ASSESSMENT OF FORAGE SPECIES AND VARIETIES FOR THE CENTRAL INTERIOR OF BRITISH COLUMBIA

by

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B. Sc. (Agr.), The University of British Columbia, 1978.

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

IN

THE FACULTY OF GRADUATE STUDIES

(Animal Science)

We accept this thesis as conforming

to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

NOVEMBER 1986

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ABSTRACT

1982 experiments were conducted to examine several aspects of forage quality in relation to animal nutrition, including the differences in quality between forage types (legumes or grasses), species and varieties; between years; between two hay mixes; and between three harvest dates. In addition, the importance of quality relative to yield is examined. In the first experiment, acid detergent fibre, neutral detergent fibre, crude protein, and nylon bag dry matter disappearance determinations were used to assess the variation in quality between forage types, species and varieties, and between years. In the second, voluntary dry matter intake and digestibility results were used to assess the variation in quality between hay mixes and harvest dates.

The results of the first experiment indicate that the legumes were of higher quality than the grasses; red and alsike clover were of higher quality than alfalfa, and orchardgrass was of higher quality than timothy. With the exception of red clovers, where Lakeland and Pacific varieties were of higher quality than Altaswede, there was little difference in quality between varieties within a species. Neutral detergent fibre analysis results suggest a difference in intake between forages grown in different years while acid detergent fibre analysis results indicate no difference in digestibility would be expected between years. The results of the second experiment indicate there was a difference in quality between forage mixtures (the early maturing

mixture was best), and harvests (early and mid bloom harvests were better than the late bloom harvest).

The parameter with the largest variability was yield. Differences were greater between years than between types and species (the clovers highest, alfalfa and timothy intermediate, and orchardgrass lowest) with the least variation occuring between varieties within species. The red clover-timothy (late maturing) forage mixture was the highest yielding. Within forage mixtures the full bloom harvest (100% bloom of the legume component) had the highest yields.

Since yield was more variable than the quality parameters studied, it was concluded that the most important consideration when selecting a forage mixture was yield. Since there tended to be little difference in quality parameters between varieties within a species, selecting the highest yielding combination would provide the largest amount of useable nutrients per hectare of land base.

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ACKNOWLEDGEMENTS

I would like to express my appreciation to Dr. Lyle Rode for his assistance and guidance over the past three years, and to Agriculture Canada for the use of facilities. I would also like to thank Dr. Malcolm Tait for providing direction and assistance. Further help from J. A. Pelter, J. N. Tingle, B. Wikeem with thoughts and resources was also gratefully acknowledged. Finally, I would like to thank Dr. J. Basarab and Alberta Agriculture for assistance with and statistical analysis.

I would like to pay special tribute to Regina who has given up holidays and weekends to see this project completed and to thank her for her patience and support throughout.

CHAPTER 1 INTRODUCTION

Agriculture in the Central Interior region of British Columbia was extensive in nature and was based mainly on forage crops intended for livestock consumption. The industry was located along river valleys possessing individual microclimates with growing conditions that differ sufficiently from other regions to require local forage crop evaluation.

Several projects have been undertaken to evaluate forage species and varieties in the region (Waldern and Burns, 1964; Tingle and Dawley, 1974; Tingle and Elliot, 1975; Waldie et al., 1983). These trials examined productivity of species and varieties as measured by yield and involved few animal related parameters. Additional laboratory techniques are available that further elucidate the suitability of those species and varieties on test for animal production.

With these points in mind the overall objective of this study was to assess the quality of selected forages grown in the Central Interior of British Columbia in terms of animal production in order to obtain information upon which better livestock recommendations could be based.

To meet this objective two projects were undertaken. The first project (the Variety Trial) involved analysis of four varieties each of orchard grass (Dactylis glomerata L.) timothy (Phleum pratense L.) and alfalfa (Medicago sativa L.) , one variety of alsike clover (Trifolium hybridum L.) and three varieties of red clover (Trifolium pratense L.). Samples of each variety were collected over three years as part of the B.C. Seed Crop Evaluation Project (1981-1983). Each forage plot was harvested at the phenological stage considered optimum for forage quality. Standing crop was then determined and the samples stored.

Determinations carried out in the Variety Trial included crude

protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF), and nylon bag dry matter disappearance (NBDMD).

The specific objectives of the variety trial were:

1) to assess the variation in the nutritional quality between forage species and varieties within species, and;
2) to assess the variation in the nutritional quality of forage species and varieties between years based on laboratory analytical procedures.

The second project (The Feeding Trial) involved an assessment of two grass-legume mixtures harvested at early, mid and full bloom of the legume component. The first mixture consisted of Tetra alsike clover, Toro timothy and Manchar smooth bromegrass (Bromus inermis L.) in a formulation intended to mature earlier in the growing season than the second mixture which consisted of Altaswede red clover and Climax timothy. Dry matter intake (DMI) and dry matter digestibility (DMD) of each mixture were determined. The specific objectives of the feeding trial were:

1) to assess the effect of an early and late maturing forage mixture on voluntary feed intake and digestibility, and;
2) to assess the effect of increasing maturity of each forage mixture on voluntary feed intake and digestibilty.

CHAPTER 2 LITERATURE, REVIEW

2.1 FACTORS AFFECTING FEED INTAKE

Ruminant animals are able to convert plant materials that are not well digested by man into food. Thus, they not compete directly with man for food rescources (Van Soest, 1982). The animal production potential of these plant materials was determined by a complex interaction between the constituents of the feed, the rumen microbial population, the physiological state of the animal and the environment. The animal production potential (or feeding value) of a forage was a function of feed intake and feed utilization. Apparent digestibility was a major component of feed utilization (or nutritive value) although other factors such as efficiency of nutrient utilization are also important (Ulyatt, 1973). It was difficult to resolve the relative importance of voluntary intake and nutritive value in determining the overall feeding value of a forage because the two feed parameters are correlated - nutritive value being a production response per unit intake. The results of Ulyatt (1973) indicated that digestibility and intake are each associated with approximately 50% of the variation in live weight gain of test animals.

The following section of the literature review will cover the factors controlling and affecting intake and digestibility and the inter-relationship between these feed quality parameters.

2.1.1 INTAKE REGULATION

Jones (1972) indicated in his review paper that the mechanisms of ruminant feed intake regulation are complex and not well understood. These mechanisms have evolved so that a certain energy balance was maintained that varies with the productive status of the animal (Baile and Della-Fera, 1981). There is evidence that the particular physiological

mechanisms controlling intake will vary depending on the quality of the feed. As digestiblity is increased feed consumption will rise to a point where the animals energy requirements are met. Above this point intake is controlled by metabolic factors, and as nutritive value increases further feed intake decreases since less is required to meet the desired energy balance. Below the point where energy requirements are met other factors such as "rumen fill" limit intake. Conrad (1966) suggested that with dairy cows this point was at about 66% dry matter digestibility.

Della-Fera and Baille (1984) indicated that the various factors controlling intake are integrated in the hypothalamus but the actual neurochemical events are not well understood. Feed intake may be mediated by chemostatic or thermostatic mechanisms (Baille and Della-Fera, 1981) such as osmolarity of body fluids, rumen pH and volatile fatty acids but "because changes of hypothalamic and surface temperatures during feeding are related more to nonspecific activity than to feeding there seems to be little evidence that temperature changes per se act under most conditions as a signal for the hunger-satiety system".

Feed intake was also controlled by the physical capacity of the alimentary tract, the rate of digestion and the rate at which undigested residues are reduced in size before they can move out of the rumen (Bines, 1971). Physical regulation of food intake probably involves stretch receptors in the walls of the rumen and intestines but the exact nature and location of these are not known (Baile and Della-Fera, 1981).

The principle factor determining rumen capacity is the size of the animal (Bines, 1971), thus, when food of relatively low digestibility is provided animal intake is broadly related to liveweight. Disappearance from the total tract also affects intake (Meijs, 1981). The rate of

disappearance of digesta from the rumen was a function of rate of breakdown by the action of both microbial fermentation and mechanical activity; including chewing, rumination and muscular contraction of the gut. The relationship between intake and digesta disappearance was reflected in the relationship between voluntary intake and digestibility of various roughages.

Meijs (1981) concluded there was a strong relationship between digestibility and feed intake. The point at which food intake regulation moves from physical to metabolic factors depends on the type of feed, physiological status of the animal and the energy concentration per unit of diet volume.

2.1.2 ANIMAL FACTORS AFFECTING INTAKE

While animal intake is regulated by physical and metabolic factors, other factors such as sensory cues, sex, age and weight, breed, lactation, pregnancy, body composition and exercise also play an important part in how much was consumed.

Ruminant animals used sensory clues including gustatory, olfactory and tactile stimulation but not vision for selection of feed since sheep fitted with blinders had the same feed preference ranking as sighted sheep (Baile and Forbes, 1974). Evidence of the olfactory effects was shown by Arnold et al. (1980) in which the voluntary intake of hay by normal sheep was significantly increased by the odor of butyric acid and amyl acetate and depressed by the odor of coumarin and glycine. Anosmic sheep were unaffected and overall had higher intakes than normal sheep for those compounds tested. Further evidence of the effect of smell was rejection of feces contaminated herbage by cattle (Meijs, 1981). Other

researchers have noted that intake was reduced when the ration contains a high percentage of fine particles. Part of this reduction may be attributed to reduced palatability of the feed (Van Soest, 1982).

Aderibigbe et al. (1982) speculated that there were animal sex related differences in the animal's preference for four varieties of ryegrass. Sex differences in preference were seen in several instances in deer (Church, 1979) where bucks showed a stronger preference for sodium acetate than does. Owens et al. (1985) found that overall feed intake of beef steers was 2.8% higher than beef heifers in a study of 745 different sets of pens of 50 cattle or more.

Owens et al. (1985) found that breed had an effect on intake with dairy breed steers eating more than beef breed steers with a mean difference of 17% during each 28 day study period, although this may be due to body weight more than breed. Blaxter et al. (1961) also noted a difference in intake between breeds of sheep, however, Weston (1982) indicated that in most studies of voluntary feed intake differences between breeds and strains more care is required in the selection and preparation of the experimental animals. Thus, the data may not reliably indicate population means.

Differences in intake due to sex and breed may be associated with differences in the initial weight of cattle (Owens et al., 1985). Starting weights when growing cattle were admitted to a feedlot were higher for dairy than beef steers and beef steers were higher than beef heifers. They noted that for a given weight, feed intake differences by beef steers and heifers was less than one percent.

Another factor affecting intake was stage of pregnancy. In late pregnancy, Campling (1966) found that the pregnant monozygotic twins ate

less hay than their non-pregnant sisters. Weston (1982) noted that the decrease in feed consumption was not confined to diets limited in intake by physical factors but also by metabolic factors. He goes on to say that the reason feed intake falls was not established, although the upward displacement of the ventral rumen wall reduced rumen volume, and may be a factor. Constant feed intakes have been recorded with a 30% decrease in rumen volume and increased estrogen secretion may also be a factor. In many cases, pregnancy and lactation are confounded making it difficult to differentiate between the two physiological states.

Campling (1966) noted that lactation had a much greater effect on intake than pregnancy with the lactating dairy cow eating 29% more hay than the dry, non-pregnant animal. Intake lagged several weeks behind the increase in milk yield. Similar results have been noted in ewes (Dulphy et al., 1980).

Weston (1982) stated that no clear quantitative relationship exists between voluntary consumption and body composition even though there was evidence that fat ruminants eat less than thin ones (Baile and Forbes, 1974). During lactation in dairy cows and ewes, voluntary feed intake tends to be inversely related to body fat content. Other studies have noted no change in intake between heavier and lighter mature animals.

Finally, Baile and Forbes (1974) indicate that exercise can have a significant effect on intake with grazing animals requiring substantially more energy for maintenance than stall fed animals. Animals tend to compensate for increased requirements by eating more.

2.1.3 PLANT FACTORS AFFECTING INTAKE

In addition to the many animal related factors that have an impact

on intake of forages, there are a number of plant factors that may affect intake. These include plant genus, species and variety; phenological stage at harvest; date of harvest; plant part (leaf or stem); and chemical composition.

Minson (1982) indicated that the main factors controlling animal intake was the proportion of undigestible residues in the feeds, residue transit time throughout the rumen and the size of the rumen. Feeds differ in the time required for them to be broken down to particles small enough to escape from the rumen and these differences, to varying degrees, are influenced by the factors discussed below. These factors also affect the relationship between intake and digestibility for various feeds.

2.1.3.1 FORAGE TYPE, SPECIES AND VARIETY

It has been recognized for some time that legumes are eaten in greater quantities than grasses of similar energy digestibility (Minson, 1982). Troelson and Campbell (1969) showed that the intake of alfalfa hay was about 10% higher than that of the grass species studied. Thornton and Minson (1973) found that the mean voluntary intake of organic matter from a legume diet was higher than that of the grass diet. The retention time in the rumen was probably a major factor contributing to the higher intake of legume. The grasses were retained 17% longer in the rumen while the voluntary intake of legumes was 28% higher than grasses when digestibility of both was 60%.

Walters (1971) found that, at the same level of digestibility, there were differences in intake of orchardgrass, tall fescue (Festuca arundinacea Schreb.), perennial ryegrass (Lolium perenne L.) and

timothy. Troelson and Campbell (1969) also noted that reed canary grass was lower in dry matter intake (DMI) than either crested wheatgrass, bromegrass or Russian wild ryegrass at similar dry matter digestibilities (DMD). Walters (1971) showed that, at the mean level of digestibility for those grasses he examined, the grasses were at different stages of growth with different proportions of leaf and stem. Meaningful comparisons between species are often confounded by morphological and anatomical differences (Norton, 1982). Digestibility, rate of digestion, chemical factors, physical factors and external factors such as mold may also influence differences in intake between forage species (Minson et al., 1964).

Seoane et al. (1981) found the intake of Bounty timothy to be greater than that of Champ and Climax timothies. Walters (1971) also found differences in intake between orchard grass, perennial ryegrass and timothy varieties measured at the same digestibility. Differences in intake between varieties was not as wide as that between different species. It was noted that the earlier heading varieties had significantly higher intakes than the later heading varieties. Troelson and Campbell (1969) reported that early in the season, DMI was similar for two varieties of alfalfa while later in the season there were differences at similar digestibilities. The authors attributed this to variations in leafiness.

2.1.3.2 PLANT MATURITY AND DATE OF CUTTING

Troelson and Campbell (1969) found that as the plant matures, intake was reduced. The authors indicated this was related to decreasing digestibility. Walters (1971) reported that digestibility accounted for a major portion of the variability of intake in first cut forage. Minson

et al. (1964) also showed a general fall in intake as herbage digestibility decreased with first harvest being done successfully later in the growing season.

When a forage was harvested two or more times during the growing season, the number of days to harvest was a major indication of nutritional value (Walters, 1971). Troelson and Campbell (1969) reported that leafiness declines with advancing maturity reducing the availability of crude protein and soluble carbohydrates. The changing leaf to stem ratio may also be a factor in decreasing nutritive value.

Akin (1982) pointed out that the total cell wall constituents of forage increases as the plant matures. In grasses, quality was reduced with the translocation of soluble carbohydrates from the stem and leaves to the inflorescence resulting in increased lignification and decreased leaf to stem ratio.

The drop in intake was less in legumes than grasses due to a smaller drop in quality (Troelson and Campbell, 1971) even though intake of alfalfa decreased with increasing maturity in conjunction with decreasing energy (Heaney, 1970).

2.1.3.3 CHEMICAL COMPOSITION

As the plant matures, an increase in the fibre level usually occurs resulting in a reduction in protein and non-structural carbohydrates with an associated reduction in intake and digestibility (Minson, 1982). As cell wall constituent levels increase, intake declines (Van Soest, 1965). In forages with a high fibre level in the cell wall, intake was related more to the individual animal's energy requirement. Cell wall constituents limit intake when 55 to 60% of the cell dry matter is made up of fibre constituents. In a general way, then, as the fibre component

of a plant increases, intake decreases.

Lignen shows the poorest and cell wall constituents the best relationship with intake (Van Soest, 1965) even though lignin was highly correlated with all fibrous plant components. This was because total fibre was not necessarily closely related with the level of lignin in a forage and does not necessarily increase uniformly as the forage matures. This was the case with alfalfa which has a higher lignin content than grasses but is generally consumed in greater amounts. In grasses, lignin tends to increase more or less linearly while cell wall constituents tend to increase rapidly early in the season and then level off.

Meijs (1981) indicated that in dairy cow rations there was no relationship between crude protein or crude fat content of the feed and feed intake by the cows. However, when the crude protein content of the feed falls below 6-8%, intake drops, apparently due to a deficiency of circulating amino acids (Baile and Forbes, 1974). Lipke (1980) found that protein was significantly related to intake but could not establish a biological basis since the supplementation of additional protein to forages with less than 6% crude protein did not appreciably increase intake or digestibility.

Minson (1982) indicated that a number of regression equations have been formulated and, although they are significant, chemical composition fails to account for all of the differences in intake between samples. Most of the variation was caused by true differences in intake of plant species of the same chemical composition. The interrelationships between intake and chemical composition are highly species-oriented (Van Soest, 1965). In addition, differences in intake between leaf and stem fractions occur with the intake of leaf considerably higher than stems of

similar chemical composition.

Van Soest (1965) indicated that chemical composition was generally more closely related to digestibility than intake due to the correlation of cell wall constituents (fibrous material) with digestibility, especially within species (Osbourn, 1978).

2.1.3.4 LEAF AND STEM

Laredo and Minson (1973) reported that the voluntary intake of leaf was always higher than that of the stem fraction at the same digestibility although the levels varied between different species and the maturity of regrowth. The difference in intake between leaf and stem fractions in 30 comparisons was 42% lower for stems than leaves with a difference of only 1% in digestibility of the two fractions (Minson, 1982). This may be the result of the leaf portion being retained for a shorter period of time in the rumen than the stem portion which allowed more feed to be consumed (Laredo and Minson, 1973; Poppi et al., 1980). Minson (1982) suggested that the larger retention time of the stem fraction in the rumen was due to the higher proportion of large particles in the masticated stem than in masticated leaf because the stem shows greater resistance to physical breakdown. These large particles of the stem will remain longer in the rumen than the large particles of the leaf fraction.

2.1.3.5 CHOPPING AND PELLETING

The intake of a forage was usually increased when it was ground and pelleted as compared to long hay (Minson, 1982). The difference in intake was associated with a faster rate of passage through the rumen but

chopping per se would not increase intake over long hay until a certain particle size (between 4 and 8 mm) was reached (Robles et al., 1980).

Weston and Hogan (1967) indicated that ground alfalfa hay consumption was 41% higher than chopped alfalfa hay and ground wheat straw consumption was 31% higher than chopped wheat straw. The authors concluded that the increased voluntary intake caused by grinding and pelleting was not accompanied by any significant changes in the chemical composition of the diet.

2.2 FACTORS AFFECTING FEED DIGESTIBILITY

Schneider and Flatt (1975) define digestibility "as the percentage of the feed or of any single nutrient of the feed which was dissolved or otherwise acted upon in the entire digestive tract so it can be absorbed and thus put at the disposal of the body cells". There are several animal and plant related factors that affect digestibility of feedstuffs which are discussed in this section.

2.2.1 ANIMAL FACTORS AFFECTING DIGESTIBILITY

Blaxter and Wainman (1961) reported that, in cattle, the animals which consumed the most feed digested it least efficiently. Ulyatt et al., (1967) obtained results that showed a significant decrease in feed digestibility in the rumen but a significant increase in digestibility in the lower alimentary tract, as feed intake was increased. The authors suggest that with increased feed intake, the rate of passage increased reducing retention time in the rumen and therefore digestibility, although there was a compensatory effect distal to the rumen.

Van Soest (1982) summarized the relationship between intake and digestibility by indicating that digestibility depression was a function

of the competition between digestion and the rate of passage. The slowest digesting fractions of the cell wall -- cellulose and hemicellulose -- are the most affected. Measurements of the rate of passage of an average forage indicate that cell wall constituents are retained for 40 to 60 hours. Doubling the feed intake will decrease the retention time to about 30 to 33 hours in sheep. Van Soest (1982) concluded that those cell wall constituents susceptible to the greatest digestibility depression are those that show a substantial increase in digestibility between 30 and 48 hours of fermentation. As a result, increased feed intake results in reduced feed digestibility in most cases.

2.2.2 PLANT FACTORS AFFECTING DIGESTIBILITY

Several plant factors affect digestibility including forage type, species and variety; maturity and cutting date; proportion of leaf and stem; chopping and pelleting; and the efects of chemical treatments.

2.2.2.1 FORAGE TYPE, SPECIES AND VARIETY

Even though DMI was higher, DMD of legumes was generally lower or only equal to that of grasses harvested at similar periods of the growing season (Troelson and Campbell, 1969; Thornton and Minson, 1973).

