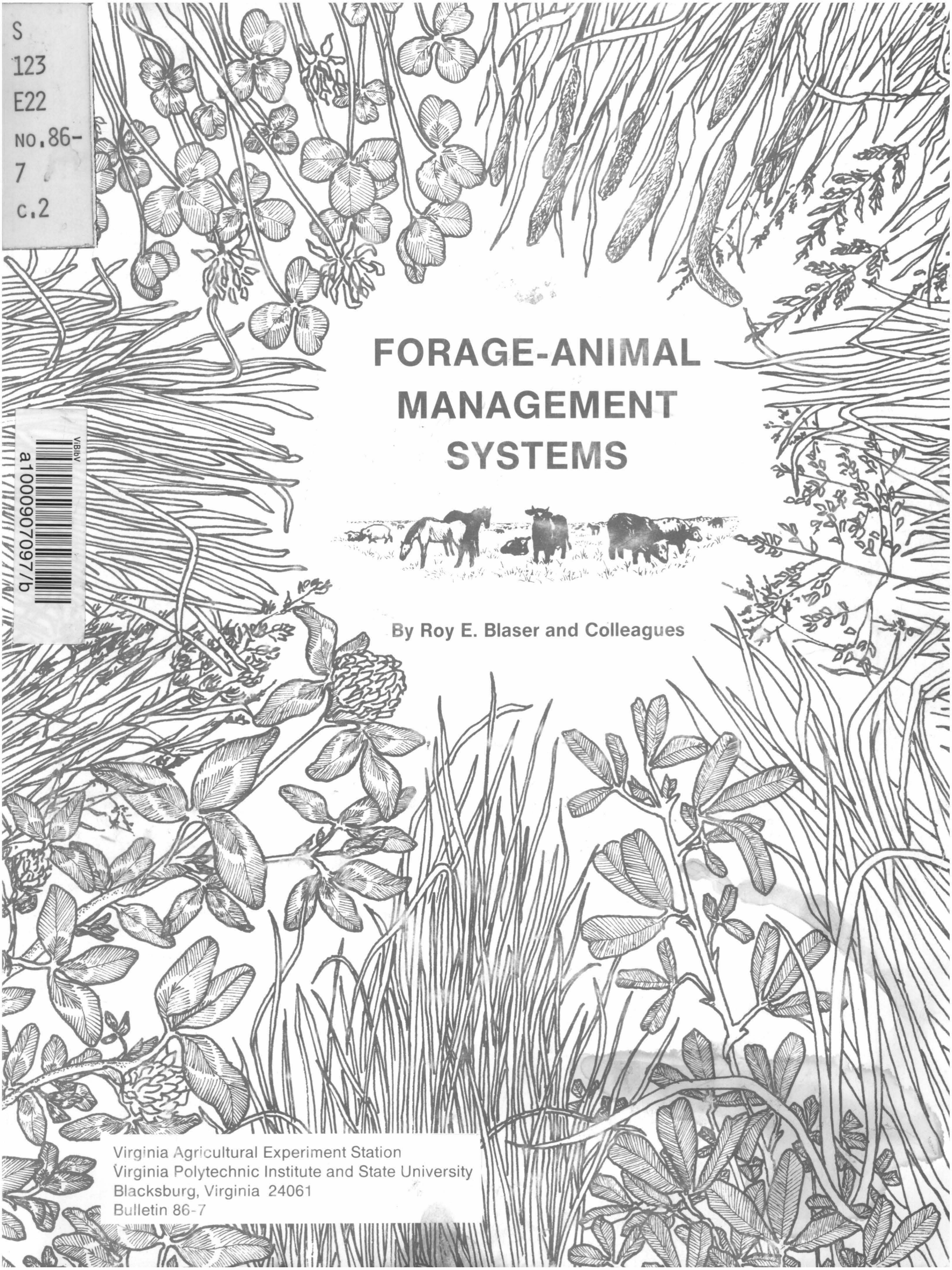

FORAGE-ANIMAL MANAGEMENT SYSTEMS

By Roy E. Blaser and Colleagues

Virginia Agricultural Experiment Station
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061
Bulletin 86-7

James R. Nichols, Dean and Director
College of Agriculture and Life Sciences
Virginia Agricultural Experiment Station
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

The Virginia Agricultural and Mechanical College came into being in 1872 upon acceptance by the Commonwealth of the provisions of the Morrill Act of 1862 "to promote the liberal and practical education of the industrial classes in the several pursuits and professions of life." Research and investigations were first authorized at Virginia's land-grant college when the Virginia Agricultural Experiment Station was established by the Virginia General Assembly in 1886.

The Virginia Agricultural Experiment Station received its first allotment upon passage of the Hatch Act by the United States Congress in 1887. Other related Acts followed, and all were consolidated in 1955 under the Amended Hatch Act which states "It shall be the object and duty of the State agricultural experiment stations . . . to conduct original and other researches, investigations and experiments bearing directly on and contributing to the establishment and maintenance of a permanent and effective agricultural industry of the United States, including the researches basic to the problems of agriculture and its broadest aspects and such investigations as have for their purpose the development and improvement of the rural home and rural life and the maximum contributions by agriculture to the welfare of the consumer . . . "

In 1962, Congress passed the McIntire-Stennis Cooperative Forestry Research Act to encourage and assist the states in carrying on a program of forestry research, including reforestation, land management, watershed management, rangeland management, wildlife habitat improvement, outdoor recreation, harvesting and marketing of forest products, and "such other studies as may be necessary to obtain the fullest and most effective use of forest resources."

In 1966, the Virginia General Assembly "established within the Virginia Polytechnic Institute a division to be known as the Research Division . . . which shall encompass the now existing Virginia Agricultural Experiment Station . . . "

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Contributors:

Roy E. Blaser, Roy C. Hammes, Jr., Joseph P. Fontenot, Harry T. Bryant, Carl E. Polan, Dale D. Wolf, Frank S. McClaugherty, Ralph G. Kline, and James S. Moore

Additional contributors:

H. John Gerken, Jr., John F. Shoulders, Harlan E. White, Vivien G. Allen, William P. Green, R. H. Brown, William S. Stringer, Keith L. Edmisten, James T. Green, Jr., and Arden N. Huff

Edited by
Mary C. Holliman

Power of Mind
267 ~~Bway~~ Broadway —
NY, NY —

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Ancestral Voices
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Dedicated

to

Mr. Paul Mellon

Special Acknowledgments:

Contributions and discussions in a partnership with faculty and many graduate associates were creative and aided in developing principles and modeling graphs for this publication. Likewise, teaching interrelationships with undergraduate and graduate students were influential in developing principles. The sharing of knowledge by professionals from many countries continues to stimulate professional growth.

Gratefully acknowledged are the creative talents, enthusiasm, and helpfulness of Georgia Minnich in designing and drawing the figures and the cover design; the diligence and expertise of Carolyn Rahnema in interpreting and assembling roughly written materials into a computer-organized manuscript with precision; the diligence of Kathy Haden in making corrections in the final copy; and finally the editing expertise of Mary C. Holliman and the university's Print Shop staff in an environment of fairness and helpfulness for improving and designing this book and managing its publication.

Roy E. Blaser
Blackbsurg, Virginia

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PREFACE

The health and nutrition of people in the future, allied with farm management to maintain the productivity and fertility of soils by using perennial forage plants alone and in rotation, is one of Mr. Paul Mellon's many concepts. Activating an interest in improving livestock farming through a grassland agriculture for the benefit of farmers and other people in northern Virginia and elsewhere, Mr. Mellon deeded two farms to Virginia Polytechnic Institute and State University in 1949, and, along with financial support, created the Virginia Forage Research Station situated in the Northern Piedmont region near Middleburg. Research and educational programs on forage and animal management began in July, 1949, and were later enlarged and improved through support from Mr. Mellon. Heifers were purchased to establish a beef cattle herd. Dairy heifers were transferred from Blacksburg to Middleburg to develop a dairy herd, and other cattle were purchased and used in various ways: (1) to measure animal growth, health, and reproduction with different perennial grasses and legumes used for grazing, hay, and silage, and to ascertain productivity per land area; (2) to obtain information and to develop forage-animal management systems; (3) to use cattle as grazing tools to study the effect of grazing animals on the soil and pasture plants; and (4) to evaluate silages made from annual plants.

Concurrently, small-plot experiments were started at Middleburg and other regions of Virginia with the many species and varieties of perennial grasses and legumes that could support animal production while controlling soil erosion and improving or maintaining soil productivity. The research gave information on establishing various grass-legume mixtures, seedling competition as related to designing mixtures for farms, inoculation of legume seeds, the influence of cutting management on yield, quality and grass-legume balance of mixtures, adaptation of varieties, and plant responses to fertilization on different soils.

Financial support from the Andrew Mellon Foundation in 1969 made it possible to reorganize animal and forage programs to test principles developed in our research in actual forage-animal systems, an important part of what is reported in this publication.

Expertise from persons from various departments working together undoubtedly improved the research. Beginning in 1950 and continuing for many years, conferences were held at the Middleburg Community Center to release the research results to farmers and agricultural professionals. About 700 farmers and agricultural professionals attended the first 2-day educational conference in 1950. Undergraduate and graduate education programs were closely allied with the research at the Virginia Forage Research Station. Research by graduate students, required for advanced degrees, contributed to this publication. Hence, this publication is an interpretive review of activities associated with the Virginia Forage Research Station, the Virginia Agricultural Experiment Station and Virginia Polytechnic Institute and State University during the period from 1949 to 1981.

As research and service personnel, we wish to say that the support and the environment of free inquiry given by Mr. Paul Mellon made the work a joy and undoubtedly advanced the quality of both research and knowledge.

I. INTRODUCTION

This publication was written for farmers, professional agricultural workers, and students. It is an interpretive summary; most of the research has been reported in scientific journals and in other publications, some of which are not easily available. We present principles of forage and animal management that are vital for developing forage animal management systems that will provide potential economic success for producers as well as desirable animal products for consumers. This publication is a condensation of experiences in the complex business of animal production where many interrelated factors must be simultaneously manipulated. The reader should study the orderly organization of principles to appreciate and implement them into practical forage-animal systems. Terms and writing style were chosen to appeal to a broad range of readers.

Information from professionals from various countries was useful in preparing this publication. To simplify the presentation, direct citations to literature have been excluded. The data in tables and figures are generally from research associated with the Virginia Forage Research Station and the graduate programs of Virginia Polytechnic Institute and State University.

Most producers, extension, teaching and research specialists, industrial professionals, and students want information on what to do or how to manage, along with "Why." An understanding of the factors on which the principles are based will aid people to employ or teach reliable practices and encourage them to develop even better management systems than those given herein.

The proficient grazier, the manager of forages and grazing animals, should understand principles rather than memorize extraneous details. Many principles and relationships are shown in graphs to save space and make it easier for readers to understand and apply concepts and principles. Yield, quality, and other biological parameters influenced by one to several interplaying factors may be readily understood by trend lines in the graphs. The reader should understand and accept the trend lines for establishing biological principles. The trend lines should not be interpreted as exact predictions because we do not know exactly how to fertilize a plant nor precisely how to feed an animal; we should strive to understand principles and the interplay of factors that influence plants and animals as shown by trend lines.

Figure 1 shows possible relationships between alfalfa yield and available soil potassium on farms using similar good cultural practices. On soil 1, Farm A, as the rate of potassium fertilizer increased from 0 to 450 lb per acre, alfalfa yields increased sharply up to 200 lb; additional potassium did not increase nor depress alfalfa growth. Alfalfa grown on soil 2, Farm B, did not respond to potassium fertilization. Such variable responses of alfalfa to fertilization on different soils establish the principle that potassium-bearing minerals and fertilization practices differ for different soils. It is known that alfalfa needs liberal amounts of potassium for high yields, but

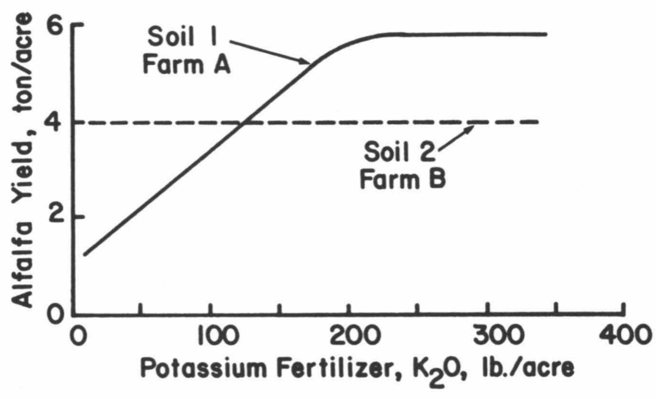


Figure 1. Alfalfa yields vary with potassium fertilization and soils. Solid line, soil 1: Alfalfa yields were dramatically increased with potassium fertilizer, up to 200 lb per acre. Dotted line, soil 2: Alfalfa yields were lower than for soil 1, and potassium did not improve yields.

excess potassium does not improve yields. Figure 1 also illustrates the principle that alfalfa yields vary with soils. The figure doesn't say why, but soil 2 may be more shallow or stony, or poorly drained as compared to soil 1.

A second exhibit (Figure 2), based on grazing research, associates increases in available pasture (AP) per land area with increases in production per animal. However, as availability becomes high, there are no further improvements in production per animal. The direct relationship between AP of a given quality and animal production is an important principle to understand and use in grazing management to supply the nutritional needs of animals. The available pasture-to-animal relationships may be described rather precisely with numbers, as with actual daily gains or milk per animal, with AP expressed as pasture height or yield per acre. These relationships are applied and discussed later.

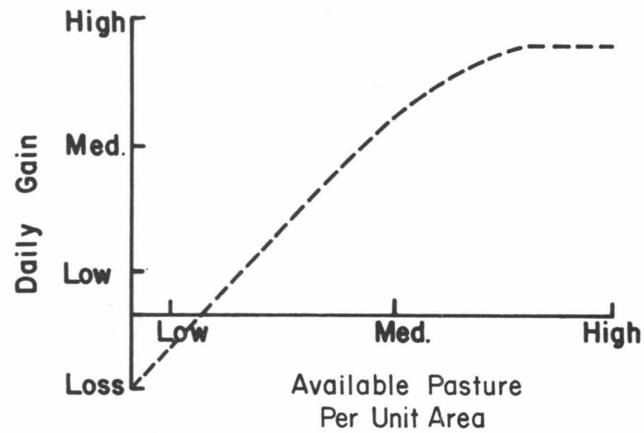


Figure 2. The dotted line shows that daily production per animal increases as available pasture (AP) per unit of land area increases to some point beyond a medium amount; a higher AP gave no additional improvements in production per animal. The association of increases in AP with production per animal illustrates a principle when pasture quality remains constant.

II. PRINCIPLES IN PLANNING FORAGE-ANIMAL SYSTEMS

II.A. Land Use

Land is a major capital cost in agricultural production; thus, economic returns from crop or animal enterprises should be given per unit of land. The system of farming should be economically relevant while maintaining or improving soil productivity and controlling or minimizing erosion and pollution. For soils suitable for intensive tillage, food and fiber crops for direct human use will generally have priority over livestock enterprises. To supply food for people, it is less efficient to convert crops into animal products as compared to direct consumption of plant materials by people. However, animal products in human diets generally improve nutrition as compared to plant foods.

Because of low and poor moisture distribution or excess moisture and topography, erosion, stoniness, structure, drainage, fertility problems and depth of soils, many areas are not suitable for cropping. However, such areas in the foreseeable future will be used to grow nutritious perennial grasses and legumes alone or in rotation with crops to support managed forage-animal systems to produce nutritious animal foods and by-products for people. During the past decade, the profitability of many livestock enterprises has often been marginal. Thus, management of all input factors of integrated forage-animal systems, along with equitable prices for animal products, is of paramount importance for profitable farm operations.

Ruminants need not compete with people for protein and energy plant foods since forages grown on land not suitable for row crops can furnish all nutritional needs for cow-calf herds and ewe-lamb flocks. These lands can provide most of the energy, protein, and minerals for meat and milk production and furnish by-products such as leather and wool. Ruminants also convert crop and animal residues not suitable for people into nutritious animal products for human consumption. As grain prices increase and forage and animal management improves, the current practice of supplementing grain to ruminants will decrease. Except in a few experiments, the beef cow herd and calves at the Virginia Forage Research Station near Middleburg have obtained all feed from perennial grasses and legumes without grain or protein supplements since 1951. Corn silage, a high quality energy feed, was rarely fed to these beef cows. The health and longevity of our cows has been excellent, averaging over a 90% weaned calf crop each year. Cows are selected for high performance on forage diets by selling cows for slaughter that have not conceived within 3 months after calving.

The management of land, plants, and animals should maximize economic potentials and produce desirable livestock products for consumers. Livestock farmers with much of their land adapted to intensive cropping will usually find it economic to supplement forages with drylot feeding systems for growing and fattening cattle and lambs and for milk production. Erosion on steep and undulating land is controlled by perennial grass-legume sod crops. These crops are suitable for raising beef calves, lambs, and growing cattle and replacements without grain feeding by integrated systems of managing forages and animals.

II.B. Natural or Introduced Plants

In Virginia and the mid-Atlantic region, natural forests are termed "climax" because forest formations are in "balance" with the climate, soil, and biota. Forages and crops from introduced plants require management skills to be successful in new environments. If lands in forage or other crops are totally abandoned, a forest cover develops naturally through several stages of plant succession. A pasture cover shifts to broomsedge (*Andropogon virginicus* L.) and weeds, followed by evergreen trees and deciduous shrubs, and finally deciduous trees. The ability to grow and maintain introduced perennial forages and crops for good economic returns from soils where forests dominate depends on knowledge and good management of all interplaying factors, as discussed herein.

II.C. Soil Acidity and Fertility

High rainfall and unfrozen soils during much of the winter have contributed for thousands of years to the leaching of minerals from soils in the natural forest area in humid eastern United States. Thus, soils have become acid and low in fertility, varying with the rock materials from which soils were formed. Without soil amendments, increases in acidity and declines in fertility are continuing processes in humid regions. The lower horizons in soils in most forest formations are low in soil organic matter and nitrogen, organic matter being high on the surface layer. Thus, the low contents of certain mineral nutrients and acidity of soils make it necessary to lime and fertilize to grow economic yields of good quality from forage and food crops.

Liming with dolomitic ground limestone supplies calcium and magnesium and reduces soil acidity and solubility of aluminum and other elements that often restrict plant growth. Lime and phosphate supplements are needed in most soils in Virginia to grow introduced grasses and legumes like clover (*Trifolium* sp.) and alfalfa (*Medicago sativa* L.) that supply nitrogen for grasses and improve forage quality and soil organic matter. For example, on a Chester soil at Middleburg, alfalfa with grass produced more than 36 tons of hay per acre during 8 years after lime, phosphate, and a little boron were applied. There were more than 6 tons of protein per acre in the harvested alfalfa-grass mixture, equivalent to the nitrogen in more than 2200 lb. of ammonium nitrate per acre. There was no response to potassium because the clay minerals in this soil are high in exchangeable and non-exchangeable potassium. However, most of the soils in humid forest regions also require potassium fertilization for economic yields.

Nitrogen fertilizer, a nutrient deficient in all Virginia soils, gives sharp yield increases of adapted annual and perennial grasses (forages and crops).

Soil testing services, including recommendations on fertilizer management for different soils and crops, are available at Virginia Tech and elsewhere. Any efficient system of producing feed for livestock depends on good soil and plant management.

II.D. Animal Products with Species, Mixtures, and Nitrogen

Soils should be limed and fertilized to produce reasonably high forage yields. Fertilizer practices augment forage quality by growing desirable plants, excluding weeds, and improving the amounts of certain minerals in forage. With perennial sod crops, it is practical to grow productive and persistent legumes or legume-grass mixtures because legumes fix nitrogen for their growth and the growth of associated grasses and for improving soil organic matter. Nitrogen fertilizer is costly. To produce grass hay, equivalent to 5 tons per acre of alfalfa or alfalfa-grass mixed hay, would require 450 to 700 lb of ammonium nitrate at a cost of $50 to $75 per acre.

II.D.1. Nitrogen vs. Legumes

Legume-grass mixtures produce better forage quality and animal production at lower costs than do perennial grasses fertilized with nitrogen. In a grazing experiment at the Virginia Forage Research Station, two grasses — orchardgrass (*Dactylis glomerata* L.) and Kentucky 31 tall fescue (*Festuca arundinacea* Schreb.) — were grown alone in separate pastures and fertilized with nitrogen at the rate of 200 lb N per acre. In other pastures these grasses were grown with ladino clover (*Trifolium repens* L.) without nitrogen fertilizer. Lime, phosphate, and potash applications were alike for all pastures. All pastures were grazed with yearling steers. Grazing results averaged for 5 years (Table 1) show that the two grass pastures with nitrogen produced 27% more growth (steer days grazing) than did the grass-ladino clover pastures. However, the quality of the herbage from the grass-clover pastures was better than that from the nitrogen-fertilized grasses, daily gains per steer being 16% higher for the grass-clover mixtures. Other data from research show much higher animal performance from grass-legume mixtures as compared to grasses alone with nitrogen fertilizer.

The quality advantage of grass-legume mixtures as compared to grasses grown alone is attributed to higher energy intake from legume mixtures. Because legumes are generally digested more rapidly than grasses, they pass through the rumen more rapidly; the speedier movement stimulates hunger and forage intake, thereby increasing daily gain.

Although the grass pastures with nitrogen produced 27% more forage than the grass-clover pastures without nitrogen, the liveweight gains per acre were only 10% higher for the grass pastures. This 10% higher production from grass pastures fertilized with 597 lb of ammonium

Table 1. Liveweight gains per steer and per acre and grazing days per acre for grasses with nitrogen and legumes (5-year averages at Middleburg)

Pasture treatments	Steer days per acre**	Liveweight gains: Daily per steer	Liveweight gains: Per acre
Orchardgrass-ladino clover, no N	257 days	1.28 lb	329 lb
Orchardgrass, no clover, 200 lb N*	311 days	1.07 lb	333 lb
Kentucky 31 fescue-ladino clover, no N	303 days	1.02 lb	309 lb
Kentucky 31 fescue, no clover, 200 lb N*	403 days	0.91 lb	367 lb
Kentucky bluegrass-white clover, no N	258 days	1.21 lb	312 lb

*200 per acre was obtained from 597 lb ammonium nitrate per acre, which was applied in four equal yearly split applications.
**Based on 700 lb yearlings, the pastures were stocked to utilize the available herbage, maintain leafy growths, and maintain similar amounts of available pasture among the pasture treatments. These values are not the length of the grazing season, but represent yields.

nitrate is equivalent to 31 lb liveweight gain at an added cost of about $65 per acre.

Nitrogen fertilization gives dramatic yield increases of perennial grasses, but animal performance for a given grass is similar with low and high available N, because digestibility and intake are similar when available pasture and growth stage are controlled. In cases where low protein inhibits animal performances, nitrogen-fertilized grass would improve output per animal.

Yields per unit of N from cool-season perennial grasses (orchardgrass, tall fescue, etc.) are much lower than for warm-season grasses such as corn, sorghum, and hybrid bermudagrasses. It may be economical to apply N for cool-season grasses in special situations such as when legumes fail, to increase early spring grazing, or to accumulate tall fescue for winter grazing. It is practical to use N liberally on summer and winter annuals such as corn and small grains.

II.D.2. Grasses

The grass species also have important economic implications. Averaging the results for the two Kentucky 31 tall fescue and the two orchardgrass mixtures (Table 1) shows that the fescue pastures produced about 24% more growth (steer days grazing) than orchardgrass, but the lower quality from the fescue pastures depressed daily liveweight gains 22%. Thus, animal products (liveweight gains) per acre for the fescue and orchardgrass pastures were similar.

Historically, inadequate and biased research at some northern latitudes of the United States indicated that common volunteer Kentucky bluegrass (*Poa pratensis* L.) and white clover (*Trifolium repens* L.) pastures were low in forage production and of little value as compared to other mixtures. Eradicating bluegrass pastures by tillage, chemical, and burning methods to establish other-grass-legume mixtures was pursued vigorously in some areas. Conversely, farmers in the cooler latitudes and higher elevations of Virginia had for many decades been producing fat cattle by grazing bluegrass-white clover pasture for markets. Thus, an experiment was established to compare the yield and quality of bluegrass-white clover with Kentucky 31 fescue and orchardgrass-clover pastures (Table 1). Yield of forage (steer days grazing), quality (daily liveweight gains of steers), and yield of animal products (liveweight gain) per acre were similar for the orchardgrass-clover and bluegrass-clover pastures. Quality (daily gain per animal) was lowest for the fescue-clover pastures. In retrospect, the "improved" perennial forage plants on limed and fertilized soils had been compared with unfertilized bluegrass pastures in earlier research in other states; also, animal data were not obtained.

Quality as shown by liveweight gains from different pastures has important implications: (1) the efficiency of converting forage to animal products increases as daily output per animal increases (section II.E), (2) small increases in daily gains per animal may improve the carcass quality to give large increases in the market value of an animal, and 3) good yields and forage quality require adequate lime and fertilization, which vary with soils and plants.

II.D.3. Tall Fescue Problems

Recent research from other states suggests that it is likely that animal data on animal performance with Kentucky 31 tall fescue reported in this publication may have been depressed by the presence of a fungus endophyte, *Epichloe typhina* (also called (*Acremonium coenophialum*), that develops within seedlings as tall fescue seeds germinate. This fungus growing within plants has no effects on appearance of tall fescue. Its presence in tall fescue pastures is verified by laboratory techniques. Samples from many Kentucky 31 tall fescue pastures from many Virginia counties show that plants within pastures were 5-100% infected, with 72 of the 123 pastures having over 50% infection. The endophyte-infected grass usually lowers fescue intake and daily gains of cattle; also, during warm summer temperatures yearling cattle often lose weight due to high respiration, increases in body temperatures, and low intake of forage. Animals may have rough hair coats. Due to high respiration, cattle stand in water ponds or lie in their excreta to cool off. When grazing relatively pure stands of Kentucky 31 fescue pastures with medium to high endophyte infection, daily liveweight gains are reported to be around 50% lower than for fescue with low or no endophyte. Legumes, especially clover, grown in pastures with endophyte-infected tall fescue may nullify body weight losses and poor animal performance. However, it is quite likely that animal performance is lower for legume-fescue mixtures with medium to high endophyte as compared to pastures with low or no endophyte. Based on data that most of the tall fescue pastures are endophyte infected, it is imperative to fertilize and manage to maintain legumes to attain good animal performance. Newly seeded fescue pastures should use tall fescue varieties with endophyte-free seed. Although not ascertained by research in Virginia, it may become economical to eradicate endophyte-infested fescue pastures to be seeded with endophyte-free tall fescue to improve animal performance.

Endophyte-infested tall fescue has not been associated nor disassociated with the old problem of fescue foot and such related harmful effects as lameness, cracked hoofs, sloughing of the end of the tail, loss of hair on the lower parts of ears, etc. Two experiments were conducted with old and new tall fescue varieties prior to the development of endophyte-free varieties. In comparing Kenland with Kentucky 31 tall fescue for milk production (both grasses with liberal nitrogen fertilizer and no legume), severe outbreaks of fescue foot occurred during two successive years with Kenland fescue. For the afflicted cows, milk flow stopped and there were drastic weight losses; some cows died and others did not recover. All cows grazing Kentucky 31 fescue stayed healthy and sustained normal milk production.

In a second experiment at the Virginia Forage Research Station with two varieties of tall fescue fertilized with nitrogen, steers in one of two Kenhy tall fescue pastures during each of four years made poor liveweight gains because of high respiration, low intake, and unknown factors. The steers were dirty and were lying in their excreta; a few steers had sore feet. The Kenhy pasture with the afflicted steers had a poorly drained area with some standing water during wet periods. Fencing-off this area during one year did not improve animal health. The yearling steers in the other Kenhy pasture were healthy, making liveweight gains similar to gains for healthy steers in the two Kentucky 31 tall fescue pastures.

In a 10-year grazing experiment with six Kentucky 31 fescue pastures (3 with and 3 without clover), yearling steers maintained good health, but hair coats were generally not as "glossy" as for steers grazing other grass-legume pastures. In other experiments where cows grazed Kentucky 31 tall fescue with little to much clover, the cows and calves maintained good health. However, one calf was born with fescue foot and two cows of similar genetic lines died in different years when grazing among bluegrass-clover and fescue-clover pastures all year. Cows grazing Kentucky 31 fescue tend to spend more time standing in water than cows not grazing fescue.

II.D.4. Seedling Competition in Mixtures

After the needed lime and fertilizer have been applied, the establishment and maintenance of nutritious and high yielding perennial forages begins with using viable seed of certified varieties of species of perennial grasses and legumes adapted to the environment (soil, climate, and biotic factors). The selected plants should be suitable for the expected methods of utilization. Grasses, grown in mixtures with legumes, help to avoid bloat of ruminants, make mixtures suitable for various utilization managements (grazing, green feeding, and harvesting for hay or silage), aid in controlling erosion and invasion of weeds, and usually increase the longevity of production. Varieties of grasses—such as Kentucky bluegrass, orchardgrass, tall fescue, and timothy—and legumes—alfalfa, red clover, and ladino and white clovers—are adapted to Virginia and the humid area of northern United States. Ryegrass and small grains at low seeding rates (to avoid seedling competition) are often used as companion species to control erosion by hastening the development of a protective soil cover.

