NUTRITIVE VALUE OF ORCHARDGRASS FOR CATTLE AND SHEEP

DISSERTATION

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INTRODUCTION

Pasture in the northeast U.S.A. has been a relatively neglected feed resource (Reid *et al.*, 1978). While the dairy industry is based on the feeding of high levels of concentrate and harvested crops such as alfalfa and corn silage, the beef and sheep industry is largely confined to marginal land, with little pasture improvement. As this beef and sheep industry is intensified there is a need for identifying and establishing forage species of superior nutritional quality. However, most forage quality studies in the Appalachian region have been based on *in vitro* and chemical composition data with limited observations on digestibility and voluntary intake (Reid *et al.*, 1978). In addition, few studies in the region have been designed to determine the nutritive value of forage species under grazing conditions.

It has been shown that the nutritive quality of herbage may be influenced by such factors as botanical composition of the pasture, stage of maturity of the plant, season of the year and level of soil fertility (Reid et al., 1976b). These factors may directly influence the digestibility of the herbage, its efficiency of utilization, and/or the level of consumption of herbage, thereby regulating the performance of the grazing animal in terms of live weight gain or milk production.

Previous trials by Reid *et al.* (1978, 1979) showed that the application of kieserite ($MgSO_4 \cdot H_2O$) to grasses and legumes which were harvested as hay and fed to sheep in balance trials

significantly increased magnesium concentration in the forage and magnesium retention by the animal. Also, high levels of kieserite (448 kg Mg/ha) were shown to increase dry matter intake of alfalfa by sheep in the first two years after application of the fertilizer. Recent trials with timothy showed that both magnesium supplementation (as Epsom salts in water) and magnesium fertilization (390 kg Mg/ha) as $MgSO_4 \cdot H_2O$ increased serum magnesium levels and magnesium retention in lambs, and that the supplement increased level of consumption (Reid et al., 1979b). Thence, it seems clear that in addition to preventing hypomagnesemic tetany, supplementary magnesium may have a role in improving forage utilization, possibly by stimulating feed intake.

These findings suggested that increasing the magnesium concentration of the diet of grazing cows, by fertilization or by supplementation, might result in improvements in animal performance, possibly in terms of milk production or increases in liveweight gain of the cows or calves. The fertilization approach, if effective, would offer advantages from the viewpoint of ease of management. However, it was shown by Metson (1974) that on fine-textured or neutral to alkaline soils, very high levels of fertilizer may be required to increase the concentration of magnesium in herbage sufficiently to prevent tetany. Reid et al. (1976) found that magnesium supplementation was more effective than fertilization in maintaining blood magnesium concentrations in lactating beef cows during the first two weeks of grazing. The problem with supplementation techniques, however, was found to be

the individual animal variation, whether or not the supplement contained palatable ingredients such as molasses.

Thus this study was undertaken with the following objectives:

a) To examine seasonal and growth stage effects on intake and dry matter digestibility of orchardgrass by grazing beef cows and by indoor sheep.

b) To examine the effects of a high level of kieserite fertilizer on the nutritive quality of orchardgrass in terms of intake and dry matter digestibility by grazing beef cows and sheep fed cut herbage in indoor trials.

c) To examine the effects of kieserite fertilization of orchardgrass on its mineral composition and utilization of calcium, phosphorus and magnesium and on the concentration of these elements in the serum of grazing cows in the period after initiation of spring grazing.

LITERATURE REVIEW

INDICATOR METHODS

The conventional methods for determining digestibility and intake involving total collection of feces from ruminant animals on pasture have posed quite a lot of problems (Maynard and Loosli, 1969). Furthermore, to achieve good results, cut herbage to be fed indoors has to be uniform throughout the trial period. The use of harnesses and bags for collecting feces in animals maintained outdoors may influence the animal's grazing behavior. Thence the expense and time involved in the total collection of feces constitute a considerable handicap in the conventional method (Schneider and Flatt, 1975).

Carter et al. (1960) showed that manually sampled forage was not necessarily similar to that selected by animals under usual grazing conditions.

The use of indicators offers some advantages over the total collection method for determining intake and digestibility on pasture. In addition to saving labor and time, total measurements of feed intake and fecal output are not required and measurements can be made on single feed and fecal samples (Van Keulen and Young, 1977).

Two principal indicator methods are used to measure the digestibility of herbage by grazing animals: the ratio technique and the fecal index technique (Reid and Kennedy, 1956).

The fecal index method makes no assumption that the indicator

substance in the feed is not changed in nature or amount either by absorption from the gut or by excretion into the gut prior to its appearance in the feces. The ratio technique does. Further, the latter method requires precise knowledge of the content of indicator substance in the food eaten; the fecal index technique does not (McManus et al., 1967).

Maynard and Loosli (1969) reported that application of the ratio technique requires a naturally occurring, totally indigestible indicator and its determination both in herbage and feces. The marker should pass through the digestive tract at a uniform rate similar to that of ingested food and have no pharmacological action on the gut (Kotb and Luckey, 1972).

Kane et al. (1953) gave the following equation to calculate digestibility by the ratio method:

$$\text{Digestibility} = 100 - \frac{(\%\ \text{Indicator in feed})}{(\%\ \text{Indicator in feces})} \times 100$$

Substances used in this technique include iron (Bergeim, 1926), chromogen (Reid et al., 1950), silica (Wildt, 1874), lignin (Ellis et al., 1946) and protein (Forbes, 1950).

In the fecal index technique, digestibility by grazing animals is estimated from a regression equation relating dry or organic matter digestibility of cut herbage fed to animals in stalls to the concentration of the fecal index substance (Langlands, 1975). The requirements for a fecal index substance as reported by Langlands (1975) are: (a) a given digestibility is always predicted from a given concentration of the indicator; (b) the fecal index substance ought to be easily determined chemically; (c) the substance should

be a natural constituent of the feces but need not be an indigestible component of the diet. Examples of this group include plant chromogens (Reid et al., 1952), nitrogen (Lancaster, 1949), crude fiber (Raymond, 1949), methoxyl (Richard and Reid, 1952), acid insoluble ash (Shrivastava and Talapatra, 1962a,b) and dissolved fecal fraction (Owen, 1961). Some of the disadvantages of this method include: (a) the pasture sampled ought to be uniform and must be representative of total pasture; (b) the labor required.

Fecal output for intake determination is estimated by the use of an external indicator (Reid and Kennedy, 1956) - a substance which is added to the diet or taken orally (Kotb and Luckey, 1972). Knowing the digestibility of the forage, forage intake of grazing animals may be calculated from estimates of the fecal output by use of these equations (Langlands, 1975):

OMI = fecal output x 100/(100 - Digestibility)

DOMI = fecal output x Digestibility/(100-Digestibility)

External indicators in general use include chromic oxide (Edin, quoted by Schneider and Flatt, 1975), iron (Bergeim, 1926) and titanic oxide (Askew, 1931).

A detailed review of the fecal nitrogen technique and chromic oxide method will be described.

Fecal nitrogen.

In this technique, cut herbage from the sward under study is given to restrained animals and a digestibility trial is conducted to derive a regression equation relating herbage digestibility to

concentration of N in feces. This equation is then used to estimate the digestibility of herbage eaten by grazing animals from their fecal N concentration (Lancaster, 1949; Thomas and Campling, 1976).

Blaxter and Mitchell (1948) and Gallup and Briggs (1948) showed that fecal nitrogen excretion was related to dry matter intake. Raymond (1948) observed that the nitrogen concentration in feces of sheep was related to that of the grass consumed. Lancaster (1949) found a relationship between fecal nitrogen and organic matter digestibility (Y) expressed by the equation: $Y=1-0.80/N$, for forages containing over 15% protein, and by: $Y=1-0.67/N$ for forages containing less than 15% protein.

Raymond (1954) obtained a linear regression between organic matter digestibility and fecal nitrogen concentration. Lancaster (1954) found a linear regression between the feed to feces ratio and fecal nitrogen. Later, Kennedy et al. (1959) demonstrated a quadratic relationship.

Contrary to the findings of Gallup and Briggs (1948), which were later supported by Hutchinson (1956, 1958), Forbes (1949) found no relationship between dry matter intake and fecal nitrogen concentration. Fecal nitrogen-digestibility relationships have been found to vary significantly with season of the year (Greenhalgh and Corbett, 1960; Minson and Kemp, 1961; Greenhalgh et al., 1960).

Several workers have observed that selective grazing of the animals can not be accounted for by these local regressions (e.g. Vercoe et al., 1962; Lambourne and Reardon, 1963). However, Greenhalgh et al. (1966) found little difference between equations

derived from top and bottom cut herbage. This was recently supported by Reid et al. (1970), who noted non-significant differences with different orchardgrass parts.

Diurnal variations of nitrogen excretion have been reported by Brisson (1960) and Lambourne and Reardon (1963). However, Soni et al. (1954) reported no significant diurnal variation in nitrogen excretion by grazing animals.

Fecal nitrogen regression equations may vary with species of pasture (Streeter, 1969; Langlands, 1973; Davis et al., 1967). Reid et al. (1978) found that the regression for tall fescue was different from that of perennial ryegrass, smooth bromegrass and orchardgrass, which were not different from each other. It was also shown by Greenhalgh et al. (1960) that the regression varies with nitrogen fertilizer application.

Raymond et al. (1956) and Minson (1958) (quoted by Greenhalgh et al. (1960)) have reported that a given concentration of nitrogen in feces may be associated with a slightly lower digestibility in the grazing animal than in its stall fed counterpart, probably because in the former, digestibility is depressed by a higher level of intake or greater infestation of intestinal parasites.

There is apparently a necessity to use different regression equations under different conditions (Thomas and Campling, 1976; Streeter, 1972). This is the basis for Owen's (1961) criticism of the fecal nitrogen index method. Despite these limitations the method continues to be used widely (Reid et al., 1978; Thomas

and Campling, 1976; Odhuba, 1965), probably because of ease of analysis and because other methods have similar inherent problems in estimating herbage intake by grazing animals.

Chromic oxide.

Coup (1950) examined the value of Cr_2O_3 as an indicator for estimation of feces output of grazing cows. He obtained good agreement between the conventional method and the Cr_2O_3 method. He further found that the amount of feces produced could be estimated accurately from "grab" samples of feces taken in the morning and evening and bulked over a 14 day period. Data on the output of feces obtained by Coup were employed by Percival (1950) in combination with indigestibility coefficients derived from fecal nitrogen concentration estimates made on grazing animals. Later, Smith and Reid (1955) proposed the following equations:

$$\text{Fecal output (DM/day)} = \frac{Cr_2O_3 \text{ consumed g/day}}{Cr_2O_3 \text{ concentration in feces dry matter.}}$$

$$\text{Herbage intake} = \frac{\text{Fecal dry matter output/day}}{\text{Indigestibility of herbage DM\%.}}$$

One of the problems associated with use of this method is the diurnal variation in the excretion rate of Cr_2O_3. Kane et al. (1952) noted such a variation in the excretion rate of Cr_2O_3 by dairy cows which were fed twice a day (at 4:30 a.m. and 1:30 p.m.). An analysis of variance of their data revealed significant differences in Cr_2O_3 concentration between AM and PM samples. Hardison and Reid (1953) observed similar results in trials in which clipped herbage was hand fed to steers. Lancaster et al. (1953) and Linkous et al. (1954) also found that concentrations of

Cr_2O_3 were lower in the afternoon fecal samples. Lambourne (1957b) noted two peaks of concentration each day when sheep were dosed at 12 hr. intervals, but only one broader peak if they were dosed at unequal intervals of, say, 8 and 16 hrs. However, recently Hopper et al. (1978) have noted that the excretion patterns were more rhythmic and more distinctly diurnal than those reported by Kane (1952) and Kameoka et al. (1956). Hopper et al. (1978) also showed that the concentration of Cr_2O_3 in the feces of all cows was at a relative maximum at 9:00 a.m. and at a relative minimum at 8:00 p.m. Brisson et al. (1957), who administered Cr_2O_3 in gelatin capsules at 8:00 a.m. and 4:30 p.m. to grazing cattle, showed the same pattern.

Chromic oxide has been administered in different forms in order to reduce the variability in excretion rate. Corbett et al. (1958) concluded that the diurnal variation in the concentration of Cr_2O_3 in the feces is due to uneven mixing of the oxide with the contents of the reticulo-rumen, and to its passage from this organ in advance of the food residues it is intended to mark.

Corbett incorporated Cr_2O_3 into paper by mixing it with wood pulp plus aluminum sulfate. The material was released slowly and approximated more closely to physical characteristics of roughage rations. With this technique the authors observed that fecal Cr_2O_3 concentration remained fairly constant at 16 to 20 mg/g after administration. Later, Corbett et al. (1960) observed that the coefficient of variation of fecal concentration of Cr_2O_3 was reduced by one third to a half by paper administration. It was also found that when paper was shredded into ribbons, a slightly

better prediction of fecal output was obtained. Cowlishaw and Alder (1963) concluded that shredded paper as a carrier for Cr_2O_3 would be a more reliable procedure under extensive range conditions where all feces can not be sampled.

In 1962, Lambourne and Reardon, using Cr_2O_3 in gelatin capsules, showed that the fecal output of an individual sheep, over the range of 50-150 g OM per day, may be estimated within 12% over a period of 10 days or more with two doses and two fecal samplings per day. Also, they found that estimates obtained by dosing and sampling only once per day were generally some 15% higher than those obtained by dosing and sampling twice daily. McGuire et al. (1966) used a complete pelleted ration and fed once at 8:00 a.m. or in six equal amounts at 4 hr intervals. They showed that the rate of excretion of Cr_2O_3 was not affected significantly by frequency of feeding and/or time of sampling.

Pigden and Brisson (1957) used "slow" dissolving pellets which incorporated Cr_2O_3 with plaster of paris. With this method, however, there is a risk of regurgitation and loss of the material during its slow dissolution. Balch et al. (1957) suggested that Cr_2O_3 might be fed in the form of macaroni. However, Langlands (1962) observed in his trials, in which sheep received Cr_2O_3 combined with macaroni or paper, that variability in the concentration of Cr_2O_3 tended to be higher when macaroni rather than paper was administered.

Lassiter (1966) incorporated Cr_2O_3 at a concentration of 0.5% into all concentrate rations fed ad libitum or hand fed. He

showed that the method did not result in estimates of digestibility quite as high nor as consistent as did the total collection method. He concluded, however, that the method would be appropriate for digestibility comparisons between rations. Crampton and Lloyd (1951) suggested with this method that accuracy could be improved by mixing the Cr_2O_3 into the concentrate portion of the ration.

Various feeding and sampling procedures have been suggested for optimal use of Cr_2O_3 as an indicator. Kane et al. (1952) proposed that samples should be taken at the time or times when the concentration of Cr_2O_3 was found to be close to the mean value for the 24 hr period. Lambourne (1957) suggested that samples should be taken twice daily at intervals of about 9 and 15 hrs and composited. A procedure for feeding and sampling at 7:00 to 9:00 a.m. and 3:00 to 5:00 p.m. has been adopted by several workers (Smith and Reid, 1955; Elam et al., 1962; Lambourne et al., 1965).

Balch et al. (1957) concluded that Cr_2O_3 should be administered to animals at pasture before the main periods of grazing to ensure that the maximum rate of passage of Cr_2O_3 from the reticulo-rumen coincided with the maximum rate of passage of dry matter. Pigden and Brisson (1956) and Brisson et al. (1957) found that Cr_2O_3 was excreted more regularly when administered six times rather than once or twice a day. However, Bradley (1959) observed that more frequent feeding with a ration containing Cr_2O_3 did not eliminate variability in the feces.

Percent recovery of Cr_2O_3 in the feces has been variable. Cowlishaw and Alder (1963), who used either oil suspensions or

shredded paper, found the average recovery of Cr_2O_3 to be 99.1% from oil and 94.4% from paper. Organic matter excretion using indicators was found to be overestimated by 3.5 to 8.0%. These authors also found that there was no significant difference between shredded paper and oil as carriers of Cr_2O_3 for estimating the organic matter excreted. Hardison and Reid (1953) obtained recoveries of Cr_2O_3 of 71.8 and 129.3%, respectively, from feces taken from grazing steers at 6:00 a.m. and 4:00 p.m. Wet bulking of the fecal samples taken at these two times of the day resulted in an average recovery of 99.5% of Cr_2O_3 by grazing animals. McGuire et al. (1966) observed recoveries of 94% occurring at 4:00 a.m. and of 106% at 6 p.m., for steers fed once daily. For steers fed six times daily the range varied from 94% at 2 p.m. to 105% at 10 p.m. Elam et al. (1962) obtained a recovery of 100.7% with sheep. However, Elam et al. (1962) showed also that the level of feeding did affect the % recovery, as follows:

Average % recovery of chromium oxide during a 10 day collection period.

Level of feeding (% of maintenance)	% Cr_2O_3 recovery
70	100.9
110	101.1
150	100.2

Other workers, e.g. Moore (1957), Clanton (1962) and Johnson et al. (1963) have reported an average recovery of Cr_2O_3 from 80 to 95%.

Raymond and Minson (1955), Langland (1967), Elam et al. (1959) and Reid (1952) found that fecal Cr_2O_3 varied with changes in the feeding behavior. Hopper et al. (1978) showed that mean fecal Cr_2O_3 concentration significantly decreased as the percentage of time spent grazing increased. They showed that the proportion of time spent grazing accounted for 41% of the variation in fecal Cr_2O_3 concentration. In contrast, Lambourne and Reardon (1963) reported no relationship between Cr_2O_3 excretion and grazing pattern.

Blaxter et al. (1956) reported different Cr_2O_3 excretion patterns for sheep fed different quantities and forms of dried grass. However, it was suggested by Kane et al. (1952) that the pattern was influenced by the faster rate of passage of concentrate, with which the Cr_2O_3 was often fed, than of the roughage which in most cases formed the greater part of the ration. Putnam et al. (1958) were of the opinion that the time of capsule dosing was more important than the ratio of concentrate to roughage in the whole diet.

Moore (1957) reported that excretion of Cr_2O_3 was inversely related to crude fiber content of the herbage. In contrast, Davis et al. (1958) reported no relationship between passage of crude fiber and the excretion of Cr_2O_3. However, it was noted by Lambourne (1957b) that the rate of Cr_2O_3 excretion was lower on more fibrous feeds than on good quality herbage, and that, within feed, Cr_2O_3 excretion was slightly more rapid the higher the level of intake.

Blaxter et al. (1956) and Putnam et al. (1967) noted that, as nutrient requirements increase, the rate of passage of Cr_2O_3 also

increases. Hancock (1953) found a relationship between grazing time and feed requirement. However, it was shown recently by Hopper et al. (1978) that cows with larger nutrient requirements had a lower fecal Cr_2O_3 concentration. Hardison and Reid (1953) noted that grazing animals had a greater variability in Cr_2O_3 excretion than stall-fed animals, possibly due to selective grazing habits. Similarly, Raymond and Minson (1955) and Brisson et al. (1957) reported differences in excretion patterns between penned and grazing animals.

Lambourne (1957a) and Raymond and Minson (1955) showed that it required 4 days for a dose of Cr_2O_3 to pass through the digestive tract. A 7-10 day dosing preliminary period is therefore suggested as adequate to saturate the rumen contents with marker (Smith and Reid 1955; Kameoka et al., 1956; Murdock et al., 1957). When massive doses were given, Lambourne (1957b) found that 3-4 days were adequate.

With regard to length of collection period, Smith and Reid (1955) found that better results could be obtained by sampling twice a day for 7 days. Putnam et al. (1958) reported a 5-7 day collection period with fecal samples pooled on an equal wet basis morning and afternoon.

FACTORS AFFECTING INTAKE

The voluntary intake of herbage is defined as the amount eaten during a period of time when the herbage is offered ad lib. It is usually expressed as g/day or as g/kg body weight $^{0.75}$/day

(Ulyatt, 1973). Ulyatt (1973) also concluded that voluntary intake accounted for at least 50% of the feeding value of herbage and that it must be an important measurement in any herbage evaluation system.

Factors which influence the voluntary intake of forages are: stage of maturity, chemical composition, fertilizer application, rate of fermentation in the reticulo-rumen, molar ratios of VFA in the rumen, forage species, palatability and processing.

(a) Stage of Maturity.

Reid and Jung (1965a), in their studies with several grass and legume species fed as clipped herbage to sheep, showed a significant effect of stage of maturity on ad lib. intake of forage. Similarly, Reid et al. (1967), in the evaluation of tall fescue pasture under different fertilization treatments, showed that intake declined with advancing maturity in the first growth herbage, but that there was no effect of date of cutting on intake in the regrowth trials. They also showed the level of consumption of regrowth herbage to be significantly higher than for first growth grass with equivalent or greater dry matter digestibility. Reid et al. (1966) also noted this trend of a higher intake of aftermath than of first cutting hay in trials with sheep fed orchardgrass. However, Hogan and Weston (1969) noted feed consumption to decline only with the most mature oat hay diet.

In comparing the nutritive value of orchardgrass using a strip grazing or zero grazing system with dairy cows, Greenhalgh and Runcie (1962) reported a higher intake (non-significant) for strip

grazed than for zero grazed cows. They further showed that during spring and summer trial periods, the intake of herbage utilized by both systems declined with advancing maturity, the rate of decline being more marked for zero grazed cows.

With mixed grass species, Corbett et al. (1963) found that dairy cows ate more digestible organic matter per unit of metabolic weight on pasture in spring than in fall. Similarly, Marsh (1975) showed intakes of digestible organic matter per unit of metabolic liveweight to be significantly higher in spring (58-84% more) than in autumn. This supported the findings of Alder and Cooper (1967).

Reid et al. (1970), in their studies of orchardgrass with different levels of nitrogen fertilization, obtained a decline in intake with increasing maturity of the pasture. However, in one year the level of intake decreased on all treatments from the vegetative to the early heading stage and then increased again at the full bloom stage. They suggested this might be due to an increased availability of vegetative regrowth herbage due to weather conditions in that year.

Recently, Reid et al. (1978), in feeding trials with perennial ryegrass, smooth bromegrass, orchardgrass and tall fescue pasture fed as cut herbage to sheep, noted a significant decline of intake of dry matter of all species with advancing maturity in 1974, while there was little effect of trial period on intake values in 1973. However, for grazing sheep the pattern was for intake to decline between May and August and to increase markedly on fall regrowth. They also reported higher intakes of digestible dry matter per

unit of metabolic weight for spring herbage than for fall regrowth pasture in 1974.