The lower DMD of legumes compared with grasses was due to a number of factors. Legumes tend to have a higher cell wall content (and less cell soluble material) than grasses (Osbourne et al., 1974). Even though this was the case, the proportion of digested cell wall material is about the same (Moir, 1972). Mosley and Jones (1984) and Beever et al. (1985) found that clover had lower level of soluble carbohydrates, comparable cellulose and higher N levels than grasses and that in clover diets, proportionately less of the ingested organic matter appeared to be

digested in the rumen. Thornton and Minson (1973) found that legumes were retained for a shorter period in the rumen with a greater percentage of white clover particulate matter than of ryegrass disappearing in the first 3 hours after consumption (Moseley and Jones, 1984).

Both Minson et al. (1964) and Troelson and Campbell (1969) found differences in digestibility between grass species depending on the stage of growth with the second authors reporting increased variability in DMD as growth progresses. The first authors concluded it was not generally valid to compare the different species at defined stages of growth but rather that data must be interpreted in conjunction with yield and season of production.

Digestibility of the regrowth of any species was much less variable than the digestibilities of the first growths (Minson et al., 1964).

Milford and Minson (1966) found that orchardgrass was less digestible than ryegrass at all growth stages reflecting the lower soluble carbohydrate content of the orchardgrass. Lower soluble carbohydrate levels would indicate increased fibre levels and Burns et al. (1985) found that in the higher quality forages studied, digestibility of other fibre constituents were also higher. The poorly digested grasses showed lower digestion coefficients for hemicellulose, cellulose and cell wall constituents.

Differences in DMD between varieties have been reported in grasses at similar growth stages or percentage of leaf (Walters, 1971). In another study the variety in another study with the highest digestibility also had the highest proportion of soluble carbohydrates while the variety with the lower digestibility had the lowest levels of soluble

carbohydrates (Bland and Dent, 1964).

2.2.2.2 PLANT MATURITY AND DATE OF CUTTING

It was generally accepted that DMD declines with advancing forage growth through the growing season (Troelson and Campbell, 1969; White and Wight, 1981). However, there can be some exceptions to the general case. For example, Hidiroglou et al. (1966) reported that timothy showed no apparent decline in digestibility from mid-August through mid-October and Troelson and Campbell (1969) indicated that later in the season alfalfas did not decline in nutritional value. Cutting retards growth but the effects are not always predictable because factors other than the stage of growth (such as environmental effects) must be considered (Van Soest, 1982). However, both Hidiroglou et al. (1966) and Minson et al. (1964) indicated that regrowth in grasses was less digestible than first growth.

Wilman and Atlimimi (1982) indicated that in ryegrass, the stem portion of the plant declined in digestibility with advancing maturity faster than the leaf blade. The digestible energy content in the stems declined at more than twice the rate of the decline in the leaves (Hacker and Minson, 1981). In addition, dry matter, crude protein, soluble sugars and cellulose were more digestible in alfalfa leaves than alfalfa stems while crude fibre was more digestible in the stems.

Reasons for the decline in DMD have been suggested by Troelson and Campbell (1969) and Kilcher and Troelson (1973). Crude protein levels declined with advancing maturity in both the leaves and stems of alfalfa and bromegrass while crude fibre levels increased in both leaves and stems. Cell wall lignin increased at a slower rate in the leaves than in the stems as the plants matured. The depressing effect of crude fibre on digestibility was due to the presence of lignin which protects some of

the cellulose and hemicellulose of the cell wall from microbial digestion (Hacker and Minson, 1981).

2.2.2.3 LEAF AND STEM

Van Soest (1982) stated that, in general, stems are usually of lower quality than leaves. In Italian and perennial ryegrass harvested at similar stages of maturity, the leaf component of the plant had a higher DMD than the stem component, which was consistent with a higher digestibility of the cell wall constituents (Wilman and Altimimi, 1982).

2.2.2.4 CHOPPING AND PELLETING

It was generally recognized that dry matter digestibility was reduced when feeds are ground and pelleted (Greenhalgh and Reid, 1973; Van Soest, 1982). The response differs between forage species, in part due to the greater depression of organic matter digestibility induced by milling the grasses compared with the legumes (Osbourne et al., 1981).

Weston and Hogan (1967) indicated that at ad libitum levels of feeding the rate of flow from the abomasum was 20-30% higher with ground hay than with chopped hay. Robles et al. (1980) found that orchardgrass and alfalfa would have to be ground through screens smaller than 8 mm before a reduction in digestibility would be expected. Chopped forages particles are longer than 8 mm and thus would not exhibit the same digestibility depression. Blaxter and Graham (1956) found that the maximum depression in digestibility of finely ground grass material occurred in the cell wall constituents. This was expected since the fermentation of structural carbohydrates was slow and, since finely ground materials have a lower retention time in the rumen, the rapid passage of food through the digestive tract would result in reduced digestibility of the fibrous components of the cell wall. The effect of

pelleting mature forages on digestibility may be limited because the lignified cell walls collapse less on pelleting than the less lignified younger forages and the intake of digestible nutrients may remain low (Van Soest, 1982).

2.2.2.5 CHEMICAL TREATMENTS

Chemical treatments (urea, ammonia or NaOH) significantly increased the digestibility of poor quality feeds (Wanapet et al., 1985). Sundstol (1984) also reports that the intake of straw was increased when treated with ammonia. Crude fibre digestibility was substantially increased (10 to 20 percentage units) due, the authors feel, to the solubilization of hemicellulose increasing the rate and extent of cellulose and hemicellulose digestion. N balances were improved by treatment with urea and anhydrous ammonia but NaOH treatment resulted in higher overall digestibilities.

2.3 ENVIRONMENTAL FACTORS AFFECTING INTAKE AND DIGESTIBILITY

Van Soest et al. (1978) reported that environmental temperature, which increases lignin, was the dominant environmental factor effecting digestibility while the other effects (temperature, water, frost, light, season and daylength) are secondary.

The effects of temperature on DMD indicate that the digestibility of temperate forages grown in warm areas can be affected in a manner similar to tropical forages and increased temperatures can result in decreased DMD and increased proportions of cell wall constituents (Deinum et al., 1968). High temperatures appear to hasten the normal process of tissue aging and apparently decrease the digestibility of existing cell wall material (Wilson et al., 1976).

Wilson and Ng (1975) concluded that water stress clearly retarded

plant development with stressed leaves being ontogenetically younger than their actual age. a comparison of water stressed and unstressed leaves at the same physiological age reveals virtually no effect of stress on the content of cell wall material or nitrogen in specific plant parts. Generally, any factor that retards plant development tends to maintain quality and thus water stress results in a more digestible crop of lower yield (Van Soest, et al., 1978).

Frost results in a rapid decline in the nutritive value of grasses with frost killed leaves declining rapidly in DMD and CP. Freezing and more thawing patterns lead to leaching and respiration losses of the more digestible plant constituents (Wilson, 1982) by degrading the components of the translocation path system and ultimately affecting other metabolic processes including photosynthesis (Bula and Massengale, 1972).

Increased light intensity increased soluble carbohydrate and DMD levels of grasses through the photosynthetic accumulation of carbohydrates (Hight et al., 1968). Light induced photosynthesis also promoted the reduction of nitrate and its conversion, with carbohydrates, to amino acids and protein. Thus forages grown under cloudy conditions or in humid, foggy areas under reduced light conditions will be lower in DMD than forages from arid environments (Van Soest et al., 1978).

The DMD of grasses was higher in the spring than fall for two studies (White and Wight, 1981; Reid et al., 1967). However, Hidiroglou et al. (1966) obtained higher DMD in fall harvested forage from northern Ontario. The first result was associated with higher cell wall constituents and lower soluble carbohydrates in the fall forage (Reid et al., 1967) while in the second case, crude fibre levels were lower and crude protein levels higher in the fall than in the spring (Hidiroglou et

al., 1966). Deinum et al. (1968) indicated that vegetative grass in high summer time will have a slightly higher DMD than in autumn due to the low light intensity and still comparatively high temperatures in the later part of the season. Thus, the effect of season and daylength upon DMD varies due to a number of factors (Van Soest et al., 1978). The relationship with temperature and daylength varies with the season, daylength being a principle factor influencing the amount of light received.

2.4 TROPICAL VERSUS TEMPERATE FORAGES

The voluntary intake of tropical grasses was usually less than for temperate grasses harvested at the same growth stage (Minson, 1981). This is associated with higher fibre levels in the tropical grasses at all stages of growth resulting in lower dry matter digestibility, larger quantities of indigestible fibre and longer retention time in the rumen. However, tropical grasses are usually consumed in greater amounts than temperate grasses of the same digestibility. This was because a tropical grass at 60% digestibility was young and relatively leafy while a temperate grass would be stemmy and mature. Norton (1982) pointed out that mesophyll cells in tropical grasses are more densely packed and intercellular air spaces lower in volume than temperate grasses. This restricts the entry of microbial digestive enzymes thereby depressing the rate of digestion of the fibrous tissues of the plant. This would result in longer retention time and therefore lower intake of tropical grasses.

The DMD of tropical grasses was generally lower than that of temperate grasses and legumes. Summaries of reported digestibilities indicate that tropical forages have digestibilities of about 15 units

lower than temperate forages (Minson and McLeod, 1970). The lower digestibility appears to be due to higher temperatures at which they are grown and not due to basic differences between them (Minson, 1981). Temperate and tropical grasses grown under the same temperature and conditions had similar dry matter digestibilities (Minson and McLeod, 1970) and the authors concluded that differences in digestibility of the two categories of forages are closely associated with differences in climate.

2.5 LABORATORY METHODS OF ASSESSING FORAGE VALUE

In vivo techniques for estimating nutritive value and intake are expensive, time consuming and require large amounts of forage (Ferreira and Collins, 1982). Laboratory analysis was generally less expensive and faster than animal feeding studies and was useful in explaining nutritional phonomena and for describing feed characteristics useful in formulating rations (Van Soest, 1982).

The major laboratory techniques used for evaluating herbage quality include *in vitro* dry matter digestibility (IVDMD), chemical (eg. fibre), and *in situ* (Nylon bag dry matter disappearance -- NBDMD) techniques. The *in vivo* parameters most often of interest include digestible energy (DE), dry matter digestibility (DMD), organic matter digestibility (OMD) and voluntary intake of dry matter (DMI). The particular laboratory technique used depends on the *in vivo* parameter to be estimated and must be based upon experimentally determined relationships with the intact animal. This section, then will review the commonly used laboratory methods and how they relate to animal productivity.

2.5.1 PROXIMATE ANALYSIS

The Proximate Analysis system was the oldest method of assessing

forage value and most work has traditionally been done using this system.

Fonnesbeck (1976) pointed out that the proximate components do not represent the feed fractions they were intended to and crude fibre (CF) from one feed was not necessarily comparable in composition with this fraction in another feed (Ferreira and Collins, 1982). Van Soest (1965) pointed out that often the least digestible parts of fibre, xylan and lignin, are extracted and included in the NFE. In addition, most of the hemicellulose was dissolved. As a result, CF, which was believed to contain the non-digestible portion of the feed, was often equal to or higher in digestibility than the NFE (Ferreira and Collins, 1982). Crampton and Maynard (1938) long ago concluded that the specific values obtained from proximate analysis have often been over-estimated and this is especially the case for the fibre fraction. They further indicated that any relation CF may have to the digestibility of a feed may be, in part, fortuitous.

In a recent evaluation of laboratory methods for predicting the organic matter digestibility of forages, Aerts et al. (1977) determined the regression coefficient of CF for estimating in vivo OMD of various forages. The results showed CF had an r^2 of 0.35 for estimating in vivo OMD in grass hay, 0.68 for silages and 0.59 for pellets. These levels were only slightly lower than ADF for grass hays (0.41) and pellets (0.68) and about the same for silages (0.65). The main criticism with the use of CF to estimate the nutritive value of a feed is variable chemical composition of the residue when compared to those fibre components actually digested by the animal.

Similar concerns are expressed about crude protein (CP) since

forages also contain varying levels of nucleic acids, water soluble non-protein nitrogen and insoluble nitrogen found in association with lignin (Van Soest, 1967).

Schneider and Flatt (1975) also indicated that the ash fraction gives no indication of the actual mineral content of the feed, nor does the proximate analysis system evaluate vitamin levels. Both types of nutrients are a concern because an inadequate supply of even an essential mineral or vitamin may result in production problems.

The proximate analysis system has continued in use due to a conservative tendency to continue to rely on established procedures despite obvious limitations and inadequate understanding of the meaning and purpose of fibre determinations (Van Soest, 1967).

2.5.2 IN VITRO DRY MATTER DISAPPEARANCE

While there are many in vitro dry matter disappearance (IVDMD) techniques, most are modifications of the Tilley and Terry (1963) technique (Rode and Satter, 1984). Tilley and Terry (1963) explain that while in vivo digestibility experiments aid in estimating forage nutritive value for ruminants such experiments are time consuming and require large amounts of feed. The correlations between in vivo herbage digestibility and the contents of individual chemical components such as CF, CP and lignin are limited and cannot be applied equally to all forage plants. As a result, in vivo digestibility and chemical techniques are not available to plant breeders for such purposes as the initial selection of new varieties.

Ferreira and Collins (1982) concluded that the IVDMD technique has generally been reported superior to other laboratory methods for

predicting *in vivo* DMD. The technique has been misused due to attempts to estimate DMI from IVDMD values, something the process was not designed for. The technique was most useful for determining the relative differences between forage samples rather than as a means of estimating *in vivo* digestibility due to the numerous factors affecting digestibility (Ferreira and Collins, 1982).

Van Soest (1982) has suggested that the main disadvantage with the IVDMD technique was the length of time and number of steps required to carry out the procedure. Another major disadvantage was the variation in innoculum. The donor animal, method of sampling and processing the innoculum, and the amount of innoculum all affect the result. Variation between animal species, individuals, or the same animal between days have also been noted (Barnes, 1973).

2.5.3 NYLON BAG DRY MATTER DISAPPEARANCE

The nylon bag dry matter disappearance (NBDMD) technique (also referred to as the *in situ* or *in sacco* technique) was useful for measuring the rate and potential extent of digestion of feeds and the effects of various ration treatments such as supplementation, on these parameters (Barnes, 1973). The technique provides a simple and inexpensive method of assessing forage quality (Playne *et al.*, 1978) and has been used to examine the disappearance of DM, fibre and CP (Rode and Satter, 1984). The main advantages of the technique was placing the feedstuff in the actual animal as opposed to simulating ruminal activity *in vitro*.

In a comparison of several different methods of estimating OMD Aerts *et al.*, (1977) found that the NBDMD technique (48 hours *in situ* followed by a 48 hour pepsin incubation) resulted in an r^2 of 0.92. This was the

highest relationship of any of the other techniques, including the IVDMD and chemical parameters, examined. However, Barnes (1973) reported that the technique was subject to considerable variation and was difficult to standardize. Sources of variation include size and type of bags, cloth mesh size, sample size, fineness of grind, number of samples per trial, diet of the host animal, individuality of host animal, method of suspension in the rumen, location and time in the rumen, methods of cleaning and rinsing incubated bags, and inclusion or exclusion of a second stage pepsin digestion step.

Several authors have examined the importance of bag pore size on subsequent DM disappearance. The three main considerations are leaching of undegraded materials from the bags, exclusion of rumen bacteria from the substrate within the bag and accumulation of exogenous material within the bag (Van Hellen and Ellis, 1977; Mehrez and Orskov, 1977). Playne et al. (1978) indicated that DM losses due to leaching could be serious and a correction factor should be used to account for such losses.

Playne et al. (1978) indicated that sample size had little effect on DMD as long as sample size to bag size ratio was held constant; however, Nocek (1985) found that clumping of the substrate in the bag increased as sample weight increased.

Fineness of the grind of the substrate also affects DMD with losses from the bag being greater for the 1 mm than the 2 mm milling size (Playne et al. 1978). Clumping of feed substrates within the bag was noted for the 1 mm size grind. Weakley et al. (1983) found the greatest difference in DMD between feeds of different particle size occurred in the first few hours and the overall differences were not as large as might be expected.

There was some indication that the individual animal affects NBDMD. Nocek (1985) reported that his data suggested variation within animals in ruminal fermentation patterns and that the inclusion of a standard feed may be necessary to monitor the variation. Mehrez and Orskov (1977) found that the greatest source of variation in their study was that due to test animal followed by day of test. The least difference occured between test bags. Weakley et al. (1983) did not observe any significant differences among cows and indicated there may be no need to be concerned with the animal effects on NBDMD in substrates similar to soybean meal. However, these authors did find a significant difference due to animal diet with DM disappearance being lower for those animals being fed a high concentrate ration and speculate that this may be due to bacterial slime sealing the pores and blocking the influx of digestive organisms. Lindberg (1981a, 1981b) also found significant differences in NBDMD due to basal diets although there was some variability depending on the substrate being examined. For example, bags containing hay and sugar beet pulp decreased in DMD when the amount of roughage of the basal diet decreased while with fish meal there was a tendency towards increasing DMD. Straw and grains showed no significant difference between basal diets. Lindberg (1981b) related this to changes in rumen activity as the microbial population shifts from fibre digesting to amyloytic and saccharolytic organisms. Rode and Satter (1984) concluded that to reduce variability it was best to use animals eating a ration similar to the feeds being evaluated. Mehrez and Orskov (1977) reported that increasing the time of incubation from 7 to 24 hours did not substantially reduce variability. Nocek (1985) indicated that the method of introducing and removing the bags in a time series affected

disappearance. Bags were either introduced at specific intervals and all removed at once or all inserted at once and removed at specific intervals. When bags were inserted at specific intervals and all removed at once there was a slightly faster rate constant and a slightly lower variations in results.

There may be differences in results due to differences in washing technique (Weakley et al., 1983). Washing caused the loss of potentially degradeable water soluble components of the substrate (Hovell et al., 1986). However, if the degradation characteristics were similar to the material left in the bags the correction would be small. Weakley et al. (1983) indicated that most authors have found little difference in washing losses between days.

De Faria and Huber (1984), in comparing NBDMD and IVDMD results found that the two methods consistently ranked the forages being studied in the same order but the NBDMD technique yielded higher percentage levels of disappearance. There was high correlation between the two techniques when the bags were removed at 48 and 72 hours but only a low correlation when the bags were removed at 24 hours. Therefore, a poor quality hay would have to be retained 3 times as long in situ as the other better quality hays to obtain results similar to those obtained in vivo. This emphasizes the difficulty in relating degradation measurements made with a fixed time period to apparent in vivo digestibility.

Lindberg (1982c) found the degradation rate measured with nylon bags was an over-estimate of actual degradation at any given time since the feed particles are prevented from leaving the rumen. This implies that the degradation characteristics of different feeds could be of greater

nutritional significance than the dilution rate from the rumen because the individual degradation rate will affect dilution rate.

2.5.4 CHEMICAL SYSTEMS

The objective of laboratory analyses was to determine the composition of a feed from which an estimate of animal response will be made. Since the nutritive value of a forage was affected by composition, the problem of practical evaluation through chemical analysis was dependent upon the understanding of the fundamental physical and chemical factors controlling the availability of nutrients. There was no such thing as a best method because the nutritive aspects of quality are complex and there was no chemical method that will isolate the indigestible fraction of the feed (Van Soest and Robertson, 1980) Cell contents are essentially completely available to the animal while the unavailable components of a feed are found within the cell wall. The problem, therefore, was determining the portion of structural carbohydrate that was unavailable.

An adequate system of analysis must not only meet scientific criteria but must also be easy to complete and economical so as to be competitive with the proximate analysis system. It must also reflect those factors affecting feed variation since variation due to an unassayed factor will result in an unsatisfactory estimate of animal response (Van Soest and Robertson, 1980). Since chemical analysis was generally less expensive and faster than animal studies the use of these techniques in assessing feed value was indispensible (Van Soest, 1982).

2.5.4.1 VAN SOEST FIBRE SYSTEM

Due to general dissatisfaction with the Weende (proximate analysis) system, and the CF analysis technique and NFE calculation in particular,

Van Soest (1967) pointed out the need for new chemical analysis techniques. There has been a conservative tendency to rely on established procedures despite obvious limitations and the CF method still remains in use even though problems have been long recognized (Crampton and Maynard, 1938).

To overcome the problems of the CF technique (gelatinization and loss of lignin in the filtrate when using sodium hydroxide in the CF determination to remove nitrogenous consistuents) a method using detergents was proposed (Van Soest, 1963a). It was intended to overcome the problems with the CF technique and those of earlier detergent techniques which left a large portion of the plant protein undissolved resulting in an inaccurate estimation of the fibre fraction.

Anionic detergents facilitate the solution of proteins in slightly alkaline conditions and quaternary ammonium compounds dissolve polysacharides, proteins and nucleic acids resulting in the preparation of fibre residues with low N contents in feed. The use of a detergent in place of NaOH under milder conditions than those of the CF technique may, in addition, help preserve the integrity of the lignin fraction.

The objective of the detergent analysis system was the fractionation of forages into nutritionally available and nutritionally unavailable fractions. The indigestible portion of the feed was recovered in the neutral detergent (ND) residue while the acid detergent (AD) step divides the fibre into those fractions that are soluble and insoluble in a 1 N acid. The acid solubles include hemicellulose and cell wall protein while the insolubles include cellulose and the least digestible non-carbohydrate fractions including lignin. AD fibre (ADF) was also useful as an initial step for the sequential estimation of lignin, cutin,

cellulose, indigestible nitrogen and silica (Van Soest and Robertson, 1980).