Mixtures should be simple, usually one or two grasses with one or two legumes in a mixture with each mixture seeded in a separate field that is managed as a part of a year-around forage system. A mixture with many grasses and legumes is destined to fail because of seedling competition. Aggressive seedlings shade the less aggressive seedlings; hence, the persistent and desirable plants in complex seeding mixtures are often killed. Soon after seeds germinate and as seedlings grow, there is competition for light, water, and nutrients in the dynamic seedling community. Competition among species is minimized by using simple mixtures and low rates of seeding of forage species with aggressive seedlings. For example, when seeded at the same date in early spring, the relative weights of 100 seedlings 51 days after seeding were: alfalfa 100, red clover 70, ladino clover 24, orchardgrass 122, tall fescue 96, annual ryegrass 646, and perennial ryegrass 336. It is clear that ryegrass seedlings are very aggressive, developing about 3 to more than 6 times faster than alfalfa and faster than seedlings of all other species.

The aggressive characteristics of perennial forage plants are associated with the speed of germination and seedling emergence and the subsequent rate of seedling growth. Also, rates of seedling growth are associated with the quantity of energy material in a seed (seed size) and genetic characteristics. Method of seeding (seed-soil contact) also influences seedling competition. Even with surface seedings, the legumes mentioned earlier germinate in a day with high soil moisture and a favorable environment. However, with soil surface seedings the grasses germinate poorly or not at all because high surface soil moisture is not sustained during the 2 to 8 days required for germination and seedling emergence of grasses. Also, with surface seedings, the first root of a legume seedling penetrates the soil readily but the initial fibrous roots of a grass seedling often wilt and die. The best seedling stand for any small-seeded forage species occurs with firm soils when the seeds are sowed about 0.5 inch deep and the soil is firmed around the seed for good seed soil contact to help establish and prolong a favorable moisture environment conducive to a high survival and growth rate of seedlings. With ideal conditions ryegrass seedlings emerge in 2 or 3 days, bluegrass requires about 7 days, and orchardgrass and tall fescue seedlings begin to appear 4 or 5 days after seeding. Although the legumes mentioned germinate quickly, the seedlings grow slowly. Based on seedling development, perennial forage plants are ranked in three categories:

Very aggressive seedlings:
- Annual ryegrass (*Lolium multiflorum* Lam.)
- Perennial ryegrass (*Lolium perenne* L.)

Aggressive seedlings:
- Alfalfa (*Medicago sativa* L.)
- Red clover (*Trifolium pratense* L.)
- Tall fescue (*Festuca arundinacea* Schreb.)
- Orchardgrass (*Dactylis glomerata* L.)
- Bromegrass (*Bromus inermis* Leyss.)

Non-aggressive seedlings:
- Ladino clover (*Trifolium repens* L.)
- White clover (*Trifolium repens* L.)
- Birdsfoot trefoil (*Lotus corniculatus* L.)
- Timothy (*Phleum pratense* L.)
- Kentucky bluegrass (*Poa pratensis* L.)

The aggressive characteristics of seedlings are altered by environmental conditions. For example, red clover and orchardgrass seedlings are often aggressive toward alfalfa in spring seedings but not in summer seedings. The cool air and soil temperatures and the favorable soil moisture usually occurring during spring cause high percentages in germination, good seedling survival, and rapid seedling growth of red clover and orchardgrass. On the other hand, the warm soil and air usual for summer seedings restrain germination and seedling growth of orchardgrass and red clover. With alfalfa, germination and seedling growth are similar for spring and summer seedings; hence, red clover and orchardgrass seedlings usually depress alfalfa stands only with cool-moist environments as with early spring seedings in the northeastern United States. Thus lower rates of seeding grasses may be used in spring than in summer or early autumn.

Plowing and/or disking to prepare a seedbed, applying and incorporating the needed lime and fertilizer nutrients into the soil, firming the soil when necessary, and passing a corrugated steel roller over the seeded area is a common seeding method. An alternative seeding method is no-till. When a seedbed is not prepared, the sod and weeds are killed or severely depressed with herbicides, and seeds are sown into sods with a no-till drill. A dead and shallow surface mulch after close grazing reduces temperatures and evaporation to conserve soil moisture. The seed are drilled in rows at optimum and controlled soil depths; also excellent seed-soil contact is established by the packer wheels on sod seeders. Thus, seeding rates as compared to conventional seed-bed preparation can be reduced. The lower rates of seeding given for the mixtures may be used with no-till seeding.

- Alfalfa 15 to 20 lb per acre (for hay).
- Alfalfa 15 to 20 and orchardgrass 3 to 7 lb per acre (for hay, silage, green chop or rotational grazing).
- Red clover 6 to 8 and orchardgrass 6 to 8 lb per acre (for hay, silage, green chop or rotational grazing).
- Red clover 2 to 4, ladino clover 1 or 2, orchardgrass 6 to 10 lb per acre (for grazing).

Red clover 2 to 4, ladino clover 1 to 2, tall fescue 10 to 14 lb per acre (for grazing, especially winter grazing).

Kentucky bluegrass 12 to 15, white clover 2, and ryegrass or orchardgrass 3 to 5 lb per acre (for grazing).

Liberal or low nitrogen fertilization causes grasses to grow rapidly and depress legumes because of light competition as compared with no nitrogen. Nitrogen fertilizer may also retard growth of legume seedlings in other ways. With soil moisture stress, grasses stimulated by nitrogen utilize available moisture in soils, causing dwarfed growth of legume seedlings. Alfalfa, with deep roots, is not depressed as much as are the clovers. As compared to legumes, grasses absorb more potassium than needed. Hence, if soil potassium is low, the nitrogen-stimulated grasses rob the soil of available potassium, causing potassium deficiencies and restricted growth of legumes. When establishing and maintaining grass-legume mixtures, it is economical to fertilize the legumes. Nodules on legume roots, developing from *Rhizobia* bacteria from inoculated seeds or from the soil, will fix nitrogen from the soil air for high yields of legumes and good growth of associated grass(es), and will increase the organic matter in soils.

Soluble fertilizer materials (ionized in soil solutions)—such as ammonium nitrate, urea, diammonium phosphate, superphosphate containing gypsum, muriate of potash—applied on the soil surface adjacent to seeds can delay germination under low soil moisture because the ionized salts compete with seeds for water. Also, soluble salts near germinating seeds often reduce seedling emergence because of moisture stress and burning of roots. Lime and fertilizer materials should be mixed with the surface 3 to 5 inches of soil when preparing seedbeds. Lime moves into soils slowly, and phosphate fertilizers remain near the soil surface because of chemical fixation; thus it is desirable to mix these materials with the soil when preparing seedbeds. However, surface applications of lime and phosphorus with sod seedings stimulate seedlings when soils are acid or low in calcium and phosphorus.

II.E. Evaluating Forages for Animal Production

A deficiency of any essential mineral nutrient, certain vitamins, protein, or energy intake can deter animal health and performance. However, with herbaceous perennials in temperate climates, insufficient digestible energy intake is the primary factor limiting the productivity of responsive ruminants and horses.

Varying with classes and productivity of ruminants, 8 to 14 times more digestible energy than digestible protein is needed for animal production. Leafy grass-legume pastures provide enough digestible protein for as much as 100 lb of milk daily; however, digestible energy intake is sufficient for maintenance and only about 45 lb of milk per cow daily.

The energy values of forages and other animal feeds are commonly expressed as digestible dry matter (DDM), digestible organic matter (DOM), or total digestible nutrients (TDN). The digestibility values of these three categories of digestible energy are similar.

In this publication, digestible dry matter (DDM) in lb or percent designates energy values of forage. Digestibility (DDM) is measured by weighing all forage dry matter eaten by a ruminant and all dry matter in fecal excreta during a 7-day feeding.

Calculations are as follows:

Digestible dry matter % (DDM %)

$$= \frac{\text{lb DM eaten} - \text{lb DM in feces}}{\text{lb DM eaten}} \times 100$$

Expected DDM digestibilities of various forages are: usual hay 50-55%, excellent leafy hay 60%, leafy grass-legume pasture 65-78%, corn silage from a grain hybrid 63-71%. All digestibility data in this publication were obtained with cattle feeding experiments rather than laboratory analysis.

The water contents of some forages are: hay 10-18%, pasture mixtures 70-90%, and silages 50-80%. Thus, expressing digestibility, intake, protein and other characteristics of forages on a DM basis, as in this publication, allows direct comparisons of forages varying in DM.

Energy values are also expressed in lb; 500 lb of hay at 50% DDM furnishes 250 lb of digestible energy, DDM or TDN.

The performance of a ruminant is usually associated with energy intake. Daily forage intake usually increases as digestibility increases up to a digestibility of about 68%. Intake of forage DM may be expressed as percent of liveweight to compare forages and ruminants. Dry matter intake values of around 2.5% of liveweight or more by yearling cattle give high performance. The digestible dry matter intake (DDMI) values are obtained by multiplying dry matter intake (DMI) by percent digestibility.

Production per animal (gain or milk per animal daily) is directly associated with DDMI when protein, minerals, and other nutritional factors are adequate (Table 2). As production per animal increases, the efficiency of converting forage to animal products increases. Energy requirements

Table 2. Dry matter, crude protein, and digestible dry matter requirements to grow and fatten a steer at various daily liveweight gains*

			Daily Feed Needed		Total Feed Needed		Requirements per lb Gain			
Daily gains	Days to fatten	Dry matter	DDM -----	Crude protein	Dry matter	Crude protein	Dry matter	DDM -----	Protein ------	DDMI daily
lbs		lbs	%	%	lbs	lbs	lbs	lbs	lbs	lbs
0.55	1200	13.4	57	8.9	16,080	1,430	24.4	13.9	2.17	7.6
1.10	600	16.4	59	9.7	9,840	950	14.8	8.8	1.44	9.7
1.65	400	16.8	67	10.2	6,720	690	10.2	6.8	1.04	11.2
2.42	273	17.5	74	11.8	4,780	560	7.2	5.3	0.85	13.0

*Calculated from "Nutritional requirements of beef cattle" (National Research Council, 1976). Calculations made for beginning weights of 340 lb and final weights of 1000 lb.

for maintenance per unit liveweight are similar among ruminant species; hence, as DDMI or energy intake increases above maintenance needs, more of the ingested forage is converted to animal products. For example, growing a 340-lb steer to a 1000 lb slaughter weight requires 16,080 lb dry matter when the steer gains 0.55 lb daily as compared to only 4780 lb dry matter when gaining 2.4 lb daily. Also, 2.5 times more protein is needed to grow and fatten a steer gaining 0.55 lb per day as compared to one gaining 2.4 lb per day. To grow a 340 lb steer to a 1000 lb slaughter weight requires 1200 days when he gains 0.55 lb per day but only about 273 days when he gains 2.4 lbs per day (Table 2).

Grazing and conservation practices and supplements to obtain high energy intake and conversion efficiencies are discussed later.

II.E.1. Growth Stages of Plants, Forage Quality, and Animal Production

When not utilized, orchardgrass and other grasses pass through successive stages of growth (Figure 3): (1) leafy, (2) boot (seedheads enclosed in sheaths in stems), (3) heading (emerging seedheads), and (4) bloom (various degrees of pollination). A final seed stage is omitted, as quality becomes too low for animal production. As grasses grow from leafy material to stemmy morphologies in bloom stages (Figure 3), there are dramatic increases in yield, fiber, and lignin. Protein yields increase at declining rates and finally decline during late bloom because stems grow and accumulate faster than leaves. In basal parts of tall growths, many leaves die and fall because of low light intensity (radiant energy) and diseases. As leaf areas enlarge, increases in photosynthesis cause nonstructural carbohydrates (sugars and starch or fructosan) to increase in plant tissues. Later, nonstructural carbohydrates decline because of high energy demands during stem production; the fiber materials in stems also dilute the percent of nonstructural carbohydrates and protein. During bloom, the shading and low light intensity within tall canopies depress photosynthesis per leaf unit, causing declines in nonstructural carbohydrates.

The morphology of legumes such as red clover also shifts from leafy to stemmy conditions, stems making up 40-60% of the DM yield during the bloom stage (Figure 4). For grasses and legumes, protein makes up 29-34% of the DM in leafy stages as compared to 6 to 13% of the DM in bloom stages (Table 3, Figure 4). Except for calcium, the percent minerals in forage is much higher in leafy than in stemmy growths. As grasses and legumes grow from leafy to stemmy bloom stages, the percentages of leaves and protein decline dramatically while lignin and fiber percentages increase (Figure 4). The mineral contents (%DM) are strongly associated with leafiness.

When grazing young, leafy cool season grass-legume mixtures during spring, DDM% is usually about 70% as compared to about 50% at stemmy full bloom growth (Figure 5). DDM intake also declines rapidly as plant canopies grow from young leafy to stemmy morphologies. Such reductions in DDM % and DDMI with advancing stages of plant growth depress production per animal. The morphology (leaf-stem contents) of plants at various growth stages on percents of protein, fiber, lignin, digestibility, and intake are summarized in Figure 5. When grazing leafy growth high in DDM% as compared to stemmy forage, the high production per animal is associated with high energy uptake. The high

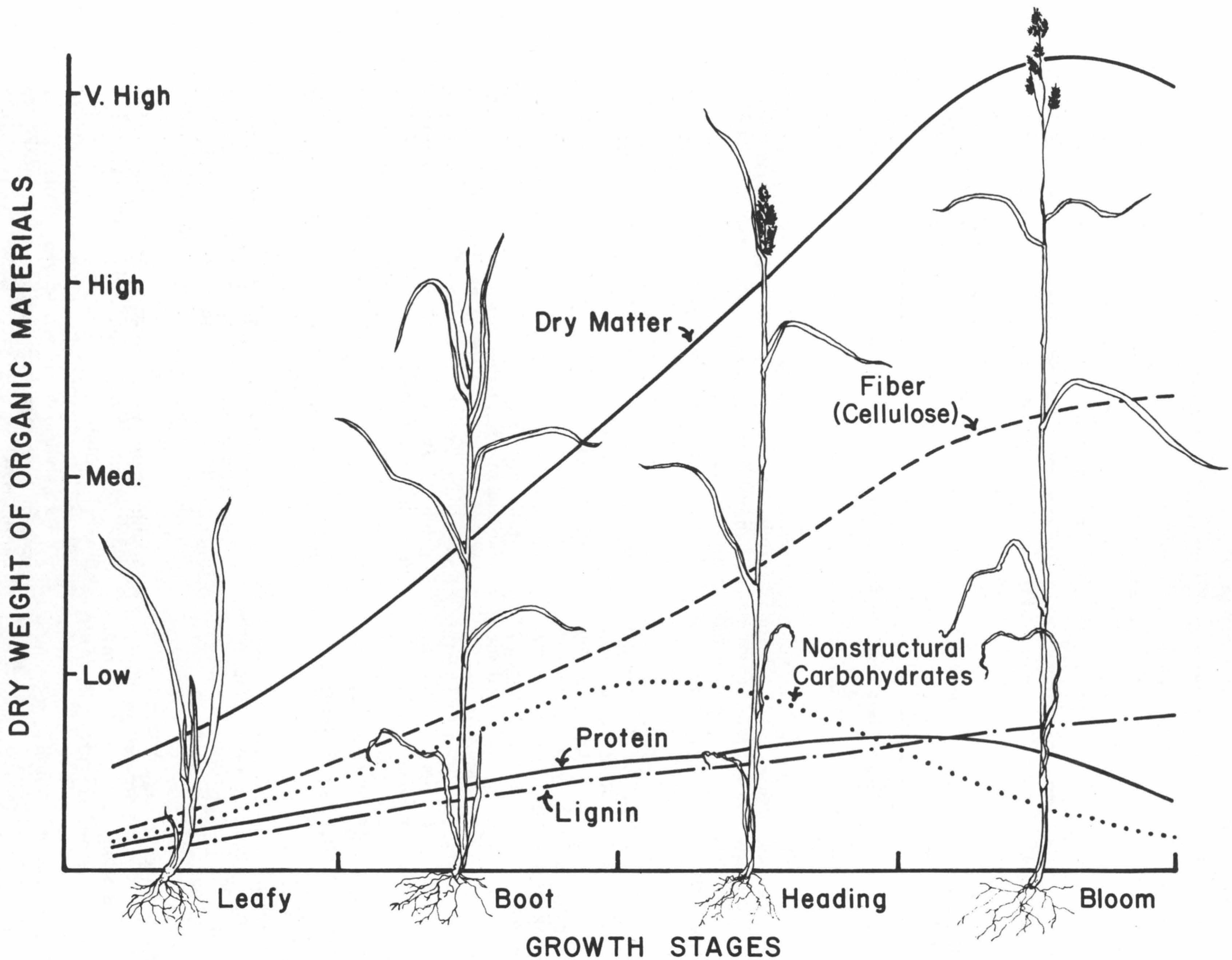


Figure 3. As unutilized cool season grasses such as orchardgrass grow from leafy to stemmy stages, dramatic increases in dry matter yields are accompanied by increases in cell wall materials (fiber and lignin) and decreases in protein and nonstructural carbohydrates.

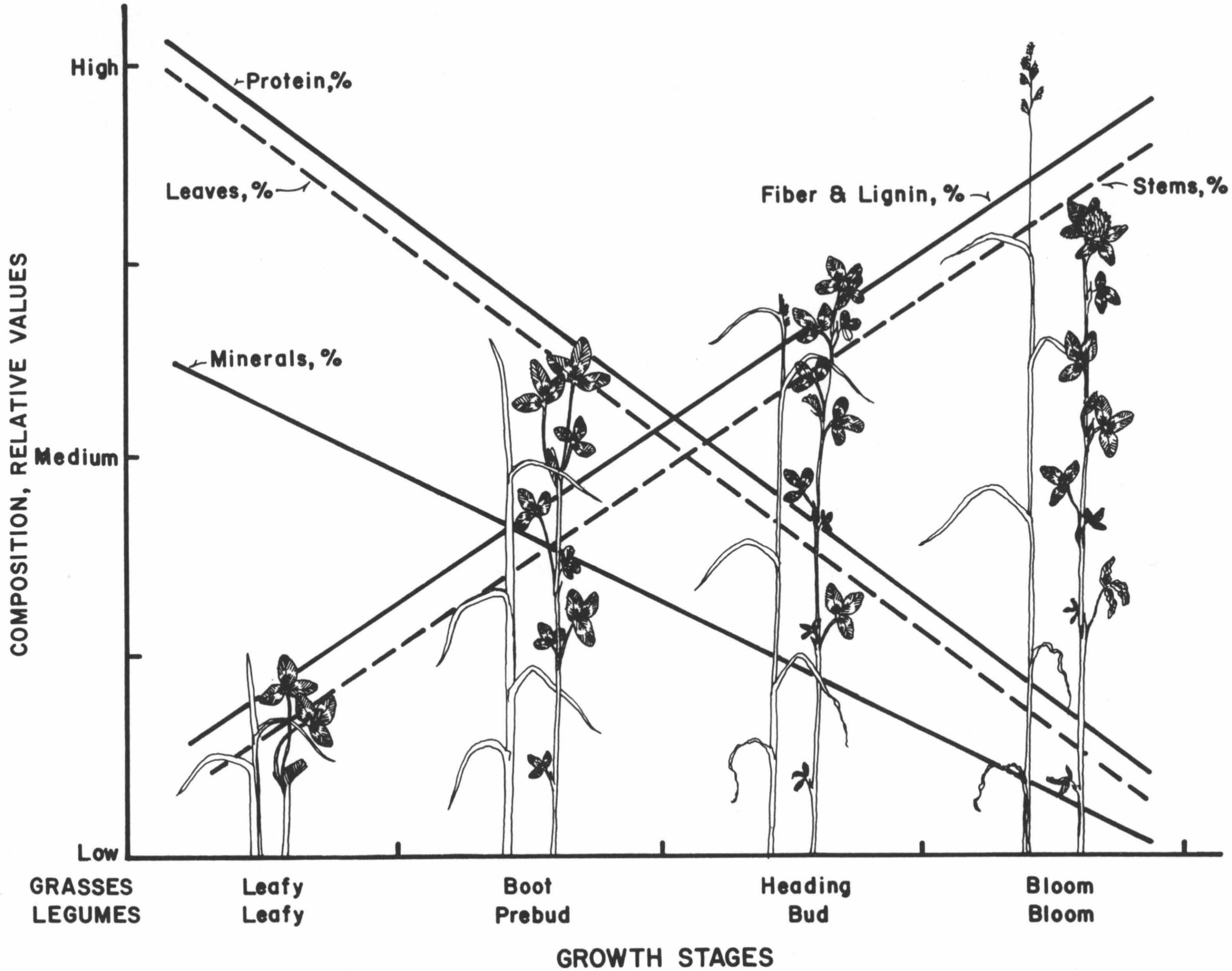


Figure 4. When perennial grasses or legumes grow from leafy to bloom growth stages, protein and mineral contents decline dramatically with leafiness. Concurrently, stemminess and cell wall materials increase rapidly as canopies grow to a stemmy bloom stage.

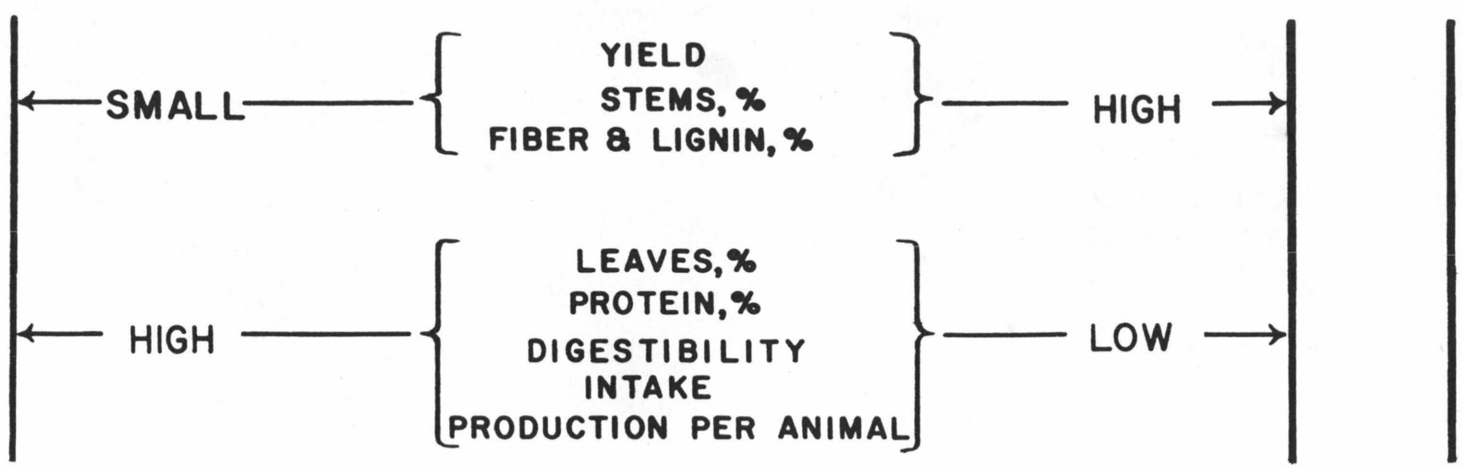


Figure 5. ***As red clover and orchardgrass grow from leafy to bloom stages of growth, animal production declines. Dry matter digestibilities (DDM) of 65-78% in leafy stages decline to about 50% at full bloom. Forage consumption declines rapidly as canopies develop into stemmy morphologies with advancing growth stages. Leafy forages allied with high DDMI cause high production per animal as compared to stemmy stages of growth.***

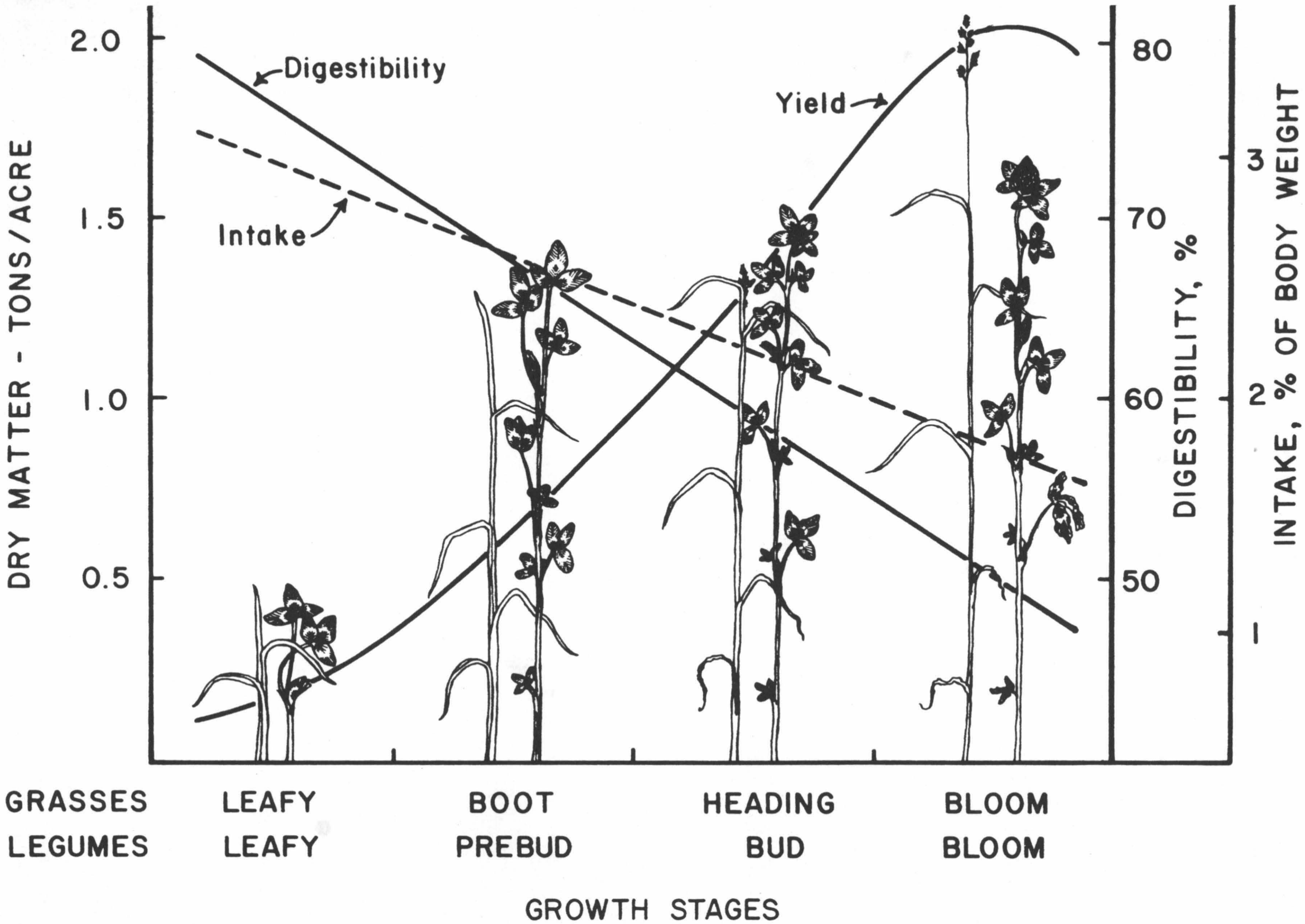

DRY MATTER - TONS/ACRE
2.0
1.5
1.0
0.5
Digestibility
Intake
Yield
80
70
60
50
DIGESTIBILITY, %
3
2
1
INTAKE, % OF BODY WEIGHT
GRASSES
LEGUMES
LEAFY
LEAFY
BOOT
PREBUD
HEADING
BUD
BLOOM
BLOOM
GROWTH STAGES

Table 3. Stages of plant growth influence crude protein and mineral contents (2-year averages at Blacksburg)

Constituents Dry Matter %	Leafy	Boot	Headed	Full Bloom	Seeding
	Stages of Growth of Orchardgrass				
Crude protein %	33.9	17.6	10.1	7.8	6.1
Phosphorus, %	0.41	0.30	0.23	0.20	0.17
Potassium, %	3.90	2.86	2.47	1.87	1.63
Magnesium, %	0.21	0.19	0.13	0.14	0.18
Calcium, %	0.47	0.36	0.26	0.35	0.42
	Stages of Growth of Red Clover				
	Leafy	Bud	Early bloom	Late bloom	Seeding
Crude Protein, %	29.3	20.5	19.5	14.0	13.2
Phosphorus, %	0.32	0.25	0.21	0.15	0.15
Potassium, %	3.48	3.17	2.14	1.39	0.85
Magnesium, %	0.38	0.41	0.37	0.43	0.29
Calcium, %	1.38	1.31	1.42	1.61	1.58

DDM% of leafy forage seems to hasten the rate of digestion and passage through the rumen to stimulate appetite and voluntary intake.

High digestibilities of leafy forages are attributed to low amounts of cell wall material (lignin and cellulose) and high cell contents (protein and nonstructural carbohydrates). Cell wall materials increase sharply while cell contents decline as plants shift from leafy to stemmy morphologies. Thus, the decline in DDM% with stemminess in advanced stages of growth is attributed to thickening of cell walls coupled with increased lignification. Fiber "cemented" with lignin obstructs microbial contact and enzymatic activity in rumens, thereby depressing the rate and amount of the fiber digested. On the other hand, cell contents composed of protein substances and nonstructural carbohydrates are almost completely digested. After metabolic needs are supplied excess protein, as in leafy grass-legume mixtures, is used for energy by ruminants. Leafiness is a good index for predicting energy intake and animal performance from perennial grass-legume pasture, hay, and silage crops.

