FACTORS AFFECTING THE SEASONAL VARIATION OF VELD QUALITY IN SOUTH AFRICA

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ABSTRACT

This project was initiated to investigate the factors affecting the seasonal variation of veld quality in South Africa, with specific objectives as follows: (1) to establish what factors might play a role in seasonal variation of plant quality in South African grassveld; (2) to provide a more objective definition of the terms sweetveld and sourveld than already exists; (3) to determine an objective and quantitative method of measuring or indexing the degree of sweetness or sourness of a representative species of both sweetveld and sourveld using Themeda triandra as the reference species and (4) to establish which factors, if any, may be manipulated to improve veld quality.

The results indicate that cellulase dry matter digestibility, neutral detergent fibre, nitrogen status and phosphorus levels were the plant factors most important in indicating veld quality.

Climate and soil fertility were found to have no consistent relationship with veld quality. Thus any definition of sweetveld and sourveld will have to be based on the winter quality of veld and not on the climate or soil fertility.

The winter quality of veld appears to be a function of the seasonal quality patterns of all species present and not only a reflection of the winter quality of T. triandra. As the seasonal quality patterns are likely to vary between species, management will influence the degree of sourness in the long term by influencing species composition and in the short term by

affecting the ontogeny of the plants present i.e. the amount of preferred material left on palatable and unpalatable species available for winter grazing.

The seasonal quality pattern and inherent winter quality of T. triandra has been shown to vary considerably from area to area. As each species is expected to show unique quality patterns, the sweetveld/sourveld situation becomes extremely complex.

There are no obvious factors (except management) that can be manipulated to improve the winter quality of veld.

DECLARATION

I hereby certify that the work reported in this thesis is the result of my own original investigation, except where acknowledged herein.

K P KIRKMAN

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CHAPTER 1

INTRODUCTION

The aim of this project was to promote an understanding of the area-specific differential seasonal variation of forage quality of veld grasses in summer rainfall regions of South Africa.

The variable nature of the geology, geography and climate of South Africa creates several broad ecological zones across the country with important implications for grazing management, livestock production and grassland conservation. Such variation has given rise to the classification of the country into zones based on the palatability of the veld over the season.

Palatability is here defined as the sum of factors which operate to determine whether and to what degree food is attractive to animals (Ivins 1955), or as plant characteristics or conditions which stimulate a selective response by animals (Heady 1964; Theron 1966). Palatability has never been quantified due to the complex interactions between plant chemical and physical factors which interact to determine the acceptability of forages to animals, so this is in itself a loose definition. One major problem here is that it is a relative, rather than an absolute measure.

Forage quality is distinct from palatability and can be defined as the sum of the factors influencing nutrient absorption by the body. In other words it is a function of the digestibility and chemical composition of a forage (Ulyatt 1973). Forage quality is also difficult to quantify as many of the chemical properties of forage which influence animal performance are unknown or difficult to quantify. There is in all probability an overlap between factors affecting palatability and quality.

The ecological zones defining palatability differences in South African vegetation are represented by sourveld, mixedveld and sweetveld. Sourveld provides palatable material only during the growing season i.e. up to six months of the year. Sweetveld provides palatable material throughout the season, even when the veld is mature. Mixedveld falls in between, and varies between the two extremes (Scott 1947 (cited by Tainton 1981)).

The above definitions are to date the only definitions describing this area-variable seasonal change in palatability of veld.

Semple (1952) states that in areas in which the soil is acid (low pH), infertile and which have considerable rainfall, the grasses are usually coarse and become quite unpalatable as they mature (i.e. analogous to our sourveld). On neutral or alkaline soils with less rainfall and higher fertility, the grasses are generally fine and remain more palatable and nutritious when

mature (i.e. analogous to our sweetveld). However under some conditions fine grasses may grow where the pH is low, and may be classed as decidedly unpalatable.

Some of the main characteristics of sweetveld and sourveld in South Africa have been summarized by Tainton (1981).

Sweetveld in summer rainfall areas

1 It occurs largely at low elevations which are almost frost free.

2 Rainfall is scanty and uncertain so that growth is erratic. The carrying capacity is generally lower than that of sourveld.

3 The cover is relatively sparse.

4 It is easily damaged by persistent grazing during the growing season, largely through a destruction of the edible species, often with a drastic reduction in cover.

5 It has the capacity to recover its composition and density rapidly provided erosion has not been excessive and sufficient soil remains.

6 It is often prone to encroachment by bushveld trees and karoo shrublets.

7 Due to spring rains generally being late, the spring period is often crucial because of the lack of sufficient grazeable material.

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6 It is often prone to encroachment by bushveld trees and karoo shrublets.

7 Due to spring rains generally being late, the spring period is often crucial because of the lack of sufficient grazeable material.

8 It is typically a tall to moderately tall grassveld.

Main characteristics of sourveld

1 It occurs mainly at high altitudes and temperatures are usually lower than those which occur in sweetveld areas.

2 The rainfall is relatively high and growth is more regular and rapid than in sweetveld. The carrying capacity is usually higher than that of sweetveld.

3 The grass sward is often dense.

4 The veld is capable of withstanding moderate levels of overgrazing, since the species composition is relatively stable, but such treatment does lead to reduced production. Degeneration under both excessive overgrazing and selective grazing is often associated not with a drop in cover, but rather with a change in species composition to more pioneer and less palatable types.

5 Recovery, by way of a change to more palatable species, is extremely slow.

6 Sourveld normally provides good spring grazing but is far less satisfactory than sweetveld in the autumn.

7 It is typically a short grassveld.

The definition and above characteristics of sweetveld and sourveld are subjective, vague and imprecise and thus open to variable interpretation. There is a need to place the terms

sweetveld and sourveld on a more scientific footing (Mentis and Huntley 1982).

At present there is no scientific or objective method of indexing or quantifying South African veld areas according to seasonal palatability changes. Some areas appear to have inherent sourness where the palatability of the grasses decreases with advancing maturity. Other areas exhibit induced sourness where degraded veld is invaded by unpalatable species.

The present study has been undertaken to expand and improve our knowledge and understanding of the factors affecting the seasonal variation of forage quality, with the following objectives in mind:

1 to establish what factors might play a role in seasonal variation of plant quality in summer rainfall regions of South African grassveld;

2 to provide a more objective definition of the terms sweetveld and sourveld than already exists;

3 to determine an objective and quantitative method of measuring or indexing the degree of sweetness or sourness of a representative species of both sweetveld and sourveld using T. triandra as the reference species because of its wide distribution;

4 to establish which factors, if any, may be manipulated to improve the digestibility of T. triandra and

to identify areas for further research in this line.

In order to answer these objectives, three separate sub-projects were carried out, namely an intensive field study (Chapter 2), designed to investigate quality variation over a season, an extensive field study (Chapter 3), designed to investigate winter quality differences between areas and an animal trial (Chapter 4) designed to investigate the effects of quality and palatability on animal preference.

T. triandra has been chosen as the index species because of its wide distribution throughout South Africa and its occurrence in sourveld and sweetveld areas (Acocks 1975).

CHAPTER 2

MONITORED SEASONAL VARIATION IN QUALITY OF THEMEDA TRIANDRA IN SOURVELD, MIXEDVELD AND SWEETVELD AREAS OVER A FULL SEASON

The aim of this intensive field study was to provide data to assist in fulfilling specifically the first and third objectives of the project, namely, to establish what factors might play a role in affecting seasonal variation in plant quality in South African veld and to determine an objective and quantitative method of measuring (indexing) the degree of sweetness or sourness of veld.

The factors affecting seasonal variation in plant quality identified from the literature will be discussed in conjunction with the data collected in this sub-project.

2.1 EFFECT OF CLIMATE ON FORAGE DIGESTIBILITY AND QUALITY

The climate and soil environments are prime determinants of the adaptation and potential growth of forage grasses as well as of the factors that influence quality of grass species in any region. Various reports in the literature about factors affecting quality are confusing as there have been very few controlled

experiments to examine environmental effects on herbage quality (Wilson 1982).

The seasonal changes in dry matter digestibility of a wide range of grass species in sub-tropical and temperate regions follows the general trend of high digestibility in spring, dropping in late summer, increasing slightly in autumn and decreasing again in winter (Hacker & Minson 1972; Powell et al. 1978; Reed 1978; Andrews & Crofts 1979). The increase in quality during autumn may be small or may not occur and the fall during winter more pronounced as one progresses from the wetter sub-tropics to drier areas or where the dry period is more defined, or in regions where frosts are severe (Wilson 1982).

These general climatically related seasonal trends may be induced by temperature, daylength or irradiance. These are climatic variables that are often correlated. For example, all increase in spring and decrease in late autumn, while rainfall and frosts are often variable and unpredictable in occurrence. Consequently the interpretation of seasonal and regional differences in nutritive quality in relation to individual climatic variables is difficult because of complex interactions between the variables measured (Wilson 1982).

The difference in palatability between sweetveld and sourveld regions is not likely to be affected by daylength or irradiance

(Heady 1984), as these are often consistent over adjacent sweetveld and sourveld areas. Temperature, or the interaction between temperature, daylength and irradiance, is more likely to play a part in determining these palatability differences.

Generally a decrease in irradiance causes a slight decrease in herbage dry matter digestibility, while the effect of daylength on digestibility, cell wall content and levels of lignin is generally small and inconsistent (Wilson 1982).

An increase in temperature has the effect of lowering the dry matter digestibility of plants. Higher temperatures promote more rapid growth and therefore stem development, which is negatively associated with dry matter digestibility of the whole plant. Cell wall content of grass leaves tends to increase at high temperatures. This is thought to be due to more rapid progress to advanced growth stages (Allinson 1971). Higher temperatures also decrease cell wall digestibility (Moir et al. 1977) which could be partly due to higher lignin levels at high temperatures (Ford et al. 1979).

The specific effects of climatic variables on plant quality factors will be referred to later. Comparisons will on occasion be made between quality of tropical and temperate grasses and the differences between tropical and temperate environmental conditions as these have certain parallels with the quality and

environmental differences between sweetveld and sourveld. These comparisons will be referred to again in Chapters 3 and 5.

In order to determine the climatic effect on palatability of grasses, it is useful to look at studies done on the effects of microclimate on grass quality (Table 2.1).

Table 2.1 Effects of aspect and consequent microclimate on forage palatability (after Bennet & Mathias 1984; Panella 1984).

Aspect	South facing	North facing
palatability	low	high
soil temp.	low	high
soil moisture	high	low
radiation	low	high
evapotranspiration	low	high
photorespiration	low	high

This information will be used to explain possible differences in quality between plots on a site.

2.2 SOIL MINERAL STATUS

The extent to which the mineral status of herbage is a reflection of the soil on which it grows depends on both the mineral under consideration, the plant and on differing soil properties.

The availability of minerals to the plant is governed by soil moisture, soil reaction, soil texture and soil organic matter. The total content in the soil of any particular mineral is very much a function of the soil parent material and the degree of leaching (Fleming 1973).

The effect of soil moisture status on the availability of mineral elements can be quite appreciable and the principles which operate may be chemical, physico-chemical or microbiological. In the case of nitrogen the microbiological factor is of particular importance in that waterlogging creates conditions favourable to denitrification (Fleming 1973).

2.3 GENERAL FACTORS AFFECTING FORAGE QUALITY

Forage plants are the product of their environment. Soil, climatic factors and management practices influence both species composition of veld and the plant chemical composition and morphology. The nutritive value and forage quality are consequences of the conditions of plant growth. There are two major aspects of plant survival and evolution relevant to the nutritive value and quality of forage, namely the storage of nutrients and defence against the environment.

Reserves (in the form of carbohydrates) are essential for the survival of the plant during cold or dry periods and for the support of regrowth following adverse weather or defoliation by grazing, cutting or fire. Reserve substances are generally highly digestible. Structural materials, consisting mainly of cellulose, have a lower digestibility than reserve materials. Resistant structures and substances include lignin, cutin, and secondary compounds such as phenols, terpenes, tannins and alkaloids. These are required for resistance against wind, disease, grazing and predation, and reduce the nutritive value of the plant and its value as a forage plant. Resistant structures are usually synthesized at the expense of reserves and the plants' metabolic pool. Soil nutrients, light, CO_2 and H_2O contribute directly to the metabolic pool, while stress, disease, weather, defoliation, predation and environmental change also affect the metabolic pool (Fig. 2.1) (Van Soest 1983).

It is necessary to find out which environmental, climatic and soil factors influence forage quality and why the influence differs between sweetveld and sourveld, resulting in an area specific differential seasonal variation of forage quality.

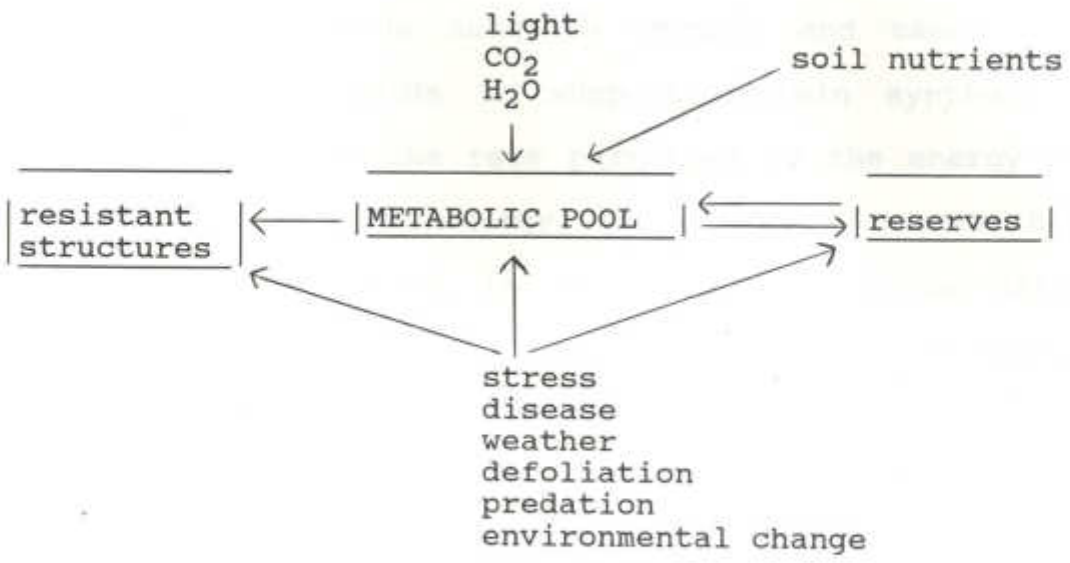

Fig. 2.1 The relationship between environmental factors and plant metabolic components (after Van Soest 1983).

2.4 PLANT CHEMICAL FACTORS AFFECTING QUALITY

2.4.1 Nitrogen status

The nitrogen in grasses is found in soluble and insoluble proteins, amino acids, amides, ureides, nitrates and ammonia. The non-protein component may represent up to 25 % of the total nitrogen, depending on the inherent fertility of the soil, the amounts of nitrogen added to the system and the nutrient status of the plant (Hegarty and Peterson 1973).

The nitrogen value of a diet is an expression of the capacity of the diet to provide adequate ammonia and essential and non-essential amino acids to support protein synthesis by rumen micro-organisms at the rate permitted by the energy supply. The interaction between energy and protein occurs both during microbial fermentation in the rumen and large intestine and during amino acid metabolism in the body tissues. Dietary nitrogen degraded by microbial enzymes in the rumen to ammonia and amino acids is partly reconverted to microbial proteins. Energy for this process is derived from carbohydrates and fats. Amino acids subsequently released are absorbed from the small intestine and incorporated into proteins in the liver. Energy is again required for this process (Hogan 1982).

Most sources in the literature indicate that forage nitrogen status is important in determining forage intake. When the nitrogen level of the forage falls below a level of about 0.96-1.28 % (corresponding to a crude protein level of about 6-8 %), intake is depressed. An increase above this critical level generally does not lead to further increase in intake (Milford & Minson 1965; Horn et al. 1979; Minson 1982).

In the vegetative stage of growth, nitrogen levels in grasses are usually fairly high and it is only as the plant approaches maturity that low nitrogen contents pose a major limitation to forage quality for grazing animals. With advancing maturity, the

decline in nitrogen content is slower in leaf than in stem, and the nitrogen content at maturity is determined by species differences in initial nitrogen levels in vegetative tissue, the rate and extent of decline and the final proportions of leaf and stem in the mature plant. The onset of flowering generally hastens the decline in nitrogen content (Aii & Stobbs 1980; Norton 1982). Generally, the inherently lower nitrogen content of C_4 grasses results in tropical grasses declining to lower levels at maturity than those found in temperate (C_3) grasses (Lyttleton 1973).

2.4.2 Carbohydrates

The description of plant composition in terms of cell components (containing non-structural carbohydrates) and cell walls (consisting mainly of structural carbohydrates) provides a separation of plant material into fractions of high (cell contents) and low (cell walls) nutrient availability to the ruminant animal (Van Soest 1967). These fractions vary not only within and between species, but are also affected by ontogenetic and environmental (light, temperature and water stress) factors (Norton 1982).

2.4.2.1 Non-structural carbohydrates

The non-structural carbohydrates form part of the cell contents, which consist of protein, minerals, soluble carbohydrates, starch and organic acids.

Glucose, fructose, sucrose and the storage polysaccharides starch and fructosan are the major non-structural carbohydrates found in plant cells. Non-structural carbohydrates accumulate in plant tissue when the rate of formation during photosynthesis exceeds the quantity required for growth and respiration (Brown & Blaser 1968). Accumulation therefore varies in different plant species and depends on those environmental factors (light, temperature and soil nutrient status) that affect plant growth. The water soluble sugars glucose, fructose and sucrose, as well as fructosan, are a readily available source of fermentable energy for microorganisms in the rumen, and forages with high levels of soluble carbohydrates are usually highly digestible (Norton 1982). To the plant itself, non-structural carbohydrates are a readily metabolizable source of energy needed for growth and survival.

Tropical (C_4) grasses generally accumulate starch and sucrose, while temperate (C_3) grasses accumulate sucrose and fructosans.

The percentage of total non-structural carbohydrates in the herbage of grasses is influenced partly by leaf:stem ratios. Generally in tropical grasses the starch concentrations are

higher in leaves than in stems, while the total non-structural carbohydrate concentrations are higher in stems. Thus with advancing maturity the starch concentration of the whole plant will drop while the total non-structural carbohydrate content will rise as the proportion of stem tissue increases. Different species reach peak carbohydrate contents at different stages of growth, and the total levels of carbohydrates in tissues vary with species (Smith 1973).

A reduction in light intensity reduces the concentration of non-structural carbohydrates in grasses, while a reduction in temperature increases the concentration (Smith 1973).

2.4.2.2 Structural carbohydrates

Structural carbohydrates in higher plants are represented by the polysaccharides cellulose (beta 1-4 linked D-glucose), hemicelluloses (beta 1-4 linked xylopyranoses, beta 1-4 linked D-glucose and D-mannose) and pectic substances (alpha 1-4 linked D-galacturonic acids, galactans and arabans). Cell walls also contain tannins, protein, minerals and the phenolic polymer lignin. These minor cell wall components affect both cellulose and hemicellulose digestion in the rumen (Norton 1982).

Plant cell walls (forming 30-80 % of plant dry matter) consist mainly of structural carbohydrates (polysaccharides) with varying

amounts of lignin and protein and they differ from the soluble carbohydrates described in the previous section in that once formed they are not normally remobilized in the plant. In pasture herbage, interest in structural carbohydrates is dominated by their importance as a source of energy for ruminants, which via their rumen microflora are able to partly digest virtually all plant structural polysaccharides subject only to the interfering effect of lignin (Bailey 1973). The nature and concentrations of structural carbohydrates in plant cell walls are major determinants of forage quality.

The cellulose to hemicellulose ratio in cell walls changes between species and within species according to environmental conditions but does not seem to affect cell wall digestibility. This is probably because the rate of hemicellulose and cellulose breakdown in grasses appears to be similar during digestion (Minson 1971; McLeod & Minson 1974; Ulyatt and Egan 1979).

The pectin content in grasses is generally less than 2 % (Norton 1982) and is not considered important in forage evaluation.

As grasses mature through the vegetative stage to flowering and seed formation, there is a proportional increase in culm or stem tissue. As the stems generally contain more structural carbohydrates than the leaves (Norton 1982), it is evident that studies on seasonal changes in amounts of these carbohydrate

fractions using samples of total herbage will give results which partly reflect changes in leaf:stem ratios (often a result of management practices) and partly changes in maturing tissue. Evidence in the literature shows that, in general, the cellulose content of grass leaves increases progressively with maturation through the season.

Climatic factors do induce changes in structural carbohydrate levels in herbage. When growth is able to continue to a certain extent through the winter, herbage appears to contain lower levels of cellulose because the process of maturation is delayed (Bailey 1973). Also, an increase in temperature generally decreases the cell wall content of grasses (Ford et al. 1979).

The physical form of cell walls or fibre is also important in controlling intake and although this importance of physical factors is recognized there is as yet no agreement on how to define these attributes (Minson 1981).

2.4.3 Resistant structures and substances

Lignin and tannins are two of the structures and substances resistant to digestion likely to have an effect on the seasonal variation of quality of T. triandra (Ellis, pers. comm., 1987).

2.4.3.1 Lignin

Structural carbohydrates in the walls of sclerenchyma and some vascular cells are bound at random points by covalent and hydrogen bonds to the phenolic polymer lignin. Lignin appears in mature plants because there, as an insoluble amorphous solid, it helps to support their larger organs in upright form by encrusting their pliable polysaccharide fibres to form a composite structural material somewhat analogous to polyester resin encrusted fibreglass.

Lignin is a heterogeneous compound which is not digested either by ruminal micro-organisms or by intestinal enzymes. By bonding to plant fibre it prevents swelling, thereby restricting entry of microbial digestive enzymes and consequently depressing fibre digestibility (Harkin 1973; Norton 1982).

The lignin content of the cell wall is often referred to as the major determinant of plant cell wall digestibility (Norton 1982), although Minson (1971) and McLeod & Minson (1976) state that lignin content is not an accurate guide to cell wall digestibility. This is possibly caused by varying levels of lignin protection of the cell wall to digestion. Ellis (pers. comm., 1987) regards the distribution of lignin within leaves and stem as more important in influencing digestibility than the overall lignin content of cell walls.

There is no exact definition of lignin and its role in herbage plants has not been clearly defined. Harkin (1973) refers to lignin and its association with polysaccharides as "Natures most closely locked secret". Lignin is simple in derivation and complicated in constitution. It is a polymer that originates in the main from only three closely related phenylpropanoid monomers, yet these are interconnected in varying proportions and random sequences and in such a variety of ways as to yield a product that defies exact description. Occasional incorporation of some extraneous substances into some plant lignins and the strong association of lignin with other plant constituents in all species further complicates the matter. Even as a unique chemically homogeneous entity, a form in which it is never encountered in reality, lignin is quite unlike any other polymer. All other biopolymers contain bonds that recur periodically within their molecules and that can be cleaved by simple hydrolysis with chemical reagents or enzymes to revert the polymer completely to its constituent monomeric units. This situation does not exist in lignin. It cannot be depolymerized by straightforward hydrolysis as the constituents of lignin are interlinked by carbon-carbon and strong ether linkages (Harkin 1973).

Lignin therefore plays a major role in the use of herbage for animal nutrition. By decreasing digestibility, its presence in feeds is deleterious, as undigested lignocellulose remains in the

rumen for long periods (Poppi et al. 1980) and reduces voluntary feed consumption (Van Soest 1965; Conrad 1966).

In the light of the above discussion, it is no surprising that it is extremely difficult to quantify lignin in grasses. The results of several trials using lignin as a quality determinant are thus confusing. Theron (1966) found that the total amount of lignin in grass leaves has no fixed relationship to the palatability of grasses. Sweetveld T. triandra apparently contained more total lignin in its leaves than the unpalatable Aristida junciformis.

