A REVIEW OF PASTURES AND MANAGEMENT IN RELATION TO THE CENTRAL INTERIOR

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Table of Contents

List of Figures

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1.0 Introduction

It is apparent that the future of livestock production in the Central Interior of British Columbia will be pasture based. Pastures imply neat, well managed fields of regular size, shape and appearance being carefully managed to obtain high, uniform yields. This is in contrast to the more traditional approach to grazing that is required in the dryer portions of the province where extensive management techniques apply. While local pastures may never be neat square parcels of grazing land, the requirement for careful management will be no different than in other pasture areas.

This report attempts to answer the question of what is careful management and the reasons why intensive management is a sound approach to producing livestock.

Many of the questions asked locally regarding productivity of plants and animals interacting on pastures are similar to those asked in other parts of Canada and the world. It follows, therefore, that many of our questions could be answered through reviews of existing work thereby avoiding needless effort.

The first section of the Pasture Review will be an overview of pasture-related work done throughout the world that can be applied to our situation. Contained in the discussion should be many answers to the questions we are asking.

The second section will cover local research work, and a comparison of Sections 2 and 3 should point out any gaps in our biological knowledge that needs addressing.

The next section will be a discussion of the points raised in the previous two sections that pertain to the local situation. This section will also contain recommendations regarding future direction of pastures in the area.

2.0 A General Review of Factors Affecting Production on Pastures

This section of the problem analysis will review research done on plant and animal productivity on pastures. The topics to be discussed include the growth of individual plants, the growth of pastures under grazed conditions, grazing behavior of animals and factors affecting forage intake by animals.

This section will provide the basics for discussion of the biological aspects of pasture production and a comparison of our situation with more developed areas.

2.1 Growth of Grasses

The most important point in grass production for grazing is that growth does not occur by having the stem internodes elongate. Rather, growth occurs from the stem apex located near the base of the plant. This stem apex, or growing point, generally remains below cutting or grazing height and continues to produce new tillers and leaves.

In tall grass species, stems can start to elongate while the apex is still in the vegetative state. This can result in the growing point being carried above the cutting or grazing height. Removal stops further leaf growth and limits the number of sites for tillering of that shoot.

The position of the stem apex is critical in frequent cutting or grazing of grasses. Growth occurs when the apical dome (see Figures 1 and 2) produces a succession of leaf primordia, tissue from which a leaf will grow. Once formed, they spread around the apex to form a collar which grows upward forming a small covering over younger leaf primordia and the stem apex. Once this occurs, the next leaf primordia will form.

2.12 Leaf Growth

Early in the development of a leaf, primordium growth is restricted to a zone of cells at the base called the "intercalary meristem".

Figure 1 Stem Apex and Leaf Primordium

A. Stem Apex

1 - 3 Leaf Primordium

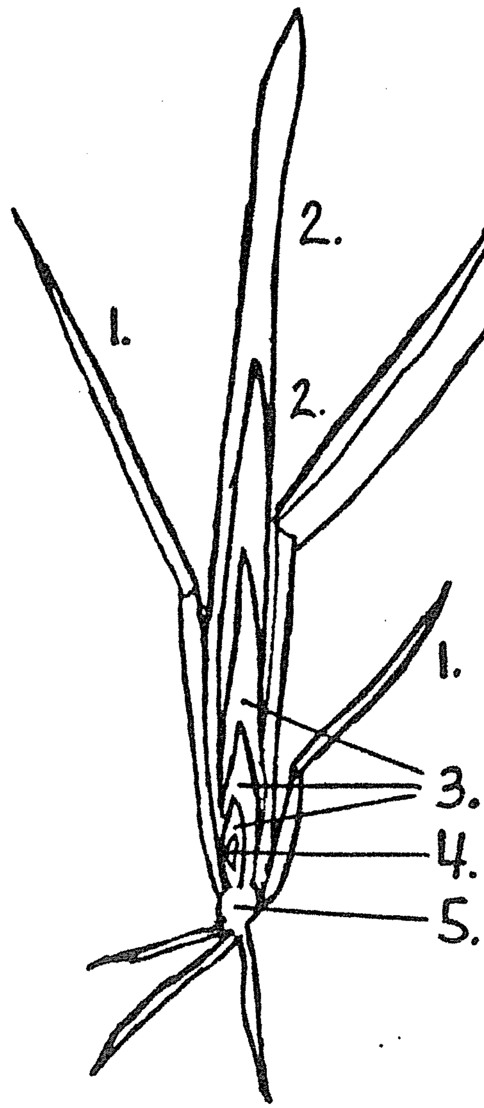

Figure 2 A Non-Elongated Tiller

1. Fully developed and photosynthetically active leaves
2. Leaves which are partly emerged from the sheaths of older leaves
3. Leaves which have not yet emerged and are dependent on leaves for nutrients
4. Stem Apex, Apical Dome (Growing Point)
5. Axillary Buds

Initially, there is no difference between leaf lamina (blade) and sheath. The leaf matures from the tip downward with the sheath the last part to mature. Once the ligule is exposed, the leaf part does not grow anymore.

The rate of leaf appearance varies with environment, but remains constant within its habitat. Leaf growth is also not affected by a change to the reproductive state of the stem apex. However, there are noticeable changes in leaf size. Leaves become larger until about the time the seed head appears and then the laminae (blade) become progressively shorter in relation to stem elongation. The shortening of the leaves may result from the plant channelling nutrients to reproduction rather than growth. The sheath increases in length at the time the blade shortens which partially compensates for loss of photosynthetic surface although the sheath is only half as efficient in photosynthesis.

Grass leaves have a relatively short life in comparison to many dicotyledonous species with the death rate matching rate of leaf growth. While the number of living leaves is constant within the plant's niche, there may be differences between environments - possibly with more leaves being present. As a leaf ages, it contributes less to the plant and may, before it dies, actually result in a net loss of nutrients. Young leaves contribute all their photosynthetic products to younger developing leaves and to the dependent tillers of older leaves. Later, they contribute to the root tips.

2.13 Tillering

A tiller is closely linked with the parent axis staying within the growing leaf sheath until it emerges from the top. There is variation between grass species in when tillering starts. Some species do not tiller for several leaf starts while others tiller sooner.

The initiation of tillering is little affected by environmental conditions since it is related to initiation of leaf primordium. However, subsequent growth is greatly affected by environment. Tillers grow faster than the rest of the plant at first due to a high net assimilation rate of photosynthates.

2.14 The Reproductive Phase

The onset of flowering is important because the plant now switches from the production of vegetative organs to the production of seed. The plant responds to environmental conditions by avoiding flowering when adverse conditions such as drought, cold or low light levels occur.