Neutral detergent fibre (NDF) estimates the plant cell wall making it a useful tool for estimating feed intake. It gives a poor estimate of digestibility since plant cell walls vary in digestibility due to different fibre constituents. Thus, the major problem with any prediction of digestibility is that of estimating the digestibility of cell wall constituents (Van Soest and Robertson, 1980). ADF was used as a quick method of determining fibre in feeds and was used in a similar manner to CF in the proximate analysis system. The use of the ADF to predict digestibility was not founded on any theoretical basis other than statistical association. Heat damanged proteins are also recovered in the fibre, specifically the lignin fractions.

Van Soest (1963b) reported that the correlation of ADF with digestibility for 18 forages showed it to be "somewhat superior" to crude fibre ($r = -0.79$ for ADF and $r = -0.73$ CF respectively) in estimating nutritional value and was useful in estimating forage digestibilities for ration formulations. Since NDF isolates the slowly digesting components and measures the ND solubles (cell contents) Mertens (1983) suggested this analysis may be a method of choice for estimating digestibility from a theoretical perspective. NDF was related to intake and was a potentially important component in ration formulations. This was the result of NDF being related to the bulk density of feeds and the particle size reduction that must occur before feed can escape from the rumen. These factors are of greatest importance when the physical limits of the digestive tract regulate intake when intake level decreases and NDF level increases. Thus NDF was useful for estimating intakes for ration

formulations.

Since Van Soest's initial paper on the detergent system several problems with the ADF and NDF techniques have been identified. Van Soest and Robertson (1980) note three areas revolving around filtering problems. The first involves the filtering of lipids, which at levels greater than 10% can result due to inadequate levels of detergent in the water phase. The second involves protein which, when present at levels greater than 30% exceeds the capacity of the detergent to form soluble complexes. Finally, starch may form a viscous solution in hot ND solution that can also cause filtering problems. Materials with a high fat content can also cause problems with the initial grinding of materials in preparation for the fibre analysis.

There was no difference in NDF levels based on the volume of ND solution and sample size provided the proportions of sample to reagent were the same. There was a difference in NDF levels when a similar sample size was refluxed in different amounts of ND solution (Mascarenhas Ferreira et al., 1983).

In a study of the chemical components of the residues of fibre analysis system, Colburn and Evans (1967) found that cellulose, lignin, CP, and ash accounted for 95% of the original plant cellulose and 6% of the CP. Similar results were obtained by Bailey and Ulyatt (1970) who found the ND residues to consist of most of the hemicellulose plus all of the cellulose.

Jorgensen et al. (1982) found NDF and intake to be highly correlated (r=-0.65 for alfalfa and r=-0.79 for grasses). Rohweder et al. (1978) indicated that ADF was highly correlated with in vivo DDM (r=-0.83 in pure legume stands and -0.93 in grasses) as a result of a

study of a wide range of temperate and subtropical grasses and alfalfa. They reported the correlation between NDF concentration and intake ranged from r=-0.32 to -0.94 which varied with species and location and was lower in the subtropical species compared to the temperate species. In his examination of laboratory methods for predicting the OMD of forages Aerts et al. (1977) stated that regressions with the separate cell wall components (NDF, ADF, cellulose and lignin) proved to be insufficiently accurate to estimate OMD. This was also true for summative equations based on the cell wall constituents. Also, the estimates of OMD were signficantly less accurate with purely chemical procedures than with methods using living micro-organisms including NBDMD and IVDMD techniques. Even so, coefficients of determination for cell wall constituents, except hemicellulose and cellulose, were greater than those obtained with the Weende system for estimating OMD.

In experiments to determine the optimum NDF content of forages for milk production, Mertens (1983) found no difference in the NDF level between forages species at maximum milk production even though ADF varied widely. Mertens concluded that since NDF was highly correlated with intake, the NDF system probably accounts for more variation in animal productivity due to the effects of forages than other techniques used to formulate rations. Jorgensen (1982) supported the use of NDF in ration formulation by indicating that the hemicellulose content of legumes, grasses and by-product feeds varies greatly, thus ADF does not adequately represent the total fibre value of feedstuffs. Hemicellulose was an important part of fibre which was overlooked by ADF or CF determinations. They concluded that fibre requirements cannot be quoted in terms of ADF or CF because it was the total fibre content (NDF) that determines the

effects.

2.5.4.2 FONNESBECK SYSTEM

Fonnesbeck (1976) indicated that most of the chemical methods for analysis of feed nutrients have been adopted on the basis of laboratory precision and ease of completion without satisfactory chemical or nutritional evaluation. More knowledge of plant chemistry, chemical technology and animal nutrition allow for more comprehensive nutritional evaluations. Thus, procedures that allow for a more precise separation of the chemical components of a feed as it was digested by animals will be more efficient for predicting nutritive value. Since feeds vary greatly in their concentrations of individual chemical components, those which involve the major digestible energy sources (soluble carbohydrates, protein and fats) or the diluting compounds (cellulose, hemicellulose and lignin) in their purest form may more accurately predict the digestible energy content of feeds in general.

Fonnesbeck (1976) stated that the neutral detergent system of Van Soest left 20-50% of the nitrogen remaining with the fibrous tissue with an undetermined amount of starch also remaining. This detracted from the procedure for separating nutritive from non-nutritive components and contributed to extreme filtering problems when analysing energy feeds, protein supplements and mixed diets.

Another procedure was required that will accurately partition the feeds into fractions used by animals by analysing for carbohydrates as complex components using simple, yet specific, analysis when standard substances are not available.

The Fonnesbeck system (Fonnesbeck and Harris, 1976) separates the plant tissue into cell walls and cell contents similar to the Van Soest

procedure. The cell wall can then be partitioned into the nutritive cell wall carbohydrates and the non-nutritive components, lignin and acid insoluble ash.

Van Soest and Robertson (1980) reviewed the system and indicated it is not as quick as the Van Soest detergent system but obtained purer fibre fractions. They feel that the nitrogen removed from the cell walls was associated with the insoluble protein that was degraded in the rumen resulting in maximal protein output and therefore was a real entity. As well, the system does not allow tannins, cutin and Maillard products to be fractioned out of the crude lignin due to ashing.

2.5.4.3 THE SOUTHGATE SYSTEM

The newer fibre methods are of limited value in human nutrition since they were developed for the ruminant and, as a result, Southgate (1976) refers to dietary fibre as applying to all constituents derived from plant cell walls in the diet which are not digested by the endogenous secretions of the human digestive tract. Since the plant cell wall carbohydrates are not available to man, the fibre techniques tend to over estimate the proportion of cell wall than can be digested by man. These indigestible carbohydrates include pectin, hemicellulose, cellulose and the non-carbohydrate lignin material (Southgate, 1973).

Southgate (1969) indicated the process was technically easy to perform, requires only simple apparatus and takes just over five working days to complete a sample. The polysaccharides are determined using chemical rather than gravimetric analysis and may be further subdivided into water-soluble and insoluble subfractions. The results indicate the method yields a virtually complete analysis of the unavailable carboyhdrate in fractions that are important from both a nutritional and

chemical point of view. Where alternatives are available to measure a given fraction a comparison of the analytical methods compared well in a wide variety of food stuffs.

In a critique of the Southgate system, Van Soest and Robertson (1980) indicate that the system does not lend itself to rapid analysis and the precision of the chemical methods may not justify the time and labour required. Also, even though although the analytical equipment used was very precise, the extractions are not definitive in their fractionation of carbohydrate.

Where sugar analysis was required, Van Soest and Robertson indicate that the Southgate system was probably the best analytical method available.

2.6 SHEEP AS MODELS FOR CATTLE

Playne (1978) indicated that intake and digestibility values for low quality feeds should not be extrapolated to cattle from values determined using sheep since low concentrations of N, S and other nutrients result in poorer utilization of these feeds by sheep relative to cattle. However, the relative difference between forages in digestibility are reasonably constant regardless of whether they are determined with sheep or cattle except for mature, low quality materials of low digestibility (Heaney et al., 1980). Relative differences in feed value of forages are similar for the two animal species even though absolute values may differ and as a result sheep data can be applied to cattle.

CHAPTER 3 THE VARIETY TRIAL

3.1 MATERIALS AND METHODS

In order to assess the variation in nutritional quality of forage species and varieties, samples were selected from a large number of grasses and legumes. These forages were tested as part of the British Columbia Seed Crop Evaluation Project conducted from 1981 to 1983 by the British Columbia Ministry of Agriculture and Food. The samples used in this study were collected at Engen, British Columbia (location -- 124°20' west longitude, 54°3' north latitude).

The species and varieties tested are shown in Table 3.1. All species were planted on May 28 and 29, 1980. The seeding rate was 11.2 kg/ha for all species except orchard grass which was planted at 13.4 kg/ha.

Each species was laid out in a separate set of plots on the site with each variety replicated four times in a randomized complete block design.

Care was taken to ensure all samples were harvested in a consistent manner and at similar phenological stage over the study period. Grasses were harvested at the early heading stage and legumes at approximately 10% bloom.

Harvest dates are shown in Table 3.2. Harvesting was done using a 0.9 m sickle mower to sample a 2.79 m^2 plot. The plots were raked and the sample weighed to determine a fresh weight. Grab samples of approximately 500g were collected, stored in plastic bags and transported to the Prince George Experimental Farm where they were placed in a cooler. Subsequently the samples were dried at 42°C for 48 hours

Table 3.1 Species and Varieties Used in Trial

Species				
Legumes			Grasses	
Alfalfa Varieties	Alsike Clover Varieties	Red Clover Varieties	Orchardgrass Varieties	Timothy Varieties
Pacer	Tetra	Lakeland	Kay	Climax
Peace		Pacific	Chinook	Salvo
Anchor		Altaswede	Sterling	Timfor
Anik			Sumas	Toro

Table 3.2 Harvest Dates for Samples of the Variety Trial

Species		Year		
		1981	1982	1983
Alfalfa				
All varieties		July 1	July 8	July 6
Orchard grass				
All varieties		June 15	June 18	June 18
Timothy				
Variety	Climax	June 29	June 29	June 28
	Salvo	June 29	June 29	June 13
	Timfor	June 29	June 29	June 28
	Toro	June 29	June 29	June 13
Alsike clover				
Variety	Tetra	July 17	June 29	June 28
Red clover				
Variety	Lakeland	June 29	June 29	June 28
	Pacific	June 29	June 29	June 28
	Altaswede	July 17	July 8	August 4

and dry matter yields were determined. Once dried, the samples were stored in paper bags in an unheated building.

The samples selected for the variety trial were re-sorted from those in storage and were dried at 42°C for 48 hours and ground through a standard No.3 Wiley mill using a 1-mm screen. The samples were then analysed chemically for neutral detergent fibre (NDF), acid detergent fibre (ADF), crude protein (CP) and, in situ, for nylon bag dry matter disappearance (NBDMD).

The Variety Trial had two main objectives:

1) to assess the variation in the nutritional quality between forage species and varieties within species, and
2) to assess the variation in the nutritional quality of forage species and varieties between years based on laboratory analytical procedures.

3.1.1 DETERMINATIONS

As discussed in the Literature Review, there are several laboratory analytical techniques available for describing feed characteristics in order to make an evaluation of the quality of a feed. Those techniques used in this study were chosen for several reasons. The major factor was the representation of a useful feed characteristic (ie. NDF to estimate intake or NBDMD to estimate digestibility). The second factor was the ease with which the analytical technique could be carried out and the results interpretated. Finally, the NBDMD technique was chosen to more fully explore its potential for evaluating feeds.

Crude protein levels (one factor in assessing overall forage quality) were determined by the technical staff at the British Columbia Soil, Feed and Tissue Testing laboratory in Kelowna, British Columbia.

Single samples were analysed using a Technicon procedure with the nitrogen levels determined colorimetrically (AOAC, 1980).

Acid Detergent Fibre (ADF) levels (used to estimate forage digestibility) were also determined by the staff at the British Columbia Soil, Feed and Tissue Testing laboratory. Single samples were analysed according to the technique outlined by Goering and Van Soest (1970). Modifications included the use of 0.5 g of substrate, 50 ml of reagent, and the elimination of decalin from the ADF and NDF and sodium sulphate from the NDF solution.

Dry matter determinations were done using approximately 1 g of sample which was dried at 100°C for at least 24 hours.

Neutral detergent fibre levels (used to estimate forage intake) were determined according to the method outlined by Goering and Van Soest (1970) as modified by Waldern (1971). Duplicate determinations were made for all samples. Approximately 0.33 g of sample was accurately weighed into a tared test tube using an analytical balance and refluxed for 1 hour in approximately 33 ml of NDF solution.

Nylon bag dry matter determinations (used to estimate relative digestibility) were done using nylon bags with inside dimensions of approximately 4 x 8 cm which were fabricated using 40u pore size Nitex material (B & S.H. Thompson and Co. Ltd., Town of Mount Royal, Quebec). The edges of the bags were double sewn and the holes sealed using Silicon Seal (Dow Corning Canada Ltd., Mississauga, Ontario).

One g samples were accurately weighed into a tared bag using an analytical balance. The bag had previously been dried at 60°C for 24 hours, the drying temperature was selected to prevent damage to the Nitex material due to excess heat. Prior to weighing, and during transfer from

the drying oven to the analytical balance, all bags and samples were placed in a dessicator.

The bags were securely attached to a sand-filled 100 ml plastic bottle by heavy nylon fishing line about 15 cm in length. To reduce problems with bags adhering to each other in the rumen only 6 bags were attached to each bottle and four bottles (a total of 24 bags) were placed in each animal. Each sample was duplicated in each of the two animals used as replicates. Thus four bags were incubated for each sample. All samples were incubated for a 24 hour period. The bottles were put into the animal through a fistula and were placed each time into the ventral area of the rumen. The animals used in this procedure were two Hereford steers weighing 550 and 600 kgs respectively being fed a ration of timothy hay along with trace mineral salt and water ad libitum. The steers were housed in a heated barn and were free to move about within the confines of the stall.

Once the bottles were removed from the rumen at the end of the 24 hour incubation period the bags were washed quickly to remove any material adhering to the outside of the bag and the bags were stored at 4° C until time was available for more careful washing. The bags were removed from the bottles prior to being washed in lukewarm water by hand until the wash water strained from the bag was clear. The bags were then removed from the bottles and placed in a drying oven at 60°C for at least 24 hours, after which they were weighed using the analytical balance and the dry matter disappearance calculated.

3.1.2 EXPERIMENTAL DESIGN AND STATISTICAL ANALYSIS

NDF, ADF and CP analysis results were statistically analysed using the following least squares model:

$$Y_{ijkl} = u + V_i + B_{j(i)} + T_k + V_iT_k + e_{l(ijk)}$$

where Y_{ijkl} = the dependent variable NDF, ADF or CP

u = the overall mean common to all samples

V_i = the effect of the i'th variety

$B_{j(i)}$ = the effect of the j'th plot - nested within the i'th variety (first error term)

T_k = the effect of the k'th year

V_iT_k = the interaction of the i'th variety with the k'th year

$e_{l(ijk)}$ = the unexplained residual error associated with each observation.

The experimental design was a completely randomized nested split plot in time. The factors analysed in the 3 x 16 factorial experiment were 3 years and 16 varieties. The same least squares model and experimental design was used to analyse Type and Species effects.

NBDMD results for variety were analysed using a slightly different model due to the use of two animals as replicates. The following least squares model was used for the analysis:

$$Y_{ijkr} = u + V_i + B_{j(i)} + T_k + V_iT_k + Ar + V_iAr + T_kAr + V_iArT_k + e_{l(ijkr)}$$

where

Y_{ijkr} = the dependent variable NBDMD

u = the overall mean common to all the samples

V_i = the effect of the i'th variety

$P_{j(i)}$ = the effect of the j'th plot nested within the i'th variety (first error term)

T_k = the effect of the k'th year

V_iT_k = the interaction of the i'th variety with the k'th year

A_r = the effect of the r'th animal

T_kA_r = the interaction of the k'th year with the r'th animal

$V_iA_rT_k$ = the interaction of the i'th variety, the r'th animal and the k'th year

$e_{1(ijkr)}$ = the unexplained residual error associated with each observation.

The experimental design was a completely randomized nested split plot in time. The factors analysed in the 2 x 3 x 16 factorial experiment were 2 animals, 3 years, and 16 varieties. The same least squares model and experimental designs was used to analyse Type and Species effects, however the number of factors were different. For Type the factors were 2 Animals, 3 Years and 2 Types and for Species the factors were 2 Animals, 3 Years and 5 Species.

In addition to the analysis carried out using the least squares models described, the NBDMD results were also manipulated to determine if it was necessary to analyse the samples using the field plots as replications or if they could be composited. If the samples for each variety could be composited by mixing the samples from each field plot together and conducting the analysis of variance using the animals as the

replicates fewer NBDMD determinations (4 per variety instead of 16) would have to be done reducing the workload. This assessment of field replications versus animal replications was done using the data from one year, thus eliminating year from the model. Two different least squares analysis were done based on the following models.

The first model (Case One) was the same as that previously described to analyse Variety effects by Year. The error term for variety was thus plot nested within variety.

A second least squares model was used to evaluate NBDMD results based on the mean value calculated from the four bags per variety placed in each of the the test steers (Case Two). The result was the same as if the samples from all plots for a variety were composited and duplicate analysis were done in two animals with the animals being the replicates. Thus, there were only four bags per variety per Year would be used instead of the sixteen used in this experiment.

The least squares model used is:

$$Y_{ij} = u + V_i + e_{ij}$$

where Y_{ij} = the dependent variable

u = the overall mean common to all samples

V_i = the effect due to the i'th varible

e_{ij} = the unexplained residual error associated with each observation.

Prior to pooling standard errors between species (since each was grown in a separate plot within the experimental area) a test of the homogeneity of variances was performed using the Bartlett's test (Steel

and Torrie, 1980).

Least squares analysis of variance was done using the General Linear Models (GLM) procedure (SAS, 1985) which allowed for manipulation of unbalanced and missing cells. Those sources of variation with signficant F values were tested for signficance by Student-Newman-Kuels multiple comparison of means (Steel and Torrie, 1980).

3.1.3 ASSESSMENT OF FEEDING VALUE

According to Ulyatt (1973) the feeding value of forage was essentially, but not exclusively based on intake and digestibility. In order to assess feeding value based on intake and digestibility these parameters were estimated using the following equations (Rohweder et al. 1985):

1) $DMD(\%) = 88.9 - 0.779 \times (ADF\%)$, and

2) $DMI(g/kg\ BW^{0.75}) = 96.4 - 0.0003\ (CP\%) - 0.04282(NDF\%) - 0.0085(NDF\%^2)$

These parameters were multiplied together to develop a Feeding Value Index (FVI) similar to that of Crampton et al. using the following equation: FVI = (DDM x DMI)/100. The resulting FVI was used as a basis for comparing differences between species and varieties. This index was based on the assumption that DM intake and digestibility are of equal importance in determining the feeding value of a forage.

3.1.4 INTEGRATION OF FORAGE QUALITY AND YIELD

In order to integrate the yield results for each of the Types, Species and Varieties with the results of the quality determinations, two calculations were made using ADF and CP values. The ADF values were used in an equation developed by Mathison et al. (1982) to estimate

digestible energy (DE) levels. This equation is:

$$DE\ (Mcals/kg) = 3.44 - 0.22(ADF\%)$$

The subsequent DE estimation was used to obtain a DE yield (DEY) in the following equation;

$$DEY\ (Mcals \times 10^3/ha) = DE \times Yield$$

No statistical analysis was done for the DE estimations since this is a transformation of the experimental data and there would be no change in the statistical significance from that obtained using the factor (ADF) upon which the DE equation was based (Steel and Torrie, 1980).

3.2 RESULTS

As mentioned in Section 3.1.1 Bartlett's test for homogeneity of variances was done prior to pooling the standard errors between species (or sites) since each was tested in a different set of plots within the study area. The test indicated the variances were similar and the pooling of the standard errors was legitimate. The results are presented by Type (legume or grass), Species (alfalfa, orchardgrass, timothy, alsike clover or red clover) and Variety.

3.2.1 YIELD

Yield data were collected by J.N. Tingle and his staff during the course of the British Columbia Seed Evaluation Project and were analysed as part of this study. The results for Type and Species are shown in Table 3.3

For Type, over all years, there was a significant difference ($P \leqslant 0.01$) in yield between legumes and grasses (4.58 ± 0.25 vs. 3.63 ± 0.25 t/ha respectively). Within years, there was no difference ($P > 0.05$) in yield between the two forage types in 1981 while in both 1982 and 1983 legumes significantly ($P \leqslant 0.01$) out-yielded grasses.