Production per animal is strongly related to DDMI from forages at various growth stages. With normal and good management, hay is stemmy as compared to pasture; thus cows on pasture produced more milk than cows fed good alfalfa hay (Table 4).

Without grain feeding during two grazing seasons, cows on pasture gave about 11 lb more milk daily than those on good alfalfa hay. Feeding a 14% protein-corn supplement at a low rate (1 lb to 8 of milk) increased milk flow, but cows on pasture still gave 11 lb more milk daily than those fed hay. With high supplementation (1 lb to 3 of milk) milk production for hay and pasture was similar. Supplementing energy with the 14% protein-corn mix increased milk production 24% for cows on pasture as compared to 68% for those fed alfalfa hay (Table 4). Thus, energy intake (DDMI) restricted milk production much more for cows fed good alfalfa hay than for cows grazing leafy pasture.

II.E.2. Animal Production from Forages and Conversion Efficiency

Without implants or feeding growth stimulants, our experiments show average daily liveweight gains of about 2.2 lb from corn silage supplemented with protein, about 1.1 lb from hay, and around 1.3 lb daily from pasture for the growing season. Daily gains for the spring grazing season are about 1.7 lb. Because high forage intake (DDMI) is coupled with high daily gains, converting the DDM in corn silage to liveweight

Table 4. Milk (4% butterfat) produced per cow fed good quality alfalfa hay as compared to cows grazing good pasture, with rates of supplementation (2-year averages at Middleburg)

	Rates of supplementing ground shelled corn		
Pasture or hay rations	None	1 lb/8 of milk	1 lb/3 of milk
Pasture	42.5	49.5	52.5
Pasture and hay	39.5	46.5	50.0
Hay	31.5	38.5	53.0

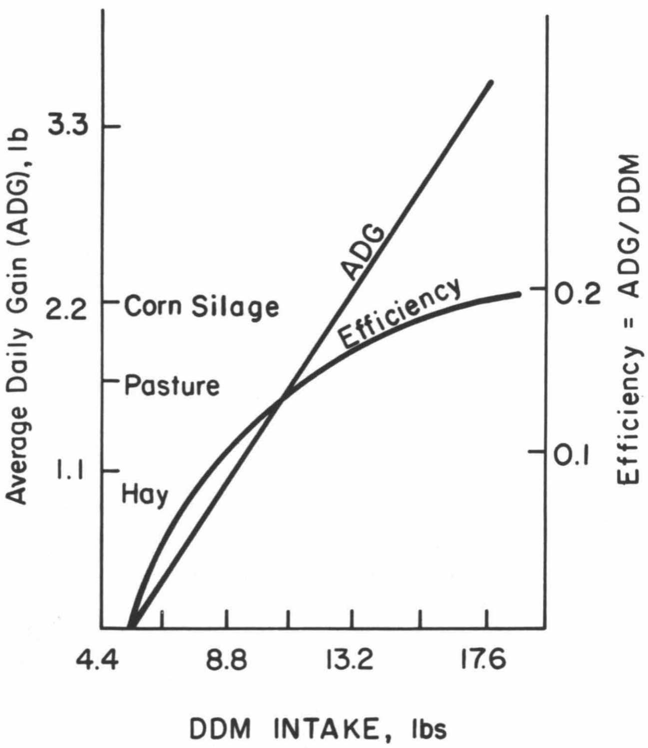


Figure 6. Meat or milk production per animal increases with digestible dry matter intake (DDMI). As production per animal increases, more of the forage is converted to animal products. Conversion efficiency for pasture is higher than for hay, corn silage supplemented with protein being the highest.

gains is about 30% higher than for average pasture and around twice as efficient as for hay (Figure 6). Conversion efficiency improves with rate of gain because less forage is used for body maintenance as outputs (meat or milk) per animal increase.

The approximate daily liveweight gains of yearling steers fed various forages (Table 5) are associated with percent DDM and digestable energy intake (DDMI). Forage sorghums harvested in the dough stage for silage and fed to yearlings gave the lowest daily gains because of low DDMI. By feeding or implanting growth stimulants, the liveweight gains (Table 5) would have increased around 12%. For forages giving high daily gains, less forage is needed per pound gain with high than with low daily gains (refer to conversion efficiencies in Table 2 and Figure 6).

Table 5. Expected daily liveweight gains of yearling cattle consuming various forages without additives

Leafy grass-legume pasture	1.3*
Leafy grass pasture—low or high N	1.1
Alfalfa 10% bloom hay or silage	1.1
Barley or wheat silage—dough stage	1.3
Forage sorghum silage low in grain—dough stage	0.5**
Grain sorghum silage—dough stage	2.0**
Corn silage—hard dent stage	2.2**

*Average for grazing season, 1.7 lb daily during the spring season.
**Supplemented with a urea protein mix.

II.F. Utilizing and Managing Perennial Grasses and Legumes

The grazier should manage forage plants to compromise yields with quality while maintaining grass-legume balances and stands for many years. Simultaneously, the grazing animals should be managed to compromise yields per animal and per acre for profitability. Cutting and grazing management of grasses and legumes vary, depending on the morphology (size, erectness, and methods of propagation) of species in mixtures.

II.F.1. Grazing and Utilization Methods

Although the best grazing and utilization practices are discussed for different species, implementation of grazing and conservation utilization methods into 12-month feeding systems is the ultimate goal. Each grazing method requires controlled management. Methods of utilizing perennial forages can be categorized as follows:

Continuous grazing. Animals graze in one fenced pasture during the growing season or even all year with supplementary hay or silage during periods of drought or cold weather.

Rotational grazing. After one group of animals has grazed a pasture, they are rotated in sequence among two or more pastures. After each pasture is grazed, the canopy is accumulated for the next grazing and the grazing sequence continues for the season in separate pastures. Rotated pastures may vary in size and have the same or different species and mixtures. The number of days each field is grazed should vary with growth rates during the season, size and number of pastures, and with mixtures. Grazing pastures at set intervals and for a set number of days ignores available pasture and may cause starvation of animals or wasted pasture (severe over or undergrazing).

Ration or strip grazing. One group of animals grazes a fresh pasture daily. This method requires 20 to 30 fields; but the number of fields can be reduced by movable electric fences within each field. This method is not usually economical, because of labor, watering facilities, shade, and fencing costs.

First and last grazers. With special rotational grazing with two groups of animals, the first grazers that require high nutrition consume about half of the grazable forage. The last grazers, with low nutritional needs, graze the residue. First and last grazing requires more than 6 fields to allow sufficiently long periods between grazings for canopies to regrow. First and last grazers may be similar or different kinds of animals.

Creep grazing. Suckling calves or lambs graze with their dams or ewes in a given pasture; when this pasture is closely grazed, the calves or lambs pass through a small opening in a fence (creep) and graze in an adjacent fresh pasture of high quality to improve DDMI and liveweight gain. Creep grazing may be used with any system where calves creep graze in a pasture high in quality and availability.

Stockpiling. Forage is accumulated during favorable growth periods for deferred grazing during seasons of little or no growth.

Green chop or zero grazing. Forage is chopped and fed green. This method may be used temporarily while silos are filled or during a shortage of pasture as a part of a system. Feeding ruminants by daily chopping over a long period is expensive, and forages cannot be chopped at appropriate growth stages; also, wet soils often prevent daily harvesting.

Hay or silage conservation. Haylage is ensiled forage from perennial grasses and legumes that is higher in dry matter than ordinary silage. Harvesting forages for winter feeding as hay or silage is an essential part of a year-around forage feeding system in temperate zones. Conserving some of the flush spring growth at an early growth stage for high quality forage for winter feeding is an excellent practice.

II.F.2. Utilization Management Related to Morphology of Plants

The outward appearance (morphology) of plants (Figures 7 and 8) dictates grazing or cutting methods. The tall, erect-growing grasses and legumes such as red clover, alfalfa, orchardgrass, and tall fescue are generally used for hay or silage because reasonably large yields justify harvesting costs; however, these forages are also suitable for grazing. Short and prostrate legumes and grasses such as white clover and blue grass that maintain many leaves when grazed may be grazed continuously.

The grazing and cutting managements of legumes, grasses, and grass-legume mixtures in Table 6 are justified and explained by four principles: (a) nonstructural carbohydrates, (b) leaf area, (c) nonstructural carbohydrates interacting with leaf areas, and (d) origin of new growth and tillers.

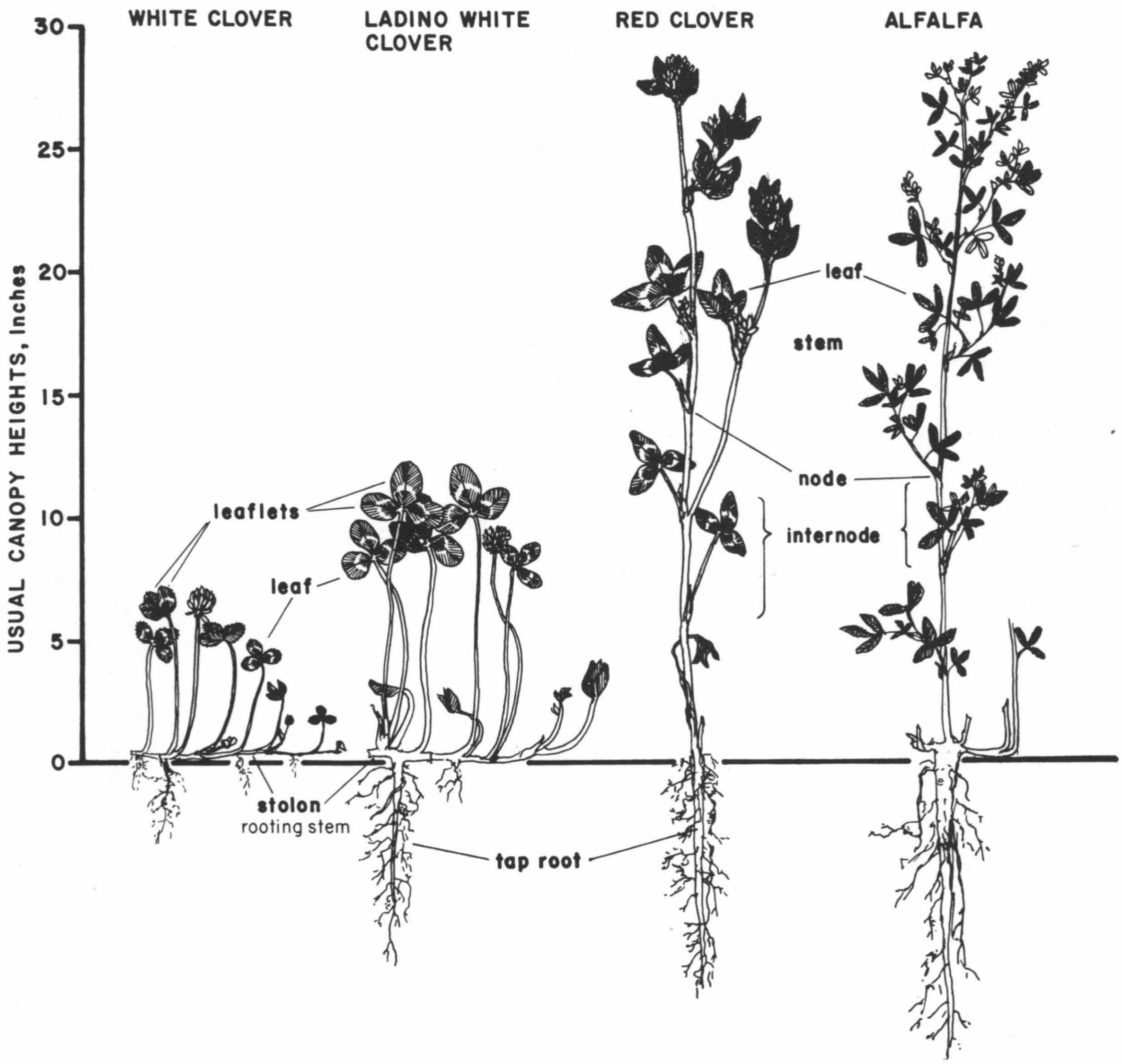


Figure 7. Morphological characteristics of the four main perennial forage legumes in Virginia. Short legumes such as white clover, where leaves grow from stolons at the soil surface, are used primarily for grazing. Tall erect legumes such as alfalfa and red clover may be used for hay, silage, and rotational grazing with special management. Alfalfa, with deep tap roots, produces higher yields than the other legumes. The "growth points" in crowns, covered with soil, moderate temperature and moisture to give drought and cold protection, making alfalfa persistent.

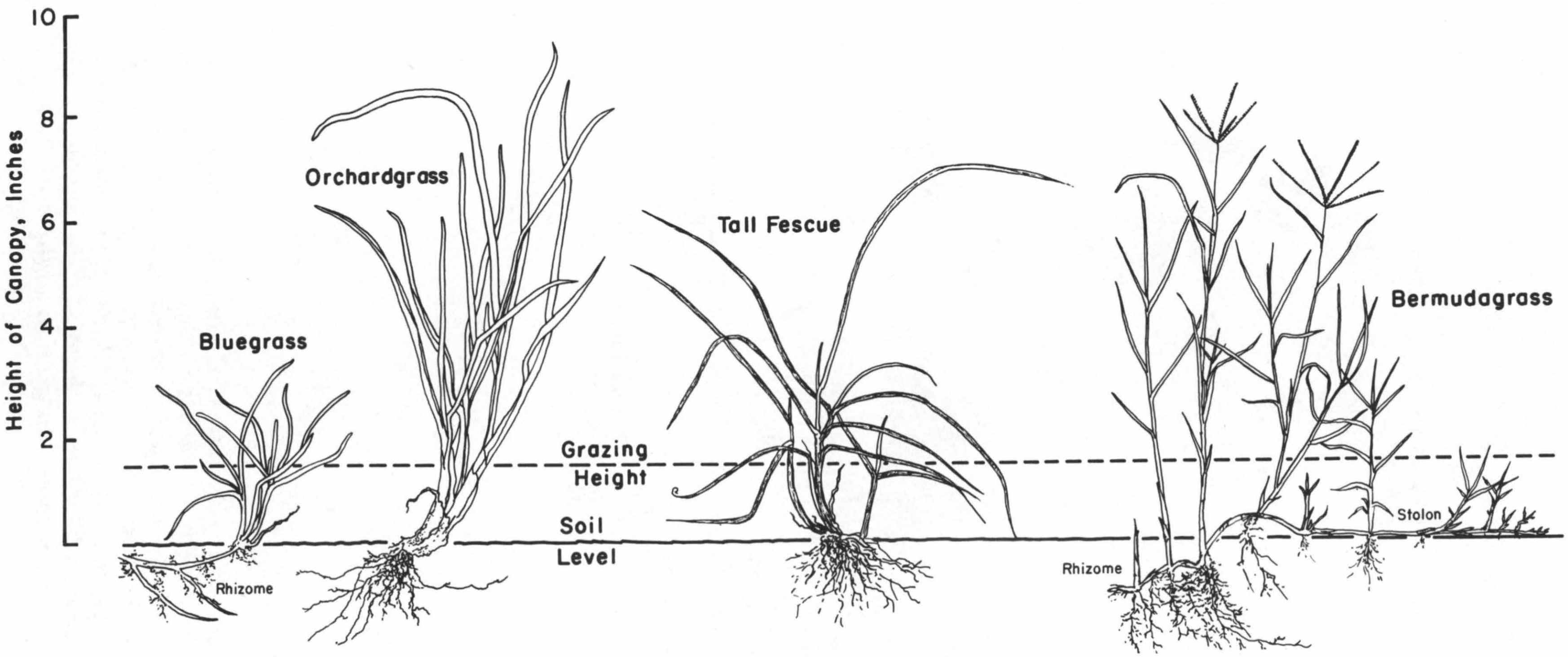


Figure 8. ***Grazing and utilization methods are related to the morphological characteristics of grasses. Bluegrass has small leaves and tillers and forms a dense sod because of invading rhizomes (underground stems) that produce roots and tillers. Orchardgrass and tall fescue have large tillers and leaves. Nonstructural carbohydrates are high in basal parts of tillers. With bluegrass and fescue reserve nonstructural carbohydrates appear in tillers and rhizomes. Close grazing depresses orchardgrass more than fescue and fescue more than bluegrass because progressively more of the leafblades and carbohydrates in tillers are removed by close grazing. Bermudagrass, a warm season grass, thrives under close or lax grazing because a high leaf area is maintained and nonstructural carbohydrates in rhizomes and stolons are protected from grazing. New tillers and roots develop from buds in rhizomes and stolons.***

Table 6. Guide for utilizing and managing forage species and mixtures

Mixtures	Continuous grazing, average height of pasture	Rotational grazing heights before and after grazing		Hay or silage heights before and after cutting	
		Before	After	Before	After
	Inches	Inches or stage	Inches	Height or stage	Inches
Bluegrass-white clover	2 to 3	4 to 5	1	Grass heading[1]	2.5
Ladino clover-orchardgrass	3.5 to 5	7 to 12	2	Grass heading[2]	2.5
White clover-bermudagrass	1 to 3	4 to 6	1	----	--
Bermudagrass + N	1.5 to 3	4 to 6	1	10 to 16	2.5
Ladino clover-fescue	2.5 to 4	5 to 8	1.5	Grass heading[3]	2.5
Alfalfa	----	----	--	4 cuts .1 BL[4]	2.5
Alfalfa with grass	----	Bud stage	2	4 cuts .1 BL[5]	2.5
Red clover	----	Bud stage	2	3 cuts .1 BL[4]	2.5
Red clover-grass	----	Bud stage	2	3 cuts .1 BL[5]	2.5
Red clover-ladino clover-grass	----	Bud stage	2	as for [4] or [5]	2.5

[1]Excess pasture "shut-off" for hay in May, thereafter grazed.
[2]Good mixture for silage or hay in May, thereafter grazed.
[3]May when grass heads, thereafter when 12-16 inches high, or accumulated after mid-August (stockpiled for winter grazing).
[4]Spring growth when yield is high or in a bud stage, thereafter in 0.1 bloom.
[5]May when grass heads, thereafter bloom or rotationally grazed during summer when alfalfa-red clover bud stage or stockpiled for winter grazing. Plants are adaptive; thus species may be managed more intensively than indicated for brief periods. During near dormancy caused by low temperatures or moisture, the plants may be continuously grazed.

II.F.2.1. Nonstructural Carbohydrates

Nonstructural carbohydrates and other substances stored in basal plant tissues (roots, rhizomes, stolons and tillers) provide energy and nutrients for growth during and after utilization, for persistence of perennial plants during drought and low and high temperature dormancies, and for growth when environments become favorable again. Nonstructural carbohydrate concentrations in basal parts of plants fluctuate due to the dynamic relationships of respiration (R) and photosynthesis (P). With rapid root and top growth (high R) and a relatively small leaf area (low P), there is a net reduction of nonstructural carbohydrates. The carbohydrate concentrations in plants, especially basal parts, are also influenced by the differential rates of P and R with differing moisture and temperature conditions. Finally, because P rate is strongly allied with radiant energy, tall plants depress carbohydrates in short plants in a mixture because of low radiant energy (light competition).

After alfalfa is cut for hay or grazed in a bud or an early bloom stage, the high contents of nonstructural carbohydrates in roots decline rapidly (Figure 9). Because there are few basal leaves after cutting, nonstructural carbohydrates in roots serve as energy for new top and root growth; R is high as compared to P at this period of regrowth.

After canopies develop sizable leaf areas at 7 to 12-inch heights, P begins to exceed R so carbohydrates accumulate again in roots and basal tissues. High to low to high concentrations of carbohydrates in basal tissues occur with each harvest or grazing and regrowth (rest) period. Continuous close grazing or frequent cutting or grazing would cause small leaf areas of tall erect-plants; thus a low rate of P as compared to R depresses nonstructural carbohydrates in basal plant tissues. Low nonstructural carbohydrates cause slow regrowth, low yields, and death of plants; hence, grasses or weeds invade.

Persistence of stands and yields of alfalfa are best when harvested three times at full bloom or four times yearly, the spring growth in a bud stage with the next three growths at 0.1 bloom. Cutting at a 12-inch height gave excellent forage quality (high in minerals, protein and DDM %) but the yield was low; also plants died in less than two years (Table 7). Maximum yields and quality are not obtainable simultaneously; the best compromise is to harvest alfalfa between a bud and 0.1 bloom. Making hay at a bud stage of growth improves quality as compared to harvesting at a bloom stage but at a sacrifice of yield. The decline in quality of hay as canopies grow to a mature stage is associated with stemmy forage that is amplified by dropping leaves (Figure 9). The basal and old leaves drop because of the low

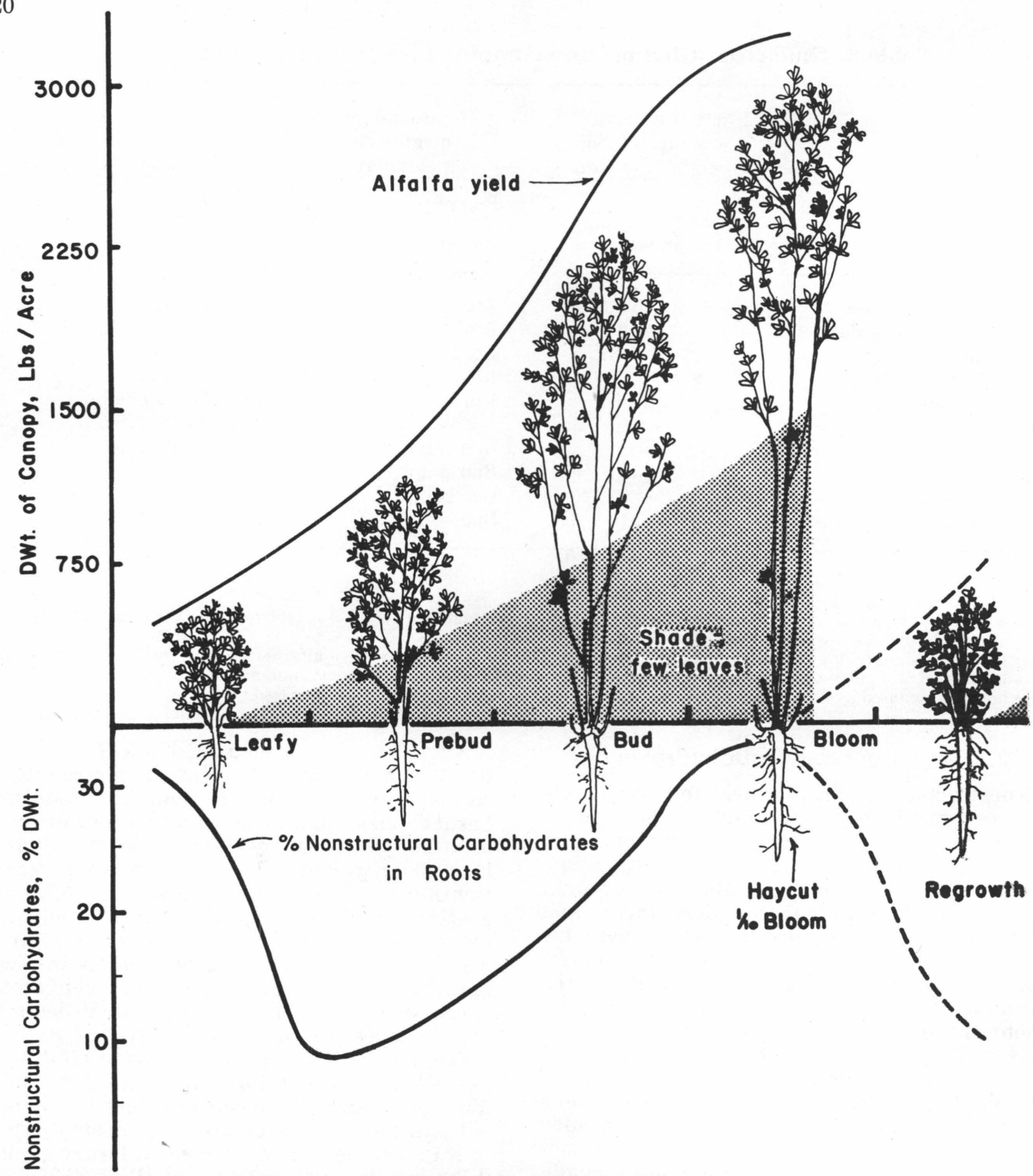


Figure 9. During winter, dormant alfalfa plants obtain energy from nonstructural carbohydrates in roots and crowns. During spring, the new growth withdraws nonstructural carbohydrates for energy from roots until the enlarging leaf area fixes enough carbohydrates (photosynthesis) to supply the energy needed for growth; the excess carbohydrates are then cycled to restore carbohydrates in roots. After harvesting for hay at about 0.1 bloom (right), there are few leaves so energy is obtained by withdrawing carbohydrates from the roots for new growth. After harvesting erect large plants such as alfalfa and red clover, long recovery periods restore nonstructural carbohydrates in roots to maintain plants for high yields. As canopies reach the bloom stage, decline in forage quality is hastened by stemmy growth, lignification, and dropping of basal leaves.

Table 7. Compromising yield and quality of hay and botanical composition of an alfalfa-orchardgrass mixture (Blacksburg data)

Stage of growth when harvested	Harvests per year	Alfalfa in mixture 1st yr. %	Alfalfa in mixture 3rd yr. %	Yields Per Acre Hay Tons	Yields Per Acre DDM Tons	Yields Per Acre Protein Tons	DDM %	Protein %
Full bloom	3	70	80	4.8	2.4	0.69	50	14.4
1st growth orchardgrass heading; others, alfalfa 1/10 bloom	4	70	70	4.8	2.8	0.95	58	20.4
1st growth orchardgrass heading; alfalfa 2nd harvest 1/10 bloom, others bud	4-5	70	60	4.0	2.4	0.86	60	21.7
10 to 12 inches high	6	70	5	2.1	1.4	0.52	65	25.0

light intensity and of leaf diseases in dense canopies. Making compromises between yield and quality to provide the nutrition for designated ruminants is a key management decision.

Plants like alfalfa and red clover may be used flexibly for hay, silage, and grazing when adequate rest periods are allowed for maintaining carbohydrates in roots, as with controlled rotational grazing. When grazing alfalfa or red clover, ruminants dislike stems; hence, grazing in a bud stage improves utilization and animal performance. After grazing once or twice in a bud stage, delaying the next harvest to 0.1 bloom restores plant vigor because of the improved status of carbohydrates in roots and basal plant tissues. Good producing alfalfa stands with adapted varieties have been maintained for six years when used flexibly for hay or silage and for summer and late fall-winter grazing.

For good winter survival, the last cutting or grazing in the growing season should be made by mid-September to allow enough regrowth for high accumulations of nonstructural carbohydrates in roots for winter survival before autumn subfreezing temperatures. After the September harvest alfalfa grows slowly because of cool temperatures; plants will not bloom because of short days. Cool temperatures depress growth and R much more than photosynthesis (P). Thus, adequate carbohydrate concentrations during autumn for winter survival of alfalfa occur with 12 to 16 inch heights of regrowth. When top growth ceases because of low temperatures, usually in November, alfalfa may be grazed continuously or harvested. Alfalfa may also be grazed continuously at any growth stage when drought stops growth. As low soil moisture or low temperatures (not freezing) depress and then stop top growth, R is depressed much more than P; hence high carbohydrate concentrations occur in roots. After soil moisture is restored at moderate temperatures, grazing should cease when new basal shoots reach grazing heights to save the carbohydrate pool. Also, with good growth environments when grazing alfalfa, the grazing period should be short (around 6 days) so young tillers will not be grazed. Grazing off new tillers depresses nonstructural carbohydrates in roots, yield, and persistence of alfalfa.

During the early spring cool-temperature period, alfalfa grows slowly (low R); but P remains high; hence, carbohydrates in roots remain high. Also, the short days and cool temperatures cause leaves and stems to cluster near the soil, thus protecting leaves during grazing. Thus, continuous light grazing of alfalfa until early May causes mild depressions in nonstructural carbohydrates in roots and basal tissues. In experiments spring grazing caused a mild or no reduction in DM yield of alfalfa for the year, when crediting the grazed DM. Spring grazing delayed the date for harvesting the first hay crop but, in practice, this delay would facilitate hay drying.

Red clover management is similar but may be less precise than for alfalfa. Even for the best varieties and management, most of the red clover plants remain productive for only two years; hence, red clover should be used intensively since longevity is not obtainable. Also, red clover is more tolerant to grazing than alfalfa because prostrate leaflets near the soil are protected from grazing. During the late August-October season, for spring seedings of red clover, intermittent cutting to simulate grazing did not depress the yield when the autumn plus next year's yield was compared with harvesting hay without autumn grazing. These data suggest that red clover during the seeding year may be grazed during the September-October season without depressing stands and yields. During the autumn season second-year stands may be grazed heavily and utilized completely to lengthen the grazing season or furnish high quality grazing as needed by weanlings or lactating dairy cows. Such closely grazed areas are ideal for no-till seeding the following spring. Red clover did not persist after two harvest seasons under any management regime.

II.F.2.2. Leaf Area

When all environmental factors are favorable, maximum growth occurs when leaves accumulate to intercept about 90% or more of the light, less than 10% of the light reaching the soil surface (Figure 10). Very high leaf areas do not give additional increases in production because basal leaves are shaded and get old and inefficient. Also, old leaves die as new ones form, nullifying additional production. Perennial grasses with semi-erect leaves need larger leaf areas than the legumes with horizontal leaves in order to intercept most of the light and maximize yields (Figure 10). Certain sub-tropical grasses such as bermudagrass (*Cynodon dactylon* L.), maintain high leaf areas with a wide range of managements; sods form dense horizontal stems with short leaf blades under continuous close grazing while erect canopies with lax grazing or hay management cause open sods with few basal leaves. Thus close continuous grazing of bermudagrass to attain leafy growth high in DDM% is desirable (Table 6).