It is felt that many temperate perennial grasses go through an ill-defined juvenile stage through which the plants are developing to the point where they can start to seed. Some factors controlling the time in this period include a threshold leaf area, apical volume, or perhaps, the number of mitotic cycles in the apical meristem. Whatever the reason, there is a certain period of time before these species can respond to photoperiods which stimulate inflorescence initiation. Other species may be able to produce reproductive structures just after germination.

The flowering phase may be induced (vernalized) by low temperatures between 0^{o} and 10^{o} C. This is common in many perennial grasses in temperate areas where vernalization occurs when active cell growth is coupled with cold temperatures. Older plants may require shorter exposure.

Vernalization is related to photoperiod such that a number of short days along with cool temperatures may prepare the plant to flower while longer days are actually required for the plant to do so. The leaf appears to be the organ of perception for photoperiod simulation.

Climatic limitations, such as cold, result in seasonal growth and reproductive patterns. Also, within a species, varieties and ecotypes can vary in their flowering reactions. This is under genetic control and can be altered by selection. It is felt that plants growing in high latitudes may have no inductive requirement ensuring an immediate seed crop in case of winter-kill. The perennial grass's ability to store resources and quickly grow in the spring is another benefit.

2.15 Physiological Aspects of Regrowth in Grasses

The rate of growth of the sward is determined by the rate of tiller production as well as the growth rate of individual tillers. The latter is a major factor; the highest production of digestible matter occurs when a high proportion of tillers are elongating. Thus, a major contribution to overall yield occurs during inflorescence formation as a result of higher relative growth and net assimilation rates.

Cutting and grazing result in different patterns of defoliation. Cutting removes all herbage above a certain level while grazing is selective with some species heavily used and younger shoots preferred. A tiller consists of: (1) fully expanded leaves, (2) visible, expanding leaves, and (3) expanding leaves still completely enclosed by the sheaths of older leaves. All exposed portions of leaves are fully expanded having obtained their size in the basal portion of the leaf. As the leaf emerges from the sheath, it begins photosynthesis, the products of which go to nourish itself. Fully expanded leaves provide nutrients to the roots, stem apex, tiller buds and very young leaves.

If all of the blades of expanded leaves are removed, growth will depend entirely on younger leaves. Provided there is adequate mineral nutrients to the roots, there is no reduction in the rate of leaf expansion in orchard grass. If nutrient levels were low, reduced production occurs. so mature leaves may affect the supply of mineral nutrients.

Removal of the expanded area of expanding leaves greatly reduced subsequent expansion. The photosynthetic area is important in promoting new leaf growth in the expanded portions of leaves which are still growing. Also, removal of portions of the leaf still within the sheath significantly reduces subsequent leaf expansion.

Defoliation can also reduce the rate of tiller production for a short period of time. It has a major effect on root growth and activity often leading to decomposition of roots and a reduction in mineral uptake. Recovery of root activity does not happen until significant leaf growth has occurred.

Reserve materials are felt to be quite important in defoliation events. This is due as much to a reduction in new supplies and use in respiration as in use for new growth. The critical period for use of accumulated materials by the defoliated plant is about the first few days following defoliation. Carbohydrate use will continue, but is partially offset by new photosynthesis. The concentration of carbohydrates at defoliation significantly influences the rate of regrowth during this period. It appears that carbohydrates stored in each growing leaf contributes to its growth while those nutrients stored in the bases of older leaves are utilized by the roots.

The amount and type of leaf surface left after defoliation also greatly influences subsequent growth. The rate of tiller production depends mainly on the supply of carbohydrates and nitrogen - defoliation results in a short period of retarded growth.

Indiscriminate clipping or grazing during inflorescence development and stem elongation may considerably reduce yield. Once the stem apex is removed, no further growth can occur and the tiller will die. Regrowth depends on the number and type of leaves remaining on those tillers with intact apices.

2.2 Growth of Legumes

This section deals generally with how legume growth differs from grasses.

Unlike grasses, the growing point of legumes is at the tip of the elongating stem. This stem is frequently elevated, and whenever the plant is cut or grazed, the growing point will be removed.

In alfalfa (other legumes are similar), the top of the tap root, the crown, has a large number of dormant buds. Several of these buds start to develop in the spring using carbohydrates stored in the root. The use of the root as a storage area also contrasts with grasses which store reserves in the stem bases.

Buds emerge as the weather warms up, and after a time, they have enough photosynthetic area to make them independent of root reserve material. The number of stems accounts for the productivity of the stand which can respond to the density of planting. Depending on environmental factors, internal regulators limit stem production. If apical dominance is released, the number of stems/plant increase.

Shading affects leaf morphology with lower shaded leaves being relatively larger than unshaded leaves. The top leaves also contain more structural cells. Temperature also affects leaf structure since leaves grown early in the season are generally larger than leaves grown in the hot summer.

Initiation of flowering is in response to photoperiod. The onset of flowering releases apical dominance, and generally, vegetative buds will start to grow from the crown. The height of the cut will determine how many buds are available for regrowth and also how much labile carbohydrate is left behind. A high cutting or grazing will enhance growth.

If plants are cut just after flowering starts, the buds will form vegetative shoots. If a plant is cut earlier, there is a delay in the initiation of regrowth. It is important that the young shoot not be defoliated before it can add to carbohydrate reserves. This would occur under conditions where grazing is continuous. The carbohydrates are depleted more after each defoliation - the plant eventually can't regrow and dies (see Figure 3). This is the same for grasses, but the number of growing points below grazing height for the legumes is much fewer than grasses.

2.22 Legume Root System

When the plant is defoliated, the root system does die off as in grasses. The root system in legumes grows much deeper than grasses and has access to more water and minerals. There is little loss in root weight, but root hairs are lost resulting in a large reduction in absorbing area.

The reduction in photosynthesis reduces CHOs to rhizobia in the root modules which are released from the root into the soil. The nitrates contained in the rhizobia may be taken up by grasses which achieve a competitive advantage - especially if the legumes are preferentially grazed.

2.23 Canopy Structure

Unlike grasses, the leaves of legumes change the orientation of upper leaves during the day following the sun.

Photosynthetic activity of the leaf declines with age after climaxing during the first 5 to 10 days. Senescence occurs over a 30-60 day period. Bottom shaded leaves do not receive photosynthesis from the top.

