals are cheap to supplement and delaying defoliation to capture increases in mineral content of kikuyu may not be worth while (Fulkerson *et al.*, 1999). Innate deficiencies of kikuyu pasture, despite grazing management, make supplementation necessary. Kikuyu under dairy management system has to be well utilised as land is limiting and suggesting the use of continuous grazing as an option is not practical or economical. Pasture quality should be improved through good pasture utilization as this prevents the mat formation later in the season (Dugmore & du Toit, 1988). There is a desire to create a more homogenous sward with less available pasture of a higher quality at a time, forcing the animals to graze the pasture down, without selection. Henning *et al.* (1995) found the autumn slump to be worse on a quick rotation of 15 days compared with longer cycles where there was more rank material.

Although there is merit in applying management practices that work for ryegrass pasture to kikuyu pasture consideration must be given to the differences that exist in sward structure and growth habit. Kikuyu, being a tropical pasture, has a higher CWC and lower NSC content which increases the demands placed on rumen microbes and mechanical digestion (Marais & Figenschou, 1990). Kikuyu has a heterogeneous sward with a lower leaf bulk density and therefore lower leaf to stem ratio

(Stobbs, 1975) than ryegrass that reduces the number of bites per unit time as well as the bite size of grazing cattle, making it more difficult for cows to consume sufficient DM (Holmes, undated). Normally, cattle can compensate for the poorer quality pasture through selective grazing (Stobbs, 1975), but trying to achieve a high level of pasture utilization rules out opportunity for selective grazing. Much research has shown no improvement in animal performance under rotational grazing compared to continuous grazing (Blaser, 1981), but these rotational grazing systems by definition are usually fixed where pasture are grazed and rested according to a set number of days at fixed stocking rates. This system causes a build up of uniformly mature herbage and selective grazing, the only means of improving the quality of the diet, is prevented because grazing intensity is high (large number of cattle per paddock). Under continuous grazing, where a lot of pasture is available, cattle have more time to be selective (Blaser, 1981). Under set stocking, there are times when there is insufficient pasture to meet animal demands and surpluses of pasture at other times of the season that cause reductions in quality. These changes in nutrient supply cause fluctuations in milk yields, hence cash flow. Rotational grazing systems should be replaced by more flexible systems. "Managed rather than set variables can improve the efficiency of animal production" (Blaser, 1981) and this is the key to improving milk production from kikuyu pasture.

The use of flexible rotational grazing systems requires decision making on a daily basis. There needs to be a basis from which management decisions can be made. The decision of when to move animals in the rotation needs to be based on plant growth characteristics to predict future shortages. Pasture height does not indicate grazing readiness, only availability (Reeves & Fulkerson, 1996a) as pasture of a particular height can vary quite considerably in quality (Bransby, 1980) and can predict future shortages. It is the quality of the pasture that is not estimated and another method such as leaf stage may overcome this problem. The pasture manager could count the number of leaves per tiller, knowing that quality is maximised at a certain leaf stage. Farmers need to be able to predict DM intake in order to establish pasture allowances and achieve high pasture utilization. Determining how much pasture to allocate each cow is also difficult. Quality affects allowance as greater allowances are needed if the pasture is more mature (Greenhalgh *et al.*, 1966), but this does not allow for high utilisation. Allocating mature grass to cows must be avoided. It is important that kikuyu pasture is grazed at the correct stage of regrowth and that it is correctly managed so that allowances can be determined free from the influence of mature herbage. Leaf density and the leaf to stem ratio are important in determining intake (Stobbs, 1975). Grazing according to leaf stage takes the quality of pasture into account and reduces the amount of pasture wasted through leaf senescence (Reeves & Fulkerson, 1996a). Use of leaf stage as an indicator of grazing readiness for ryegrass has been successful but kikuyu is very different in morphology and growth habit. Kikuyu should be grazed at the four and a half leaves per tiller stage of regrowth. This method only works well on well managed pastures (Reeves & Fulkerson, 1996a). In working out pasture allowances, only the grass that is considered to be available or palatable to the cow should be taken into account. Therefore, the use of both leaf stage and the disc meter can indicate when to graze and how much area to offer cows.

The low leaf to stem ratio makes measuring kikuyu pasture with a disc meter very difficult (Reeves *et al.*, 1996c). The disc meter is also difficult to calibrate by cutting the pasture down to ground level with sheep shears (Bartholomew, 1985) because it is difficult to distinguish between rhizomes and stolons. Alternatively, the pasture that is thought to be available to the animal can be harvested, by cutting the pasture down to 5cm for example (Fulkerson & Slack, 1993). This method of calibration by measuring shoot DM improved mass estimates but determining what is available to the animal is also subjective. The heterogeneity of the sward and build up of stoloniferous material reduces the accuracy of determining pasture mass (Fulkerson & Slack, 1993). Bransby (1983) had separate calibrations for early and late season in an attempt to improve estimates of pasture mass, but the difficulty here lies in determining when early season ends and late season begins. The accuracy of determining intake of kikuyu pasture is likely to be less than half that of ryegrass pasture because kikuyu has a higher dry matter on offer and less is removed after each grazing (Fulkerson & Slack, 1993).