Perennial grasses and legumes tend to adapt to utilization methods, shoots and leaves being smaller and more prostrate with heavy continuous grazing than with hay harvesting. Grazing and forage conservation practices should be planned for persistence and optimum yields and quality by maintaining adequate leaf areas and establishing new leaves quickly during or after utilization.

II.F.2.3. Nonstructural Carbohydrate and Leaf Area Interactions

For grasses similar to orchardgrass, new leaf growth was stimulated by either the leaf area or nonstructural carbohydrates; the best growth occurred when both the leaf area and nonstructural carbohydrates were high (Figure 11). However, the best development of new basal shoots occurred on old tillers high in carbohydrates. The rate of regrowth of grasses depends on the combined influence of leaf area and

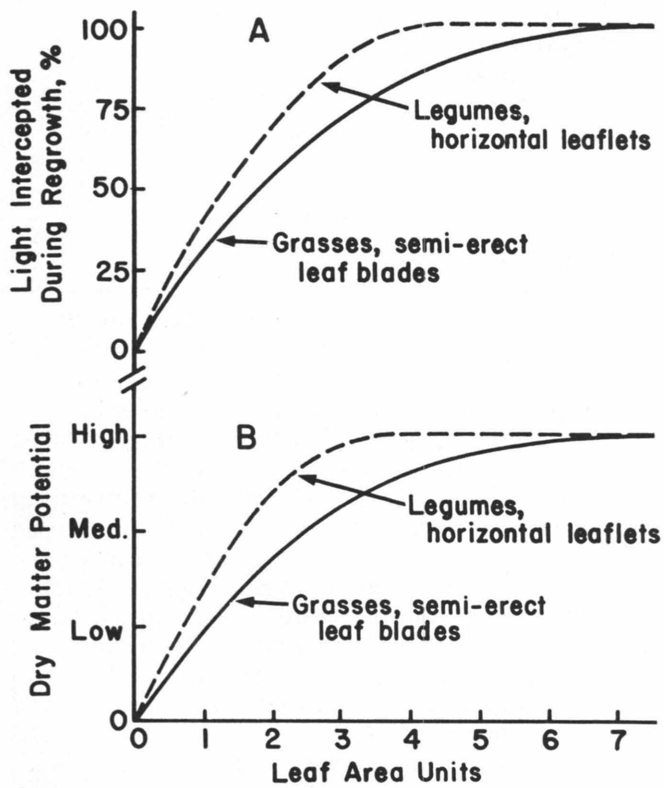


Figure 10.
Above: Light interception by forage canopies increases and then plateaus as the leaf area increases. Legumes with horizontal leaves intercept more light per leaf area unit than grasses with semi-erect leaves.
Below: The potential dry matter production is associated with increases in leaf area up to a point where about 90% of the light is intercepted. A leaf area unit means one square foot of leaf surface (one side of leaf) per square foot of soil.

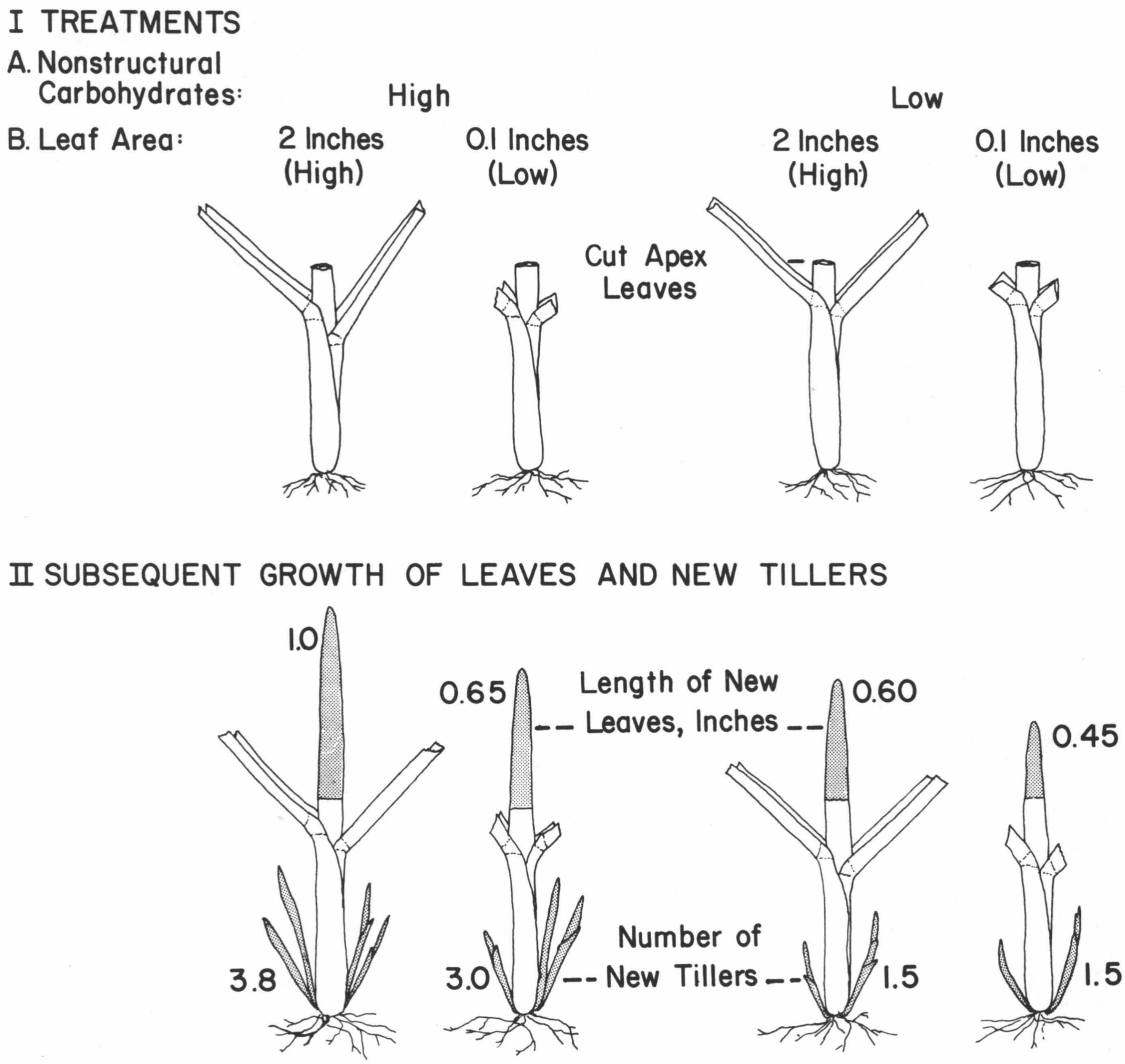
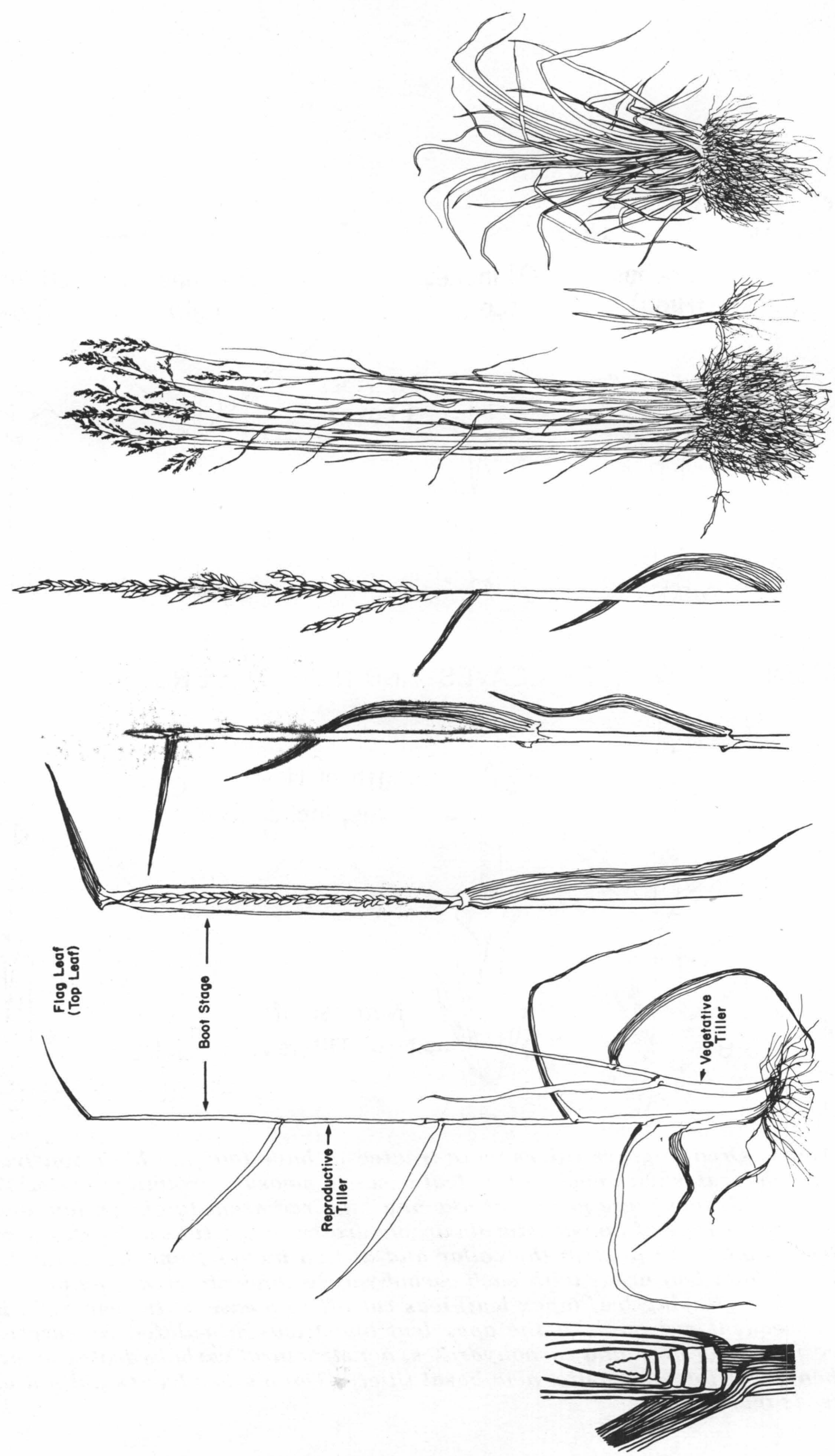


Figure 11. Above: Orchardgrass tillers were treated to have low and high nonstructural carbohydrates with each of two leaf areas to measure growth potential. Tillers with all leaves were grown at low and high radiation to obtain low and high concentrations of nonstructural carbohydrates in the tillers. Next, the mature leaves were cut next to the collar and at two inches from the collar to have 0 and high leaf areas with each carbohydrate concentration. The blade of the actively growing leaf (apex leaf) was cut off to measure its regrowth. Below: Subsequent regrowth of the apex leaf blade was stimulated concurrently by residual leaf area and carbohydrates, nonstructural carbohydrates being most beneficial for developing new basal tillers. The mature leaves did not expand (see Figure 12).


Flag Leaf
(Top Leaf)
Boot Stage
Reproductive Tiller
Vegetative Tiller
A
B
C
D
E
F
G

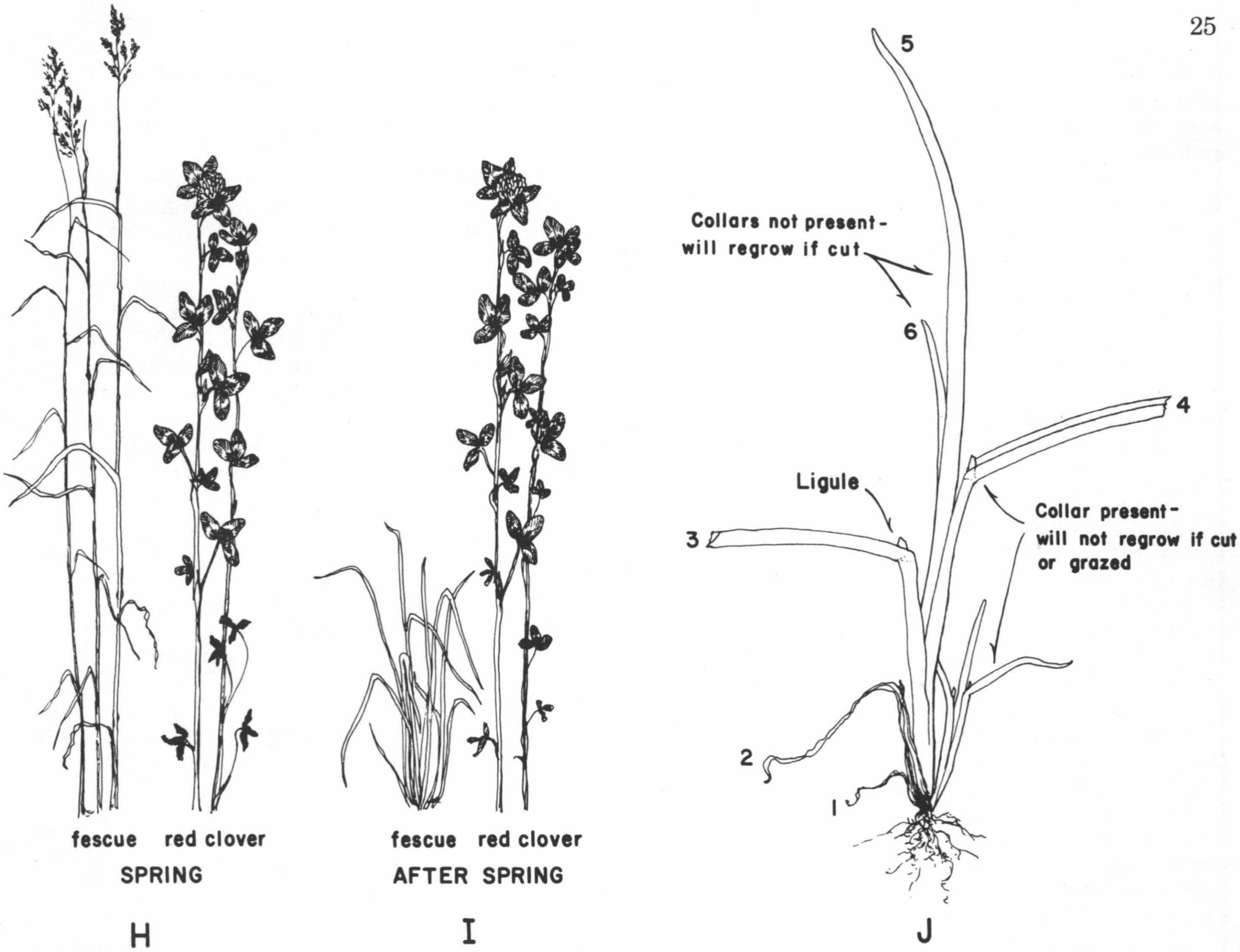


Figure 12. Morphological development of grasses of temperate origin as exemplified with tall fescue in A through I. A is an enlarged floral bud in a grass. This bud in the tiller at the soil level was induced by long night-low temperature conditions during winter. B is a tiller with a floral bud developed into a reproductive tiller or stem with a seed-head; however, many tillers without induced buds are vegetative tillers that produce leafy growth. Stages of seed-head development designate maturity or growth stage. C is the boot stage; seedhead is enclosed in a boot. D and E - two stems are in early and late heading stages, respectively. F - tillers where floral buds developed into stems with seed-heads in late spring in response to short nights. These stems in a late bloom to soft dough seed stage have suppressed basal vegetative tillers, causing slow regrowth. G - leafy tillers that developed after harvesting fescue in a boot stage. (Sketches F and G represent identical dates). H - the early tall, stemmy grass growth in spring is aggressive, suppressing even tall legumes such as alfalfa and red clovers. Early harvesting or early heavy grazing reduces grass competition. I - after the spring growth is harvested, the leafy grass regrowths are rarely aggressive toward red clover or alfalfa. Note: after the first harvest, grasses from temperate zones are leafy and higher in DDM % than are red clover and alfalfa. J - an old vegetative orchardgrass tiller with a young tiller sprouting from the base of an old tiller. On the old tiller with six leaves (J) the two oldest basal leaves 1 and 2 have died; leaves 3 and 4 are photosynthetically active but these mature leaves will not expand (grow). Leaves 5 and 6, the youngest leaves, will expand until the collar and ligule appear. All leaves develop from meristem cells within the base of a tiller.

nonstructural carbohydrates. When blades of young leaves are clipped or grazed during the evening, the elongation by dawn is attributed to energy and other materials in tillers.

Extremely close grazing of plants similar to orchardgrass causes slow regrowth because animals graze most of the leaves and basal parts of tillers that are high in nonstructural carbohydrates. In grasses from temperate zones, nonstructural carbohydrates accumulate in tillers, stolons, and/or in rhizomes, but are very low in the roots.

Consideration of the morphology of three cool-season grasses (Figure 8) shows that very close continuous grazing suppresses new growth, but the morphologically small bluegrass is less affected than tall fescue or orchardgrass because of less leaf and tiller grazing than for the larger two grasses. Nonstructural carbohydrates in rhizomes in bluegrass also serve as a source of energy when overgrazed, for survival during dormant periods caused by drought and very low temperatures, and for regrowth when environments become favorable. Lax grazing would cause the two tall grasses (fescue and orchardgrass) to dominate over bluegrass because of shading (light competition). In a fescue-orchardgrass mixture, fescue usually subdues orchardgrass for several reasons: (1) fescue grows under wider ranges of temperature, moisture, and soil fertility than orchardgrass; (2) the semi-prostrate shoots allow less leaf and tiller grazing as compared to orchardgrass; and (3) when the grasses are grown together, animals overgraze the palatable orchardgrass. Because of its low palatability, fescue should be used alone or in legume mixtures in separate fields with special management.

II.F.2.4 Origin of New Growth and Tillers

The kind and position of tillers that develop new leaves, new tiller development, and size of organs are management considerations. Cool season grasses from temperate zones such as bluegrass, orchardgrass, fescue, and timothy grow flowering stems once yearly. All flowering tillers die after seed production or when grazed or cut below the terminal bud (seed-head) in telescoping stems (Figure 12). Long nights with cool temperatures during the fall-winter season cause primordial flower buds to form in the base of tillers. These flower-inducted tillers grow to seed-producing stems in mid-spring due to short nights.

About half the tillers are young; they produce only leaves; as old leaves die new leaves appear (Figures 11 and 12). Under favorable environments with good management, as many as seven new leaves may develop from meristem cells in the base of vegetative grass tillers. Thus, cool season grasses produce stemmy growths with seed-heads only once yearly.

New vegetative tillers also arise adjacent to the base of old tillers, as for orchardgrass tillers (Figures 11 and 12), or from rhizomes, as with bluegrass.

With alfalfa and red clover, new growth develops from buds on crowns, stem bases, stolons or rhizomes; partly-grazed stems of red clover and alfalfa do not grow, except from axillary branching. Legumes like alfalfa and red clover produce stemmy growths during the growing season in response to short nights. The shortest nights generally cause the highest stem to leaf ratio; hence, DDM% for a given stage of growth is lower in summer than in spring or fall. Warm summer temperatures interacting with short nights also depress forage quality.

The warm season grasses of tropical or semi-tropical origin produce seedheads repeatedly during the warm summer because the short nights stimulate physiological changes that cause seedhead development. Thus, grasses such as bermudagrass decline rapidly in quality because of stemminess unless grazed to maintain leafy foliage (Figure 8). Bermudagrass is an aggressive invader because of its maintaining high leaf areas with lax or close grazing, and because it spreads by stolons and rhizomes. Bermudagrass has deep roots and is tolerant of drought.

II.F.3 Forage Management Interrelationships

Canopy managements for the various species given in Table 6 are now explained and justified. With continuous grazing, pastures should be stocked so the sod residue maintains an adequate leaf area to generate new growth. Grazing closely to 1 inch depresses orchardgrass because of a low leaf area and because parts of tillers with nonstructural carbohydrates are grazed (Figure 8). Thus, with continuous or rotational grazing, the ungrazed residues should be taller for grasses like orchardgrass than for bluegrass.

For grass-clover mixtures, prolonged close grazing depresses ladino clover because large leaflets are grazed off easily (Figure 7). With bluegrass-white clover pastures, close grazing to a 1-inch sod depresses bluegrass regrowth more than that of white clover, causing clover dominance (Figure 13). Small horizontal white clover leaves escape grazing, but grazing off the semi-erect bluegrass leaves deters bluegrass regrowth (Figure 13). However, with a 2-inch or higher sod residue, bluegrass depresses white clover. A 2-inch grazing height allows rapid regrowth of the apex leaves of bluegrass (Figure 13), causing low light intensity and slow development of clover leaves originating from stolons at the soil surface. Thus grazing control

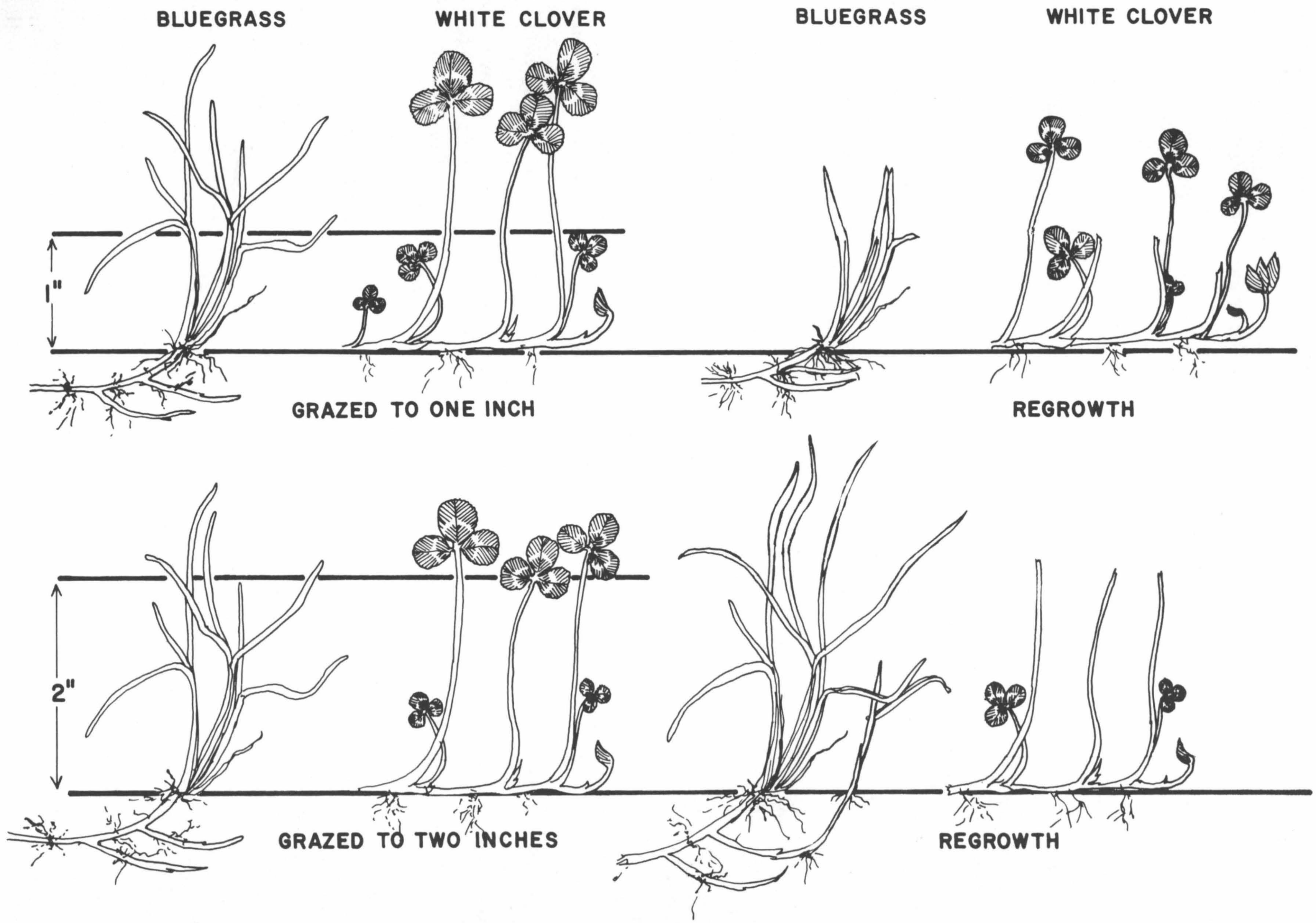


Figure 13. Grazing management controls balance of plants. Left: Bluegrass-white clover mixtures grazed to one and two inches. The subsequent regrowths are shown at right. Under close grazing (upper left and right) white clover recovers more rapidly than bluegrass, giving clover-dominant pasture. The reverse occurs with lax grazing (lower left and right).

can increase or decrease white clover or grass in pastures.

With continuous grazing, some farmers waste as much as 50% of spring growth because of understocking. As spring advances, the shift from little to flush growth should be anticipated and controlled by early grazing and high stocking. When grasses with flowering tillers start to expand into stemmy growths, they should be grazed while still leafy, palatable, and high in DDMI. Grazing below the flower buds in developing grass stems kills such tillers, allowing the shorter vegetative tillers to persist and produce high quality leafy forage (Figure 12). Temperate grasses grow earlier in spring than legumes because they grow at lower temperatures. Thus, early close grazing encourages white clover by reducing light competition. Dense stemmy grass accumulations with undergrazing in spring depress growth of grass in summer because severe shade (light competition) kills or inhibits vegetative tillers and prevents the formation of new tillers. Growth of prostrate clover (white and ladino) is severely depressed by tall growth of grasses. It is difficult to overcome the harmful effects from undergrazing, as ruminants refuse to graze old, stemmy, and dead forage. Undergrazing could have been prevented by using some of the pasture land for hay.

Rotational grazing and hay or silage managements of perennial grasses and legumes (Table 6) are associated with (a) height or stage of growth when cut or grazed, (b) closeness of grazing or cutting, and (c) length of the grazing periods with rotational grazing.

Grazing of ladino-clover grass mixtures may begin with continuous grazing in early spring, when growth and available pasture are low. A little later, as growth exceeds consumption, the grazing area should be reduced by progressive closing of gates of some fields or by reducing grazing areas with electric fences. This practice allows early grazing and provides stair-step growths for later sequences of rotational grazing. During flush spring growth, some of the pasture area may be reserved for hay or silage, harvesting when grasses begin to head. Depressing of the short ladino clover by the early and tall grass growth is minimized by early grazing or harvesting. After the spring harvest when reproductive grass stems (tillers) die, the less aggressive leafy tillers may be grazed when they reach heights of 7 to 14 inches at each rotational grazing, leaving 1 to 2.5 inch ungrazed residues (depending on morphology) to maintain a balance of grasses and ladino clover (Table 6). Brief periods of close grazing depress grasses more than ladino clover, because clover leaflets arising from stolons encounter less light competition, as described previously for white clover-bluegrass (Figure 13).

Because the low palatability of tall fescue limits intake during the growing season and because of its aggressiveness toward ladino clover, fescue should be kept in a short, leafy condition to encourage DDMI intake. Short ungrazed residues also aid clover maintenance.

Either tall fescue or orchardgrass alone or with red and ladino clovers (Table 6) may be accumulated after mid-August until November (stockpiled) for late fall-winter grazing. However, fescue has several advantages over orchardgrass for fall-winter grazing: (1) it grows at lower temperatures for more dry matter accumulation for fall and winter grazing, (2) its leaves remain greener because of freeze tolerance, (3) its erect rigid leaves make little soil contact to avoid decay, and (4) nonstructural carbohydrates are higher in fescue than in orchardgrass. After the spring harvest grasses produce leafy regrowths which may be reserved (stockpiled) for summer or winter grazing. However, massive accumulations that are not harvested or grazed during summer decline in quality as leaves die because of old age and disease.

The need for red clover and alfalfa alone or in grass mixtures to reach a bud to bloom stage when harvested or grazed during the growing season was discussed earlier. The first growth in spring may be harvested when yield justifies harvesting or in a prebud stage. When grown with grasses, the early growth and later erect stemmy growth of grasses can cause severe shading (light competition), depressing the legumes (Figure 12). Cutting when grasses begin to head is the best stage for silage and also for hay if the crop can be dried and baled. Such early harvesting usually assures a high yield for the next growth as soil moisture and temperatures are more favorable than with later harvesting. Close grazing for a short period or close cutting reduces the leaf growth and light competition from orchardgrass which tends to favor alfalfa or red clover in grass mixtures (Figure 14).