Table 3.3 Least Square Means ± SEM[¶] of Forage Yields by Type and Species

Designation	YIELD (t/ha)			
	Year			All Years
	1981	1982	1983	
Type				
Legumes	4.52±0.40[a]	2.86±0.20[b]	6.37±0.29[b]	4.58±0.25[b]
Grasses	4.15±0.40[a]	1.53±0.19[a]	5.17±0.29[a]	3.63±0.25[a]
Species				
Alfalfa	3.38±0.41[a]	1.95±0.23[a]	6.71±0.35[bc]	3.98±0.29[b]
Orchardgrass	2.49±0.40[a]	1.33±0.21[a]	4.10±0.35[a]	2.64±0.28[a]
Timothy	5.93±0.42[b]	1.75±0.22[a]	6.25±0.35[b]	4.62±0.29[b]
Alsike Clover	6.96±0.80[b]	3.86±0.43[b]	4.94±0.70[ab]	5.25±0.56[c]
Red Clover	5.18±0.49[b]	3.65±0.26[b]	6.40±0.43[b]	5.11±0.34[bc]

¶ SEM=Standard Error of the Mean.
a,b Means with different superscripts in each column and designation are significantly different ($P \leq 0.05$).

When the results were analysed by Species for all years alsike clover (5.25 ± 0.50 t/ha) significantly ($P \leq 0.01$) out-yielded alfalfa (3.98 ± 0.29 t/ha), orchardgrass (2.64 ± 0.28 t/ha) and timothy (4.62 ± 0.29 t/ha) but was not significantly different from red clover (5.11 ± 0.34 t/ha). In 1981 timothy, alsike and red clover produced more ($P \leq 0.01$) forage than alfalfa and orchardgrass. The results from 1982 were similar in that timothy was not signficiantly different ($P > 0.05$) from the lower yielding alfalfa and orchardgrass. In 1983, alfalfa, timothy and red cover significantly out-yielded orchardgrass ($P \leq 0.01$) while alsike clover yields were intermediate.

When analysed by variety within species across all years (Table 3.4) there was no significant difference ($P > 0.05$) between orchardgrass, alfalfa or timothy varieties. However, there was a difference between red clover varieties ($P \leq 0.05$). In this case Pacific yielded much less than Lakeland and Altaswede (2.4±0.10, 4.9±0.10 and 7.9±0.09 t/ha respectively). Over all years, is no significant difference ($P > 0.05$) between orchardgrass, alfalfa or timothy varieties. Again, there was a significant difference ($P \leq 0.05$) between red clover varieties with Altaswede out-performing Lakeland which out-yielded the Pacific variety. In 1982 there was no significant difference between varieties for either alfalfa, timothy or orchardgrass ($P > 0.05$) but within the red clover varieties Altaswede significantly out-yielded Lakeland which had a significantly higher yield than Pacific variety ($P \leq 0.05$). Orchardgrass varieties were not significantly different in 1983. However, Climax and Timfor significantly out performed Salvo and Toro timothy varieties ($P \leq 0.05$). As in each of the preceding years, Altaswede significantly

Table 3.4 Least Square Means ± SEM[¶] of Forage Yields by Variety

Species and Variety	YIELD (t/ha) Year 1981	1982	1983	All Years
Alfalfa				
Pacer	3.3±0.5^{abc}	2.0±0.4^{a}	6.8±0.4^{cd}	4.0±0.1^{bcd}
Anchor	3.0±0.5^{abc}	1.7±0.3^{a}	6.2±0.4^{bcd}	3.6±0.1^{abc}
Peace	3.6±0.6^{bcd}	1.9±0.3^{a}	6.1±0.4^{bcd}	3.7±1.0^{abc}
Anik	3.7±0.5^{bcd}	2.4±0.4^{a}	7.7±0.4^{d}	4.6±0.1^{cd}
Orchardgrass				
Kay	3.0±0.5^{abc}	1.7±0.3^{a}	4.4±0.4^{ab}	3.0±0.1^{ab}
Chinook	2.4±0.5^{abc}	1.1±0.3^{a}	3.8±0.4^{a}	2.5±0.1^{a}
Sterling	2.1±0.5^{ab}	1.4±0.3^{a}	4.2±0.4^{ab}	2.6±0.1^{a}
Sumas	2.4±0.5^{abc}	1.0±0.3^{a}	4.0±0.4^{a}	2.5±0.1^{a}
Timothy				
Climax	6.3±0.5^{ef}	2.0±0.3^{a}	7.4±0.4^{d}	5.2±0.1^{d}
Timfor	6.2±0.5^{ef}	1.9±0.3^{a}	7.6±0.4^{d}	5.2±0.1^{d}
Salvo	5.7±0.5^{ef}	1.7±0.4^{a}	5.3±0.4^{abc}	4.2±0.1^{bcd}
Toro	5.4±0.6^{def}	1.4±0.3^{a}	4.7±0.4^{ab}	3.9±0.1^{bcd}
Alsike clover				
Tetra	7.0±0.5^{f}	3.9±0.3^{b}	5.0±^{abc}	5.3±0.1^{d}
Red clover				
Lakeland	4.6±0.5^{cde}	3.6±0.4^{b}	6.2±0.4^{bcd}	4.9±0.1^{cd}
Altaswede	8.7±0.5^{g}	5.2±0.3^{c}	9.7±0.4^{e}	7.9±0.1^{e}
Pacific	1.2±0.6^{a}	2.1±0.3^{a}	4.2±0.4^{ab}	2.4±0.1^{a}

¶ SEM=Standard Error of the Mean.

a,b Means with different superscripts in each column are significantly different ($P \leq 0.05$).

out-yielded Lakeland and Pacific varieties ($P \leq 0.05$).

Overall, Altaswede red clover was consistently the highest yielding forage on test producing 8.7 ± 0.5, 5.2 ± 0.3 and 9.7 ± 0.4 t/ha for all years respectively. In addition, only the red clovers showed a significant difference in yields between varieties.

There was a significant difference in yield among Years ($P \leq 0.01$) for Type, Species and Variety (Table 3.5) with the yield being highest in 1983 and lowest in 1982 ($P \leq 0.05$).

There were significant Type, Species and Variety x Year ($P \leq 0.01$) interactions.

3.2.2 CRUDE PROTEIN

Over all years and within each year legumes had significantly higher ($P \leq 0.01$) levels of crude protein than grasses (13.7±0.21% vs 9.8±0.21%) (Table 3.6).

CP levels between Species were significantly different ($P \leq 0.01$) over all years except for alsike clover and red clover. In descending order were alfalfa (14.0 ± 0.22%), alsike clover (14.0 ± 0.42%), red clover (13.2 ± 0.25%), orchardgrass (10.8 ± 0.22%) and timothy (8.8 ± 0.22%). In 1981 timothy levels were significantly lower ($P \leq 0.05$) than orchardgrass or alfalfa which, in turn, were significantly lower than the clover levels. Similar results were obtained in 1982 with the exception that there was no significant difference ($P > 0.05$) between alfalfa and clover which had the highest CP level. Each Species was significantly different ($P \leq 0.01$) for CP in 1983 in the descending order of Alfalfa, Clover, Orchardgrass, and Timothy ($P \leq 0.05$).

By variety across all years (Table 3.7) Timfor timothy had significantly ($P \leq 0.05$) lower CP levels than Toro. Kay and Chinook orchardgrass also had significantly lower levels of CP than Sumas with

Table 3.5 Least Square Means ± SEM[¶] of Yield, CP[¶¶] , NDF, ADF, and NBDMD Levels by Year

	Determinations				
Year¶	Yield	CP	NDF	ADF	NBDMD
1981	4.25^{b}	10.3^{a}	53.5^{a}	32.7^{a}	72.3^{a}
1982	2.19^{a}	11.8^{b}	55.7^{b}	32.0^{a}	72.8^{a}
1983	5.83^{c}	13.1^{c}	56.6^{b}	32.7^{a}	72.4^{a}
SEM	0.1	0.1	0.4	0.3	0.3

¶ SEM=Standard Error of the Mean

¶¶ CP=Crude Protein, NDF=Neutral Detergent Fibre, ADF=Acid Detergent Fibre NBDMD=Nylon Bag Dry Matter Disappearance

a,b Means with different superscripts within columns are significantly different ($P \leq 0.05$).

Table 3.6 Least Square Means ± SEM[¶] of Crude Protein Levels by Type and Species

Designation	Crude Protein Level			
	Year			All Years
	1981	1982	1983	
Type				
Legumes	11.2±0.33^{b}	13.6±0.24^{b}	16.3±0.34^{b}	13.7±0.21^{b}
Grasses	9.4±0.32^{a}	10.0±0.23^{a}	9.9±0.34^{a}	9.8±0.21^{a}
Species				
Alfalfa	10.4±0.32^{b}	13.4±0.29^{c}	18.0±0.33^{d}	14.0±0.22^{d}
Orchardgrass	11.0±0.31^{b}	10.9±0.27^{b}	10.4±0.33^{b}	10.8±0.21^{b}
Timothy	7.8±0.32^{a}	9.0±0.28^{a}	9.3±0.33^{a}	8.8±0.22^{a}
Alsike Clover	11.0±0.63^{bc}	14.3±0.54^{c}	16.7±0.66^{d}	14.0±0.42^{cd}
Red Clover	12.3±0.38^{c}	13.5±0.32^{c}	13.9±0.38^{c}	13.2±0.25^{c}

¶ SEM=Standard Error of the Mean.
a,b Means with different superscripts in each column and designation are significantly different ($P \leq 0.05$).

Table 3.7 Least Square Means ± SEM[¶] of Crude Protein Levels by Variety

Species and Variety	Crude Protein (%) Year 1981	1982	1983	All Years
Alfalfa				
Pacer	10.1±0.5^{bcd}	12.7±0.6^{cde}	17.3±0.6^{d}	13.5±0.1^{gh}
Anchor	10.0±0.5^{bcd}	13.3±0.5^{cde}	18.6±0.6^{d}	14.0±0.1^{gh}
Peace	11.5±0.6^{de}	13.8±0.5^{de}	18.8±0.6^{d}	14.8±0.14^{h}
Anik	10.4±0.5^{cd}	14.0±0.6^{de}	17.2±0.6^{d}	13.8±0.1^{gh}
Orchardgrass				
Kay	9.3±0.5^{abcd}	10.4±0.5^{ab}	10.5±0.6^{b}	10.1±0.1^{cd}
Chinook	10.8±0.5^{cd}	10.4±0.5^{ab}	9.6±0.6^{ab}	10.2±0.1^{cd}
Sterling	11.6±0.5^{de}	11.3±0.5^{abc}	10.6±0.6^{b}	11.2±0.1^{de}
Sumas	12.2±0.5^{de}	11.6±0.5^{bcd}	11.0±0.6^{b}	11.6±0.1^{ef}
Timothy				
Climax	8.0±0.5^{ab}	8.9±0.5^{a}	8.6±0.6^{ab}	8.5±0.1^{ab}
Timfor	7.5±0.5^{a}	9.0±0.5^{a}	7.9±0.6^{a}	8.1±0.1^{a}
Salvo	7.6±0.5^{a}	9.1±0.6^{a}	10.1±0.6^{b}	8.9±0.1^{abc}
Toro	8.5±0.6^{abc}	9.2±0.5^{a}	10.9±0.6^{b}	9.5±0.1^{bc}
Alsike clover				
Tetra	11.0±0.5^{d}	14.3±0.5^{e}	16.7±0.6^{d}	14.0±0.1^{gh}
Red clover				
Lakeland	12.4±0.5^{de}	14.5±0.6^{e}	14.0±0.6^{c}	13.5±0.1^{gh}
Altaswede	11.3±0.5^{de}	13.3±0.5^{cde}	13.1±0.6^{c}	12.5±0.1^{fg}
Pacific	13.5±0.6^{e}	13.0±0.5^{cde}	14.8±0.6^{c}	13.6±0.1^{gh}

¶ SEM=Standard Error of the Mean.
a,b Means in each column with different superscripts are significantly different ($P \leq 0.05$).

Sterling variety being intermediate. Overall, there was no signficiant difference between alfalfa or between red clover varieties ($P > 0.05$).

The result by variety for 1981 showed no significant difference ($P > 0.05$) between timothy, orchardgrass or alfalfa varieties. Pacific red clover had significantly higher ($P \leq 0.05$) CP levels (13.5 ± 0.6%) than Lakeland (12.4 ± 0.5%) or Altaswede (11.3 ± 0.5%) red clovers or Tetra alsike clover (11.0 ± 0.5%). In 1982 there were no significant differences ($P > 0.05$) in CP level for timothy, orchardgrass, alfalfa or red clover varieties. However in 1983 Climax and Timfor varieties were significantly lower ($P \leq 0.05$) in CP level than Salvo and Toro varieties. There was no difference between orchardgrass, clover or alfalfa varieties ($P > 0.05$) for CP level. Overall, the alfalfa varieties and Tetra alsike clover had the highest CP levels, however, there was little difference between CP levels of varieties for a given species.

There was a significant difference in overall CP levels between years ($P \leq 0.01$) with the highest level in 1983 (13.1 ± 0.13%) and the lowest in 1981 (Table 3.5).

There were significant interactions ($P \leq 0.01$) for Type, Species and Variety by Year.

3.2.3 NEUTRAL DETERGENT FIBRE

The results for the NDF analysis for Type and Species are shown in Table 3.8. Overall years, and within years, the grasses had significantly higher ($P \leq 0.01$) NDF levels than the legumes (64.3 ± 0.64 vs. 46.1 ± 0.65%).

When examined by Species over all years, each Species was significantly different than the others ($P \leq 0.01$) with clovers having the

Table 3.8 Least Square Means ± SEM[¶] of Neutral Detergent Fibre Levels by Type and Species

Designation	Neutral Detergent Fibre Levels (%)			
	Year			All Years
	1981	1982	1983	
Type				
Legumes	47.1±1.11^{a}	44.5±0.59^{a}	47.0±0.90^{a}	46.1±0.65^{a}
Grasses	60.1±1.09^{b}	66.4±0.57^{b}	66.3±0.87^{b}	64.3±0.64^{b}
Species				
Alfalfa	51.0±0.99^{b}	44.4±0.63^{b}	49.0±1.23^{b}	48.1±0.63^{b}
Orchardgrass	55.0±0.96^{c}	65.1±0.59^{d}	64.5±1.23^{c}	61.5±0.61^{c}
Timothy	65.5±0.99^{d}	67.9±0.63^{e}	68.1±1.23^{d}	67.1±0.63^{d}
Alsike Clover	46.5±1.91^{a}	38.6±1.17^{a}	41.2±2.60^{a}	42.2±1.27^{a}
Red Clover	42.1±1.15^{a}	47.0±0.74^{c}	45.7±1.36^{ab}	44.8±0.75^{a}

¶ SEM=Standard Error of the Mean.

a,b Means with different superscripts in each column and designation are significantly different ($P \leqslant 0.05$).

lowest level (42.2 ± 1.27 and 44.8 ± 0.75% for alsike and red clover respectively) alfalfa next (48.1 ± 0.65%), then orchardgrass (61.5 ± 0.63%), followed by timothy with the highest NDF level (67.1 ± 0.65%). The results were also the same by year ($P \leq 0.01$) with the exception that alfalfa ranked intermediate between alsike and red clover in 1982.

NDF levels by variety are shown in Table 3.9. Over all years there was a significant difference ($P \leq 0.01$) between each of the red clover varieties with the levels in ascending order being Lakeland (41.5 ± 0.91%), Pacific (44.9 ± 0.87%) and Altaswede (48.8 ± 0.87%). Peace alfalfa (45.0 ± 0.87%) had significantly lower ($P \leq 0.05$) levels of NDF than Pacer (49.1 ± 0.87%), Anchor (47.9 ± 0.83) or Anik (50.1 ± 0.87%) varieties. There was no significant differences ($P > 0.05$) between either orchardgrass or timothy varieties.

There was some variation in red clover NDF levels from year to year. In 1981, both Lakeland and Pacific varieties showed significantly lower ($P \leq 0.05$) NDF levels than Altaswede while in 1982 there was no signficant difference ($P > 0.05$) between the varieties. Lakeland was signficantly lower ($P \leq 0.05$) in NDF than Altaswede in 1983 and Pacific levels were intermediate but not significantly different ($P > 0.05$) from either of the other varieties.

As with red clover, there was some year to year variation with alfalfas. In 1981 Peace is significantly lower ($P \leq 0.05$) than Anik for NDF while Pacer and Anchor level were intermediate but not significantly different ($P > 0.05$) from Anik. There was no significant difference ($P > 0.05$) between varieties in 1982 but there was a trend to higher NDF levels in Pacer and Anik. Again, there was no significant difference ($P > 0.05$) between alfalfa varieties in 1983 although Pacer

Table 3.9 Least Square Means ± SEM[¶] of Neutral Detergent Fibre by Variety

Species / Variety	Neutral Detergent Fibre Levels (%) Year 1981	1982	1983	All Years
Alfalfa				
Pacer	50.7±1.02^{cd}	46.0±1.07^{bcd}	51.1±2.07^{c}	49.1±0.87^{c}
Anchor	50.5±1.02^{cd}	43.9±0.93^{bc}	49.3±2.07^{abc}	47.9±0.83^{c}
Peace	46.4±1.18^{b}	42.4±0.93^{b}	46.8±2.07^{abc}	45.0±0.87^{b}
Anik	55.0±1.02^{d}	46.3±1.07^{bcd}	48.6±2.07^{abc}	50.1±0.87^{c}
Orchardgrass				
Kay	55.2±1.02^{d}	68.8±0.93^{f}	66.4±2.07^{d}	63.5±0.83^{de}
Chinook	54.7±1.02^{d}	63.0±0.93^{e}	63.3±2.07^{d}	60.3±0.83^{d}
Sterling	55.2±1.02^{d}	65.1±0.93^{ef}	63.3±2.07^{d}	61.2±0.83^{d}
Sumas	54.8±1.02^{d}	63.3±0.93^{e}	65.0±2.07^{d}	61.1±0.83^{d}
Timothy				
Climax	66.3±1.02^{e}	67.9±0.93^{f}	70.4±2.07^{d}	68.2±0.83^{f}
Timfor	66.7±1.02^{e}	68.2±0.93^{f}	71.4±2.07^{d}	68.7±0.83^{f}
Salvo	65.6±1.02^{e}	66.9±1.07^{f}	65.0±2.07^{d}	65.9±0.83^{ef}
Toro	63.0±1.18^{e}	68.4±1.07^{f}	65.7±2.07^{d}	66.1±0.91^{ef}
Alsike clover				
Tetra	46.5±1.02^{b}	38.6±0.93^{a}	41.2±2.39^{ab}	42.2±0.87^{ab}
Red clover				
Lakeland	36.7±1.02^{a}	46.9±1.31^{cd}	40.4±2.07^{a}	41.5±0.91^{a}
Altaswede	50.8±1.02^{cd}	45.2±0.93^{bcd}	49.9±2.39^{bc}	48.8±0.87^{c}
Pacific	37.7±1.18^{a}	48.8±0.93^{d}	47.8±2.07^{abc}	44.9±0.87^{b}

¶ SEM=Standard Error of the Mean.

a,b Means within columns with different superscripts are significantly different ($P \leq 0.05$).

had slightly higher NDF levels.

There was no significant difference ($P>0.05$) between orchard grass or timothy varieties in 1981 and 1983 or between varieties in 1982. Kay orchardgrass (68.8 ± 0.93%) had a significantly higher ($P\leq 0.05$) NDF level in 1982 than either Chinook (63.0 ± 0.93%) or Sumas (63.3 ± 0.93) while Sterling (65.1 ± 0.93%) was intermediate but not significantly different ($P>0.05$) from either group.

Neutral detergent fibre levels in 1981 (53.3 ± 0.38%) were significantly lower ($P\leq 0.05$) in 1981 than in 1982 (55.7 ± 0.40%) or 1983 (56.6 ± 0.38%) as shown in Table 3.5.

There were significant interactions ($P\leq 0.01$) for Type, Species and Variety x Year.

3.2.4 ACID DETERGENT FIBRE

Table 3.10 shows the ADF results by Type and Species. Over all years there was no significant difference ($P>0.05$) in ADF level between legumes and grasses with determinations of 32.9 ± 0.47% and 32.0 ± 0.46% respectively. The result was similar in 1983 but there was a significant difference between legumes and grasses in 1981 and 1982 ($P\leq 0.01$).

When the ADF levels were examined by species, both orchardgrass (31.0 ± 0.55%) and red clover (30.9 ± 0.56%) were significantly lower ($P\leq 0.05$) in ADF than alfalfa (34.6 ± 0.57%), timothy (33.1 ± 0.56%) and alsike clover (32.3 ± 1.10%). ADF levels in 1981 followed a similar pattern with the exception that timothy was intermediate to and significantly different ($P\leq 0.05$) from either orchardgrass and red clover or alfalfa and alsike clover. In 1982 both alsike and red clover were significantly lower ($P\leq 0.05$) than alfalfa, orchardgrass or timothy. In 1983 there were no significant differences ($P>0.05$) between any of the

Table 3.10 Least Square Means ± SEM[¶] of Acid Detergent Fibre Levels by Type and Species.