(b) Chemical composition.

Van Soest (1964), working with 83 grass samples from W.Va. trials, obtained a highly significant overall correlation of -0.65 between cell wall constituents (CWC) and ad lib intake, although there were interspecies differences and a low correlation of -0.13 between lignin and ad lib intake. He suggested that CWC limit intake when the proportion of these constituents increases to more than 55 to 60% in the dry matter.

Reid and Jung (1965b) found a more highly significant correlation of -0.69 between intake and CWC than between intake and cellulose, acid detergent fiber, acid insoluble lignin, soluble carbohydrate or protein concentration of the forage in trials to compare the consumption levels of fertilized fescue hays with alfalfa. Reid and Jung (1965a) concluded that the higher intake of leguminous forages was related to their chemical composition. In comparison with a grass of equal digestibility, they showed that alfalfa had a higher content of soluble carbohydrate and lignin, a lower cell wall and hemicellulose fraction and a lower fiber digestibility.

Powell et al. (1978), using a stepwise regression analysis, noted that the most important factor in the prediction of intake of four perennial grasses by lambs was not the organic components but the concentration and apparent absorption of phosphorus.

(c) Rate of fermentation.

As stated by Ulyatt (1973), there are three main factors which might influence ruminal fermentation rates: rumen capacity, rate of breakdown and rate of passage. Campling (1970) in his review concluded that the voluntary intake of certain roughage diets is limited by the capacity of the reticulo-rumen and by retention time.

Ulyatt et al. (1967) stated that ruminants of similar physiological status eat to a constant rumen volume. Van Soest (1964) noted that with an increase of total fibrous components, e.g. cell wall constituents, intake would become increasingly restricted by the volume in the rumen occupied by the fibrous mass. He concluded also that fiber mass inhibits intake in those forages with a high cell wall content. The total fibrous fraction of legumes, represented by cell wall constituents, does not appear to be large enough to inhibit intake. Several reports suggest that the intake of very young, highly digestible herbage is probably not limited by its filling effect in the reticulo-rumen (Campling, 1964). Hutton (1962), by offering cows freshly cut herbage ad lib, showed little if any decrease in intake of dry matter as the digestibility of the herbage decreased rapidly from about 77 to 70%; below this level, intake appeared to decline with decreasing digestibility. It was also shown by Armstrong (1960) with sheep that the voluntary intake of very highly digestible, artificially dried grass was lower than that of slightly less digestible material.

The rate of breakdown of a forage is largely a function of its composition, both chemical and physical (Ulyatt, 1973). Compared to structural carbohydrates, soluble carbohydrates and proteins are rapidly digested by rumen microorganisms, so the higher the ratio of soluble/structural components, the faster should be the rate of breakdown and the higher the intake (Van Soest, 1965; Weston, 1968, quoted by Ulyatt, 1973).

Reid and Jung (1965a), in a comparison of grasses and legumes of several species, observed rates of degradation, as measured by incubation of samples in the rumen of the animal, to be highly related to rates of cellulose breakdown, acid formation or gas production *in vitro*.

Hogan *et al.* (1969) noted in their experiment with *Phalaris tuberosa* that as ruminating and eating time increased, intake decreased.

The intake of herbages of low nutritive quality has been increased by the addition of nitrogenous compounds (Campling *et al.*, 1962) or by the addition of certain minerals (Blaxter, 1962). Ulyatt (1973) claimed that these substances may aid microbial digestion of the herbage.

The rate of breakdown of herbage and the rate of passage of undigested residues out of the rumen are normally closely related (Ulyatt, 1973). Thornton and Minson (1972) showed that the rate of disappearance of food from the rumen was positively related to the voluntary intake. Rees and Minson (1976) recently noted the voluntary intake to be increased by calcium fertilization, due to

an 18% reduction in the period of time the dry matter was retained in the reticulo-rumen of sheep fed pangola grass (Digitaria decumbens).

(d) Molar ratios of VFA.

Measurement of the production and molar distribution of VFA in the rumen has also been considered as a procedure for the prediction of forage quality (Reid and Jung, 1965a). Ulyatt (1973) stated that herbages containing a low ratio of soluble to structural carbohydrate tend to produce high molar proportions of acetic acid in the rumen, while herbage containing a high ratio of soluble to structural carbohydrate tend to be associated with high molar proportions of propionate and butyrate. Thus there is a tendency for the ratio of acetate/propionate and butyrate to decrease with increasing nutritive value.

Reid and Jung (1965b), in their studies with a number of grass species and legumes harvested at different stages of growth and fed in the fresh form to sheep, observed a significant negative correlation between intake of NVI and the molar proportion of ruminal acetic acid. They also noted inter-species forage differences in the molar ratios of VFA - a relatively lower proportion of acetic acid and higher proportion of propionic acid was found consistently in the rumen fluid of animals consuming alfalfa or clover.

Reid and Jung (1965a) also demonstrated marked differences in the ruminal ratios of acetic to propionic acid between the fescues

as a group and alfalfa - the acetic/propionic acid ratio in rumen fluid from sheep receiving alfalfa was significantly lower. They noted that intake and NVI values showed a significant negative correlation with the acetic/propionic acid ratio in rumen fluid.

(e) Herbage species.

Reid and Jung (1965a) reported that intake of the legume species alfalfa and red clover was consistently higher than that of grasses. In their study they observed that the intake of alfalfa was some 60% higher than that of tall fescue of equal digestibility. Also, they showed a lower intake of tall fescue by wether sheep than of other perennial grasses at equivalent DMD levels. Recently, Reid et al. (1978) have shown that the intake of tall fescue fed as cut herbage at an early growth stage was apparently lower than intake of other grass species, although the differences were not significant. For the grazing sheep, they noted significant differences in intake between grass species.

In comparative studies of perennial ryegrass and orchardgrass as food for the calf, Alder and Cooper (1967) found in indoor experiments that, with calves of the same age, consumption was higher with ryegrass than with orchardgrass, although when the calculations were made as a percentage of liveweight, differences in DM or OM consumption were not apparent. In their grazing experiments made in 1961, the digestible organic matter consumption was higher on ryegrass, while organic matter consumption was similar for the two species.

(f) Palatability.

Tribe and Gordon (cited by Reid and Jung, 1965b) have regarded palatability as a function of the animal rather than of the food. Reid and Jung (1965a) showed that intake of phosphate fertilized fescue was higher than that of other fertilized forage treatments, although not significantly so. In cafeteria trials, sheep showed a marked preference for the fescue treated with phosphate. Also, the sheep tended to reject the fescue hays fertilized with medium and high levels of nitrogen.

Cowlishaw and Alder (1960) observed that a preference ranking was associated with the content of water soluble dry matter, ash and carbohydrate, and was negatively correlated with lignin. Reid and Jung (1965a) found the highest level of soluble carbohydrate (13%) to be in the phosphate fertilized fescue, and demonstrated a higher rate of *in vitro* cellulose digestion of this treatment than of other fertilized fescues.

In cafeteria trials with sheep, Reid *et al.* (1966) showed that both the level and form of nitrogen fertilizer markedly affected the palatability of orchardgrass hays. Acceptability of orchardgrass declined with increasing levels of nitrogen fertilization and there was evidence for a relationship between palatability and a soluble carbohydrate-nitrogen imbalance in the plant. In both hay cuttings, preference rankings by sheep for orchardgrass fertilized with different forms of nitrogen were in this order: sodium nitrate >ammonium nitrate >ammonium sulfate >urea and diammonium phosphate. They also showed an animal species

difference in feeding behavior between sheep and rabbits; rabbits consumed relatively more of the non-fertilized orchardgrass than of the fertilized hay and ranked the nitrogen source treatments in the order: ammonium sulfate > urea > sodium nitrate > diammonium phosphate and ammonium nitrate.

The grazing animal has the opportunity, within the herbage available, to select that portion which it finds acceptable. The senses of smell, sight, taste and touch are used, singly or in combination, by the animal to accept certain components of the herbage and to reject other components (Ulyatt, 1973). Arnold (1970) provided evidence that sheep do discriminate in response to smell and taste. The mechanism(s) by which such factors as taste and smell may influence the preference of animals is largely unknown (Campling, 1964).

In grazing trials, Reid and Jung (1964) observed on fescue fertilized herbage that sheep on free-choice herbage strips spent more time and harvested markedly more grass from the nitrogen-fertilized plots than from the control or phosphorus or potassium-fertilized areas. The difference between this behavior and that of stall-fed animals mentioned earlier was ascribed in part to the effect of herbage availability on feeding patterns. Ivins (1952) showed that nitrogen fertilization increased the palatability of herbage, particularly of the grass. Similarly, Burton et al. (1956) found that for coastal bermudagrass fertilized at levels of nitrogen from 0 to 1684 kg per hectare, the percent of forage selected by grazing cows increased as the nitrogen rate

increased.

Ivins (1955) claimed that palatability may be affected by the level of potassium and phosphorus in herbage. Ozanne (1971) observed that sheep grazing a green subterranean clover pasture preferentially selected feed to which high levels of phosphorus had been applied. However, Reid and Jung (1965a) showed no consistent relationship between mineral composition and palatability, although fertilizer treatment influenced the level of major and minor elements in the fescue hays.

Some feeds contain toxic or inhibitory materials or substances that impart taste (either objectionable or desirable) or alter the metabolism of the animal (Van Soest, 1965). Thomas et al. (1961) observed poor consumption of high moisture silages, where the juice appeared to contain a factor that reduced intake.

Alkaloids have been associated with a decrease of feed intake in ruminants (Boling et al., 1975). The predominant alkaloids found by Bush et al., 1972a) in tall fescue were perloline, festucine and perlolidine. Pyrrolizidine alkaloids from fescue seed have been shown to decrease feed intake and weight gains when added to a synthetic diet at a concentration of 0.2% (Robbins et al., 1972). Rifas et al. (1973) found another alkaloid in fescue identified as betaine, the levels of which increased as nitrogen fertilization increased.

(g) Fertilization.

Nitrogen:

Reports in the literature on the effect of nitrogen on forage intake are conflicting. Mahoney and Poulton (1962) reported no differences in intake by sheep on timothy fertilized at 45 or 134 kg of nitrogen per hectare, and Holmes and Lang (1963) could show no difference in dry matter intake by steers on grass fertilized with either high or low levels of nitrogen. With sudangrass fed in fresh chopped form, Reid et al. (1964) showed no effect of nitrogen fertilization on voluntary intake of the grass by sheep. In their evaluation studies of the effects of different fertilizer treatments, Reid and Jung (1965) found no significant differences in intake due to nitrogen treatment with either first cutting or aftermath tall fescue hay. Similarly, Reid et al. (1966) reported that neither level nor source of nitrogen fertilizer had a significant effect on the level of intake by sheep of the first cut hays. With orchardgrass fertilized at four nitrogen levels (0, 56, 168 and 504 kg/ha), Reid et al. (1967a) noted little effect on intake in trials with cut herbage.

McCarrick and Wilson (1966) found that nitrogen fertilizer had no effect on intake of conserved herbage. Similarly, Hodgson and Spedding (1966) found only minor differences in intake by calves of ryegrass herbage treated with levels of nitrogen ranging approximately from 190 to 1000 kg N/ha/annum.

Hogan and Weston (1969) reported that feed consumption of oats was not affected by high and low levels of nitrogen fertilization, even though the high nitrogen diet supplied 4-5g nitrate nitrogen per day and relatively small amounts of soluble

carbohydrates. Cameron (1967) also found that rates of nitrogen fertilizer up to 112 kg N/ha had little effect on the intake of mature grass hays by wethers.

In contrast to these various observations, Reid et al. (1967b) noted a lower intake of tall fescue fertilized with nitrogen than of the non-nitrogen treated grass in one trial, although in subsequent trials the level and type of fertilizer had little effect on ad lib. consumption of clipped herbage. Further, Reid et al. (1974), in an experiment designed to examine the effects of imposing four nitrogen levels on orchardgrass on the performance of a flock of ewes over a five year period, reported that for grazing sheep during the period of May to July, 1968 and 1969, high nitrogen treatments significantly depressed dry matter intake. But there was no effect of fertilizer on intake when the herbage was cut and fed ad lib. at four growth stages to ewes in metabolism stalls in 1971.

It was noted by Reid et al. (1972), in their studies on the nutritive evaluation of orchardgrass pasture, that the level of nitrogen fertilization did significantly affect the level of intake. In two years the intake of dry matter by ewes on low and medium nitrogen treatments was higher than on high nitrogen treatments. The effect was especially marked in the early growth period in 1968. This was in agreement with work by Bryant and Ulyatt (1968), who showed in trials with cut short rotation ryegrass fed to sheep that, although there was no difference between grasses for the first period, intake of the low-nitrogen grass was

significantly greater than that of the high-nitrogen grass in the second period. On the other hand, Odhuba et al. (1965) reported a significant increase in the intake of tall fescue associated with high levels of nitrogen fertilization, and they noted a small increase in intake by sheep with increasing crude protein content of the herbage.

Sulfur.

It is difficult to interpret the effects of sulfur fertilization on forage quality because the results may be confounded by effects due to yield responses or to changes in botanical composition (Reid and Jung, 1974). Rees and Minson (1976) observed an increase in voluntary intake of pangola grass due to the application of sulfur fertilizer. They also concluded that the lower intake of the control grass was due to primary sulfur deficiency, since feeding a sulfur supplement increased voluntary intake by 28%. In contrast, however, Reid (1980) observed that fertilization of alfalfa with elemental S did not affect intake.

By adding Na_2SO_4 to low-sulfur corn silage rations, Jacobson et al. (1967) observed an increased dry matter intake by dairy cows. Similarly, Playne (1969) obtained an increase in dry matter consumption when sulfate was added to a diet of spear grass and Townsville stylo. This has also been supported by the study of Kennedy and Siebert (1972), who reported an increase of intake with the addition of as little as 0.12g sulfur/day to the diet of sheep fed spear grass.

Magnesium.

Reid et al. (1979), in trials with growing lambs fed alfalfa hay fertilized with four levels of magnesium (0, 112, 224 and 448 kg Mg/ha), observed that ad lib. intake was increased at the highest (448 kg Mg/ha) level of magnesium fertilization in the first two years after application, with no effect in the third year. They considered the increased intake to be due in part to lower levels of cell walls in the alfalfa fertilized at higher levels of kieserite. Recent studies in West Virginia with cattle and sheep have shown the following responses (Reid, 1980): supplying MgO to cows fed corn stover in balance trials increased intake of the stover; the provision of supplementary Mg as $MgSO_4$ in the water to sheep fed timothy hay in balance trials also resulted in significant increases in dry matter intake of the hay. These results could not be attributed to cell wall reduction.

Ammerman et al. (1971) observed a reduction in intake by sheep fed purified diets deficient in magnesium. Fisher and Wilson (1979) also observed a depression in daily gain, feed efficiency and dry matter intake in lambs fed a diet containing 0.04% as compared with 0.12% Mg.

(h) The Animal.

The amount of food eaten will depend to a considerable degree on the animal and on its physiological status. Among similar animals there may be variations in voluntary food intake when expressed per unit of metabolic body weight (Greenhalgh and

Runcie, 1962). Corbett et al. (1963) and Blaxter and Wilson (1962) have reported coefficients of variation for voluntary food intake of between 10 and 13%. Mather (1959) observed that the fatter an adult animal becomes, the lower will be its food intake.

Reports of differences in intake associated with animal species are conflicting. Cipolloni et al. (1951), Alexander et al. (1962) and Buchman and Hemken (1964) observed that when cattle were offered a roughage which was more than 50% digestible, they consumed more of it per unit of metabolic body size ($W^{0.75}$) than did sheep. In contrast, Thomas and Campling (1976), in their trials with cut herbage from a sward consisting mainly of Manawa ryegrass and perennial ryegrass, observed that voluntary intakes of dry matter (g/kg^{-1} liveweight) were on average 22% higher in sheep than in cows and that differences between species were significant in all periods. Recently it has been observed by Playne (1978) that there were no differences between cattle and sheep in their relative intake per kg liveweight ($W^{0.9}$) of a low quality tropical grass hay.

(i) Other factors.

Intake can also be influenced by changes in the climatic environment (Macdonald and Bell, 1958). Wayman et al. (1962) observed that a rise in ambient temperature resulted in a decrease in hay intake and they suggested that part of this effect might be due to a decreased rate of passage of digesta through the rumen. A decrease in temperature is generally associated with an increase in hay consumption (Campling, 1964).

Bergen (1972) reported that an increase in rumen osmolarity decreased food intake. Contrary to this finding, Kato et al. (1979) recently reported that food intake was affected by changes in the concentration of sodium and/or potassium in rumen fluid rather than by changes in rumen osmolarity.

FACTORS AFFECTING DIGESTIBILITY

The apparent digestibility of any feed constiuent is defined by Ulyatt (1973) as:

$$\frac{\text{(Amount in feed-amount in feces)}}{\text{Amount in feed}} \times 100$$

Forage digestibility may be affected by these factors: stage of maturity, chemical composition, the level of intake, fertilization, forage species, processing, animal and environmental factors.

(a) Stage of maturity.

Stage of maturity affects the digestibility of forage not only because of changes in the chemical composition but also because of changes in physical state of the forage (Schneider and Flatt, 1975). With advancing plant maturity there is an increase in cell wall material and a decrease in nitrogen concentration, and because of this the nutritive value decreases (Streeter et al., 1971; Hume and Purser, 1974).

Minson et al. (1960), in their studies of the digestibility of S 37 orchardgrass and S 23 ryegrass and S 24 ryegrass, found that digestible organic matter (%) of first growth in spring remained constant until the emergence of the inflorescence from

the leaf sheath, and then fell rapidly at the rate of approximately 0.5% per day. This rate is similar to that reported by Reid et al. (1959). Similar changes have also been observed by Corbett et al. (1963) in a mixed species pasture composed mainly of ryegrass, orchardgrass, timothy and clover. They found that organic matter digestibility in spring remained at about 82% for some time, before declining to approximately 65%; in summer there was a continuous decline from the spring maximum at the rate of 0.2 units daily. Corbett et al. (1963) concluded that the digestibility of organic matter of aftermath herbage was at least 5 to 10 units lower than that of early spring grass, but that it declined more slowly than in first growth forage.

Reid and Jung (1965a), in their studies with several grass and legume species fed as clipped herbage, showed a significant effect of stage of maturity on dry matter digestibility. Reid et al. (1976b) also demonstrated with clipped tall fescue under different fertilization treatments that there were significant differences in dry matter and protein digestibility due to stage of maturity in both growth phases of the grass (first cutting and regrowth). In the first growth, the rate of decline in dry matter digestibility was 0.45% units per day for the N treated herbage and about 0.25% units per day for the non-nitrogen treated grass. They further showed that the dry matter digestibility of tall fescue in the vegetative phase in all regrowths was uniformly lower than digestibility of the vegetative growth in the first cutting. In evaluation studies with orchardgrass, Reid et al. (1967a) reported

a marked decrease of digestibility of frost-killed herbage in March. These results agree with the studies of Greenhalgh and Runcie (1962), who observed that the digestibility of orchardgrass declined with advancing maturity under two grazing systems (strip grazing and zero grazing).

New Mexico workers have noted that the digestibility of range grasses was highest during the months of June, July and August, when protein, ether extract, phosphorus and carotene contents were highest (Hatch, 1968; Boggine, 1970; Cordova, 1977; cited by Van Eys, 1978).

(b) Chemical composition.

Schneider and Flatt (1975) noted that apparently similar feeds, which differ in chemical composition, will show differing digestibilities. Also, Schneider and Lucas (1950) showed that between 25 and 45% of the total variability in digestibility of differing samples of the same feed could be traced to variations in the chemical composition.

It was noted by Van Soest (1964) that chemical composition is much more closely related to digestible dry matter than to voluntary intake. In 1969, Van Soest stated that digestibility is the cumulative effect of cellular contents which ferment rapidly and of the more slowly digesting cellulose and hemicellulose. This suggests that a reliable method of predicting digestibility would depend on the accurate assessment of chemical constituents in a forage.

Van Soest and Jones (1968) noted a decline of 3.0 units of dry matter digestibility per unit of silica in the dry matter of grasses. Powell *et al.* (1978), in a stepwise multiple regression analysis of herbage composition on *in vivo* dry matter digestibility of four temperate grasses, found the concentration of acid detergent fiber (ADF) to be the most important single factor influencing dry matter digestibility of the herbage for lambs, accounting for 68% of the variability in *in vivo* digestibility. Incorporation of magnesium concentration (%) and apparent absorption of calcium increased the proportion of the variability accounted for to 81%, and inclusion of silica (%) and potassium (%) further increased the R^2 value to 87%. Powell *et al.* (1978) also showed that the *in vitro* dry matter digestibility (%) of pasture samples in all trial periods was related significantly to concentrations of N, cell wall components (CWC), cell solubles, acid detergent fiber, hemicellulose, lignin and silica, and that the concentration of lignin was the most important variable, accounting for 79.9% of the variation in IVDMD. Earlier, Smith (1971) had shown that IVOMD of range forage could be predicted from a multiple regression equation involving only CWC, acid detergent lignin (ADL), silica and ether extract. Silica decreased IVOMD by 1% for each percent increase in silica content of the forage.

As lignin is bound tightly to the plant polysaccharides, it causes marked reductions in the digestibility of plant fiber by rumen or cecum microorganisms in the alimentary canal (Maynard and

Loosli, 1969; Gould, 1969; Tarkow and Feist, 1969). Lignin probably reduces fiber digestibility through physical incrustation effects and the formation of lignin-carbohydrate complexes and molecular bonds (Raymond, 1969). Lignin may form direct linkages to the structural carbohydrates, cellulose and hemicellulose (Van Soest, 1968). Several workers have shown that as the concentration of lignin increases, percentage dry matter digestibility decreases (Jones 1970; Tomlin et al., 1965; Morrison, 1972).

(c) Grass species.