Severe light competition between mature, tall growth and short leafy grass tillers near the soil, with delays in grazing or harvesting dense canopies, causes slow recovery and low yields later in the season (Figure 15). Very dense unutilized reproductive grass growths, stimulated by nitrogen fertilizer, often cause brownish dead stubbles for several weeks after harvesting as many or almost all of the vegetative and new tillers died. Such deaths of tillers are probably associated with (1) prolonged light competition; (2) high humidities that augment diseases; (3) in response to low radiant energy, the long erect vegetative tillers being cut below the leaves; (4) low nonstructural carbohydrates, caused by low light intensity; and (5) drastic alteration of the radiant energy-temperature-humidity complex that causes tillers to die after being mowed or

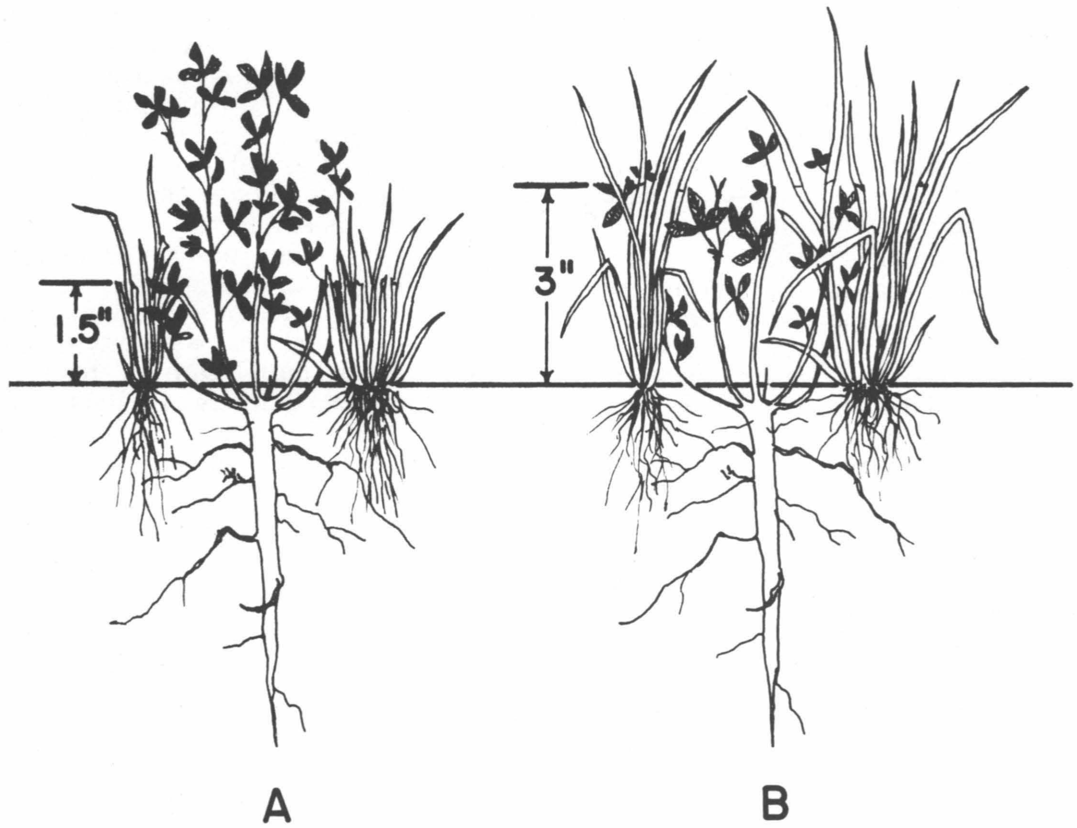


Figure 14. After grazing or cutting, new shoots of alfalfa originate from stem bases and crowns near or below the soil. Close grazing or cutting depresses growth of orchardgrass, thus reducing light competition and favoring alfalfa dominance (A, cut at 1.5 inches, and B, cut at 3 inches).

Figure 15. Left: Overgrazing causes a poor soil cover resulting in water runoff, soil erosion, and poor insulation. Thus, high soil temperatures in summer and low water infiltration cause poor growth or death of plants. Right: Very dense tall sods, undergrazing, or late harvesting often kill the short leafy tillers and depress yield, quality, and later growth.

grazed. Harvesting or grazing canopies when grasses begin to head gives a good quality forage in the first growth and provides much more forage for the summer than delayed harvests at bloom or later stages. Also, in associations, legume survival is substantially improved by early harvesting of tall temperate grasses, which reduces competition during mid spring.

Manipulating animals to retain desirable sods can minimize adverse environmental effects. For example, extremely close grazing causes adverse indirect effects: (1) on hilly pastures the water runoff aggravates drought; (2) temperature elevations with poor sod insulation reduce growth because of increased respiration, reductions in photosynthesis, and high water loss; and (3) plants suffer from winterkill due to low temperatures and heaving (plants elevated by ice, severing root-soil contact). The probability of occurrence of harmful environmental effects is low during the moist-cool spring season as compared to the summer-fall season; hence, continuous grazing in spring might be shifted to controlled rotational grazing later in the season.

The utilization management of forages must be associated with the morphology of species when grown alone or in mixtures where yield and quality of forage are compromised to maintain production and species. Some plants may be grazed continuously with small yield advantages from rotational grazing. Other species persist and give high yields only with judicious cutting for hay or silage or controlled rotational grazing. Stages of growth or height before utilization, and sod residues after harvesting or grazing, influence both yields and amounts of grasses and legumes in mixtures. Different species and mixtures in separate fields should be managed to develop forage systems of adequate nutrition for ruminants.

II.G. Available Pasture, Stocking Rates, and Animal Products

Grazing experiments in this section were managed to obtain reliable information for pasture treatments on: 1) production per animal, 2) carrying capacity per acre, and 3) animal products per acre. Managing grazing to control available pasture (AP) profoundly affects these three measurements.

Quality of pastures, expressed as daily liveweight gain, was obtained by weighing each tester animal every 28 days. Tester animals grazed a given pasture treatment during the grazing year or for several months. Carrying capacity, a measure of pasture yield, was obtained by calculating the number of 700-lb animal units per acre, including both testers and grazers. Grazers, animals similar to testers, were added before and removed after grazing a rotationally grazed pasture so that AP would be controlled and nearly constant for the grazing season for pasture treatments. In experiments with continuous grazing, grazers were introduced or removed from pastures at 2- to 12-week intervals. Adding or removing cattle on a constant area of pasture to control AP is similar to grazing more or less pasture area on farms when the number of cattle is nearly constant.

Animal liveweight gains per acre, a measure of quality and yield of pastures, were obtained by multiplying daily gain of testers by the carrying capacity per acre of testers and grazers. Stocking rates may be expressed as animals per acre or as acres per animal, both expressions being used in this publication.

II.G.1. Available Pasture and Animal Products

Controlled stocking to maintain nearly constant amounts of leafy available pasture (AP) among pasture treatments gave consistent and reliable results during a 5-year grazing experiment (Table 1). Reliable results for seasonal carrying capacity (yield) and daily liveweight gains (quality) of bluegrass-white clover pastures were obtained by controlling the quantity and quality of AP. The carrying capacity of the bluegrass pastures during spring was about twice that during the summer-fall season (Figure 16). The quality or daily liveweight gains of steers grazing bluegrass-clover pastures show the highest values during spring. However, daily gain per animal declined during spring, being lowest in summer with a slight increase in fall (Figure 16). Data for tall fescue or orchardgrass, grown alone with nitrogen or with clover, in the same experiment showed similar trends, the nitrogen-fertilized grasses having much higher carrying capacities, especially in spring, than do bluegrass-clover pastures (Table 1).

Management to control AP of bluegrass-clover pastures is now described. Four pastures were grazed in rotation with one group of tester and grazer steers. Three tester steers stayed in a pasture all year; and grazers were added and removed to control AP. Stocking was managed by estimating and predicting AP in the pasture being grazed and growths in the other three pastures to be grazed in a sequence. Grazing a pasture began when the growth was 3 to 5 inches high and ended when the residue was an average of about 1.5 inches high. During the flush spring growth a pasture was grazed in 3 to 6 days; this schedule allowed about 15 days between grazings of a given pasture. During slow pasture growth in the summer-fall season a pasture was grazed in 6 to 12 days, varying with rate of growth; thus

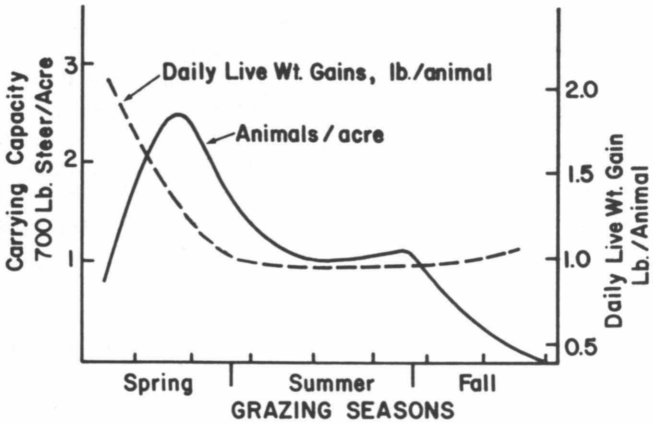


Figure 16. Pasture growth and quality, with available pasture nearly constant, differ with seasons. The yield or carrying capacity of bluegrass-white clover pastures is about twice more in spring than in summer. The quality of pasture forage as shown by production per animal is highest during spring.

periods between grazing a pasture ranged from 15 to 36 days, depending on rate of growth after grazing.

The height of pasture growth before and after grazing obviously controls the amount of AP offered and consumed; quality is concurrently controlled by maintaining leafy growth with 20-60% white clover. Based on the morphology of plants discussed earlier, this management compromises yield and quality of bluegrass-white clover pastures and helps maintain a balance of plant species. It is necessary to observe pastures several times daily as grazing ends, in a rotationally grazed pasture, to avoid a critically low AP.

Four rotationally grazed pastures were replicated three times for each of the mixtures in Table 1 to obtain valid results. Because pasture growth varied among replications, steers were not rotated on a given date; thus, AP was independently controlled for each pasture treatment in each replicate.

The taller growing species — orchardgrass, tall fescue and ladino clover — were taller than bluegrass when grazing a rotational pasture; also, the ungrazed residues at the end of a grazing period were taller than for bluegrass. The length of rest periods between grazings varied with seasons and was similar to rest periods for bluegrass. Guides for utilizing and managing different plants in pasture mixtures (Table 6) control AP, compromising yield and quality while maintaining desirable species. To accomplish these objectives, it is necessary to use grazers in experiments or variable grazing areas on farms.

The flush pasture growth during spring when quality is best (Figure 16) is attributed to cool temperatures and favorable soil moisture. These environmental factors stimulate rapid growth of leafy forage that is high in digestibility and is consumed in large amounts. Such spring-grown forage is high in protein and minerals and low in lignin, so that even the digestibility of cell wall materials is quite high. High temperatures during summer depress growth because of moisture stress, high evaporation, and transpiration. Also, high temperatures reduce digestibility for two primary reasons: (1) nonstructural carbohydrates decline because photosynthesis is depressed and because high plant respiration increases utilization of carbohydrates; and (2) lignification causes cell wall materials to be less digestible with high than low temperatures. During cool autumn seasons, high photosynthesis and low respiration cause nonstructural carbohydrates to increase and cellulose to be more digestible as compared to summer.

Digestibility of leafy grass-white clover pasture herbage ranges from around 70-78%, 58-62%, and 64-68% in spring, summer and autumn, respectively. Stockpiled tall fescue for fall-winter grazing is high in nonstructural carbohydrates and DDM%. Ruminants use forages more efficiently during cool as compared to warm periods.

II.G.2. Controlled vs. Constant Stocking

This experiment measures animal production and carrying capacity for two stocking methods: 1) a constant stocking rate, a widely used practice by farmers and some research personnel; and 2) controlled stocking based on maintaining a desirable quality and quantity of available pasture (AP).

Eight similar 2-acre pastures, with equal areas of bluegrass-white clover, orchardgrass-ladino clover, and alfalfa-orchardgrass in each pasture, were stocked with two similar tester steers weighing about 550 lb when grazing began. Continuous grazing with all pastures began in spring and ended in fall. With constant stocking, only two tester steers grazed in each of four pastures all season; with controlled stocking for the other four pastures, grazer steers were added or withdrawn independently in each pasture to coincide with present and predicted growth to maintain an AP averaging 2 to 4 inches high.

With constant stocking, based on 700-lb animals, the stocking rate began with less than one animal per acre and ended with about 1.4 animals per acre, increasing as animals grew during the year (Figure 17). Conversely, with controlled stocking, the stocking rate peaked at about 2.5 animals per acre during spring and 1.2 to 1.4 animals per acre during summer and fall, averaging 30% more than for constant stocking.

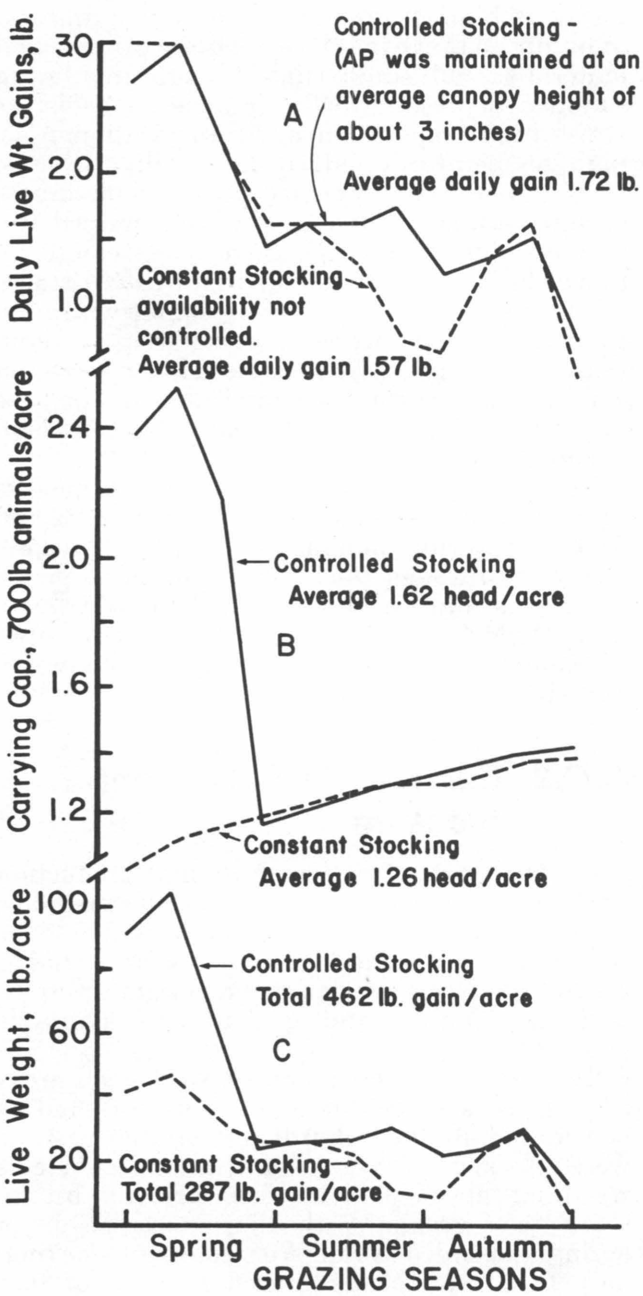


Figure 17. Controlled stocking based on available pasture gave higher liveweight gains per animal and per acre than constant stocking.

There were good utilization of AP, little spotted grazing, and few weeds with controlled stocking. With constant stocking, the initially leafy grass-legume pastures during early spring shifted to large accumulations of stemmy, reproductive growth, low in legumes and high in dead leaves and stems by summer and fall. This ungrazed accumulation of forage, being low in quality and unpalatable, caused spotty grazing and invasion of weeds; the animals overgrazed small scattered areas of leafy forage, refusing the tall growth. Although some new leaves grew within the undergrazed areas, dead leaves and stems obstructed plant growth and grazing.

Liveweight gain or quality of pasture was highest during spring and then declined (Figure 17). The average daily liveweight gains for the year were higher with controlled (1.72 lb) than with constant stocking (1.57 lb). The amount of AP was much higher for constant than controlled stocking; the reverse occurred for quality of AP. During summer the massive accumulation of low quality AP with constant stocking caused low DDMI and low gains as compared to gains of steers with controlled stocking (Figure 17).

Liveweight gains per acre were much higher with controlled than with constant stocking because of higher daily gains and carrying capacity. Gains per acre during spring, when growth and quality of pastures peak, were 151 lb with constant as compared to 287 lb with controlled stocking. For the year, gains per acre were 287 lb for constant and 462 lb for controlled stocking. The 61% higher gain per acre with controlled stocking is attributed to good management that maintained a desirable AP, both quality and quantity. Also, as compared with controlled stocking, much pasture was wasted with constant stocking.

It is concluded that constant stocking causes low summer liveweight gains and low gains per acre because much of the AP is wasted and its quality is not controlled. Managing the quality and quantity of AP by controlled stocking is easy to put into farm practice. To take advantage of these principles, animals would be restricted to about half of the grazing area during spring; the ungrazed area may be harvested for hay or silage for winter feeding. Then, during summer and fall, the land area for grazing is doubled by grazing the area that had been harvested. This plan, used with the Middleburg beef herd for many years, is a simple 12-month forage system (Section III).

II.G.3. Two Amounts of Available Pasture

Bluegrass-white clover pastures were stocked with tester steers to measure animal production and carrying capacity with two amounts of available pasture (AP). Grazer steers were added or withdrawn from the pastures to maintain a medium and a high AP (about 1235 and 2225 lb of forage DM per acre, respectively). AP was measured by cutting forage at the soil surface. The pastures were leafy and contained about 40% white clover.

Daily liveweight gains per steer were almost doubled by high AP: 1.77 lb daily for high as compared to 0.92 for a medium AP (Figure 18). The higher gains with high AP are attributed to higher digestibility of ingested forage; also, steers generally consumed more DM with a high than with a medium AP. The average stocking rates for the year were 0.33 acre and 0.66 acre per steer to maintain medium and high AP, respectively. Utilizing most of the forage with the medium AP (higher stocking rate) gave the highest liveweight gains, 432 lb per acre as compared with 380 lb per acre with high AP (lower stocking rate).

It is concluded that the higher AP is directly associated with higher digestible energy intake and higher output per animal than for the medium AP. Available pasture is a grazing management "tool" obtained by controlled stocking.

II.G.4. Available Pasture Designates Stocking Rate

Experiments with bluegrass-clover pastures, and other mixtures already discussed, showed that the carrying capacity is about twice more for the spring months than for the summer-fall months when available pasture (AP) remains similar for the grazing year. Thus, three stocking rates, each with the spring season stocking being twice as high as in the summer-fall season, were investigated. Acres of pasture per animal during the spring season were 0.75, 0.50, and 0.375 for low, medium, and high stocking respectively; the area per animal was doubled during the summer-autumn season.

During each of three years, four similar tester heifers in each pasture during spring were reduced to half the number of tester heifers per pasture during the summer-fall season. When AP at the medium stocking rate was judged low enough to depress daily gains, two testers were removed from each pasture for all stocking rates. The length of the double stocking rate during the spring season varied from 90 to 120 days over the three years. The experiment took place at two locations, Blacksburg and Glade Spring.

The liveweight gains per animal for all stocking rates were highest during spring, lowest during summer, and intermediate during autumn (Figure 19). The average daily liveweight gains of 1.29, 1.06, and 0.88 lb per animal for low, medium, and high stocking are generally associated with the amounts of AP (Figure 19).

The available pasture per acre averaged 1540, 1002, and 570 lb DM per acre, respectively for low, medium, and high stocking. Best relationships between AP and liveweight gains per animal occurred during spring grazing when the quality of pastures for the three stocking rates tended to be similar. During the summer-autumn seasons, the highest AP with low stocking was of low quality, being stemmy, weedy, and low in clover content; hence, gains per animal were similar to those with medium AP (medium stocking rate). During summer-autumn grazing, the low AP with high stocking depressed gains per animal even though the forage was leafy, higher in clover, and less weedy than for other stocking rates.[1]

The liveweight gains per acre were increased substantially for each of the three stocking rates by doubling the stocking rates during the spring season as more of the flush high quality AP was utilized. The liveweight gains per acre per year were 264 lb for low, 329 lb for medium, and 332 lb per acre for high stocking. The lowest gains per acre with the low stocking rate are attributed to a low carrying capacity of 206 days, as much of the forage was not consumed. The best forage utilization and carrying capacity of 377 days occurred with the highest stocking rate; however, the low AP depressed the daily and liveweight gains per animal.

It is concluded that doubling the stocking rates during the spring season increased animal products with all three of the stocking rates because more of the flush high quality forage was consumed and converted to livestock products. With similar quality, a high as compared to low AP stimulates output per animal but reduces livestock products per acre. With a constant area of pasture, a desirable AP may be maintained by reducing the stocking rate during summer by selling some animals after the flush spring growth.

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[1]The AP values in Figure 19, obtained by cutting to a 1-inch height, should not be compared with values in Figure 18, which were harvested at the soil surface.

II.G.5. Compromising Production Per Animal and Per Acre

Managing the stocking rate to maintain a desirable AP (quality and quantity) is necessary to compromise the production per animal and per acre for profit (Figures 17, 18, 19 and 20). Desirable AP values are obtained by controlled stocking on farms when the number of animals is nearly constant by varying the land area grazed.

Maximum outputs per acre and per animal cannot be obtained simultaneously (Figure 20). Creep grazing (discussed later) is an exception. With responsive ruminants the output per animal (meat or milk) increases with AP but finally levels off or even declines. When a high AP is made up of much dead material or stemmy growth, DDMI and output per animal decline (Figures 17 and 19). Animal products per acre are negative with a very low AP as DDMI is too low for maintenance, so animals lose weight. As AP increases, animal products per acre increase as production per animal increases to a place on the curve where output per animal and amount of AP utilized are both reasonably high. As AP values pass through the high range, progressively more forage remains ungrazed with declining stocking rates. When added increments of AP with decreasing stocking rates do not give increases in output per animal, there are drastic declines in animal products per acre as pasture is not utilized (Figure 20). It should be recalled that animal products per acre are calculated by daily output per animal x carrying capacity; carrying capacity declines as AP increases. Stocking rate, meaning land area per animal, deviates from and is not usually related to AP because of variable pasture yields due to seasons, soils, mixtures, and management.

Controlling AP is a "management tool" to compromise livestock products per animal and per acre for economic relevance. There is not one optimum AP; the magnitude of AP depends on net returns per acre from animal products. For example, when high daily gains improve quality and carcass value, it is profitable to sacrifice animal products per acre for products per animal attained by increasing AP.

II.G.6. Conclusions

The results from the grazing experiments discussed in this section lead to the conclusion that AP is an important grazing management tool to maintain species and high production of pastures while controlling animal production. Quality and quantity of AP is managed by controlled stocking, where land area per grazing animal is altered; adjustments in the grazing area are based on the present and predicted pasture growth. Constant stocking does not give valid results in research nor achieve high production potentials on farms because AP is not controlled. AP is managed to make compromises in production of animal products per animal and per acre for profit.

To obtain reliable data from grazing trials and maximize profits on farms, it is necessary to control AP by judicious management. The AP principle is useful both for managing and for understanding the results from grazing utilization methods, as discussed in the next section.

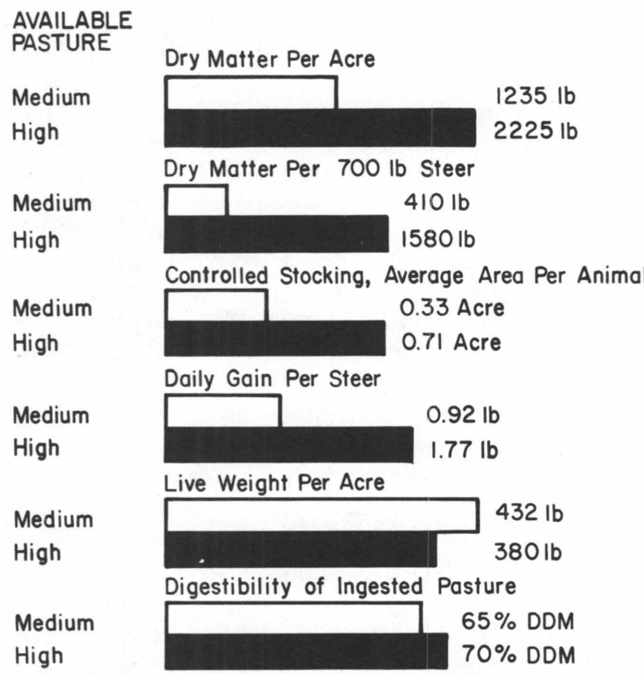


Figure 18. Medium and high amounts of available bluegrass-white clover pasture were maintained by controlled stocking. A high as compared to a medium AP increased the liveweight gain per steer but decreased the carrying capacity and liveweight gain per acre. APs were designated and controlled by heights of continuously grazed pasture, ranging between ¾ and 2½ inches with medium AP and between 1 and 5 inches for the high AP.

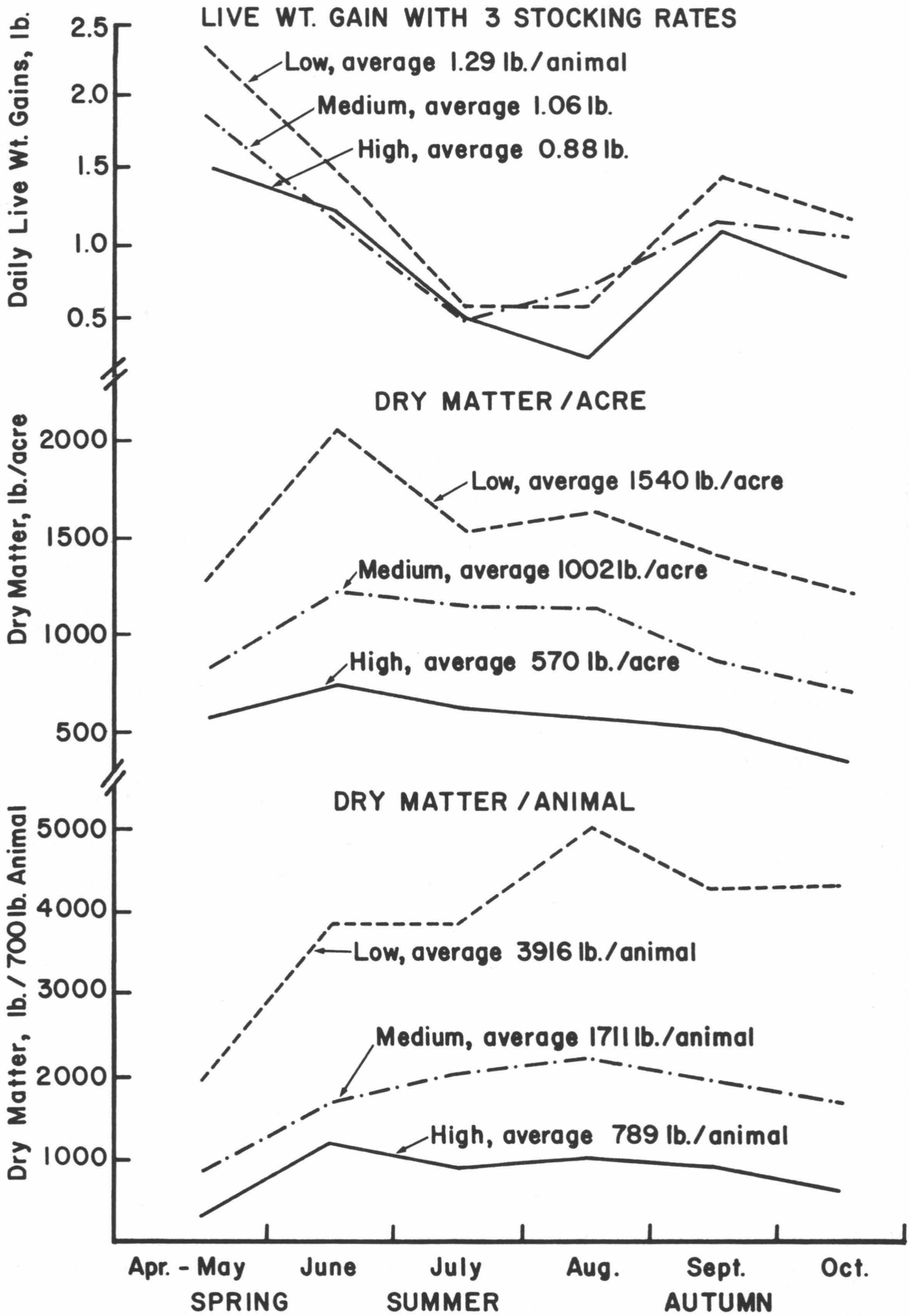


Figure 19. Pastures were stocked at three rates (low, medium, and high), stocking rates being twice as high in the spring as for the summer-autumn season. The graphs from top to bottom show liveweight gain per animal, available pasture per acre, and available pasture per animal, respectively.