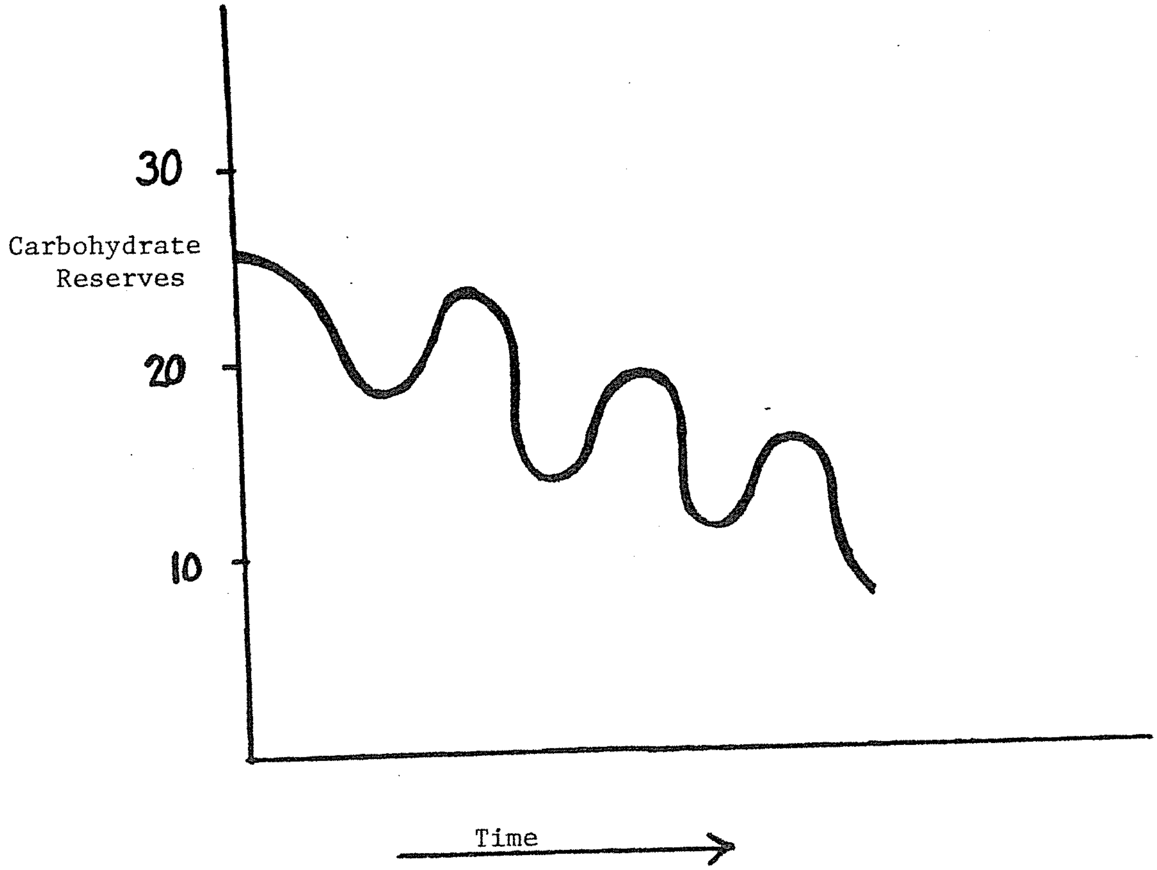

Figure 3 Decline in Carbohydrate Reserves Associated with the Repeated Defoliation of Alfalfa Shoots

2.3 Pasture Growth Under Grazing

Now that we have reviewed growth characteristics of individual grass and legume plants, the next step is to look at a complete pasture sward under grazed conditions.

Regrowth of pasture swards is influenced by the frequency and intensity of previous grazings. Regrowth can be divided into three areas:

1) the efficiency with which the leaf area of the plant community intercepts light energy for growth;
2) organic reserve status of plants; and
3) interaction between pasture production, stocking rate and annual production on a per head and per hectare basis.

Leaves are the primary component of dry matter production. The aim is to keep all leaves at the point where they are receiving light so that photosynthesis and respiration would be equal. Below this level, lower leaves would be respiring with a resulting net loss in productivity. Eventually a point is reached where the lower leaves die at the same rate new ones open. To obtain an optimum leaf area index (LAI; the ratio of leaf surface to covered soil surface), the plant needs light. Frequent grazing does not promote maximum growth rates.

2.32 Organic Reserves

There is a close association between leaf area, light interception and photosynthesis with the production of organic reserves. Reserve compounds are all organic compounds synthesized by the plant and stored in the roots, rhizomes, stolons and tiller bases of pasture plants. Following grazing or cutting, there is always an associated decrease in the carbohydrate reserve of the plant. This decrease is related to continued respiration of the plant with little effect in initiating regrowth. Regrowth depends on both the leaf area remaining and carbohydrate level and varies at different times of the year. For example, once apical dominance is established, further tillering and regrowth does not occur even if carbohydrate reserves are sufficient.

Environmental conditions predisposing high growth rates tend to keep carbohydrate levels low. If nitrogen is applied, this could further extend the period required before reserves start to build. In summary, organic reserve compounds, proteins and carbohydrates are used during the first week of regrowth and later growth is dependent on leaf area and photosynthesis.

Grazing affects root mass in grasses and legumes. This in turn will affect the capacity of the pasture to withstand periods of soil moisture stress and to compete for soil nutrients. The result is a dynamic process - photosynthesis initially causes an increase in root weight which leads to greater mineral absorption and further shoot growth.

2.4 Grazing Management, Species Composition and Pasture Production

There are several mechanisms resulting in vegetational changes. These are:

1) plants may be of low palatability or accessibility;
2) animals vary in grazing behavior (i.e. selectivity);
3) botanical composition can be influenced by the level or spatial distribution of plant nutrients; and
4) climate and physical environment exert powerful direct and interactive effects with the previous three mechanisms.

The most complex situation is the pasture containing both grasses and legumes. The reaction of each to defoliation differs and different management techniques can give one or the other the competitive advantage. In checking the use of pastures, one must consider the changes in botanical composition as well as yield. It is important to note that lax management favours upright species while intensive management favours prostrate species such as clovers.

Animals will be selective in grazing forage down to a certain level to obtain more digestible foodstuffs. Below this level, they will not be selective.

It is important to note the position of the basal tiller bud in relation to defoliation height. There is also a large difference in a plant species' ability to withstand trampling under moist conditions. These factors are important in determining the ability of the sward to regrow after use.

Frequently cut swards produced more clover, but less grass and total dry matter. Infrequent clipping produced more grass. Under reduced grazing, tall plants shade and suppress more prostrate species.