Minson et al. (1960), in 125 digestion trials with cut herbage fed to sheep, found that, for both first growth and regrowth grass, orchardgrass was consistently lower in digestible organic matter (%) than ryegrass at the same growth stage. From this study it was concluded that different grasses can, in fact, have different digestibilities even when at the same stage of morphological development. Similarly, Alder and Cooper (1967), in feeding trials with calves, reported that perennial ryegrass was more digestible than orchardgrass at all growth stages. Powell et al. (1978), in feeding trials with cut herbage, found significant differences between the in vivo digestibility of cool temperate grass species and showed that tall fescue was lower in DMD than perennial ryegrass, smooth bromegrass and orchardgrass in the vegetative growth in two years, although differences were not so evident for more mature herbage in either year. For the same grass species, Powell et al. (1978) showed also that the IVDMD for tall fescue during the grazing

season was lower than for all other grasses. In contrast, Reid and Jung (1965a) reported little difference between the dry matter digestibility of several species of grass and legume harvested on the same date and fed as cut herbage to wether lambs. Similarly, Jacobson et al. (1970) found no differences in the dry matter digestibility of tall fescue, orchardgrass and bluegrass in grazing trials with yearling cattle.

(d) Level of intake.

Increasing the level of intake is associated with a decrease in digestibility (Schneider and Flatt, 1975). Forbes et al. (1930) showed that the decline in digestibility was greater at higher levels of feed intake. It was also shown by Eckles (1911) that Jersey cows digested feeds more efficiently on a maintenance than on a full ration. On a full feed, 66.3% of the ration was digested, as compared to 73.8% at the maintenance level of intake. Irman and Smith (1941), however, showed that digestibility was not affected by higher levels of feed intake.

Mitchell et al. (1932) also found that the lowest level of feeding resulted in the most complete digestibility of all nutrients. This was supported by Forbes et al. (1937), who noted with steers that the digestibility of crude protein, dry matter and organic matter was highest at the maintenance level of feeding. Blaxter and Wainman (1964) showed the same effect with sheep. Watson et al. (1935), however, found no decrease in digestibility by increasing the amount of hay fed to steers from 4.5 to 9.0 kg per head daily.

Waite et al. (1962) fed ryegrass hay cut at four different stages of growth to sheep at various levels of intake. They found that the first two cuts, with crude protein concentrations of 18 and 15%, had little difference in digestibility, but that the third and fourth cuts, with crude protein levels of 14 and 10%, respectively, showed a higher digestibility of structural carbohydrate when fed below maintenance level.

It was observed by Watson et al. (1939) with corn silage fed to steers at intakes ranging from 8 kg per day to ad lib. consumption, that the apparent digestibility of dry matter, organic matter, crude fiber and nitrogen-free-extract decreased with increasing levels of intake, whereas protein digestibility remained unchanged. Colovos et al. (1970) also found that the digestibility of corn silage decreased with increasing level of intake both with sheep and cattle.

With first growth green forage, Anderson et al. (1959) found no change in digestibility associated with level of feeding, but with the aftermath green forage the digestibility was increased by 2-4% at the lower level of intake. Campling et al. (1961) noted little or no effect of level of intake on digestibility of long hay. The same authors (1963) observed with chopped hay no significant change in digestibility associated with increasing level of consumption. However, Blaxter and Graham (1955) and Armstrong (1964) reported that digestibility of both long and chopped forages decreased with increasing level of intake. Blaxter (1961) and Campling et al. (1963) also showed that digestibility of ground and pelleted

forages decreased as forage intake increased.

e) Fertilization.

Magnesium.

Studies on the effect of magnesium fertilizer on dry matter digestibility are limited. Florida workers reported that magnesium is required for optimum cellulolytic activity by rumen micro-organisms (Martin et al., 1964; Ammerman et al., 1971). Studies in West Virginia by Reid et al. (1974) indicated that fertilization with magnesium oxide at low or high levels of 67 or 336 kg Mg/ha resulted in an increase in dry matter digestibility of orchardgrass by sheep. Recent studies by Reid et al. (1979) have shown that kieserite fertilization had no effect on dry matter digestibility of alfalfa treated with four levels (0, 112, 224 and 448 kg Mg/ha) of magnesium. It has also been shown by Shockey (1979) that dry matter digestibility of orchardgrass by lambs remained unchanged by kieserite fertilization in first and regrowth herbage. Reid (1980) found Mg level to have a negative effect on digestibility, with an estimated depression of 4.6 DMD units for each increase of 0.1% Mg in the forage.

Nitrogen.

Reid et al. (1967) investigated the effects of amount and type of fertilization on the nutritive value of K.31 tall fescue, and noted that for zero-grazed and grazed forage, the digestibility of dry matter was increased significantly by level of nitrogen, or nitrogen and phosphorus, fertilization. This was also noted earlier by Holmes and Lang (1963), who observed a higher

digestibility of cut herbage treated with a high level of nitrogen in steer feeding experiments. In contrast, McCarrick and Wilson (1966) reported that the digestibility of dry matter of conserved herbage by sheep was depressed by nitrogen. However, Hodgson and Spedding (1966) found minor differences in *in vitro* digestibility of ryegrass pastures treated with levels of nitrogen ranging from about 190 to 1000 kg N/ha/annum.

In 1967, Reid *et al.* made a study of the nutritive quality of orchardgrass fertilized at four nitrogen levels (0, 56, 168 and 504 kg N/ha) and showed that nitrogen fertilization had a significant effect on the digestibility of protein in the cut herbage. They also observed that, while there was little difference in digestibility coefficients for dry matter, cellulose and protein among three cuttings made in 1965, there was a significant decline in digestibility of all treatments fed as cut herbage in March, 1966.

For first-cut hay, Bratzler *et al.* (1959) and Mackley *et al.* (1959) found an increase in the percent of protein and in its apparent digestibility with nitrogen fertilization. Poulton (1962), with aftermath hays, found a similar increase in the digestibility of protein with increasing levels of nitrogen application.

Sulfur.

Kennedy *et al.* (1972) studied the influence of sulfur on the digestibility of spear grass and observed that when 0.2g sulfur was added to the diet of sheep, the dry matter digestibility

increased significantly, from 35.8 ± 4.9% to 51.9 ± 1.2%. Australian workers (Rees et al., 1974) have reported that sulfur fertilizer increased dry matter digestibility of pangola grass. They also showed that the higher digestibility of the sulfur treated grass appeared to be due to a more active rumen fermentation, which increased digestibility of dry matter in the rumen from 13% for the control to 34% for the sulfur-fertilized grass. This is supported by the results of other workers - Bull (1971), for example, found that sulfur was required to promote cellulose and starch digestion by rumen microorganisms under in vitro conditions. Lancaster et al. (1971) showed that increasing levels of sulfur added to sulfur deficient soil significantly influenced rumen microbial activity on orchardgrass and Ladino clover, but not on alfalfa.

Bray and Hemsley (1969) are of the opinion that a primary effect of sulfur deficiency is an inhibition of rumen microbial function. Using diets based on oat hulls, urea and a mineral mixture, they found that supplementation with sulfate increased crude fiber and dry matter digestibility; they thus concluded that S deficiency inhibited rumen microbial protein synthesis.

(f) Environmental factors.

Christopherson (1976) observed a reduction in the digestibility of food in calves and steers exposed to cold winter temperatures in Western Canada. Westra (1975), in an experiment with shorn sheep given brome grass either as hay or pellets, observed a significant reduction of the apparent digestibility of dry matter

and fiber for sheep exposed to 0.8°C for 4 weeks as compared to animals maintained at 17.7°C. He found that the reduction were associated with a significant depression of mean retention time of forage in the alimentary tract. Graham (1964) obtained similar results for closely shorn sheep exposed to a temperature of about 10°C in the laboratory. Similarly, Kennedy et al. (1972) in trials with closely shorn sheep given brome grass pellets at 1 hr intervals and maintained at ambient temperatures of -1 to 1°C and 18 to 21°C for 28 days, observed a reduction in apparent dry matter and organic matter digestibility at the lower temperature. They also noted a decrease in apparent digestibility in the rumen. Similar results were obtained by Thomson (1972), who reduced the particle size of forages by grinding and pelleting.

(g) Animal Species.

Lancaster (1949) and Ivins (1960) reported that sheep digested herbage to a greater extent than cattle. Other workers have observed only small differences between cattle and sheep (Corbett, 1960; Harkess, 1963; Langlands et al., 1963). It was noted by Thomas and Campling (1976) that coefficients of digestibility of organic matter tended to be slightly higher in cows than in sheep, but the differences were small and statistically significant on only two occasions.

Playne (1978) concluded that cattle digested low quality tropical hays significantly better than did sheep, and that differences increased as digestibility decreased. This supports

reports by other workers, who have shown that when roughages of low digestibility (<50%) are consumed, cattle usually digest them much better than do sheep (Playne, 1970; Siebert and Kennedy, 1972; Bird, 1974). Playne (1978) showed that 60% more of the hemicellulose and 35% more of the cellulose were digested by cattle than by sheep. Playne (1978) therefore proposed the following equation to be used for low quality forages of less than 60% apparent digestibility to convert data for sheep to cattle:

$$Y = 0.673\ X + 20.3$$

where Y = digestibility of hay by cattle (%) and X = digestibility by sheep.

As suggested by Bird (1974), part of the difference in dry matter digestibility may relate to the fact that cattle recycle relatively more sulfur in the saliva to the reticulo-rumen than do sheep.

Gihad (1976) observed that sheep and goats had a similar ability to digest the various nutrients present in hay, with the exception that goats digested crude fiber better than did sheep. These results are in agreement with those of Jang and Majumdar (1962), but contrary to those of Jones et al. (1972).

MINERAL UTILIZATION

Magnesium.

Magnesium is closely associated with calcium and phosphorus, both in its distribution and in its metabolism. Approximately 70% of the body supply is in the skeleton, the remainder being found widely distributed in the various fluids and other soft tissues (Maynard et al., 1979). Apart from being a constituent of bones and teeth, magnesium activates various enzymes - all enzymes transferring phosphate from ATP to ADP. It is also a cofactor for decarboxylation for certain peptidases and for alkaline and acid phosphatases. Animals require magnesium for proper neural function; magnesium deficiency leads to increased neuron excitability and neuromuscular transmission (Wacker and Parisi, 1968).

Magnesium deficiency is the primary cause of hypomagnesemic tetany in cattle and sheep and the clinical signs are: nervousness, twitching of muscles, labored breathing, rapid pulse, convulsions and death (Underwood, 1966). These clinical signs are associated with subnormal levels of magnesium in the blood. Clinical signs may be found at blood levels of 1.0 to 1.7 mg Mg per 100 ml but are most likely to occur when the concentration falls below 1.0 mg/100 ml (Underwood, 1966). Subnormal serum calcium levels have been found to accompany the low serum magnesium values in most studies of hypomagnesemic tetany in cows and ewes (Underwood, 1966).

Availability of magnesium may be affected by a number of

factors associated both with the animal and with the diet. These include: a) species and physiological status of the animal; b) level of intake of the element and feed; c) condition of the forage, i.e. whether fed as fresh herbage or in a conserved form such as hay or silage; d) type of forage; possible class, genus, species, cultivar differences; e) stage of maturity and cutting (Reid, 1980).

a) Species and physiological status of the animal.

In trials in which orchardgrass was fed at fixed intake to young guinea pigs and growing wether lambs, Reid et al. (1978) found mean apparent absorption coefficients of magnesium of 30.7% and 85.7% for the lambs and guinea pigs, respectively. Trials by Van Eys et al. (1980) with tall fescue and fescue-red clover pastures fed ad lib. to wether sheep, beef calves (4-5 months old) and dry beef cows, showed that apparent absorption of magnesium was consistently higher for the mature sheep than for the beef cows. Also, the apparent absorption of magnesium by the calf tended to be higher than for the beef cow fed the same herbage.

Lomba et al. (1968) investigated the effects of pregnancy and lactation on magnesium absorption. By feeding a variety of rations, they found a mean value of 23.1% for dry dairy cows as compared to a mean value of 27.8% for lactating cows.

b) Level of intake.

It has been stated by Mills (1969) that the percentage of magnesium absorbed is not affected materially by dietary amount, as urinary magnesium excretion is the main route of homeostatic

regulation in ruminants. Balance trials by Joyce and Rattray (1970a) support this statement. These workers fed diets containing white clover and perennial ryegrass to lambs at ad lib. and restricted intake levels. At mean magnesium intakes of 2.20 and 1.31 g/day for the ad lib. and controlled groups, respectively, there were no differences in apparent absorption of magnesium. Similarly, Hutton et al. (1965) observed no relationship between magnesium intake and percentage absorption in dairy cows fed pasture herbage. In contrast, considerable evidence suggests that the availability of magnesium may be dependent on the amount of magnesium consumed. Lomba et al. (1968) found a significant correlation between intake and absorbed amount of magnesium; the greater the magnesium intake, the greater was the absorption. Garces and Evans (1971) also observed a marked influence of ingested magnesium on its apparent absorption in growing cattle. Similarly, Dutton and Fontenot (1967) found significantly higher absorption of magnesium in wether sheep fed high magnesium diets.

c) Condition of forage.

Generally, Mg fertilization appears to be significantly reduced when animals are fed fresh herbage. From ^{28}Mg studies, Care and Ross (1961) observed a decrease in plasma Mg concentration following a change in diet from hay to young green grass. They also found marked differences in magnesium absorption values for hay and grass diets, 16% and 10%, respectively.

d) Type of forage.

A review by Mayland and Grunes (1979) has shown variations between plant species in their ability to accumulate magnesium. It is recognized that hypomagnesemic tetany in cattle occurs less frequently when the diet contains appreciable proportions of legumes (Reid, 1980). Balance trial data by Van Eys et al. (1980) also indicate that magnesium in fescue-red clover herbage is generally more available in terms of apparent absorption and retention to ruminant species than is the magnesium in pure fescue. Also, in a study with four perennial grass species (perennial ryegrass, smooth brome, orchardgrass, tall fescue) fed as fresh herbage at two growth stages to lambs, Powell et al. (1978) reported differences ($P<0.05$) in apparent absorption of magnesium.

e) Stage of growth.

Stage of growth appears to affect the availability of magnesium in herbage. L'Estrange et al. (1967) found that as herbage dry matter digestibility declined with maturity from 80 to 73%, magnesium availability increased. Similarly, Rook and Campling (1962) observed increased availability of magnesium with stage of growth. They found that 7 to 10% of magnesium intake was absorbed at early stages and 12 to 20% at later stages of growth. They suggested that there may be certain characteristics of herbage at an early stage of growth which reduce the availability of magnesium. However, it was proposed by Care and Ross (1961)

that lower magnesium availability in spring herbage was a result of processes taking place in parts of the alimentary tract by which the permeability of the intestinal wall to Mg^{+2} within the Lumen was diminished. It was also shown by Kemp et al. (1961) with lactating cows, that there was an increase in the availability of magnesium as herbage matured, and that the change was associated with a decrease in the concentration of N, K and P in the plant.

f) Other factors.

Magnesium absorption may also be influenced by plant concentrations of nitrogen, potassium, readily available carbohydrate, calcium, organic acids and higher fatty acids (Fontenot, 1979; Littledike and Cox, 1979). Fontenot et al. (1973) reported that potassium fertilization decreased magnesium utilization in ruminants by causing a decrease in magnesium absorption. This worker considered also that high nitrogen levels did not interfere with magnesium absorption but decreased magnesium utilization either by increasing urinary magnesium or through some alteration in the plant (increased crude protein and potassium concentrations). L'Estrange et al. (1967) agreed with the conclusions of Fontenot et al. (1973). Wethers fed herbage from pastures that received high levels of nitrogen fertilizer did not utilize magnesium differently from wethers fed control herbage. In contrast, Stillings et al. (1964) reported a low magnesium absorption by ruminants consuming nitrogen fertilized pastures. Similarly, Reid et al. (1974) showed that the availability of magnesium to

lactating goats was reduced by nitrogen at higher levels of fertilization.

Higher fatty acids (long chain fatty acids) are thought to complex magnesium and form insoluble soaps of magnesium which may pass undigested through the alimentary tract (Butler and Jones, 1973).

Organic acids can be thought of as chelating agents which can bind magnesium and reduce its availability. Burau and Stout (1965) found unusually high concentrations of transaconitic acid in tetany prone pasture in early spring. While concentrations of 1 to 2.5% organic acids on a dry weight basis are common in mixed pasture grass, work by Stout et al. (1967) showed that 47% of the 95 forage species sampled contained high levels of transaconitic acid (<0.2% low; 0.2-1% medium; > 1% high). Periods of cool weather, such as late fall, winter or early spring, were the conditions conducive to organic acid production.

Dietary calcium appears also to affect magnesium utilization. Chicco et al. (1973) concluded, from evidence based on fecal excretion and bone and plasma magnesium levels, that increased dietary calcium decreased magnesium utilization in ruminants. This may be related to the suggestion that calcium and magnesium may compete for the same absorption sites in the alimentary tract (Rook and Storry, 1962; Care and Van't Klooster, 1965).

Calcium and Phosphorus.

The amount and utilization of digestible dietary calcium and

phosphorus may be related to the amounts of either mineral in the diet. The ratio of calcium to phosphorus also appears to be an important determining factor. Young et al. (1966) reported lowered calcium absorption in sheep given a diet low in phosphorus. With a phosphorus deficient diet they observed that not only was the availability of phosphorus lower but that this reduction in phosphorus availability was due to a wide Ca:P ratio (10.4 to 1), since a wide ratio had no apparent effect when dietary P was adequate. However, Leuker and Lofgreen (1961), in feeding studies with growing lambs, observed no effect of three dietary ratios of Ca:P (0.8 to 1, 2.8 to 1 and 6.0 to 1) on the amount of either Ca or P absorbed. They found that the amount absorbed was directly related to the amount fed.

In contrast to the apparent effects of calcium and phosphorus on their utilization, it appears that magnesium has little effect on the utilization of either calcium or phosphorus. Studies by Hjerpe (1968a) in which sheep were fed varying levels of dietary magnesium have shown that low and normal levels of dietary magnesium had no effect on calcium absorption. However, with high levels of magnesium intake he observed that the most slowly equilibrating body calcium pools were significantly reduced in size. From this and other results (Hjerpe, 1968b), it was suggested that chronic hypomagnesemia had little effect on calcium metabolism. Similarly, Field (1962) found no interrelationships between calcium and magnesium metabolism in wethers fed various levels of grass.

The apparent absorption of calcium and phosphorus in ruminants fed fresh herbage may be quite low and may vary considerably between animals. Joyce and Rattray (1970) reported average phosphorus availabilities in sheep of 10%, while the availability of calcium averaged 26%. L'Estrange and Axford (1966) found the percentage of calcium intake excreted in the feces of sheep on grass diets to be 99 to 100%, with Phosphorus values of 63 to 92%. They pointed out that sheep were in marked negative calcium balance on these grass diets. In balance studies with dairy cattle fed pasture herbage, Hutton et al. (1967) observed mean calcium and phosphorus availabilities of 22.5% and 34%, respectively. For wether lambs fed chopped alfalfa hay, the apparent availability of calcium was shown by Lofgreen and Kleiber (1953) to be 22%.

Another factor which affects the absorption and utilization of calcium and phosphorus is age of the animal. Hansard et al. (1957) noted that the true digestibility of 15 different inorganic sources of calcium was greater in young than in mature cattle, and that the difference due to age was greater than that due in the calcium source itself.

Estimates of the apparent availability of dietary calcium and phosphorus are generally considerably lower than true availability values, since they ignore metabolic endogenous losses were accounted for, but only 12% when they were not. Similarly, Lofgreen and Kleiber (1953) found the apparent and true

availabilities of phosphorus in sheep given alfalfa hay to be 22% and 91%, respectively.

NUTRITIVE VALUE OF ORCHARDGRASS

Orchardgrass is a cool season grass that grows in clumps, producing an open sod. It starts growth early in spring, develops rapidly and flowers during late May or early June depending on day length temperature and cultivar.

In North America, orchardgrass is found from southeastern Canada to the Northern part of the Gulf States and from the Atlantic Ocean to the Eastern Great Plains (Jung and Baker, 1976).

As the spring crop advances from the vegetative stage to seed formation, protein concentration and dry matter digestibility decrease whereas cell wall components increase. These changes are associated with decreasing levels of consumption. Fructosan concentration, which is an indication of available energy, appears to be lower in orchardgrass than in some other grasses such as ryegrass. It is especially low in summer and when fertilized with high rates of nitrogen (Waite, 1958; Waite and Boyd, 1953). Aftermath forage is leafy and generally does not decline in feeding value with time (Jung and Baker, 1976).

In orchardgrass, percent of K, P, Ca, Mg, Zn, Co and Mo on a dry matter basis decreases with advancing growth stage. Copper however, appears to be uniform at successive stages of growth. First cut herbage is generally higher in K, Cu, Zn and Fe than aftermath but P, Ca and Mg are generally higher in the aftermath

(Reid *et al.*, 1970).

EXPERIMENTAL PROCEDURE

A series of grazing and digestibility trials on orchardgrass were carried out in 1977 and 1978 using sheep and beef cows. The major objectives of the trials were: (1) In 1977, to examine seasonal variation in the dry matter digestibility and intake of orchardgrass pastures by grazing beef cows. (2) In 1978, a) to determine effects of fertilization of orchardgrass pastures with with kieserite onnutritive quality and on its mineral composition and utilization; b) to examine seasonal and growth stages effects on intake and digestibility of pasture by grazing cows.

In 1977, four indoor and outdoor trials were conducted using 22 mature beef cows (Angus and Hereford ranging from 5-10 years of age). Eighteen lactating cows with their calves were assigned to pasture and four indoor cows were fed cut herbage in individual stalls. In 1978, three indoor trials using mature wether sheep and four outdoor trials using 24 mature lactating cows with their calves were conducted. The indoor animals were used to establish a regression equation to predict dry matter digestibility of herbage using fecal N as an indicator. The indoor and outdoor trials were run concurrently.