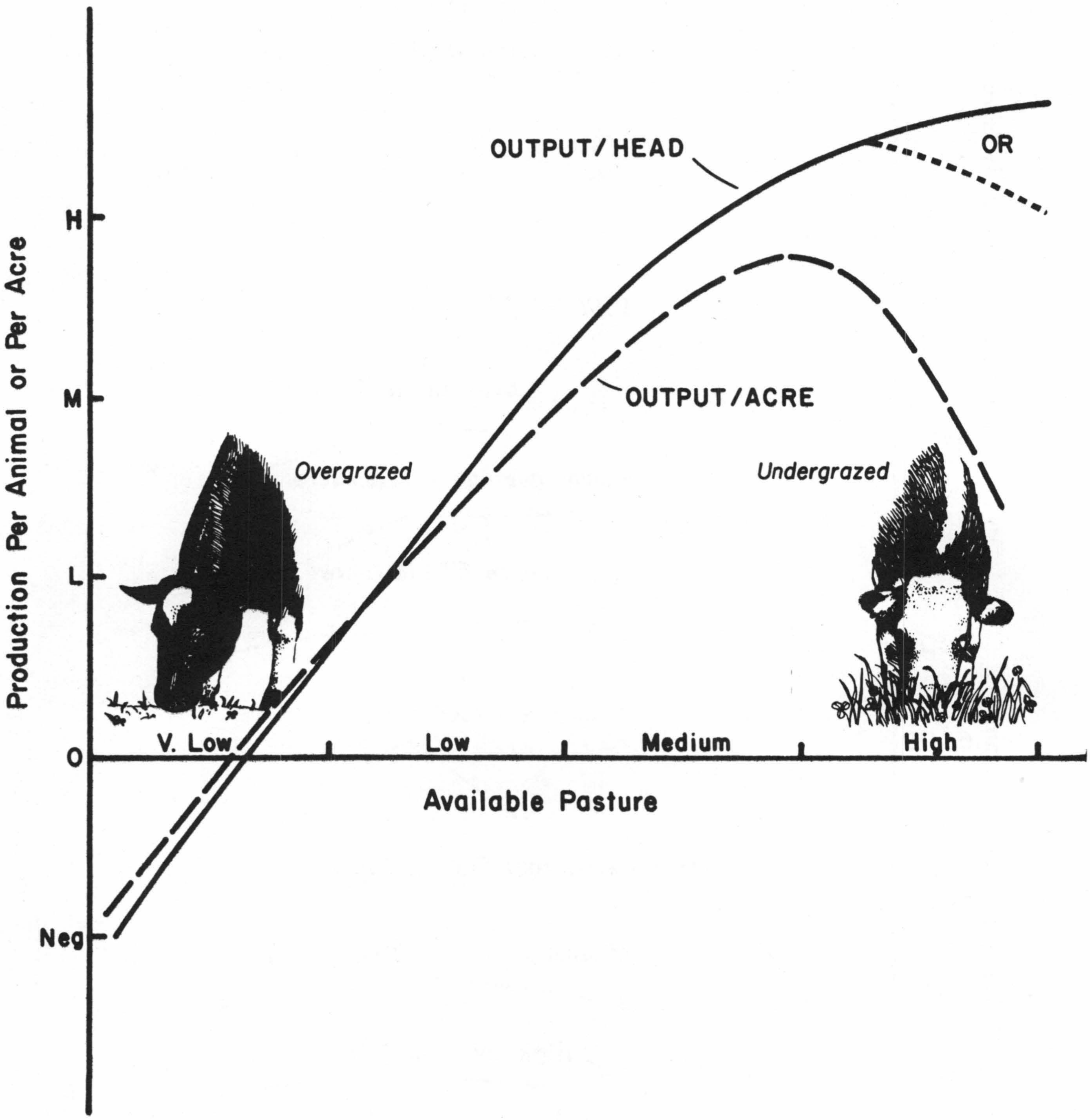


Figure 20. ***Maximum production per animal and per acre cannot be obtained simultaneously; hence, these two values must be compromised for profit. For example, when high daily gains are associated with high carcass quality and market value, it becomes desirable to sacrifice animal products per acre.***

As available pasture (AP) increases to medium-high level, production per animal increases; with high APs production per animal levels off or may decline. Animal products per acre peak when AP is managed to obtain reasonably high production per animal and reasonably good utilization of pasture.

Implementing the management of AP to provide needed nutrition of ruminants and to manage species in forage animal systems will be discussed later.

The daily liveweight gains of cattle from our experiments are conservative estimates of pasture quality because: 1) cattle were in good condition, having gained 0.75 lb or more daily before assignment to experiments; 2) good pasture utilization was practiced, i.e., available pasture (AP) was in a medium range, grazed to a low AP when experiments terminated; and 3) growth stimulants were not generally used. Likewise, liveweight gains of animals fed hay or silage (discussed later) are realistic because animals were in good condition when experiments started; also, the amount of forage offered restricted selective consumption.

In a grazing experiment with bluegrass-white clover pastures in western Virginia almost 50 years ago, steers gained about 2.0 lb daily for the grazing season as compared to about 1.3 lb daily at the Virginia Forage Research Station. The inflated daily gains in western Virginia were compensatory gains as large and thin 3-year old steers had been fed just enough hay for maintaining body weights during the winter season. Animal condition and AP can inflate or deflate liveweight gains in any forage evaluation endeavor.

II.H. Animal Production with Grazing Methods

The production per animal and per acre for any grazing and utilization method depends on AP, both amount available and quality. It is essential to manage grazing to maintain an AP to give a desirable balance of species and to compromise yield and quality of the pasture forage. In comparing grazing methods, any method can be superior in animal production, depending on the accidental or known managements that bias AP.

II.H.1. Continuous and Rotational Grazing

With reasonably good control of the quality and quantity of AP, the daily liveweight gains or milk per animal were similar for continuous and rotational grazing when measured for five different mixtures or species (Table 8). However, animal products per acre were up to 41% more for rotational than for continuous grazing. With alfalfa-grass pastures, more than 90% of the alfalfa died by the second year with continuous grazing; stands with rotational grazing were excellent. The 40% higher milk production from rotational than continuous grazing of the alfalfa-grass mixture during two years would have been substantially higher in later years because of a poor alfalfa stand and growth with continuous grazing. With mixture 4, the carrying capacity or yield of orchardgrass in the absence of a legume or nitrogen fertilizer did not respond to rotational grazing. With other mixtures (Table 8) the higher yields of animal products per acre from rotational as compared to continuous grazing are attributed to (1) better forage growth in response to maintaining desirable leaf areas, (2) nonstructural carbohydrates, and (3) their interplay that stimulated growth and maintained better legume stands. When AP (quantity and quality) is not controlled, as with constant (uncontrolled) stocking, either method may give the highest values for animal products per acre or per animal.

Concerning pastures 6a and 6b (Table 8), the daily gains of steers for continuously-grazed bluegrass-white clover pastures were higher than those for steers grazing rotationally among bluegrass-white clover, orchardgrass-ladino clover, and alfalfa orchardgrass pastures. The somewhat lower gains with rotational grazing are attributed to the lower DDMI for steers grazing the usual stemmy alfalfa. The AP values for pastures 6a and 6b were thought to be similar. However, the rotationally grazed pastures with alfalfa mixtures in 3 of 5 fields gave a 72% increase in carrying capacity and 41% more liveweight gain per acre as compared with continuous grazing of bluegrass-white clover pastures.

The data on rotational grazing were generally obtained by rotating cattle among 4 to 6 fields; more fields could have increased the yield of responsive grass-legume mixtures. In an experiment with orchardgrass and ladino clover, the carrying capacity and milk per acre were 24% higher when cows rotated among 10 as compared to 2 pastures; milk per cow was similar for the two rotational systems. Based on AP, DDMI, and animal production relationships, it should be clearly evident that rotational or continuous grazing will give similar outputs per animal when AP is controlled.

Table 8. Animal days grazing and products per animal and per acre with rotational and continuous grazing*

Mixtures	Production per animal		Production per acre: Animal days grazing		Production per acre: Meat or milk per acre		Incr. from rot graz.
	Cont. grazed	Rot. grazed	Cont. grazed	Rot. grazed	Cont. grazed	Rot. grazed	
	lb	lb	days	days	lb	lb	
Milk Production							
1 Alfalfa-orchardgrass	27.1	28.4	150	216	3726	5233	40%
2 White clover-birdfoor trefoil-orchardgrass	25.4	25.6	147	187	3077	4204	37%
3 Ladino clover-orchardgrass**	38.0	39.4	125	150	4750	5910	24%
4 Orchardgrass	27.4	23.3	144	149	3288	3265	-1%
Liveweight Gains							
5 Orchardgrass, Nitrogen fertilized	1.30	1.23	300	330	364	388	7%
6 Bluegrass-white clover							
a. Grazed continuously,alone	1.38	--	223		306		
b. Grazed rotationally with other mixtures***		1.25		384		432	41%

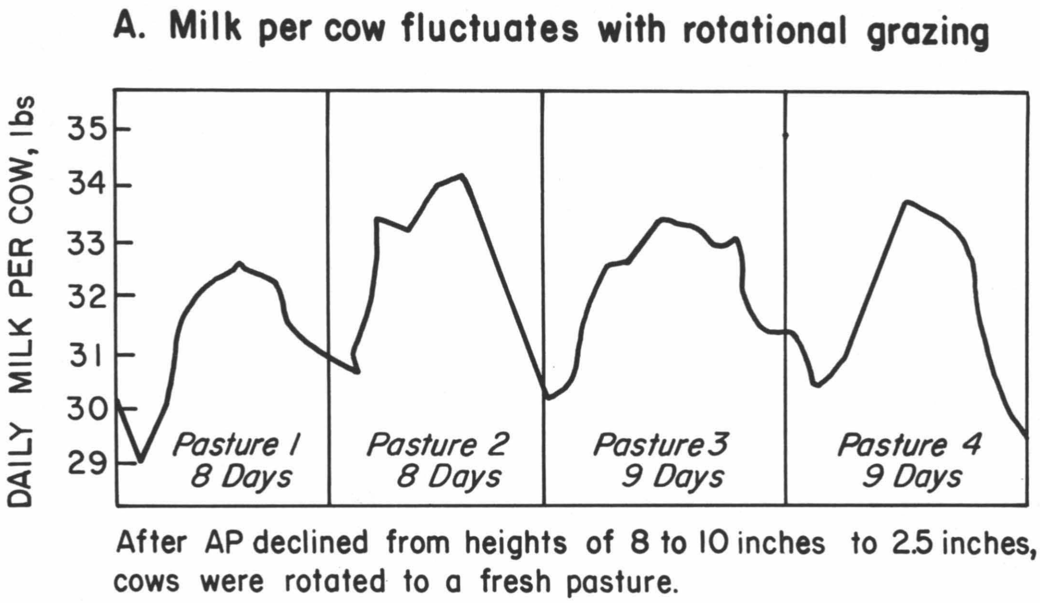
*The duration of the various experiments at Middleburg ranged from 2 to 5 years.
**Rotational grazing among 10 pastures vs 2 pastures grazed alternately, which approaches continuous grazing.
***Alfalfa-orchardgrass fields harvested for winter feed were rotationally grazed with bluegrass-white clover and orchardgrass-ladino clover pastures, a 12-month forages system; the harvested forage was credited to the acre production data. The carrying capacity averaged 72% more for the system than for the continuously grazed bluegrass-clover pastures.

II.H.2. Variable Nutrition with Rotational Grazing

Milk cows without supplementary energy feeding, sensitive to shifts in nutrition, show changes in milk production while utilizing forage within a rotationally grazed pasture (Figure 21A). The daily milk per cow increased, plateaued, and then declined while grazing a rotationally grazed pasture. Digestibility and intake (DDMI) of ingested forage shifted from high to low while the cows were consuming the forage in each rotationally grazed pasture (Figure 21B). These shifts from high to low DDMI and milk production are attributed to concurrent shifts from high to low values for AP, selective grazing, digestibility, and intake.

The 2- to 3-day lag in milk production after shifting to a fresh pasture is explained by the carryover of low digestible parts of forage remaining in rumens from the previously-grazed pasture. Note that the digestibility curves of ingested forage measured from fecal samples of steers in another experiment agree with the milk production curves (Figure 21 B).

The values for AP and nutrition are more variable for rotational than for continuous grazing, but the average AP and nutrition with controlled stocking for a given pasture mixture is similar for rotational and continuous grazing, as verified by daily animal outputs (Table 8).



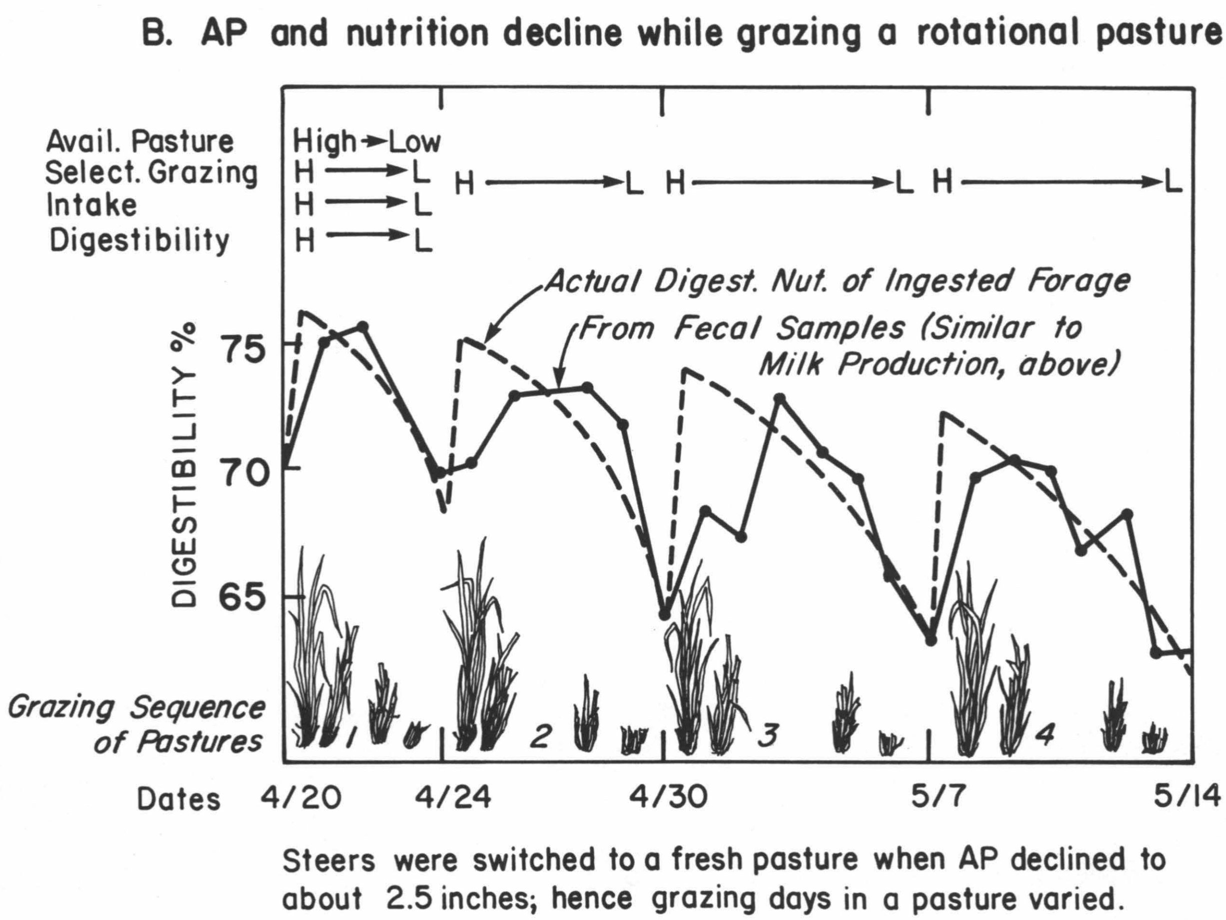


Figure 21. A, Above: Milk per cow varies daily while grazing a rotational pasture. B, below: The daily fluctuations in milk production are caused by variable nutrition associated with available pasture. Grazing each of the pastures shown in A (above) in one day would give uniform nutrition but average values for nutrition and milk per cow.

II.H.3. Rotational Grazing for High and Low Production per Animal

Since available pasture (AP) designates selective grazing and DDMI, experiments with rotational grazing that allocate a high AP to first grazers and a low AP to last grazers were planned as diagrammed in Figure 22. First-grazing milk cows, consuming about 50% of the AP, produced 55% more milk than the last grazers (Table 9). In other experiments without supplements the first grazers produced 24 and 49% more milk than the last grazers. As animals consumed the forage in a pasture, the fiber content in ungrazed residue increased and the protein declined because animals selected leafy plant parts high in energy and protein (Figure 23).

Liveweight gains of steers grazing two mixtures were 41% higher for first than for last grazers (Table 10). Together, the average daily gains of first and last grazers were almost identical to the daily gains of steers with ordinary rotational grazing (one group of animals). These data show that the low production of last grazers (milk or meat products) cannot be attributed to an acute pasture shortage before the animals were shifted to a fresh pasture. Last grazers and whole-plant rotational grazers were moved to a fresh pasture before utilizing all of the AP. The data also show that AP visual estimates of ungrazed residues, when animals were moved to a fresh pasture, were both consistent and reliable for various pasture mixtures and different ruminants (Tables 10 and 11).

Table 9. Milk production per cow, dry matter intake, and digestibility of ingested pasture by first and last grazers (at Middleburg)*

Data categories	Kind of grazing: First grazers	Kind of grazing: Last grazers	Differences
Milk, lb per cow per day	28.9	18.7	55%
Ingested forage			
Digestible dry matter %	64.4	61.8	4%
Dry matter intake, lb per cow per day	33.2	28.4	17%

*Without supplements during three years, first grazers produced 24, 54, and 49% more milk than last grazers. The pastures were usually orchardgrass-ladino clover in rotation with orchardgrass-alfalfa.

Two animal groups, first and last grazers, will not increase animal products per acre above that for ordinary rotational grazing with one group of animals when AP residues are similar (Table 11). The combined values of first and last grazers for daily liveweight gains, carrying capacity, and liveweight gain per acre were almost identical

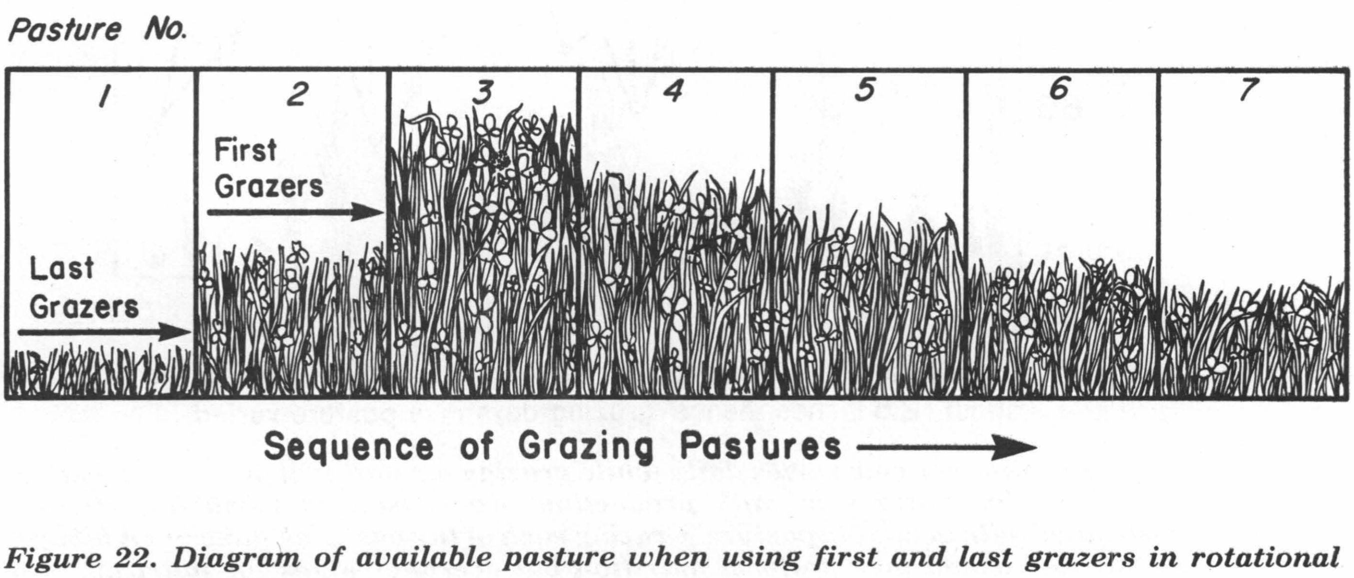


Figure 22. Diagram of available pasture when using first and last grazers in rotational grazing.

Table 10. Liveweight gains per animal grazing the entire canopy (rotational grazing) as compared to first and last grazers (special rotational grazing) (2-year averages at Middleburg)

Pasture mixtures	Rotational grazing with two groups of steers: First grazers	Last grazers	Average	Ordinary rotational grazing, one group steers
	Daily gain, lb.			
Bluegrass-white clover	1.53	1.14	1.34	1.31
Orchardgrass-ladino clover	1.49	1.00	1.25	1.29
Average	1.51	1.07	1.30	1.30
Increase for first grazing, %	+41%			

Table 11. Liveweight gains per animal and per acre with first and last grazers as compared to rotational grazing where animals graze the entire canopy (2-year averages at Middleburg)

	Rotational grazing with first and last grazers: First grazers	Last grazers	Average or total	Ordinary rotational: Average for one group of animals
Daily gain per steer, lb.	1.35	0.81	1.08	1.07
Steers per acre per day	1.03	1.03	2.06	1.99
Liveweight gain per acre, lb.	238	144	382	371

with these respective values for whole canopy or ordinary rotational grazing. In practice, first grazers should be ruminants that require and respond to high nutrition, such as high-producing milk cows or fattening steers; last grazers could be dry cows or replacements that require lower nutrition. Illustrating this management technique, a farmer used the ewe-lamb flock as first grazers during spring to get fat lambs for an early market and a high price, dairy cows being last grazers. After the lambs were sold, the ewes became last grazers. Another example is to first graze the best yearling cattle until they are sold in July; cattle to be sold in fall would be last grazers. For the rest of the year, the last grazers would graze twice the land area; also these animals could be grouped into first and last grazers.

All AP allocations were based on visual evaluations by experienced graziers. The animal responses in Table 11 show very similar values for the production per animal and per land area for rotational grazing and for the average of first and last grazers. These data and forage weights (not presented) show that eye evaluations of AP are reliable parameters.

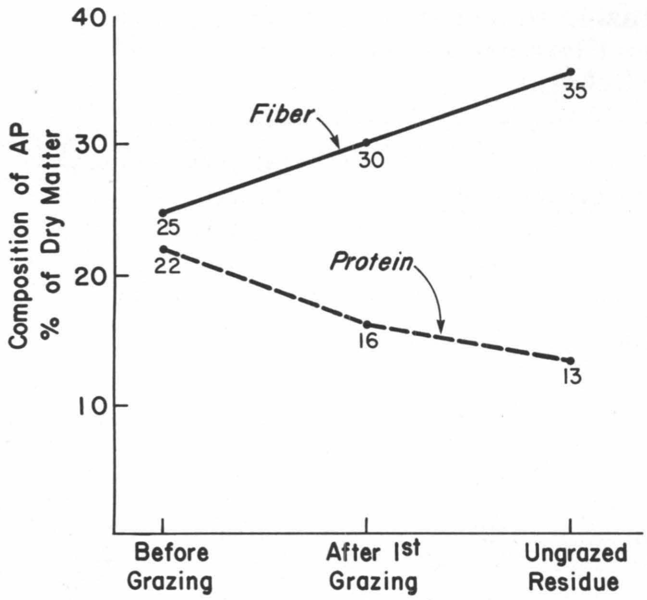


Figure 23. Animals select leafy forage high in protein and digestibility and low in fibrous material; thus, as a pasture is consumed, stemmy or basal plant fractions in the ungrazed residue increase, causing declines in protein percent and increases in fiber and lignin.

II.H.4 Strip Grazing, Green Chop, Hay, and Silage

Strip or ration grazing means grazing an adequate area of fresh pasture to furnish the nutrition daily. With growth stage and the ungrazed residue (AP) both controlled, strip grazing cannot improve products per animal above that for rotational grazing, nutrition of the canopy consumed in one day being similar to the average nutrition during several days of rotational grazing. The day-to-day nutrition is more uniform with strip than with rotational grazing. With good management, forage yield or carrying capacity is also similar for strip and rotational grazing; however, potential production per acre may be a little higher for strip than for rotational grazing because of higher forage yields resulting from faster regrowth due to better control of leaf area, nonstructural carbohydrates, and their interplay. Strip grazing is similar to many pasture subdivisions for rotational grazing.

With green chop, the potential output per animal is slightly less than for rotational grazing because of more selective utilization with rotational grazing. In practice, the trend for more selective grazing and a leafier growth stage with rotational grazing as compared to green chop results in slightly higher production per animal with rotational grazing. However, a low AP that restricts DDMI or an adverse environment (no shade) with rotational grazing would result in highest animal outputs with green chop. Thus, with a given mixture with growth stage and AP controlled and similar animal environments, the livestock products per animal or per acre are similar for rotational grazing, strip grazing, or greenchop.

For a given plant or mixture of plants, animals fed hay or silage produce less than do similar animals grazing (Tables 4 and 5 and Figure 6) because of reductions in DDMI caused by:

1. the growth stage being more advanced with hay or silage harvesting than for plants when grazed;
2. harvest or storage losses of the most digestible fractions reduce quality as compared to fresh forage; and
3. there is more selective utilization with grazed than conserved forage.

However, overgrazed pasture (low AP) could give lower outputs per animal than liberal feeding of hay or silage.

Dry matter production and animal products per acre are usually higher with hay and silage operations than with grazing because:

1. harvesting in advanced growth stages increases dry matter yields, but reduces quality and output per animal;
2. wasted and unutilized forage with grazing is probably similar to nutrient losses with conservation;
3. it is likely that the beneficial effects from recycling excreta by grazing animals are offset by compaction and other harmful grazing effects that depress regrowth as compared to mechanical harvesting; and
4. harvested forages are usually grown on more productive soils than is pasture.

II.H.5. Creep Grazing and Creep Feeding

Creep grazing allows calves or young cattle or lambs to graze pastures high in AP (amount and quality) adjacent to those grazed by nursing cows or ewes through a creep (Figure 24). Creep grazing is based on the principle that calves, lambs, or young stock require higher nutrition than do dams or ewes and food in addition to milk to sustain rapid growth. The AP and animal output values for first and creep grazing would be similar.

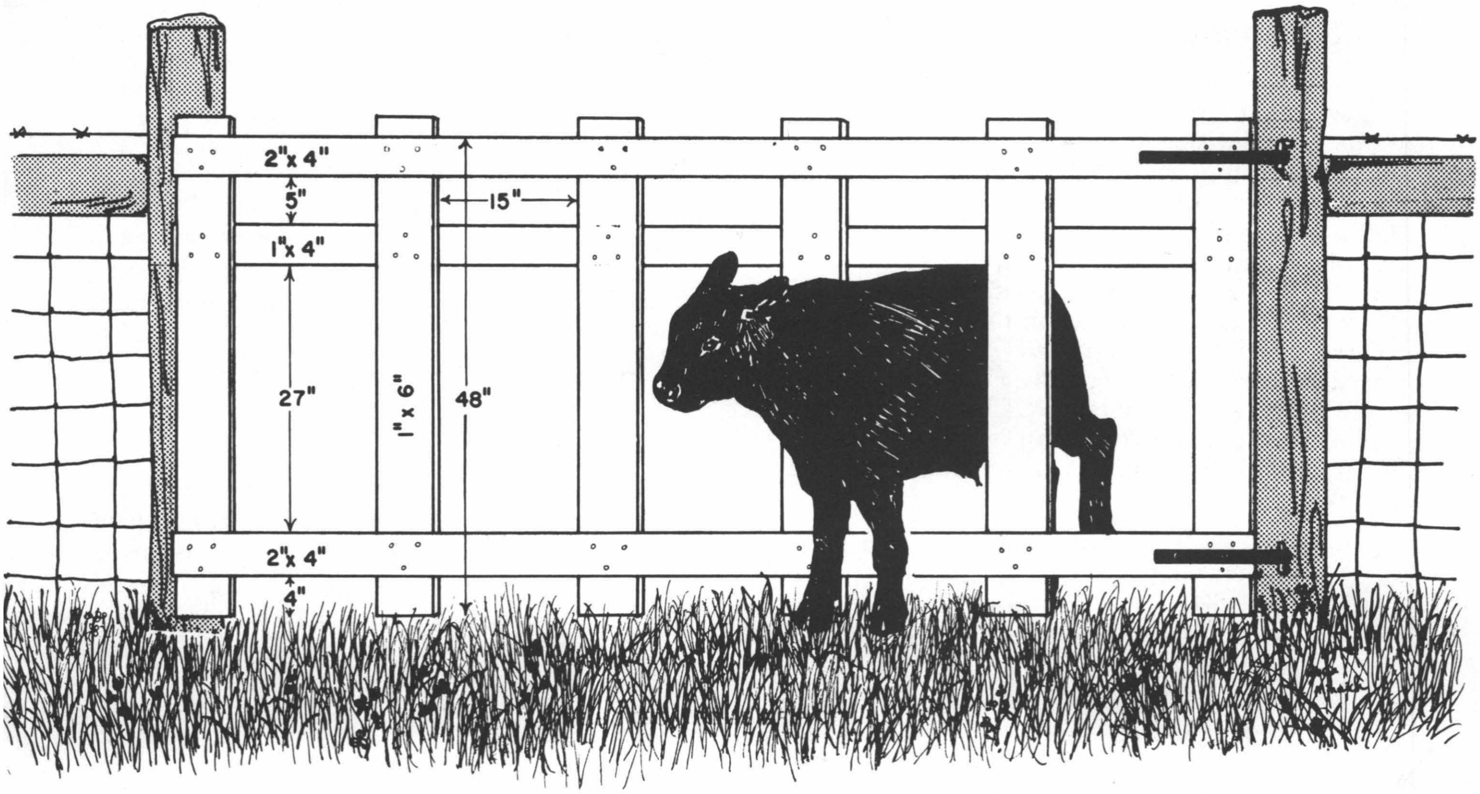


Figure 24. A 12-foot gate serves for creep grazing. The horizontal board just above the aperture restricts large ruminants. Calves up to 700 lb pass through the creep easily.