Because the NPN content of kikuyu pasture negatively affects CF digestibility (Dugmore *et al.*, 1986) fertiliser must be applied carefully. Strategic fertilization can improve the economics of farming with kikuyu pasture. Kikuyu should be fertilized according to the amount of DM desired (Manson *et al.*, 2000). Nitrogen fertilizer should be applied in smaller dressings more often to improve efficiency of utilization (Miles, 1997). Farmers should make use of MUN tests to monitor the effect of N on the dairy cow and adjust fertiliser accordingly.

Irrigating kikuyu pasture removes the economical advantage, shown in Table 9, of kikuyu over temperate pastures. Irrigation may allow for higher yields and stocking rates, but requires a large initial capital outlay and perennial ryegrass will probably be more economical. Water use is likely to become increasingly strict in the future. Irrigation is required when kikuyu is oversown with ryegrass or legumes. Kikuyu can reduce the amount of irrigation required by the oversown plants by keeping the soil surface cool. Most legumes cannot co-exist with kikuyu, so careful management is needed. Use of N fertilized kikuyu instead of oversowing with legumes is easier in terms of demands on management (Teitzel *et al.*, 1991). The acidic soils in South Africa also make establishment of clover difficult. The major problem with oversowing kikuyu with ryegrass or legumes is that each pasture type has different demands and requirements for optimal performance. Production of all species cannot be simultaneously maximised. This can be advantageous in that it may extend the growing season of the pastures. Oversowing kikuyu pasture can improve land utilization in that separate areas for kikuyu and ryegrass are not needed. There is the possibility that ryegrass may have a negative effect on the growth of kikuyu. Clover does not remove the need for N fertilizer completely. The extra milk yields from the oversown kikuyu pasture must outweigh the extra costs. Clover may increase the Ca content of the pasture (Davison *et al.*, 1997b), but supplements are probably a cheaper option. Milk yields also tend to fluctuate more because of the selective grazing of the oversown species against kikuyu. Kikuyu oversown with clover is not a reliable alternative to the annual ryegrass system as if there is frost; annual ryegrass will be needed anyway and the costs of resowing clover, when required, are high (Davison *et al.*, 1997b).

Kikuyu is low in NSC, which is only 5% DM, and experiences a drop in CF digestibility with increasing N fertilization (Marais, 1998). It is also lower in ME than temperate grasses. Production is lower than expected on kikuyu from chemical analyses because of the negative relation between CP and the CF (Dugmore, 2002). NSC determines the efficiency of protein metabolism in the rumen (Marais, 1998). The ratio of DIP to NSC should optimally be two (Hoover & Stokes, 1990 cited by Fulkerson *et al.*, 1998), but the ratio in kikuyu was 2.8: 1 (Fulkerson *et al.*, 1998). A lack of NSC causes excess ammonia excretion in the urine (Marais, 1998). The manipulation of WSC intake by cattle grazing kikuyu by grazing the grass when it contains maximum WSC cannot be regarded as an effective means of balancing the protein to energy ratio, because NSC content of kikuyu is still too low at this time (Marais, 1990). CP only takes N into account and not the quality of the protein. Kikuyu yields are maximised at a CP content of 17.5% (Miles, 1998). Excess ammonia reduces milk yields because energy that should be used for milk production is used in converting the excess ammonia into urea and in its excretion (Fulkerson *et al.*, 1998). MUN tests are not effective as once off measures of individual cows MUN because results are very variable and MUN is a relative measure (Trevaskis & Fulkerson, 1999). Action should only be taken according to the majority of the herds results (Hutjens & Barmore, 1995). MUN tests were in the optimal range for Holstein-Friesian cows grazing kikuyu for 24 hours a day and receiving 3kg of maize meal.