	Acid Detergent Fibre Levels (%)			
	Year			
Designation	1981	1982	1983	All Years
Type				
Legumes	34.5±0.85^{a}	30.9±0.38^{a}	33.3±0.67^{a}	32.9±0.47^{a}
Grasses	31.1±0.84^{b}	32.9±0.37^{b}	32.1±0.67^{a}	32.0±0.46^{a}
Species				
Alfalfa	37.0±0.85^{c}	32.3±0.48^{b}	34.3±0.95^{a}	34.6±0.57^{b}
Orchardgrass	28.4±0.82^{a}	32.9±0.45^{b}	31.6±0.95^{a}	31.0±0.55^{a}
Timothy	34.1±0.85^{b}	33.9±0.46^{b}	32.5±0.95^{a}	33.1±o.56^{b}
Alsike Clover	38.2±1.65^{c}	28.2±0.90^{a}	30.5±1.89^{a}	32.3±1.10^{b}
Red Clover	29.6±1.00^{a}	30.2±0.54^{a}	32.8±1.09^{a}	30.9±0.65^{a}

¶ SEM=Standard Error of the Mean.

a,b Means with different superscripts in each column and designation are significantly different ($P \leq 0.05$).

species.

The ADF results by variety (Table 3.11) over all years showed no significant difference ($P > 0.05$) between Lakeland (28.3 ± 0.8%) and Pacific red clover varieties (29.4 ± 0.8%) although Altaswede red clover (34.6 ± 0.7%) had a significantly higher ($P \leq 0.05$) ADF level. There was no significant difference ($P > 0.05$) between alfalfa, orchard-grass and timothy varieties.

When the varieties were examined by year Altaswede red clover is significantly greater ($P \leq 0.05$) in ADF level than Lakeland and Pacific varieties in 1981 and Lakeland varieties in 1982. There was no signficant difference ($P > 0.05$) between Lakeland ,Pacific and Altaswede red clover in 1983 although the Altaswede ADF levels were at least 6.6 percentage points higher.

Alfalfa ADF levels in 1981 were not significantly different ($P > 0.05$). In 1982 Pacer had significantly higher values than Peace while both Anchor and Anik showed intermediate levels in 1983 there was again no significant difference ($P > 0.05$) between varieties.

There was no significant difference between ($P > 0.05$) between orchardgrass varieties in 1981, 1982 and 1983 or between timothy varieties in any year except that in 1983 Salvo was significantly lower ($P \leq 0.05$) in ADF than Climax, Timfor or Toro varieties.

There was no significant difference between years (Table 3.5) for Type and Variety ($P > 0.05$). However, when analysed by Species there was a significant difference between years ($P \leq 0.01$).

Type, Species and Variety x Year interactions were all significant ($P \leq 0.01$).

Table 3.11 Least Square Means ± SEM[¶] of Acid Detergent Fibre Levels by Variety

Species and Variety	Acid Detergent Fibre Levels (%) Year 1981	1982	1983	All Years
Alfalfa				
Pacer	36.4±1.1^{efg}	34.7±0.9^{d}	36.4±1.6^{b}	35.6±0.8^{e}
Anchor	36.2±1.1^{efg}	31.7±0.7^{bcd}	33.6±1.6^{ab}	33.8±0.7^{cde}
Peace	35.1±1.3^{efg}	30.7±0.7^{abc}	33.8±1.6^{ab}	33.1±0.8^{bcde}
Anik	39.9±1.1^{g}	33.0±0.9^{bcd}	33.5±1.6^{ab}	35.8±0.8^{e}
Orchardgrass				
Kay	30.0±1.1^{bcd}	34.0±0.7^{cd}	32.4±1.6^{ab}	32.2±0.7^{bcde}
Chinook	27.7±1.1^{ab}	33.5±0.7^{cd}	30.8±1.6^{ab}	30.6±0.7^{abcd}
Sterling	28.7±1.1^{abc}	32.3±0.7^{bcd}	30.2±1.6^{ab}	30.4±0.7^{abc}
Sumas	26.9±1.1^{ab}	31.8±0.7^{bcd}	33.1±1.6^{ab}	30.6±0.7^{abcd}
Timothy				
Climax	35.0±1.1^{efg}	33.1±0.7^{bcd}	35.4±1.6^{ab}	34.5±0.7^{cde}
Timfor	34.3±1.1^{def}	32.8±0.7^{bcd}	35.9±1.6^{ab}	34.3±0.7^{cde}
Salvo	34.0±1.1^{def}	31.8±0.9^{bcd}	28.1±1.6^{a}	31.3±0.8^{abcd}
Toro	32.6±1.3^{cde}	33.6±0.7^{cd}	30.8±1.6^{ab}	32.5±0.8^{bcde}
Alsike clover				
Tetra	38.2±1.1^{fg}	28.2±0.7^{a}	30.5±1.6^{ab}	32.3±0.7^{bcde}
Red clover				
Lakeland	26.6±1.1^{ab}	28.1±0.9^{a}	29.8±1.6^{ab}	28.3±0.8^{a}
Altaswede	36.5±1.1^{fg}	29.7±0.7^{ab}	37.6±1.6^{b}	34.6±0.7^{de}
Pacific	24.5±1.3^{a}	32.3±0.7^{bcd}	31.0±1.6^{ab}	29.4±0.8^{ab}

¶ SEM = Standard Error of the Mean.

a,b Means with different superscripts in each column are significantly different ($P \leq 0.05$).

3.2.5 NYLON BAG DRY MATTER DISAPPEARANCE

Table 3.12 shows the NBDMD results by Type and Species. Over all years there was no significant difference ($P > 0.05$) in disappearance between legumes and grasses (72.3±0.71 vs. 72.9±0.73% respectively). There was a significant difference in NBDMD between types in 1981 ($P \leq 0.01$) with values of 68.7 ± 1.26% and 75.8 ± 1.24% and in 1982, with figures of 74.8 ± 0.64 and 71.1 ± 0.62% for grasses and legumes respectively. There was no difference between Type in 1983 ($P > 0.05$).

For species, over all years, both alfalfa (68.6 ± 0.60%) and timothy (70.0 ± 0.60%) were significantly different ($P \leq 0.05$) from orchardgrass (75.7 ± 0.58%), red clover (76.1 ± 0.71) and alsike clover (75.9 ± 1.17%). There was some variation in results by species from year to year. In 1981 all species are significantly different ($P \leq 0.01$) with orchardgrass showing the highest disappearance (81.7 ± 0.99%) and red clover (75.7 ± 1.11%), timothy (69.6 ± 1.03%), alsike clover (68.7 ± 1.84) and alfalfa (63.6 ± 1.03%) following in descending order. In 1983 alfalfa, orchard grass and timothy were not significantly different from each other ($P > 0.05$) but were significantly different ($P \leq 0.05$) from the clovers.

The results by variety within species for red clover show that Altaswede (71.4 ± 0.08%) NBDMD was significantly lower ($P \leq 0.05$) in dry matter disappearance than either Lakeland (79.2 ± 0.88%) or Pacific (77.3 ± 0.84%) over all years (Table 3.13). There was no significant difference ($P > 0.05$) between alfalfa, timothy and orchardgrass varieties.

In 1981 red clover varieties followed a similar pattern with Altaswede NBDMD significantly lower ($P \leq 0.05$) than Lakeland and Pacific

Table 3.12 Least Square Means ± SEM[¶] of Nylon Bag Dry Matter Disappearance Levels by Type and Species

	Nylon Bag Dry Matter Disappearance Levels (%)			
	Year			All
Designation	1981	1982	1983	Years
Type				
Legumes	68.7 ± 1.26^{a}	74.8 ± 0.64^{b}	73.1 ± 0.95^{a}	72.3 ± 0.72^{a}
Grasses	75.8 ± 1.24^{b}	71.1 ± 0.62^{a}	71.7 ± 0.95^{a}	72.9 ± 0.73^{a}
Species				
Alfalfa	63.6 ± 0.95^{a}	72.2 ± 0.63^{b}	69.9 ± 1.23^{a}	68.6 ± 0.60^{a}
Orchardgrass	81.7 ± 0.92^{d}	73.1 ± 0.59^{b}	72.2 ± 1.23^{ab}	75.7 ± 0.59^{b}
Timothy	69.6 ± 0.95^{b}	68.9 ± 0.63^{a}	71.1 ± 1.23^{ab}	70.0 ± 0.60^{a}
Alsike Clover	68.7 ± 1.84^{b}	79.6 ± 1.18^{d}	79.3 ± 2.45^{c}	75.9 ± 1.17^{b}
Red Clover	75.7 ± 1.11^{c}	76.4 ± 0.74^{c}	75.1 ± 1.42^{bc}	76.1 ± 0.71^{b}

¶ SEM = Standard Error of the Mean.

a,b Means with different superscripts in each column and designation are significantly different ($P \leq 0.05$).

Table 3.13 Least Square Means ± SEM[¶] of Nylon Bag Dry Matter Disappearancd Levels by Variety

Species and Variety	Nylon Bag Dry Matter Disappearance Levels (%) Year 1981	1982	1983	All Years
Alfalfa				
Pacer	63.5±1.2^{b}	71.1±1.3^{abcd}	67.2±1.8^{ab}	67.5±0.8^{a}
Anchor	65.6±1.2^{ab}	71.7±1.1^{abcd}	69.0±1.8^{abc}	68.8±0.8^{ab}
Peace	66.2±1.3^{bc}	73.3±1.1^{bcd}	71.0±1.8^{abc}	70.3±0.8^{ab}
Anik	59.7±1.2^{a}	72.1±1.3^{abcd}	72.4±1.8^{abcd}	68.0±0.8^{ab}
Orchardgrass				
Kay	82.0±1.2^{d}	72.2±1.1^{abcd}	72.3±1.8^{abcd}	75.5±0.8^{cd}
Chinook	81.1±1.2^{d}	71.1±1.1^{abcd}	69.1±1.8^{abc}	74.0±0.8^{c}
Sterling	82.3±1.2^{d}	72.8±1.1^{abcd}	72.4±1.8^{abcd}	75.8±0.8^{cd}
Sumas	81.5±1.2^{d}	75.8±1.1^{cde}	75.1±1.8^{bcd}	77.5±0.8^{de}
Timothy				
Climax	70.7±1.2^{c}	70.4±1.1^{abc}	66.0±1.8^{a}	69.0±0.80^{ab}
Timfor	69.7±1.2^{c}	69.6±1.1^{ab}	65.8±1.8^{a}	68.4±0.8^{ab}
Salvo	67.9±1.2^{bc}	67.2±1.3^{a}	76.5±1.8^{cd}	70.6±0.8^{ab}
Toro	70.2±1.3^{c}	67.5±1.3^{a}	76.2±1.8^{cd}	70.7±0.9^{ab}
Alsike clover				
Tetra	68.7±1.2^{c}	79.6±1.1^{e}	79.3±1.8^{d}	75.9±0.8^{cd}
Red clover				
Lakeland	80.7±1.2^{d}	76.7±1.6^{de}	79.8±1.8^{d}	79.2±0.9^{e}
Altaswede	67.8±1.2^{bc}	77.1±1.1^{de}	69.2±1.8^{abc}	71.4±0.8^{b}
Pacific	79.6±1.3^{d}	75.5±1.1^{cde}	76.4±1.8^{cd}	77.3±0.8^{cde}

¶ SEM = Standard Error of the Mean.

a,b Means with different superscripts in each column are significantly different ($P \leq 0.05$).

varieties. Anik variety alfalfa (59.7 ± 1.2%) was significantly lower ($P<0.05$) than either Pacer (63.5 ± 1.2%), Anchor (65.6 ± 1.2%) or Peace (66.2 ± 1.3%) varieties. There was no significant difference ($P>0.05$) between orchardgrass and timothy varieties.

There was no significant difference ($P>0.05$) between red clover, timothy, orchard grass or alfalfa varieties in 1982.

In 1983 Altaswede had was significantly lower NBDMD levels ($P\leq0.05$) than Lakeland variety. Pacific and Lakeland varieties were not significantly different ($P>0.05$). There was no significant difference ($P>0.05$) between alfalfa and orchardgrass varieties, however, there was some variation in timothy varieties. Both Climax (66.0 ± 1.8%) and Timfor (65.8 ± 1.8%) timothy were significantly different ($P\leq0.05$) from Salvo (76.5 ± 1.8%) and Toro (76.2 ± 1.8%) varieties.

Again the red clovers continued to show differences between varieties in a manner consistent with those seen with previous determinations.

Table 3.14 shows the effects of year on NBDMD for Type, Species and Variety. There was no significant difference between Years for Type ($P > 0.05$), however there was a significant difference ($P \leq 0.01$) between years for Species with NBDMD levels being significantly lower in 1981 ($P\leq0.05$) than in Years 2 or 3 (72.0 ± 0.39, 74.3 ± 0.04 and 73.6 ± 0.38% respectively). There was no significant difference ($P>0.05$) between years for variety.

The results of the effect of animal on NBDMD are shown in Table 3.15. Over all years there was a significant difference ($P\leq0.01$) between animals for Type, Species and Variety. The results of the

Table 3.14 Least Square Means ± SEM[¶] of Nylon Bag Dry Matter Disappearance Levels by Year

Nylon Bag Dry Matter Disappearance Levels (%)			
	Designation		
Year	Type	Species	Variety
1981	72.4[a]	72.0[a]	72.3[a]
1982	73.1[a]	74.3[b]	72.8[a]
1983	72.4[a]	73.6[b]	72.4[a]
SEM[¶]	0.4	0.4	0.4

¶ SEM=Standard Error of the Mean.
a,b Means with different superscripts in each column are significantly different ($P \leq 0.05$).

Table 3.15 Least Square Means ± SEM[¶] of Nylon Bag Dry Matter Disappearance Level by Animal

Designation	Animal	Nylon Bag Dry Matter Disappearance Levels (%)			
		Year			All Years
		1981	1982	1983	
Type					
	1981	72.9±0.33^{b}	73.2±0.38^{a}	73.1±0.33^{b}	73.1±0.34^{b}
	1982	71.7±0.33^{a}	72.8±0.38^{a}	71.7±0.33^{a}	72.1±0.34^{a}
Species					
	1981	73.0±0.35^{b}	74.9±0.31^{b}	74.2±0.36^{b}	74.2±0.32^{b}
	1982	70.8±0.35^{a}	73.2±0.31^{a}	72.9±0.36^{a}	72.4±0.32^{a}
Variety					
	1981	72.9±0.3^{b}	73.0±0.3^{a}	73.1±0.3^{b}	73.0±0.2^{b}
	1982	71.7±0.3^{a}	72.6±0.3^{a}	71.7±0.3^{a}	72.0±0.2^{a}

¶ SEM = Standard Error of the Mean.

a,b Means with different superscripts in each column and designation are significantly different ($P \leqslant 0.05$).

effect of animal upon NBDMD by year show there was a significant difference ($P \leq 0.01$) between animals for Type, Species and Varieties for 1981 and 1983. There was no significant difference ($P > 0.05$) between animals for 1982.

The Type x Animal interaction was significant in 1981 and 1982 ($P \leq 0.01$) but not in 1983 ($P > 0.05$) or over all Years (P 0.05). The Species x Animal interactions were significant ($P \leq 0.01$) for all Years. The Variety x Animal interaction was significant ($P \leq 0.01$) over all Years and for 1981 and 1982 but not for 1983 ($P > 0.05$).

The Type, Species and Variety x Year interactions were significant ($P \leq 0.01$) over all Years and within Years, however, the Year x Animal interactions for Type, Species and Variety were not significant ($P > 0.05$). in any of the cases.

The Type and Species x Year x Animal interactions were significant ($P \leq 0.01$) but the Variety x Year x Animal interaction was not significant ($P > 0.05$).

3.2.6 ASSESSMENT OF THE FEEDING VALUE

The results of the FVI calculation are shown in Table 3.16 along with the DMI and DDM values upon which they are based. Timothy varieties have the lowest index with orchardgrass varieties having the next lowest index. Both alfalfa and clover had a higher index than the grasses with the alfalfas having generally lower values than the clovers. As expected, the largest variation in index values occured between the red clover varieties with a range of 7 index points. There was also some variation between alfalfa varieties with Peace indexing 5 points higher than Anik (53.2 vs. 48.2 index points respectively).

Overall Pacific (57.3) and Lakeland (54.2) red clover varieties had

TABLE 3.16 Estimations of Dry Matter Intake (DMI)[¶], Digestible Dry Matter (DDM) and Feeding Value Index (FVI).

	ESTIMATIONS		
Variety	Dry Matter Intake ($gm/kg\ BW^{0.75}$)	Digestible Dry Matter (%)	FVI[¶¶]
Alfalfa			
Pacer	77.8±0.82	63.1±0.58	49.1
Anchor	79.1±0.78	64.8±0.67	51.3
Peace	81.2±0.57	65.5±0.49	53.2
Anik	77.0±1.53	62.6±1.18	48.2
Orchardgrass			
Kay	64.9±1.92	66.1±0.37	42.9
Chinook	68.2±1.35	66.8±0.40	45.6
Sterling	67.3±1.38	67.1±0.30	45.2
Sumas	67.5±1.36	66.1±1.52	44.6
Timothy			
Climax	60.1±0.76	64.3±0.61	38.6
Timfor	59.5±0.79	64.5±0.45	38.4
Salvo	62.8±0.55	66.4±0.58	41.7
Toro	62.8±0.87	66.1±0.34	41.5
Alsike Clover			
Tetra	83.0±1.34	65.0±1.21	54.0
Red Clover			
Lakeland	84.4±0.95	67.9±0.22	57.3
Altaswede	78.6±0.76	63.8±0.89	50.1
Pacific	80.9±1.08	67.0±0.38	5420

¶ DMI = 96.4-(0.0003*CP%)-(0.0482*NDF%)-(0.0085*NDF^2%) (Rohweder et al., 1985).
DDM = 88.9-0.779*(ADF%) (Rohweder et al., 1985).
¶¶ FVI =(DMI * DDM)/100.

the highest index values followed by Peace (53.2) and Anchor (51.3) alfalfas and, then, fifth in rank, Altaswede red clover.

3.2.7 INTEGRATION OF FORAGE QUALITY AND YIELD

Over all Years and within each Year the DEY of legumes was significantly greater ($P \leq 0.01$) than that of grasses (Table 3.17). DEY levels were 12.3 ± 0.66 and 9.8 ± 0.64 Mcals x 10^3/ha respectively.

When examined by species, orchardgrass had the lowest DEY level (P 0.01) (7.3 ± 0.73 Mcals x 10^3/ha), alfalfa levels were intermediate (10.6 ± 0.76 Mcals x 10^3/ha) and timothy, red and alsike clovers had the highest levels (12.4 ± 0.75, 13.9 ± 0.87 and 14.2 ± 1.47 Mcals x 10^3/ha respectively) across all years. There was little variation between years with DEY results for 1981 the same as those for all Years. In 1982 timothy levels were not significantly different ($P \leq 0.05$) from alfalfa and orchardgrass while in 1983 alfalfa, timothy and red clover and orchardgrass and alsike clover were not significantly different.

For Varieties within species (Table 3.18) the only significant difference ($P \leq 0.05$) over all years in DEY was between red clover varieties. This was also the case in 1981 and 1982. However, there was some variation in 1983 when Anik alfalfa had significantly higher ($P \leq 0.05$) DEY levels than Anchor and Peace. Climax and Timfor also had significantly higher DEY levels than Salvo and Toro timothy varieties.

There was a significant difference ($P \leq 0.01$) in DEY between Years with levels of 12.6 ± 0.33, 6.9 ± 0.33 and 15.6 ± 0.32 Mcals x 10^3/ha for all years respectively. Type, Species and Variety x Year interactions were also significant ($P \leq 0.01$).

Similar to the case for DEY, CPY levels were significantly greater ($P \leq 0.01$) for legumes than grasses over all years (0.64 ± 0.26 and 0.34 ±

Table 3.17 Least Square Means ± SEM[¶] of Digestible Energy Yields by Type and Species

Designation	Digestible Energy Yields (Mcals x 10^3/ha)			
	Year			All Years
	1981	1982	1983	
Type				
Legumes	12.0±1.04^{b}	7.8±0.56^{b}	17.2±0.76^{b}	12.3±0.66^{b}
Grasses	11.3±1.03^{a}	4.2±0.54^{a}	14.1±0.75^{a}	9.8±0.64^{a}
Species				
Alfalfa	8.9±1.07^{a}	5.3±0.65^{a}	18.1±0.92^{c}	10.6±0.76^{b}
Orchardgrass	7.0±1.04^{a}	3.6±0.61^{a}	11.2±0.92^{a}	7.3±0.73^{a}
Timothy	15.9±1.07^{b}	4.8±0.65^{a}	17.0±0.92^{bc}	12.4±0.75^{bc}
Alsike Clover	18.1±2.07^{b}	10.9±1.21^{b}	13.7±1.83^{ab}	14.2±1.47^{c}
Red Clover	14.1±1.25^{b}	9.9±0.77^{b}	17.4±1.10^{c}	13.9±0.87^{c}

¶ SEM=Standard Error of the Mean.

a,b Means with different superscripts in each column and designation are significantly different ($P \leq 0.05$).