Several Middleburg experiments show that rapid growth of beef calves after they reach an age of about three months depends primarily on food other than milk, milk from mother cows giving small additional benefits.

In an experiment, cows with 3-month old calves were divided into two similar groups: a) calves were penned in a cool dry lot with water but without feed; and b) similar calves grazed with their dams. All cows grazed together. Cows were brought to the penned calves twice daily for nursing. During 42 days the calves restricted to milk from their dams lost 0.09 lb liveweight daily; calves with milk and pasture gained 1.78 lb daily. The a) and b) calves then grazed together until weaned. The calves restricted to milk for 42 days were 86 lb lighter at weaning than the nursing calves that had pasture and milk.

When AP or its quality is low in pastures grazed by cows with calves or ewes with lambs, creep grazing into a leafy pasture high in AP stimulates growth of calves or lambs. With creep grazing, animals select plant parts high in DDM and protein and low in fiber and lignin; hence, DDMI as described for first grazers increases.

Creep grazing will improve liveweight gains and weaning weights of nursing calves and lambs only under high stocking when a low AP limits selective grazing and DDMI. When cows and calves graze in a pasture with high AP, calves rarely pass through open creeps to graze an adjacent pasture. With limited AP, calves creep graze in an adjacent pasture for prolonged periods several times daily. Creep grazing becomes a natural interplay between cows and their calves with heavy stocking where forage is utilized efficiently. Creep grazing, an innovative "management tool," imposes high stocking and a variable to low AP for unresponsive cows without sacrificing liveweight gains per calf. Contrary to Figure 20, high stocking rates for cows with creep grazing for calves is a management giving both high gains per calf and high calf production per acre (Section III). Creep feeding (Section II.I), like creep grazing, will improve calf gains only when AP is low or when low forage quality inhibits DDMI.

II.H.6 Conclusions

At this stage the reader should have tools to analyze and understand the potentials of animal products per animal and per land area for grazing and utilization methods with mixtures or species. Excluding first and creep grazing, any grazing method can give the highest production per animal when quality and quantity of AP, knowingly or unknowingly, favor a specific system, grazing, or utilization method. Likewise, grazing utilization designated by dates can give biased and even incorrect data. For example, with rotational grazing where AP is ignored, as with grazing on date bases (grazing 7 days and resting 28 days among 5 pastures) will give invalid results because:

1. with poor forage utilization by a set 7-day grazing period leaving a high AP after shifting animals to the next pasture would over-estimate the production per animal and underestimate the production per land area;
2. if forage is utilized before the designated 7-day grazing period ends, a very low AP would cause a low output per animal, and production per land area could be low or even negative; also severe overgrazing, AP not controlled, suppresses regrowth and future dry matter production; and
3. rest periods after grazing vary because growth rates with seasonal environments and with plants vary.

When allowing excessive pasture (high AP), as is common with a constant stocking rate with continuous grazing during the spring season, and practicing good utilization with rotational grazing, ending with a low AP when animals are switched to a fresh pasture — ruminants with continuous grazing will obviously produce more per animal than for rotational grazing. However, animal products per acre will be low with continuous grazing because much of the forage will be wasted (very high AP).

When controlling the quality and quantity of AP, there is little difference in potential production per animal with rotational or continuous grazing (Figure 25). In practice, with continuous grazing it is necessary to allow excess AP because ruminants are restricted to one pasture. Conversely, with many subdivisions in rotational grazing, the grazier tends to force good utilization of each pasture, i.e., low AP. Thus, production per animal tends to be higher for continuous than rotational grazing during spring (Figure 25). With given AP's during the summer-fall season, the better leafy growth with rotational grazing usually causes slightly higher animal outputs than does continuous grazing.

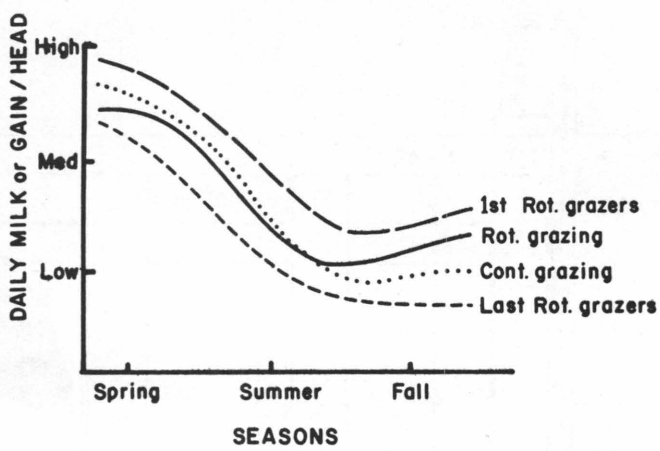


Figure 25. The potential production per animal with grazing methods and with grazing seasons. Animal production is directly related to quantity and quality of available pasture for each grazing method.

With special rotational grazing, first grazers can produce from 40% to 60% more per animal than last grazers depending on AP allocation. Ruminants needing high nutrition, such as high-producing milk cows, should be first grazers; less responsive animals should be last grazers. With silage and hay crops, frequent harvesting depresses yields but improves forage quality and output per animal; the reverse occurs with less frequent harvesting. Also, feeding excess hay that allows selective utilization of leaves that are highest in digestibility overestimates animal output; less than ad lib feeding would do the reverse.

With growth stage and AP control, expected outputs per animal are similar for rotational and strip grazing and for green chop. For a given mixture with ad libitum feeding of hay or silage, the outputs per animal would be lower than for any grazing methods except for last grazers.

The forage dry matter production potentials per acre are highest with judicious hay and silage harvesting, intermediate with rotational grazing, and lowest with continuous grazing. When comparing rotational and continuous grazing, the potential increases in dry matter above those for continuous grazing are small with morphologically short species and huge with tall erect species.

Creep grazing encourages high stocking by managing AP for good pasture utilization by cows while giving high liveweight gains per calf and per land area (Section III.E).

Controlling and allocating AP to supply the nutrition for classes of ruminants and horses should be incorporated into grazing systems and supercedes the number of pasture subdivisions.

II.I. Nutritional Needs of Ruminants

When perennial grasses and legumes are used, one or a combination of nutritional factors may deter production of ruminants, but insufficient energy intake (DDMI) is the primary deterrent and the most costly factor. Thus managing animals and forages concurrently for high quality and intake of forage is important. However, nutritional needs vary for classes of ruminants and for cycles of production. An awareness of the differing nutritional needs of animal categories and fulfilling the requirements through forage-animal management systems of production are imperative for profitability and for producing desirable products for consumers.

This section relates energy needs to potential responses of classes of ruminants and cycles of production and gives management practices that may be implemented into forage-animal systems.

II.I.1. Nutritional Needs of Beef Cows with Nursing Calves

The liveweight gains of calves from the age of about 4 months to around 8 months when weaned, and gains of their dams, each fed different rations, were evaluated in a series of experiments. Good milking purebred Angus cows, weighing about 1100 lb before calving and bred to calve in July to September, were managed as a herd for meat production. This breeding season was ideal to control and study the nutrition of cows and their nursing calves, which were fed separately during winter. Nursing calves were restricted to milk alone from the mother cow (dam) and supplemented with creep feed; calves were also weaned when 4 months old and fed like the nursing creep-fed calves. Cows were fed various amounts of alfalfa-orchardgrass hay. Rations were controlled by feeding given amounts of hay twice daily to cows while the calves were shut off in pens with or without creep feeding. The creep feed, generally a corn silage-protein mixture, was fed in small shelters with manger space for all calves to eat at the same time but not a large enough space to house the calves.

After weaning, the calves were used in grazing experiments and the cows grazed mainly bluegrass-clover pastures but also utilized residues that had been grazed by replacements. During late fall and early winter the cows grazed pasture residues and were fed restricted amounts of alfalfa-orchardgrass hay or silage. The calf gains were obtained without implants or growth stimulants. Although all experiments were done during the winter, housing was not provided. Cows and calves maintained excellent health, calf mortality was very low, and there was an average annual weaned calf crop of more than 90% during 20 years of July-September calving.

II.I.1.1. Milk From Dams Not Adequate for Calves

During two years the liveweight gains of nursing calves restricted to milk averaged 0.33 lb daily as compared to 2.0 lb daily with milk plus creep feed (Table 12, Figure 26). Similar calves, weaned when 4 months old and fed corn silage with protein and mineral supplements, gained 1.71 lb daily. These data with weaned or nursing calves during the age of 4 to 8 months show that the milk from cows provided enough energy for only about 0.3 lb liveweight gain per day. The nursing calves restricted to milk were healthy but thin and very hungry.

Other creep feeding experiments with weaned calves about 4 months old, supplemented with

Table 12. Nursing calves older than 4 months require food in addition to milk (2-year averages at Middleburg)*

Cow ration	Calf ration	Daily liveweight gains: Cows	Daily liveweight gains: Calves
Cows with nursing calves during 4 to 8 months**			
(a) Full-fed	Milk only	0.4 lb	0.33
(b) Full-fed	Milk and creep feed	0.6 lb	2.00
Weaned calves, 4 to 8 months old**			
(c) See Table 13	Creep feed only	----	1.71

*The cows were fed good alfalfa-orchardgrass hay; the creep feed was high quality corn silage and protein supplement.
**The experiment began when the average age of calves was 4 months and ended when the average age was 8 months.

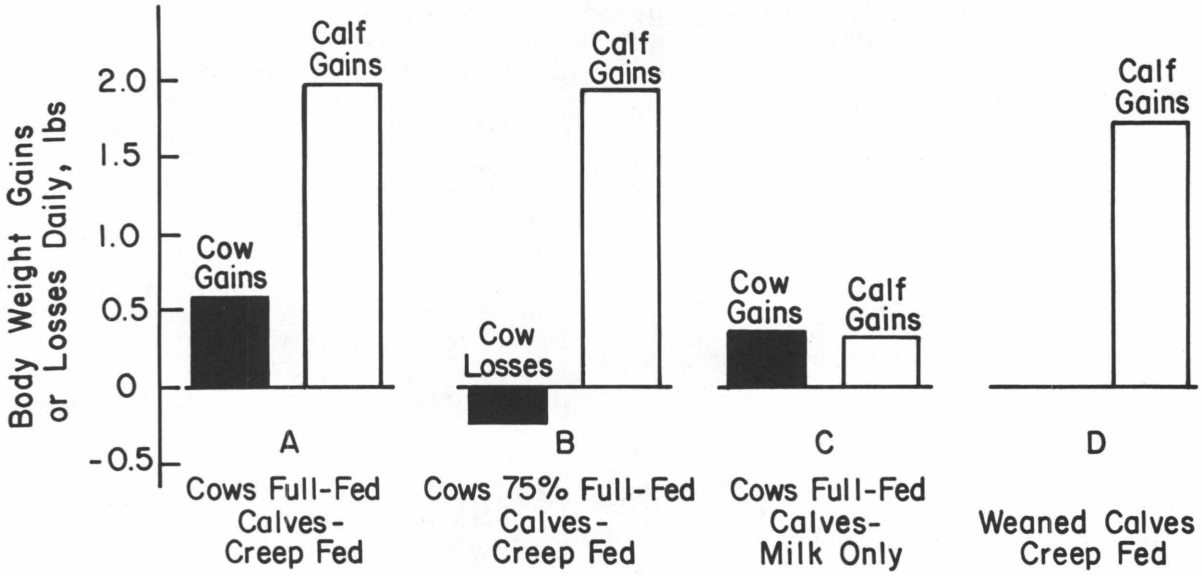


Figure 26. ***During 2 years at Middleburg nursing calves, 4 to 8 months old, gained 0.33 lb daily when restricted to milk, as compared to a 2 lb daily gain for creep-fed nursing calves. Similar calves, weaned and creep fed, gained 1.71 lb daily. Liberal feeding of the nursing cows did not improve calf gains.***

milk substitutes, gave liveweight gains equal to those of nursing calves with creep feed. Even though the milk from dams augments liveweight gains of 4-month old nursing calves by only about 0.3 lb daily, reducing the feed costs of cows by a low AP or restricted feeding makes nursing practical.

II.I.1.2. Good Calf Gains with Limited Feed for Cows

In a series of experiments, nursing cows were fed different amounts of alfalfa-grass hay during the period when nursing calves were about 4 to 8 months old. The calves were creep fed a corn silage-protein mixture. During 2 years, nursing calves gained about 2 lb daily when cows were fed full rations or 75% of full rations of good alfalfa-grass hay (Figure 26 and Table 12). In another 2-year experiment at Middleburg, cows fed 13 and 25 lb of hay (7 and 13.5 lb DDM) had daily liveweight losses of 1.2 lb and gains of 0.5 lb per day. Whether cows lost as much as 250 lb or gained up to 90 lb during the experiment did not influence the gain of creep-fed nursing calves.

During five successive years, cows at Middleburg were restricted to 13, 16, and 20 lb of alfalfa-grass hay daily (7, 9, and 11 lb DDM) after calves were about 4 months old until weaning at 8 months (Table 13 and Figure 27). After weaning the calves, the cows grazed bluegrass and other pastures at a medium AP by high stocking rates. After about three months of grazing, the cows that had been subjected to low or medium amounts of hay were similar in condition.

Conception rates, percent weaned calves, birth weights, and weaning weights were similar for the three hay-feeding rates of dams. The calves creep-fed on a corn-silage protein mixture gained about 2.0 lb daily and were fat, weighing 500 to 600 lb when weaned. The milk production per cow was highest (7 lb daily) when fed 20 lb and lowest (5.2 lb daily) when fed 13 lb of hay daily. The calves ate more creep feed to compensate for declines in milk production.

Note that weight losses of cows attributed to low energy intake, obtained by feeding good quality legume grass hay, maintained excellent health. Also, the nutrition of cows was managed (1) to supply good nutrition during about one month before calving until 4 months after calving to encourage milk flow for young nursing calves and to stimulate estrus, and (2) to impose low energy intake of cows after conception and during the age period when calf gains depend primarily on food other than milk.

Many farmers and agriculturalists wrongly associate heavy weaning weights of calves with high nutrition for cows obtained from lax grazing (high AP) to stimulate milk production during

Table 13. Low energy rations for cows do not restrict growth of 4 to 8 month old creep-fed calves (2-year averages at Middleburg)

Amount of good legume hay daily, lb*	Daily liveweight gains, lbs — Cows with nursling calves: cows lb	calves lb	Gains of dry cows calves weaned at 4 months lb
13	- 1.2	+ 2.1	- 0.1
16	- 0.5	+ 2.1	+ 0.4
20	- 0.1	+ 1.9	+ 0.8
Full fed	+ 0.5	+ 2.0	

*Hay at 13, 16, and 20 lb per cow daily is equal to 7, 9, and 11 lb of DDM or TDN daily.

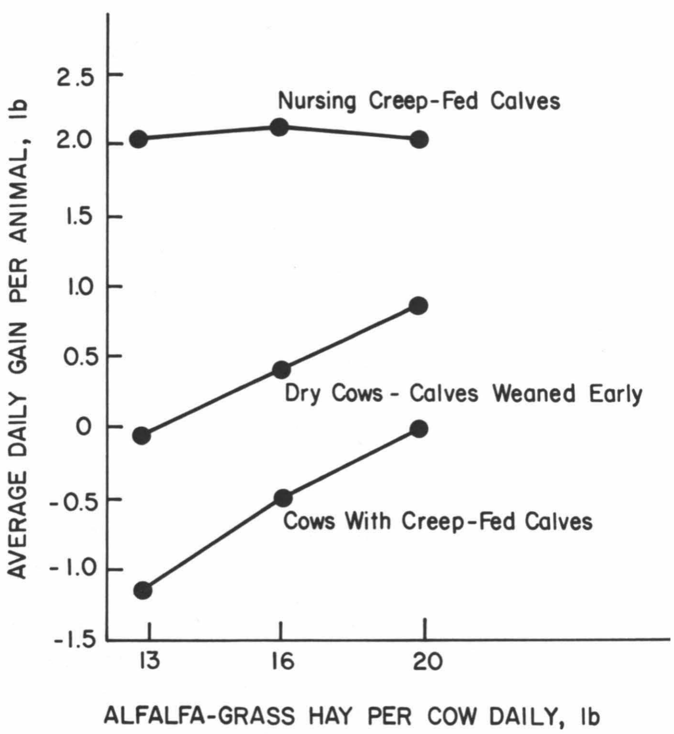


Figure 27. Liberal feeding of beef cows did not improve liveweight gains of 4 to 8 month old nursing calves with creep feed during 2 years at Middleburg. Dry cows thrived on lower nutrition than nursing cows.

entire nursing periods. Such high weaning weights should be attributed to the high AP and pasture intake by the calves rather than additional milk produced by cows.

Cows with calves weaned at 4 months maintained their body weight when fed 11 lbs of alfalfa-grass hay daily (7 lb DDM); similar nursing cows on the same diet lost around 1.2 lb per day (Figure 27 and Table 13). These data suggest that early weaning of calves might be a good practice to reduce forage requirements in case of a very low forage supply due to unexpected adverse environments.

Data from other locations show:

1. that nursing calves grazing good pastures with their dams sustain high daily gains even though the daily milk flow declined progressively and rapidly with age of calves; and
2. beginning at about four months after calving, the milk production per cow of various beef breeds, including dairy crosses, was not improved by high nutrition and was inadequate for high calf gains.

II.I.1.3. Efficiency in Converting Forage to Calf Production

Restricting the energy intake of cows from pasture or other forage during designated cycles of production, with liberal and high quality forage feeding of calves, increases conversion efficiency, i.e., gives higher calf weight production per unit of feed or per acre of pasture.

In a series of experiments from about 4 months after calving until 8 months at weaning, cows with nursing calves were fed forage with different systems. Alfalfa-orchardgrass hay was fed to cows alone or to cows and calves together; and a creep feed of a corn silage-protein mixture was fed ad libitum to other calves.

System A - When full feeding alfalfa-grass hay to cows and calves together, when calves were about 4 months old until weaned, a cow and calf ate about 30 lb of alfalfa-grass hay (16.2 lb DDM) daily. The nursing calves without creep feeding gained 1.4 lb and the dams gained 0.3 lb daily. Each lb of calf gain required 22 lb of hay, 12 lb DDM. The full feeding of hay to cows and calves eating together gave a low efficiency of converting forage to calf production because alfalfa-grass hay restricted DDMI of calves and their gains; hay gives lower DDMI than pasture or a corn silage-protein mix. Also, calves could not compete with cows for the leafy parts of hay; hence, the cows with liberal hay feeding were excessively fat.

Systems B and C - The creep-fed calves also had access to the hay fed to cows. The daily alfalfa-grass ration was a moderate rate of 20 lb hay (11 lb DDM) for System B and a high 36 lb rate of hay (20 lb DDM) daily per cow and calf for System C. The cows lost 1.0 lb and gained 0.2 lb daily, respectively. The gains of calves in the two systems were similar, being 1.90 to 1.98 lb daily. The energy required to produce 1 lb calf gain was 7.3 lb DDM and when feeding 20 lb of hay (System B) as compared to 11.9 lb DDM with 36 lb of hay daily (System C).

Systems D and E - The cows were fed restricted amounts of hay twice daily while the calves had creep feed all of the time but were penned to their creep feeding areas of corn silage and protein while the cows ate. With System D at a moderate rate of 20 lb hay (11 lb DDM) and System E at a low rate of 13 lb hay (7 lb DDM) daily per cow, the cows lost 0.11 and 1.11 lb daily for these moderate and low rates of feeding hay. The daily gains for the creep-fed calves were 2.06 and 2.04 lb for the two systems. Converting forage into gains of nursing creep-fed calves was improved by restricting the hay fed to the nursing cows; it required 6.4 lb DDM per lb of calf gain when cows were fed 13 lb of hay daily as compared to 8.1 lb DDM when cows were fed 20 lb of hay daily.

Converting forage into gains of nursing calves was almost doubled by creep feeding a high quality corn silage-protein mixture along with restricted hay feeding to dams (System D) as compared to ad libitum hay feeding to cows and calves eating together in System A. System B, in principle, is similar to good creep grazing management:

1. Restricting the amount of hay per cow and calf is similar to controlled stocking to medium-low AP.
2. With restricted forage intake of cows, creep feeding a high quality corn silage-protein mixture is similar to creep grazing leafy grass-legume pasture high in AP; either augments DDMI, rate of gain, and conversion efficiency (amount of calf gain per unit of forage eaten by a cow and her nursing calf).

Body weight losses of nursing beef cows by restricted feeding of good hay or a low AP of grass-legume mixtures of temperate zone plants are caused by a low energy intake, less than needed for maintenance. Because digestibility and protein, minerals, and vitamin contents in such diets are of good nutrition, the cows had good longevity, health, and conception even when losing up to 250 lb of liveweight during a designated production cycle and giving a better than 90% raised calf crop year after year.

II.I.2. Nutritional Needs of Ruminants and Horses Differ

The varying nutritional needs of animals are generally recognized, but the possibility of supplying the nutritional needs by controlling AP is usually ignored. Insufficient energy intake, DDMI, is the primary factor that limits milk production of dairy cows or liveweight gains of ruminants and horses consuming perennial grass-legume forage in temperate regions. To sustain high milk production of dairy cows or near maximum liveweight gains of lambs, calves, and young cattle and horses on perennial forage diets, it is necessary to feed energy supplements such as cereal grains or high dry matter corn silage from grain varieties.

Classifying ruminants and horses on the basis of energy requirements is useful for designating, controlling, and allocating the needed nutrition by managing AP and designating the need of supplementing grain. With perennial grasses and legumes, good grazing management provides higher DDMI than good forage storage practices, the latter being depressed in quality by growth stage (stemminess) and by nutrient losses while harvesting and during storage. With growth stage and species controlled, energy intake by grazing depends on AP, being highest with first grazing, creep grazing, or low stocking of productive pastures. Low AP and low DDMI occur with high stocking and last grazers. Stocking rate does not designate a given AP but controlled AP designates the stocking rate.

Animal forage systems, where AP is controlled, can furnish the needed nutrition of most ruminants, without grain supplements. Categories of ruminants and horses, based on energy needs for efficient production, are:

1. high-producing milk cows — very high, energy supplements needed;
2. calves, lambs, and young growing horses — very high energy;
3. ewes and mares — variable medium to low energy;
4. beef cows — variable medium to low energy, medium from about a month before to 4 months after calving, thereafter low;
5. replacement heifers and stockers — medium to high energy; young ruminants require better nutrition than older ones; and
6. finishing cattle for slaughter — high energy needs; energy supplements improve liveweight gains and shorten the period to attain a given carcass quality.

To supply the differential nutritional needs of ruminants by the grazing phase of animal-forage systems, it is important to associate DDMI with the quality and quantity of AP. With leafy grass-legume pasture, AP has a direct linear relationship with DDMI, plateauing at a very high AP (Figure 28). Thus, the variable energy needs for ruminant categories and for cycles of production should be furnished by controlling AP and supplementing when AP cannot supply the nutrition to sustain production. Providing the nutritional needs of different ruminants is associated with AP as controlled by grazing methods, management, growth stage and species of plants, and quality of hay and silage. For example, grain feeding of high-producing milk cows can be reduced by implementing first grazing, dry stock and low producers being last grazers. Animals being finished for slaughter may be first grazers, replacements being last grazers.

The grazier is challenged to manage the AP of perennial grasses and legumes to maintain high quality, high yields and legumes, and good season distribution of forage and to compromise production per animal and per acre (Figure 20) while furnishing the nutrition of classes of ruminants and horses (Figure 28).

II.J. Hay and Silage Crops

The uneven seasonal growth and little or no growth during the 3 to 5-month winter season in Virginia and the Mid-Atlantic states (Figure 16) make it practical to harvest perennial grasses and legumes during flush growth to feed ruminants and horses when there is little grazing. Small grains, corn, sorghum, and other annuals grown on soils with little erosion or in rotations with perennials and harvested as hay, but mainly as silage, are desirable parts of forage-animal management systems. Land with gentle slopes, not subject to erosion, may be double cropped with two annuals per year continuously to augment forage production. For example, barley or wheat seeded after harvesting corn or grain sorghums for silage may be grazed or harvested for silage in spring. No-till corn or sorghum planted immediately after harvesting small grains usually give high yields.

The nutritional value, animal performance, and yield potentials from harvested annual and perennial crops are discussed in this section.

I.J.1. *Perennial Grasses and Legumes*

The quality of hay or silage depends on growth stage, but yield and quality must be compromised as discussed earlier. Young leafy growth, if wilted, produces good silage. For example, yearling steers fed spring-harvested unwilted silage from a mixture of orchardgrass in a boot stage and alfalfa in prebloom gained 0.64 lb daily as compared to only 0.23 to 0.28 lb daily when orchardgrass was in full bloom and alfalfa in 0.1 bloom (Table 14). Steers gained 0.69 lb daily when fed summer-grown hay, when alfalfa was in 0.1 bloom and orchardgrass was leafy. The leafy as compared to the stemmy harvest causes higher energy intake. Animals consumed more forage as digestibility increased, except for high-moisture silage.

The average liveweight gains of steers eating alfalfa-grass hay or silage were doubled or tripled by supplementing an energy feed of 3 lb ground ear corn daily (Table 14). Leafy perennial forages are high in protein and medium in energy value; thus energy rather than protein supplements augment animal production with such forages.

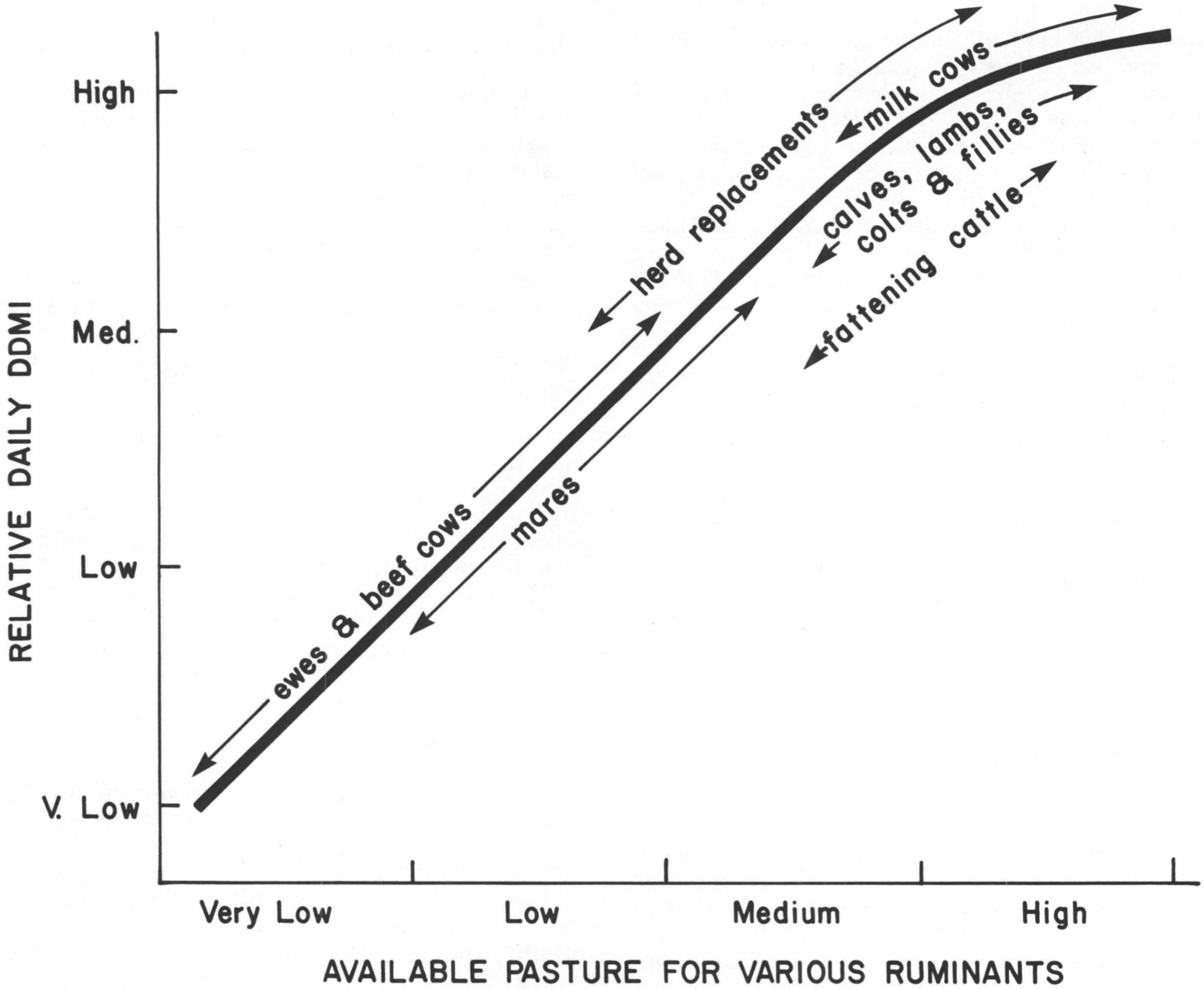


Figure 28. For leafy pasture, energy intake by horses and ruminants (DDMI) is directly related to available pasture (AP). Thus AP should be managed to furnish the energy needs of various ruminants and production cycles.