These results must, however, be looked at in the light of the difficulty of analysing for lignin, and a consideration of the possibility that the distribution of lignin within a leaf is more important than the total amount (Pigden 1953). Bearing in mind the effect of lignin on enzymatic hydrolysis, a cellulase dry matter digestibility analysis may be a more appropriate measure of quality than a lignin analysis.

2.4.3.2 Tannin

Tannins are a group of polymeric phenolic constituents. The term tannin originally referred to substances with the ability to tan leather. It is now generally used to include any naturally occurring compound of high molecular weight (500-3000) and containing a sufficiently large number of phenolic hydroxyl

groups (1-2 per 100 molecular weight) to enable it to form links between proteins and other macromolecules (Wong 1973).

The most important property of tannins in relation to animal nutrition is undoubtedly their capacity to bind proteins. Tannins are thus enzyme inhibitors (Swain 1965).

Unfortunately not much work has been done on the tannin levels and possible nutritional effects of tannins in grasses. Some investigation has been done into the tannin content of Lespedeza cuneata, a forage legume, where it has been found that tannin content is inversely related to palatability and the content of digestible dry matter (Wilson 1955; Donnelly & Anthony 1969; Donnelly & Anthony 1970). Here tannin content has been shown to increase with increasing maturity (Clarke et al. 1939). Work done by Wilson (1955) has indicated that L. cuneata contained less tannin when grown on a fertile soil than when grown on infertile soil.

Green T. triandra leaves from certain sourveld areas of South Africa appear to have a higher tannin content than comparable material from some sweetveld areas harvested during winter (Ellis, pers.comm., 1987). This hypothesis has been derived from circumstantial evidence and has not been quantified.

It is unfortunate that no laboratory method has been found suitable for analysing tannin contents in grass leaves, since they could play an important role in determining palatability in grasses. However, the low concentration of tannins in grasses makes analysis difficult (Garbutt, pers. comm., 1987).

2.4.4 Mineral content

The mineral elements constitute some 10 % of herbage dry matter. Among the many elements detected in herbage, some 16 are currently regarded as essential in animal nutrition. These are classified as macro- or trace-element nutrients, depending on the quantity required by the animal. The macro-elements are mainly utilized either for structural purposes (e.g. calcium, phosphorus, sulphur), or in the maintenance of acid-base balance (e.g. sodium, potassium, chlorine), as well as making vital contributions to energy transfer, nerve impulse transmission and enzyme activation (e.g. potassium, calcium, magnesium). The trace-elements function mainly as enzyme co-factors (e.g. manganese, copper), or by contributing structurally or functionally to the activities of enzymes (e.g. zinc, molybdenum, selenium), hormones (e.g. iodine) or vitamins (e.g. cobalt). A deficiency in any one of the several elements considered essential for animals will limit digestion, absorption and

utilization of all dietary components, as will toxic levels of minerals (Little 1982).

The mineral composition of herbage is determined by two sets of rate processes, namely those governing the rate of change in its mineral content and those governing the rate of change of the amount of herbage i.e. its rate of growth (Longeran 1973).

A low content of minerals in plants may be caused by low availability in the soil, low genetic capacity for accumulation or by low requirement for growth. The changes in mineral content that occur with advancing plant maturity are partly related to alterations in proportions of leaf and stem, and to flowering and seed set.

2.4.4.1 Phosphorus

The phosphorus content is lower in tropical than in temperate grasses and it generally declines with advancing maturity. The rate and extent of decline varies with species and environment (Norton 1982). There is some evidence that high phosphorus contents may improve herbage palatability (Reid & Jung 1965) and dry matter intake (Powell et al. 1978). The minimum dietary requirements for a 400-450 kg animal gaining 1 kg per day is 0.2 % (Church 1971).

2.4.4.2 Calcium

Tropical grasses contain less calcium than temperate grasses. The calcium content of herbage generally declines with advancing maturity (Fleming 1973), and the minimum dietary requirements for Ca are 0.2 % of the diet (Church 1971). Calcium in plant tissue may be rendered unavailable by formation of insoluble salts with oxalic acid. The relatively low calcium levels in tropical grasses and the high levels of oxalic acid generally found in such grasses suggests that calcium availability (as opposed to calcium content) may limit forage quality (Jones et al. 1970; Dijkshoorn 1973).

2.4.4.3 Magnesium

Tropical grasses tend to have higher magnesium contents than temperate grasses. Magnesium deficiency in terms of animal nutrition is generally not common in tropical grasses (Norton 1982). The minimum dietary requirements for Mg are 0.07 % of the diet (Church 1971).

2.4.4.4 Sulphur

Sulphur is required in the formation of bacterial protein in the rumen so that any deficiency of sulphur is likely to lead to a protein deficiency, followed by reduced intake (Rees et al. 1974; Minson 1982).

The significance of the nitrogen : sulphur ratio as an index of the sulphur status of plants is now recognized (Dijkshoorn et al.

1960; Dijkshoorn & van Wyk 1967). A nitrogen : sulphur ratio of greater than 17:1 is considered to indicate a sulphur deficiency for ruminant nutrition.

2.4.4.5 Potassium

Potassium content appears to have little effect on herbage dry matter digestibility (Miller et al. 1964; Reid & Jung 1965; Johnston et al. 1968; Van Adrichen & Tingle 1975). The minimum recommended level of K in the diet is 0.67 % (Church 1971).

2.4.4.6 Trace elements

Forage intake may be limited by deficiencies of trace elements (Minson 1982), although not much is known about the effects of trace element deficiencies on palatability.

2.5 PROCEDURE AND METHODS

2.5.1 Description of sites and plots

Three sites, represented by sourveld, mixedveld and sweetveld, were selected in the Pietermaritzburg area.

The sourveld site was located on Baynesfield estate in veld type 45 (Natal Mistbelt Ngongoni Veld) (Acocks 1975). Baynesfield has a mean annual rainfall of 795 mm, a mean maximum temperature of

23.8 °C, a mean temperature of 17.2 °C and a mean minimum temperature of 10.7 °C. It is unfortunate that the meteorological station is located some distance away from the site and in veld type 5 (Ngongoni Veld) (Acocks 1975), and so the meteorological data are not as accurate as one would wish.

The mixedveld site was located on Ukulinga Research Farm in veld type 65 (Southern Tall Grassveld) (Acocks 1975). Ukulinga has a mean annual rainfall of 697 mm, a mean maximum temperature of 23.9 °C, a mean temperature of 18.3 °C and a mean minimum temperature of 12.8 °C.

The sweetveld site was located on the farm Norferg near Ashburton, also in veld type 65. The closest meteorological station was at Ukulinga. Thus the same meteorological data were used for the mixedveld and sweetveld sites. This is unfortunate but was unavoidable. The Norferg site was expected to be somewhat warmer and dryer than the Ukulinga site.

Two plots were located on each site for sampling purposes. These plots were subjectively chosen on areas with enough T. triandra to sample. The slope, aspect, and altitude were quantified for each plot (Appendix 1). The soil depth on each plot was greater than 400 mm.

Soil samples were taken from each plot to a depth of 200 mm for chemical analysis (Appendix 2). Five auger samples were taken from each plot and lumped together to form one composite sample per plot. These soil samples were taken once only on the assumption that soil chemistry does not vary seasonally (Zacharias, pers. comm., 1986).

2.5.2 Leaf sampling and analysis

The monthly harvesting of T. triandra leaf material started in June 1986 and was completed in May 1987. The harvesting took place at the beginning of each month. The top two leaves and a bud of each tiller on designated plants (i.e all the material above the ligule of the second expanded leaf from the top) only were harvested in order to get comparable material of similar physiological age across all three sites (Tainton, pers. comm., 1986). The two leaves and the bud from each tiller were harvested from at least 20 plants per plot, this number having been derived from the results of a previous harvesting techniques investigation (Zacharias, in preparation).

The leaf samples were then subjected to a full quality analysis consisting of cellulose digestibility (Appendix 3), neutral detergent fibre analysis (Appendix 4), nitrogen status (Appendix 5) and chemical elemental analysis (Appendix 6).

2.6 RESULTS AND DISCUSSION

2.6.1 Soil chemical status

On the assumption that soil chemistry does not vary appreciably over the season, the soil chemical differences between sites, and within the sites between the plots, may account for some of the total variation in plant quality between plots and sites (Appendix 7). The Norferg site has a higher pH and general fertility, partly confirming its classification as a relatively sweetveld area, while the Baynesfield site has a low pH and general fertility, partly confirming its classification as a sourveld area (using the characteristics of sweetveld and sourveld as classification criteria (Tainton 1981)). Ukulinga falls between Norferg and Baynesfield in terms of pH and general fertility.

2.6.2 Meteorological data for the experimental period

The annual and monthly meteorological data for Baynesfield and Ukulinga, the two meteorological stations used over the experimental period, may account for some of the initial differences as well as the seasonal changes in plant quality as a result of climatic influence on plant growth (Appendix 8 and 9).

Minimum temperature or possibly temperature range are thought to be most likely to affect seasonal change in forage quality. Rainfall may play a part but it will be difficult to determine this effect due to the erratic nature of rainfall within and between seasons.

The Ukulinga station recorded a higher mean minimum temperature than Baynesfield, while the mean maximum temperatures were similar for the two sites. Baynesfield's mean temperature range was greater than that of Ukulinga. These data recorded for the two stations will be used later in the interpretation of results.

2.6.3 Plant quality

In order to identify the individual plant quality factors that vary consistently over the season, each quality factor has been examined for each plot per site over the season. The slope, aspect, and consequent microclimatic effects as well as the soil chemical data have been brought into the data interpretation.

The means of the plant quality factors of each plot per site have been calculated to obtain data for each of the three sites. These data have been summarized in Appendix 10, and have also been presented graphically to improve the visual perception of a comparison between sites in terms of the individual quality factors. There is no strict criterion for determining the

validity of using the mean of the two plots to characterize a site. However Figs. 2.2-2.10 highlight the relationship between plots on a site.

Finally the plant quality as a whole has been examined for each site over the season.

2.6.3.1 Cellulase dry matter disappearance (CDMD)

The patterns of CDMD variation over the season was similar for the two Baynesfield and the two Ukulinga plots (Fig. 2.2A; Fig. 2.2B). One of the Norferg plots showed lower CDMD values than the other plot over most of the season (Fig. 2.2C) although they showed fairly similar patterns of variation.

The three sites (using means of the two plots per site for the three sites), showed similar patterns of variation over the season. The sites all showed a sharp increase in CDMD during September, followed by a more gradual decrease from October (Fig. 2.2D). This pattern corresponds to the general seasonal changes in dry matter digestibility mentioned earlier (section 2.1).

Baynesfield showed the highest maximum value and the lowest minimum value, with Norferg and Ukulinga in between. There were no clear-cut differences between the sour-, mixed- and sweetveld sites.

2.6.3.2 Neutral detergent fibre (NDF)

The two Baynesfield plots showed reasonably similar variations in NDF over the season (Fig. 2.3A), with the highest values occurring during October, and to a lesser extent from February through to April. The lowest values occurred during June to

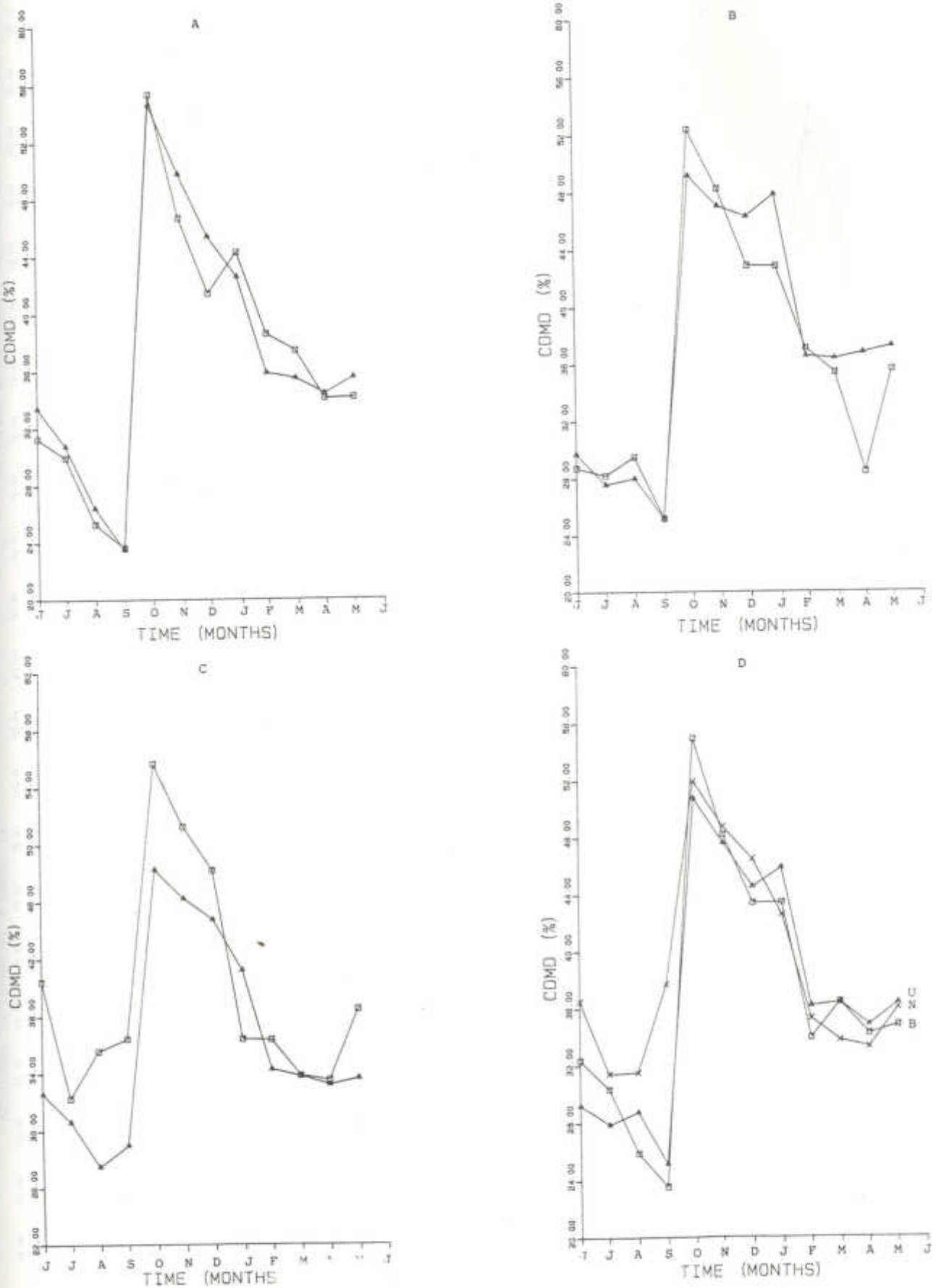

Fig. 2.2 Cellulase dry matter disappearance for the material from the Baynesfield (A), Ukulinga (B) and Norferg (C) plots over the season, and meaned for the three sites D) over the season.

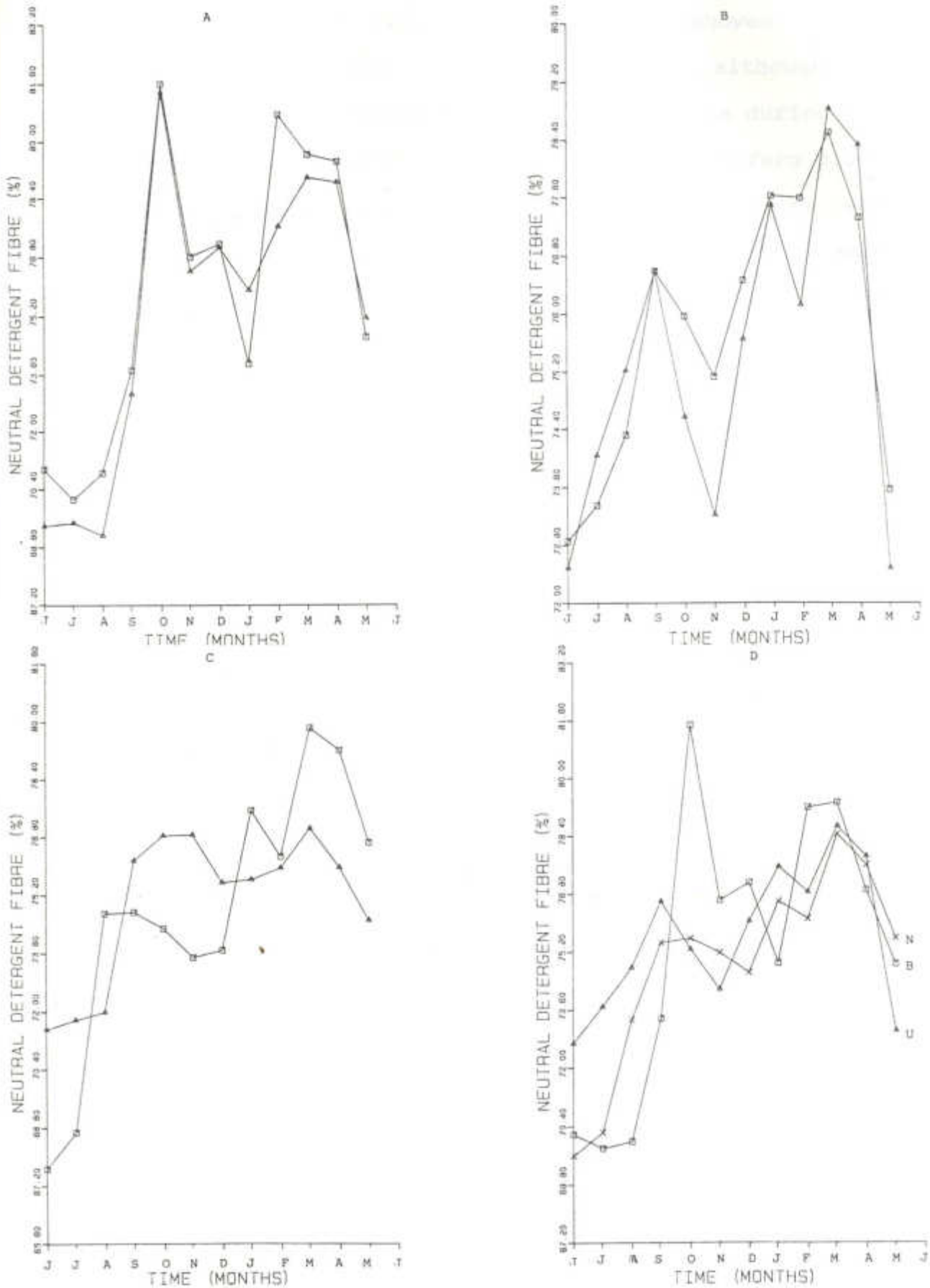

Fig. 2.3 Neutral detergent fibre values for the material from the Baynesfield (A), Ukulinga (B) and Norferg (C) plots over the season, as well as the means for the three sites over the season (D).

August. The two Ukulinga plots also showed fairly similar variations in NDF over the season, although there were substantial differences between the two plots during October, November and February (Fig. 2.3B). The two Norferg plots likewise showed similar general trends, although there were fairly substantial differences between them in certain months (Fig. 2.3C). The NDF of material from Ukulinga and Norferg showed fairly similar patterns of variation over the season, with Baynesfield differing by having a peak during October (Fig. 2.3D), which was not evident at the other sites.

The early season peak in NDF (or cell wall material) for Ukulinga and Norferg corresponds to a probable decrease in soluble carbohydrates due presumably to rapid growth at this time (see 2.4.2.1). The peak in March for all sites is followed by a rapid decline which could be caused by a build-up of soluble carbohydrates in the plant following a decrease in growth rate at this time. This pattern was rather unexpected. Intuitively one would expect low NDF levels during spring and summer, with higher levels during winter.

2.6.3.3 Nitrogen status (N)

The nitrogen status of the material from the two Baynesfield plots showed similar patterns of variation over the season (Fig. 2.4A), as did the material from the Ukulinga (Fig. 2.4B) and

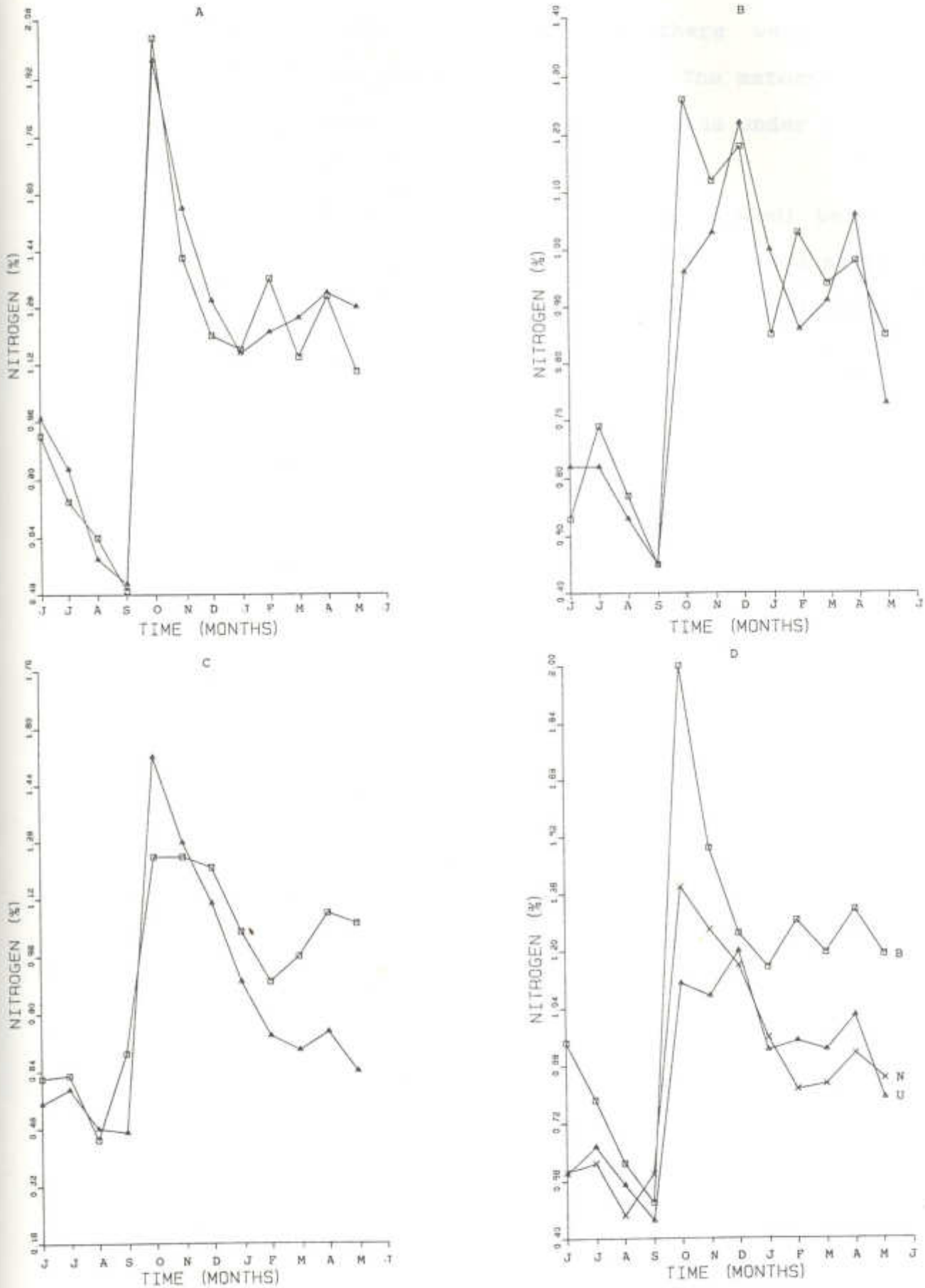

Fig. 2.4 Nitrogen status of the material from the Baynesfield (A), Ukulinga (B) and Norferg (C) plots over the season, as well as the means for the three sites (D) over the season.