Work with alfalfa shows that when nitrogen is applied at 150 kg/ha three times during the season, both timothy and bromegrass were dominated. With frequent clipping, a 50:50 balance was maintained and orchard grass could compete better with alfalfa. The greatest cumulative yields were obtained with the lowest cutting frequency.

2.42 Pasture Growth and the Physical Environment

The optimum temperature for growth of many grasses is between 20 and 23^{o} C. Growth rate drops quickly below 10^{o} C although growth continues until about 5^{o} C. Above 25^{o} C, growth slows and usually stops above 30 - 35^{o} C. This may result in better growth in early and late portions of the day. Root growth usually has a lower optimum temperature than shoot growth.

Water shortages can reduce growth - this is most critical when plants are initiating new tillers. Severe and prolonged water shortages result in substantial plant deaths. If accompanied by heavy grazing, the problem is made worse resulting in greater losses. As soil moisture level drops, photosynthesis is reduced followed by a drop in moisture level of the leaves. However, nighttime respiration is also depressed so energy conservation occurs. Red clover and alfalfa are most resilient and orchard grass is the least. It takes up to 12 hours for plants to recover from moisture stress.

Improved pasture species show better transpiration ratios than native species. This could result in very low levels of soil moisture and prolonged periods of soil moisture stress for tame species compared with areas growing native species. Research has suggested that it may only be necessary to fully rewet the upper portions of the soil profile to obtain maximum regrowth. Also, reduced moisture levels may make some plant nutrients unavailable. Grazing reduces the size of root systems and could yield higher soil moisture levels on more intensively grazed pastures. The result of reduced leaf area for evapotranspiration and reduced root growth is the inability of the plant to fully explore soil volume and extract moisture. Overall, there is more impact in reduced shoot growth than root growth.

2.43 Grazing Animal and Pasture Growth

The selective nature of animals combined with high stocking rates can cause long term composition changes. It may also remove any gain in the use of extra forage left after grazing under moderate stocking rates. It is difficult to examine pastures without considering frequency and intensity of grazing or cutting and animal selectivity factors. Clipping studies cannot easily be done to reflect animal grazing - the effects of selectivity, trampling and defecation are not simulated.

Intensive, short term grazing with relatively long rests gave the best production from a grass clover sward while lax grazing gave a reduced yield. Relative to frequency and intensity of grazing, it would appear that production per animal declines linearly with stocking rate. High frequencies of grazing result in a lowering of the quantity of pasture available per head.

2.44 Grazing Behavior

Animals typically graze after dawn and later in the afternoon. Ruminating, resting and drinking generally occupy the remainder of the day. At temperatures greater than 25^{o} C, night grazing begins to occur. In one study, there was no relation between grazing time and temperature in the 0 - 30^{o} C range. However, time spent grazing decreases below 0^{o} C and cattle may graze more during the day. In warm, humid climates, grazing time decreased above 26^{o} C. These variations probably reflect different physiological effects of temperature upon animals along with factors such as age, size and physiological status.

Time spent grazing by calves increases rapidly as the milk supply drops. Also, there may be differences in grazing time associated with age. Lactation and pregnancy also effect grazing time with animals eating more to meet their requirements. Animals can also adjust intake by eating faster without increasing grazing time. This occurs in humid periods or when there is little available forage. Supplemental feeding also reduces grazing time. When feed is short, on either range or pasture, more time will be spent grazing, the number of bites per minute increases while intake per hour decreases. More energy is expended to get less.

Animal responses to swards of varying structure are not well understood.

2.45 Pasture Use Patterns

Certain sites on a pasture are favoured for resting and areas closer to these points will be more heavily used. This effects:

1) the degree and frequency of defoliation; and
2) growth potential because of the redistribution of nutrients.

Most urination and defecation occur while adjacent to resting areas. These resting sites will change relative to temperature, wind exposure and other environmental factors.

A relationship between wind and pasture use has been noted with cattle using the area into the wind. If the wind is cold, the animals will seek shelter.

Cattle graze a particular plant shoot in response to yield and length of herbage as well as stocking rate. Animals in an intensive stocking situation will bite the same shoot several times.

Cattle will select a leaf in preference to stem and green parts of a plant in preference to a dry portion. They usually eat material higher in nitrogen, phosphorus and gross energy. Also, they select plants lower in fibre than the average. It is not understood why this occurs although it is known that touch, taste and smell are used in the selection process. For example, cattle will attempt to smell dung patches, etc. Young animals also select a diet with a higher digestibility.

In studies done to compare relative eating preferences of different species, cattle ate less grass and more forbs and browse than sheep. These differences also change with time. In another study, sheep ate more clover and less grass than cattle for a portion of the grazing season. Selection of the diet was related to:

1) degree of greenness;
2) useful bulk;
3) total bulk; and
4) ratio of dry grass to dry clover.

Cattle and sheep change their diets throughout the day. The general trend is to increase nitrogen later in the day while also becoming more particular about what is consumed.

2.5 Factors Affecting Intake of Animals on Pasture

There are many factors that control or influence intake of animals' grazing pastures. This section is intended to review these factors to allow future discussion of pasture management.

2.52 Animal Intake Controls

The obvious factor controlling intake of animals is reaction to physical structure of food. Animals being fed bulky feeds may stop eating before receiving sufficient nutrients. This results from two factors: the first is the capacity of the alimentary tract, especially the reticulo-rumen, to receive food. When food of relatively low digestibility is given to a number of animals, intake is broadly related to individual live weight, thus; varying with the size of the animal. The signal to stop eating probably involves stretch receptors in the wall of the rumen or abdomen - the exact nature is not known. Foetal development and deposition of fat reduce rumen capacity leading to reduced intake.

The second physical factor affecting intake is the rate of breakdown of digesta by combined microbial fermentation and mechanical activity of the gut. Soluble products are absorbed, gaseous products are eructed and the remainder passes to the abomasum and intestine.

The rate of digestion is closely related to the chemical composition of feeds. With poor quality roughage, if the level of nitrogen is increased, microbial activity within the rumen will increase resulting in a higher rate of breakdown and voluntary intake. Rates of passage also depend on saliva production and rumen pH.

A second factor inhibiting intake by animals is metabolic. Animals adjust feed intake to meet energy requirements with the desired result of maintaining net energy intake almost in balance with energy output, if feed availability and energy content are not limiting.

The average daily intake of digestible energy remains fairly constant. If the digestible energy level of a feed increases above a certain level, food intake will drop depending on the requirement and physiological state of the animal. Volatile fatty acids (VFA) generated in the rumen play an important role in metabolic control of intake.

Changes in environmental temperature may have an effect on food intake. Thermostatic controls appear to take over if temperatures become too high or low with a concomitant reduction in intake.