The dates of the trials and corresponding growth stages of orchardgrass were as follows:

Year	Trial Number	Date	Growth stage of orchardgrass
1977	1	4/27-5/6/77	1st Growth (Vegetative stage)
1977	2	6/20-6/29/77	Mature (Full bloom stage)
1977	3	8/13-8/22/77	1st Regrowth (Vegetative stage)
1977	4	10/9-10/18/77	2nd Regrowth (Vegetative stage)
1978	1	5/9-5/18/78	1st Growth (Vegetative stage)
1978	2	6/12-6/21/78	1st Regrowth (Full bloom stage)
1978	3	8/9-8/18/78	2nd Regrowth (Vegetative stage)
1978	4	10/18-10/27/78	3rd Regrowth (Vegetative stage)

In 1977, six orchardgrass paddocks of 0.7 ha each at the West Virginia University Agronomy farm were used for the trials. The pastures were established on a Gilpin silt loam soil, a member of the fine-loamy, mixed, mesic family of typic Hapludults. The soil analysis showed that pH was in the range of 6.3-6.6 and contained adequate phosphorus and a high level of potassium. For each grazing trial, two paddocks were used. All 18 cows with their calves remained in one paddock for 5 days and then were moved to the second paddock for the 5 days collection period.

A small area within the one used by the grazing animals

was reserved for feeding herbage in the indoor trials. Every morning enough herbage was cut for the indoor animals using a rotary mower. These indoor animals were fed ad lib. with a 10-15% rejection level twice a day - at 9:00 a.m. and 3:00 p.m.

In 1978, replicated orchardgrass pastures (0.7 ha each) were treated with and without kieserite ($MgSO_4 \cdot H_2O$) at the rate of 2240 kg/ha (equivalent to 390 kg Mg/ha) in March, 1978. The soil analysis showed that pH was in the range of 6.3-6.8, with adequate P and a high K status as defined by West Virginia University soil testing procedures. All pastures also received nitrogen (112 kg N/ha as ammonium nitrate) following the kieserite treatment.

Twenty four lactating beef cows (Angus and Hereford) were allocated to kieserite treated and untreated pastures (six cows on each of four pastures) on a completely randomized basis at the beginning of May, 1978, with the orchardgrass at the vegetative stage. The cows had calved within the previous six weeks and had been maintained on a good quality orchardgrass hay with a salt and dicalcium phosphate supplement.

Two paddocks (fertilized and unfertilized) were used for the indoor trials with sheep in 1978. Herbage from fertilized and unfertilized areas was clipped once daily with a rotary mower and fed ad lib. with a 10-15% rejection level. Feeding was done twice a day, at 9:00 a.m. and 4:00 p.m.

In both trial years, dry matter determinations on the cut herbage were made immediately by drying weighed quantities of

herbage in a forced draft oven at 65°C. The dried samples were then composited for the 5 day period, ground through a 1 mm stainless steel sieve in a Wiley mill and retained for chemical analysis.

In both trial years, common salt was supplied as a supplement to grazing and stall-fed animals and water was provided by means of automatic waterers.

Chromic oxide was used as an external indicator to estimate fecal output by the grazing animals. During each trial, every morning between 9:00 a.m. and 12:00 noon, cows were brought into a holding pen and administered chromic oxide (Cr_2O_3). In 1977, the cows were dosed with 50 g of chromic oxide impregnated paper by balling gun each day. In 1978, the grazing cows were dosed with 20 g of chromic oxide in oil suspension in gelatin capsules. In all trials, the administration of chromic oxide was carried out for 5 days prior to and during a 5 day collection period.

In all trials animals were weighed at the beginning and end of each period. The average of the two weights was used to calculate metabolic size ($KgBW^{0.75}$) on which voluntary dry matter intake was based (Gihad, 1976).

Fecal samples for the indoor trials were obtained by total collection in a 5 day trial following a 5 day adjustment period. Cows in stalls were fitted with urinary catheters to separate feces from urine. Grab samples of feces from each animal on pasture were taken from the rectum once daily during the collection

trial periods. Fecal samples were composited for each animal. All fecal samples were dried at 65°C in a forced draft oven and ground in a Wiley mill through a stainless steel sieve (1 mm mesh) then stored for mineral and nitrogen determinations.

Pasture samples were taken each morning from the paddocks during the 5 day collection periods. Small samples representative of the pasture available were clipped at a height approx. 2 cm from the surface of the ground at several points throughout each paddock. These samples were bulked together for the 5 day period (about 1 kg was taken), dried at 65°C and ground in a Wiley mill (1 mm mesh), then stored for mineral and cell wall analysis.

Representative samples of refusals from grass fed in the indoor trials were also taken daily for cell wall analysis.

During the first two weeks of grazing trials in 1978, jugular blood samples were taken from all cows on pasture between 9:00 and 11:00 a.m. Blood samples were taken on these dates: May 5, 8, 9, 10, 12, 14, 15, 17 and 19. Serum separated from blood samples was frozen and stored for mineral analysis.

Analytical Procedures.

Chromic oxide in feces was analyzed according to the modified method of Stevenson and DeLangen (1960).

Nitrogen analyses on forage, feces, were run using the boric acid modification of the Kjeldahl method with copper sulfate and potassium sulfate as a catalyst (Willard et al., 1956).

Cell wall components (CWC) and acid detergent fiber (ADF) were

determined according to the method of Goering and Van Soest (1970). Lignin was determined by potassium permanganate treatment of the ADF residue. Cellulose was then estimated as weight loss after ashing the permanganate residue at 550°C for 3 hours. Silica determinations were made by treating the ash remaining after cellulose determinations with 48% hydrobromic acid (Goering and Van Soest, 1970). Cell solubles were calculated as (100-CWC) and hemicellulose as the difference between CWC and ADF (Goering and Van Soest, 1970).

Mineral analyses on forage and feces samples were run by an emission spectrographic technique at the forage testing laboratory, Pennsylvania State University, University Park, PA. Sulfur in herbage was determined by a Leco induction furnace procedure.

Serum samples for calcium and magnesium analysis were diluted 1:50 in 0.5% lanthanum chloride solution. The analysis for calcium and magnesium was by atomic absorption. Phosphorus was determined in serum by the Fiske and Subbarow (1925) method.

Dry matter digestibility (DMD) and intake were determined for indoor animals using standard procedures. For grazing animals, DMD (%) was determined from regression equations established with indoor animals using fecal N as an indicator (Lancaster et al., 1960). Intake by grazing animals was estimated from fecal chromic oxide analysis (Stevenson and DeLangen, 1960), combined with estimates of digestibility. Apparent absorptions of calcium, magnesium and phosphorus for herbage fed in indoor trials run in 1978 were determined using standard procedures.

Analysis of variance, regression, correlations and Duncan's

(1955) Multilpe Range analyses on experimental data were run by standard methods (Steel and Torrie, 1960). The following models were used in the analysis of variance:

1977 model: DMD(%), intake = plot x trial/solution

Test H: Trial; Error = plot (trial)

1978 model: DMD(%), %Fecal N, intake, apparent absorption of P, Ca, Mg = trial x fertilizer/solution.

Test H: Trial and Fertilizer, Error = Trial x Fertilizer.

RESULTS AND DISCUSSION

Grazing studies in 1977.

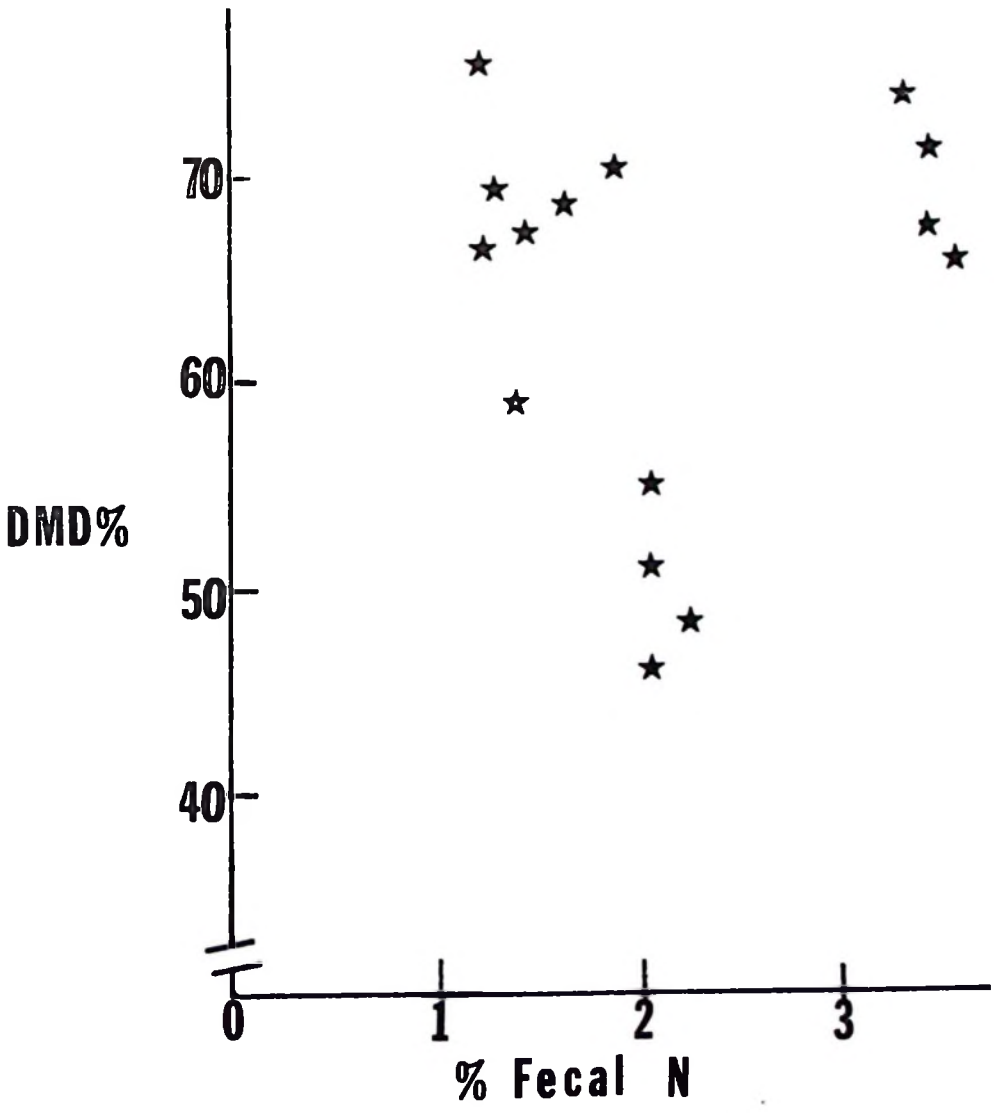
Trials run in 1977 were used primarily to look at seasonal variations in the dry matter digestibility and intake of orchardgrass pasture by grazing beef cows using fecal index and external indicator techniques. The basic principles for use of these techniques were discussed by Corbett (1960) and Brisson (1960).

Fecal N has been used most frequently as an indicator for the estimation of digestibility by grazing animals (Lancaster, 1949; Thomas and Campling, 1976). Regressions are established between the dry or organic matter digestibility of herbage cut at a range of growth stages from pasture similar to that grazed and the N content of feces from cows fed the forage in metabolism stalls. The nature of these regressions has been found to be either linear or quadratic in function (Raymond, 1954; Lancaster, 1954; Kennedy et al., 1959).

It is assumed that the nature of digestion of the cut herbage is essentially the same as that in the grazing animals, recognizing, however, that the animal on pasture has an increased opportunity for selection and that the N content of feces from the grazing cow or sheep will therefore generally be somewhat higher than that of its counterpart fed cut grass.

Data for the establishment of local regressions between dry matter digestibility and fecal N concentrations of cows fed cut orchardgrass in four trials in 1977 are plotted in figure 1. Mean

Fig. 1 Relationship between Fecal N and dry matter digestibility 1977 trials.



values for fecal N concentration, DMD(%) and intake are summarized in table 1 and values for individual cows are given in appendix table 1. It can be observed from this figure that the regression calculated between dry matter digestibility of cut orchardgrass fed *ad lib*. to cattle and the concentration of nitrogen in fecal dry matter was not significant. The lack of a relationship in these trials is not in agreement with many observations in the literature but might be due either to the short time of collection within trial (5 days), or to the number of animals being insufficient to determine the regression with an acceptable degree of precision. This was observed by Greenhalgh *et al*. (1960). However, it was shown by Minson and Raymond (1958) and Minson and Kemp (1961) that the major source of error was not animal variation but true differences in the nitrogen percentages of feces produced from different herbages having the same digestibility.

Since there was no relationship between DMD(%) and fecal N, the dry matter digestibility of grazed herbage was estimated from a previously established regression equation for orchardgrass developed under similar conditions (Reid *et al*., 1978). The equation was: $Y=47.9 + 9.02\ (\pm 1.0)$, where Y = DMD(%) and X = fecal nitrogen (%). Intake values were calculated from the estimated dry matter digestibility and fecal output data as measured by the chromic oxide technique, using the following equation (Smith and Reid, 1955):

Table 1. Effects of growth stage on intake (g/kgBW$^{.75}$) and DMD(%) of orchardgrass (Indoor cattle, 1977)[a]

Growth Stage	Date	Intake g/kgBW$^{.75}$	DMD	Fecal N %
1st Growth (Vegetative stage)	5/2-5/6/77	79.7^{c}	70.3^{a}	3.22^{a}
Mature (Full bloom stage)	6/25-6/29/77	98.8^{a}	65.6^{b}	1.50^{c}
1st Regrowth (Vegetative stage)	8/18-8/22/77	93.6^{ab}	64.2^{b}	1.41^{c}
2nd Regrowth (Vegetative stage)	10/14-10/18/77	90.2^{b}	50.4^{c}	2.02^{b}

[a]Mean values in 1st, 2nd and 4th trials for 4 indoor cows and in 3rd trial for 3 indoor cows.

[abc]Columns with different superscripts are different at 0.05% level by Duncan's Multiple range test.

$$\text{Herbage intake} = \frac{\text{Fecal dry matter output}}{\text{Indigestibility of Herbage DM(\%)}}$$

Effects of growth stage on intake and DMD(%) by grazing cows.

The effects of growth stage on intake and digestibility of herbage by grazing cows are summarized in table 2. The intake of first growth grass in early May was higher ($P<0.05$) than intakes at other growth periods. This may relate to the lower cell wall content of first growth herbage as compared to the other growth stage (Appendix Table 7). Intake of mature (full bloom) orchardgrass was not different from that of the first regrowth, but was greater than that of the second regrowth. Herbage harvested in these trials had similar concentrations of cell wall components (Appendix Table 7).

The correlation coefficient between DMD(%) and intake of orchardgrass by grazing cows was + 0.34 and significant ($P<0.01$). Reid et al. (1976b) found a non-significant correlation between digestibility and intake in trials with first growth herbage, but with aftermath herbage the correlation was positive and highly significant. Trials by Harris and Raymond (1963) with sheep showed no relationships. With strip grazed cows, Corbett et al. (1963) found a curvilinear relationship between digestibility and intake.

Dry matter digestibility (%) for first growth herbage in May was not higher ($P>0.05$) than for the October regrowth herbage, but was higher ($P<0.05$) than for mature and first regrowth orchardgrass. However, DMD(%) for mature herbage was not different ($P>0.05$) from

Table 2. Effects of growth stage on feces output, fecal nitrogen, DMD(%) and intake by grazing cows in 1977[a].

Growth Stage	Date	Feces	Fecal N %	DMD %	Intake g/kgBW.75
1st Growth (Vegetative stage)	5/2/-5/6/77	2573[b]	2.57[a]	71.2[a]	88.1[a]
Mature (Full bloom stage)	6/25-6/29/77	3056[a]	1.66[c]	63.1[bc]	83.6[b]
1st Regrowth (Vegetative stage)	8/18-8/22/77	3070[a]	1.37[c]	60.3[c]	79.6[bc]
2nd Regrowth (Vegetative stage)	10/14-10/18/77	2444[b]	2.18[b]	67.6[ab]	76.4[c]

[a]Mean values for 15, 17, 18 and 15 cows for the 1st growth, mature, 1st and 2nd regrowth stages, respectively.
[abc]Columns with different superscripts are different at 0.05% level by Duncan's multiple range test.

that of first regrowth herbage. Concentrations of CWC, cell soluble material, ADF, lignin and silica were shown to be quite similar (Appendix Table 7) at these growth stages. Van Soest and Jones (1968) noted a decline of 3.0 units of dry matter digestibility per unit of silica in the dry matter of grasses. The silica content of first growth grass in this study was 0.67%, compared to 1.4% and above in herbage grazed later in the season. Also the lignin, CWC, ADF and cellulose concentrations were lower, and level of cell soluble material markedly higher, for the first growth orchard-grass than for the other growth stages. Several workers have shown that as the concentration of lignin, or the ratio of lignin to ADF, increases, percentage dry matter digestibility, decreases (Jones, 1970; Tomlin et al., 1965; Morrison, 1972).

Analysis of variance (Appendix Table 4) showed that intake influenced DMD(%) ($P<0.01$). However, relatively high DMD(%) values were maintained throughout the grazing season, even during the summer period. Since herbage availability was not a limiting factor, this probably reflected the ability of the animal to select herbage of higher digestibility.

Data for the comparison of DMD(%) and intake by indoor and grazing animals are given in table 3. Intake of herbage estimated by the two systems was not different with the exception of trial 2 in which intake of cut herbage was higher than that of grazed herbage. The results were unexpected in light of the fact that the grazing cows were lactating and lactating cows have generally been found to consume higher levels of pasture than

Table 3. Comparison of digestibility and intake data for indoor and grazing animals (1977)[a].

System	1977							
	I	II	III	IV	I	II	III	IV
	intake, g/kgBW$^{.75}$				DMD%			
Indoor	79.7	98.6	93.6	90.2	70.3	65.6	64.2	50.4
Grazing	88.1	83.6	79.6	76.4	71.2	63.1	62.3	67.6
Significance	NS	*	NS	NS	NS	NS	NS	*

[a]Mean values in first period for 4 indoor and 15 grazing cows; in second period for 4 indoor and 17 grazing cows; in third period for 3 indoor and 18 grazing cows, and in fourth period for 4 indoor and 15 grazing cows.

*, NSSignificance of F values at the 0.05 level, and not significant, respectively.

non-lactating animals (Engles and Malan, 1979). It is possible that intake by the grazing cows may have been limited to some extent by effects of environmental stress. The grazing cows were not provided with shade on pasture and high temperatures are known to reduce pasture intake (Kellaway and Colditz, 1975). Climatological data taken in the area indicated that temperatures at the time of the second grazing trial were 75°F and above (Appendix Table 23).

The DMD(%) of herbage by grazing animals was higher ($P<0.01$) than that of cut herbage only in the fourth trial. It is difficult to explain these differences. Other workers have shown a higher DM digestibility of grazed as compared with harvested herbage. Reid et al. (1967a) found a difference of 10 to 15 percentage units of digestibility for sheep between grazed and cut orchardgrass, with the higher digestibility being apparently due to the increased opportunity for selection by grazing animals. Also, in their trials with tall fescue, Reid et al. (1976) noted an average of 2 percentage units difference in dry matter digestibility associated with the selection of herbage by grazing as compared to zero grazed sheep. Pearce et al. (1962) found the organic matter digestibility for grazing sheep to vary from 57 to 80% as compared to a range of 40 to 70% for caged sheep fed Wimmera ryegrass. Recently, Reid et al. (1978) noted minor differences in digestibility for grazing and housed animals, with the exception of one trial in 1973 in which DMD(%) of grazed herbage was 5 to 10 units higher than for cut herbage.

Digestion and Grazing Studies in 1978.

The major objectives of grazing trials conducted in 1978 were (a) to determine effects of fertilization of orchardgrass pastures with kieserite on nutritive quality and on its mineral composition and utilization; (b) to examine seasonal and growth stage effects on intake and digestibilities of pasture by grazing cows.

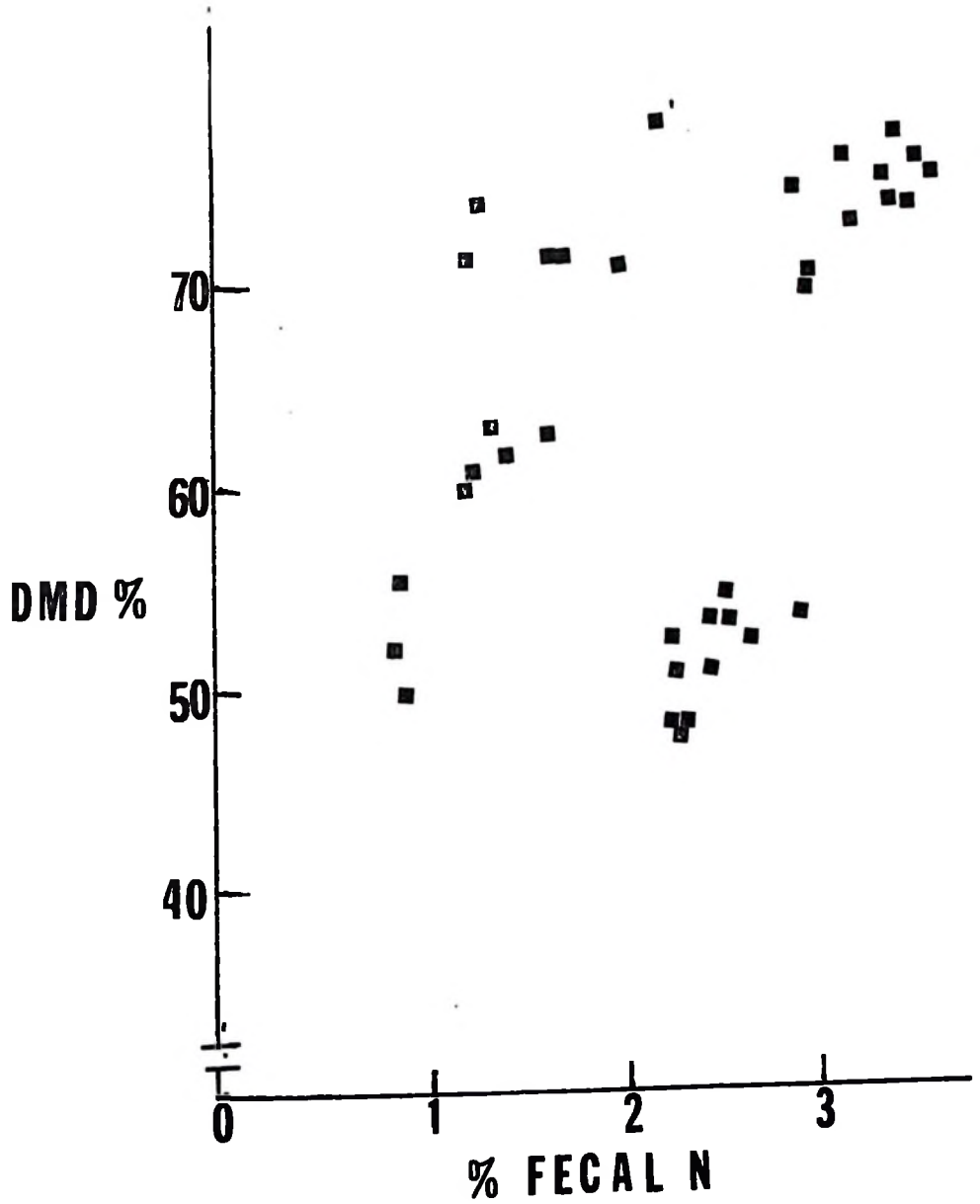
In 1978, sheep were used in the indoor trials both to examine the relationship between DMD(%) and fecal nitrogen and to determine seasonal effects on intake and digestibility and mineral availability of pasture. Several workers have shown that sheep and cattle digest herbage to about the same extent (Langlands, 1973; Thomas and Campling, 1976; Corbett, 1960). Also, Thomas and Campling (1976) showed that fecal N-DMD(%) relationship were the same in sheep and cattle. Labor saving is another advantage of using sheep instead of cattle. Data for dry matter digestibility (%), intake and mean fecal N concentration in trials in which fertilized and non-fertilized orchardgrass were fed to sheep are summarized in tabel 4 and values for individual cows are given in Appendix table 14. Results are plotted in figure 2. Again, statistical analysis failed to establish significant regressions between the DMD(%) of cut herbage and fecal N concentration. In considering possible reasons for the lack of success in obtaining significant relationships in both 1977 and 1978 it may be suggested that while in both years a reasonable range in DMD values was obtained(e.g. 56.6-73.3% in 1978 for combined treatments), regressions may have been affected

Table 4. Effects of growth stage on intake ($g/kgBW^{.75}$) and DMD(%) of orchardgrass (Indoor sheep, 1978).