Norferg (Fig. 2.4C) plots, although there were substantial differences between plots in some months. The material harvested from the three sites all had a nitrogen status under 1.0 %

(critical value below which intake is suppressed) between June and September. During September the values increased sharply. The values for the Ukulinga and Norferg sites dropped below 1.0 % again during late December, while those for the Baynesfield site continued to remain above 1.0 % to the end of the sampling period (Fig. 2.4D).

2.6.3.4 Phosphorus (P)

The material from the two Baynesfield plots showed very similar patterns of variation in P content over the season (Fig. 2.5A) as did the two Ukulinga plots, except in April when a substantial difference was found (Fig. 2.5B). There were some substantial differences between P values for the Norferg plots (Fig. 2.5C), although the two plots showed the same basic trend.

The three sites all showed similar trends over the season (Fig. 2.5D), with Baynesfield having the lowest minimum values (in September), and the highest maximum value (in October). The material from all the sites was well below the 0.2 % level, which is the minimum dietary requirement figure. The P content in the Baynesfield material approached 0.2 % during October only.

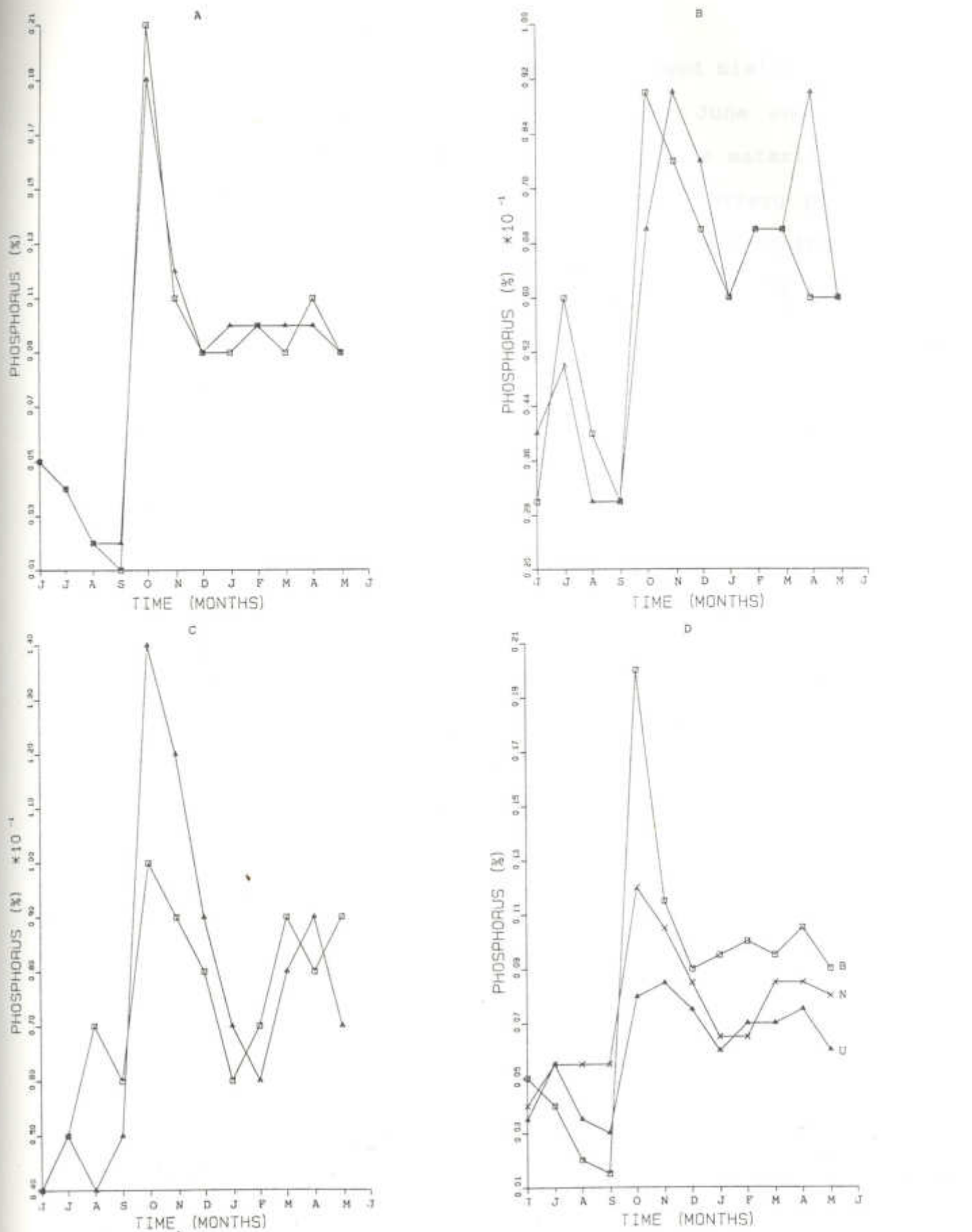

Fig. 2.5 Phosphorus levels of the material from the Baynesfield (A), Ukulinga (B) and Norferg (C) plots over the season as well as the means of the three sites over the season (D).

2.6.3.5 Potassium (K)

The material from the Baynesfield plots showed similar variations in K content over the season, except for June and May (Fig. 2.6A). There were some differences between the material from the Ukulinga plots (Fig. 2.6B) as also in the Norferg plots (Fig. 2.6C). The only clear trend to emerge from the K contents of the three sites was the decrease in K during June, July and August, followed by a sharp increase during September. There were substantial differences in K content between sites over the season (Fig. 2.6D). The K content was above the 0.67 % level (minimum dietary requirement) for most of the season for all sites.

2.6.3.6 Sulphur (S)

The S content of the material from the two Baynesfield plots showed a similar pattern of variations over the season (Fig. 2.7A), as did the material from the Ukulinga plots (Fig. 2.7B), although some differences were apparent between the two plots. The material from the Norferg plots, however, showed some wide and inconsistent differences in S content over the season (Fig. 2.7C). The seasonal variation in S content appears to be inconsistent and varies greatly from month to month (Fig. 2.7D).

The N:S ratio was consistently below 17:1, indicating that there was sufficient sulphur for animal nutrition over the whole season for the material from all plots.

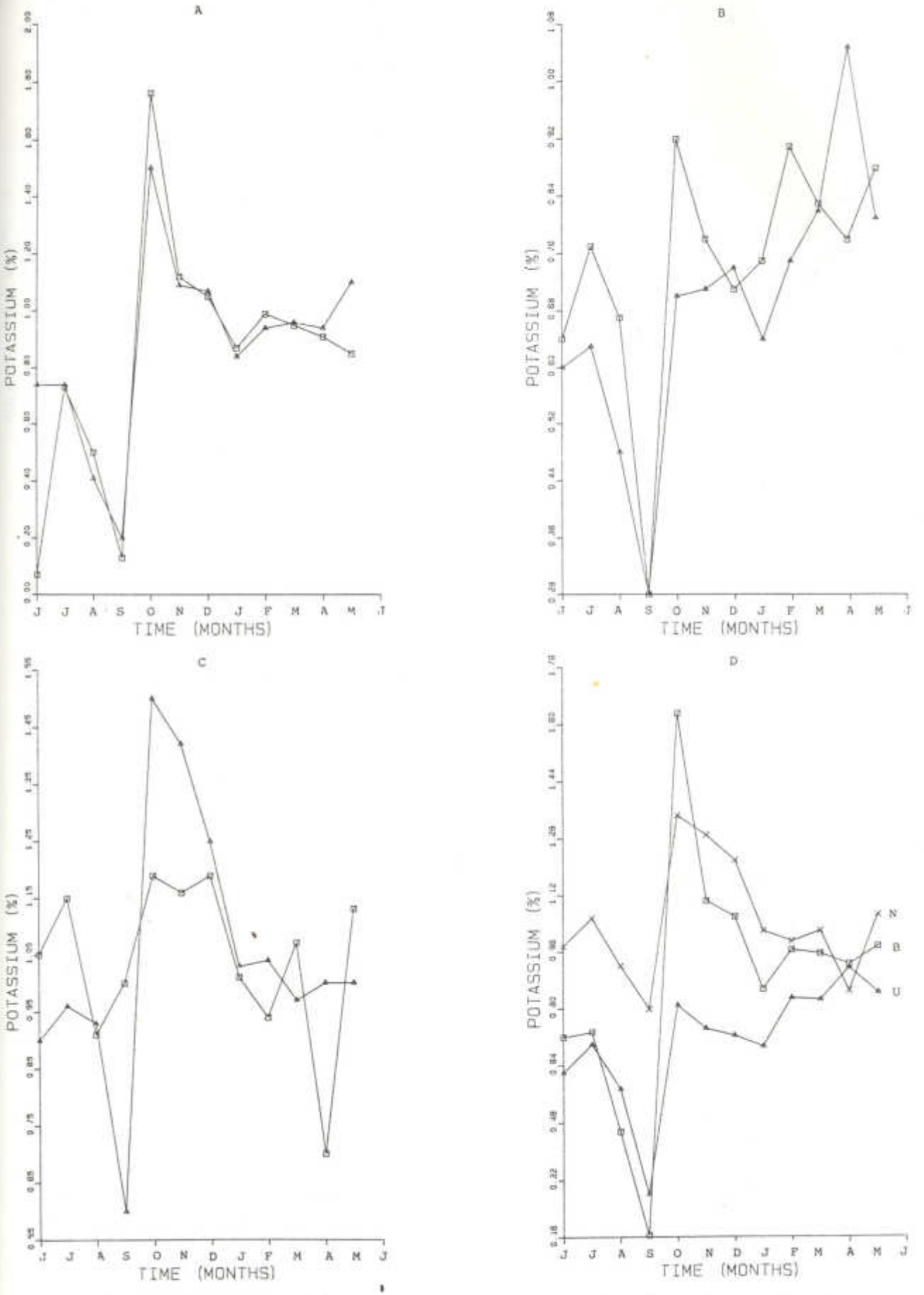

Fig. 2.6 Potassium levels of the material from the Baynesfield (A), Ukulinga (B) and Norferg (C) plots over the season as well as the means for the three sites over the season (D).

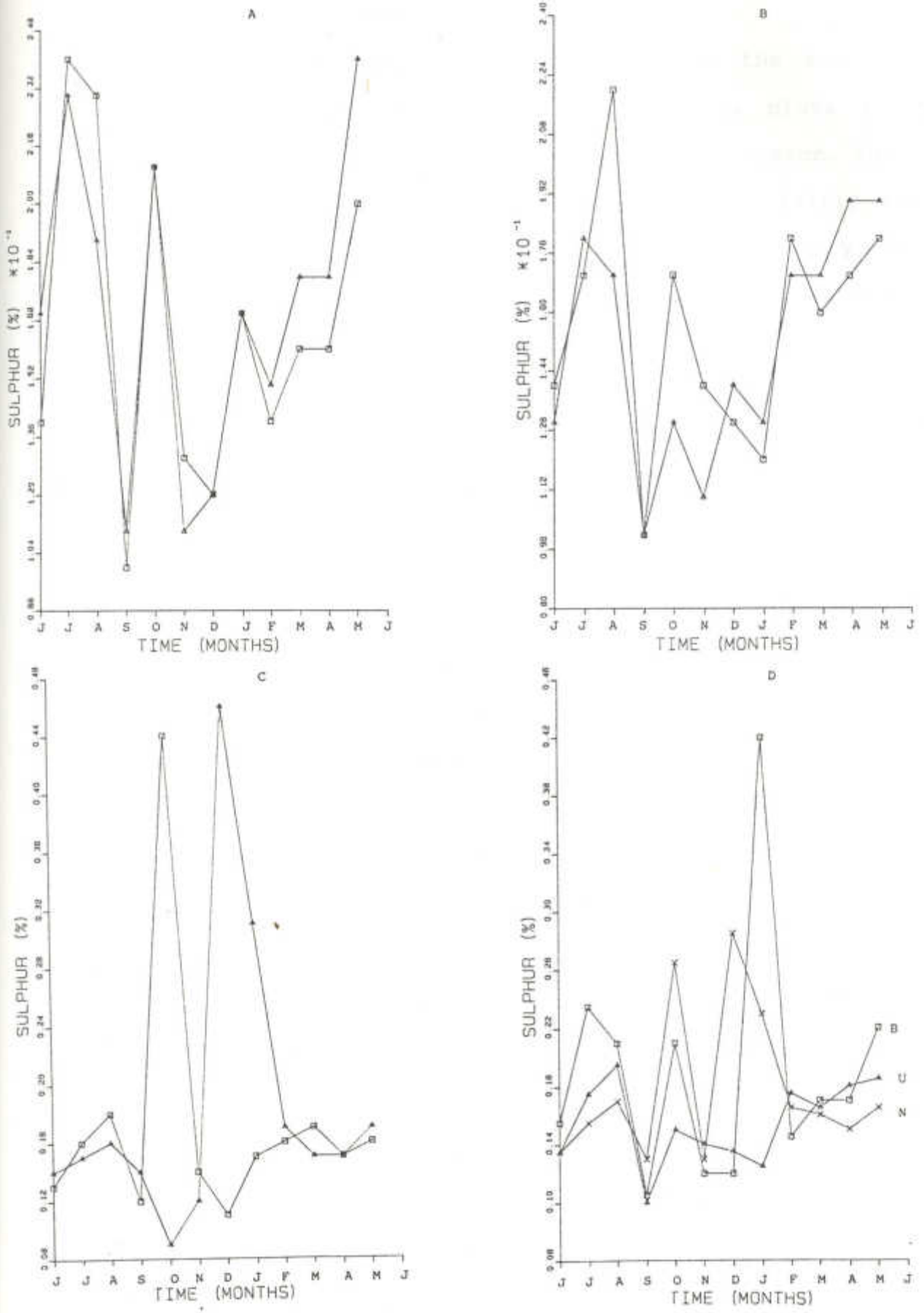

Fig. 2.7 Sulphur levels of the material from the Baynesfield (A), Ukulinga (B) and Norferg (C) plots over the season as well as the three sites over the season.

2.6.3.7 Calcium (Ca)

The calcium content of the material from the two Baynesfield plots (Fig. 2.8A) and of the two Ukulinga plots (Fig. 2.8B) differed greatly and inconsistently over the season. The material from the two Norferg plots, however, showed fairly consistent variation over the season (Fig. 2.8C). In summary, the three sites showed wide and inconsistent variation in Ca content over the season (Fig. 2.8D), with material from the Baynesfield site generally having the lowest Ca content. The Ca levels were above 0.2 % (minimum dietary requirement) for the whole season except for the material from one of the Baynesfield plots which dropped below 0.2 % on occasions.

2.6.3.8 Magnesium (Mg)

The material from the two Baynesfield plots showed similar variations over the season (Fig. 2.9A) except from November to April, when there were wide differences between plots. The Ukulinga (Fig. 2.9B) and Norferg (Fig. 2.9C) plots, on the other hand, showed wide variation over most of the season. The only general trends to emerge from comparing Mg contents between sites was a decrease in August and an increase during September (Fig. 2.9D). The Mg levels were above 0.07 % (minimum dietary requirement) on all sites over the season.

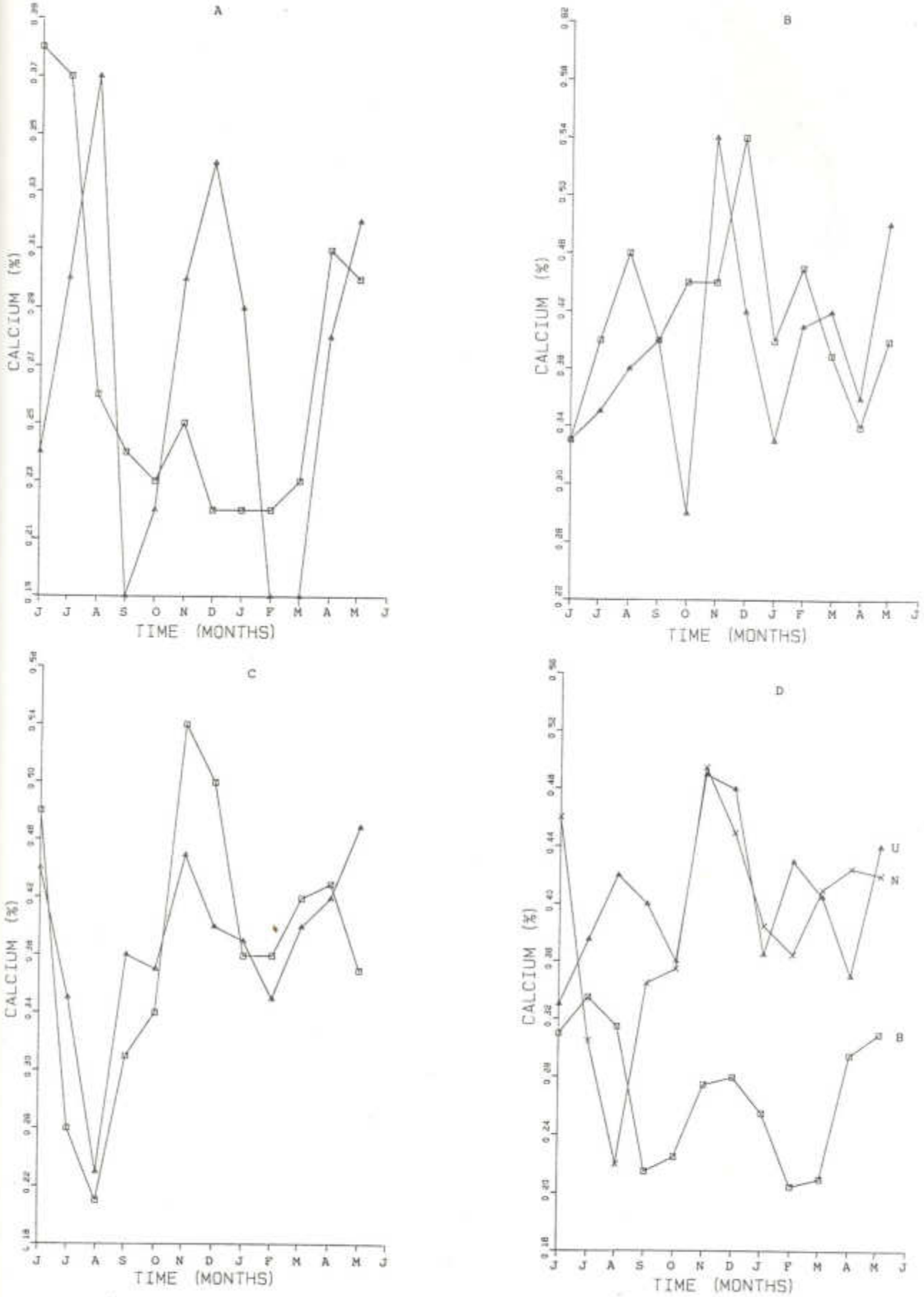

Fig. 2.8 Calcium levels of the material from the Baynesfield (A), Ukulinga (B) and Norferg (C) plots over the season, as well as the means of the three sites over the season.

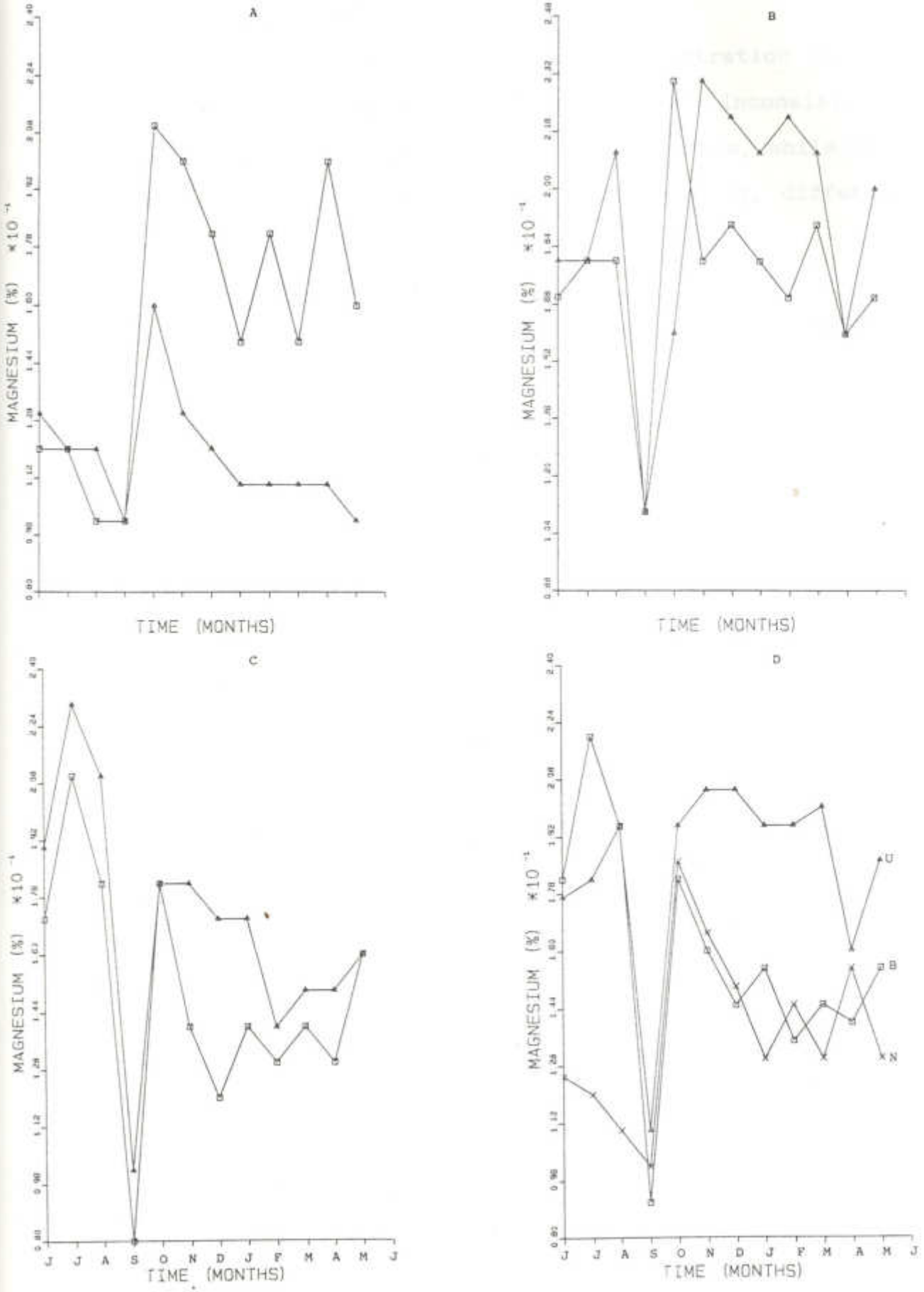

Fig. 2.9 Magnesium levels of the material from the Baynesfield (A), Ukulinga (B) and Norferg (C) plots over the season as well as the means for the three sites over the season.

2.6.3.9 Zinc (Zn)

The general seasonal pattern of Zn concentration in the herbage from the two plots at each site was most inconsistent but for Ukulinga (Fig. 2.10B). At the other two sites, while the general seasonal trends showed a degree of similarity, differences were sometimes large at certain times.

The general pattern was for Zn concentration to increase during June and July, followed by a decrease during September and October and an increase in November or December (Fig. 2.10D).

Not much is known about the effects of Zn levels on plant quality or palatability.

2.6.4 Discussion

It is difficult or impossible to quantitatively or objectively rate the quality of the material from the three sites over the season using several quality factors, as it is impossible to rate the importance of each factor on its own or relative to the other factors measured or not measured.