Another control appears to be related to body fat levels. These lipostatic controls may result in thin animals trying to build up body fat while those with low intakes may mobilize body fat to meet needs.

2.53 Factors of Animal Origin Affecting Intake

Intake varies with animal age and weight. The live weight and size of the growing animal is highly correlated as is the relationship between body size and the capacity of the alimentary tract. Food consumption increases with live weight. In cattle, the total dry matter consumption increases roughly by 1.0 kg for each 100 kg of live weight.

Consideration of the effects of pregnancy on intake can be confounded by the effects of lactation or animal growth. There is an increase in intake in early to middle pregnancy - the reasons are not understood since fetal energy requirements do not become large until the third trimester. The fetus and associated tissues occupy a considerable volume of the intestinal cavity later in pregnancy. Any decline in intake may be attributed to the reduction in the volume of the rumen. Changes in endocrine balance may also be involved.

Lactation results in increased intake and weight of the rumen in cattle. The cows can eat more than dry cows without affecting dilution (disappearance from the reticulo-rumen) greatly.

The condition of the animal also influences intake.

As mentioned, fat or pregnant animals reduce intake. If the cow is fat at parturition, then food consumption is down at the critical period in early lactation. The amount of abdominal fat has restricted voluntary intake of herbage by steers on test.

Social behavior and stress may also affect intake, especially if the animal is introduced to a strange environment.

2.54 Factors of Sward Origin Affecting Intake

Evidence shows declines in intake in relation to declining digestibility; fouling of forage by feces may have some impact on this. Increased consumption could also result due to the need to eat more of a poorer quality feed provided it is not excessively poor. There is a strong positive relationship between digestibility and intake up to about 70% digestibility. Above 70% there is little effect on intake.

Herbage mass also impacts consumption and is related to the maturity of the sward and digestibility. As mentioned, high quality feed results in less consumption. After herbage mass and digestibility, research shows sward height to be the next most important factor affecting intake.

Species and chemical composition of forages also affect intake. These factors are again related to digestibility with intake varying between species. In relation to chemical composition, the greater the cell wall (A.D.F.) and crude fibre constituents, the lower the digestibility. Also, increased crude fibre and saliva production result in higher cellulolytic bacteria activity in the rumen. As can be deduced, the higher the crude fibre, the lower the intake.

2.55 Factors of Management Origin Affecting Intake

The herbage allowance is perhaps the most obvious factor affecting food consumption. Reductions in available forage below a certain point reduce intake.

Concentrates also affect eating. Studies suggest that when more concentrate was made available to the animals, more was used relative to feed consumed. Supplementation decreased herbage intake.

Pasture contamination, already alluded to, was a major factor affecting food consumption whether found as dung, urine or a slurry application. Cattle were found not to graze urine covered forage immediately after the event, but grazed it preferentially on the next pass. Thus, urine does not necessarily lead to a major rejection of herbage. Dung deposition depends on food intake, faeces consistency and weather. The area that is rejected is greater than the area of the actual dung pat, and without topping the pasture, wolf plants can occur. In a study on feces contamination, it was found that herbage intake was about 8 - 13% higher on a clean pasture.

Nitrogen fertilization, while thought not to directly influence intake, is important in terms of species composition. Intake on fertilized pastures increases for a number of reasons including increased volume.

Climate and season also play a part in determining animal intake. High ambient temperatures depress feed intake depending on breed and production level of the animal on pasture. Temperatures, as already mentioned, will reduce total grazing time and daylight grazing time and will also affect the quality of the feed. If heavy rains are encountered, the animal will have to increase intake to compensate for reduced dry matter levels. Seasonal changes in food consumption tend to revolve around differences in the digestibility of the herbage. Other factors that change seasonally include forage composition, degree of fouling, herbage availability and climate.

This completes the section on general knowledge about plant and animal production on pastures determined from world-wide research. The next section looks at work done in the Central Interior that relates to pastures.

3.0 A Review of Local Research Relating to Pasture Productivity

As can be seen from the preceding section, a great many factors come into play when looking at pasture management. Most of the research covered in section 2 was done outside of Canada although much of it applies locally, especially in relation to animal production. What work has been done locally? Section 3 will look at work done in the Central Interior and Peace River areas of British Columbia and place the local situation in perspective.

In general, the northern portion of the province is characterized by warm summers, cold winters and restricted growing seasons modified, to a degree, by long summer day lengths.

The forest vegetation is characterized by species of the genera *Picea*, *Pinus*, *Abies*, *Batula*, *Populus* and *Alnus*. The common native grasses are Bluejoint reedgrass (*calamagrostis canadensis*), Slender wheatgrass (*Agropyron trachycaulum*), *Poa* spp. Fireweed (*Epilobium angustifolium*) is a common forb.

In the Peace River area, grass-legume pastures produce 1,000 to 3,000 kg/ha of forage on a dry matter (D.M.) basis with a grazing season of 90 to 155 days. A major problem is volunteer regrowth of poplars and willow. Similar productivity may be found in the Central Interior. Animals left on pasture later in the season usually loose weight as forage values drop off, but over the season, animal production can be in excess of 100 to 250 kg/ha.

Historically, the first areas settled were the pockets of prairie or open spaces along rivers that were easy to clear. Gradually, heavy equipment was developed which could clear large areas quickly and economically. During the 1960's, 80,000 ha a year were put into production in the Peace River as "V" cutter bars, buncher pilers, large plows and root rakes were developed to clear aspen forests. Since prairie agriculture techniques do not transfer directly to boreal areas, local techniques had to be developed.

3.1 PLANTS

A fair amount of work has been done in the area on forage species production, nutrient value, brush control, renovation and effects of fertilization.

Several research projects have been conducted in which dry matter (D.M.) yield of forages and grains have been determined. These have almost exclusively been done on crop lands, and no data is available on yield from community pastures.

Yields of an alfalfa, red clover and timothy mix grown in the Smithers area were 2.38 tons/acre for an early cut (June 12 - 14), 2.81 tons/acre for a medium cut (June 27 - 29) and 3.56 tons/acre in a late cut (July 19 - 20). The aftermath yield was 0.69 tons/acre although there was little regrowth on the late cut areas. In a study of cereals harvested at silage stage, yield varied from about 2.3 to 4.5 tonnes/ha at McBride and Smithers on orthic gray-wood clay loam and orthic gray-brown loam soils respectively.

Another study looked at yield and quality of fifteen grasses harvested at the early heading stage and found that Pubescent wheatgrass (Agropyron trichophorum), Timothy (Phleum pratense), bromegrass (Bromus inermis) and Intermediate wheatgrass (A. intermedium) and Reed canary grass (Phalaris arundinacea) outgrew the other species tested with yields of 4,069 to 4,812 kg/ha D.M.