Supplementation should make up for the short falls in the ability to optimally manage pasture and animals. Supplementation has been misused in the past as an expensive means of overcoming the mismanagement of kikuyu pasture. Supplements should improve the retention of nutrients and increase the digestibility of grass (Marais, 1990) and optimise pasture quality by providing cattle with a feed source when the supply of pasture cannot meet the demands of the cattle (Doonan & Irvine, 2002). Supplementation is vital for cattle grazing kikuyu pasture because of its innate nutrient deficiencies, but is also essential for improving production per cow so that the unit costs of production can be reduced (Fulkerson *et al.*, 1998). Supplementation is therefore only justifiable if the unit costs of production are being reduced. Supplementation on kikuyu is the key to overcoming the antiquality factors of kikuyu as only nitrate levels can be eliminated through good management (Marais, 1998). Existing mineral licks are generally unable to fully overcome the mineral imbalances of kikuyu (Marais, 1990) raising the need for more kikuyu specific supplements. Dairy cows are sensitive to mineral imbalances because of the high demands of lactation and pregnancy. Most deficiency symptoms are sub clinical and have therefore largely been ignored (Miles *et al.*, 1995). Successful supplementation requires that the nutrients in pasture are taken into account in addition to the requirements of the dairy cow (Black, 1990 cited by Fulkerson *et al.*, 1998). Although oxalate cannot be removed through good management, the problem can be partially overcome through careful N fertilizer management as it is positively related to N content of the pasture (Marais, 1990). The soils of KZN are acidic that further reduce the Ca content of kikuyu (Marais *et al.*, 1992). Kikuyu has K content in excess of those tolerated by the dairy cow, which may interfere with the absorption of Ca and Mg, causing metabolic problems (Fulkerson *et al.,* 1998). Supplementing with NaCl is essential as kikuyu is a natrophobe (Reeves *et al.,* 1996b) containing less than half the requirement for Na. A Na deficiency can cause reproductive problems (Fulkerson *et al.,* 1998). The kikuyu specific supplements need to be more nutrient dense and affordable to try and urge farmers not to feed less concentrates to save costs. Feeding concentrates at lower than the recommended levels is futile in trying to balance the diet of dairy cows grazing kikuyu pasture. The supplement must not be a substitute for kikuyu pasture that would have been consumed had the concentrate not been fed. Reeves *et al.* (1996a) was unable to get a response above 3kg of cereal concentrate supplementation indicating that feeding large quantities of concentrates, as many farmers with dairy cattle grazing kikuyu pastures are tempted to do, is not justifiable. Finding the right supplementation for dairy cattle on kikuyu will only be possible once the pasture is being properly managed to overcome some of the variation in quality. It will be possible to more accurately predict intakes of kikuyu when it is properly managed and determine which nutrients are innately deficient. Energy is also required to balance the protein to energy ratio. An imbalanced ratio means that the N in kikuyu cannot be captured by the microbes and is instead excreted which uses up energy in the conversion of ammonia to urea that could otherwise have been used for milk production. Supplementing with silage and hay is crucial in achieving high pasture utilization as it provides a buffer against poor animal performance under unfavourable weather conditions when pasture is not growing at a desired rate (Doonan & Irvine, 2002). However, supplementation cannot fully make up for a poor roughage base (Dugmore, 2002).

The motivation for this trial work was to try to determine what management strategies are best for improving the quality of kikuyu pasture and to possible identify some new strategies. The role of kikuyu pasture is becoming more important on dairy farms where irrigated pastures are becoming more costly or of more difficult to make use. Registering irrigable areas and building dams is becoming more difficult. As these costs and inconveniences have increased over the past few years, there has been an integration of kikuyu pastures into existing ryegrass lands. It is observed that kikuyu pasture offers ryegrass some protection against desiccation, therefore reducing irrigation, and improves soil structure and quality. The ryegrass improves the quality of the kikuyu pasture. Recent advances in the no-till equipment now available have made drilling ryegrass into kikuyu lands increasingly successful. Pastures need not be irrigated in summer when the kikuyu is available, which reduces costs. Many farms have reached the limit of their cultivation and the ability to grow grass year round on the same area of land is critical to dairy farm profitability. This shift in pasture management towards increased use of kikuyu has made correct management of it more crucial.

5.1 Summary of kikuyu pasture management guidelines

1. Kikuyu pasture should be mulched to 3 cm at the end of the growing season. Alternatively, it should be burnt either in autumn or at the end of winter. This removes dead stem material.
2. Kikuyu should be measured weekly with a disc meter to calculate dry matter availability and assess the patchiness of the sward.
3. The pasture should be grazed according to dry matter availability, but not before 4.5 new leaves have emerged. Alternatively, it should be grazed at canopy closure (i.e. when the pasture starts to fall over) if this occurs before 4.5 leaves.
4. The pasture should be grazed to the same height at each grazing to prevent the build up of dead material. If this is not achieved, the pasture should be mulched. This height should be 5cm.
5. Nitrogen dressings of 40 to 75 kg/ha should be given on established kikuyu to maximise yields, depending on frequency of application and soil quality. More frequent smaller dressings are recommended to prevent the buildup of nitrates and improve the efficiency of response. Nitrogen should be strategically applied and not in mid summer when feed is not limiting.
6. The response of kikuyu to P and K have been debatable, but a recommendation is 14 to 20kg/ha P and 40 to 65kg/ha K depending on soil quality.

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