Growth Stage	Date	Intake $g/kgBW^{.75}$	DMD %	Fecal N %
1st Growth	5/14-5/18/78	41.1^{b}	73.3^{a}	2.50^{a}
1st Regrowth (Full bloom stage)	6/17-6/21/78	57.0^{a}	66.4^{ab}	1.18^{c}
2nd Regrowth (Vegetative stage)	8/14-8/18/78	55.3^{a}	56.6^{b}	1.70^{b}

[a]Mean values for 12 sheep (treatments combined)
[abc]Columns with different superscripts are different at 0.05% level by Duncan's multiple range test.

Fig. 2 Relationship between Fecal N and dry matter digestibility 1978 trials.



by inclusion of both first growth and regrowth herbage in the analysis. Some evidence has been produced that the fecal N-DMD relationship may differ between different cuttings of pasture (Langlands, 1975). This appears to be the most probable cause of the discrepancy and it would indicate that a larger number of trials should have been conducted on orchardgrass between the vegetative and full bloom stage in the first growth cycle, and that further trials should have been run with regrowth herbage.

Again, therefore, estimates of DMD(%) by grazing cows in the 1978 trials were obtained by use of the established regression equation employed in the 1977 trials. While it would be expected that this approach would not result in accurate absolute values for estimated DMD values, it should allow for comparison of relative measurement of intake and digestibility associated with fertilizer treatment and growth stage of the pasture.

Effects of magnesium fertilization on intake and digestibility of cut and grazed herbage.

Data for DMD(%) and ad lib. intake of fertilized and non-fertilized orchardgrass by sheep fed cut herbage in 1978 are summarized in tables 5 and 6. Although magnesium fertilizer had no significant effect ($P > 0.05$) on DMD(%) and intake, it tended to decrease intake and digestibility. Results in the literature bearing on this relationship are conflicting; Reid et al. (1979) found no effect of magnesium fertilizer treatment on DMD(%) of alfalfa hay by lambs, but a significant positive effect ($P < 0.05$) on ad lib. intake in the first two years

Table 5. Effects of fertilization with kieserite on intake and DMD(%) of orchardgrass (Indoor sheep, 1978)[a]

Treatment	Trial 1 5/14-5/18		Trial 2 6/17-6/21		Trial 3 8/14-8/18	
	Intake $g/kgBW^{.75}$	DMD%	Intake $g/kgBW^{.75}$	DMD%	Intake $g/kgBW^{.75}$	DMD%
Fertilized	41.4	73.0	58.8	63.9	52.8	53.4
Non-fertilized	40.9	76.6	62.3	69.0	57.8	59.7
Significance	NS	NS	NS	NS	NS	NS

[a]Mean values for 6 sheep
NSNot significant

Table 6. Effects of fertilization with kieserite on intake and DMD(%) of orchardgrass (combined indoor trials for sheep, 1978)[a]

Treatment	Intake $g/kgBW^{.75}$	DMD %
Fertilized	50.0	63.5
Non-fertilized	53.6	67.4
S.D.	4.8	5.6
Significance	NS	NS

[a]Mean values for 18 sheep in three trials.
NSNot significant.

of the study but not in the third. They considered the increased intake to be due in part to lower levels of cell walls in the alfalfa fertilized at higher levels of kieserite. In this study the magnesium concentration (Table 12) was not increased and there was no difference in CWC concentration between the fertilized and control herbage (Appendix Table 21).

Reid and Jung (1974) observed with orchardgrass hays grown on magnesium-deficient soils in West Virginia that magnesium fertilization resulted in increases of DMD(%) by sheep, but had no effect on intake. Martin et al. (1964) and Ammerman et al. (1971) found that intake was much reduced in sheep fed purified diets deficient in magnesium. The concentrations of magnesium obtained in orchardgrass for control and fertilized treatments were much higher than in the Florida studies. It is therefore possible that the lack of effect of magnesium fertilization on digestibility and intake noted in the present trials may relate to the fact that magnesium concentration, or the availability of magnesium, in both fertilized and non-fertilized grasses may have been more than adequate to meet the metabolic requirements of the rumen micro-organisms, the host animal, or both. Results of balance trials (discussed in a later section) indicated that magnesium in orchardgrass is highly available.

Recent studies in West Virginia with cattle and sheep have shown that supplying MgO to cows fed corn stover in balance trials increased intake of the stover significantly (Bona et al., 1980). Also, provision of supplementary magnesium $MgSO_4$ in the water to

sheep fed timothy hay in balance trials resulted in significanct increases in dry matter intake of the hay (Reid et al., 1979). In both of these forages the concentrations and apparent absorption of magnesium were low, and magnesium supplementation markedly improved mineral retention and increased serum magnesium concentrations.

While differences in DMD(%) between fertilized and non-fertilized orchardgrass were not significantly different, the trend towards a lowered digestibility of dry matter with kieserite fertilization in all three trials is of considerable interest. Florida workers (Martin et al., 1965; Ammerman et al., 1971) reported that magnesium is required for optimum cellulolytic activity of rumen microorganisms and, as already noted, Reid et al. (1974) found that fertilization with MgO at levels of 67 or 336 kg Mg/ha resulted in an increased dry matter digestibility of orchardgrass hays by sheep. However, in reviewing the results of digestibility, intake and mineral balance trials run with a population of 221 herbages and hays fed to sheep over a 15 year period, Reid (1980) demonstrated that magnesium concentration of the herbage had a significant negative effect on digestibility, with an estimated depression of 4.6 DMD units for each increase of 0.1% Mg in the forage. Magnesium, calcium and phosphorus concentrations each had a significant and positive effect on dry matter intake by sheep. In a limited number of trials with temperate grasses (including orchardgrass), Powell et al. (1978) also found that not only the concentrations but the availability of magnesium, calcium and

phosphorus had a significant influence on the dry matter digestibility and intake of herbage.

Data for the effects of magnesium fertilization with kieserite on predicted intake and DMD(%) of grazed herbage are given in tables 7 and 8. Kieserite fertilization had a tendency to suppress intake and DMD(%). This is in agreement with the data obtained with cut herbage.

Effects of growth stage on intake and DMD(%) of cut and grazed herbage.

Data for the effects of growth stage on DMD(%) and ad lib. intake of cut herbage are given in table 4. There were significant effects ($P<0.05$) of trial on intake. Dry matter intake was lower ($P<0.05$) for first growth herbage than for other growth stages. Other workers have found similar effects (Reid et al., 1966; Reid et al., 1967; Shockey, 1970). The low intake of first growth in this study may in part be related to the dry matter content of the herbage (the correlation between dry matter content and intake in first growth herbage was -0.34 (Appendix Table 8). The effects of dry matter content on intake in the literature are conflicting. Arnold (1962) showed that voluntary dry matter intake of sheep was related to the dry matter content of the herbage when this fell below 25%. In this study, the dry matter content was below 15% in the first trial and over 20% in the other trials (Appendix Table 8). However, Reid et al. (1967a) showed no significant relation between herbage intake and the dry matter content of the

Table 7. Effects of fertilization with kieserite on digestibility and intake by grazing cows[a].

Treatment	Feces g	Fecal N %	DMD %	Intake $g/kgBW^{.75}$
(a) Trial 1	5/14-5/18/78			
Fertilized	2668	2.44	69.8	85.3
Non-fertilized	2648	2.55	70.9	84.3
Significance	NS	NS	NS	NS
(b) Trial 2	6/17-6/21/78			
Fertilized	2488	1.69	63.1	62.3
Non-fertilized	2614	1.69	63.1	66.4
Significance	NS	NS	NS	NS
(c) Trial 3	8/14-8/18/78			
Fertilized	2581	1.87	64.8	72.6
Non-fertilized	2463	1.88	64.8	69.6
Significance	NS	NS	NS	NS
(d) Trial 4	10/23-10/27/78			
Fertilized	2562	2.53	70.7	85.5
Non-fertilized	2470	2.66	71.9	86.6
Significance	NS	NS	NS	NS

[a]Mean values for 12 cows in each trial.
[NS]Not significant.

Table 8. Effects of fertilization with kieserite on DMD(%), intake, fecal output, fecal N% (%) (combined grazing trials for cows, 1978)[a]

Treatment	Feces g	Fecal N %	DMD %	Intake $g/kgBW^{.75}$
Fertilized	2611	2.1	66.4	74.8
Non-fertilized	2581	2.2	67.5	76.8
S.D.	401	0.1	1.1	14.0
Significance	NS	NS	NS	NS

[a]Mean values ±SD for 48 cows in 4 trials.
NSNot significant.

grass. Similar results have also been reported by McClusky (1955) and Holmes and Lang (1963) with cows.

The dry matter intake of vegetative orchardgrass was increased ($P<0.05$) (41.1 to 55.3 g/kgBW$^{.75}$) during the regrowth period although the DMD(%) of the regrowth was markedly lower. These values compare well with those of Reid et al. (1978), who showed an increase of 37.1 to 63.2 g/kgBW$^{.75}$ and those of Shockey (1978), who demonstrated an increase of 39.3 to 57.1 g/kgBW$^{.75}$ on feeding cut first growth and regrowth orchardgrass to sheep.

The intake of first regrowth orchardgrass at full bloom was not different from that of second regrowth at the vegetative stage. This may be related to similar concentrations of CWC in the grasses at these two growth stages (Appendix Table 18).

The regression equation obtained between intake and dry matter digestibility was: $Y = 6.92 - 0.005\ X$, sy. x $\pm$ 0.566, where Y = intake in kg and X = dry matter digestibility (%). The intercept was positively significant and the slope was not. This essentially means that dry matter digestibility had no effect on intake. These results are in agreement with the findings of Hutton (1963), who failed to show a relationship between the voluntary intake of cut herbage and its digestibility. Harris and Raymond (1963), Crampton et al. (1960) and Thomas and Campling (1976) reported that at high levels of digestibility there may not be any relationship between intake and DMD(%). In contrast, Hutton (1962a,b) showed that intake appeared to decline with decreasing digestibility of

herbage of less than 70% DMD.

Dry matter digestibility (%) of cut herbage was higher in May than in June and August. This may be related to the significant ($P<0.05$) differences in the ADF, lignin and silica contents of the herbage (Appendix Table 18). For example, the silica content of first growth herbage was 0.44% as compared to 1.47% and above at later periods.

The DMD(%) of first regrowth was not different ($P>0.05$) from that of second regrowth, although the first regrowth had a slightly higher DMD(%). Differences in their silica contents possibly accounted for this minor difference.

The effects of growth stage on feces output, fecal N concentration, intake and digestibility of grazed herbage are summarized in Table 9. The intake of first growth herbage was not different ($P>0.05$) from intake of herbage grazed in October, and intakes of first and second regrowth herbages were not different ($P>0.05$) from one another. This again may relate to similar concentrations of cell wall components (at these two periods) (Appendix Table 18).

However, these estimated intakes are relatively lower than those obtained by Reid *et al.* (1978) at the same site in earlier studies. For one period in May, intakes of 125.3 $g/kgBW^{.75}$ were obtained, compared to 83.8 $g/kgBW^{.75}$ in the present study. The general pattern in these trials was for intake to decline between May and June to August, and to increase again markedly on fall regrowth in October. Reid *et al.* (1978) showed in one year that

Table 9. Effects of growth stage on feces output, fecal nitrogen, DMD% and intake by grazing cows in 1978[a].

Growth Stage	Date	Feces g	Fecal N %	DMD %	Intake $g/kgBW^{.75}$
1st Growth (Vegetative stage)	5/14-5/18/78	2699[a]	2.59[a]	70.4[a]	83.8[a]
2nd Regrowth (Full bloom stage)	6/17-6/21/78	2550[b]	1.68[b]	64.0[b]	64.4[c]
2nd Regrowth (Vegetative stage)	8/14-8/18/78	2521[c]	1.87[b]	64.8[b]	66.1[b]
3rd Regrowth (Vegetative stage)	10/23-10/27/78	2619[ab]	2.61[a]	78.5[a]	88.8[a]

[a]Mean values for 24 cows.
[abc]Columns with different superscripts are different at 0.05% level by Duncan's multiple range test.

intake of digestible dry matter in g/kgBW$^{.75}$ from spring herbage was generally higher for all grass species than from fall regrowth pasture. Similarly, Corbett et al. (1963) found with grazing dairy cows that the intake of digestible organic matter during summer grazing trials was significantly less than in spring trials. Also, Marsh (1975) obtained higher intakes of digestible organic matter on perennial ryegrass-white clover pasture in spring than in autumn.

The correlation between DMD(%) and intake was 0.17 and non-significant, indicating that intakes in this year were not influenced by DMD(%). Reid et al. (1976b) found a non-significant correlation between digestibility and intake in trials with first growth herbage, but with aftermath herbage the correlation was positive and highly significant. Trials by Harris and Raymond (1963) with sheep showed no relationships. With strip-grazed cows, Corbett et al. (1963) found a curvilinear relationship between digestibility and intake.

Dry matter digestibility (%) of first growth orchardgrass at the vegetative stage was not different ($P>0.05$) from DMD(%) of October regrowth, and DMD(%) values for first regrowth and second regrowth were not different from each other (64.0 vs 64.8%). Again, this might have been due to their similar concentrations of cell wall components. The analysis of variance (Appendix Table 13) showed that intake did not influence DMD(%) ($P>0.01$) in 1978 trials.

Data for comparisons between DMD(%) and intake by indoor and grazing animals are given in Table 10. Intakes of herbage were

Table 10. Comparison of digestibility and intake data for indoor and grazing animals (1978)[a]

System	1978 Periods					
	I	II	III	I	II	III
	Intake g/kgBW$^{.75}$			DMD%		
Indoor	41.1	57.0	55.3	70.4	66.4	56.6
Grazing	83.8	64.4	66.1	73.3	65.1	64.8
Significance	**	*	**	*	NS	*

[a]Mean values for 12 sheep and 24 grazing cows.
**,*,NSSignificance of F values at 0.01 and 0.05 levels, and not significant, respectively.

higher for the indoor animals when expressed on a metabolic weight basis. This was expected since the grazing animals were lactating (Engles and Malan, 1979) and had an increased opportunity for selection.

The DMD(%) of herbage by grazing animals was higher ($P<0.05$) in the first and third trials than for the indoor animals, while DMD(%) was not different in the second trial. The difference in digestibility between grazed and cut herbage was approximately 3 and 8 units in the first and third trials, respectively. This again was probably due to selective grazing by the cows on pasture as has been demonstrated by other workers (Pearce et al., 1962; Reid et al., 1967a).

MINERAL COMPOSITION AND UTILIZATION

Mineral concentrations in orchardgrass.

The effects of magnesium fertilization on mineral concentrations in orchardgrass in the 1978 indoor trials are summarized in table 11. For the three trials combined, fertilization with kieserite caused an increase ($P<0.05$) in the concentration of sulfur, with no effect on the concentration of other minerals.

The small increase in magnesium concentration from kieserite application, from 0.29 to 0.30%, is not in agreement with results generally obtained on soils of reasonable fertility at fairly high levels of magnesium fertilization. Several workers (Reid et al., 1979; Gross and Jung, 1978; Mayland and Grunes, 1974) have shown significant increases in plant magnesium concentration with $MgSO_4$. However, such responses are known to relate both to plant species and to magnesium availability of the soil. For instance, Reid et al. (1979) reported an increase of 58% in magnesium concentration, from 0.20 to 0.32%, in the first cutting of alfalfa in response to treatment with 448 kg Mg/ha as kieserite in the third year after fertilizer application. Similarly, Gross (1973) noted an increase of 73% in magnesium concentration of Kentucky bluegrass with an application of 448 kg Mg/ha as kieserite on a Hagerstown soil, but found that the effect on magnesium concentration differed markedly with the plant species studied and the percentage magnesium saturation of the soil. It was observed by Reid et al. (1978a) that the application of 112 kg Mg/ha as $MgSO_4$ resulted in an

Table 11. Effects of fertilization with kieserite on mineral concentration (% of dry matter) in orchardgrass[a]

Treatment	N %	P %	K %	Ca %	Mg %	S %	Mg	Fe	Cu	Zn
							ppm			
Fertilized	2.76	0.24	2.55	0.64	0.30	0.27	123	341	8	31
Non-fertilized	2.79	0.25	2.54	0.56	0.29	0.22	134	326	9	35
S.D.	0.32	0.02	0.47	0.11	0.08	0.1	29	87	1	7
Significance	NS	NS	NS	NS	NS	*	NS	NS	NS	NS

[a]Mean values of 9 pasture replicates in 3 trials.
*, NSSignificance of F values at the 0.05 level, and not significant, respectively.

increase ($P<0.01$) in mean magnesium concentration, from 0.17 to 0.20%, in a number of grass and legume hays grown on different soils in Pennsylvania and West Virginia. Again, however, the change in magnesium concentration varied with soil type and forage species.

In this study, magnesium concentration was increased from 0.23 to 0.29% in the first trial, ($P<0.05$) from 0.23 to 0.36% ($P>0.05$) in the second trial and was decreased from 0.40 to 0.35% in the third trial ($P>0.05$). Reid et al. (1978a) noted previously that the response to magnesium fertilization varied with growth stage of the plant. They showed that the increase in magnesium concentration resulting from fertilization with 112 kg Mg/ha in the sulfate form was greatest early in spring and least at the hay stage and in the regrowth cutting. The relatively higher levels of magnesium in regrowth than in first growth herbage were also reported by these workers (Reid et al., 1970).

Fertilization with kieserite caused an increase ($P<0.05$) in sulfur concentrations during the first and third trials but not in the second trial (from 0.21% to 0.30% in the first trial and from 0.22 to 0.31% in the third). Other workers have obtained slight or no increases of sulfur after application of $MgSO_4$. Reid et al. (1979), for example, found that levels of sulfur application up to 647 kg/ha (equivalent to 448 kg Mg in kieserite) did not increase the mean concentration of sulfur in alfalfa markedly (an increase from 0.21 to 0.24%). Similarly, Reid et al. (1978b) observed that kieserite fertilization had no effect ($P>0.05$) on the level of sulfur in a range of grass and legume hays (an increase

from 0.20 to 0.22% S). In general, little response to supplemental sulfur has been observed in forage crops in the North-east United States.

There was no effect ($P>0.05$) of level of magnesium fertilizer on the concentrations of nitrogen, potassium, phosphorus, calcium, manganese, iron, copper and zinc in orchardgrass. A similar lack of effect has been noted by Reid et al. (1978a) and by McNaught et al. (1968) in New Zealand. However, Reid et al. (1978b) observed in one study that while magnesium fertilization had no effect on the level of calcium and phosphorus in hays, it did cause a slight increase ($P<0.05$) in the concentration of potassium in the forage. McNaught et al. (1968) noted a tendency for calcium concentration to be depressed with magnesium fertilization.

Effects of growth stage on mineral concentrations.

Effects of growth stage on mineral concentrations are given in Table 12 Magnesium concentration was higher ($P<0.05$) at the vegetative regrowth stage than in the vegetative first growth (0.38 vs 0.26%). This might be expected because the concentrations of nitrogen and potassium were lower in the vegetative regrowth than in herbage sampled in the spring. These elements are known to depress magnesium concentration in the forage (McNaught, 1968). The results of this study are in agreement with the findings of other workers; Reid et al. (1970) found that the magnesium concentration of regrowth forage was generally higher than that of the first growth. Also, Fleming (1973) reported that the concentrations

Table 12. Effects of growth stage on mineral concentration (% of dry matter) in orchardgrass.[a]

Growth Period	N %	P %	K %	Ca %	Mg %	S %	Mn ppm	Fe ppm	Cu ppm	Zn ppm
1st Growth (vegetative stage)	3.77[a]	0.27[a]	2.98[a]	0.64[a]	0.26[b]	0.25[a]	103[b]	136[b]	9[b]	30[b]
2nd Regrowth (full bloom stage)	1.92[c]	0.22[c]	2.23[c]	0.51[b]	0.24[b]	0.22[b]	143[a]	418[a]	7[c]	27[c]
3rd Regrowth (vegetative stage)	2.63[b]	0.25[b]	2.47[b]	0.65[a]	0.38[a]	0.26[a]	139[a]	477[a]	10[a]	41[a]

[a]Mean values of 3 pasture replicates
[abc]Columns with different superscripts are different at 0.05% level by Duncan's multiple range test.

of magnesium in tall fescue, perennial ryegrass and timothy were higher in September and October than at other times of the year. Similar results for orchardgrass were obtained by Shockey (1979).