In another project looking at the forage yield and quality of seven perennial grasses at the sites throughout the Central Interior, it was found that Chief intermediate wheatgrass averaged more first cut D.M. yield over all sites and was one of the highest yielding at six out of seven sites. The exception was Prince George where Carlton bromegrass out yielded Chief. Carlton bromegrass, Meadow foxtail, Boreal red fescue and Chief intermediate wheatgrass exhibited much reduced yields after the first harvest year. Frontier reed canary grass had sufficient regrowth to rank it equal to Chief in total D.M. yield.

In work done in the Peace River, recorded D.M. yields of a pasture mix (Rambler alfalfa, 3 lbs/acre; Manchar bromegrass, 5 lbs/acre; Olds creeping red fescue, 3 lbs/acre; and Aurora alsike clover, 2 lbs/acre) seeded onto areas that had previously been renovated were recorded. Yields were found to drop in the years following seeding.

Crude protein (C.P.) levels were also determined in many of the studies just discussed. One found that C.P. levels dropped from 16.29% in the early cut to 10.66% in the late cut.

Another study shows that C.P. percent varied from 9.1 to 10.93 for the cereals examined. In another study on quality of perennial grasses, Chewings fescue contained more C.P. than Intermediate and Pubescent wheatgrass and reed canary grass more than Pubescent wheatgrass. C.P. varied from 10.5 to 13.3%.

In a study looking at the analysis of results from three years of sampling of community pastures in the Prince George area, the average protein content of forages is insufficient for lactating cows, and the content for growing or finishing steers or heifers was borderline to deficient. In this study, no yield or intake information was collected so it is not known if the animal could selectively increase protein intake by increasing overall intake. A comparison of seasonal trends over all pastures and all years show that protein is lowest in August with the levels sufficient for beef cattle in June with a possible period of deficiency from mid July to early September. Variations in protein levels were noted between individual pastures.

Very little is available on energy levels in forages in the area. One study looked at total digestible nutrients (T.D.N.) for early, medium and late cut silage used and found that T.D.N. percent dropped from 56.44% to 47.1% between the early and late cuts.

T.D.N. levels are thought to vary between 40 and 65% in most areas.

Many of the projects already mentioned also analysed forage crops for mineral content. While these studies reflect content of the plants, the animal may actually be obtaining different levels through selective grazing.

In one study, the Ca and P levels appeared to be borderline to deficient for steer calves and yearlings growing at 0.9 kg/day and deficient for growing heifer calves and yearlings (NRC, 1976). The Ca and P levels were deficient for milking cows, but adequate for mature bulls. For growing steers and heifers, Cu levels were borderline, Mn adequate, Zn was deficient at Vanderhoof and Mg levels were adequate.

In another study on perennial grasses harvested at the early heading stage, mineral levels (Ca, K, Mg, Zn, Mn and Cu) were recorded. Ca levels were best in red fescue while K best in orchard grass. Orchard grass, tall fescue and reed canary grass contained the highest levels of Mg. Mn varied the most of those minerals examined between species. Ca was highest in bromegrass, and the lowest levels were recorded in intermediate and pubescent wheatgrass.

Ca levels were borderline of deficient for growing steers and deficient for growing heifers and milking cows. Mg levels were adequate for growing steers and heifers and borderline for lactating cows. Zn levels were borderline to adequate for growing cattle while Mn was adequate to excessive and Cu was borderline.

However, in a summary of forage crop production research in the McBride region, grasses had adequate levels of Ca, Mg, K, Mn and Cu with Carlton, Summit and Chief varieties being borderline in P and Zn while Red clover was borderline in P content.

Forage samples collected from 1978 to 1980 on community pastures in the Central Interior were analysed, and reports on Ca, P, Cu, Fe, Mn, Zn and Mg obtained. Yearly trends for all pastures show that Cu levels are just above the NRC recommended levels in 1978 and 1979 and were adequate in 1980. P levels were below requirements for lactating cows and borderline for steers and heifers while Ca levels were sufficient for all classes. Mg exceeded the requirements for growing steers and heifers and was borderline for lactating cows. Fe and Mn levels were high. This would be due to contamination of the samples with soil. Zn levels were always adequate. Levels of each element varied from year to year due most likely to variations in weather.

A look at seasonal trends for all pastures studied over all years showed that Ca, P and Mg peaked in mid June and then declined. P levels were lower in early August while Ca and Cu levels were lowest at the beginning of July. Mg levels were lowest in mid July.

Ca levels were sufficient throughout the season; P levels were marginal to deficient. Cu levels were acceptable; Zn levels were high in the early and late parts of the grazing season, but borderline in mid season. Mg levels met requirements for steers and heifers, but were insufficient for lactating cows.

It was noted that there was variation in quality between pastures depending on soils, management, weather and stage of development of the site sampled.

In a review of work done at Sunset Pasture in the Peace River, notes that Ca, Cu, Fe, Mn, Zn and Mg levels were adequate while P levels were below NRC guidelines. On the native pasture, P was also low.

Dry matter digestibility (D.M.D.) and digestible dry matter (D.D.M.) yields were determined for whole-plant cereals harvested at the silage stage at McBride and Smithers. It is felt that D.M.D. percent was too low for moderate milk or live weight yields. The short strawed, high energy cultivars are more valuable than high D.M. lines with poor digestibility and protein levels.

In another study in which the quality of perennial grasses was examined, the results show that Bromegrass and meadow fescue were the most digestible. Bromegrass and pubescent wheatgrass produced the most D.D.M. per hectare.

No specific work has been done on winter-kill, but it was noted in the literature the birdsfoot trefoil and sainfoin as well as less hardy grass cultivars were hard to keep in the sward.

Only one study on renovation in the Peace was found. It looked at aspen regrowth in pastures in the late 1960's. The trees had originally been walked down and piled by crawler tractor, and plots of 50 x 48 feet were established. Legumes died out over five-year period and Creeping red fescue became the dominant species. Other general comments included the D.M. yield was low in the year following seeding; drilling did not result in higher herbage yields and herbage yields fluctuated greatly from year to year reflecting precipitation.

It was found that aspen filled in untreated areas within five years. Other results show least regrowth with the moldboard plow, possibly due to the shearing action of the blade through roots, etc., and the subsequent deposition of these on the surface. The Rome disc was next best, but medium and shallow depths were not up to the quality acceptable for pasture. At these depths, the roots and crowns were split compounding the problem. The deep setting did throw roots to the surface. The rotovator, set at depths of 4" - 6", jumped over the larger stumps and willow crowns allowing regrowth to occur. The One-way yielded results similar to the shallow rome disc. The tandem disc was too light and it did not penetrate or cut tree crowns.