Nonetheless, most reports in the literature consider nitrogen status of forage to be the most limiting of the quality factors and that when nitrogen levels in forage drop below 1.0 %, intake will be depressed. However, even this is not proven to be the

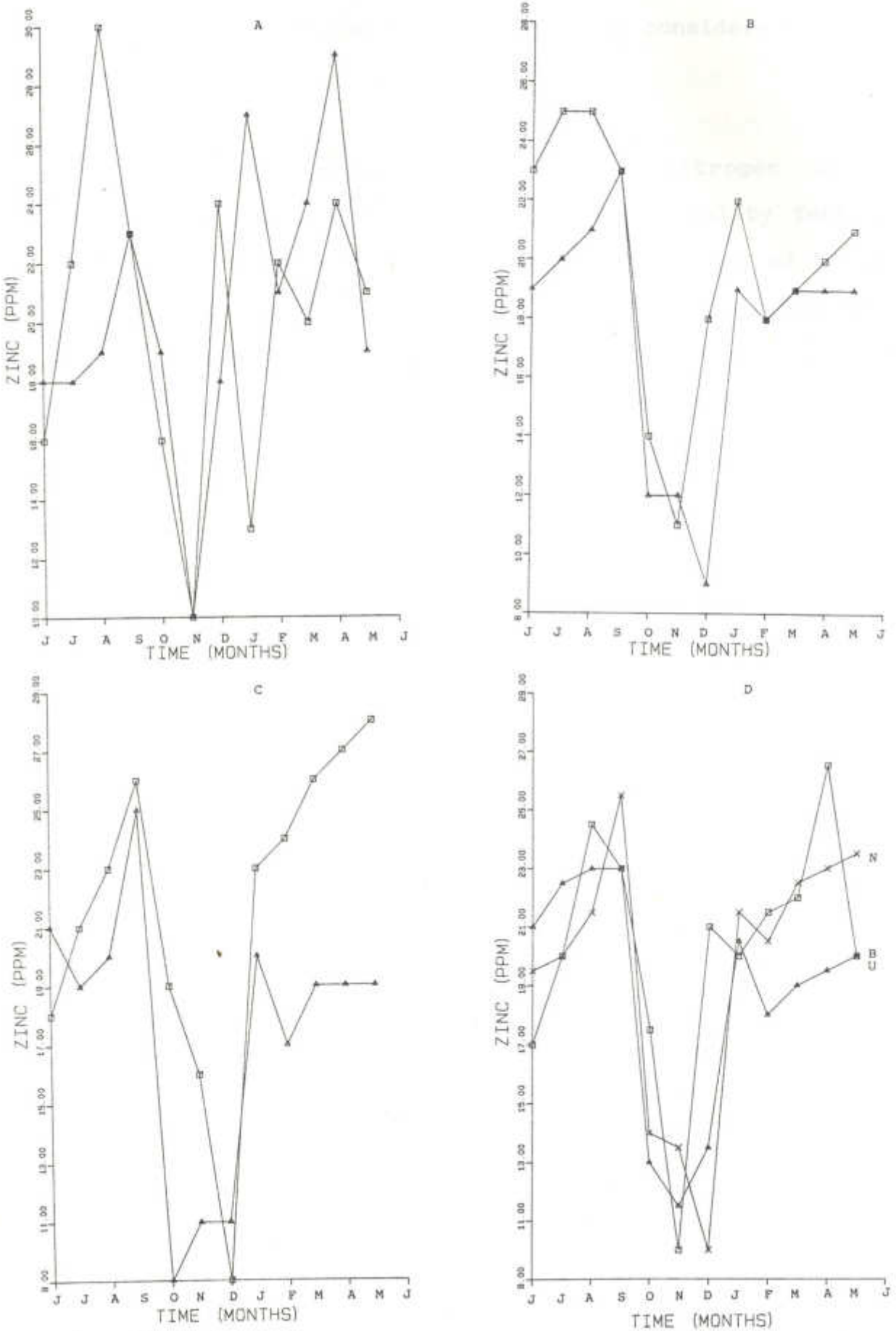

Fig. 2.10 Zinc levels of the material from the Baynesfield (A), Ukulinga (B) and Norferg (C) plots over the season as well as the means for the three sites over the season.

case in all situations and thus cannot be considered an objective guideline.

Cellulase dry matter disappearance, nitrogen status and phosphorus levels appear to be the plant quality factors that follow the expected seasonal variation in quality of the samples tested viz. high values or levels during spring and low values or levels during winter. This ties in well with the majority of reports in the literature which state that digestibility, fibre, nitrogen status and phosphorus content are important in determining palatability and intake of tropical grasses. Potassium, sulphur, calcium, magnesium and zinc, the other quality variables measured, are not considered to have an overriding influence on forage quality although they may play a part in determining quality.

The variation in quality within each site showed an expected pattern. However, the expected pattern of Norferg maintaining reasonably high quality forage over the winter period relative to Ukulinga and Baynesfield did not materialize. Instead the forage from all sites dropped in quality over the winter period and no real differences could be detected during this period between the three sites in terms of all the quality factors measured. It would seem that the winter quality of T. triandra is not much different between the three sites, being low for all three.

Although soil chemistry presumably remains constant over the season, plant quality varies markedly, leading one to suspect that soil fertility does not have a dominating influence on quality of T. triandra. Also, the variations in plant quality do not seem to follow temperature or rainfall as measured over the season. A combination of temperature, soil moisture status, daylength and irradiance may control the onset of growth at the start of the growth period and control growth throughout the growing season, both of which would play a major role in determining quality variation over the season.

From the results presented previously, it is impossible to pinpoint any climatic or soil factors that have a controlling influence on any of the four most important quality factors, namely, digestibility, fibre, nitrogen status and phosphorus content.

These considerations will be discussed in chapter 5.

CHAPTER 3

FACTORS AFFECTING WINTER QUALITY OF THEMEDA TRIANDRA IN CERTAIN AREAS OF SOUTH AFRICA

The characteristics of sourveld and sweetveld areas as summarized by Tainton (1981) hold true on a large scale for large parts of the country. However certain areas of the country do not conform to expectation, e.g. the Stormberg plateau which yields a sweet grassveld (Acocks 1975) at high altitude and extreme cold, and the Pondoland plateau which produces a sour grassveld (Acocks 1975) at low altitude and warm temperatures. The present lack of knowledge regarding the factors affecting sweetness or sourness of veld precludes any explanation of these anomalies.

This extensive field study was initiated to determine the extent of plant quality differences between sites in relation to the main environmental differences between sweetveld and sourveld sites in an attempt to provide answers specifically to the first, second and third objectives of the project, namely to establish what factors might play a role in seasonal variation in plant quality in South African veld, to provide a more objective definition of the terms sweetveld and sourveld than already exists and to determine an objective or quantitative method of measuring or indexing the degree of sweetness or sourness of veld using Themeda triandra as the index species.

This sub-project is based on the assumption that T. triandra growing in sweetveld areas will maintain a higher quality than in sourveld areas during winter.

3.1 PROCEDURE AND METHODS

Various sites of varying sweetness or sourness were chosen in Natal, Orange Free State and the Eastern Cape. These sites were visited during July 1986 to collect grass samples for quality analysis, as well as to collect soil samples and physiographic data in order to compare quality and environmental data between sites.

3.1.1 Description of sites and plots

The sites selected were typical sweetveld areas, typical sourveld areas, mixedveld areas and atypical sweetveld and sourveld areas (Table 3.1).

Table 3.1 List of sites used for the extensive field study classified according to Acocks (1975).

No.	List of sites	Area	Veld type no.
1	Ukulinga	Pietermaritzburg	65
2	Norferg	Pietermaritzburg/Ashburton	65
3	Baynesfield	Pietermaritzburg/Richmond	45
4	Glen	OFS	50
5	Excelsior	OFS	49
6	Tweespruit	OFS	48
7	Rossouw	E. Cape mountains	58
8	Stormberg	Stormberg Plateau	59
9	Steynsburg	Karoo mountains	60
10	Grahamstown H	Highlands area (Grahamstown)	70
11	Grahamstown M	Mosslands farm (Grahamstown)	7
12	Bedford	E. Cape	21
13	Post Retief	E. Cape (Winterberg)	44(b)
14	Port Edward	Natal South Coast	3
15	Umfolozi	Zululand	6/10
16	Hluhluwe	Zululand	6
17	Mkuze	Zululand	10
18	Highmoor	Drakensberg	44(a)
19	Cathedral Peak	Drakensberg	44(a)
20	Kloof	Pinetown area	1

A brief description of the veld types in which the sites were located is useful for the interpretation of results. A comparison of the veld type description with the corresponding site description will provide a check that the site was in fact representative in terms of environmental conditions of the area sampled. This description has been taken from Acocks (1975) and follows the chronological order of sites from Table 3.1.

Veld type 65 (Southern Tall Grassveld)

This veld type is generally a sourish mixed grassveld dominated by T. triandra and Hyparrhenia hirta. Altitude ranges from 600-1350 m above sea level with rainfall ranging between 650 and 900 mm per annum.

Veld type 45 (Natal Mistbelt Ngongoni Veld)

The grassveld occurring in this veld type (having largely replaced the original forest), is sour, initially dominated by T. triandra but now largely dominated by Aristida junciformis. Altitudes range from 900-1350 m above sea level and the mean annual rainfall ranges from 900 to 1150 mm.

Veld type 50 (Dry Cymbopogon-Themeda veld)

The central variation of this veld type (in which this site occurred) is dominated by T. triandra. It occurs between altitudes of 1000 and 1350 m above sea level and receives summer rainfall of between 450 and 500 mm per annum. This area produces a sweet grassveld.

Veld type 49' (Transitional Cymbopogon-Themeda Veld)

This veld type is dominated mainly by T. triandra and occurs mainly on dolerite belts. The rainfall ranges between 400 and 600 mm per annum with altitudes between those of veld types 48 and 50. This veld type produces a mixed to sour grassveld.

Veld Type 48 (Cymbopogon-Themeda Veld)

T. triandra is the dominant grass in this veld type. The altitude ranges from 1350 to 2000 m above sea level and the rainfall varies between 450 and 750 mm per annum. The winters are severely frosty. This area produces a mixed to sour grassveld.

Veld type 58 (Themeda- Festuca Alpine Veld)

T. triandra is the dominant grass in some parts of this veld type, which according to Acocks, varies from sweet- to mixedveld. The altitude ranges from 1850 to 2150 m above sea level. The rainfall ranges between 600 and 1900 mm per annum.

Veld type 59 (Stormberg Plateau Sweetveld)

This veld type occupies a plateau on parent material which weathers into a deep soil. The altitude ranges from 1500-2000 m above sea level. The rainfall is low, ranging from 500-600 mm per annum. This area supports a sweet grassveld dominated by T. triandra.

Veld type 60 (Karroid Merxmuellera Mountain Veld)

Merxmuellera disticha is dominant in this veld type, although T. triandra also occurs abundantly. This mountain veld varies considerably in altitude and rainfall, as it is widespread in the Karoo regions. It is considered to be a sourveld.

Veld type 70 (False Macchia)

The false macchia is today similar to true macchia. It is widespread throughout the Cape Province, occurs over a range of altitudes and has varying rainfall in different areas. T. triandra does occur in some areas of this veld type. The grassveld produced within this veld type is considered to be sour.

Veld type 7 (Eastern Province Thornveld)

T. triandra is the dominant grass of a sourish mixed grassveld. The mean annual rainfall ranges between 600 and 750 mm.

Veld type 21 (False Thornveld of the Eastern Cape)

T. triandra occurs abundantly in this sweetveld area which has a rainfall of 400-650 mm per annum.

Veld type 44

(a) Highland Sourveld (IA)

This sour grassveld is dominated by T. triandra. This veld type occurs at altitudes of 1350-2150 m above sea level. Frosts are severe in winter. The rainfall ranges between 750 and 1500 mm per annum.

(b) Dohne sourveld

This veld type occurs at altitudes of 600-1350 m above sea level. The rainfall ranges between 650 and 1000 mm per annum. It is

generally warmer than the Highland Sourveld. T. triandra is the dominant grass of this sourveld.

Veld type 3 (Pondoland Coastal Plateau Sourveld)

The sour grassveld produced within this veld type is dominated by T. triandra. It occurs at altitudes of 300-450 m above sea level. The rainfall ranges between 1150 and 1300 mm per annum.

Veld type 6 (Zululand Thornveld)

This veld type ranges in altitude from about 150-1050 m above sea level. The rainfall ranges from 650-1000 mm per annum. T. triandra is the dominant grass. The grassveld has been described as sour to mixed.

Veld type 10 (Lowveld)

This veld type occurs on plains at altitudes of 150-600 m above sea level. The rainfall ranges between 500-750 mm per annum. T. triandra is the dominant grass in a sweet grassveld on the areas with heavy soils, while on areas with sandy soils the grassveld becomes more mixed to sour.

Veld type 1 (Coastal Forest and Thornveld)

This veld type occurs at altitudes between sea level and about 450 m above sea level. The rainfall ranges between 900 and 1500 mm per annum. T. triandra occurs abundantly in the sour grassveld.

The classification of these sites into sweet-, mixed- or sourveld is summarized in Table 3.2. These classifications are subjective, probably based on observations of animal performance over the winter period. There should be no major differences between the mixedveld and the sweetveld sites during July, as by definition the mixedveld sites should be "sour" at that time of the year.

Table 3.2 Classification of sites used in the extensive field study according to degree of sweetness/sourness (summarized from the previous discussion).

No.	List of sites	Veld type no.	Sweetveld/sourveld classification
1	Ukulinga	65	sour/mixed
2	Norferg	65	sour/mixed
3	Baynesfield	45	sour
4	Glen	50	sweet
5	Excelsior	49	mixed/sour
6	Tweespruit	48	mixed/sour
7	Rossouw	58	sweet/mixed
8	Stormberg	59	sweet
9	Steynsburg	60	sour
10	Grahamstown H	70	sour
11	Grahamstown M	7	sour/mixed
12	Bedford	21	sweet
13	Post Retief	44(b)	sour
14	Port Edward	3	sour
15	Umfolozi	6/10	sour/mixed/sweet
16	Hluhluwe	6	sour/mixed
17	Mkuze	10	sweet
18	Highmoor	44(a)	sour
19	Cathedral Peak	44(a)	sour
20	Kloof	1	sour

The harvesting technique was similar to that of the intensive field study reported in Chapter 2. Two plots were subjectively located within each site on areas with sufficient T. triandra to sample. Slope, aspect and altitude were quantified for each plot (Appendix 11). These data will be used to interpret possible differences in quality between plots on a site.

Soil samples were taken on each plot at each site by taking five auger samples to a depth of 200 mm throughout the sampling area and lumping them together to form one composite sample. A full chemical analysis (Appendix 5) was carried out on all the samples to further describe the plots.

Meteorological data were later obtained for each site from the closest meteorological station.

3.1.2 Leaf sampling and analysis

Herbage was sampled using the method described in Chapter 2 (section 2.5.2), i.e. the top two leaves and the bud were harvested. In order to determine the quality differences between sites, and within sites between plots, a full quality analysis was carried out on the leaf material viz. cellulase dry matter digestibility (Appendix 3), neutral detergent fibre (Appendix 4), nitrogen status (Appendix 5) and chemical elemental analysis (Appendix 6).

3.1.3 Statistical analysis

This sub-project was executed along the lines of a survey rather than a trial. The data fit two forms of statistical analysis, namely multiple regression and principal components analysis (Draper & Smith 1981; Gaugh 1982; Greig-Smith 1983; Digby & Kempton 1987; Clarke, pers comm., 1987; Dicks, pers comm., 1987). Both of these methods were used as an aid to interpreting the data.

3.2 RESULTS AND DISCUSSION

3.2.1 Soil chemical status

The soil chemical differences between sites and within sites between plots may account for some of the differences in plant quality encountered, although soil fertility levels generally have a more pronounced effect on forage yield than on forage nutritive value (Johnson 1972). The soil samples were taken during July 1986, i.e. at the same time as the leaf samples were collected. On the assumption that soil chemistry does not vary appreciably over the season, these data should reflect the inherent soil chemical status of the respective plots (Appendix 12.1). Some variation between plots is to be expected. However

the means of the two plots at each site should give an indication of the soil chemical status of the site (Appendix 12.2).

3.2.2 Meteorological data for the sites

The meteorological data for all the sites sampled throughout this extensive field study have been collected in the form of mean maximum temperature, mean temperature, mean minimum temperature and mean temperature range, as well as the mean annual rainfall (Appendix 14). These data have been collected from the closest meteorological station to each site. In some cases the same data set had to be used for two sites. Bearing in mind geographical and topographical effects on temperature and rainfall, none of the meteorological data can be considered very accurate except where the site was in the immediate vicinity of the station. The meteorological data used in this study thus only provide a rough estimate of the conditions at each site. Any climatic differences between plots were not quantified.

3.2.3 Plant quality

The plant quality factors have been quantified in an attempt to rate the various sites according to quality. The plant quality data for each site (Appendix 13.2) have been obtained by using the means for the two plots per site (Appendix 13.1). (Note that the Port Edward site has only one plot.) Some variation in

quality is to be expected between plots on a site. This variation is tabled in Appendix 13.1.

It is difficult to rate the sites according to plant quality, as several potential quality determinants have been used. It is impossible to rate the relative importance of each quality determinant within or between sites, as this may change from area to area. Any one of the factors measured, or perhaps others not measured (e.g. tannin or lignin content), may be the factor limiting quality, palatability or both at any particular site.

An assessment of the quality at each site, using relative values of cellulose dry matter disappearance (CDMD), neutral detergent fibre (NDF), nitrogen status (N), phosphorus (P), calcium (Ca), magnesium (Mg), potassium (K) and sulphur (S) has been used in an attempt to rank the sites according to sweetness/sourness.

3.2.4 Degree of sweetness/sourness of the sites

The quality of the material from each site, judged by the quality parameters used, has been looked at in relation to the soil chemical factors (pH, P, K, Ca and Mg being the most important) and the environmental parameters quantified. The quality of the material at each site can be assessed in relation to the quality of the material at the other sites and in terms of the minimum dietary requirements for animal nutrition e.g. N=1 %, P=0.2 %,

Ca=0.2 %, Mg=0.07 % and K=0.67 % (Church 1971; McDowell et al. 1984). These figures are for a 400-450 kg steer for an average daily gain of 1 kg.

From these minimum requirement figures, it appears that Ca and Mg and S are not limiting on any of the sites. Potassium is low on only three sites while N, and particularly P, are deficient on most of the sites. Those factors that do not appear to limit quality have been left out of the analysis. This leaves CDMD, NDF, N and P as the quality factors used.

The graphs (Figs. 3.1-3.3) used in the following section enable the reader to immediately locate a particular site relative to any other site in relation to the factor quantified. Note that each site is not in the same position along the X-axis from graph to graph. The data displayed in these graphs were extracted from appendices 12 (soil chemical data), 13 (meteorological data) and 14 (plant quality data).

3.2.4.1 Ukulinga

The material from the Ukulinga site was of very low quality, characterized by relatively low CDMD, high NDF, low N and P (Fig. 3.1). This low quality concurs with the classification of Ukulinga as a sourveld area at the time of sampling.

The soil chemical status is low (Fig. 3.2), possibly indicating sourness, while the climate is intermediate (Fig. 3.3).

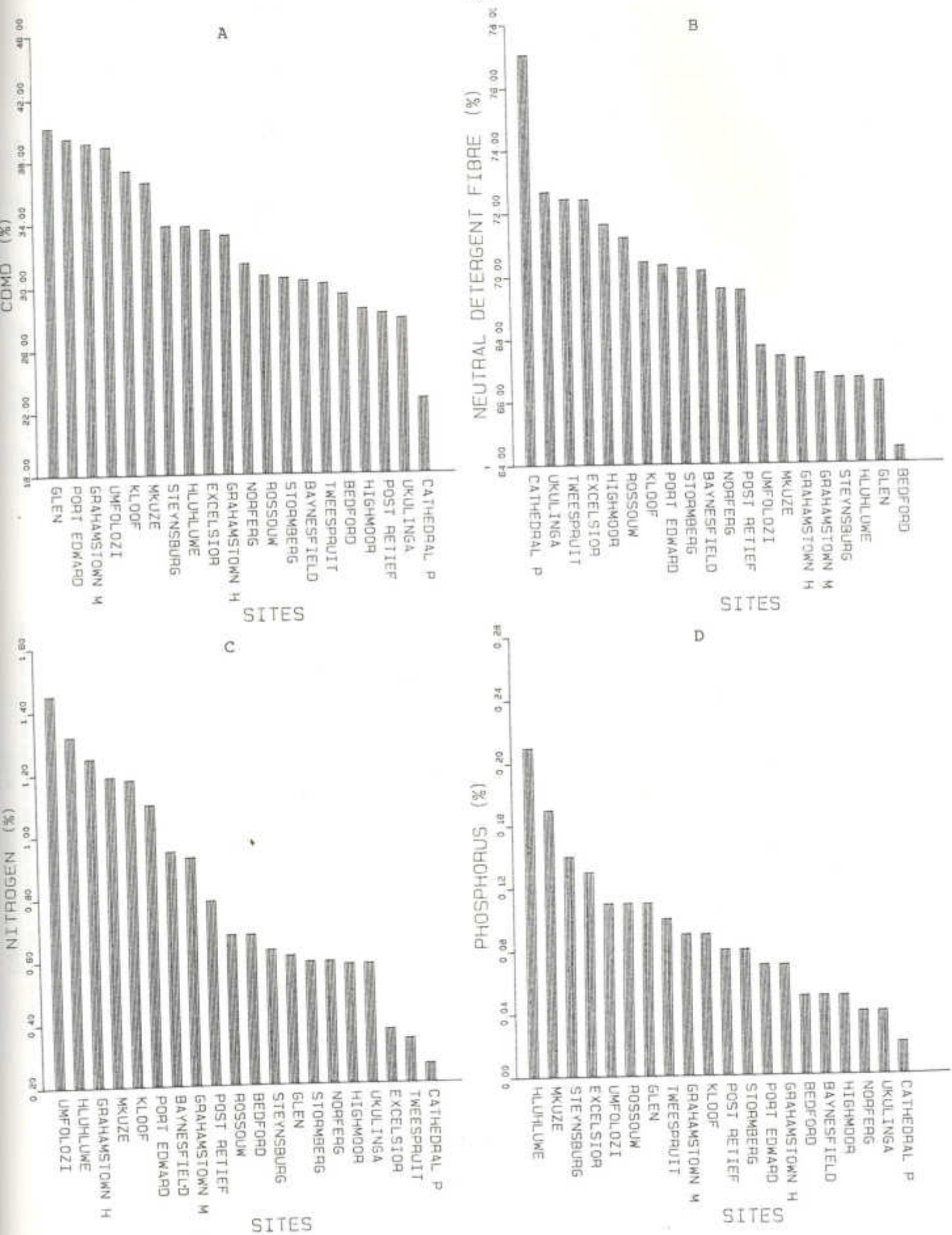

Fig. 3.1 Extensive field study sites ranked in descending order of the plant quality factors CDMD (A), NDF (B), N (C) and P (D).