There was some decline in magnesium concentration between the vegetative first growth and full bloom stage in first regrowth, although the difference was not significant. Reports on the effects of plant maturation on magnesium concentrations differ. Shockey (1979), for example, found that magnesium concentrations in orchardgrass, tall fescue and alfalfa grown on a similar soil type in Morgantown decreased with maturation. A similar decrease was reported in temperate grasses and legumes by Reid et al. (1970), and Mayland and Grunes (1974) also found that the magnesium concentration of Crested wheatgrass declined with age. Follett et al. (1975) reported the highest concentrations of magnesium in smooth bromegrass during early May. In contrast, Powell et al. (1978) observed little difference in the magnesium concentrations of a number of cool season grasses sampled at early and late stages in the first growth cycle.

The levels of nitrogen, phosphorus and potassium were higher ($P<0.05$) in the vegetative first growth than in regrowth. Phosphorus, potassium and nitrogen concentrations have been shown to decrease markedly with advancing maturity in all plant species (Underwood, 1966).

The calcium concentration in vegetative first growth orchardgrass was higher than at the full bloom regrowth stage but not

different from that of vegetative regrowth. It is known that the concentration of calcium in plants does not change greatly with advancing maturity (Underwood, 1966). Sulfur concentrations were not affected substantially by growth stage in this study.

Concentrations of copper and zinc have been shown to decline as the plant matures (Underwood, 1966). This is in agreement with the present data. The levels of copper and zinc were higher ($P<0.05$) in the vegetative first growth and second regrowth than in first regrowth at the full bloom stage. However, concentrations of manganese and iron were higher in regrowth herbage than in spring grass. Underwood (1966) noted that the levels of iron and manganese tend to fluctuate in a manner not clearly related to stages of growth. Similarly, McNaught and Dorofaeff (1968) found maximum manganese levels in grasses in summer, which agrees with these results (104 ppm in May vs 145 ppm in June).

Effects of fertilization on the apparent absorption of minerals.

Data for the effects of magnesium fertilization on the apparent absorption of minerals are summarized in table 13. Fertilizer treatment decreased ($P<0.01$) the apparent absorption of magnesium (31.5 vs 50.2% for fertilized and non fertilized treatments, respectively). There is no obvious reason for this fairly large difference in apparent absorption of magnesium between treatments. The Dutch workers (Committee on Mineral Nutrition, 1973) have established that high concentrations of nitrogen and potassium in herbage may depress magnesium utilization substantially. In

Table 13. Effects of magnesium fertilization with kieserite on the apparent absorption of minerals.[a]

Treatment	Apparent absorption %		
	P	Ca	Mg
Fertilized	-1.3	-1.1	31.5
Non-fertilized	10.0	32.7	50.2
S.D.	14.3	25.9	8.4
Significance	*	*	**

[a]Mean value ± S.D. for 18 sheep in 3 trials.
**, *, N.S. Significance of F values at the 0.01 and 0.05% levels, and not significant, respectively.

this study, however, there was little difference in the concentrations of nitrogen and potassium between non-treated orchardgrass and grass which had been treated with kieserite fertilizer (Table 11). The fertilized grass, however, did contain higher concentrations of calcium and sulfur. Chicco et al. (1973) concluded, from evidence based on fecal excretion and bone and plasma magnesium, that increased dietary calcium decreased magnesium utilization in ruminants. This may be related to the suggestion that calcium and magnesium compete for the same absorption sites (Rook and Storry, 1962; Care and Van't Klooster, 1965). In this study calcium level was 0.64% for the fertilized as compared to 0.56% for the non-fertilized herbage. Little is known about possible effects of sulfur on the apparent absorption of magnesium. It is also possible that the depression of apparent magnesium absorption in the fertilized orchardgrass may have been due to the presence of compounds which were not analyzed i.e. organic acids or higher fatty acids. However, the results of this study are in contrast with those obtained by Reid et al. (1978b) and Reid et al. (1979), who obtained an increase in the apparent absorption of magnesium due to magnesium fertilization with kieserite.

Fertilizer treatment caused a negative apparent absorption of phosphorus and calcium. This might have been due to the higher Ca:P ratio in the fertilized as compared to the non-fertilized herbage (a ratio of Ca:P of 2.6:1 vs. 2.24:1 for fertilized and unfertilized treatments respectively). In support of this possibility, Young et al. (1966) reported lowered calcium absorption

in sheep given a diet low in phosphorus. With a phosphorus deficient diet, they observed a lowered availability of phosphorus. Again, however, Reid et al. (1979) found that kieserite application to alfalfa had no effect ($P>0.05$) on the availability of calcium and phosphorus.

Effects of growth stage on the apparent absorption of minerals (Ca, P and Mg).

Data for the effects of growth stage on the apparent abosrption of minerals are given in table 14. Mean intakes of magnesium by sheep were 2.02, 3.52 and 6.59 g/day for the three growth periods, respectively. Despite this difference, the availability of magnesium in the full bloom first regrowth herbage was higher than in the first growth herbage. A number of workers have demonstrated that stage of growth affects the availability of magnesium in herbage. L'Estrange et al. (1967) found that as herbage dry matter digestibility declined with maturity from 80 to 73% magnesium availability increased. Similarly, Rook and Campling (1962) observed an increased availability of magnesium with stage of growth. They found that 7 to 10% of the magnesium intake was apparently absorbed at early stages and 12 to 20% at the later stages of growth. It was proposed by Care and Ross (1961) that the lower magnesium availability in spring herbage is a result of processes taking place in parts of the alimentary tract by which the permeability of the intestinal wall to Mg^{+2} within the lumen is diminished. Kemp et al. (1961) showed with lactating

Table 14. Effects of growth stage on the apparent absorption of minerals.[a]

Growth stage	Apparent absorption %		
	P	Ca	Mg
1st Growth (vegetative stage)	-11.5[c]	-21.3[c]	25.3[c]
1st Regrowth (full bloom stage)	26.4[a]	50.1[a]	57.8[a]
2nd Regrowth (vegetative stage)	-1.9[b]	18.5[b]	39.4[b]

[a]Mean values for 12 sheep (combined fertilizer and unfertilized treatments).

[abc]Columns with different superscripts are different at 0.05% level by Duncan's multiple range test.

cows that there was an increase in the availability of magnesium as herbage matured and that the change was associated with a decrease in the concentration of nitrogen, potassium and phosphorus in the grass. In this study, the concentrations of nitrogen, phosphorus and potassium were significantly lower in the matured regrowth at the full bloom stage as compared to the other growth stages (table 12).

Reports on the relationship of the level of intake of magnesium to its absorption tend to be conflicting. Mills (1969) stated that the percentage of magnesium absorbed is not affected materially by dietary amount, urinary magnesium excretion being the main route of homestatic regulation in ruminants. Balance trials by Joyce and Rattray (1970) support this statement. These workers fed diets containing white clover and perennial ryegrass to lambs at ad lib. and restricted intake levels. At magnesium intakes of 2.20 and 1.31 g/day for the ad lib. and controlled groups, respectively, there were no differences in apparent absorption of magnesium. Similarly, Hutton et al. (1965) observed no relationship between magnesium intake and apparent absorption in dairy cows fed pasture herbage.

In contrast, considerable evidence also suggests that the availability of magnesium may be dependent on the amount of magnesium consumed. Lomba et al. (1968) found a significant correlation between intake and absorbed amount of magnesium; the greater the magnesium intake the greater was the level of absorption

in stall fed cattle. Similarly, Grace et al. (1974) noted that magnesium intake markedly influenced magnesium absorption by sheep fed fresh herbage.

The mean apparent absorption noted in the three trials was 40.8%, with a range of 25.3 to 57.8% (dietary magnesium intake ranged from 2.02 to 6.59 g/day). A value for apparent absorption of magnesium of 43.5% obtained by Powell et al. (1978) for cut orchardgrass fed ad lib. to lambs is similar to the results of this study (dietary magnesium intakes in their study ranged from 0.60 to 1.14 g/day). Apparent absorption coefficients of magnesium in orchardgrass in the study by Powell and in the present work are definitely high in relation to values reported for other grass species in similar conditions, e.g. a mean value of 17% was obtained in a large number of trials with perennial ryegrass by Dutch workers (Committee on Mineral Nutrition, 1973). The high values may reflect both the fact that sheep apparently utilize magnesium more efficiently than do cattle (Reid, 1979) and that there may be real differences between plant species in magnesium availability (Reid, loc. cit.). The results do not support the assertion that orchardgrass may be a tetanigenic plant species (Mayland and Grunes, 1979) and may partially explain the relatively small response in serum magnesium concentrations in grazing cows to kieserite fertilization discussed in a later section.

Apparent absorption of phosphorus and calcium were negative in the first growth herbage and increased significantly in later cuttings. Phosphorus intakes for the three periods were, 1.82, 1.74

and 2.90 g/day, respectively, and calcium intakes were 4.32, 7.58 and 8.57 g/day, respectively. The ratios of Ca:P in herbage for the three periods were 2.37:1, 2.32:1 and 2.60:1, respectively. It seems unlikely that the ratio of Ca to P may have been a determining factor in the percentage absorption of these two elements. However, the amount fed may have affected absorption, as has been noted by other workers (Young et al., (1966); Luecker and Lofgreen, 1961). Luecker and Lofgreen (1961), in feeding studies with growing lambs, observed no effect of three dietary ratios of Ca:P (0.8 to 1, 2.8 to 1 and 6.0 to 1) on the amount of either calcium or phosphorus absorbed. They found that the amount absorbed was directly related to the amount fed.

Concentrations of nitrogen were, however, lower for regrowth at full bloom stage than for the other growth stages examined. Evidence concerning the effects of dietary nitrogen on the utilization of calcium and phosphorus in diets fed to ruminants has been equivocal. Leibholz et al. (1974) found a significant correlation between the retention of calcium and phosphorus and that of nitrogen in sheep fed diets adequate in calcium and phosphorus but with varying levels of nitrogen. Garces and Evans (1971) found no effect of nitrogen level on the absorption of calcium in steers, while Moore (1972) demonstrated an increase in the apparent absorption of phosphorus in sheep fed high levels of crude protein; calcium retention, however, was lower in lambs fed high nitrogen diets, apparently due to an increased excretion of calcium in the

urine. In contrast to these results, Stillings et al. (1964) found that calcium tended to be retained in greater amount by sheep consuming high nitrogen containing forages.

The mean apparent absorption of calcium was 15.8% (ranging from -21.3 to 50.1%) and the mean dietary calcium intake was 6.82 g/day, ranging from 4.32 to 8.57 g/day. Availability of calcium was lower than the value of 26% found by Joyce and Rattray (1970) for sheep fed white clover and perennial ryegrass with dietary calcium intakes ranging from 2.68 to 8.16 g/day. Site and forage species differences might offer a reasonable explanation for these differences. Powell et al. (1978) found mean apparent absorption values of 31.2% (ranging from 18.9 to 38.5%), with dietary calcium intakes ranging from 1.10 to 2.34 g/day, for the apparent absorption of calcium in sheep fed cut orchardgrass grown on a similar soil in West Virginia. However, their studies were run with growing lambs as compared with the mature wethers used in the present trials and it is well established that growth stage of the animal may affect the apparent absorption of minerals.

A mean availability of phosphorus of 4.4% (ranging from -11.5 to 26.4%), with dietary phosphorus intakes ranging from 1.74 to 2.90 g/day, is low when compared to a value of 10% reported by Joyce and Rattray (1970b) for sheep with dietary phosphorus intakes ranging from 1.70 to 3.14 g/day. Powell et al. (1978) recorded a mean apparent absorption for phosphorus of 14.7% for lambs fed orchardgrass at phosphorus intakes of 0.94 to 2.24 g/day. Again, site, plant species and age of animal might explain these differences in

the apparent absorption of phosphorus.

The low value of 4.4% apparent absorption of phosphorus from orchardgrass in this study reflects the fact that mature ruminant animals generally adjust their phosphorus output to that of intake (by endogenous fecal excretion) to achieve equilibrium. Output of phosphorus in the urine is extremely low.

Serum mineral composition of grazing cows.

Changes in the concentration of serum magnesium with fertilizer treatment and with time after the beginning of grazing are summarized in figure 3. Magnesium fertilization caused a constant but non-significant ($P>0.05$) increase in serum magnesium (1.62 vs 1.73 $\pm$ 0.93 mg/100 ml for control and treated groups, respectively over all grazing periods). These values are low, as Simesen (1970) gives mean values for cattle of 2.05 $\pm$ 0.25 mg/100 ml for serum magnesium.

Period (days after cows were turned on to pasture) had a significant ($P<0.01$) effect on serum magnesium. Lowest blood magnesium concentrations were observed one day after grazing started with a mean decline of 0.5 mg/100 ml. for serum magnesium. A fall in serum magnesium a day or two after the animals were put on lush pasture was also observed by Simesen (1970). A sudden change in quality and quantity of the herbage might have been a factor as was observed by Swan and Jamieson (cited by Simesen 1970). Dutch workers (Committee in Mineral Nutrition, 1973) observed similar results. In the first trial of this study the herbage contained high levels of nitrogen and potassium. These elements are known to depress magnesium

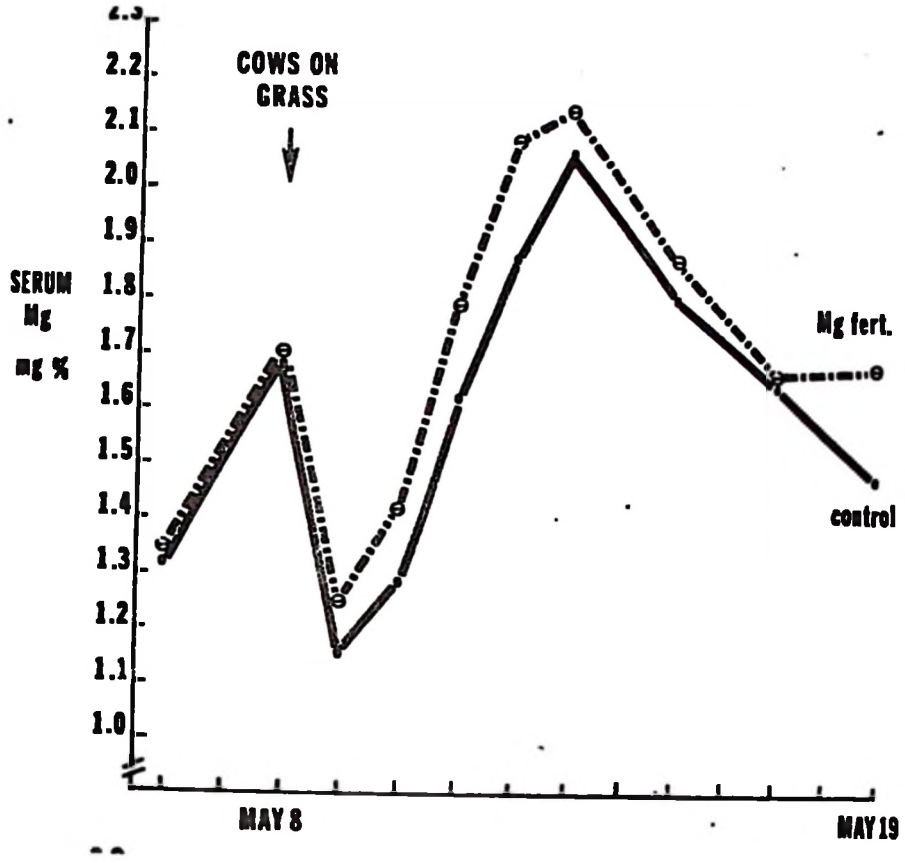


Figure 3. Changes in concentration of serum magnesium in cows on unfertilized and kieserite-fertilized orchardgrass pastures during the early grazing period. Mean values for 12 cows per treatment.

utilization substantially (Committee on Mineral Nutrition, 1973). Serum magnesium concentrations, however, increased rapidly during the next 3-4 days to mean values of 2.0-2.1 mg/100 ml, with a subsequent decline to pre-grazing levels. The increase might have possibly been due to the adaptation of rumen microorganisms to this diet. As observed in many studies (e.g. Bartlett et al., 1957; Storry, 1961) marked individual animal variation in blood magnesium response to a change from winter feeding to grass was apparent. This is illustrated in figure 4, which gives typical patterns of serum magnesium concentration in individual cows. Serum magnesium concentrations in individual animals declined at times to levels of 0.5-0.6 mg/100 ml in the early grazing period. However, if a serum magnesium concentration of 1.0 mg/100 ml is accepted as indicative of severe magnesium deficiency (Committee on Mineral Nutrition, 1973), 50% of the cows on the unfertilized pastures showed values lower than this one day after commencement of grazing compared to 25% of cows on the kieserite-treated herbage.

The effects of fertilization and time on concentrations of serum inorganic phosphorus and serum calcium are summarized in figure 5. Pasture fertilization with kieserite resulted in a slight but non-significant ($P>0.05$) increase in mean serum phosphorus (4.78 vs 5.26 $\pm$ 1.75 mg/100 ml for control and treated groups, respectively). A decline in serum inorganic phosphorus during the early grazing period has been noted in high yielding dairy cows by Thompson et al. (1978). Blood calcium values have frequently been found to be

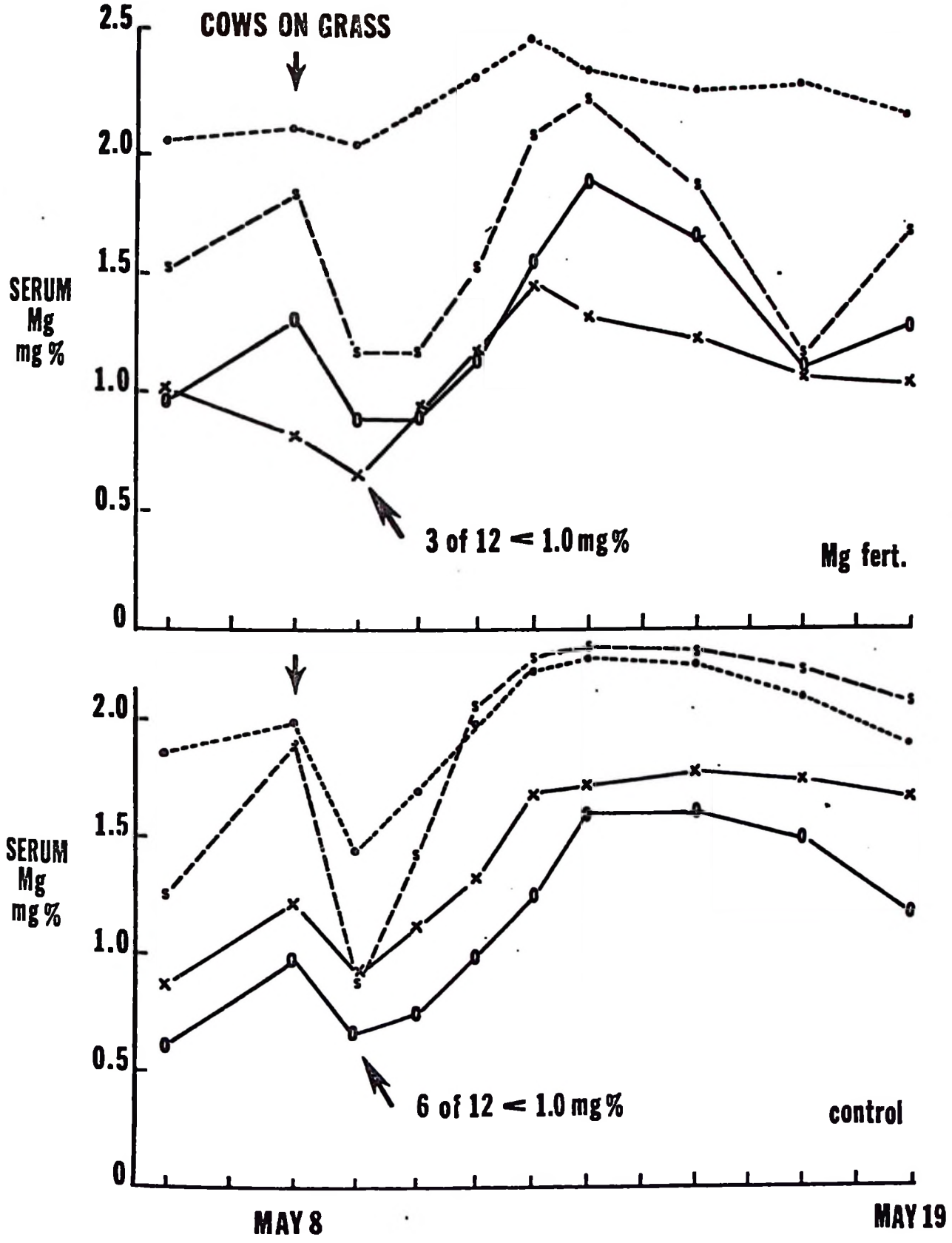


Figure 4. Serum magnesium concentrations in individual cows with initially high and low blood magnesium values following beginning of grazing.

depressed at the same time as concentrations of serum magnesium during the development of hypomagnesemic tetany in cattle (Simesen, 1970; Fontenot, 1979) but in this study there were no marked changes in concentration of serum calcium. These results were expected as the apparent absorption of calcium and phosphorus were low and in fact negative values were obtained for the fertilized herbage. Possibly the mobilization of these minerals from bones was high. It has been noted by Simesen (1970) that in conditions with poor absorption of these minerals from the intestinal tract, the plasma calcium and phosphorus level is maintained primarily by its mobilization from the bones through the action of the parathyroid hormone.