It was concluded that the various methods tested did not control suckering adequately to yield good quality, permanent pasture. The production of large scale pastures cannot be successful using rough or once-over methods.

The effects of fertilizer on forage production have also been mentioned in many of the studies already discussed. It becomes apparent from the data to be presented that fertilizer has a substantial impact on forage yields and subsequent animal gains.

In a study looking at the effects of nitrogen and phosphorus on the yield and chemical composition of meadow foxtail, the results show that each increase in N increased the D.M. yield except the 112 kg/ha and 224 kg/ha levels in the first cut. The D.M.D. percent was not directly correlated with N or P application rates, but there was a consistent decrease in D.M.D. percent with advancing season. Digestible dry matter (D.D.M.) showed increases in yields similar to D.M. yields with increasing N application with the exception of aftermath. Each increment of N increased crude protein (C.P.) content in first-cut forage, but only heaviest rates increased C.P. in second and third cuts. Phosphorus did not alter either C.P. content or yield. Further results show that phosphorus alone did not affect mineral composition, nitrogen depressed phosphorus content in most cuts, phosphorus content for each treatment did not vary appreciably for successive cuts. Ca in the first cut was not affected by N, but in later cuts, high rates of N depressed Ca content. At lower rates, the content of Ca in successive cuts increased. An increase in N levels increased the level of K in the first and second cuts, but only the heaviest N level affected the third cut. Phosphorus, in combination with N, increased K content in the first cut over the comparable individual N and P treatments. Mg content increased with each successive cut of forage during the season except at high H levels. The application of N reduced levels of Mg in the second and third cuts. Zn levels in forage were increased in the first cut by high levels of N, but increases in the second cut occurred only at the highest level. There was little variation in Zn between cuts. Mn was reduced by application of N in the first and second cut, but only by the highest level in the third cut. Mn content increased with advancing season. Cu content was increased in all cuts by N, but Cu levels in the grass decreased over the season.

It was noted that grasses did not suffer from S deficiency, and the conclusion was that earliness of growth of meadow foxtail, its efficient use of nitrogen, satisfactory D.M. yield with good regrowth and high protein and mineral levels indicate the potential of meadow foxtail.

In the work done on seven cultivated perennial grasses, it was shown that for all species over all locations the combined application of N, P, K and S increased first cut and total D.M. yields by 1,798 and 2,411 kg/ha respectively. The total D.M. yield response to fertilizer varied from a 1,600 kg/ha increase at Williams Lake to a 3,200 kg/ha increase at Prince George and McBride. Frontier reed canary grass produced the highest D.M. response to fertilization. Over all species and locations, C.P. content increased by 3.9% ranging from 2.8% at Smithers to 5.6% at Prince George. Meadow foxtail and Boreal red fescue showed the best response. Fertilizer application did not affect the level of D.M.D. It was concluded that there was sufficient variability to require additional testing of fertilizers on grass production.

In the summary of forage crop research in the McBride region from 1969 to 1974, it was noted that fertilized grass species have out yielded the legumes at McBride in all of the three seedings made at this location. The average increase in D.M. yield due to fertilizer application for all grass species was 1.8 tons/acre D.M. for the 1971 seeding and 1.0 ton/acre for the 1972 seeding. Chief intermediate wheatgrass showed an increase of 2.2 and 1.4 tons D.M./acre for 1971 and 1972 respectively over the non-fertilized plots.

3.2 Animals

While a fair amount of work has been done with plant species, there has been little done with animals.

In an experiment to determine the productivity of Climax timothy and Frontier reed canary grass as sources of grass pasture for Hereford yearling steers, the pastures were stocked at 1 steer/ac with the use of put and take animals to remove excess forage. The pastures were fertilized in the first year with 16-20-0 at 150 lbs/ac, and in later years, with split treatments of 34-0-0 at 100 lbs/ac. Three treatments with two replications were used. They were:

1) Reed canary grass,
2) Timothy, and
3) Reed canary grass plus a grain supplement fed at a rate of 1 lb of grain for each 100 lbs of beef on pasture.

Results show that 264 lbs and 303 lbs/ac of beef on Reed canary grass and timothy respectively over the test period. Average Daily Gain (A.D.G.) averaged 1.84 and 2.05 lbs/day and the use averaged 143 and 147 steer days/ac for Reed canary grass and timothy respectively. It is interesting to note that on the pasture receiving supplemental grains, the period of use is greater.

The 1971 Experimental Farm Annual Report points out that on fertilized pastures the stocking rate was 0.38 ha/A.U./month and the A.D.G. was 2.54 lbs/day while on a non-fertilized pasture the stocking rate was 0.44 ha/A.U./month and the A.D.G. was 2.39 lbs/day.

It was noted in a review of work done on the Sunset Pasture that calves grew at a steady rate over the pasture season on both native and tame pastures (about 0.95 kg A.D.G.) while the cows gained weight at different rates on the native and tame pastures. The cows on tame pasture averaged about 50 kg more than those on native pasture over the year.

Most of the projects done with cattle on tame pastures have used variations of a rotation grazing system. It is felt that the best production is obtained this way, but this has not been tested in the area. Work on the Sunset Pasture suggests that, on native ranges, a two pasture rotation system may yield lower A.D.G.'s than a set stocked pasture.

This concludes the review of work done in the local area. It points out the fact that the region has potential for supporting a forage-based livestock industry, but several problems must be overcome and new management procedures implemented. These concerns are discussed in Section 4.

4.0 Discussion

It is evident that, with good management, a respectable amount of forage can be produced on pastures in the Central Interior. Dry matter yields of 4 - 5 tonnes/ha are common. Problems arise, however, when one considers the overall quality of the forage produced.

In studies measuring dry matter digestibility, it was felt D.M.D. is too low for moderate milk or live weight yields. Very little information has been collected on the energy levels of feeds, but it is also felt that they are low for acceptable live weight gains in swards consisting mainly of grasses.

Crude protein levels, again on pastures with little legume content, are also low at certain times of the year. This is especially true during periods of drought or when little fall regrowth occurs. At these times, C.P. levels of grasses can reach 6%. Legumes, which have not been predominant in community pasture swards have had much higher C.P. contents - often peaking in excess of 20% and often not falling below 9% during dry weather. It is well documented in local studies that the addition of N fertilizers will raise the C.P. content of forages as much as 4%. This would have a substantial affect on the quality of grasses.