Table 3.18 Least Square Means ± SEM[¶] of Digestible Energy Yields by Variety

Species and Variety	Digestible Energy Yield (Mcals x 10^3/ha)			
	Year			All Years
	1981	1982	1983	
Alfalfa				
Pacer	8.6±1.26^{b}	5.2±1.05^{ab}	18.1±1.20^{efg}	10.5±0.84^{bc}
Anchor	7.9±1.26^{b}	4.7±0.91^{ab}	16.7±1.20^{def}	9.7±0.84^{bc}
Peace	9.7±1.45^{bc}	5.2±0.91^{ab}	16.5±1.20^{cdef}	10.1±0.84^{bc}
Anik	9.6±1.26^{bc}	6.4±1.05^{bc}	20.8±1.20^{g}	12.2±0.84^{cd}
Orchardgrass				
Kay	8.2±1.26^{b}	4.6±0.91^{ab}	11.9±1.20^{ab}	8.2±0.65^{ab}
Chinook	6.8±1.26^{ab}	3.1±0.91^{a}	10.6±1.20^{a}	6.8±0.65^{a}
Sterling	6.0±1.26^{ab}	3.9±0.91^{ab}	11.6±1.20^{ab}	7.2±0.65^{a}
Sumas	6.9±1.26^{ab}	2.8±0.91^{a}	10.9±1.20^{a}	6.9±0.65^{a}
Timothy				
Climax	16.7±1.26^{de}	5.4±0.91^{ab}	19.8±1.20^{fg}	14.0±0.65^{d}
Timfor	16.7±1.26^{de}	5.1±0.91^{ab}	20.2±1.20^{fg}	14.0±0.65^{d}
Salvo	15.3±1.26^{de}	4.6±1.05^{ab}	14.9±1.20^{bcde}	11.6±0.84^{cd}
Toro	14.8±1.45^{de}	3.8±1.05^{ab}	12.9±1.20^{abc}	10.9±0.88^{c}
Alsike clover				
Tetra	18.1±1.26^{de}	10.9±0.91^{d}	13.7±1.20^{abcd}	14.2±0.65^{d}
Red clover				
Lakeland	13.2±1.26^{cd}	9.0±1.29^{cd}	17.3±1.20^{defg}	13.5±0.88^{d}
Altaswede	23.0±1.26^{f}	14.5±0.91^{e}	25.0±1.38^{h}	21.0±0.65^{e}
Pacific	3.6±1.45^{a}	5.8±0.91^{ab}	11.7±1.20^{ab}	6.8±0.84^{a}

¶ SEM=Standard Error of the Mean.

a,b Means with different superscripts in each column are significantly different ($P \leq 0.05$).

0.26 t/ha respectively) and within each year (Table 3.19).

Both orchardgrass and timothy had significantly lower ($P \leq 0.01$) CPY levels than either alfalfa, alsike clover or red clover. There was however variation from year to year in CPY with alfalfa and orchardgrass having the lowest levels in 1981 while alfalfa had the highest level in 1983. Timothy had significantly higher ($P \leq 0.05$) CPY levels than alfalfa in 1981, similar levels in 1982 and lower levels in 1983. Alsike and red clover yields were not significantly different ($P > 0.05$) in any Year or over all Years.

Again as expected, the only species with significant differences ($P \leq 0.05$) in CPY levels between varieties was red clover (Table 3.20). These differences occurred both within years and over all years. There is no significant difference ($P > 0.05$) between Varieties within either alfalfa, orchardgrass or timothy species over all years or within each year.

CPY was significantly different ($P \leq 0.05$) between years with levels of 0.42 ± 1.46, 0.26 ± 1.54 and 0.77 ± 1.91 t/ha for all years respectively. The Type, Species and Variety x Year interactions were also significant ($P \leq 0.01$).

3.2.8 NBDMD RESULTS USING PLOTS OR ANIMALS AS REPLICATES

The experimental design used for evaluating NBDMD levels between varieties in this study called for sixteen nylon bags to be incubated per variety per year (2 bags / animal x 2 animals x 4 replicates). Thus, the data were analysed using the field plot samples as the replicates. In order to attempt to reduce the amount of work involved the results for each variety were mathematically composited (the mean of the four replicates per variety was determined) and animals were used as replicates. Even though duplicate determinations would still be done for

Table 3.19 Least Square Means ± SEM[¶] of Crude Protein Yields by Type And Species

Designation	Crude Protein Yields (t/ha)			
	Year			All Years
	1981	1982	1983	
Type				
Legumes	0.50±0.40^{b}	0.38±0.28^{b}	1.04±0.38^{b}	0.64±0.26^{b}
Grasses	0.37±0.41^{a}	0.15±0.27^{a}	0.50±0.38^{a}	0.34±0.26^{a}
Species				
Alfalfa	0.36±0.47^{a}	0.26±0.33^{a}	1.20±0.45^{c}	0.60±0.35^{b}
Orchardgrass	0.27±0.46^{ab}	0.14±0.31^{a}	0.43±0.45^{a}	0.28±0.34^{a}
Timothy	0.47±0.47^{bc}	0.16±0.32^{a}	0.57±0.45^{a}	0.39±0.35^{a}
Alsike Clover	0.77±0.92^{d}	0.55±0.62^{b}	0.82±0.89^{b}	0.71±0.68^{b}
Red Clover	0.61±0.55^{cd}	0.48±0.37^{b}	0.89±0.51^{b}	0.66±0.40^{b}

¶ SEM=Standard Error of the Mean.

a,b Means with different superscripts in each column and designation are significantly different ($P \leqslant 0.05$).

Table 3.20 Least Square Means ± SEM[¶] of Crude Protein Yields by Variety

Species and Variety	Crude Protein Yield (t/ha) Year 1981	1982	1983	All Years
Alfalfa				
Pacer	0.33±0.60^{abcde}	0.25±0.57^{ab}	1.18±0.74^{e}	0.58±0.44^{ef}
Anchor	0.30±0.60^{abcde}	0.23±0.50^{ab}	1.14±0.74^{e}	0.56±0.44^{ef}
Peace	0.42±0.70^{bcdef}	0.26±0.50^{ab}	1.15±0.74^{e}	0.58±0.44^{ef}
Anik	0.39±0.60^{bcdef}	0.33±0.57^{bc}	1.32±0.74^{e}	0.68±0.44^{ef}
Orchardgrass				
Kay	0.28±0.60^{abcd}	0.18±0.50^{a}	0.45±0.74^{ab}	0.31±0.43^{abc}
Chinook	0.25±0.60^{abc}	0.12±0.50^{a}	0.37±0.74^{a}	0.25±0.43^{a}
Sterling	0.25±0.60^{ab}	0.16±0.50^{ab}	0.44±0.74^{ab}	0.28±0.43^{ab}
Sumas	0.30±0.60^{abcde}	0.12±0.50^{a}	0.44±0.74^{ab}	0.29±0.43^{ab}
Timothy				
Climax	0.50±0.60^{ef}	0.18±0.50^{ab}	0.64±0.74^{bc}	0.44±0.43^{cd}
Timfor	0.47±0.60^{def}	0.17±0.50^{ab}	0.60±0.74^{abc}	0.41±0.43^{bc}
Salvo	0.43±0.60^{bcdef}	0.15±0.57^{a}	0.54±0.74^{ab}	0.38±0.44^{abc}
Toro	0.46±0.60^{cdef}	0.13±0.57^{a}	0.51±0.74^{ab}	0.38±0.47^{abc}
Alsike clover				
Tetra	0.77±0.70^{g}	0.55±0.50^{d}	0.82±0.74^{cd}	0.71±0.43^{f}
Red clover				
Lakeland	0.59±0.60^{f}	0.45±0.71^{cd}	0.87±0.74^{d}	0.64±0.47^{ef}
Altaswede	0.99±0.60^{h}	0.70±0.50^{e}	1.25±0.85^{e}	0.98±0.43^{g}
Pacific	0.16±0.70^{a}	0.28±0.50^{ab}	0.63±0.74^{bc}	0.34±0.44^{abc}

¶ SEM=Standard Error of the Mean.

a,b Means with different superscripts in each column are significantly different ($P \leq 0.05$).

each variety only 4 bags per variety per year would be incubated thereby reducing the work load.

Table 3.21 shows the results obtained when data from 1981 were analysed using the field plots as replicates or compositing the field plot samples and using the animals as replecates. In both cases (Case One -- Field plot samples as replicates and Case Two -- Animals as replicates) there was a significant difference ($P \leq 0.01$) between varieties and in Case 1 there was a significant difference ($P \leq 0.05$) in NBDMD levels between animals. In both cases there was no significant difference ($P > 0.05$) between orchardgrass and timothy varieties. There was a significant difference ($P \leq 0.05$) between alfalfa varieties within cases and these differences were the same in both cases. Similarly, within the clovers, Tetra alsike clover is not significantly different ($P > 0.05$) from Altaswede red clover but both were signficantly different in both cases ($P \leq 0.05$) from Lakeland and Pacific red clovers .

3.2.9 WEATHER

Weather data for the Engen area (Appendix 1) were supplied by the British Columbia Ministry of Environment. The temperature and precipitation data were from the Vanderhoof station and the sunshine data were from the Fort St. James station. Although the data were not collected directly from the site Cheesman (Pers. comm.) suggested that "the data should be reasonably representative". The cumulative hours of sunshine and millimetres of precipitation for May and June (most of the plots were harvested in June) indicate that 1982 was much drier than the other two years of the trial. This was also reflected in the higher figure for growing degree days for 1982. As well, the June mean temperature was much higher in 1982 than in either 1981 or 1982.

Table 3.21 Least Square Means ± SEM[¶] for Nylon Bag Dry Matter Disappearance

Variety	Nylon Bag Dry Matter Disappearance (%) Case One[¶¶]	Case Two
Pacer	63.5 ± 1.2^{b}	63.7 ± 1.0^{b}
Anchor	65.7 ± 1.2^{bc}	65.7 ± 1.0^{bc}
Peace	66.1 ± 1.4^{bc}	66.2 ± 1.0^{bcd}
Anik	59.7 ± 1.2^{a}	59.7 ± 1.0^{a}
Kay	81.1 ± 1.4^{d}	82.1 ± 1.0^{f}
Chinook	80.5 ± 1.2^{d}	80.5 ± 1.0^{f}
Sterling	82.3 ± 1.2^{d}	82.3 ± 1.0^{f}
Sumas	81.5 ± 1.2^{d}	81.5 ± 1.0^{f}
Climax	70.7 ± 1.2^{c}	70.7 ± 1.0^{e}
Timfor	69.7 ± 1.2^{c}	69.7 ± 1.0^{cde}
Salvo	68.5 ± 1.2^{c}	68.5 ± 1.0^{cde}
Toro	70.4 ± 1.4^{c}	70.4 ± 1.0^{de}
Tetra	68.7 ± 1.2^{c}	68.7 ± 1.0^{cde}
Lakeland	80.7 ± 1.2^{d}	80.7 ± 1.0^{f}
Altaswede	67.8 ± 1.2^{bc}	67.8 ± 1.0^{cde}
Pacific	79.7 ± 1.4^{d}	79.7 ± 1.0^{f}

¶ SEM = Standard Error of the Mean

¶¶ Case One = Field plot samples used as replicates (16 bags/variety).
Case Two = Field plot samples mathematically composited Animals used as replicates.

a,b Means with different superscripts in each column are significantly different ($P \leq 0.05$).

3.3 DISCUSSION

3.3.1 YIELD

The results in this study showed that legumes out-yielded grasses in 2 of 3 Years. Similar results have been reported by McElgunn et al. (1972) for alfalfa and bromegrass but Tingle (1975) achieved opposite results in which Climax timothy produced higher yields than Altaswede red clover at McBride, British Columbia. In the present study the higher legume yield was mainly due to the high production level of Altaswede red clover. Otherwise results would be similar to those reported by Tingle (1975).

In the same study (Tingle, 1975) timothy out-yielded orchardgrass and both grasses out-yielded alfalfa and red clover. At Engen, the results were similar in that timothy out-yielded alfalfa but different in that both clover and alfalfa produced more forage than orchardgrass. Fairbourne (1983) reported yields of orchardgrass grown under irrigated conditions that were slightly higher than under the dryland conditions at Engen (3.3 vs. 2.65 t/ha.). It appears that orchardgrass, even under good conditions, may not be high yielding. Another factor of importance according to Fairbourne (1983) was winter weather which stressed plants resulting in considerable variation in yield even though the orchardgrass plants were irrigated.

Taylor (1976) compared the yields of Sumas, Sterling and Kay orchardgrass varieties and obtained yields of 9.0, 8.8 and 7.7 t/ha respectively in a test at Agassiz, British Columbia. This study was done to assess the Sumas variety, a mid season variety adapted to the lower Fraser Valley and the yields were much higher than those obtained at Engen. This was further indicated by the yields obtained by Childers et

al. (1978) for Chinook, Kay and Sterling varieties (3.3,3.0 and 2.6 t/ha respectively) at Lethbridge, Alberta. The climate at Engen would be closer to that at Lethbridge than at Agassiz (Sanderson, 1985) and even though Chinook orchardgrass was described as a winter hardy variety yields at either site did not approach those at Agassiz. It would appear that orchardgrass is not well adapted to the Engen site when compared to the yields of timothy, alfalfa and clover varieties. However, orchardgrass may be suited to grazing as a pasture crop where it's leafiness would assist in pasture management programs.

Lawrence and Warder (1979) reported average yields over 4 years for Climax timothy grown under irrigated conditions of 7.7 t/ha. These were higher than the overall yields for all the varieties tested in this trial although Climax and Timfor produced similar levels in 1983. Similar to the Engen results, there was little difference in yields between Salvo and Climax varieties at three sites in Ontario (5.9 and 5.0, 9.3 and 8.9, and 6.5 and 6.2 t/ha. for Salvo and Climax at Ottawa, Guelph and Ridgetown respectively) even though the absolute yields varied (Childers and Suitor, 1981). These results suggest that timothy is well suited to the Engen area.

Overall there were no significant differences between varieties within species of orchardgrass, timothy or alfalfa. Only in the clovers were there significant differences between varieties. These differences in yield of the clovers may in part be explained by the variations in the environment for which they were originally developed. Taylor (1976) reported that most red clover varieties are not well adapted to areas climatically different from where the variety was developed. The Lakeland variety was developed in Wisconsin for Wisconsin conditions

3.3.2 QUALITY DETERMINATIONS

The results for crude protein from this trial are similar to those of Mertens (1986), Theander and Aman (1986) and Koller et al. (1978) who all reported that legumes had higher crude protein levels than grasses. For example, Theander and Aman (1986) reported CP levels for grasses and legumes of 14.4 and 8.1% respectively; similar to 13.7% for legumes and 9.8% for grasses obtained in this study.

In relation to species, Mertens (1986) reported values of 23.4% for early vegetative stage alfalfa hay and 14.9% for red clover hay. The difference between alfalfa and clovers in this study was not nearly as large with levels of 14.0 and 13.2% respectively. Similar to the results in this study McQueen (1986) and Aman and Lindgren (1983) obtained higher CP levels in orchardgrass than in timothy at an early stage of growth.

There appear to be few references in the literature to different CP levels between varieties of a forage species. There was little difference in CP levels between Salvo (10.8%), Timfor (11.9%) and Climax (12.8%) varieties reported by McQueen (1986). Similar results were obtained in this trial with no significant difference between any alfalfa or clover variety and only one orchardgrass variety (Sumas) over all years.

There was however, a significant difference in CP level between years. Since the lowest level was in 1981 and the highest in 1983, weather does not appear to be the main factor. The CP level in grasses is higher in 1982 and 1983 than in 1981 and increased over each year in legumes.

The significant interactions between Year and Type, Species and Variety may be explained by the change in the CP level of alfalfas and clovers from 1981 to 1983. In the first year the clovers and two

orchardgrass varieties had higher CP levels than the alfalfas. In 1982 the levels had changed so both species of legume had higher CP levels than orchardgrass. 1983 contrasted with 1981 in that the alfalfa varieties had higher CP levels than the clover varieties.

Few literature values are available for NDF. Mertens (1986), Theander and Aman (1980), and Koller et al. (1978) each reported lower NDF levels in legumes than in grasses. The results of this study add further to this generalization. Mertens (1986) reported NDF values of 50% and 56% for alfalfa and red clover hays respectively while Koller et al. (1978) obtained values of 67.5% and 75.7% for orchardgrass and timothy respectively. Aman and Lindgren (1983) also reported higher NDF values for orchardgrass than timothy (57.9 vs. 62.7%). These levels vary enough to have a significant impact on intake and agree with the results of this study. The NDF values obtained from the Engen samples are lower than those reported by Mertens (1986) due to the more mature plant material which he tested.

Overall, there was little difference in NDF values between timothy and orchardgrass varieties. Peace alfalfa had lower NDF levels than the other varieties and each of the red clovers had different NDF levels. These differences may be due to variations in the strain developed for each climate or the physiological requirement for increased fibrous material in the plant stem as yields increased.

No data on the variation of NDF levels over years was found in the literature. While 1981 levels (53.5±0.4%) were lower than either 1982 (55.7±0.4%) or 1983 (56.6±0.4%) no overall trend within species or varieties was apparent. The other fibre based parameters (ADF and NBDMD) do not vary between years and only the 1981 NDF level was significantly

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different.

The interaction between Year and Variety, Species, Class and Type was a result of changes in NDF levels of one species relative to another over the test period. In 1981 the alfalfa varieties had NDF levels similar to orchard grass while in 1982 and 1983 the alfalfas had higher values than orchardgrass.

Unlike NDF levels, ADF levels in the test forages did not vary greatly between legumes and grasses. Theander and Aman (1980) also reported similar levels between grasses and legumes (31.3 vs 32.4%). However, care must be taken when interpreting ADF values between grasses and legumes due to the effect of phenological stage.

At the species level both red clover and orchardgrass were lower in ADF than alsike clover, timothy and alfalfa. Aman and Lindgren (1983) also reported slightly lower ADF values for orchardgrass than timothy (32.6 and 34.1%) cut at the same growth stage.

With the exception of the red clovers there was no difference in ADF levels between varieties. Within species McQueen (1986) obtained similar results to this study with Salvo (36.3%), Timfor (36.5%) and Climax (38.1%) timothy varieties harvested near the boot stage. As with NDF levels the variation in ADF values between red clover varieties may be the result of the need for additional fibrous material to physically support the extra plant material for the higher producing Altaswede variety or may be due to variation in red clover strains due to the variation in climates for which they were developed.

There was no difference in ADF values between years over all species, however there were significant Type, Species and Variety interactions with Year. This result occurred because grasses had higher

ADF levels than legumes in 1982, possibly as a result of higher temperatures affecting fibre production within the plant. In the other years legumes tended to have higher ADF values than grasses.

As with ADF levels, NBDMD values did not vary between grasses and legumes. Koller et al. (1978) obtained somewhat different results with NBDMD levels of 88.8±1.0% for alfalfa, 71.7±1.2% for orchardgrass and 52.2±2.0% for timothy for a 24 hour incubation period. Thus, in addition to the higher NBDMD levels for alfalfas rather than grasses, he also obtained much more varied results between these species than was obtained with the Engen samples. In this study, the clovers (76.1±0.71%) and orchardgrass (75.7±0.59%), and timothy (70.0±0.60%) and alfalfa (68.6±0.60%) had less varied disappearance values.

Seone et al. (1981b) reported NBDMD values (24 hour incubation) for Toro, Climax and Timfor timothy varieties of 45.4, 35.7 and 38.0% respectively. McQueen (1986), also using a 24 hour incubation reported NBDMD values for Toro and Climax timothy varieties of 40 and 45% respectively. These levels are considerably lower than those values obtained in this study and may be explained in the case of McQueen by the more mature samples used resulting in higher ADF levels (Toro and Climax -- 44.3 and 47.5% compared with ADF levels of 32.5 and 34.5 obtained in this study) and lower NBDMD. In the case of Seone et al. (1981b) bags with a much smaller pore size (5 u vs. 40 u pore size for bags used in this study) in their experiment would result in much lower NBDMD levels.

As with NDF and ADF determinations there was no difference in NBDMD values between varieties within species except for the red clovers. As expected, Altaswede variety had the lowest disappearance level in keeping with the higher NDF and ADF levels relative to the other red clover

varieties. There was a significant difference between test animal for NBDMD results for all designations. This may have been due to differences in DMI relative to the other yearling steers on the Experimental Farm. One animal had a much lower DM intake relative to the herd average (D. Croy, Pers. Comm.). There was no significant interaction between Year and Animal.

There was no significant variation in NBDMD levels due to year for Type and Variety. There was a difference between years for Species due possibly to the variation in alsike clover levels which were lower in disappearance in 1981 than orchardgrass and timothy but had higher levels than either in 1982 and 1983.

There was an interaction between Year and Type, Species and Variety. The Type x Year interaction was due to grasses having a higher NBDMD value in 1981 (75.8±1.24 vs. 68.7±1.26% respectively) and the legumes having a higher value in 1982 (74.8±0.64 vs 71.1±0.62% respectively). In year 3 NBDMD levels were similar for grasses and legumes (71.1±0.95 and 73.1±0.95 respectively). This would also explain the Species and Variety by Year interactions.