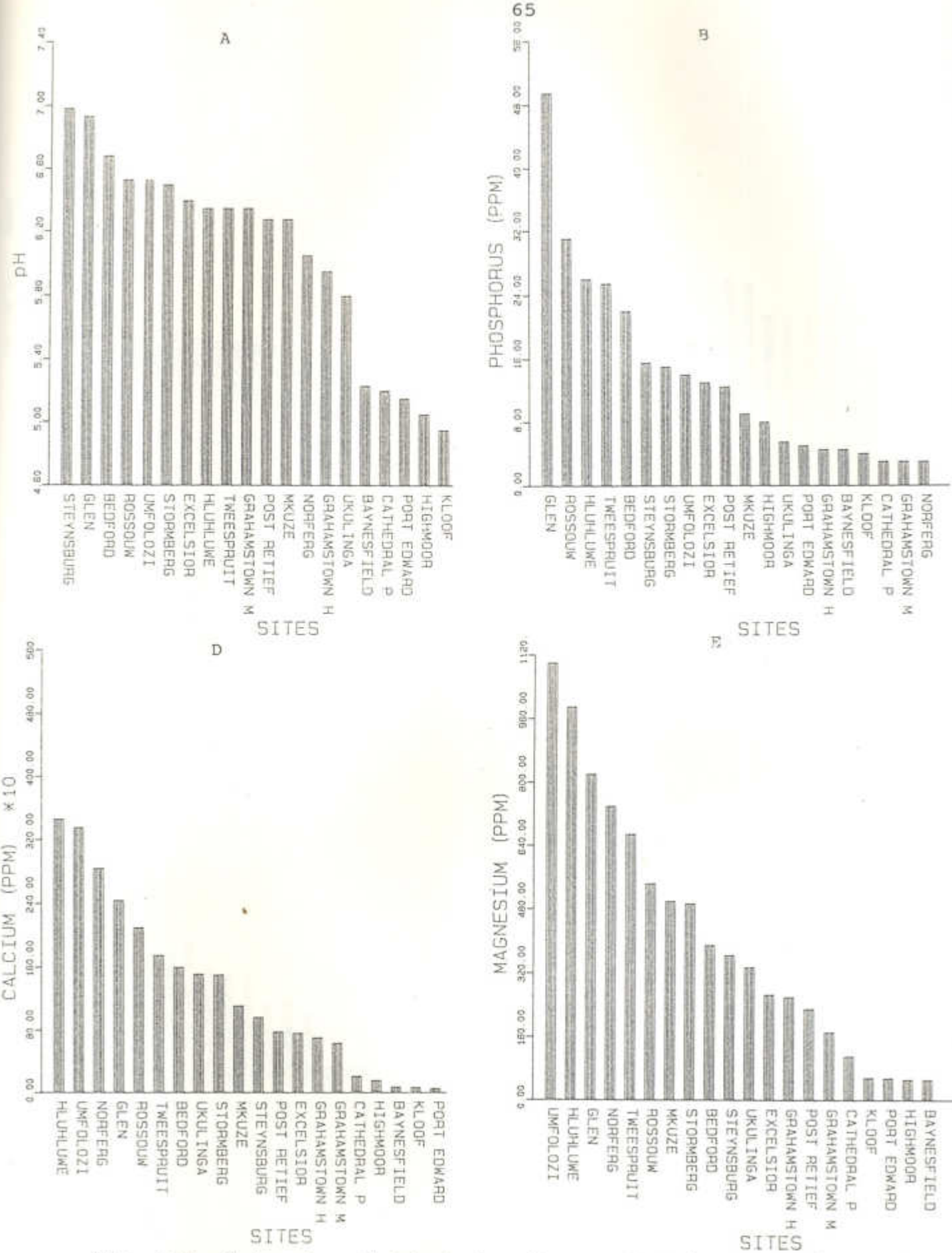

Fig. 3:2 Extensive field study sites ranked in descending order of the soil chemical factors pH (A), P (B), K (C), Ca (D) and Mg (E).

POTASSIUM (PPM)
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
SITES
MKUZE
ROSSOUW
HLUHLUWE
GLEN
TWEESPRUIT
NORFERS
STEYNSBURG
GRAHAMSTOWN M
UMFOLOZI
BEDFORD
EXCELSIOR
STORMBERG
GRAHAMSTOWN H
HIGHMOOR
POST RETIE
CATHEDRAL P
BAYNESFIELD
UKULINGA
PORT EDWARD
KLOOF

C

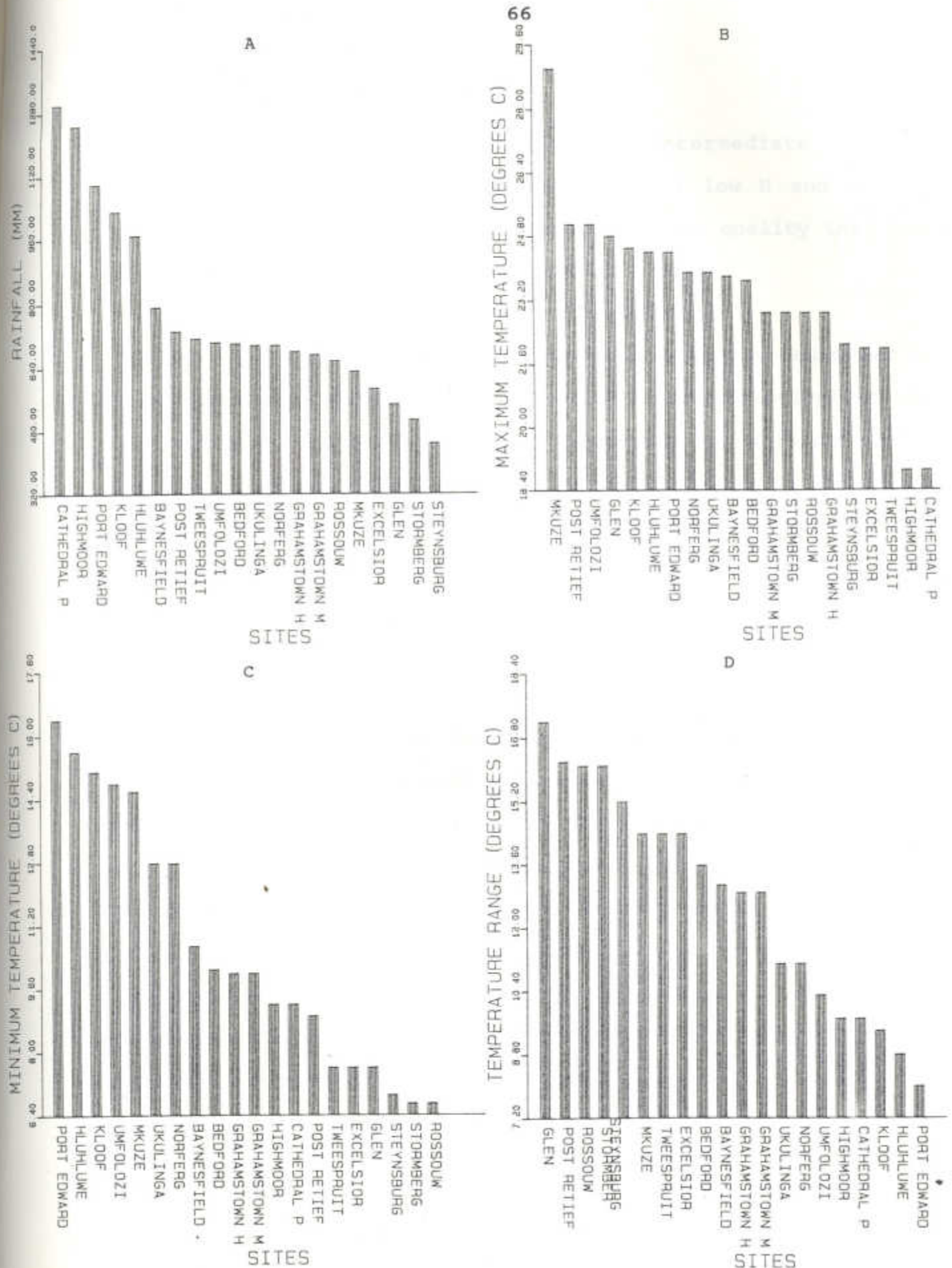

Fig. 3.3 Extensive field study sites ranked in descending order of the climatic variables rainfall (A), mean maximum temperature (B), mean minimum temperature (C) and mean temperature range (D).

3.2.4.2 Norferg

The material from Norferg was of intermediate quality, characterized by intermediate CDMD, NDF and low N and P (Fig. 3.1). This material was of considerably higher quality than that of Ukulinga in terms of CDMD and NDF.

Climatic differences between Norferg and Ukulinga could not be established, due to the lack of a suitable meteorological station near Norferg. The difference in quality may be explained by the difference in soil fertility, where Norferg has a higher pH, K, Ca, and Mg (Fig. 3.2). This higher fertility may create more favourable growing conditions conducive to the plant having higher quality.

3.2.4.3 Baynesfield

The material from Baynesfield was characterized by intermediate CDMD and NDF, with reasonably high N and relatively low P. The quality of the Baynesfield material did not differ by much from that of Ukulinga and Norferg. The most surprising aspect about the material from Baynesfield was the relatively high N status, as Baynesfield is generally considered to be extremely sour. This sour classification is backed up by the low pH and the low soil chemical status (Fig. 3.2), as well as the relatively high rainfall and the low mean temperatures (Fig. 3.3).

It seems so far that leaf quality is not a reflection of the soil fertility.

3.2.4.4 Glen

The material from Glen was characterized by having the highest CDMD, low NDF, fairly low N and fairly high P (Fig. 3.1). In spite of the N status being fairly low, the high CDMD and low NDF values suggest that the Glen samples were among the highest quality sampled.

This high quality seems to reflect the high soil pH and high soil chemical status (Fig. 3.2). The low rainfall fits in with the classic sweetveld characteristics. While the mean minimum temperature is low, the mean maximum is high, giving rise to an intermediate mean temperature, and an extremely high temperature range (Fig. 3.3).

3.2.4.5 Excelsior

The Excelsior material was characterized by intermediate CDMD, high NDF, very low N and high P (Fig. 3.1). The quality of this material was considerably lower than that from Glen.

The soil was characterized by intermediate pH and intermediate chemical status (Fig. 3.2). The mean annual rainfall is low, and the mean temperatures are low (Fig. 3.3).

This site can be classified as fairly sour at the time of sampling. The lack of any extreme limiting soil or climatic factors may put it in the mixedveld category according to the characteristics listed earlier.

3.2.4.6 Tweespruit

The material from the Tweespruit site was characterized by intermediate CDMD, high NDF, very low N and intermediate P (Fig. 3.1). The quality of this site was distinctly lower than that of the Excelsior site.

The soil in this area was characterized by intermediate pH, while the chemical status was higher than that of Excelsior in all respects (Fig. 3.2). Once again the soil chemistry was not reflected in the plant quality, when compared with the Excelsior and Glen sites.

The mean annual rainfall is higher than that of Excelsior (Fig. 3.3), while the same temperature data had to be used for both sites.

3.2.4.7 Rossouw

The material from the Rossouw site was characterized by intermediate CDMD, fairly high NDF, fairly low N and intermediate P, (Fig. 3.1).

The soil from this area was characterized by high pH and high chemical status (Fig. 2.1), while the rainfall and temperatures were low (Fig. 3.3).

While the environmental parameters characterize the area as sweet, the plant quality is fairly low, suggesting mixedveld.

3.2.4.8 Stormberg

The material from the Stormberg plateau was characterized by intermediate CDMD and NDF and fairly low N and P (Fig. 3.1). This site appears to have slightly lower quality than the Rossouw site.

The soil pH is slightly lower than that at Rossouw, while the soil chemical status is substantially lower than that at Rossouw (Fig. 3.2). The mean annual rainfall is lower than that of Rossouw, while the temperatures are very low (Fig. 3.3).

This area's classification as sweetveld does not concur with the data collected.

3.2.4.9 Steynsburg

The material from the Steynsburg site was characterized by intermediate CDMD, low NDF, fairly low N and high P (Fig. 3.1). This material appears to be of higher quality than that of Stormberg or Rossouw, particularly in terms of CDMD, NDF and P.

The soil pH at Steynsburg was the highest at any site, while the soil chemical status was intermediate (Fig. 3.2). The rainfall was the lowest of any site while the mean temperature was very low (Fig. 3.3).

3.2.4.10 Grahamstown H

The material from the Highlands area near Grahamstown was characterized by intermediate CDMD, low NDF, high N and fairly low P (Fig. 3.1). The quality of this material was judged to be fairly high.

The soil was characterized by fairly low pH and chemical status (Fig. 3.2). The rainfall and temperature for this region are intermediate (Fig. 3.3).

Again the relatively high quality of the herbage from this site does not reflect the low soil fertility.

3.2.4.11 Grahamstown M

The material from the farm Mosslands near Grahamstown was characterized by high CDMD, low NDF, intermediate N and fairly low P (Fig. 3.1). This material appears to be of higher quality than that of the Highlands site, mainly due to the higher CDMD.

The soil was characterized by intermediate pH, and fairly low chemical status (Fig. 3.2). The rainfall and temperature figures were similar to those of the Highlands site (Fig. 3.3).

3.2.4.12 Bedford

The material from the Bedford site was characterized by fairly low CDMD, very low NDF, fairly low N and low P (Fig. 3.1). The extremely low NDF component could mean that this site has relatively high quality.

The soil was characterized by high pH and intermediate chemical status (Fig. 3.2). The rainfall and temperature was intermediate (Fig. 3.3).

3.2.4.13 Post Retief

The material from the Post Retief site was characterized by low CDMD, intermediate NDF and N, and fairly low P (Fig. 3.1). The quality of this material is apparently fairly low.

The soil was characterized by intermediate pH and fairly low chemical status (Fig. 3.2). The annual rainfall is intermediate while mean maximum temperature is high and the mean minimum temperature is low, causing a high temperature range (Fig. 3.3).

This site appears to be a characteristic sourveld site.

3.2.4.14 Port Edward

The material from the Pondoland Plateau was characterized by very high CDMD, intermediate NDF, high N and fairly low P (Fig. 3.1).

The soil was characterized by very low pH and very low chemical status (Fig. 3.2). The rainfall in this area is high, with the mean maximum and mean minimum temperatures also high, resulting in a very small temperature range (Fig. 3.3).

The apparently high quality does not reflect the low soil fertility. Possibly the high minimum temperatures during winter causes the quality to be maintained.

3.2.4.15 Umfolozi

The material from Umfolozi Game Reserve was characterized by high CDMD, low NDF, very high N and intermediate P (Fig. 3.1).

The soil was characterized by high pH and fairly high chemical status (Fig. 3.2). The rainfall is intermediate, with high mean maximum and mean minimum temperatures (Fig. 3.3).

This appears to be a characteristic sweetveld site.

3.2.4.16 Hluhluwe

The material from Hluhluwe Game Reserve was characterized by intermediate CDMD, low NDF, high N and very high P (Fig. 3.1).

This material appeared to have slightly lower quality than that of Umfolozi, although the P level was higher.

The soil was characterized by intermediate pH and high chemical status (Fig. 3.2). The pH was lower than that of Umfolozi, while the chemical status was generally higher. The annual rainfall was substantially higher than that of Umfolozi, while the temperatures were fairly similar (Fig. 3.3).

3.2.4.17 Mkuze

The material from Mkuze Game Reserve was characterized by high CDMD, low NDF and high N and P (Fig. 3.1), resulting in an apparently high overall quality.

The soil was characterized by an intermediate pH and chemical status (Fig. 3.2). The annual rainfall is relatively low, with extremely high mean maximum and minimum temperatures (Fig. 3.3).

3.2.4.18 Highmoor

The material from Highmoor was characterized by low CDMD, high NDF, low N and low P (Fig. 3.1).

The soil was characterized by very low pH and low chemical status (Fig. 3.2). The mean annual rainfall is very high, while the mean maximum and minimum temperatures are low (Fig. 3.3).

3.2.4.19 Cathedral Peak

The material from the Cathedral Peak area was characterized by very low CDMD, very high NDF and very low N and P (Fig. 3.1). This material apparently has the lowest quality of any material sampled during this trial.

The soil was characterized by low pH and low chemical status (Fig. 3.2). The annual rainfall is the highest of all sites, while the temperature regime is similar to that of Highmoor (Fig. 3.3).

This site, together with Highmoor, can be considered characteristic sourveld areas.

3.2.4.20 Kloof

The material from Kloof Nature Reserve was characterized by high CDMD, intermediate NDF, high N and fairly low P (Fig. 3.1).

The soil pH for this site was the lowest of all sites, while the chemical status was extremely low (Fig. 3.2). The rainfall for this area is high, while the maximum and minimum temperatures are high, resulting in a small temperature range (Fig. 3.3).

This site was very similar to the Port Edward site in terms of plant quality, soil chemistry and climate.

3.2.5 Statistical analysis

The picture presented in the previous section is complex. There is no way of objectively rating the quality of the sites in order to get an index of the winter quality of T. triandra over all sites. There does not seem to be a single quality factor suitable for this purpose. Any quality index would have to take into account several relevant quality factors.

The quality data were thus subjected to principal components analysis (PCA) in order to arrive at an index of quality.

The PCA (Appendix 15) yielded the most objective index of quality (Table 3.3) that fitted in well with the subjective quality description in the previous section.

This rating then provided a basis for multiple regression analysis to determine the climatic and soil factors affecting the quality. A series of exhaustive multiple regression analyses did not however yield any satisfactory model for predicting quality, or degree of sweetness/sourness of veld from climatic and soil data.

Table 3.3 Quality index of the sites from the extensive field study as determined by PCA on CDMD, NDF, N and P.

Quality rating		Site
Low	1	Cathedral Peak
	2	Ukulinga
	3	Highmoor
	4	Tweespruit
	5	Norferg
	6	Stormberg
	7	Post Retief
	8	Excelsior
	9	Baynesfield
	10	Rossouw
	11	Bedford
	12	Grahamstown H
	13	Port Edward
	14	Kloof
	15	Steynsburg
	16	Glen
	17	Grahamstown M
	18	Umfolozi
	19	Mkuze
High	20	Hluhluwe

It seems that each situation is unique, and that different factors may contribute or interact to determine quality in different areas. It follows that plant quality is not a reflection of soil fertility or climate and that the degree of sweetness/sourness of veld may not be reflected by the quality of T. triandra. This will be followed up in Chapter 5.

CHAPTER 4

ANIMAL BASED DETERMINATION OF PREFERENCE, INTAKE AND IN VIVO DIGESTIBILITY OF THREE FORAGES OF DIFFERING QUALITY

The specific aim of this trial was to determine whether there is a relationship between forage quality, in vivo digestibility and animal preference.

The definition of forage quality should be restricted to properties of the feed alone (intrinsic properties) because of all the other variable factors (extrinsic factors) which may affect animal performance. Ulyatt (1973) defines herbage feeding value as the total animal response to a herbage. The nutritive value of a forage is defined as the animal response per unit of feed consumed. This definition includes only those properties which influence absorption of nutrients by the body directly, and includes only digestibility and chemical composition (Ulyatt 1973). Here forage quality will be defined in this way.

The performance of ruminants is determined by the animal itself on one hand and by the properties of the feed on the other. Nutrient absorption by the body from the alimentary canal also influences animal performance directly. Although this process will be affected by animal and environmental factors it is determined to a large degree and influenced directly by two

factors, namely forage nutrient content and digestibility. Intake is directly influenced by such factors as chemical composition of feed, by physical factors and by the digestibility of feed, all of which interact to partly determine nutrient absorption (Baker 1966; Bransby 1981). See Fig. 4.1.

The seasonal variation in grass quality which characterizes sourveld thus has a direct effect on animal performance via seasonal fluctuations in intake, digestibility and nutrient absorbtion.

The variations and changes in the preference which animals exhibit for different grassland types as well as the various species constituting a particular veld type have not received much attention in the past. It is generally accepted that animals prefer "sweeter" veld types when the constituent grasses are mature and that within each veld type some grasses are preferred to others. It is also accepted that grasses become less palatable with advancing maturity, but as yet no attempts have been made to quantify the relative rates at which these changes take place in different areas (Theron 1966).

The specific objectives of this trial were to :

1) determine animal preference and differences in intake between high, medium and low quality forages;

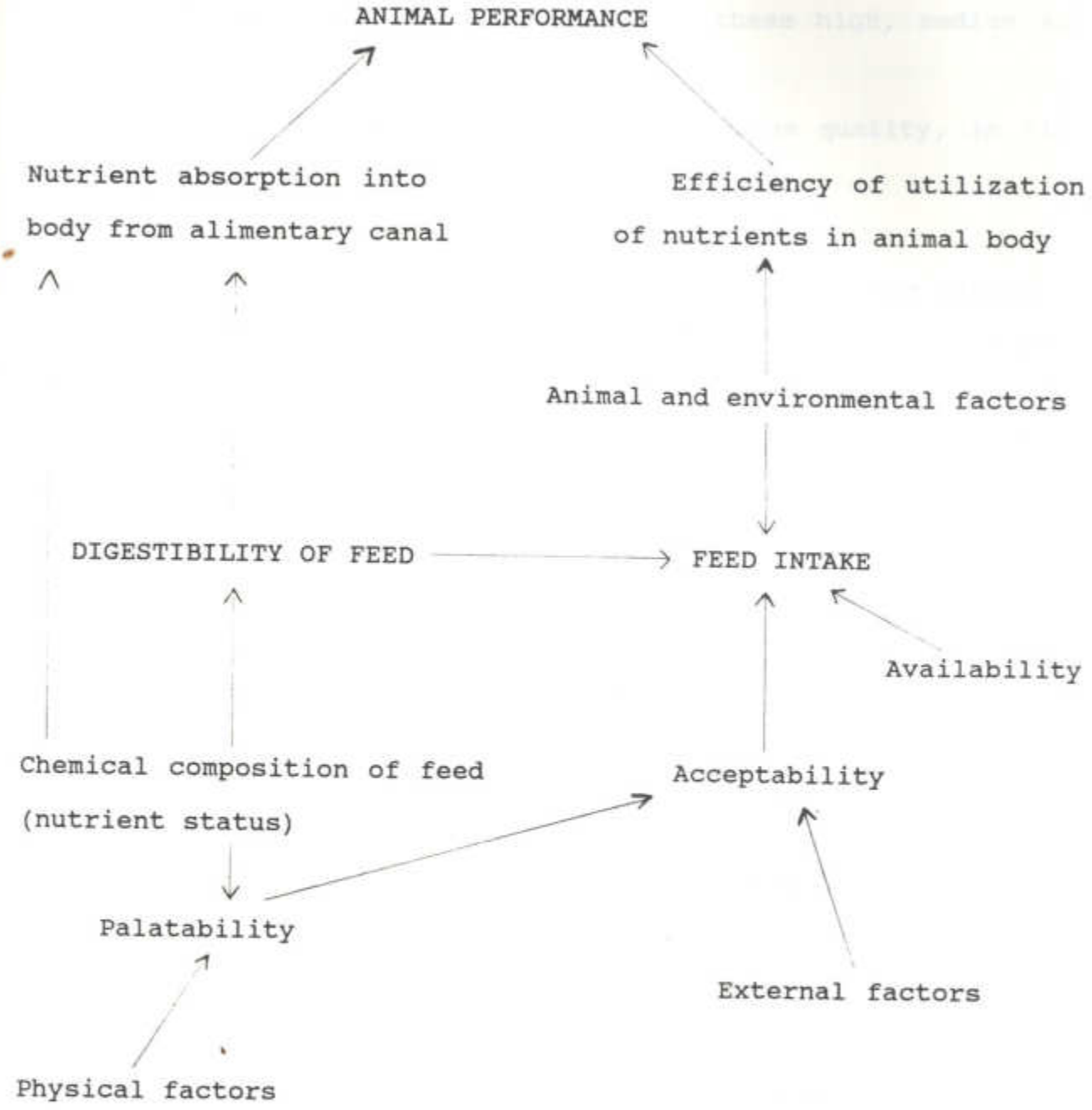

Fig. 4.1 The relationship between variables which influence animal performance (after Bransby 1981).

2) determine in vivo digestibility of these high, medium and low quality forages and to

3) determine the relationship between forage quality, in vivo digestibility and preference.

Animal preference (and thus forage palatability) cannot always be related entirely to a single factor or even a group of related factors. Numerous factors not necessarily related to one another could be involved. Also, the relative merit of a single factor may change with respect to both those factors related to and those unrelated to it during the course of a single season. The significance of a single factor may alter in its relative importance amongst various grasses (Theron 1966) and under different environmental conditions.

4.1 QUALITY FACTORS AFFECTING HERBAGE INTAKE IN RUMINANTS

The animal production that can be achieved when herbage is consumed by ruminants will be determined by complex interactions between the constituents of the feed, the physiological condition of the animal and the environment.

The level of intake and efficiency of utilization of ingested feed can together be called feeding value, which is a function of

intake and nutritive value (Ulyatt 1973). The simplest measure of utilization efficiency is digestibility. This represents the portion of feed not represented in the faeces. However gaseous, urinary, and metabolic losses do occur in the animal and these contribute to a reduction in the efficiency of utilization (Cullison 1981).