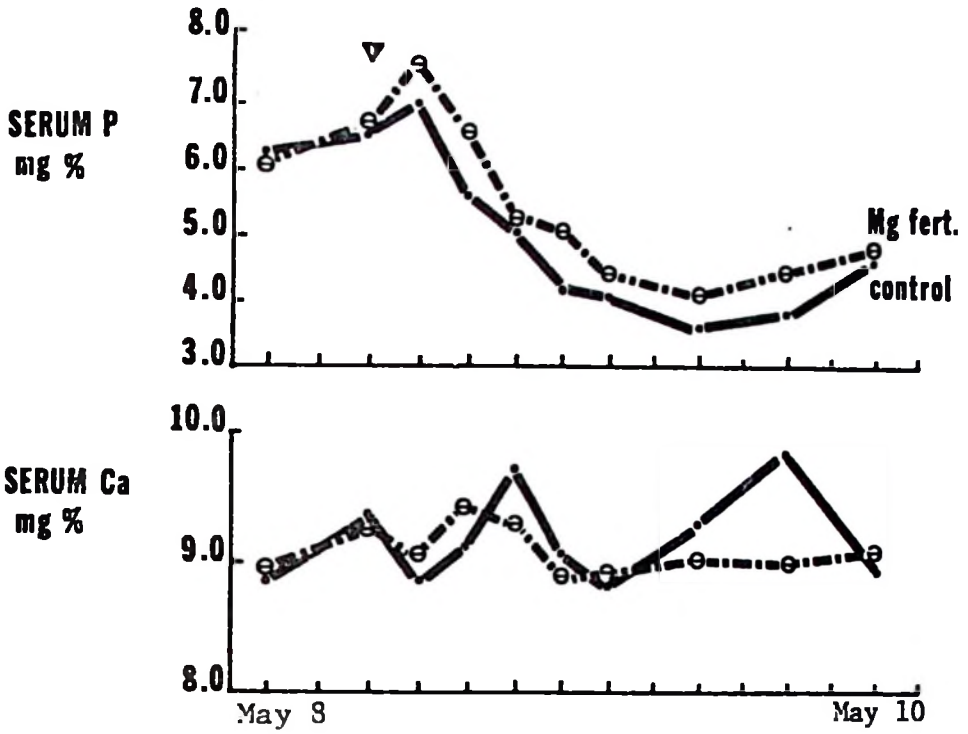


Figure 5. Concentrations of serum inorganic phosphorus and serum calcium in cows grazing unfertilized and kieserite-fertilized orchardgrass pastures. Mean values for 12 cows per treatment.

SUMMARY AND CONCLUSIONS

Digestion and grazing trials were undertaken in 1977 and 1978 to look at seasonal variation in the dry matter digestibility and intake of orchardgrass pasture by grazing beef cows and to determine effects of fertilization of orchardgrass with kieserite on its nutritive quality and on its mineral composition and utilization. In both years, herbage was fed at different growth stages in indoor trials and regression techniques (Fecal N-chromic oxide) were used to estimate the nutritional value of pasture herbage by grazing cattle. In 1977 trials, 18 lactating cows with their calves were used for the outdoor and four dry cows were used for the indoor trials. In 1978 trials, 12 sheep (6 per treatment) were used for the indoor trials and 24 lactating cows with their calves were used for evaluations of pasture.

In the grazing trials run in 1977, it was found that intake of first growth grass in the spring period was higher ($P<0.05$) than intake of the other growth stages of herbage. However, the intake of mature herbage was not different from the intake of first regrowth herbage. Contrary to what might have been expected, the 1977 results on the average showed that beef cows fed cut herbage ad lib. ate more forage than the grazing cows.

In 1978 grazing trials, intake of first growth vegetative herbage was not different from intake of herbage grazed in October. The intake of first regrowth at the full bloom stage and of second regrowth grazed in August were similar. The DMD(%) of first

growth herbage in May were higher than DMD(%) of the other growth stages of herbage.

The 1978 trials with cut herbage showed that dry matter intake of the first growth herbage was lower than at other growth periods. However, DMD(%) was higher in the first growth grass than at other growth stages. In 1978 trials, grazing cows at more dry matter on a metabolic body weight basis, than the indoor sheep. The estimated mean DMD(%) of orchardgrass by grazing cows was higher ($P<0.05$) than that of cut herbage fed sheep in metabolism stalls.

In neither year did the calculated relationships between DMD(%) and fecal N concentrations of beef cows or sheep fed cut herbage in indoor trials provide an acceptable regression for the estimation of digestibility by grazing animals. This may reflect either the validity of the technique or as suggested, the fact that data for both first growth and regrowth orchardgrass were included in the analysis and a limited amount of evidence suggests that regressions may be significantly affected by characteristics of the cutting of herbage

Magnesium fertilizer had no effect ($P>0.05$) on DMD(%) and intake of either cut or grazed herbage.

In all three trials in 1978, kieserite fertilization significantly increased the concentration of sulfur in herbage with no effect on the concentration of other minerals. Fertilizer treatment caused a reduced apparent absorption of phosphorus, calcium and magnesium.

Magnesium concentrations were higher ($P<0.05$) in regrowth orchardgrass than at other growth stages of the pasture. The

levels of nitrogen, phosphorus and potassium were significantly ($P<0.05$) higher in vegetative first growth grass than in the other growth stages, apparently accounting for the lower availability at this time than later in the season. Grazing lactating cows showed a marked decrease in serum magnesium concentration during the first few days after their introduction to pasture.

Magnesium fertilization caused a consistent but non-significant ($P>0.05$) increase in serum magnesium in grazing beef cows in the two week period after turning the animals out to pasture. Pasture fertilization also resulted in a slight but non-significant increase in mean serum phosphorus concentrations and had no effect on mean serum calcium levels.

Among the general conclusions which might be reached from this study would be the following:

(a) Within the limits of the techniques used, results tended to support data in the literature, viz. a generally higher digestibility of grazed than of cut herbage and significant effects of growth stage and season on the nutritional quality of orchardgrass. Differences in the digestibility of orchardgrass in the vegetative phase in spring and autumn are of considerable interest and may help to explain the generally poorer performance of livestock in the fall, even though the composition of herbage in the two seasons is apparently similar. British studies have demonstrated that the net energy content of grass during the fall grazing season is lower than in spring.

(b) The results relating magnesium fertilization to digestibility and intake of herbage showed no differences in nutritional quality associated with fertilization, in contrast to data obtained with other forages in W.Va. trials. It may be suggested that the lack of response in the present study may have resulted from the fact that (1) orchardgrass in these trials did not show any consistent differences in magnesium concentration between fertilized and control treatments; the only significant difference was in the concentration of sulfur in the grass, (2) levels of minerals in the forages were generally more than adequate to meet N.R.C. requirements for lactating cattle and for lambs. Possibly the main application of magnesium supplementation, directly or by fertilization, may therefore lie in the feeding of low quality crop residues, such as corn stover, or in the grazing or feeding of grass species, such as timothy, which naturally accumulate low concentrations of magnesium from the soil, or which have a low availability of magnesium in the digestive tract.

(c) Fertilization was shown to somewhat improve the concentration of magnesium in the blood of grazing beef cows, and to reduce the proportion of animals experiencing a severe decrease in serum magnesium in the blood immediately following the initiation of spring grazing. When comparing these effects with results obtained in previous trials, where fertilization was compared with the provision of palatable magnesium blocks, it would appear that more effective control of hypomagnesemia would be obtained by direct supplementation.

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APPENDIX

Appendix Table 1. Forage intake, intake per unit of metabolic wt., fecal dry matter, DMD, DMD%, % Forage N and % Fecal N. 1977.

Trial	Plot	Anim. #	Wt. kg.	Int. kg.	Int. $g/kgBW^{.75}$	Fec. DM kg	DMD %	Forage N	% Fe. N
1	1	243	409	7.30	80.2	2.81	71.4	3.37	3.22
1	1	231	484	8.21	79.7	2.84	69.0	3.37	3.23
1	1	609	420	7.35	79.2	3.49	66.5	3.37	3.28
1	1	99	461	6.85	68.8	1.95	74.2	3.37	3.15
2	2	243	413	8.22	89.9	2.53	69.3	1.36	1.40
2	2	231	493	9.87	94.4	3.26	66.9	1.36	1.42
2	2	609	424	8.21	93.4	2.53	69.2	1.36	1.75
2	2	78	343	9.30	91.7	2.50	73.2	1.36	1.40
3	3	78	384	8.60	99.1	2.79	67.5	1.09	1.51
3	3	609	451	8.82	90.2	3.00	65.9	1.09	1.32
3	3	231	531	1.01	91.7	4.13	59.3	1.09	1.40
4	4	107	371	7.95	94.1	4.21	47.0	2.33	1.97
4	4	609	427	8.30	88.4	3.73	55.0	2.33	2.00
4	4	569	514	9.54	88.4	4.88	48.9	2.33	2.09
4	4	243	40	8.09	89.9	3.98	50.8	2.33	2.03

Appendix Table 2. Analysis of variance for the dependent variable, DMD(%) (Indoor trials, 1977)

Source	DF	DMD MS	F Value	PR > F
FEC N	1	46.33	1.57	0.1603
Trial	3	24.37	1.35	0.3442
FEC N x Trial	3	23.98	1.33	0.3500

Analysis of variance for the dependent variable DMD(%) (Indoor trials, 1977)

Source	DF	Trial 1 MS	Trial II MS	Trial III MS	Trial IV MS
FEC N	1	69.920 NS	0.464 NS	2.734 NS	0.078 NS

NS Not significant.

Appendix Table 3. Analysis of variance for dependent variables (Grazing trials, 1977)

Source	DF	Feces	FEC N%	DMD%	Intake $g/kgBW^{.75}$	AAN%
		MS	MS	MS	MS	MS
Trial	3	1697.78**	4.68**	375.06**	455.74	2565.46**
Plot trial	0	0.00	0.00	0.00	0.00	0.00

Appendix Table 4. Analysis of variance for the dependent variable, DMD% (grazing trials, 1977)

Source	DF	DMD MS	F Value	PR> F
Intake	1	16.94**	9.98	0.0025
Trial	3	353.27****	208.18	0.0001
Plot (trial)	0	0.00	0.00	

Parameter	Estimate	T for HO: Parameter=0	PR >!T!	S.E. of Estimate
Intercept	64.84	69.65	0.0001	0.93
Intake	0.0004	3.16	0.0025	0.0001
Trial 1	3.1449	6.36	0.0001	0.4942
2	-4.7099	-10.03	0.0001	0.4695
3	-7.3748	-16.18	0.0001	0.4559
4	0.0000	-	-	-

**Significant (P<0.01)
****Significant (P<0.0001)

Appendix Table 5. Analysis of variance for the dependent variable, intake (grazing trials, 1977)

Source	DM	INT ($g/kgBW^{.75}$) MS	F Value	PR> F
MDMD	1	210188.1402	0.65	0.506

Parameter	Estimate	T for HO: Parameter=0	PR >!T!	S. E. of Estimate
Intercept	4463.60	0.99	0.4261	4503.67
MDMD	55.14	0.80	0.5058	68.58

Appendix Table 6A. 1st Grazing Trial 1977

Cow	Wt kg	Feces g	Fec. N%	DMD %	DM INT. g	INT g/kgBW$^{.75}$	Total N intake g	Total Fec N Excr. g	AAN%
76	502	2924	2.40	69.5	9604	90.5	323.6	70.2	78.3
166	398	2727	2.54	70.8	9342	104.8	315.8	69.3	78.0
117	416	2056	2.55	70.9	7065	76.7	238.1	52.4	78.0
134	455	2899	2.50	70.4	9809	99.6	330.6	72.5	78.1
48	489	2354	2.44	69.9	7824	75.2	263.7	57.4	78.2
91	514	3057	2.38	69.4	9981	92.5	336.4	72.8	78.4
235	409	2587	2.85	73.6	9803	107.8	330.4	73.7	77.7
140	409	2616	2.27	68.4	8270	90.9	278.7	59.4	78.7
133	407	2943	2.51	70.5	6659	73.5	224.4	73.9	67.1
106	527	2616	2.58	71.2	9073	82.5	305.8	69.5	77.9
67	530	2160	2.50	70.4	7309	66.2	246.3	54.0	78.1
83	457	1986	2.81	73.2	7424	75.5	250.2	55.8	77.7
156	452	2961	3.03	75.2	11954	121.9	402.8	89.7	77.7
126	423	2597	2.55	70.9	8923	95.7	300.7	66.2	78.0
109	543	2111	2.75	72.7	7737	68.8	260.7	58.0	77.7

Appendix Table 6B. 2nd Grazing Trial 1977

Cow	Wt. kg	Feces g	Fec. N%	DMD %	DM INT. g	INT $g/kgBW^{.75}$	Total N intake g	Total Fec N Excr. g	AAN%
156	448	2127	1.59	65.2	5634	57.9	76.6	33.8	55.9
134	442	2402	1.17	58.2	5782	60.0	78.6	28.1	64.3
76	473	2803	1.74	63.5	7679	75.7	104.4	48.5	53.6
106	486	2675	1.48	61.2	6904	66.7	93.9	39.6	57.8
67	453	2961	1.74	63.6	81.33	82.8	110.6	51.5	53.4
126	407	3576	1.69	63.1	9701	107.1	131.9	60.4	54.3
133	405	2127	1.52	61.6	5541	61.4	75.4	32.3	57.1
83	464	3688	1.81	64.2	10310	103.1	140.2	66.7	52.4
78	469	3698	1.82	64.3	10364	102.8	140.9	67.3	52.2
235	393	2727	1.77	63.9	7547	85.5	102.6	48.3	53.0
109	496	2478	1.77	63.9	6859	65.3	93.3	43.9	53.0
166	399	3174	1.71	63.3	8659	96.9	117.7	54.3	53.9
140	409	2064	1.57	62.1	5443	59.8	74.0	32.4	56.2
91	514	3990	1.92	65.2	11470	106.2	156.0	76.6	50.9
87	415	3603	1.65	62.8	9681	105.3	131.7	59.4	54.8
117	412	3891	1.60	63.3	10611	116.0	144.3	62.3	56.9
48	481	3968	1.75	63.7	10924	106.4	148.6	69.4	53.3

Appendix Table 6C. 3rd Grazing Trial 1977

Cow	Wt. kg	Feces g	Fec. N%	DMD %	DM INT. g	INT g/kgBW$^{.75}$	Total N intake g	Total Fec. N excr. g	AAN%
117		2911	1.37	60.3	7073	77.2	77.1	38.5	50.0
83		3018	1.57	62.1	7955	81.4	86.7	47.4	45.4
140		2568	1.19	58.6	6208	66.9	67.7	30.6	54.8
608		3293	1.47	61.2	8477	74.9	92.4	48.4	47.6
48		2871	1.33	59.9	7160	68.6	78.0	38.2	51.1
67		2778	1.39	60.4	7022	71.3	76.5	38.6	49.6
106		3009	1.26	59.3	7387	70.0	80.5	37.9	56.9
156		2513	1.42	60.7	6397	65.3	69.7	35.7	48.8
126		3028	1.48	61.2	7814	84.5	85.2	44.8	47.4
235		3678	1.32	59.8	9152	100.3	99.8	48.5	51.3
76		3304	1.42	60.7	8409	95.8	91.7	46.9	48.8
109		3098	1.43	60.8	7902	76.2	86.1	44.3	48.6
134		2811	1.31	59.7	6979	70.7	76.1	36.8	51.6
87		3594	1.21	58.8	8726	93.2	95.1	43.5	54.3
166		3807	1.28	59.4	9389	105.0	102.3	48.7	52.4
78		2906	1.47	61.2	7483	70.6	81.6	42.7	47.6
133		3363	1.41	60.6	8540	97.1	93.1	47.4	49.1
91		2811	1.35	60.1	7041	64.2	76.7	37.9	50.5

Appendix Table 6D. 4th Grazing Trial 1977

Cow	Wt. kg	Feces g	Fec. N%	DMD %	DM INT.	INT g/kgBW$^{.75}$	Total N intake g	Total Fec. N excr. g	AAN%
126	434	2059	2.32	68.8	6066	69.4	153.9	47.8	68.7
78	486	2859	2.10	66.8	8623	83.3	200.9	60.0	70.1
133	415	2302	2.24	68.1	7217	78.5	168.2	51.6	69.3
106	493	2732	2.23	68.0	8540	81.6	199.0	60.9	69.4
117	444	2511	2.12	67.0	7614	78.7	177.4	53.2	70.0
140	426	2193	2.12	67.0	6650	70.9	154.9	46.5	70.0
48	500	2090	2.09	66.7	6284	59.4	146.4	43.7	70.2
166	408	2053	2.25	68.3	6475	71.3	150.9	46.4	69.2
83	463	2286	2.16	67.4	6994	70.1	163.0	49.4	69.7
76	479	2666	2.17	67.5	8197	80.1	191.0	57.8	69.7
91	517	2102	2.23	68.0	6571	60.6	153.1	46.9	69.4
67	469	2525	1.99	65.8	7393	73.4	172.3	50.2	70.8
156	441	2478	2.06	66.5	7393	76.8	172.3	51.0	70.4
135	419	3084	2.49	70.4	10405	112.3	242.4	76.8	68.3
109	492	2727	2.15	67.3	8337	79.8	194.2	58.6	62.8

Appendix Table 7. Effects of growth stage on cell wall components of orchardgrass 1977[a].

Growth Stage	CWC	Cell Solubles	ADF	Hemicellulose	Cellulose	Lignin	Silica
	%DM						
1st Growth (Vegetative stage)	59.6	40.4	33.5	26.1	22.6	5.10	0.67
Mature (Full bloom stage)	70.5	29.5	43.3	27.2	33.1	7.20	1.51
1st Regrowth (Vegetative stage)	70.6	29.4	40.0	30.6	29.4	7.32	1.40
2nd Regrowth (Vegetative stage)	65.0	34.9	38.2	26.9	27.6	8.43	1.91

[a]Values are from one paddock.

Appendix Table 8 . Correlation coefficients between intake and dry matter content of orchardgrass.

Variable	Dry matter content. 1977. 1st trial	2nd trial	3rd trial
Intake	-0.32	-0.11	-0.18
Significance	*	NS	NS

Variable	Dry matter content. 1978. 1st trial	2nd trial	3rd trial	4th trial
Intake	-0.34	-0.13	-0.14	-0.13
Significance	*	NS	NS	NS

*, NS Significance of F values at the 0.05% level, and not significant, respectively.

Appendix Table 9. Analysis of variance for dependent variables, DMD%, fecal N%, intake and fecal output (indoor sheep, 1978)

Source	DF	DMD % MS	FEC. N% MS	Intake $g/kgBW^{.75}$ MS	Fecal output MS
Trial	2	845.98**	5.92**	1071.40**	0.361**
Fert.	1	139.91	0.43**	119.28	1.38
Trial x Fert.	2	25.77	0.048	40.04	0.20

** Significant ($P < 0.01$)

Appendix Table 10. Analysis of variance for the dependent variable, DMD(%) (Indoor sheep, 1978)

Source	DF	DMD MS	F values	PR > F
	1	2.347	0.07	0.7987
Trial	2	16.604	0.47	0.6303
FEC N% x Trial	2	27.002	0.77	0.4762
Fert.	1	0.555	0.02	0.9013
FEC N% x Fert.	1	3.010	0.09	0.7728
Trial x Fert.	2	5.176	0.15	0.8643
FEC N% x Trial x Fert.	2	6.319	0.18	0.8371

Appendix Table 11. Analysis of variance for the dependent variable, DMD(%) (Indoor trials, 1978)

Source	DF	Trial=1 Fert=1 MS	Trial 2 Fert=0 MS	Trial=2 Fert=1 MS	Trial=3 Fert=0 MS	Trial=3 Fert=1 MS
FEC N%	1	1.075 NS	25.936 NS	36.441 NS	0.369 NS	29.303 NS

NS Not significant.

Appendix Table 12. Analysis of variance for the dependent variables FEC N%, DMD%, Intake and AAN% (Grazing cows, 1978)

Source	DF	Feces MS	FEC N% MS	DMD% MS	Intake $g/kgBW^{.75}$	AAN% MS
Fert.	1	39504	0.059*	4.789*	8.076	1.126
Plot (fert.)	2	50630	0.046*	4.294*	0.062	7.245*
Trial	3	154312	3.782***	305.179**	2380.964**	738.160**
Fert. x Trial	3	83166	0.021	2.007	63.088	7.022*
Plot x Trial (Fert.)	6	49531	0.022	1.860	65.362	39.270**

Appendix Table 13. Analysis of variance for dependent variable, intake, (Grazing trials, 1978)

Source	DF	Intake MS	F Value	PR >F
MDMD	1	16442861.536	114.31	0.0001

Parameter	Estimate	T for Ho: Parameter=0	PR> |T|	S.E. of estimate
Intercept	-10891.034	-6.12	0.0001	1778.248
MDMD	281.495	10.69	0.0001	26.329

Appendix Table 14. Forage intake, intake per unit of metabolic wt., fecal dry matter, DMD, %Forage N, %Fecal N and apparent absorption of minerals by sheep, 1978

Trial	Fert.	Plot.	Anim. #	Wt. kg	Int. kg	Int. $g/kgBW^{.75}$	Fec DM kg	DMD %	%N	%Fec. N
1	1	5	238	49.5	0.757	40.5	0.208	72.6	3.35	2.09
1	1	5	97	38.6	0.762	49.2	0.201	73.6	3.34	2.55
1	1	5	611	57.3	0.761	36.5	0.206	72.9	3.34	2.52
1	1	5	234	53.6	0.761	38.4	0.198	74.0	3.34	2.42
1	1	5	262	46.8	0.761	42.5	0.223	70.7	3.34	2.25
1	1	5	249	49.1	0.761	41.0	0.196	74.3	3.34	2.27
1	0	6	261	48.6	0.735	39.9	0.193	73.7	4.16	2.66
1	0	6	269	51.4	0.735	38.3	0.192	73.9	4.16	2.60
1	0	6	265	48.6	0.714	38.8	0.198	72.3	4.16	2.93
1	0	6	145	35.4	0.728	50.1	0.196	73.0	4.16	2.73
1	0	6	247	50.9	0.733	38.5	0.193	73.6	4.16	2.52
1	0	6	285	48.6	0.731	39.7	0.192	75.0	4.16	2.53
2	1	5	249	69.5	1.278	53.1	0.324	74.6	2.01	1.14
2	1	5	269	70.9	1.409	57.7	0.522	63.0	2.01	1.27
2	1	5	261	67.3	1.376	58.6	0.548	60.2	2.01	1.12
2	1	5	234	75.4	1.361	53.2	0.590	56.7	2.01	0.73
2	1	5	611	83.2	1.481	53.8	0.441	70.2	2.01	0.84
2	1	5	262	70.0	1.417	58.5	0.586	58.6	2.01	0.73
2	0	6	145	49.1	1.229	66.3	0.367	70.7	2.15	1.31
2	0	6	285	65.4	1.311	57.0	0.398	69.7	2.15	0.87
2	0	6	238	68.6	1.330	55.8	0.402	69.8	2.15	2.17
2	0	6	265	64.1	1.431	63.2	0.482	66.3	2.15	1.18
2	0	6	97	55.0	2.296	64.3	0.300	76.9	2.15	1.57
2	0	6	247	69.5	1.619	67.2	0.638	60.6	2.15	1.25

Appendix Table 14 Continued.