The interaction between Type, Species and Variety and Animal (while statistically significant) does not appear to be of great importance since Animal 1 always showed greater disappearance levels than Animal 2 (73.1±0.34 vs. 72.1±0.34% respectively for Type). The only variation was in the relative difference in disappearance levels between those samples incubated in Animal 1 and Animal 2 for samples collected in different years.

The variation in NBDMD levels of grasses relative to legumes over the 3 study years may also explain the significant Type and Species x

Animal x Year interactions. The Variety x Animal x Year interaction is not significant.

3.3.3 ASSESSMENT OF FORAGE QUALITY

Crude protein was a positive indicator of forage quality while NDF was inversely related to intake, ADF was inversely related to digestibility (Van Soest, 1982) and NBDMD reflects the digestibilities of one forage relative to another (Aerts et al., 1977). Using the CP, NDF, ADF and NBDMD determinations carried out in this trial the feeding value of one forage relative to another should be estimated with some reliability.

In considering the relative forage quality of legumes compared with grasses NDF and CP levels become important because overall there was no difference between the two types for NBDMD or ADF determinations. Therefore, it can be assumed that overall digestibilities will be similar for the Engen samples. However, DMI will be greater for legumes than grasses and this fact, coupled with higher CP levels, indicate that legumes will be nutritionally superior to the grasses evaluated in this study. This conclusion was reached since the animal will obtain more digestible nutrients from the legumes than from the grasses and follows reports in the literature that intake of legumes was generally greater than grasses of the same digestibility (Minson, 1982).

In terms of species NBDMD and ADF values indicate that orchardgrass was more digestible than timothy and that the clovers are more digestible than alfalfa. NDF values indicate that orchardgrass would be consumed more readily than the timothy and the clovers more readily than alfalfa. In addition, CP levels for orchardgrass were higher than for timothy so that it may be concluded that orchardgrass was nutritionally superior to

timothy in this study. Even though alfalfa had a higher CP level then the clovers (14.0 vs. 13.3) it can be concluded that clover was nutritionally superior to alfalfa. Orchardgrass and clover were of better quality because they would be eaten in greater amounts than timothy and alfalfa and would be more digestible. Therefore, in descending order of nutritional quality, would be clovers, followed by alfalfa, then orchardgrass and finally timothy.

When considering intake and digestibility factors between varieties within species only the red clover varieties show significant differences. Since Altaswede had lower NBDMD and higher ADF values than either Lakeland or Pacific varieties it might be concluded that it was the least digestible red clover variety. Altaswede would also be eaten in lesser amounts than the other two varieties (as evidenced by a higher NDF level) so that in terms of nutritional quality, even though there was no difference between any of the varieties in CP level, Pacific and Lakeland varieties were of better nutritional quality than Altaswede.

NDF values for Peace alfalfa indicate it would be consumed at higher levels than the other alfalfa varieties, however, in terms of digestibility and CP levels there was no difference between any of the alfalfa varieties.

NBDMD levels suggest that Sumas orchardgrass would be more digestible than Chinook variety, however, ADF levels did not suggest such a difference. Crude protein levels for the Sumas variety were also higher than the other varieties pointing to a possible difference between orchardgrass varieties with Sumas being somewhat superior in nutritional quality.

The only variation between timothy varieties for any of the

determinations was in CP level for Toro which was higher than Timfor. Overall there was no difference in quality between timothy varieties.

Thus, with the exception of Lakeland and Pacific red clovers being superior to Altaswede red clover it can be concluded that there was no difference in nutritional quality between varieties within species. Therefore, any of the alfalfa varieties were superior to any of the orchardgrass varieties which, in turn, we superior to any of the timothy varieties.

Heaney et al. (1966) found that the rate of decline of DMI (as indicated by NDF) was affected more than digestibility (as indicated by ADF) by year-to-year fluctuations in growing conditions. Heaney et al. (1966) suggested that greater variability would occur in intake than in digestibility overall and especially between years. This is the case in the present study. These authors also had similar results with varieties in that the differences in varietal digestibilities were minor and inconsistent between years.

3.3.4 ASSESSMENT OF FEEDING VALUE

Weighing the intake and digestibility results evenly in the FVI suggested that the feeding value of Altaswede red clover, which had the highest yields of DE and CP, was lower than any of the other clovers. The clovers however, still had the highest feeding value since both intake and digestibility were higher than for the other species. Alfalfa would be the second best species in terms of feeding value since intake would be much higher and DDM was only slightly lower than for either of the grasses. Orchardgrass would have a higher feeding value than timothy since both DMI and DDM were higher for orchardgrass.

As was the case with the quality parameters there would be little

difference for either DMI or DDM for the varieties within each species since these estimates are based on NDF and ADF determinations respectively. For the same reason it would be expected that feeding value results would closely parallel the results suggested by the quality determinations.

3.3.5 INTEGRATION OF FORAGE QUALITY AND YIELD

When yield was integrated with the DE estimate (digestible energy yields) there were some diferences in the conclusions that result when only quality parameters are examined. It was concluded that, overall, the clover varieties were the highest quality, followed by alfalfa then orchardgrass and finally timothy. The DEY results show that one of the best quality forages, Pacific red clover, yields very low levels of DE and that Altaswede red clover, second in terms of quality, produces substantially more DE than any other species or variety. Timothy, which was the lowest quality forage, produced equal levels of DE to the clovers (except Pacific) and superior levels to both alfalfa and orchardgrass. In terms of DEY the clovers and timothy had higher levels than alfalfa and orchardgrass had the lowest levels.

When yield was taken into consideration there was some variation between varieties with Salvo and Toro timothy producing less DE than Climax and Timfor varieties. Anchor alfalfa produced less DE than Anik while Sumas and Chinook orchardgrass produced less DE than Kay variety.

When CPY results were examined there were also differences in the conclusion drawn when only quality parameters are assessed. As was the case with DEY, Altaswede red clover yielded the highest amount of CP with Pacific variety producing at much lower levels. Alfalfa produced similar levels of CP to the clovers and both alfalfa and clover had greater CPY

levels than timothy and orchardgrass. Timothy yielded more CP than orchardgrass in a similar situation to that which occurred with DEY.

These results showed that, for those Types, Species and Varieties studied, yield alone was a good criteria for selecting the forage species and variety. This was due to the desire to obtain the highest level of usable nutrients per hectare of land while still harvesting at a phenological stage that provides optimum quality. The end result was the most nutrients for animal production from the smallest area.

3.3.6 NBDMD RESULTS USING PLOTS OR ANIMALS AS REPLICATES

The results of this portion of the study indicate that there was no difference in the assessment of varieties and species when forage samples were analysed for NBDMD in either Case 1 or Case 2. In Case 1 the NBDMD results were analysed based on the actual field plot samples while in Case 2 the samples were mathematically composited by taking the mean value of the 4 field plot replicates and statistically analysing them as single data points. Since there was no difference between the two cases in statistical significance between varieties within species it would reduce the work load to 4 nylon bags per treatment (duplicate samples in each animal) rather than the 16 bags used in this study (duplicate samples in each animal for each field replicate plot). This conclusion appears to be valid even though fewer degrees of freedom would result in the need to obtain larger F values in the ANOVA and less precision in means separation (Table 3.21).

The differences in NBDMD levels between Altaswede and Lakeland and Pacific red clover indicate that, even with fewer observations, reliable differences would be determined.

CHAPTER 4 FEEDING TRIAL

4.1 MATERIAL AND METHODS

4.1.1 FORAGES

In order to assess the nutritional quality of two forage mixtures harvested at three different growth stages two 0.5 ha plots were planted in the spring of 1983 with forage mixtures intended to mature at different times in the growing season. The earlier maturing forage mixture (EM) consisted of Tetra alsike clover, Toro timothy and Manchar bromegrass and the later maturing forage mixture (LM) consisted of Altaswede red clover and Climax timothy. Agronomic practices were those recommended for the area and crop. The plots were fertilized with 34-0-0-11 at the rate of 180 kg/ha in the spring prior to harvest.

Each plot was harvested in 1984 at 10%, 50% and 100% of legume bloom (early bloom, EB; mid bloom, MB; full bloom, FB). Table 4.1 shows the harvest dates and yields for each of the hay cuts. Forages were field-cured and three of the six samples recieved some precipitation while being dried (EM-EB,EM-FB and LM-EB).

Once cured, the hay was baled into small square bales and transported to the Prince George Experimental Farm where it was stored under cover in the barn where the feeding trial was conducted.

The objectives of the feeding trial were:

1) to assess the effect on animal intake and digestibility of an early and a late maturing forage mixture, and;
2) to assess the effect on animal intake and digestibility of harvesting at the early, mid and full bloom growth stages of the legume component of each forage mixture.

Table 4.1 Harvest Date and Yield of Test Forages

Hay Mix	Harvest Date	Yield (T/ha)
Early Maturing (EM)[+]		
Early Bloom (EB)[++]	July 9	5.6[¶]
Mid Bloom (MB)	July 15	7.6
Full Bloom (FB)	July 22	9.4
Late Maturing (LM)[¶¶]		
Early Bloom (EB)	July 22	9.2
Mid Bloom (MB)	July 30	9.9
Full Bloom (FB)	August 8	11.0

\+ EM = alsike clover - timothy - bromegrass forage mix.
++ EB,MB,LB = 10%,50% 100% of bloom of the legume component of the forage mix.
¶ Estimate for EM-EB based on known weight of air dry material removed from 0.1 ha.
¶¶ LM = red clover - timothy forage mix.

4.1.2 EXPERIMENTAL DESIGN AND STATISTICAL ANALYSIS

This experiment evaluated the intake and digestibility of two forage mixes each cut at three stages of growth. Thus, there were six treatment combinations. Since intake and digestibility vary between animals it was desirable to test each treatment combination with each animal. In turn, variability may arise due to test periods since considerable time may elapse from the beginning to the end of the experiment. Therefore, in addition to treatment effects the varibility due to animal and period was also accounted for. The intake and digestibility of the six treatment combinations was analysed as a 2x3 factorial experiment in a 6x6 Latin square design.

The factors used in the experiment were:

1) 1982 forages mixes;
   a) Early Maturing (EM),
   b) Late Maturing (LM), and
2) Three harvest dates;
   a) 10% Bloom (EB),
   b) 50% Bloom (MB),
   c) 100% Bloom (FB).

The following least squares model was used to analyse all of the data in the feeding trial:

$$Y_{ijkl} = u + A_i + P_j + M_k + H_l + M_kH_l + e_{ijkl}$$

where

Y_{ijkl} = the dependent variable intake and digestibility,

u = the overall mean common to all samples

A_i = the effect due to the i'th animal

P_j = the effect due to the j'th period

M_k = the effect of the k'th forage mix

H_l = the effect of the l'th harvest

M_kH_l = the interaction of the k'th forage mix with the l'th harvest

e_{ijkl} = the unexplained residual error associated with each sample.

As in the variety trial analysis of variance was done using the General Linear Models (GLM) procedure (SAS, 1985). Those sources of variation with significant F values were tested for significance by Student-Newman-Kuels multiple comparison of means (Steel and Torrie, 1980). In addition, the RSQUARE procedure (SAS, 1985) was used to determine if multiple factor regression equations could be developed to predict the above parameters.

4.1.3. INTAKE AND DIGESTIBILITY TRIAL METHODOLOGY

Six wether sheep were placed in metabolism crates designed for individual feeding and fecal collection. Each animal had access to trace mineral salt and water and all animals were weighed at the end of each period.

Prior to feeding all forages were chopped through a 2.5 cm screen in a hammer mill. The forages were fed twice daily at 08:30 and 16:00 h. Samples of each chopped forage were taken weekly for analysis and stored in a freezer until analysed.

Each of the 6 test periods consisted of 5 days for adjustment to the new feed, 7 days for ad libitum feed intake, 3 days for adjustment to 70% of ad libitum intake followed by 6 days for fecal collection. The sheep

were fed at 08:30 each day after which fecal samples and orts were collected. Feed offered each day was adjusted so that the level of orts remained at about 10% of intake. Total collection of the orts during the ad libitum intake period was done and and the material stored in a freezer until analysed. Feces were collected and weighed daily and a representative sample of 20% of daily fecal output was collected. Fecal samples were added to previous subsamples and returned to the freezer after each days collection. Orts and fecal samples were composited within periods.

Feed, orts and fecal samples were dried at 45°C for 48 hours and ground through a 1 mm screen using a Wiley mill prior to further analysis.

4.1.4. ANIMAL MANAGEMENT

Seven Suffolk wether lambs were purchased about 6 weeks before the start of the trial. When purchased, the lambs were about 3.5 months of age and had a mean weight of 29.3 kg with a range of 26.8 to 30.9 kg. The animals were housed indoors in group pens until two weeks before the start of the trial when they were placed in the metabolism cages. While housed in the pens they were fed a growing ration and were treated with and anthelmintic wormed, given a clostridial innoculation, treated for sheep keds and given an injection of selenium and vitamin E. There were no health problems or problems with animals refusing feed over the entire trial period.

4.1.5. ANALYTICAL PROCEDURES

Lambs were weighed at the end of each period.

Feed, feces and orts were analayzed for CP using the macro-Kjehdahl technique (AOAC, 1980) with copper as a catalyst. The AD and ND fibre

techniques of Goering and Van Soest (1970) were used with the exclusion of decalin and sodium sulphate from the reagents. Dry matter determinations were done as outlined in Section 3.1.1.

The composition of the forage mixes for clover and grass content is determined by selecting 3 flakes from a bale of each feed and trimming a 23cm x 23cm section from the middle of each flake. Care is taken to ensure the integrity of this subsample and the grass and legume components were separated by hand. Once separated the components were dried for 48 hours at 45°C and weighed. The mean for each treatment combination was then determined and this represented the relative levels of grass and legume for the six treatment combinations.

In order to integrate yield with the Feeding Trial results CP Yield DE Yield were calculated as outlined in Section 3.1.4.

4.2 RESULTS

The nutrient composition of the hay mixes was shown in Table 4.2. The dry matter levels ranged from 86.3 to 88.9%. Crude protein varied little between hay mixes with EM levels ranging from 11.4 to 11.5% and LM levels from 11.9 to 12.7%. Similarily, ADF and NDF levels varied little with a range of 34.5 to 37.8% ADF and 48.5 to 54.9% NDF for EM, and 38.2 to 41.7% ADF and 51.4 to 52.6% NDF for LM respectively. Digestible energy (DE) levels were highest for the EM ranging from 2.42 to 2.60 Mcal/kg and lowest for the LM mix ranging from 2.24 to 2.42 Mcal/kg.

There was a continuous increase in the level of the legume component in the EM mix from 48 to 57 to 74% for EB, MB and FB respectively with a concurrent drop in the percent grass in the mix (Table 4.3). However, the legume and grass levels in the LM mix were relatively stable ranging from 83 to 91% for the legume and 9 to 17% for

Table 4.2 Nutrient Composition of Hay Mixes (Dry Matter Basis).

Hay Mix	NUTRIENT			
	Crude Protein (%)	ADF[+] (%)	NDF (%)	DE (Mcal/kg)
Early Maturing(EM)[++]				
Early Bloom(EB)[¶]	11.5	37.8	54.9	2.61
Mid Bloom (MB)	11.5	34.5	48.5	2.68
Full Bloom (FB)	11.4	36.9	50.9	2.63
Late Maturing(LM)[¶¶]				
Early Bloom(EB)	12.7	38.2	52.6	2.60
Mid Bloom(MB)	11.9	38.5	51.4	2.59
Full Bloom(FB)	11.9	41.7	52.3	2.52

+ ADF = Acid Detergent Fibre, NDF = Neutral Detergent Fibre
DE = Digestible Energy Estimate (Mathison et al., 1982)
++ EM = alsike clover - timothy - bromegrass hay mix
¶ EB,MB,FB = 10%,50%,100% of bloom of the legume component of the forage mix.
¶¶ LM = red clover - timothy hay mix.

Table 4.3 Proportion of Grass and Legume in Each Hay Mix

Hay Mix	Component	
	Legume (%)	Grass (%)
Early Maturing(EM)[+]		
Early Bloom(EB)[++]	48	52
Mid Bloom(MB)	57	43
Full Bloom(FB)	74	26
Late Maturing(LM)[¶]		
Early Bloom(EB)	83	17
Mid Bloom(MB)	91	9
Full Bloom(FB)	89	11

+ EM = alsike clover - timothy - bromegrass mix.
++ EB, MB, FB = 10%, 50%, 100% of bloom of the legume component of the forage mix.
¶ LM = red clover - timothy mix.

the grass components respectively.

Table 4.4 shows the feed intake results of the early maturing (EM) forage mix compared with the late maturing (LM) forage mix. There is a significant difference ($P \leq 0.01$) in intake for all factors measured except acid detergent fibre intake (ADFI) with the EM mix being more readily consumed than the LM mix. DMI for the EM mix was 80.2 ± 1.02g/$BW^{0.75}$ and for the LM forage mix was 72.2 ± 1.02g/$BW^{0.75}$ ($P \leq 0.01$).

Similarily, there was a significant difference ($P \leq 0.01$) between the EM and LM forage mixes for all digestibility factors measured (Table 4.5). DMD for the EM mix was 64.9±0.43% versus 61.2±0.43% for the LM mix.

There was a significant difference between harvests for DOMI ($P \leq 0.01$) and CPI ($P \leq 0.01$) but there was no significant difference between harvests for ADFI, NDFI or DMI ($P > 0.05$) (Table 4.6). There were significant differences in digestibility between harvests for all factors measured with levels of 63.5%, 64.4% and 61.1% for DMD; 65.4, 65.3 and 61.6% for CPD; 54.1, 51.7 and 49.9% for ADFD and 57.4, 54.3 and 51.2% for NDFD ($P \leq 0.01$) for the EB, MB and FB harvests respectively (Table 4.7).

The Forage Mix X Harvest interaction was significant for DOMI and CPI ($P \leq 0.05$) but not for DMI, ADFI, NDFI, DMD, CPD, ADFD and NDFD ($P > 0.05$).

The effects due to animal were significant for all intake factors ($P \leq 0.01$) but not for any digestibility factor except ADFD ($P > 0.05$). Similarily, the effects due to period were significant for all intake factors (DMI, DOMI, CPI ($p \leq 0.05$); ADFI, NDFI ($p \leq 0.01$)) but not for any of the digestibility factors ($P > 0.05$).

TABLE 4.4 Means of Intake Parameters for Early Maturing and Late Maturing Forage Mixes.

Hay Mix	DMI[+] ($g/BW^{0.75}$)	DOMI ($g/BW^{0.75}$)	CPI (g/day)	ADFI (g/day)	NDFI (g/day)
EM[++]	80.2[a]	48.1[a]	158[a]	485[a]	685[a]
LM[¶]	72.7[b]	41.1[b]	144[b]	477[a]	640[b]
SEM[¶¶]	1.02	0.66	2.77	7.98	9.81

+ DMI = Dry Matter Intake; DOMI = Digestible Organic Matter Intake; CPI = Crude Protein Intake; ADFI = Acid Detergent Fibre Intake; NDFI = Neutral Detergent Fibre Intake;

++ EM Forage Mix = alsike clover, timothy, and bromegrass.

¶ LM Forage Mix = red clover and timothy.

¶¶ SEM = Standard Error of the Mean

a,b Means within columns with different superscripts are different ($P \leqslant 0.05$).

TABLE 4.5 Means of Digestibility Parameters For Early Maturing and Late Maturing Forage Mixes.

Hay Mix	DMD[+] (%)	CPD (%)	ADFD (%)	NDFD (%)
EM[++]	64.9[a]	66.1[a]	54.7[a]	57.3[a]
LM[¶]	61.2[b]	62.0[b]	49.1[b]	51.3[b]
SEM[¶¶]	0.43	0.54	0.62	0.72

+ DMD = Dry Matter Digestibility; CPD = Crude Protein Digestiblity; ADFD = Acid Detergent fibre Digestibility; NDFD = Neutral Detergent Fibre Digestiblity.
++ EM Forage Mix = alsike clover, timothy, and bromegrass.
¶ LM Forage Mix = red clover and timothy.
¶¶ SEM = Standard Error of the Mean
a,b Means within columns with different superscripts are different ($P \leq 0.05$).

TABLE 4.6 Means of Intake Parameters for Early, Mid and Full Bloom Harvests.

Harvest	DMI[+] ($g/BW^{0.75}$)	DOMI ($g/BW^{0.75}$)	CPI (g/day)	ADFI (g/day)	NDFI (g/day)
Early[++] Bloom	76.2^{a}	45.1^{a}	157^{a}	482^{a}	682^{a}
Mid Bloom	78.6^{a}	46.6^{a}	154^{a}	479^{a}	656^{a}
Full Bloom	74.4^{a}	42.2^{b}	140^{b}	481^{a}	649^{a}
SEM[¶]	1.25	0.81	3.40	9.77	12.01

+ DMI = Dry Matter Intake; DOMI = Digestible Organic Matter Intake; CPI = Crude Protein Intake; ADFI = Acid Detergent Fibre Intake; NDFI = Neutral Detergent Fibre Intake.