Digestibility is generally considered to be the most useful single measure of nutritive value because it is usually well correlated with digestible energy, it has a direct effect on the absorption of nutrients from the alimentary canal and it influences the amount of food consumed by the animal. Herbages of similar digestibility may however be of significantly different nutritive value and digestibility is seldom well correlated with animal performance (Laredo & Minson 1973; Bransby 1981). Digestibility is however an indication of the proportion of the ingested food available to the animal for maintenance and production.

The relationship between digestibility and voluntary intake is generally linear up to digestibilities of 67-70 % (Cullison 1982; Sibanda 1984).

With ruminants on a diet consisting mainly of roughages, voluntary intake is also limited by the capacity of the rumen and the rate of disappearance of ingesta (Purser and Noir 1966;

Campling 1972). In addition to the capacity of the rumen, the amount and quality of digesta it contains at any one time is also important. As the quality of ingested food declines the effect of rumen fill on voluntary intake increases because of the subsequent decrease in the rate of passage of ingesta (Pattinson 1981).

The relationship between palatability and intake has never been satisfactorily quantified. This is a difficult field because palatability can't be quantified and there is no generally accepted method of measuring intake on a large scale.

Because selection is a relative response a term "relative forage palatability" has been defined by Greenhalg and Reid (1967) as "a plant characteristic eliciting a proportional choice among two or more forages, conditioned by animal, plant or environmental factors which stimulate a selective response by the animal". The exact nature of the influence of palatability on the intake of grazed forage is unclear. The effect of the relationship between palatability and digestibility tend to obscure the possible direct effects of palatability (Greenhalg and Reid 1967).

Forage digestibility appears to affect voluntary intake in two ways, namely by affecting preference (palatability) and by affecting intake via the rate of passage and rumen fill.

4.2 REVIEW OF METHODS USED FOR EVALUATION OF HAY

There are many available methods of measuring or estimating digestibility and palatability, as well as several laboratory techniques for evaluating forage. The methods used here are critically reviewed in this section.

4.2.1 Intake

No reliable method of estimating intake is available. The only way to measure intake reliably is to physically measure what is eaten by the animal i.e. by cutting feed, weighing what is given to the animal and weighing what is left over. One problem is that the behaviour of the confined animal may not be representative of the behaviour of animals in a field situation. Grazing animals generally have a higher intake and higher degree of selection than similar animals in stalls (Arnold 1970).

4.2.2 In vivo digestion

In vivo digestibility is determined by means of a digestion trial using live animals and can be determined as follows (Bransby 1981):

$$\% \text{ digestibility} = \frac{\text{amount of feed consumed - amount of faeces}}{\text{amount of feed consumed}} * 100$$

Digestion trials usually use two or more animals. The feed under investigation is fed to the animals in measured amounts and the faeces output is quantified. The measurement of faeces output is best done directly using faecal collection bags on male animals. Errors may arise from incomplete collection of the faeces and from the effects of the bags and harnesses on the animals' behaviour and feed intake. The labour requirements for this method are high (Langlands 1975). Several animals have to be used because of the variation between animals. Replication also accounts for errors of measurement. The feed required for the trial should be fed for at least one week before the collection of faeces commences. This accustoms the animal to the diet and clears the digestive tract of any residues of previous foods. This preliminary period is followed by a period when food intake and faecal output are recorded. This experimental period is usually 5-14 days long. The animals should be fed at the same time every day and the amounts of feed given should be constant (McDonald et al. 1981).

The procedure gives a measure of apparent digestibility rather than true digestibility, from which it differs in several ways. Firstly apparent digestibility considers nutrients lost as

methane as having been digested and absorbed by the animal. Secondly apparent digestibility regards all nutrients remaining in the faeces as not digested or not digestible, which is not always the case. Some nutrients may have been digested but not absorbed. Others possibly were not digested but would have been had they remained in the digestive tract for a longer period or were fed again. Thirdly, apparent digestibility regards all nutrients in the faeces as undigested feed when actually considerable amounts of other materials such as mucosa and bacteria are present in the faeces (Cullison 1982). Apparent digestibility is thus only an estimate of true digestibility.

4.2.3 Palatability

One method of measuring or indexing the palatability of forage is to measure the preference or relative preference of forages. There are several methods of measuring preference, the most reliable being the direct measurement of the herbage consumed in a free choice situation (cafeteria trial) between several herbages on offer (Ivins 1955). This method is far more accurate than some of the popular cafeteria methods employed whereby time spent grazing the different forages on offer is measured, because time spent grazing is no indication of the amount of forage taken (Reid 1951; Jones 1952).

Rumen fistulated animals have also been used in preference studies (Heady 1964). Samples of rumen contents are sorted and the amounts of various species found are expressed as fractions of the feed offered. This technique is expensive, does not provide a measure of quantity eaten and appears to have poor repeatability.

4.3 PROCEDURE

Veld grass from three different areas, namely sourveld, mixedveld and sweetveld, was cut during April and dried as hay. This hay was then milled to a uniform size and used for the feeding trials which were carried out at Ukulinga Research Farm using hamels between eight and ten months old.

4.3.1 Description of the areas from where hay was cut

The three areas from which the hay was cut are typically "sourveld", "mixedveld" and "sweetveld" (Tainton, pers. comm., 1986).

4.3.1.1 Sourveld

The sourveld area used was located on Baynesfield estate in the Natal Mistbelt Ngongoni Veld (Veld Type 45) (Acocks 1975) at an altitude of 1120 m above sea level. The area was fairly flat,

tending towards a south west facing slope. The mean annual rainfall for Baynesfield estate is 795 mm. A soil chemical analysis (Appendix 5) revealed a low pH and mineral status for all minerals relative to the other two areas except phosphorus (P) where Norferg had the lowest P levels (Table 4.1).

4.3.1.2 Mixedveld

The mixedveld area was located on Ukulinga Research Farm in the Southern Tall Grassveld (Veld Type 65) (Acocks 1975) at an altitude of 840 m above sea level on a flat area. The mean annual rainfall for Ukulinga is 697 mm. A soil chemical analysis revealed an intermediate pH and mineral status for all minerals except P relative to the other two areas (Table 4.1).

4.3.1.3 Sweetveld

The sweetveld area was located on the farm Norferg near Ashburton in an area classified as Southern Tall Grassveld (Veld Type 65) (Acocks 1975) at an altitude of 725 m above sea level. The closest meteorological station is at Ukulinga, therefore the same mean annual rainfall figure had to be used for Ukulinga and Norferg. The area was located on an east through to south facing slope. The soil chemical analysis revealed a high pH and mineral status for all minerals except P relative to the other two areas (Table 4.1). This was perhaps not a typical sweetveld site due to its aspect and its close proximity climatically and

geographically to Ukulinga, but it was the best available sweetveld site in the area suitable for cutting hay.

Table 4.1 Soil chemical analysis of soil samples taken from the three areas from which the hay was cut.

	Baynesfield	Ukulinga	Norferg
pH (water)	5.28	5.87	6.13
P (ppm)	3.75	4.50	3.50
K (ppm)	49.60	77.75	274.75
Ca (ppm)	57.75	1452.45	2727.50
Mg (ppm)	42.00	432.50	762.50
Na (ppm)	23.75	58.25	64.50
PDI	0.27	0.28	0.21
Zn (ppm)	0.80	0.65	1.10
OM %	4.80	5.10	5.70
CEC	5.75	14.30	21.35

4.3.2 Hay cutting procedure

The grass from the three areas was cut and dried as hay in order to facilitate running a trial whereby preference, intake and digestibility could be measured simultaneously for the material from three areas. Although it may have been preferable to feed fresh grass, this was impractical due to the geographic location of the three areas.

It was impossible to cut the hay from the three areas at exactly the same time due to geographic location and prevailing weather conditions. However the three areas were cut within a period of 10 days. The treatment of the hay was kept as uniform as possible

but differences in treatment between areas could have arisen due to differing weather conditions at the time of cutting and drying. The hay was milled to pass through a 12 mm screen in an attempt to eliminate selection due to possible differences in leaf:stem ratios and species composition over the three types of hay.

4.3.3 Quality of hay

Generally hay has a lower quality or nutritive value than the freshly cut material from which it is made. The drying and storing of hay results in this general loss of quality (Sullivan 1973). However, the factors affecting quality of the standing grass crop at the time of cutting affect the quality of the resulting hay. With veld hay, one of the main factors is species composition. Environmental factors such as soil chemistry and climate affect the species composition as well as the morphology of species in different areas.

The stage of maturity of the plants affects the leaf:stem ratio and the chemical composition of the plants in several ways, depending on the environmental conditions. The cell wall:cell contents ratio is one important factor affected by stage of maturity and growth conditions.

4.3.4 Laboratory analysis of hay

The three types of hay were subjected to cellulase digestibility analysis (Appendix 3), neutral detergent fibre analysis (Appendix 4), nitrogen status (Appendix 5) and chemical elemental analysis (Appendix 6).

4.3.5 Experimental procedure

Throughout the trial two sheep were used for each treatment i.e. as one "eating unit" or "unit". All the sheep were weighed before the trial and grouped accordingly so that each unit had a mass close to the mean mass of the group. They were weighed after being starved overnight.

The sheep were all kept on a kikuyu pasture for at least three weeks before the commencement of experimentation to ensure uniformity of pretreatment.

In order to meet the stated objectives, two separate trials were carried out with trial 1 used to determine the relative preference of the three hay types and trial 2 to determine the relative intake of each type of hay.

Both trials used randomized blocks designs with three

replications. The trials were run concurrently, using common blocks for convenience of layout.

4.3.5.1 Trial 1

In order to determine animal preference for the three types of hay, the animals were offered a free choice on a cafeteria trial basis for a period of 12 days to determine the intake of each type and thus the relative preference.

Each unit was enclosed in a pen with three feed troughs and a water trough kept filled with fresh water. Each feed trough contained hay from either Baynesfield, Ukulinga or Norferg. The hay was weighed into the troughs daily at 8:30 a.m. An excess of hay was fed and the residual was weighed out before feeding fresh hay. The position of the feed troughs was randomly changed relative to one another at irregular intervals to prevent any pattern of eating from influencing the results.

The floors of the pens were cleaned regularly to enable any spillage to be removed and excluded from the measured intake.

4.3.5.2 Trial 2

Intake and in vivo digestibility were determined by offering one type of hay only to a unit. This was repeated for all three hay types.

As in trial 1, the intake was determined by weighing the hay in and out of the feed troughs. The trial ran for a nine day preliminary period to ensure uniformity of rumen contents before faecal collection started. The faecal collection period lasted six days. Faecal collection took place twice daily to reduce spillage from the faecal collection bags. The floors were kept clean so that any spillage of feed or faeces could be collected and accounted for.

The faeces were dried in forced drought oven at 60°C before being weighed.

4.4 RESULTS AND DISCUSSION

4.4.1 Quality analysis

The results of the quality analysis carried out on the three hay types (Table 4.2) suggests that the Ukulinga had the highest quality hay in terms of nutritive value, followed by the Norferg hay, with the Baynesfield hay having the lowest quality.

Table 4.2 Quality analysis of the hay used in trial 1 and trial 2.

	CDMD %	NDF %	N %	P %	K %	S %	CA %	MG %	ZN ppm
BAYNESFLD	16.80	84.05	0.43	0.05	0.45	0.15	0.26	0.12	19
UKULINGA	30.58	70.83	0.68	0.05	0.59	0.19	0.37	0.20	18
NORFERG	26.56	76.87	0.51	0.04	0.58	0.19	0.53	0.15	22

Unexpectedly, the sweetveld hay appeared to be of lower quality than the mixedveld hay. This was probably associated with a more favourable species composition of the mixedveld hay or a higher leaf:stem ratio in the Ukulinga hay caused by different past management practices. The reason for this is unimportant as this situation made no difference to the overall result of the trial as the hay types were then referred to as high quality (Ukulinga), medium quality (Norferg), and low quality

(Baynesfield). The chemical factors affecting preference and intake remain unchanged because of this. The N and P levels were well below the minimum dietary requirements (N=1 % and P=0.2 %), whereas the rest of the minerals were above the minimum dietary requirements (Church 1971).

4.4.2 Trial 1

The intake figures for the three types of hay as well as the total intake over the 12 day duration of the trial fluctuated considerably from day to day (Fig. 4.2).

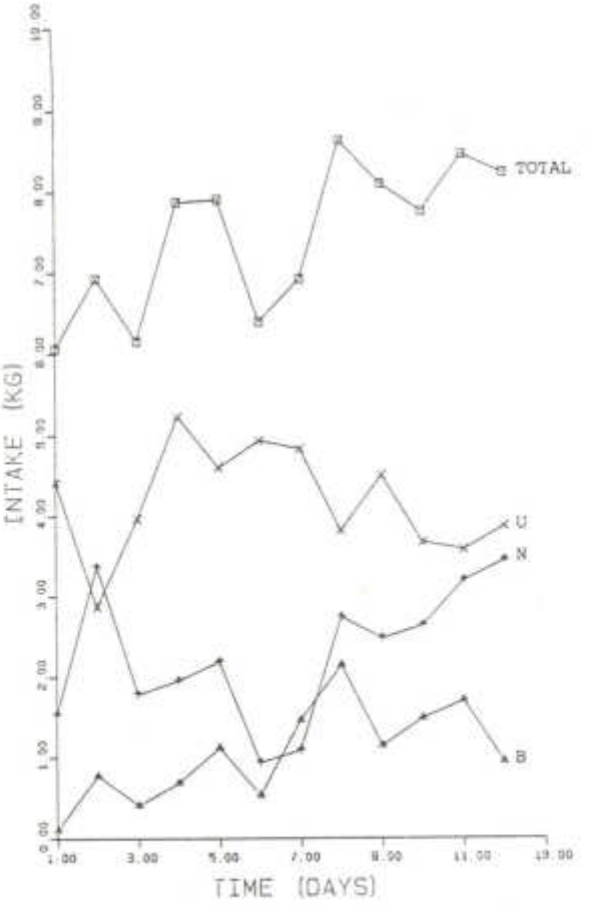

Fig. 4.2 Intake from different quality hays over 12 days using two sheep per treatment.

When considering the means of intake of the three hay types, some

significance emerges (Fig. 4.3 and Appendix 16). These results are for two sheep per treatment.

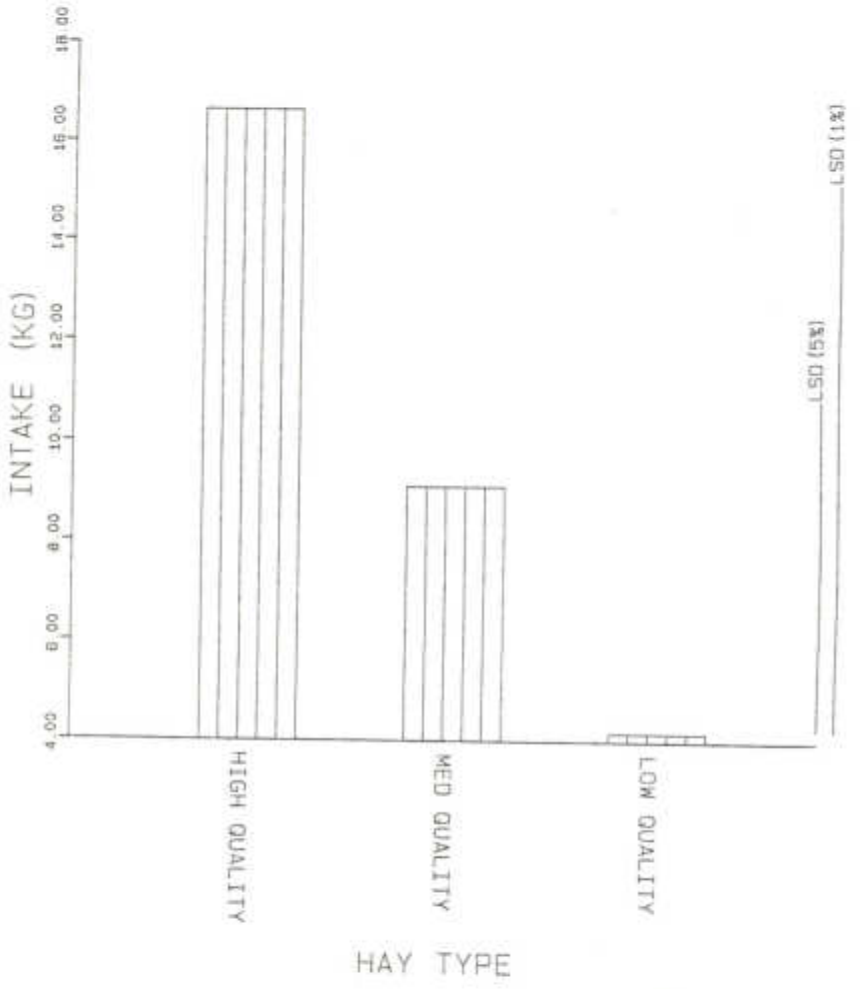

Fig. 4.3 Total intake of each of the three hay types over the 12 day period.

It is clear from the data of Table 4.3 that differences in intake are related to forage quality in that the high quality hay had the highest intake and was thus the most preferred, followed by the medium and then the low quality hay.

4.4.3 Trial 2

The intake over the six day experimental period showed some day to day fluctuation (Fig. 4.4). However, there were significant differences between the mean intake figures of the low quality hay and the other two types of hay for the experimental period (Fig. 4.5 and Appendix 17).

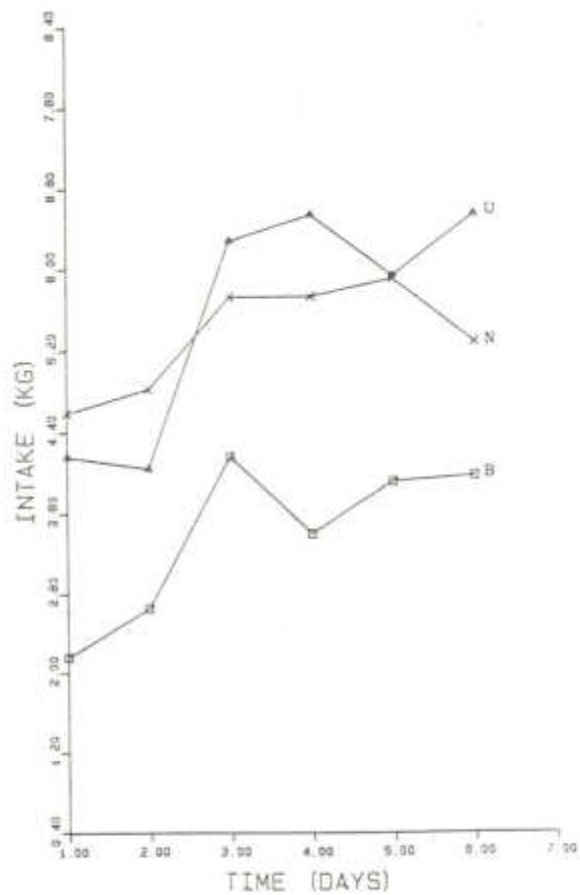

Fig. 4.4 Intake over the six day experimental period.

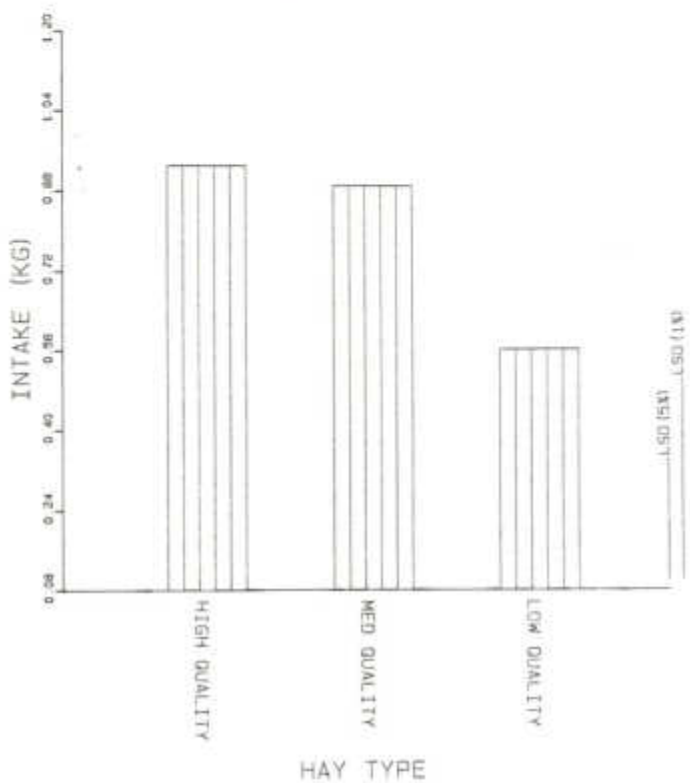

Fig. 4.5 Mean intake of each of the three hay types over the six day experimental period.

The faecal output of the sheep is shown in Fig. 4.6. There were significant differences between faecal outputs of the sheep on the low quality hay and those on the other types of hay (Fig. 4.7 and Appendix 18).

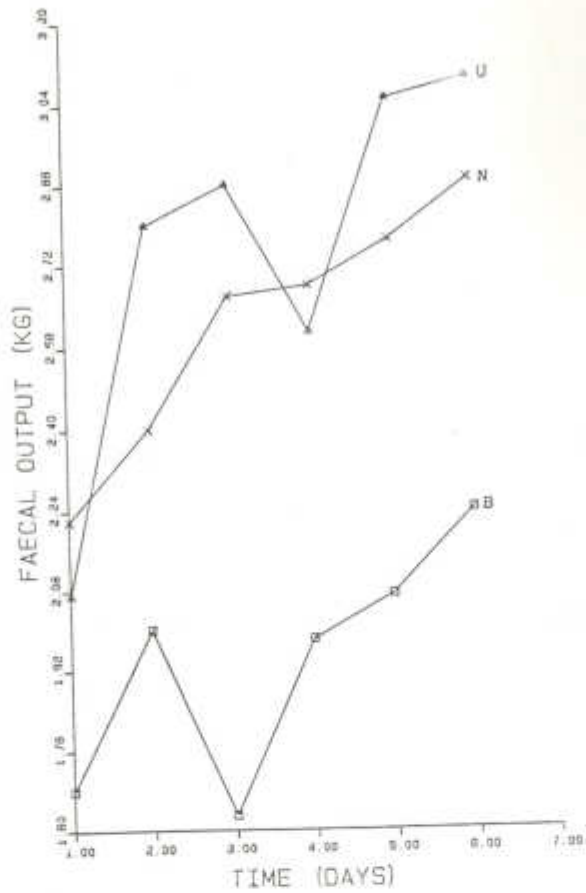

Fig. 4.6 Faecal output over the six day experimental period.

The in vivo digestibility values, calculated on the basis of mean intake and output per sheep, were not significantly different, but they do indicate that the high quality hay had the highest in vivo digestibility, followed by the medium and then the low quality hay respectively (Fig. 4.8 and Appendix 19).