Calcium (Ca) and phosphorus (P) levels varied, but on pastures, it is felt they are generally borderline to deficient for steer calves and yearlings and deficient for grazing heifer calves, yearlings and milking cows. Where this varies, calcium may be adequate, but P appears to remain low and requires supplementation.

Legumes, which tend to have higher levels of Ca, may aid in overcoming deficiencies of this mineral.

Selenium and copper levels are also a problem in the area. This is well recognized and involves supplementation since management of the sward does not appear to provide an answer. Magnesium levels may also be a concern with certain classes of livestock at certain times of the year.

Although not extensively documented, pasture development and renovation have caused concern due to several factors. The degree of development (rough clearing vs. root raking) has affected overall management and success of seeding establishment. It is becoming apparent that a high degree of development is needed to ensure seed establishment, survival and production for forage. It may also become important in enlarging our management alternatives. Another concern is regrowth of deciduous species on cleared areas. It was felt that regrowth relates to the quality of pasture development as well as long-term management.

Most of the work done with cattle has been carried out at the Prince George Experimental Farm and Sunset Community Pasture. It has not yet been well documented. A preliminary look at the data reveals that stocking rates of about 1.0 ha/animal/year and A.D.G.'s in excess of 1 kg/day may become common depending on the area and management method.

In summary, the pastures of the Central Interior, while producing an adequate volume of forage, suffer from problems of quality. This is especially true in terms of protein and digestibility of the feeds.

However, these problems are not unsurmountable, and it becomes clear from the discussion in Section 2 that most, including protein and digestibility problems, can be overcome by adjusting management practices. Let's look at a proposed management system and how it will offset the problems encountered in relation to the biological considerations discussed earlier.

In Section 2, it is noted that lax grazing favours upright species while intensive management favours low species. This implies that careful, close management of the sward by judicious manipulation of the grazing animal consuming cultivated species will provide the greatest benefits. This high stocking rate, short duration grazing system is the proposed management system to overcome production problems.

In terms of production, the goal is to keep the grasses in the vegetative state. If the plant is moderately grazed so that most of the immature leaf blades are left, then growth is not impaired and root reserves, after a short period, continue to build up. By not impairing root action, the plant can continue uptake of soil moisture and nutrients to successfully compete with other plants. There is some indication that even though tame grass species use more water than native species, grazing moderates use resulting in longer soil water availability.

If the grass plant is heavily grazed; photosynthetic area is reduced, root size is reduced and the growing point may be clipped. The reduction in root size limits the plant's ability to take advantage of wetting of upper soil layers. Pasture forage species can recover relatively quickly from moisture stress if the upper soil layers are wetted and they have the available root surface areas.

When heavy grazing occurs, new tillers have to form before new leaves can grow, and a substantial period passes before mature leaves can develop and feed root reserves and new tillers. If this process is continuous, root reserves are depleted, and after an extended period, the plant will die.

Due to the nature of the local climate, cool nights and long days, the grass plants are subjected to exactly the right stimulus to enter the reproductive phase. Moderate grazing on a regular basis is required to inhibit this.

By keeping the plant in the vegetative state, a couple of other interesting things occur. The height of the sward is limited reducing shading of lower growing legumes that should be present in the sward. Managing for legumes thus aids in keeping grasses in the vegetative state, but also, and possibly more importantly, increases the protein content and digestibility of the sward substantially. As a result, one of our major problems is addressed.

The second event of interest that results when the grass plant is kept in the vegetative state is that highly nutritious green shoots are available on a continuous basis and the growing point remains at the base of the plant. Since animals select for green shoots, more are offered, selection time is reduced, animals can eat faster and both intake and digestibility are increased. The green shoots also contain more nutrients including protein than dried brown reproductive stems. By keeping the grasses in the vegetative state, they are always growing and do not enter dormancy as early.

Since legumes develop a tap root and seek nutrients deeper in the soil, they do not necessarily compete directly with grasses. However, since the growing point of a legume shoot is located at the tip, regrowth depends on new shoots sent up from the crown of the plant. Once the plant has been grazed, energy from stores in the root must be topped until enough photosynthetic area develops to support growth. If the plant is continuously grazed, as would occur in a sward of mostly mature grass, the tap root would soon be depleted and the plant would die. Moderate grazing on a regular schedule would reduce the photosynthetic material removed and reduce the dependency on tap root reserves. Legumes would be maintained longer in the sward with the resulting benefit in increased protein, energy, calcium and digestibility levels.

It is obvious from the material in Section 2 and this discussion that a short duration, intensive grazing system is beneficial to the pasture plants. It reduces clipping of growing points in grasses, keeps them in a productive vegetative state, reduces shading of legumes and does not continuously deplete root reserves of either plant. This system also favours those factors discussed in Section 2.5 that promote increased intake by animals such as reduced fouling of pastures and more even use of pastures because habitual resting areas are eliminated.

How will this system impact on those nutritional factors recognized as contraints? Consider digestibility, which is a function of the forage species and age of the plant in relation to the cell wall and fibre content. In order to increase and maintain digestible levels of forages, the cell wall and fibre contents must be kept to a minimum. On pastures, this can be accomplished by management to keep the grasses in the vegetative state and to keep legumes in the sward. The animal is offered only green shoots with good nutrient levels.

Protein levels also tend to fall off as the grass plant enters the reproductive stage and becomes dormant. This is in part due to the increase in the fibre component of the forage resulting in less protein in the plant on a weight basis. By keeping the grass plant in a vegetative state and managing the sward to maintain legumes in it, the protein levels of the pasture can be greatly enhanced. Fertilizing the sward is a very important factor for increasing protein levels.

Much the same story occurs with energy; as the fibre content of the plant increases, relative levels of energy decrease. By maintaining lush, green grass and legume swards, energy levels are enhanced.

Traditionally, pastures have been low in calcium and phosphorus at certain times of the year. Since legumes have higher calcium levels than grasses, managing the sward for legumes will also help alleviate this problem.

Phosphorus, copper and selenium would probably require supplementation in the usual manner since these minerals are often below requirement, and sward management may not enhance their availability.

It is evident that many of the constraints to animal productivity on pastures can be overcome with changes in our philosophy of pasture management. Rather than the traditional range management doctrines predominant in the dry areas of the province, we must use different concepts to fully realize the production potentials of pastures. It is the application of these concepts to the local situation that will be the role of extension staff in the near future.

In conclusion, while this paper addresses the biological constraints to production, it makes no attempt to discuss the economics of pasture use. Such a discussion is a major project in itself even with the necessary background material which is contained in this paper.

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