++ Early, Mid and Full Bloom = 10%, 50% and 100% of bloom of the legume component of the forage.

¶ SEM = Standard Error of the Mean

a,b Means within columns with different superscripts are different ($P \leq 0.05$).

TABLE 4.7 Means of Digestibility Parameters for Early, Mid and Full Bloom Harvests.

Harvest	DMD[+] (%)	CPD (%)	ADFD (%)	NDFD (%)
Early[++] Bloom	63.5[a]	65.4[a]	54.1[a]	57.3[a]
Mid Bloom	64.4[a]	65.3[a]	51.7[b]	54.3[b]
Full Bloom	61.1[b]	61.6[b]	49.9[b]	51.2[c]
SEM[¶]	0.53	0.66	0.76	0.88

+ DMD = Dry Matter Digestibility; CPD = Crude Protein Digestiblity; ADFD = Acid Detergent fibre Digestibility; NDFD = Neutral Detergent Fibre Digestiblity.

++ Early, Mid and Full Bloom = 10%, 50% and 100% of bloom of the legume component of the forage.

¶ SEM = Standard Error of the Mean

a,b Means within columns with different superscripts are different ($P \leq 0.05$).

Even though there were only six data points, the RSQUARE procedure is used to determine if a regression equation could be developed to predict DMI, DOMI or DMD (Table 4.8). The results indicate that the codfficients of determination based upon a single factor would vary little from those based on multiple factors. Thus, there would be little improvement in predictability with equations based on these results if more than one factor was included in the regression equation. Overall, there were no coefficients of determination sufficiently large to warrent developing a predictive equation.

The DE values used to estimate DEY in Table 4.9 were calculated from the ADF values shown in Table 4.1. Only 6 values for each parameter could be estimated and therefore there were insufficient degrees of freedom to analyse the calculated values using an ANOVA procedure. However, when the CPY and DEY values were examined the LM mix had greater DE and CP yields than the LM mix. As well, each of the DE and CP yields increased from the EB to the FB harvest.

Table 4.8 Coefficients of Determination for Simple and Multiple Factor Models

Number of Factors in Model	Factor in Model	Dependent Variable R-Square Values		
		DMI[¶]	DOMI	DMD
1	CP[¶¶]	0.020	0.034	0.038
1	ADF	0.109	0.184	0.195
1	NDF	0.143	0.195	0.460
2	CP ADF	0.109	0.188	0.199
2	CP NDF	0.144	0.195	0.470
2	ADF NDF	0.145	0.211	0.487
3	CP ADF NDF	0.145	0.211	0.498

¶ DMI = Dry Matter Intake, DOMI = Digestible Organic Matter Intake DMD = Dry Matter Digestibility.

¶¶ CP = Crude Protein, ADF = Acid Detergent Fibre, NDF = Neutral Detergent Fibre

Table 4.9 Hay Mix, Harvest Date and Yield of Test Forages

Hay Mix	CP Yield (T/ha)	DE Yield$_3$ (Mcals x 10^3/ha)
Early Maturing (EM)[+]		
Early Bloom (EB)[++]	July 9	5.6[¶]
Mid Bloom (MB)	July 15	7.6
Full Bloom (FB)	July 22	9.4
Late Maturing (LM)[¶¶]		
Early Bloom (EB)	July 22	9.2
Mid Bloom (MB)	July 30	9.9
Full Bloom (FB)	August 8	11.0

+ EM = alsike clover - timothy - bromegrass forage mix.
++ EB,MB,LB = 10%,50% 100% of bloom of the legume component of the forage mix.
¶ Estimate for EM-EB based on known weight of air dry material removed from 0.1 ha.
¶¶ LM = red clover - timothy forage mix.

4.3 DISCUSSION

4.3.1 INTAKE AND DIGESTIBILITY

According to Van Soest (1982) NDF was better related to intake and ADF to digestibility. Therefore it should follow that, since the NDF level of EM was lower than the NDF level of LM the EM mix would be consumed in greater amounts than the LM mix. While this was the case the difference between EM and LM NDF levels was small (51.8 vs 52.1% respectively) and would not account for the difference in DMI.

The difference in ADF levels between EM and LM (39.7 vs 42.1% respectively) was larger than the difference in NDF levels and, as indicated by Van Soest (1982), explains the differences in digestibility between the two mixes. Digestibility may also explain the difference in DMI obtained between the two mixes. It has been reported (Blaxter et al., 1961; Bines, 1971) that intake of forages with digestibilities greater than 66% was limited by the animal's requirement for energy and intake of forages with digestibilities of less than 66% was limited by rumen fill. In addition, retention time in the rumen increases and dilution rate decreases. The digestibility of the EM mix was only 1 percentage point below 66% while the LM mix is 5 percentage points lower. This indicates that retention time was increased and dilution rate decreased in LM relative to EM and therefore passage rate of the forage was slowed and the intake of LM reduced.

Since the intake of dry matter was greater for EM than LM it would follow then, that CPI, NDFI AND ADFI would also be significantly greater. This was true in all cases except ADFI and indicated that the animal consumed each forage to the point where intake was limited by digestibility since the intake of ADF (the fibre fraction relating best

with digestibility) was not different between mixes.

The differences in the digestibility of the CP, ADF and NDF fractions would relate to the increased energy available from the EM mix allowing for greater microbial activity and therefore greater digestion of the cell wall component of the plant. This would result from a greater percentage of soluble cell contents and a lesser percentage of indigestible fibrous material (Van Soest, 1982).

Since there were significant differences between EM and LM for both intake and digestibility it would also follow that DOMI would be different as a result of the combination of factors just discussed.

There was no significant difference in DMI between the Early (EB), Mid (MB) and Full Bloom (FB) harvests. This result would be expected based on the small variation in NDF levels occurring between harvests (38.0,36.5 and 39.3% respectively). Again, as expected, ADFI and NDFI levels were not significantly different, however, CPI levels were lower for FB than for EM and MB harvests. This may be due to the slightly lower DMI for FB coupled with a slightly lower CP level relative to EM and MB (12.1, 11.7 and 11.65% respectively).

The DMD results for EB, MB and FB closely parallel the ADF levels (38.0, 36.5 and 39.3% respectively) obtained in each harvest in that the FB-ADF levels were higher while DMD was lower. As well, CPD, ADFD and NDFD levels for FB were lower than EB and MB indicating that, as expected, the FB material was of lower nutritional value than the earlier harvested material. Since each feed was consumed to the point where fibre intakes were equal even though fibre levels in the feed were different, energy values must impact on digestibility since digestible energy (DE) estimates were lowest in the FB harvest (2.35 vs. 2.42 and

2.49 Mcals/kg for FB, EB and MB respectively) as predicted from ADF values.

DOMI was significantly higher for EB and MB than for FB harvests due to a combination of higher intakes and digestibilities for the earlier cut harvests.

Overall, these results indicate that the EM forage mix harvested at the mid-bloom stage was the best forage based on intake and digestibility parameters. For the most part, interactions between hay mix and harvest were not significant, however a significant interaction is obtained for DOMI and CPI. For DOMI the interaction may be explained by the degree of variation between the values for the EM and LM mixes at the FB harvest relative to the values obtained at the EB and MB harvests. The values for the first two harvests were much closer than for the last harvest (48.0 vs. 42.2, 42.2 vs 44.2 and 47.5 vs. 37.0 g/BW $^{0.75}$ for the EM and LM mixes harvested at the EB, MB and FB stages respectively). The situation for CPI was the same with the EM and LM values being 160 vs. 155 ,157 vs. 151 and 157 vs. 125 g for the EM and LM mixes harvested at the EM, MB and FB stages respectively. Thus both interactions were significant due to larger differences in the values of the last harvest relative to the earlier harvests, not due to one mix having a higher value for a determination at one harvest date and the other mix having a higher value at another date.

With the exception of ADFD there was no effect on any digestibility determination due to the test animal or the test period. However, the effect of test animal and test period was significant for all intake parameters. There was a 13% difference in the live weight of the largest and smallest sheep at the time of purchase and this variation in size

continued through to the end of the trial period at which point there was a range of about 5 kg (or 10%) in animal live weight between test sheep.

Since food consumption increases with increasing liveweight at a comparable fatness (Meijs, 1982) it would be expected that there would be differences in intake between animals at any time during the trial. Similarily, it would be expected that differences in intake would occur between test periods because the test animals were still growing and their weights increased an average of 9.4 kgs or about 25% of total body weight from the start of the trial. Weston and Margan (1979) reported increases in the intake of sheep on trial between the ages of 24 and 40 weeks (compared with 21 to 39 weeks of age for sheep used in this study) of about 20% of the intake at 24 weeks of age. This level of variation in intake over the trial period would certainly result in an effect on intake parameters due to period. These authors also reported a small but significant decrease in the level of cell wall constituents digested in the alimentary tract between the ages of 24 and 40 weeks. While they were not considering differences between animals this effect must be related to the changing size of the test animals and may explain the significant effect of animal on ADFD since there was a 10% variation in animal liveweight.

4.3.2 UNCONTROLLED FACTORS

There were two major uncontrolled factors that may have had an impact on the outcome of the experiment. These were:

1) the precipitation that was received by the EM-EB, EM-FB and LM-EB forages, and
2) the relative level of grasses and clovers in each forage mix and harvest.

While no measurements were taken of the actual amounts of rain falling on the site there were at least several millimeters of precipitation, usually falling later in the drying period. Anderson (1976) indicated that a relatively heavy rain immediately after cutting will do minimal damage if followed by favourable weather whereas the same amount of rain on dry hay can cause heavy nutrient losses. Both Collins (1983, 1985) and Fonnesbeck et al. (1982) reported that wetting did not change the percentage of N in the hay, however there was increased leaf and overall dry matter losses with the effects being greater at bud stage than at bloom stage in red clover. Fonnesbeck et al. (1982) reported that these dry matter losses were in the range of 10% after 20 mm of rain fell representing the soluble ash, lipid and available carbohydrate portion of the plant. With increasing amounts of rain the percentage of cell wall increased (Fonnesbeck et al., 1982) resulting in increased ADF and NDF levels (Collins 1983, 1985).

These observations help explain the nutrient composition of the hay mixes. There was little effect on CP level due to precipitation (Table 5.7) since there was little difference between wetted and rain free harvests, but rainfall does appear to have affected ADF and NDF levels. According to Van Soest (1982) the amount of cell wall material should increase with increasing plant maturity. This was evidenced by the increases in ADF and NDF values between Mid and Full Bloom harvests for both the early and late mixes. However, both fibre measurements are greater for EB than for MB and FB (except for ADF in the LM mix) and since both EB-EM and EB-LM received precipitation this would explain this unexpected result.

The second uncontrolled factor was the species composition (Table

4.2). The level of red clover in the LM mix was higher than expected for all harvests and the level of alsike clover in the EM mix increased between the EB and FB harvests. The levels of both clovers were higher than what would be expected when the percentage of each in the seed mix was considered.

Collins (1985) reported that in a red clover-smooth bromegrass mixture the red clover made up about 92% of the total mixture. McBratney (1981, 1984) also reported similar findings with red clover and grass mixes in which timothy contributed the least of any of the test grasses to the total DM yield. The author indicated that this concentration was about 15% of the yield over several years. Since legumes tend to maintain their nutritive value longer through the growing season than grasses (Van Soest, 1982) and alfalfa and red clover are lower in cell wall constituents and digestible fibre and higher in cell solubles than perennial ryegrass at similar growth stages (Campling, 1984), it would be expected that high levels or increasing levels of legumes in the mixture would reduce the differences in feed value between EB and FB harvests.

In combination then, the rainfall on the EB harvests and the high levels of legume in the FB harvests acted to reduce the variation in nutrient levels between harvests. This would partially explain why there was no difference in any intake parameters or in DMD and CPD between EB and MB harvests even though a difference could be expected.

4.3.3 LINEAR AND QUADRATIC REGRESSION ANALYSIS

The coefficients of determination obtained by regression analysis were all less than 0.5. The highest coefficient obtained was that for estimating DMD from NDF determinations. The regression coefficients for DMD using multiple factors did not increase significantly. This may be

expected since only six data points were used in the analysis. Narasimhalu et al. (1982) reported that neither NDF nor ADF were correlated with DMD in work done on orchardgrass, bromegrass or timothy. Aderibigbe et al. (1982) in a trial with ryegrasses reports there was no relationship between CP and DMI -- a result similar to that obtained in this trial.

The difference in actual intake and digestibility results of the Feeding Trial and that suggested by the results of the Variety Trial, as discussed in the previous section, further support the finding of relatively low coefficients of determination obtained when regressing laboratory results upon digestibility parameters. There was still a great deal of variation to be accounted for before the intake and digestibility of feedstuffs by ruminants can be predicted.

4.3.4 INTEGRATED RESULTS WITH YIELD

When quality parameters were integrated with the yield of the two hay mixes over the three harvests different conclusions were reached than when just quality parameters were considered. Even though the LM mix is lower in intake and digestibility it was higher yielding. Thus, in terms of CP and energy produced from a given area of land the LM mix was more productive than the EM mix. When considering the value of a given forage species or mix, yield as well as quality must be considered.

4.3.5 COMPARISON WITH VARIETY TRIAL RESULTS

The intake and digestibility results obtained in the feeding trial between hay mixes vary somewhat from what would be expected based on laboratory results obtained in the variety trial. NDF levels for alsike clover and red clover were not significantly different suggesting that the intakes of the two clovers would also not be different.

In terms of digestibility, NBDMD results from the variety trial would again suggest no differences between mixes since there was no signficant difference between red and alsike clover. With regard to the grass component of each hay mix the results of Seone et al. (1981b) for NBDMD suggested that Toro was more digestible than Climax (45.4 vs. 35.7% disappearance respectively). This agrees with the feeding trial result in that the EM (containing Toro timothy) was more digestible than the LM mix (containing Climax timothy). However, the large percentage of legume in each mix at all harvests would limit the validity of this observation. The ADF values obtained in the Variety Trial also contradict the results of the feeding trial in that the levels for alsike clover (32.2±1.10%) were significantly greater than for the red clover (30.9±0.65%). This indicates that the red clover mix should be more digestible than the alsike clover mix. Seone et al. (1981b) found only a 1.7% difference in DMD between Toro and Climax timothy varieties.

CHAPTER 5 - GENERAL DISCUSSION AND CONCLUSIONS

The experiments conducted in this study examined several aspects of forage quality (in terms of animal nutrition) including the differences between Type, Species and Varieties within species; the differences between years; the differences between two forage mixes; the differences between three harvest dates and the importance of quality relative to yield.

In general, this study showed that the legumes were of better nutritional quality than grasses; that the clovers were of better quality than alfalfa, and that orchardgrass was of better quality than timothy. When the nutritional quality of varieties within species was examined, only the red clover varieties (Altaswede, Pacific and Lakeland) showed significant differences. Therefore, there was no difference in quality between those alfalfa, orchardgrass or timothy varieties examined. Over the 3 study years, there were differences in CP and NDF but not in ADF or NBDMD indicating there would be a difference in intake and overall quality between years but there would be little difference in digestibility of the test forages between years.

The results of the Feeding Trial showed that the early maturing mix had higher intake and digestibility than the late maturing mix. An examination of the species composition revealed that the clovers made up a major portion of each mix and therefore would have had the largest effect on intake and digestibility. The Feeding Trial results are different than would be expected based on the results of the variety trial. There was no difference in NDF levels between red and alsike clover in the Variety Trial suggesting that intakes would not be different. Also, alsike clover had significantly higher ADF values than

red clover (although NBDMD values were not different) suggesting that red clover is more digestible than alsike clover. In the Feeding Trial the alsike clover mix was consumed at greater levels than the red clover mix while the red clover was less digestible than the alsike clover. This comparison of results from each trial illustrates the point that the laboratory determinations used to predict a particular feeding parameter still have great variability associated with them.

Differences were also found in intake and digestibility between harvests. This was expected since the plants mature and lose nutritional value over the growing season resulting in a progressive drop in forage quality from harvest to harvest. However, the results of this study were not as expected with the early bloom harvest being of similar quality to the mid bloom, both of which were of better quality than the late bloom harvest. Furthermore, NDF and ADF values for the early bloom harvest were as high or higher than the later harvests, contrary to expectations. These results may be explained by two uncontrolled factors - precipitation and the level of legume in each forage mix. Both factors worked to reduce the variability between harvests and point out that precipitation can have a large negative effect on forage quality, while the level of legume in the mix (especially if the proportion increases as occurred with the EM mix) can have a large positive influence on forage quality.

However, the factor with the largest variation, whether discussing differences between forages, years, forage mixes, or harvest dates, was yield. In the feeding trial, the largest difference in yield was between years due to the different growing conditions occurring in each of the three years that samples were collected for the variety trial. The next

largest difference occurred between different species or forage mixes, and the least difference in yield was between varieties. The one exception was in the case of red clover where there was considerable differences in yield between varieties with Altaswede being the highest and Pacific the lowest yielding of all the varieties examined. In the variety trial, the largest difference in yield was between hay mixes and then between harvests.

Yield and quality results may be integrated by determining the yield of nutrients per hectare indicating the nutrient production of one forage relative to another. Different conclusions were reached in the of red clover when both yield and quality were considered. Lakeland and Pacific varieties were the highest quality forages on test but Lakeland is the lowest, and Pacific only intermediate, in yield. Altaswede is of somewhat lower quality than the other two red clover varieties but is the highest yielding forage overall. Therefore, the highest quality forage produced the least amount of nutrients per hectare while the somewhat lower quality but much higher yielding Altaswede variety yielded far more nutrients per hectare. In a practical situation one would have to recommend the lower quality but higher yielding Altaswede red clover based on these results. Another more general example of the importance of yield relative to quality occurred with orchardgrass and timothy. Orchardgrass was of better quality than timothy but because timothy produced more forage, the yield of nutrients per hectare is greater for timothy. A final example was from the feeding trial where the EM mix was of better quality than the LM mix; however, since the LM mix produced higher yields of forage than the EM mix, the LM mix provided the most nutrients per hectare. Thus, unless there was a vast difference in

quality between two forages, the forage with the highest yield will provide the beef cattle producer with the most yield of nutrients per hectare.

One must temper these conclusions, especially those regarding red clover, with other considerations. In the case of red clover, drying of the harvested crop is difficult and this, coupled with the fact it is a short lived species, indicated that considerations other than yield or quality must be accounted for before forage reccomendations are made.

The following general conclusion was based on the assumption that the forage crop being harvested was intended as feed for beef cows. From this study, it was concluded that yield was the parameter with the largest variation and that, overall, the largest variations in yield occur from year to year, the next largest between types, then between species, with the least difference in yield occurring between varieties within a species. The differences in quality parameters between types, species, varieties, hay mixes or harvests was not as great and yield will be the most significant factor determining the production of nutrients for cattle production from a given area of land.

Therefore, when a beef cattle producer was deciding on what forage or forage mixture to grow for winter feed, he should select the species and variety with the highest yield over several years to obtain the most nutrients per hectare of land and to reduce the impact of year to year variation. In addition to selecting the highest yielding forages, the producer must harvest his crop at the correct phenological stage to obtain the highest level of useable nutrients - in the case of this study, the early to mid bloom stage of the legume component.

CHAPTER 6 RECOMMENDATIONS

Several recommendations follow from this study.

Recommendation 1

It is recommended that variety testing continue since there can be differences in quality and yield parameters between varieties as was shown with red clover.

Recommendation 2

It is recommended that management practices such as harvest procedures, storage methods, fertilization and irrigation techniques also be investigated in conjunction with variety trials. Each of these factors can affect the yield and quality of forages harvested for livestock. Therefore, forage evaluation is not complete until management considerations are taken into account.

Recommendation 3

Research must continue in order to provide better interpretation of existing forage laboratory evaluation techniques or to provide new techniques so more efficient use of research resources may be made. In particular, a technique for more accurately estimating feed intake is needed.

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APPENDIX 1

CLIMATE OF THE ENGEN AREA[¶]

Climate Factor	Year	Month				Total For Growing Season
		May	June	July	August	
Sunshine (Hours)	1981	238.3	240.2	317.3	304.2	864.7
	1982	248.0	363.0	236.6	236.4	1084.0
	1983	272.3	147.8	193.0	251.1	864.2
Precipitation (mm)	1981	36.0	56.7	22.4	18.2	133.3
	1982	25.7	14.9	70.8	57.6	169.0
	1983	13.3	67.5	86.1	40.8	207.7
Temperature (°C)	1981	11.6	11.6	16.9	17.4	
	1982	9.5	17.3	16.8	14.4	
	1983	12.5	12.9	15.3	15.2	
GGD[¶¶]	1981	205	198	369	384	1156
	1982	140	369	366	291	1166
	1983	233	237	319	316	1105

¶ Temperature and precipitation data are from Vanderhoof and sunshine data are from Fort St.James.

¶¶ GGD = Growing Degree Days (estimated from the monthly mean temperature).