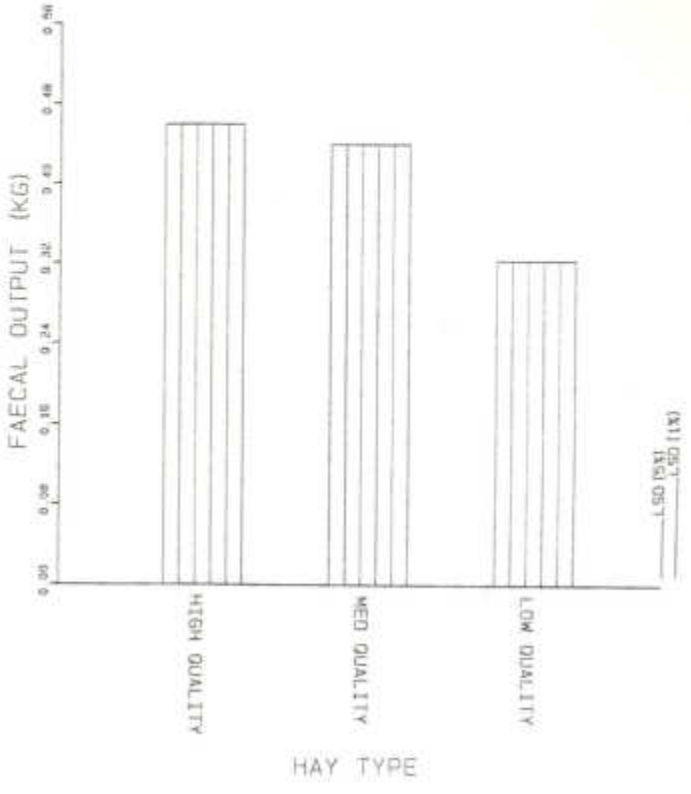

Fig. 4.7 Mean faecal output of the three types of hay over the six day experimental period.

The results of these trials, although inconclusive due to there only being three hay types tested, do indicate that animals will select feed of a higher nutritive value and that intake is proportional to nutritive value.

From studying data extracted from a correlation matrix of the quality factors and the measured parameters (Appendix 20) it

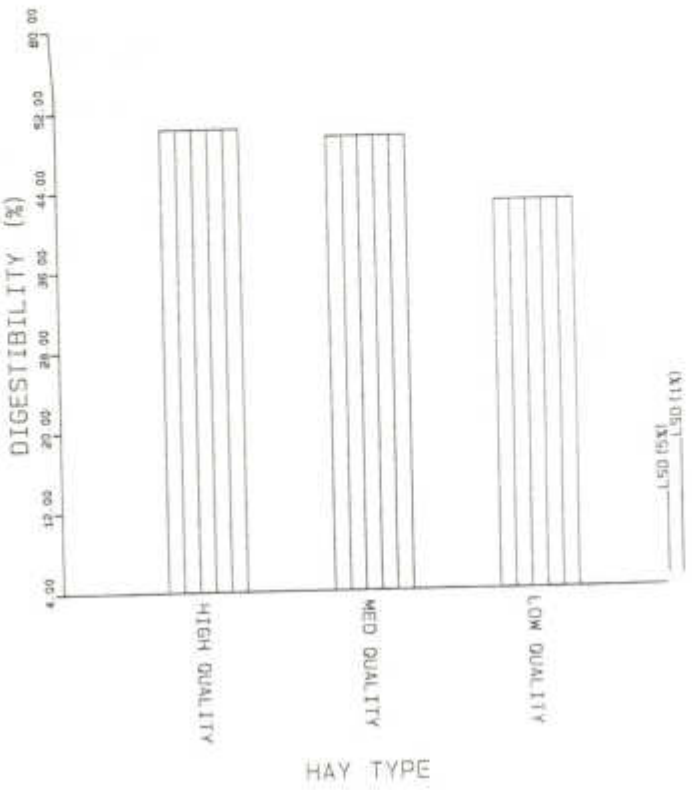

Fig. 4.8 In vivo digestibilities of the three types of hay.

appears that CDMD, NDF, N, K, Mg and in vivo digestibility have a consistently high (0.8 or above) correlation coefficient with the intake figures for the three hay types in trial 1 and trial 2, indicating that in this trial the above mentioned factors were important in determining preference and intake. Note that the P levels were extremely low in all three hay types.

IVD, CDMD, K, S and Ca appeared to have a more significant effect on intake than on preference, while NDF, N and Mg appeared to

effect preference more than intake. Zinc did not have any significant effect while the P levels were extremely low and very similar for the three forages, and were thus not expected to show much significance.

Table 4.3 Extract from a correlation matrix (Appendix 20) showing the correlation between the intake figures for trial 1 and trial 2, and the quality parameters measured.

	TRIAL 1 INTAKE (PREFERENCE)	TRIAL 2 INTAKE
CDMD	0.9373	0.9822
NDF	-0.9856	-0.9304
N	0.9964	0.8081
P	0.1198	-0.4123
K	0.8367	0.9994
S	0.7999	0.9951
Ca	0.2927	0.7460
Mg	0.9997	0.8428
Zn	-0.3547	0.1814

These two trials proved adequate for evaluating forage using animals, and verified the laboratory techniques used during the other sections of the project.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

It is accepted that forage quality is at its highest during the growing season, from October to December/January, and lowest during the winter, from June to August/September. The results from the intensive field study (Chapter 2) indicate that nitrogen and phosphorus are undoubtedly at their highest during the growing season, while the cellulase dry matter digestibility is also highest during this period. The other elements quantified are less consistent in their pattern of variation over the season. Neutral detergent fibre, although sometimes fairly high during the growing season, must be looked at in the light of the interaction between the digestibility and the amount of fibre. Although the NDF levels tend to be high during the growing season, the CDMD is also high. Thus the fibre present can presumably be utilized to a large extent by animals. During winter, the CDMD is low, thus any fibre present can presumably not be utilized to the same extent.

From the intensive field study (Chapter 2) it would appear that the factors having the greatest effect on overall plant quality are CDMD, NDF, N and P. Both N and P were below the minimum dietary requirement for most of the season.

These results tie in with those of the animal trial (Chapter 4), where CDMD, NDF and N were highly correlated with intake and preference. Note that in this case P was extremely low in all three forages tested and thus did not show significance. Certain other minerals, namely K and Mg, were also highly correlated with intake and preference. It is interesting to note the variable effects of the quality parameters measured on intake and on preference (Table 4.3). It is reasonable to suppose here that the factors affecting intake should have a greater effect on animal performance than the factors affecting preference.

Attempts to establish the environmental factors influential in determining forage quality were unsuccessful. Firstly, looking at the intensive field study, it is obvious that plant quality varies substantially over the season. On the assumption that soil chemistry remains effectively constant over the season, one can conclude that soil chemistry or fertility does not have a controlling influence on plant quality. This assumption is reinforced by the results of the extensive field study where soil fertility had no consistent effect on the quality of T. triandra.

Temperature and rainfall did not have a consistent effect on forage quality. The intensive field study revealed that the highest quality forage occurred during October, while the highest temperatures occurred during February and the highest rainfall occurred during the period November to March. Temperature and

rainfall did not appear to have any consistent effect on the quality of T. triandra in the extensive field study.

From the intensive field study it would seem probable that once the optimum growth conditions are attained (e.g. soil moisture status, temperature and daylength), the plant quality rises sharply (associated with spring growth), and then tails off to a low quality period during the winter.

It was impossible to quantify any factors in the intensive or the extensive field studies that would determine the inherent minimum quality (winter quality) of T. triandra for an area or site. Each situation or area appears to be unique and may have different factors interacting at different levels to determine the inherent area specific herbage quality of a species.

The winter quality of T. triandra does not appear to conform to the classical sweetveld/sourveld concept, as the quality index of T. triandra (Table 3.2) does not match the previous classification of the country into sweetveld and sourveld areas (Acocks 1975) which have been broadly based on subjective observations of animal performance during the winter. Sourness of veld appears to be a function of the seasonal quality patterns of all species present. Since these patterns vary among species, management, by influencing species composition, will influence the degree of sourness in the long term. Management will also

influence the degree of sourness in the short term because it affects the ontogeny of the plant, giving rise to different leaf/stem ratios within the herbage produced and it will give rise to different proportions of leaf and stem in the winter according to the amount of leaf left after grazing.

The winter quality of T. triandra is thus not an index of the sourness of veld. For example T. triandra may maintain high quality during winter relative to other associated species and will thus be grazed preferentially during autumn and winter when the quality of the associated sour species drops off. This will reduce the quantity of T. triandra, particularly if it is only a minor component of the sward, as any regrowth will be slow at this time of the year. Animals will then have to resort to eating other unpalatable or low quality species, resulting in lower intake and poor performance. Hence the classification as a sourveld. This situation may be analogous to the Pondoland Plateau Sourveld and Kloof Nature Reserve areas where the T. triandra is of high quality during the year, yet the areas are classified as sour (Acocks 1975), possibly because of low quantity of associated species in winter veld.

However, if there is a large amount of T. triandra of high quality present during winter, then T. triandra should form a high proportion of the animals' diet. This appears to be the situation in Umfolozi and Mkuze Game Reserves, both of which are

classified as sweetveld, although this classification may be partly due to the palatable nature of associated species.

If quality of T. triandra is low, it should have low palatability. The effect of this may be negligible if there are other palatable associated species, which seems to be the case in the Stormberg Plateau Sweetveld. If, however, there are mainly unpalatable species associated with T. triandra then the area would definitely be classified as sour e.g. Highmoor and Cathedral Peak.

Each individual species in a particular area will react differently to the same environmental variables. Thus it can be expected that each species has an inherent quality which is unique to that species, and each species will have a unique pattern of seasonal quality variation. The sweetveld/sourveld situation is thus an extremely complex dynamic system.

In conclusion then, it has been found that CDMD, NDF, N and P are the plant based variables important in determining plant quality in T. triandra. The environmental factors controlling the CDMD and the levels of NDF, N and P could not be quantified.

Any definition of sweetveld and sourveld has to be based on the winter quality of the veld as a whole. There can be no climate or

soil based definition of sweetveld or sourveld as the effects of climate and soil fertility on plant quality are not consistent.

Any method of objectively quantifying the degree of sweetness or sourness of veld will have to be plant based, using the full spectrum of species available, and taking into account the quality by quantity interaction for the principal species (i.e. species that make up the bulk of the animal's diet). Note, however, that the proportion that a species contributes to an animal's diet may vary over the season.

There are no obvious factors that can be manipulated to improve the quality of T. triandra, or of veld in general.

Further research will have to take into account the species composition of different areas and the relative contribution of the principal species over the season.

APPENDIX 1

Environmental data for the six plots used for sampling during the extensive field study.

site	plot	slope (degrees)	aspect (degrees)	altitude (m)
Baynesfld	1	7.5	75	1180
	2	18.5	85	1170
Ukulinga	1	0.0	0	840
	2	2.0	64	840
Norferg	1	5.0	104	725
	2	6.0	60	690

APPENDIX 2

SOIL CHEMICAL ANALYSIS

A soil chemical analysis was carried out on all the soil samples taken throughout this project. The analyses were done at the South African Sugar Association Experiment Station at Mount Edgecombe and included pH (water), phosphorus, potassium, calcium, magnesium, sodium, phosphorus desorption index, zinc, organic matter and cation exchange capacity determinations.

APPENDIX 3

CELLULASE DRY MATTER DIGESTIBILITY (CDMD)

The cellulase dry matter disappearance procedure has been used throughout this project to index the dry matter digestibility of herbage samples. This procedure is used as an estimate of the dry matter digestibility of herbage. For the purposes of this project the CDMD is not compared to or converted to supposedly equivalent in vitro rumen fluid (Tilley and Terrey 1963) or in vivo dry matter digestibility figures.

The decision to use the CDMD procedure instead of the Tilley and Terrey in vitro procedure was made after considering the following:

1 no rumen fistulated animals are required;

2 anaerobic conditions are not required;

3 analysis may be conducted when required without the correct pretreatment to donor animals;

4 large numbers of samples may be handled simultaneously as the volume of the digesting agent is not limiting;

5 repeatability within and between runs is better than in vitro rumen fluid methods;

6 simple methodology is compatible with automation;

7 the cellulase enzyme solutions are relatively inexpensive (Minson 1981; Zacharias 1986) and

8 in vitro rumen fluid is an artificial technique in that it is not an exact simulation of the required test. Thus, if one is to use an artificial technique, one may as well use a simple, more precise, repeatable and economical method.

However, there are several potential sources of variation in the enzymatic procedures. These include the experimental conditions of the assay such as the composition and pH of the buffer, incubation temperature, duration of incubation and the ratio of the substrate to buffer volume (McQueen and Van Soest 1975). These variables are, however, easy to standardize. The enzyme source should also be standardized.

The precision and repeatability of the procedure was investigated by analysis of variance on four standard samples included in each of 30 runs carried out during this project (Appendix Table 1.1). The variance ratio is significant at the 1 % level, indicating differences between runs. Thus all values obtained were corrected according to the difference between the mean of the four standard determinations carried out during each run and the overall mean for the standards over 30 runs.

The accuracy of the technique cannot be quantified but may be assessed in terms of the requirements of the researcher. The procedure can be considered economical relative to in vitro rumen fluid techniques of estimating digestibility.

The following procedure has been used for CDMD determinations (Zacharias 1986) :

1 approximately 0.5 g samples (dried in a forced draught oven at 65 ^{o}C for 48 hours and milled to 1 mm) are weighed directly into 120 ml glass tubes in duplicate with a standard of known CDMD included in each run;

2 approximately 2 g samples are weighed into porcelain crucibles of known weight and their dry matter determined gravimetrically;

3 an acid pepsin solution (4.8 g pepsin powder per litre of 0.125 M HCL (10.7 ml HCL (sp. gr. 1.18) per litre)) is made up fresh and 25 ml is dispensed into each tube;

4 tubes are covered with parafilm, agitated gently and incubated at 39 ^{o}C for 48 hours;

5 tubes are agitated gently three times a day during incubation;

6 after 48 hours the tubes are removed from the water bath and 1.5 ml sodium carbonate added down the sides of each tube to adjust the pH to between 4.5 and 4.7;

7 Cellulase buffer solution (800 IU cellulase per litre of acetate buffer (4.10 g anhydrous sodium acetate and 2.9 ml glacial acetic acid per litre)) is made up when required and 50 ml added to each tube;

8 tubes are resealed and incubated at 39 ^{o}C for a further 48 hours;

tubes are removed after incubation and the contents transferred quantitatively to preweighed, oven-dry sintered glass crucibles (porosity one) and filtered under vacuum; samples are rinsed in the sintered glass crucibles with 10 ml acetone and then oven dried over night at 105 ^{o}C and after drying, the crucibles are removed, desiccated to cool and weighed for CDMD determination by weight lost from the sample.

Due to possible variations between runs, all values are corrected according to the four standard determinations carried out during each run.

The term cellulase dry matter digestibility and cellulase dry matter disappearance can be used synonymously.

Appendix table 1.1 Analysis of variance of 30 runs of a standard sample of veld hay of known CDMD.

***** ANALYSIS OF VARIANCE *****

VARIATE: DIG

SOURCE OF VARIATION	DF	SS	MS	VR
REPS STRATUM	3	0.324	0.108	
REPS.*UNITS* STRATUM				
TREATS	29	111.275	3.837	3.262 **
RESIDUAL	87	102.340	1.176	
TOTAL	116	213.616	1.842	
GRAND TOTAL	119	213.939		
GRAND MEAN		17.506		
TOTAL NUMBER OF OBSERVATIONS		120		

***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****

STRATUM	DF	SE	CV %
REPS	3	0.0600	0.3
REPS.*UNITS*	87	1.0846	6.2

APPENDIX 4

NEUTRAL DETERGENT FIBRE (NDF)

One of the main problems in forage evaluation has been to find a practical and rational replacement for the crude fibre method of analysis. This involves clarification of what is meant by fibre in the nutritional sense and the problem of the relationship of fibre to nutritive value. At the moment these present contrasting and confusing philosophies (Van Soest 1983).

There is no guarantee that a division of plant carbohydrates which conforms to an acceptable definition of dietary fibre will yield an improved relationship with nutritive value. The relationship of fibre to any parameter of nutritional quality is purely a statistical one and depends on the association of the major compounds (cellulose and hemicellulose) with the primary factors that control nutrient availability. Such association is controlled by environmental factors of plant growth.

Lignin analysis has been proposed as a replacement for crude fibre. There are however problems with the chemical and nutritional definitions of lignin. Lignin appears to be more closely related to the indigestible portion of feeds than any other constituent, but it may not represent all the truly indigestible matter present in the plant material. There are also

problems with the complexity of analytical procedures. These factors rule out the feasibility of a lignin analysis to replace crude fibre (Van Soest 1983).

The search for a viable replacement for crude fibre led Van Soest to propose his detergent system of fibre analysis. One of the principle obstacles in preparing plant cell wall residues where indigestible components are recovered has been to remove contaminating protein. The detergents used in this system form strong protein complexes which are soluble under certain conditions (Van Soest 1983).

The neutral detergent system consists of the separation of feed matter into two fractions. The first fraction is of high digestibility and the other fraction of low digestibility. The neutral detergent solubles consist for the most part of the cell contents which are comprised of lipids, starches, sugars and proteins and are all highly digestible. The average true digestibility of the cell contents is about 98 percent. Their digestibility does not seem to be influenced by the amount or proportion of neutral detergent insolubles present.

The neutral detergent insolubles are usually referred to as neutral detergent fibre (NDF) and consists mainly of plant cell wall (cellulose, hemicellulose, pectin, lignin, silica and some protein). Essentially all the lignin, cellulose and hemicellulose

fractions are included in NDF. The NDF values are thus usually higher than corresponding crude fibre values (Cullison 1982; Van Soest 1983), and correspond more closely to the total fibre fraction than does crude fibre. However, NDF is not an entirely uniform chemical entity. It is a variable chemical mixture of cell wall components whose overall nutritive availability is influenced to a certain degree by the proportion and distribution of lignin present. The different NDF components are entirely dependent on the micro-organisms of the digestive tract for digestion (Van Soest & Wine 1967; Cullison 1982).

PROCEDURE

Grass leaf samples were first air dried and milled to pass through a sieve with circular 1 mm diameter openings.

1 REAGENTS

1.1 Neutral detergent solution

30 g sodium lauryl sulphate
18.61 g EDTA - disodium salt ($Na_2EDTA\ 2H_2O$)
6.81 g sodium borate decahydrate
4.56 g disodium hydrogen phosphate (anhydrous)

10 ml 2 - ethoxyethanol (purified)

1 l distilled water

Place EDTA and $Na_2B_4O_7.10H_2O$ in a beaker, add some of the distilled water and heat until dissolved. Add this to the solution containing sodium lauryl sulphate and 2 - ethoxyethanol. Dissolve by heating the Na_2HPO_4 separately in a beaker with distilled water and then add to other ingredients. Check pH range 6.9 to 7.1 .

2 ENZYME SOLUTION

40 mg alpha amylase type X1-A (Sigma A1278) is dissolved in 2 ml distilled water for each sample to be analyzed. Prepare only sufficient enzyme for immediate use.

METHOD

1 Weigh approximately 1 g samples exactly into glass flasks.

2 Add 50 ml of cold neutral detergent solution (NDS) to each flask. The flasks are then placed in a reflux condenser and the solution brought to the boil with the cooling water turned on.

3 Remove the flasks after boiling for 30 minutes and add 2 ml

of the alpha amylase solution to each flask. To each flask add a further 50 ml of cold NDS and bring to the boil again.

4 The extraction is terminated exactly 1 hour after boiling first commenced.

5 Filter the solution through sintered glass crucibles (porosity 1) under vacuum and wash with hot water.

6 Rinse with acetone.

7 Dry the residue overnight at 105 degrees C, cool in a desiccator and weigh.

8 Ash the filtrate at 500 degrees C for a minimum of 4 hours, cool in a desiccator and weigh.

The percentage NDF is calculated as follows :

%NDF = (residue after drying - residue after ashing / original mass) * 100

(After Davie, pers. comm., 1987).

APPENDIX 5

NITROGEN STATUS

Most of the nitrogen required by the animal is used for protein synthesis. Most of the food nitrogen is also present as protein, and it is convenient and almost universal for the nitrogen requirement of animals and the nitrogen status of foods to be stated in terms of protein (McDonald et al. 1981). The direct determination and identification of the various proteins and amino acids present in a feed is an impractical procedure, particularly when analyzing feed of a generally low quality such as veld grasses. In a sense there are no essential amino acids for ruminants as they can be maintained on a protein free diet with nitrogen provided by some non-protein source such as urea.

The protein content of a feedstuff is calculated from its nitrogen (N) content which is generally determined by the Kjeldahl technique. This is a procedure which converts all of the protein and some other nitrogenous components to ammonium sulphate. This gives a figure for most forms of nitrogen although nitrites, nitrates and certain cyclic nitrogen components require special techniques for their recovery.

Two assumptions are made in calculating the protein content from the nitrogen, namely that all the nitrogen in the food is present

as protein and that all food protein contains 16 % nitrogen. The nitrogen content of the feed is then expressed in terms of crude protein (CP) as follows:

% CP = g $N.kg^{-1}$ * 6.25 (Dennison 1977; Maynard et al. 1979; McDonald et al. 1981).

Both of these assumption are unsound. There are certain feedstuffs that contain non-protein nitrogen and different food proteins have different nitrogen contents. Although fundamentally unsound, the use of an average conversion factor 6.25 for food proteins is justified in practice since protein requirements for ruminants, expressed in terms of N * 6.25 are requirements for nitrogen and not for protein. It seems thus that the use of the widely used term crude protein for expressing nitrogen status is somewhat out of place. The expression of animal nitrogen requirements and of the nitrogen status of forage would be more logical (McDonald et al. 1981). Thus the nitrogen content of plant material will be referred to as nitrogen status measured as percentage nitrogen on a dry matter basis.

One further point is that on a low protein diet, the kidney reabsorbs a large proportion of urea and returns it to the blood to be recycled into the rumen to provide added nitrogen for microbial fermentation (Maynard et al. 1979). This is an animal and environment determined factor and cannot be quantified in a study of this type.

Nitrogen levels in the leaf samples collected were determined by the Kjeldahl technique at the South African Sugar Association Experiment Station at Mount Edgecombe.

APPENDIX 6

CHEMICAL ELEMENTAL ANALYSIS

The levels of phosphorus, potassium, sulphur, calcium, magnesium and zinc were determined in the grass leaf samples collected.

The analyses were done at the South African Sugar Association Experiment Station at Mount Edgecombe using an atomic absorption spectrophotometer.

APPENDIX 7

Soil chemical analysis data for the six plots used during the intensive field study with means for the three sites included.

site	plot	pH	P ppm	K ppm	Ca ppm	Mg ppm	Na ppm	PDI	Zn ppm	OM %	CEC
Baynesfld	1	5.25	4.0	153	91	56	19	0.22	1.0	6.0	6.0
	2	5.20	5.0	55	48	34	21	0.33	0.9	4.4	6.1
	mean	5.23	4.5	104	70	45	20	0.28	1.0	5.2	6.1
Ukulinga	1	5.85	5.0	75	2140	220	48	0.24	0.7	5.3	17.8
	2	5.75	6.0	67	872	450	56	0.32	0.7	4.8	11.8
	mean	5.80	5.5	71	1506	335	52	0.28	0.7	5.1	14.8
Norferg	1	6.10	4.0	285	2600	700	77	0.22	1.4	4.9	20.0
	2	6.00	2.0	250	3070	780	56	0.22	1.1	4.0	23.2
	mean	6.05	3.0	268	2835	740	67	0.22	1.3	4.5	21.6

APPENDIX 8

Meteorological data for Baynesfield over the experimental period June 1986 to May 1987.

Month	max. temp. (°C)	mean temp. (°C)	min. temp. (°C)	temp. range (°C)	rain (mm)
June	21.5	13.2	4.9	16.6	32.8
July	21.6	12.8	4.0	17.7	0.5
August	22.6	15.1	7.7	14.9	50.4
Sept.	23.1	16.3	9.4	13.6	19.6
Oct.	23.4	17.2	11.0	12.4	77.8
Nov.	22.9	17.8	12.6	10.2	112.3
Dec.	25.7	20.3	14.9	10.8	132.4
Jan.	25.6	20.9	16.1	9.5	82.0
Feb.	29.1	23.0	16.9	12.1	131.4
March	26.2	20.2	14.3	11.9	130.7
April	25.5	19.2	12.8	12.4	18.2
May	25.6	16.9	8.2	17.4	8.1
	mean	mean	mean	mean	total
	24.4	17.7	11.1	13.3	796.2

APPENDIX 9

Meteorological data for Ukulinga for the experimental period June 1986 to May 1987.