Trial	Fert.	Plot.	Anim. #	Wt. kg	Int. kg	Int. g/kgBW$^{.75}$	Fec DM kg	DMD %	%N	%Fec. N
3	1	5	238	65.4	1.063	46.2	0.531	50.1	3.09	1.70
3	1	5	142	42.3	1.052	63.5	0.381	53.7	3.09	1.58
3	1	5	285	60.9	1.139	52.2	0.529	53.5	3.09	1.79
3	1	5	234	70.4	1.149	47.7	0.579	50.1	3.09	1.65
3	1	5	262	64.1	1.237	54.6	0.577	53.3	3.09	1.58
3	1	5	247	65.4	1.216	52.8	0.602	50.5	3.09	1.68
3	0	6	261	61.4	1.195	54.5	0.550	54.0	2.84	1.71
3	0	6	265	59.5	1.313	61.2	0.604	54.0	2.84	1.70
3	0	6	611	75.0	1.298	50.9	0.506	61.0	2.84	1.87
3	0	6	269	64.3	1.327	58.4	0.636	51.9	2.84	1.72
3	0	6	97	49.1	1.227	66.2	0.293	56.1	2.84	1.69
3	0	6	249	64.5	1.261	55.4	0.492	61.0	2.84	1.74

0=Non-fertilized
1=Fertilized

Appendix Table 14 Continued.

Trial	Anim. #	AAN%	AAP%	AAK%	AACa%	AAMg%	AAS%	AAMn%	AACu%	AAZn%
3	238	71.9	-15.4	92.9	6.7	4.4	46.7	-32.3	-5.4	26.8
3	142	81.8	16.0	92.9	25.3	36.4	61.3	2.5	39.6	57.8
3	285	74.3	-18.5	80.0	12.5	16.7	54.5	-24.7	-13.6	8.2
3	234	72.2	-21.5	75.0	14.6	20.4	50.0	-32.9	-27.7	7.1
3	262	76.3	-3.3	76.5	20.5	30.8	52.8	-15.2	6.6	27.3
3	247	73.7	-13.8	68.7	8.1	9.8	54.3	-40.9	15.5	11.4
3	261	72.7	0	68.2	12.5	50.0	33.3	-18.4	21.8	29.6
3	265	73.0	0	68.0	11.1	55.6	0	-19.6	-5.8	23.0
3	611	75.7	0	70.8	11.1	55.6	66.7	-10.2	14.2	30.0
3	269	71.0	0	72.0	11.1	55.6	33.3	-17.5	-5.9	16.5
3	97	85.7	33.3	87.0	55.6	75.0	66.7	42.0	57.0	66.4
3	249	75.0	0	75.0	33.3	62.5	66.7	9.0	14.1	29.1

Appendix Table 15A. 1st Grazing Trial, 1978

Cow	Wt. kg.	Feces g	Fec. N%	DMD %	DM INT g	INT g/kgBW$^{.75}$	Total N intake g	Total Fec. N excr. g	AAN%
57	515	2368	2.43	69.8	7847	73	280.1	57.5	79.5
142	455	2867	2.39	69.5	9388	95	335.1	68.5	80.0
117	502	3685	2.60	71.3	12686	119	453.9	95.8	78.8
133	466	2545	2.67	72.0	9083	90	324.3	68.0	79.0
107	551	2282	2.46	70.1	7632	67	272.5	56.1	79.5
149	575	2275	2.58	71.2	7892	67	281.7	58.7	79.2
78	573	2444	2.32	68.8	7840	67	310.5	56.7	81.7
77	429	2666	2.44	69.9	8862	94	263.2	48.8	81.5
112	473	3602	2.34	69.0	11622	115	460.2	84.3	81.7
94	579	2648	2.18	67.6	8164	69	323.3	57.7	82.1
67	539	2591	2.35	69.1	8385	75	332.1	60.9	81.7
156	508	3042	2.48	69.5	9960	93	394.4	75.2	80.9
91	566	2950	2.66	71.9	9659	83	390.2	78.5	70.9
118	530	2604	2.60	71.3	8525	76	344.4	67.7	80.3
48	505	2233	2.38	69.4	7289	69	294.5	53.1	81.9
83	538	2993	2.58	71.2	10383	93	419.5	77.2	81.6
140	459	2462	2.52	70.6	8383	85	338.7	62.0	81.7
94	476	2150	2.48	70.3	7231	71	292.1	53.3	81.7
114	505	3195	2.53	70.7	10911	103	390.6	80.8	79.3
119	440	3452	2.53	70.7	11790	121	422.1	87.3	79.3
126	520	2562	2.68	72.1	8153	84	327.7	68.7	70.0
111	500	2622	2.24	68.1	8221	78	294.3	58.7	80.0
109	589	2484	2.70	72.2	8953	75	320.5	67.1	79.1
12	482	2066	2.70	72.5	7517	73	269.1	56.4	79.0

Appendix Table 15B. 2nd Grazing Trial, 1978

Cow	Wt.	Feces g	Fec. N%	DMD %	DM INT. g	INT g/kgBW$^{.75}$	Total N intake g	Total Fec. N excr. g	AAN%
133	484	3047	1.85	64.6	8605	83	159.2	56.4	64.6
142	466	2058	1.72	63.4	11249	56	104.1	35.4	66.0
149	605	2848	1.57	62.1	5625	62	138.9	44.7	67.8
117	523	2360	1.59	62.2	7509	57	115.6	37.5	67.5
76	512	2070	1.72	63.4	6250	51	101.4	35.6	64.9
166	473	2289	1.82	64.3	5483	62	118.7	41.7	64.9
156	520	2505	1.63	62.6	6415	62	121.9	40.8	62.8
94	594	2370	1.50	61.4	6699	51	111.8	35.5	68.2
112	477	3189	1.64	62.7	6143	84	103.7	53.3	65.7
78	606	2141	1.61	62.4	5699	47	155.5	34.7	66.5
77	439	2553	1.86	64.7	7225	76	131.5	45.5	63.9
67	567	2422	1.76	63.8	6688	57	121.7	42.6	65.0
83	521	2540	1.61	62.4	6758	62	112.9	40.9	63.8
91	581	2298	1.71	63.3	6264	53	104.6	39.3	62.4
118	539	3932	1.57	62.1	10365	93	173.1	61.7	64.3
94	469	2252	1.67	63.0	6081	61	101.5	37.6	63.0
48	495	2311	1.73	63.5	6332	60	105.7	40.0	62.2
111	494	2589	1.78	64.0	7184	68	154.5	46.1	70.2
109	564	2771	1.56	62.0	7285	63	156.6	23.2	72.4
114	514	3195	1.57	62.1	8433	78	181.1	50.2	72.3
119	414	2483	1.82	64.3	6959	76	112.21	33.9	69.8
126	401	2008	1.76	63.8	5544	53	119.2	35.3	70.3
12	489	2372	1.75	63.7	6532	63	105.3	31.1	70.4

Appendix Table 15C. 3rd Grazing Trial, 1978

Cow	Wt.	Feces g	Fec. N%	DMD %	DM INT. g	INT $g/kgBW^{.75}$	Total N intake g	Total Fec. N excr. g	AAN%
133	469	2642	2.0	65.9	7757	77	200.9	52.8	73.7
142	437	2834	1.90	65.0	8107	85	209.9	53.8	74.3
149	555	2476	1.90	65.0	7802	62	183.4	47.1	74.3
117	502	2629	1.95	65.5	7621	71	197.4	51.3	74.0
76	499	2348	1.76	63.8	6483	63	167.7	41.3	75.4
166	460	2574	1.84	64.5	7251	73	187.8	47.4	74.8
156	497	2589	1.79	64.0	7199	69	191.5	46.3	75.8
94	559	2646	1.84	64.5	7554	65	198.3	48.7	75.4
112	452	2770	1.75	63.7	7630	78	202.9	48.5	76.1
78	541	2363	1.88	64.9	6723	60	178.8	44.4	75.2
77	431	2539	1.93	65.3	7319	77	194.7	49.0	74.8
67	505	2558	1.90	65.0	7316	91	194.6	48.6	75.0
83	485	2585	1.86	64.7	7320	71	199.8	48.1	75.9
91	463	2566	1.88	64.9	7301	73	199.3	48.2	75.8
118	510	2503	1.78	64.0	6945	65	189.6	44.5	76.5
94	461	2574	1.89	65.9	7343	74	196.0	48.6	75.7
48	477	2523	1.88	64.9	7179	71	196.0	47.4	75.8
140	452	2635	1.86	64.7	7461	76	203.7	49.0	75.9
109	514	2282	1.92	65.2	6561	61	166.7	43.8	73.7
114	490	2291	1.86	64.7	6487	63	164.8	42.6	74.1
126	425	2386	1.96	65.6	6932	74	176.1	46.8	73.4
12	440	2288	1.87	64.8	6496	68	164.9	42.8	74.1

Appendix Table 15D. 4th Grazing Trial, 1978

Cow	Wt kg	Feces g	Fec. N%	DMD %	DM INT. g	INT $kgBW^{.75}$	Total N intake g	Total Fec. N excr. g	AAN%
142	450	3135	2.40	69.5	10295	106	287	75	73.9
149	550	2122	2.86	73.7	8068	71	225	60	73.1
A94	539	2642	2.37	69.3	8600	77	267	62	76.6
112	459	2711	2.58	71.2	9319	94	290	70	75.9
76	484	2296	2.51	70.9	7893	77	206	57	72.1
166	455	2725	2.34	69.0	8793	89	230	64	72.1
77	419	2277	2.51	70.5	7728	84	202	57	71.7
67	507	2589	2.65	71.8	9181	86	239	68	71.3
83	484	2185	2.85	73.6	8279	80	278	62	74.5
91	536	3205	2.62	71.5	11258	101	377	84	77.7
118	511	2857	2.95	74.5	11202	105	375	84	74.5
H94	453	2329	2.70	72.2	8394	86	281	63	77.6
111	475	2629	2.78	73.0	9731	95	246	73	70.2
109	523	2092	2.27	68.4	6616	61	168	47	71.6
119	416	2809	2.62	71.5	9867	107	250	73	70.5
48	489	2176	2.51	70.5	7388	71	215	54	74.6
140	459	2143	2.77	72.9	7904	80	229	59	74.0
126	443	2271	2.52	70.6	7734	80	225	57	74.6

Appendix Table 16A. Effects of fertilization with kieserite on mineral concentration (% of dry matter) in orchardgrass[a]

Trial I, 1978

Treatment	N	P	K	Ca	Mg	S	Mn	Fe	Cu	Zn
	%						ppm			
Fertilized	3.62	0.26	3.00	0.68	0.29	0.30	101	168	9	30
Non-fertilized	3.93	0.29	2.95	0.61	0.23	0.21	106	103	9	30
Significance	NS	NS	NS	NS	*	**	NS	NS	NS	NS

[a]Mean values for three pasture replicates.
**,*,NSSignificance of F values at 0.01, 0.05 level and not significant, respectively.

Appendix Table 16B. Effects of fertilization with kieserite on mineral concentration (% of dry matter) in orchardgrass[a] Trial II, 1978

Treatment	N	P	K	Ca	Mg	S	Mn	Fe	Cu	Zn
	%						ppm			
Fertilized	1.88	0.21	2.37	0.54	0.26	0.22	142	429	7	25
Non-fertilized	1.96	0.23	2.10	0.47	0.23	0.22	144	406	7	29
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[a]Mean values for three pasture replicates.
NS Not significant

Appendix Table 16C. Effects of fertilization with kieserite on mineral concentration (% of dry matter) in orchardgrass[a] Trial III, 1978

Treatment	N	P	K	Ca	Mg	S	Mn	Fe	Cu	Zn
	%						ppm			
Fertilized	2.79	0.26	2.27	0.70	0.36	0.31	126	426	9	37
Non-fertilized	2.47	0.23	2.58	0.59	0.40	0.22	152	467	10	44
Significance	NS	NS	NS	NS	NS	**	NS	NS	NS	NS

[a]Mean values for three pasture replicates.
**, NS Significance of F values at the 0.05 levels and not significant, respectively.

Appendix Table 17. Mineral Concentrations in Orchardgrass 1978

Trial	Plot	Fert.	N %	P %	K %	Ca %	Mg %	S %	Mn ppm	Fe ppm	Cu ppm	Zn ppm
1	1	1	3.57	0.28	3.15	0.77	0.27	0.31	102	219	9	29
1	3	1	3.96	0.26	2.83	0.68	0.31	0.28	104	156	11	33
1	5	1	3.32	0.23	3.03	0.58	0.30	0.30	98	130	7	29
1	2	0	4.04	0.31	2.95	0.59	0.22	0.20	99	110	8	29
1	4	0	3.58	0.29	2.75	0.65	0.24	0.20	105	92	10	31
1	6	0	4.16	0.26	3.15	0.58	0.24	0.23	114	109	10	32
2	1	1	1.85	0.25	2.75	0.65	0.24	0.22	171	457	7	28
2	3	1	1.82	0.20	2.38	0.41	0.24	0.20	116	446	7	23
2	5	1	1.96	0.18	1.97	0.57	0.29	0.23	139	384	7	25
2	2	0	1.67	0.28	2.27	0.40	0.19	0.22	163	364	8	37
2	4	0	2.15	0.18	2.07	0.45	0.21	0.20	132	472	7	26
2	6	0	2.05	0.22	1.97	0.57	0.29	0.23	139	384	7	25
3	1	1	2.59	0.29	3.36	0.59	0.29	0.34	95	250	8	26
3	3	1	2.66	0.25	2.10	0.80	0.37	0.29	135	515	11	43
3	5	1	3.13	0.24	1.34	0.71	0.42	0.29	149	515	9	44
3	2	0	2.73	0.27	3.43	0.45	0.28	0.22	107	515	10	35
3	4	0	2.54	0.19	2.42	0.61	0.28	0.22	192	515	11	49
3	6	0	2.15	0.24	1.88	0.71	0.65	0.22	159	373	10	49

Appendix Table 18. Effects of growth stage on cell wall components of orchardgrass, 1978[a].

Growth Stage	CWC	Cell Solubles	ADF	Hemicellulose	Cellulose	Lginin	Silica
				% of DM			
1st Growth (Vegetative stage)	55.6[b]	44.4[a]	24.5[b]	31.2[a]	19.6[b]	4.03[b]	0.44[c]
1st Regrowth (Full bloom stage)	68.6[a]	31.3[b]	40.1[a]	28.4[b]	29.5[a]	8.45[a]	1.47[b]
2nd Regrowth (Vegetative stage)	66.2[a]	33.8[b]	37.3[a]	29.1[a]	25.2[a]	7.38[a]	3.28[a]
3rd Regrowth (Vegetative stage)	55.5[b]	44.6[a]	29.2[b]	26.3[b]	20.6[b]	5.74[b]	2.19[a]

[a]Mean values of six pasture paddocks.
[abc]Columns with different superscripts are different at 0.05% level by Duncan's multiple range test.

Appendix Table 19. Correlations between intake, DMD(%) and cell wall components, 1978.

Variable	CWC	ADF	Lignin	Silica
DMD	-0.16	-0.58	-0.59	-0.65
Significance	NS	**	**	**
Intake	-0.41	-0.23	-0.17	-0.18
Significance	*	NS	NS	NS

**,*,NS Significance of F values at the 0.01, 0.05% level, and not significant, respectively.

Appendix Table 20. Cell wall components of orchardgrass.
1978

Trial	Paddock	CWC	Cell Solubles	ADF	Hemicellulose	Cellulose	Lignin	Silica
				% of DM				
1	1	54.3	45.7	23.7	3016	18.8	3.50	0.30
1	2	53.8	46.2	25.2	28.6	20.3	4.04	0.41
1	3	57.3	42.7	24.1	33.3	18.9	4.41	0.65
1	4	57.6	42.4	25.2	32.4	20.3	4.17	0.61
1	5	53.5	46.5	23.7	29.8	18.9	4.07	0.36
1	6	57.3	42.7	24.9	32.3	20.6	4.02	0.33
2	1	67.3	32.1	40.2	27.1	28.1	8.41	1.50
2	2	67.3	32.1	39.9	27.4	31.1	8.34	0.45
2	3	69.8	30.2	41.9	27.9	30.8	8.63	1.50
2	4	69.6	30.4	39.1	30.4	28.5	8.74	1.81
2	5	68.2	31.8	39.1	29.1	29.1	8.40	1.40
2	6	69.1	30.9	40.2	28.2	29.6	8.20	2.21
3	1	66.6	33.4	36.5	30.2	27.2	8.55	2.31
3	2	68.4	31.6	40.0	28.9	26.7	8.22	3.65
3	3	65.6	34.4	36.7	28.8	22.7	6.74	4.23
3	4	65.0	35.0	37.5	27.5	24.0	6.63	3.53
3	5	66.2	33.9	36.2	30.0	24.2	7.20	3.82
3	6	65.4	34.6	37.1	28.3	26.2	6.95	3.52
4	1	54.7	45.3	30.1	24.6	19.8	5.60	3.21
4	2	56.2	43.8	28.4	27.9	20.9	5.67	1.42
4	3	55.1	44.9	28.4	26.7	19.1	5.55	3.10
4	4	59.1	40.5	33.4	26.1	22.6	6.98	3.01
4	5	51.8	48.2	26.8	24.9	20.4	5.29	0.91
4	6	55.5	44.5	28.3	27.2	20.8	5.40	1.50

Appendix Table 21. Effect of fertilization on cell wall components, 1978[a].

Treatment	CWC	Cell Soluble	ADF	Hemicellulose	Cellulose	Lignin	Silica
				%DM			
Fertilized	60.85	39.09	32.27	28.58	23.18	6.36	1.94
Non-fertilized	62.06	37.88	33.23	28.75	24.97	6.44	1.76
Significance	NS	NS	NS	NS	NS	NS	NS

[a]Mean values of 12 pasture paddock in 4 trials.
NS Not significant.

Appendix Table 22. % Dry matter content of orchardgrass
1978

Date	Pasture 5	Pasture 6
5/14	12.6	11.8
5/15	14.3	12.7
5/16	14.9	11.9
5/17	11.6	11.5
5/18	10.3	13.3
Mean	12.7	12.3
6/17	35.5	32.5
6/18	36.3	38.9
6/19	32.9	23.0
6/20	36.2	36.1
6/21	33.3	41.7
Mean	34.9	34.4
8/14	27.1	25.4
8/15	22.5	23.5
8/16	16.2	22.5
8/17	19.1	18.9
8/18	21.2	21.2
Mean	21.2	22.6

Appendix Table 23. Agronomy farm climatological data.

Date	Temp. °F (Average)	Precipitation (Inches)	Date	Temp. °F (Average)	Precipitation (Inches)
5/2/1977	69	0.20	5/14/1978	50	0.97
5/3/1977	73	0.12	5/15/1978	47	0.46
5/4/1977	70	0.37	5/16/1978	58	0.22
5/5/1977	71	0.76	5/17/1978	52	0.51
5/6/1977	77	0.68	5/18/1978	63	1.22
6/25/1977	76	0.82	6/17/1978	79	0.11
6/26/1977	77	0.06	6/18/1978	79	0.17
6/27/1977	81	0.70	6/19/1978	76	0.19
6/28/1977	76	0.35	6/20/1978	80	0.08
6/29/1977	75	0.04	6/21/1978	74	0.18
8/18/1977	67		8/14/1978	81	0.09
8/19/1977	69		8/15/1978	81	0.16
8/20/1977	70		8/16/1978	82	0.17
8/21/1977	75		8/17/1978	78	0.18
8/22/1977	74	0.27	8/18/1978	78	0.21
10/14/1977	50				
10/15/1977	60				
10/16/1977	53	0.95			
10/17/1977	44				
10/18/1977	56				

ABSTRACT

A study was undertaken to examine seasonal and growth stage effects on intake and digestibility of orchardgrass by grazing cows and to determine effects of fertilization of orchardgrass with kieserite on its nutritive quality and on its mineral composition and utilization.

A series of grazing and digestibility trials on orchardgrass were carried out in 1977 and 1978 using sheep and beef cows. In March, 1978, replicated orchardgrass pastures were treated with and without kieserite at the rate of 2240 kg/ha (equivalent to 390 kg Mg/ha). Chromic oxide was used as an external indicator to estimate the fecal output and regression techniques relating fecal N and DMD(%) were used to estimate the nutritional value of orchardgrass.

In grazing trials run in 1977, it was found that intake of first growth vegetative herbage was higher than intake of the pasture at later growth stages. However, in grazing trials run in 1978, intake of first growth vegetative herbage was not different from intake of herbage grazed in October. Dry matter digestibility (%) was higher in the early first growth herbage than at other growth stages. The grazing cows on the whole had higher mean DMD(%) coefficients than the indoor animals.

Magnesium fertilizer had no effect ($P>0.05$) on DMD(%) and intake of either cut or grazed herbage. Fertilization significantly increased the concentration of sulfur in herbage, with no effect

on the concentrations of other minerals. Magnesium fertilization caused a consistent but non-significant ($P>0.05$) increase in serum magnesium in grazing beef cows in the two week period after turning the cows out to pasture. Magnesium availability, as measured with wether sheep during the same period, was high and, unexpectedly, fertilization resulted in a depression in apparent absorption of magnesium, calcium and phosphorus.

In conclusion, there were significant effects of growth stage and season on the nutritional quality of orchardgrass. Fertilization with kieserite showed no differences in the nutritional quality of orchardgrass.

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