Month	max. temp. (°C)	mean temp. (°C)	min. temp. (°C)	temp. range (°C)	rain (mm)
June	22.2	16.0	9.8	12.4	25.3
July	21.8	15.6	9.4	12.4	0.0
August	21.8	16.4	10.9	10.9	36.4
Sept.	23.3	17.9	12.5	10.8	13.0
Oct.	22.3	17.5	12.8	9.4	52.5
Nov.	21.9	17.7	13.3	8.5	116.6
Dec.	25.6	20.8	16.0	9.6	100.2
Jan.	25.6	21.3	16.9	8.7	68.3
Feb.	29.2	23.9	18.5	10.7	94.5
March	25.8	21.2	16.5	9.3	101.6
April	25.0	20.3	15.5	9.5	49.1
May	25.7	19.6	13.3	12.4	12.4
	mean	mean	mean	mean	total
	24.2	19.0	13.8	10.4	669.9

APPENDIX 10

Seasonal variation of the nutrient status of the material harvested from plots at Baynesfield (B), Ukulinga (U) and Norferg (N) over the season during the intensive field study.

		CDMD %	NDF %	N %	P %	K %	S %	Ca %	Mg %	Zn ppm
June	B	32.37	70.17	0.95	0.05	0.72	0.16	0.31	0.18	17.0
	U	29.32	72.86	0.58	0.04	0.62	0.14	0.33	0.18	21.0
	N	36.52	69.59	0.59	0.04	0.98	0.14	0.46	0.13	19.5
July	B	30.36	69.80	0.79	0.04	0.74	0.24	0.34	0.22	20.0
	U	27.90	73.70	0.66	0.06	0.70	0.18	0.38	0.18	22.5
	N	31.46	70.23	0.61	0.06	1.06	0.16	0.31	0.12	20.0
Aug.	B	25.89	69.99	0.61	0.02	0.46	0.21	0.32	0.20	24.5
	U	28.77	74.78	0.55	0.04	0.58	0.20	0.42	0.20	23.0
	N	31.55	73.35	0.47	0.06	0.92	0.17	0.22	0.11	21.5
Sept.	B	23.58	73.38	0.50	0.02	0.17	0.11	0.22	0.09	23.0
	U	25.17	75.59	0.45	0.03	0.28	0.10	0.40	0.11	23.0
	N	37.73	75.46	0.58	0.06	0.80	0.13	0.35	0.10	25.5
Oct.	B	54.97	81.48	2.00	0.20	1.63	0.21	0.23	0.18	17.5
	U	50.79	75.28	1.11	0.08	0.81	0.15	0.36	0.20	13.0
	N	52.00	75.58	1.38	0.12	1.35	0.27	0.36	0.19	14.0
Nov.	B	48.26	76.64	1.49	0.12	1.11	0.12	0.28	0.16	10.0
	U	47.67	74.18	1.08	0.09	0.75	0.14	0.49	0.21	11.5
	N	48.80	75.19	1.26	0.11	1.29	0.13	0.50	0.17	13.5
Dec.	B	43.45	77.12	1.25	0.09	1.06	0.12	0.28	0.15	21.0
	U	44.60	76.06	1.20	0.08	0.73	0.14	0.48	0.21	13.5
	N	46.54	74.64	1.16	0.09	1.22	0.29	0.45	0.15	10.0

Appendix 10 continued

		CDMD %	NDF %	N %	P %	K %	S %	Ca %	Mg %	Zn ppm
Jan.	B	43.48	74.90	1.16	0.10	0.86	0.42	0.26	0.16	20.0
	U	45.93	77.56	0.93	0.06	0.70	0.13	0.37	0.20	20.5
	N	46.62	76.60	0.96	0.07	1.02	0.23	0.39	0.13	21.5
Feb.	B	34.01	79.19	1.29	0.10	0.97	0.15	0.21	0.14	21.5
	U	36.24	76.86	0.95	0.07	0.83	0.18	0.43	0.20	18.0
	N	35.34	76.12	0.82	0.07	0.99	0.17	0.37	0.15	20.5
March	B	36.48	79.32	1.20	0.10	0.96	0.17	0.21	0.15	22.0
	U	36.47	78.67	0.93	0.07	0.83	0.17	0.41	0.20	19.0
	N	33.82	78.45	0.83	0.09	1.02	0.16	0.41	0.13	22.5
April	B	34.29	76.91	1.32	0.11	0.93	0.17	0.30	0.14	26.5
	U	34.90	77.83	1.02	0.08	0.92	0.18	0.35	0.16	19.5
	N	33.35	77.60	0.92	0.09	0.85	0.15	0.43	0.16	23.0
May	B	34.88	74.87	1.19	0.09	0.98	0.22	0.31	0.16	20.0
	U	36.41	73.03	0.80	0.06	0.85	0.19	0.44	0.19	20.0
	N	36.07	75.59	0.85	0.08	1.07	0.17	0.42	0.13	23.5

APPENDIX 11

Physiographic data for the plots sampled during the extensive field study.

Site	Plot	Slope (degrees)	Aspect (degrees)	Altitude (m)
Ukulinga	1	0	0	840
	2	2	64	840
Norferg	1	5	104	725
	2	6	60	690
Baynesfield	1	8	75	1180
	2	18	85	1170
Glen	1	0	0	1300
	2	5	200	1300
Excelsior	1	0	0	1450
	2	0	0	1450
Tweespruit	1	0	0	1620
	2	0	0	1600
Rossouw	1	7	98	1750
	2	5	80	1700
Stormberg	1	0	0	1700
	2	6	45	1850
Steynsburg	1	3	8	1600
	2	0	0	1550
Grahamstown H	1	11	150	600
	2	12	120	650
Grahamstown M	1	0	0	400
	2	7	62	390
Bedford	1	8	180	850
	2	11	250	750
Post Retief	1	2	100	1100
	2	2	205	1100
Port Edward	1	3	180	300

Appendix 11 continued

Site	Plot	Slope (degrees)	Aspect (degrees)	Altitude (m)
Umfolozi	1	5	334	145
	2	9	68	230
Hluhluwe	1	5	74	300
	2	5	180	120
Mkuze	1	4	275	60
	2	0	0	60
Highmoor	1	12	4	2020
	2	15	60	2000
Cathedral Peak	1	4	175	1170
	2	0	0	1840
Kloof	1	26	180	500
	2	13	200	400

APPENDIX 12

Appendix table 12.1 Soil chemical data for the plots used in the extensive field study.

Site	pH	P ppm	K ppm	Ca ppm	Mg ppm
1	5.85 5.75	5 6	75 67	2140 872	220 450
2	6.10 6.00	4 2	285 250	2600 3070	700 780
3	5.25 5.20	4 5	153 55	91 48	56 34
4	6.90 6.95	18 80	419 185	2450 2420	1050 590
5	6.40 6.40	8 18	257 113	647 864	202 330
6	6.25 6.45	32 19	334 238	2830 660	680 170
7	6.35 6.70	17 45	300 419	1361 2820	240 850
8	6.45 6.55	5 25	187 175	1149 1840	280 710
9	6.80 7.15	8 23	184 274	1014 902	440 290
10	5.80 6.10	6 3	224 113	808 582	370 149
11	6.25 6.45	2 4	243 213	543 711	152 190
12	6.55 6.80	20 24	117 255	1527 1660	360 420
13	6.25 6.30	20 5	182 828	715 310	152 62
14	5.15	5	62	50	56

Appendix table 12.1 continued...

Site	pH	P ppm	K ppm	Ca ppm	Mg ppm
15	6.50	8	156	2990	1030
	6.55	20	270	3710	1170
16	6.20	7	556	2520	1040
	6.50	45	180	4390	940
17	6.20	7	345	775	330
	6.35	11	636	2130	670
18	5.20	7	106	113	37
	4.90	9	172	192	26
19	5.20	4	133	182	110
	5.20	2	128	227	112
20	5.00	4	60	57	71
	4.90	4	52	73	42

Appendix table 12.2 Soil chemical data for the sites used in the extensive field study (using means of the plot data).

Site	pH	P ppm	K ppm	Ca ppm	Mg ppm
1	5.80	5.5	71	1506	335
2	6.05	3.0	268	2835	740
3	5.23	4.5	104	70	45
4	6.93	49.0	302	2435	820
5	6.40	13.0	185	756	266
6	6.35	25.5	286	1745	425
7	6.53	31.0	360	2091	545
8	6.50	15.0	181	1495	495
9	6.98	15.5	229	958	365
10	5.95	4.5	169	695	260
11	6.35	3.0	228	627	171
12	6.68	22.0	186	1594	390
13	6.28	13.0	142	772	231
14	5.15	5.0	62	50	56
15	6.53	14.0	213	3350	1100
16	6.35	26.0	368	3455	990
17	6.28	9.0	491	1103	500
18	5.50	8.0	149	153	52
19	5.20	3.0	131	205	111
20	4.95	4.0	56	65	57

APPENDIX 13

Appendix table 13.1 Plant quality data for the plots used in the extensive field study

Site	CDMD %	NDF %	N %	P %
1	28.22 27.57	73.35 74.04	0.69 0.62	0.06 0.05
2	32.29 30.63	68.68 71.78	0.63 0.59	0.05 0.06
3	29.95 30.76	70.12 69.48	0.74 0.83	0.04 0.04
4	42.21 38.10	66.15 66.99	0.57 0.64	0.13 0.07
5	32.86 34.41	72.49 72.38	0.34 0.39	0.11 0.14
6	33.03 27.28	71.11 73.80	0.31 0.40	0.08 0.11
7	30.80 30.60	71.19 71.29	0.73 0.62	0.15 0.07
8	31.15 29.92	70.97 69.52	0.50 0.67	0.08 0.08
9	34.47 33.37	67.39 66.04	0.63 0.63	0.10 0.18
10	31.78 34.84	67.82 66.85	1.23 1.26	0.07 0.07
11	35.27 43.08	68.27 65.44	0.93 0.92	0.12 0.06
12	27.59 31.33	61.83 67.10	0.70 0.65	0.04 0.06
13	30.32 26.11	70.47 68.62	0.85 0.72	0.11 0.05
14	39.50	70.36	1.10	0.07

Appendix table 13.1 continued

Site	CDMD %	NDF %	N %	P %
15	41.92 35.98	67.32 68.62	1.62 1.27	0.14 0.08
16	34.05 33.75	66.12 67.29	1.19 1.44	0.10 0.31
17	35.64 37.66	70.72 64.02	1.45 0.93	0.13 0.20
18	28.10 28.80	70.08 73.24	0.56 0.59	0.05 0.04
19	23.06 22.50	76.67 77.43	0.27 0.25	0.02 0.01
20	37.81 37.00	71.71 69.19	1.29 1.06	0.08 0.09

Appendix table 13.2 Plant quality data for the sites used in the extensive field study (means of the quality data for the plots).

Site	CDMD %	NDF %	N %	P %
1	27.90	72.68	0.58	0.04
2	31.46	69.59	0.59	0.04
3	30.36	70.17	0.95	0.05
4	40.19	66.57	0.61	0.10
5	33.64	72.43	0.37	0.13
6	30.16	72.45	0.34	0.10
7	30.70	71.24	0.68	0.11
8	30.54	70.25	0.59	0.08
9	33.92	66.71	0.63	0.14
10	33.31	67.34	1.25	0.07
11	39.18	66.85	0.93	0.09
12	29.46	64.47	0.68	0.05
13	28.22	69.54	0.79	0.08
14	39.50	70.36	1.10	0.07
15	38.95	67.75	1.45	0.11
16	33.90	66.70	1.32	0.21
17	36.65	67.42	1.19	0.17
18	28.50	71.66	0.58	0.05
19	22.75	77.05	0.26	0.02
20	37.41	70.45	1.18	0.09

Appendix table 13.3 Additional plant quality data for the sites used in the extensive field study (means of the quality data for the plots).

Site	K %	S %	Ca %	Mg %	Zn ppm
1	0.70	0.18	0.38	0.18	23
2	1.63	0.16	0.31	0.12	20
3	0.74	0.24	0.34	0.34	20
4	0.98	0.08	0.35	0.18	13
5	1.02	0.07	0.28	0.14	14
6	0.32	0.05	0.36	0.13	13
7	0.99	0.07	0.30	0.11	16
8	0.85	0.08	0.26	0.13	17
9	0.88	0.06	0.28	0.20	16
10	1.02	0.15	0.34	0.18	38
11	1.01	0.10	0.31	0.13	20
12	0.63	0.08	0.32	0.10	24
13	0.91	0.08	0.33	0.12	18
14	0.81	0.15	0.26	0.22	23
15	1.10	0.19	0.36	0.19	22
16	0.82	0.30	0.44	0.15	17
17	0.14	0.29	0.48	0.16	17
18	0.87	0.18	0.35	0.10	13
19	0.44	0.11	0.38	0.14	15
20	1.05	0.28	0.41	0.15	18

APPENDIX 14

Meteorological data for the sites used for the extensive field study.

Site	Max. temp.	Mean temp.	Min. temp.	Temp. range	Rain (mm)
Ukulinga	23.9	18.3	12.8	11.1	697
Norferg	23.9	18.3	12.8	11.1	697
Baynesfield	23.8	17.2	10.7	13.1	796
Glen	24.8	16.2	7.6	17.2	548
Excelsior	22.0	14.8	7.6	14.2	588
Tweespruit	22.0	14.8	7.6	14.4	715
Rossouw	22.9	14.8	6.7	16.1	657
Stormberg	22.9	14.8	6.7	16.1	507
Steynsburg	22.1	14.4	6.9	15.2	448
Grahamstown H	22.9	16.4	10.0	12.9	681
Grahamstown M	22.9	16.4	10.0	12.9	673
Bedford	23.7	16.9	10.1	13.6	703
Post Retief	25.1	17.0	8.9	16.2	735
Port Edward	24.4	20.4	16.4	8.0	1100
Umfolozi	25.1	19.9	14.8	10.3	705
Hluhluwe	24.4	23.4	15.6	8.8	973
Mkuze	29.0	21.8	14.6	14.4	631
Highmoor	18.9	14.0	9.2	9.7	1243
Cathedral Peak	18.9	14.0	9.2	9.7	1301
Kloof	24.5	19.8	15.1	9.4	1032

APPENDIX 15

PRINCIPAL COMPONENTS ANALYSIS (PCA)

Principal components analysis is a multivariate analysis technique which has been described as a form of factor analysis (Goodhall 1954). The PCA produces ordination axes from the data set alone (Gauch 1982). The main function of PCA is the projection of points in multidimensional space into fewer dimensions such that the arrangement of point suffers the least possible distortion (Pielou 1977).

The first ordination axis (or first principal component (PCA1)) is extracted to account for the greatest amount of variation in the data set (by minimizing squared deviations). The second axis is orthogonal to the first. The third is orthogonal to the second and so on. Using matrix algebra the amount of variation accounted for by PCA1 and higher axes may be calculated. This figure is referred to as an eigen value and is important in that it gives an indication of the success of the ordination in extracting the major amount of variation in the data set with the first axis. (Gauch 1982; Greig-Smith 1983; Hardy 1984; Digby and Kempton 1987).

All the PCA analyses done in this project were based on a correlation matrix rather than the more commonly used covariance

matrix. The correlation matrix centers and standardizes the data automatically (Clarke, pers. comm., 1987).

Principal components analysis was used on the plant quality data in order to rank the sites according to quality. Four quality factors were used, namely CDMD, NDF, N, and P.

Extracts from the GENSTAT output are presented below, with an explanation of interpretation following.

***** PRINCIPAL COMPONENTS ANALYSIS *****

*** LATENT ROOTS ***

1	2	3
2.548831	0.613782	0.453872

PERCENTAGE VARIANCE

1	2	3
63.7208	15.3445	11.3468

*** LATENT VECTORS(LOADINGS) ***

	1	2	3
CDMD	-0.5302	0.1472	0.2012
NDF	0.5077	-0.2269	0.8133
NL	-0.5084	0.3968	0.5417
PL	-0.4503	-0.8772	0.0684

***** PRINCIPAL COMPONENT SCORES *****

	1	2	3
1	0.446923	0.084777	0.049699
2	0.217195	0.146140	-0.106661
3	0.125533	0.178673	0.051635
4	-0.270341	0.006381	-0.185366
5	0.157165	-0.316776	0.045778
6	0.325469	-0.219295	-0.008160
7	0.115640	-0.170186	0.046885
8	0.177797	-0.046571	-0.060113
9	-0.199960	-0.209080	-0.215675
10	-0.208973	0.241642	0.014680
11	-0.318079	0.121587	-0.066391
12	0.013033	0.202683	-0.416694
13	0.142631	0.001746	-0.056602
14	-0.200908	0.194584	0.216023
15	-0.497382	0.154357	0.183283
16	-0.575292	-0.312852	0.050682
17	-0.497757	-0.186029	0.066984
18	0.355576	0.043144	-0.002435
19	0.893570	-0.047124	0.159351
20	-0.201840	0.132201	0.233098

***** RESIDUALS *****

	1
1	0.033425
2	0.058991
3	0.112633
4	0.312250
5	0.197601
6	0.093210
7	0.034036
8	0.001086
9	0.026244
10	0.155553
11	0.169549
12	0.128653
13	0.171693
14	0.182144
15	0.029599
16	0.267811
17	0.078067
18	0.036439
19	0.055554
20	0.062387

CORRELATIONS BETWEEN THE ORIGINAL VARIATES (ROWS)
AND THE PRINCIPAL COMPONENTS (COLUMNS)

COR	1	2	3
1	-0.84643	0.11530	0.13558
2	0.81052	-0.17779	0.54789
3	-0.81160	0.31086	0.36495
4	-0.71885	-0.68720	0.04608

ASYMPTOTIC 95% CONFIDENCE INTERVALS FOR THE LATENT ROOTS

LOWER	VALUE	UPPER
1.55805	2.54883	7.00051
0.37519	0.61378	1.68579
0.27744	0.45387	1.24659

The first principal component thus accounts for 63.72 % of the variation in the data, while the first three components combined account for 90.41 % of the variation. The rating of sites according to quality was obtained by plotting the principal component scores of each site, using the latent vectors for each quality factor. The sites with high quality forage (high CDMD, N and P, and low NDF) appeared to have low principal component scores on the first axis. The sites with low quality forage appeared to have high scores. The rating was obtained from the first principal component, reverting to the second only where sites on the first principal component had the same score. The third principal component was reverted to under similar circumstances on the second principal component.

This procedure was felt to be the most objective method of rating the sites in terms of quality.

APPENDIX 16

Analysis of variance of the three types of hay in trial 1.

***** ANALYSIS OF VARIANCE *****

VARIATE: INTAKE

SOURCE OF VARIATION	DF	SS	MS	VR
REPS STRATUM	2	12.766	6.383	
REPS.*UNITS* STRATUM				
TREATS	2	234.709	117.355	13.453
RESIDUAL	4	34.894	8.724	
TOTAL	6	269.603	44.934	
GRAND TOTAL	8	282.369		

GRAND MEAN 9.96
TOTAL NUMBER OF OBSERVATIONS 9

***** TABLES OF MEANS *****

VARIATE: INTAKE

GRAND MEAN 9.96

TREATS	2	3	1
	6.59	9.11	4.17

***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****

TABLE	TREATS
REP	3
SED	2.412

***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****

STRATUM	DF	SE	CV%
REPS	2	1.459	14.7
REPS.*UNITS*	4	2.954	29.7

APPENDIX 17

Analysis of variance of intake for the three types of hay in trial 2.

***** ANALYSIS OF VARIANCE *****

VARIATE: INTAKE

SOURCE OF VARIATION	DF	SS	MS	VR
REPS STRATUM	2	0.02569	0.01284	
REPS.*UNITS* STRATUM				
TREATS	2	0.24276	0.12138	10.514
RESIDUAL	4	0.04618	0.01154	
TOTAL	6	0.28893	0.04816	
GRAND TOTAL	8	0.31462		

GRAND MEAN 0.794
TOTAL NUMBER OF OBSERVATIONS 9

***** TABLES OF MEANS *****

VARIATE: INTAKE

GRAND MEAN 0.794

TREATS	2	3	1
	0.930	0.890	0.563

***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****

TABLE	TREATS
REP	3
SED	0.0877

***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****

STRATUM	DF	SE	CV%
REPS	2	0.0654	8.2
REPS.*UNITS*	4	0.1074	13.5

APPENDIX 18

Analysis of variance of faeces output for the three types of hay in trial 2.

***** ANALYSIS OF VARIANCE *****

VARIATE: OUTPUT

SOURCE OF VARIATION	DF	SS	MS	VR
REPS STRATUM	2	0.0038889	0.0019444	
REPS.*UNITS* STRATUM				
TREATS	2	0.0326889	0.0163444	23.536
RESIDUAL	4	0.0027778	0.0006944	
TOTAL	6	0.0354667	0.0059111	
GRAND TOTAL	8	0.0393556		
GRAND MEAN	0.4078			
TOTAL NUMBER OF OBSERVATIONS	9			

***** TABLES OF MEANS *****

VARIATE: OUTPUT

GRAND MEAN 0.4078

TREATS	2	3	1
	0.4600	0.4400	0.3233

***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****

TABLE	TREATS
REP	3
SED	0.02152

***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****

STRATUM	DF	SE	CV%
REPS	2	0.02546	6.2
REPS.*UNITS*	4	0.02635	6.5

APPENDIX 19

Analysis of variance of in vivo digestibility of the three types of hay in trial 2.

***** ANALYSIS OF VARIANCE *****

VARIATE: DIG

SOURCE OF VARIATION	DF	SS	MS	VR
REPS STRATUM	2	245.85	122.93	
REPS.*UNITS* STRATUM				
TREATS	2	103.80	51.90	4.178
RESIDUAL	4	49.69	12.42	
TOTAL	6	153.49	25.58	
GRAND TOTAL	8	399.34		

GRAND MEAN 47.4
TOTAL NUMBER OF OBSERVATIONS 9

***** TABLES OF MEANS *****

VARIATE: DIG

GRAND MEAN 47.4

TREATS	2	3	1
	50.3	49.4	42.7

***** STANDARD ERRORS OF DIFFERENCES OF MEANS *****

TABLE	TREATS
REP	3
SED	2.88

***** STRATUM STANDARD ERRORS AND COEFFICIENTS OF VARIATION *****

STRATUM	DF	SE	CV%
REPS	2	6.40	13.5
REPS.*UNITS*	4	3.52	7.4

APPENDIX 20

Correlation matrix of the quality factors measured on the three hay types and the intake figures for trial 1 (I1) and trial 2 (I2).

*** CORRELATION MATRIX ***

CDMD	1.0000					
NDF	-0.9827	1.0000				
N	0.9044	-0.9677	1.0000			
P	-0.2338	0.0497	0.2035	1.0000		
K	0.9751	-0.9172	0.7872	-0.4435	1.0000	
S	0.9589	-0.8898	0.7462	-0.5000	0.9979	1.0000
CA	0.6076	-0.4501	0.2106	-0.9143	0.7686	0.8080
MG	0.9289	-0.9814	0.9981	0.1429	0.8237	0.7857
ZN	-0.0066	0.1916	-0.4327	-0.9707	0.2153	0.2774
IVD	0.9840	-0.9340	0.8139	-0.4032	0.9990	0.9941
I1	0.9373	-0.9856	0.9964	0.1198	0.8367	0.7999
I2	0.9822	-0.9304	0.8081	-0.4123	0.9994	0.9951
	CDMD	NDF	N	P	K	S
CA	1.0000					
MG	0.2703	1.0000				
ZN	0.7902	-0.3764	1.0000			
IVD	0.7393	0.8481	0.1716	1.0000		
I1	0.2927	0.9997	-0.3547	0.8602	1.0000	
I2	0.7460	0.8428	0.1814	1.0000	0.8551	1.0000
	CA	MG	ZN	IVD	I1	I2

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