II.J.2. Wilted Silage and Animal Production

Grass-legume mixtures contain about 80% water when harvested in spring. Thus, in another experiment (Table 15), alfalfa-orchardgrass mixtures cut when the grass was heading and alfalfa was in a prebud stage produced a 23% dry matter silage. Animals fed this unwilted silage gained only 0.30 lb daily even though the digestibility (59% DDM) was high. The same mixture (59% DDM), harvested on the same day, wilted in the field to give a silage with 40% dry matter, gave daily gains of 1.1 lb., almost 4 times more than for the low dry matter silage. With a little wilting to 27% DM of this early spring-harvested silage, the steer gains were more than doubled as compared to unwilted silage (Table 15). As dry matter of ensiled forage increases to around 40%, fermentation processes and silage quality apparently improve, causing animals to consume more silage dry matter. For example, increasing the dry matter from 23 to 40% by wilting increased the daily dry matter intake 50% (Table 15).

Table 14. Daily gain, intake, and digestibility of alfalfa-orchardgrass hay and unwilted silage harvested at different growth stages and fed to steers with and without grain (2-year averages at Middleburg)

Feed*	Daily gains: No grain	Daily gains: 3 lb ground ear corn	DM intake per steer, daily: No grain	DM intake per steer, daily: 3 lb ground ear corn	Digestibility DDM
	lb	lb	lb	lb	%
A. Alfalfa prebud, orchardgrass heading					
Unwilted silage	0.64	1.17	11.0	11.7	59
B. Alfalfa 0.1 bloom, orchardgrass in full bloom					
1) Unwilted silage	0.23	0.69	10.2	11.4	52
2) Hay	0.28	0.73	10.6	11.3	50
C. Alfalfa 0.1 bloom, orchardgrass leafy					
Hay	0.69	----	11.5	----	56

*A and B were first growths in spring and C was summer growth when grass is leafy.

Table 15. The influence of dry matter content and growth stage of orchardgrass-alfalfa silage on digestibility, intake, and daily gain of steers (2-year averages of spring growths at Middleburg)

Treatment before ensiling	Dry matter in silage	Digestibility	DM intake daily per steer	Daily gain
	%	%	lb	lb
Orchardgrass heading, alfalfa in prebloom				
Not wilted	23	59	10.7	0.30
Some wilting	27	59	11.4	0.73
Wilted	40	59	16.1	1.10
Orchardgrass in late bloom, alfalfa .01 bloom				
Some wilting	30	52	10.1	0.23

Harvesting when alfalfa was in 0.1 bloom and orchardgrass was in late bloom, with a little wilting before ensiling and a rather favorable dry matter of 30% due to late maturity, gave low animal gains (0.23 lb daily) attributable to a reduction in digestibility causing low DDM intake (Table 15 and Figure 5).

Feed intake and animal gains from alfalfa-orchardgrass hay or silage are improved by supplementing ground ear corn (energy) or corn silage (Table 16). Steers fed unwilted, high moisture alfalfa-grass ensiled in early spring gained only 0.14 lb daily due to a low intake. Even when feeding such high-moisture silage harvested

Table 16. Intake and liveweight gains of steers fed alfalfa-orchardgrass hay or silage alone and supplemented with energy feeds (2-year averages at Middleburg)

Hay and unwilted silage crops*	Average initial weights of steers	Feed consumed daily per steer		Daily gains per steer
		As fed	Dry matter	
	lb	lb	lb	lb
A. Alf-grass silage, E. spring harvest				
1. Alf-grass silage alone	611	31.9	8.6	0.14
2. Alf-grass silage and	629	38.4	8.8	1.15
ground ear corn		4.0	3.4	
3. Alf-grass silage and	612	30.3	6.8	1.20
corn silage 50:50		19.4	6.7	
B. Alf-grass silage, 4th harvest				
1. Alf-grass silage	612	45.3	13.6	0.69
2. Alf-grass silage and	619	44.0	12.8	1.57
ground ear corn		4.0	3.4	
3. Alf-grass silage and	621	30.0	8.0	1.62
corn silage		26.8	8.0	
C. Alf-grass hay, 2-4th harvest				
1. Alf-grass hay	609	17.8	13.9	0.97
2. Alf-grass hay and	609	15.1	12.0	1.34
ground ear corn		4.0	3.4	
3. Alf-grass hay and	615	8.7	6.5	1.41
corn silage 50:50		24.9	7.8	

*A - Alfalfa-orchardgrass was ensiled without wilting when orchardgrass was heading and alfalfa in prebloom; B - the 4th growth was ensiled without wilting when alfalfa was in bud to early bloom and orchardgrass leafy; C - typifies 2nd-4th cutting when alfalfa was in 0.1 bloom and orchardgrass leafy.

in spring with grain or 50% of the ration as corn silage, the daily gains were low (1.15 to 1.20) as compared to gains of 1.57 to 1.62 lbs with 4th harvest silage fed with supplements. Early first and 4th silage harvests were both leafy and around 60% DDM; the low dry matter of the spring-harvested silage caused low intake and low animal gains as compared to the 4th harvest. The higher daily gains of 0.97 lb daily for steers fed only alfalfa-grass hay than for steers fed either of the two alfalfa grass silages is attributed to less DDMI for the silages high in moisture. When supplementing ground ear corn or corn silage, feed intake and gains were higher with alfalfa-grass silage than for hay.

It is concluded that energy supplements to perennial grass-legume silage or hay diets improve output of responsive ruminants. Also, wilting of hay crop silages to about 40% dry matter improves intake and liveweight gain. However, grass-legume hay and silage crops, with good management, provide adequate nutrition for replacements and dry and nursing beef cows.

II.J.3. Corn Silage, A High Energy Forage

During 30 years of research at Middleburg, high yielding grain varieties of corn harvested in a hard dent stage have invariably produced excellent silages, giving high outputs by milk cows, replacements, cattle being fattened, and nursing and weaned beef and dairy calves. Such corn silage, high in digestibility and intake, is a high energy silage needing only protein and mineral supplements for fattening cattle. Likewise, when adapted, corn silage should be a primary forage ration for young cattle and high-producing dairy cows. To make high quality corn silage, keep the knives sharp to clean-cut short pieces to improve packing and fill silos quickly.

At Middleburg steers fed corn silage supplemented with protein gained 2.6 lbs daily during 140 days, producing choice carcasses (Table 17). Steers fed a high grain ration, 13.4 lb ground ear corn daily supplemented with protein, gained 2.7 lb daily, carcass quality being similar to steers fed only corn silage supplemented with protein. Conversion of feed to gain was similar, requiring 5.5 and 6.3 lb DDM per lb gain for the corn silage and the high grain ration, respectively. Savings in feed costs were more than $4.00 per 100 lb gain for the corn silage. The nutritive value of the silages (Table 18) shows similar digestibilities for the two rations: 71% for corn silage and 73% DDM for the grain ration.

Table 17. Corn silage supplemented with protein compared to a high grain ration for fattening steers (2-year averages at Middleburg)

Data	Corn silage with protein	Grain fattening ration
Initial wt. per steer, lb	669	655
Final wt. per steer, lb	1017	1020
Daily gain, lb	2.6	2.7
Daily feed per steer, lb		
Corn silage	41.0	15.0
Alfalfa-orchardgrass hay	---	2.0
Ground ear corn	---	13.4
Cottonseed meal	3.9	3.1
DDM per lb gain, lb	5.5	6.3
Dressing, %	57.6	58.7
Carcass grade*	11.9	12.6

*Code: 11 = high good; 12 = low choice.

Table 18. The composition and digestibility of corn silage and a fattening ration fed to steers at Middleburg

	Crude protein	Ether extract	Crude fiber	Digestibility, %
	--------- Composition, dry basis, % --------			
Corn silage	8.4	3.0	21.8	71
Fattening ration	13.8	2.9	17.9	73

A grain variety of corn, ensiled in a glazed hard dent stage, was fed to steer calves born in winter and weaned in November, with each of three grain rations (0, 6.3 and 12.3 lb) daily. All steers were fed cottonseed meal at the rate of 2.4 lb daily per animal. The experiments began soon after weaning. The steers fed corn silage supplemented with cottonseed meal gained 2.02 lb daily as compared to 2.16 and 2.25 lb when supplementing with the medium and high grain rations (Table 19). Supplementing grain increased the efficiency of converting feed to liveweight gains and improved the carcass grades a little. However, there was a marked difference in feed costs per 100 lb gain, costs being $4.60 less for the no grain than the high grain ration.

High energy corn silage rations with four rates of supplementing protein (cottonseed meal) increased liveweight gains and feed conversion efficiencies as cottonseed meal was increased to 2.7 lb daily (Table 20). The highest rate of supplementing cottonseed meal, 4.2 lb daily, tended to increase daily gains but did not improve feed conversion efficiency. The low choice carcass grades and dressing percentages were similar for low and high rates of supplementing protein.

The principles for making and feeding high energy silages from the best grain varieties of corn are summarized in Figure 29 and Table 21. The condition of developing corn grains expresses growth stage or maturity. The successive changes in maturity of grain from milk to dough to dent stages are accompanied by dramatic increases in yield (Figure 29). After reaching the hard glazed dent stage, plants make only small increases in yield. As the grain develops and matures, the dry matter percent of corn plants increases sharply since ears (grain and cobs) are higher in dry matter percent than stems or leaves. Except for leaves that are dead, stems and leaves remain high in moisture content. Husks (cover of ears) and tassels (male inflorescence) also increase rapidly in percent dry matter as plants mature.

Digestibility (DDM %) of corn plants, even in forage before ears develop, is very high, but the yield is low and water content high, about 80%. As corn plants pass from a milk stage through mature grain, the digestibility declines slightly, only 2 to 4 percentage units (Figure 29). These small reductions in digestibility are attributed to low digestibilities and increasing amounts of husks, tassels, and cobs as plants mature.

Voluntary dry matter intake of corn silage is high at all growth stages, but increases rapidly as plants mature, peaking at a glazed-hard dent stage, when silage dry matter is about 42% (Table 21 and Figure 29). Daily liveweight gains,

Table 19. Results when feeding corn silage supplemented with different amounts of grain to steer calves (averages of four 195-day trials at Blacksburg)*

Data	Grain feeding		
	None	Half full feed	Full feed
Initial steer wt., lb	511	517	515
Daily gain, lb	2.02	2.16	2.26
Daily gain, lb per steer			
Corn silage	40.3	30.4	18.1
Cottonseed meal	2.4	2.4	2.3
Grain	0	6.3	12.3
Feed per lb gain, lb			
Corn silage	20.1	13.8	8.1
Cottonseed meal	1.2	1.1	1.1
Grain	0	2.9	5.5
Carcass grade**	12.0	12.6	12.6

*The low gains are attributed to the small animal weights and not administering stilbestrol. The grains were a mixture of ground ear corn and barley for 2 years, the same with a little hay during 1 year and ground ear corn during the other year.
**Code: 12 = low choice, 13 = average choice.

Table 20. Liveweight gains, feed intake, conversion efficiency, and carcass characteristics of steers fed corn silage with rates of supplementing protein (2-yr averages at Middleburg)

Dig. protein, % (air day basis)		6.0	7.5	9.6
Cottonseed meal, per day	0	1.5	2.7	4.2
Initial wt., lb	658	680	652	668
Final wt., lb	986	1078	1079	1116
Daily gain, lb	2.0	2.54	2.72	2.85
Daily feed, lb				
Silage	43.1	48.8	47.1	46.0
Cottonseed meal	0	1.5	2.7	4.2
DDM per lb gain, lb	8.16	7.99	7.58	7.58
Carcass grade*	11	12.5	12.5	12.3
Dressing, %	55.3	57.3	57.1	57.9

*Code: 12 = low choice; 13 = average choice.

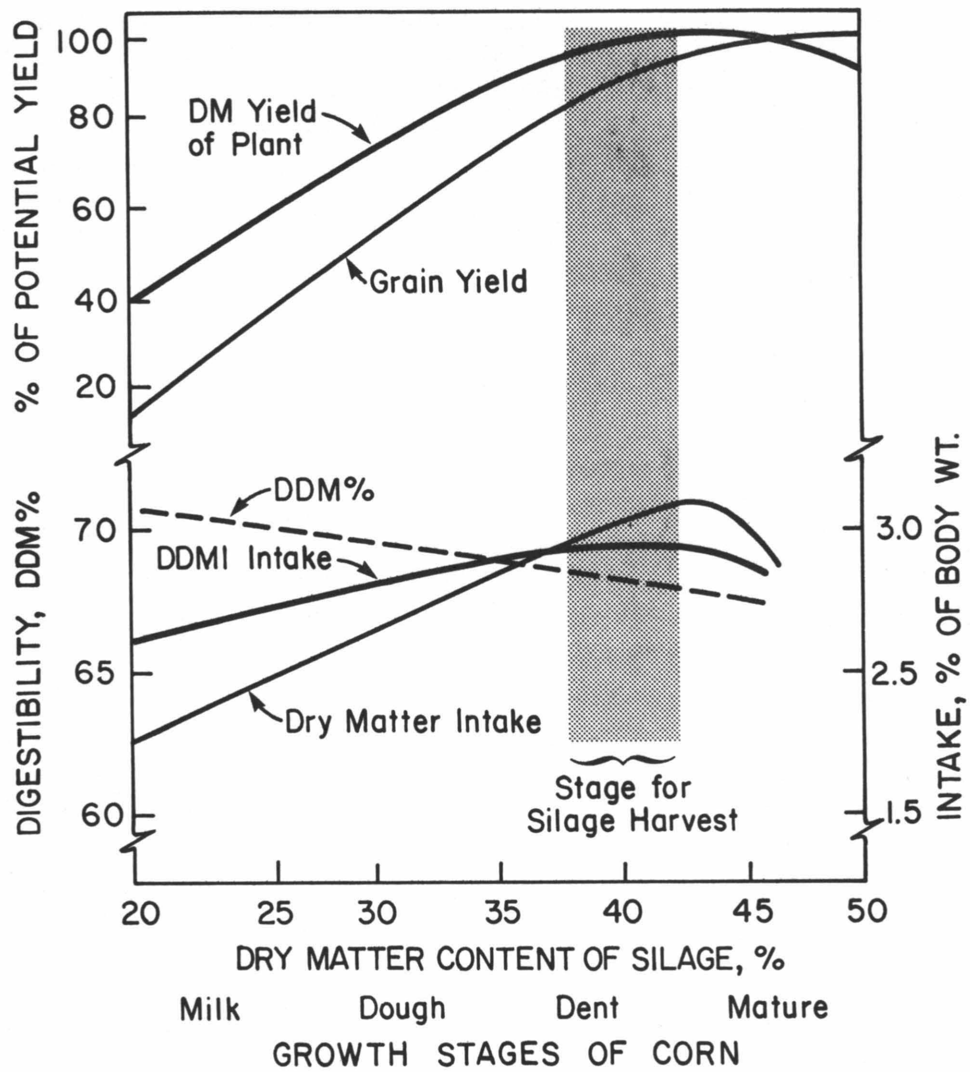


Figure 29. Ensiling a grain variety of corn in a hard dent stage when yields are high and about 40% in dry matter makes a high energy silage because high digestibility and intake (DDMI) cause high animal outputs. Fortunately corn silage harvested when yield is at a near maximum also produces the best silage.

conversion efficiency, carcass grade, and dressing percent are also highest for silage harvested at the advanced maturities. A magnificent biological and economic relationship shows that corn silage harvested at a glazed hard dent stage, when yields are nearly at a maximum, produces a high energy silage for ruminants because of the concurrent desirable effects of high consumption and digestibility (DDMI). It is recalled that, with herbaceous perennial grasses and legumes, digestibility, intake, and animal output decline drastically as yields increase and plants mature (compare Figures 5 and 29).

II.J.4. Sorghum and Small Grains

Because of frequent periods of moisture stress during warm summer temperatures, as in the Central Piedmont, sorghum is better adapted than corn. Also when double cropping where a summer annual follows a winter annual small grain, sorghum may produce more dry matter than a late planting of corn.

The winter annual small grains grow during favorable moisture periods when there is usually a low forage supply. Rye produces the most dry

Table 21. Stages of growth (maturity) of corn plants influence the dry matter percent of silage and feed intake and performance of steers (2-year average for 140-day period at Middleburg)

Animal data	Growth stages and silage dry matter, % Milk stage 26% DM	Hard dent 42% DM	Advanced dent 48% DM
Initial wt., lb	704	691	678
Daily gain, lb	2.22	2.60	2.49
Daily dry matter intake, lb	16.1	19.8	19.6
Dry matter per lb gain, lb	7.3	7.6	7.9
DDM per lb gain, lb	4.9	5.1	5.3
Carcass grade	Good	Choice-	Good+
Dressing percent	56.0	58.3	57.4

*The silages were supplemented with a urea protein mixture.

matter during the low temperature fall-spring season and reaches a silage or hay harvesting stage earlier in spring than barley, wheat being latest. Small grains may be grazed during the fall-spring season or harvested for hay or silage. Near full-season yields of corn or sorghum silage may be obtained, if no-till plantings after small grains are made in May.

II.J.4.1. Sorghum Silage

Animals were fed corn silage to compare with short 4-ft and tall 8-ft grain varieties and a tall 14-ft forage sorghum (male sterile, no grain); each silage was fed alone with 1.5 lb of protein supplement per animal daily and with protein plus ground ear corn at 1% liveweight (Table 22). The daily liveweight gains with the respective silages plus protein were: 1.84 lb for corn silage, 1.78 lb for 4-ft grain sorghum, 1.61 for 8-ft grain sorghum, and only 0.51 lb daily for forage sorghum. The dry matter requirements per lb liveweight gain for the silages were: 8.7 lb for corn silage, 10.1 lb for 4-ft grain sorghum, 10.2 lb for 8-ft grain sorghum, and 21.7 lb silage dry matter per lb gain for the forage sorghum. The carcass grades were good+ for the corn and short grain sorghum, good for the tall grain sorghum silage, and standard for animals fed forage sorghum with protein. Carcass dressing percentages were highest, 59%, for corn silage and lowest, 54.7%, for animals fed forage sorghum silage.

Feeding ground ear corn daily at 1% of bodyweight (averaging 7.3 lb daily per animal) caused small increases in liveweight gains with corn silage and large increases with the forage sorghum; the percent increases as compared with no grain feeding were: 6.5 for corn silage, 11.8 for 4-ft grain sorghum, 16.7 for 8-ft grain sorghum and 269% for steers fed the 14-foot forage sorghum. Even when eating 14.2 lb ground ear corn daily with the forage sorghum, the animals gained only 1.61 lb daily as compared to 1.84 lb daily for animals fed corn silage without grain. The lower daily liveweight gains of animals fed corn silage than for other experiments are attributed to small animals—weanlings and yearlings—and to half of the animals being heifers; also, growth stimulants were not fed.

In another experiment sorghum silages from a bird-resistant grain variety gave similar liveweight gains as for animals fed a non-bird-resistant grain sorghum.

It is concluded that forage sorghum produces the highest dry matter yield but a silage not acceptable for responsive ruminants that require high energy intake. Short grain varieties of sorghum with more than half of the dry matter composed of grain make better energy silages than taller grain types. The yield potential of short grain varieties of sorghum could be increased substantially by high plant populations, achieved by narrow rows. Although lower in yield than corn, short-high grain varieties of sorghum should replace corn for silage where the latter is not well adapted or for late planting.

Table 22. Performance of young cattle during 140 days fed various silages, supplemented with protein or protein and ground ear corn (Middleburg silage crops produced in 1973 and 1974)*

	Silages with and without ground ear corn								
	Corn silage		Grain silage 4 ft. high		Grain sorghum 8 ft. high		Forage sorghum 14 ft. high		
Silage and Animal Data	No Grain	1% Grain	No Grain	1% Grain	No Grain	1% Grain	No Grain	1% Grain	2% Grain
Silage, dry matter %	39.1	39.1	35.2	35.2	30.5	30.5	29.1	29.1	19.1
Silage digestibility, DDM %	67.0	67.0	59.5	59.5	56.7	56.7	56.2	56.2	56.2
Ground ear corn daily, lb	0	7.3	0	7.5	0	7.4	0	7.0	14.2
Silage intake daily, lb	37.8	24.1	47.3	35.2	50.3	33.7	33.3	27.2	12.1
Daily liveweight gain, lb	1.84	1.96	1.78	1.99	1.61	1.88	0.51	1.37	1.61
Dry feed per lb gain, lb	8.7	8.7	10.1	10.1	10.2	9.8	21.7	11.0	10.5
Carcass grade**	G+	G+	G+	G+	G	G+	S+	G	G+
Dressing, %	59.0	59.3	56.4	58.2	57.8	57.8	54.7	54.7	61.0

*The animals for all rations were fed 1.5 supplement (89% cottonseed meal and 11% urea); grain was ground ear corn at 1% of bodyweight, averaging 7.3 lb per steer daily.

During each year there were 27 animals (9 lots with 3 animals each) in each of two replications, one with steers and one with heifers; for steers 27 were yearlings and 27 were weanlings (calved in January-March and weaned in spring), and for heifers 18 were yearlings and 36 were weanlings. The average initial weight per animal during two years was 597 lb.

**G = good; S = standard.

II.J.4.2. Small Grains for Silage

The influence of growth stage on digestibility as related to morphology of small grains when harvested is similar to that of perennial forages (compare Table 23 and Figure 5); however, digestibility declines less with maturity than for perennial grasses and legumes. The digestibilities of small grains in leafy morphologies (not shown) are around 70% DDM. In an experiment where silage harvests began with a boot stage, the digestibilities of wheat and rye declined sharply as harvests were delayed to bloom and soft dough stages of growth; barley was highest in digestibility at the boot stage but similar and lower at bloom and soft dough maturities (Table 23). As maturity advanced, rye declined more rapidly in digestibility than did barley and wheat because stems made up larger portions of the dry matter yield than for the other small grains. Rye stems apparently decline very rapidly in digestibility as plants mature because nonstructural carbohydrates in stems decline as seedheads form.

Dry matter consumption for each of three winter annual small grain silages was higher in the boot than the bloom stage (Table 23). However, dry matter intake was higher in the soft dough than the bloom stage of rye and similar for boot and dough stages of barley silages. The intake data among maturities are likely confounded with percent dry matter of the ensiled small grain crops; the high consumption at dough stage harvests is probably associated with better fermentation due to the high dry matter in the silage. Dry matter percent increases with maturity for all small grains.

Grain varieties of corn, sorghum, wheat, and barley ensiled in a hard dough stage, and rye in a 50% heading stage, were fed to cattle with a cottonseed meal-urea supplement (Table 24). The silages and daily liveweight gains of cattle were: corn, 2.30; grain sorghum, 2.08; wheat, 1.50; barley, 1.34; and rye silage, 0.86 lb daily gain. The efficiency of converting silage dry matter was associated with liveweight gains; for example, 6.1 lb more dry matter was needed per lb gain with rye than with corn silage. The best carcass grades occurred with corn and grain sorghum silage and the poorest with rye silage.

When the small grains were supplemented with grain (6.6 lb ground ear corn daily), the daily gains, averaged for the small grains, were increased from 1.23 to 2.28 lb; adding grain to diets of cattle fed grain sorghum caused only a small increase of 0.12 lb in daily gain (Table 24).

Table 23. The digestibility and intake of small grain silages ensiled at different growth stages without wilting at Middleburg (data are 2-year averages, except for wheat, 1-year average)

	Growth stages of small grains		
Silage Crops	Boot	Bloom	Soft dough
	Digestibility dry matter (DDM), %		
Barley	66.5	59.5	60.9
Wheat	64.8	61.8	56.6
Rye	63.9	56.4	54.5
Alfalfa-orchardgrass*	58.9	---	---
	Dry matter intake, % of liveweight		
Barley	1.85	1.69	1.93
Wheat	1.84	1.73	1.62
Rye	1.61	1.34	1.51
Alfalfa-orchardgrass	2.40	---	---

*Alfalfa in bud, orchardgrass in a heading stage of spring harvests.

Supplementing small grain silages with grain improved the carcass grades and dressing percentages; supplementing the high energy sorghum silage with grain did not improve carcass grade nor dressing percentage. Steers fed corn silage without grain had liveweight gains and carcass qualities of cattle similar to those animals fed other silages supplemented with grain.

Rye silage harvested at 50% heading was higher in digestibility and protein content than were wheat and barley harvested in a hard dough stage (Table 25). Corn silage was more digestible than other grain silages, and lowest in fiber, 16.4%; and the small grain silages were highest in fiber, 29.5 to 31.7%. The efficiency of utilizing rye silage could have been improved by substituting energy for protein.

II.J.5. High Energy and High Protein Silage Rations

When properly ensiled, corn silage is a high-energy forage but low in protein. Thus we conducted an experiment to fatten weanling cattle on corn silage rations supplemented with protein from a urea-cotton seed mixture, alone and with ground ear corn, as compared with protein from soybean forage or two legume-grass hay crop silages (Table 26). Two grain sorghums (bird- and non-bird-resistant varieties), each with protein alone and protein plus ground ear corn, were also included in the experiment. About 5% more silage was fed daily than consumed.

The daily liveweight gains of weanling heifers fed different rations averaged for silage crops grown in 1976 and 1977 were: 2.02 lb for corn silage with protein supplement, 1.95 lb for a mix of 72% corn silage and 28% alfalfa-orchardgrass silage; 1.86 lb for a mix of 70% corn silage and 30% Kentucky 31 tall fescue-red clover silage, and 1.95 lb daily for a mix of 75% corn silage and 25% soybean silage (Table 26). The carcass grades for the four rations were similar, ranging from medium good to high good, and dressing percentages ranged from 56.5 to 57.9%. The plan of feeding 25% of the dry matter from the 2 haycrop or soybean silages and 75% dry matter from corn silage was not realized, especially with the fescue-red clover plus corn silage ration. The trend of lower daily gains for cattle fed corn and fescue-red clover silages than for other silage rations may be attributed to a lower DDMI. Feeding less high energy corn silage with the fescue-red clover silage than with the other high protein silages fed with corn silage could have depressed DDMI and liveweight gains. Corn silage was 65.1% DDM as compared to 58 to 59.7% DDM for the high protein non-grain silages (Table 26).

The daily liveweight gains of cattle fed high-energy grain crop silages, corn, and bird- and non-bird-resistant sorghums, were high and similar, about 2.0 lb, when the silages were supplemented with a urea-cottonseed meal protein mix (Table

Table 24. Feedlot performance of fattening cattle fed corn, grain sorghum, or small grain silages with and without grain (2-year averages at Middleburg)

	Silages*				
	Corn	Sorghum	Barley	Wheat	Rye
	Silages supplemented with protein, no grain				
Slaughter wt., lb	1071	1043	936	935	837
Daily gain, lb	2.30	2.08	1.34	1.50	0.86
Daily feed, lb					
Silage	44.0	57.0	44.1	39.1	31.8
CSM-urea**	1.6	1.6	1.6	1.6	1.6
Dry matter per lb gain, lb	8.0	9.5	11.3	10.4	14.1
Carcass grade***	C-	C-	G	G	G-
Dressing %	57.8	57.9	55.4	53.7	56.5
	Except for corn silages, 6.6 lb ground ear corn daily				
Slaughter wt, lb	1071	1063	1019	1027	1022
Daily gain, lb	2.30	2.20	2.96	1.97	1.92
Daily feed, lb					
Silage	44.0	44.7	37.4	32.1	32.1
CSM-urea**	1.6	1.6	1.6	1.6	1.6
Ground ear corn	0	6.6	6.6	6.6	6.6
Dry matter per lb gain, lb	8.0	9.6	11.3	9.4	9.3
Carcass grade***	C-	C-	C-	G+	C-
Dressing %	57.8	58.1	56.7	57.1	59.2

*Rye was 50% headed; other silages were in a hard dough stage.
**89% cottonseed meal, 11% urea mix.
***Carcass grades: C = choice, G = good.

Table 25. The nutritive value of silages (2-year average at Middleburg)

	Stage when harvesting silage	Percent, dry basis: Crude protein	Crude fiber	DDM, %
Corn	Hard dough	7.2	16.4	61.4
Grain sorghum	Hard dough	8.7	23.1	58.5
Wheat	Hard dough	8.0	29.5	56.8
Barley	Hard dough	7.9	31.7	55.6
Rye	Boot	15.1	30.8	68.7

Table 26. Silage rations for fattening weanling beef heifers at Middleburg (average values for two 140-day experiments, 1976 and 1977 ensiled crops)

Corn and grain sorghum silages supplemented with high protein silages vs protein and energy	Daily gain	Dressing percent	Carcass grade	Silage Digestibility	Silage DM Content
	lb	%		%	%
Corn silage				65.1	41.5
a) With protein (P)*	2.02	57.3	11.1**		
b) With P and ear corn	2.06	57.7	11.6		
Grain sorghum, ordinary				59.1	36.9
a) With protein (P)*	2.01	57.1	11.2		
b) With P and ear corn	1.89	56.6	10.4		
Grain sorghum, bird res.				59.8	33.2
a) With protein (P)*	2.01	56.5	10.9		
b) With P and ear corn	2.02	59.6	11.1		
Alfalfa-orchardgrass, 28%***				59.7	55.9
With corn silage	1.95	56.5	11.0		
Fescue-red clover silages, 30%***				59.6	66.0
With corn silage	1.86	57.7	11.0		
Soybean silage, 25%***				58.0	33.2
With corn silage	1.95	57.9	10.9		

*Protein = 1.5 lb daily of a mixture of 89% cottonseed meal and 11% urea; ear corn = ground ear corn @ 6 lb daily. Averaged for all rations, the beginning and ending weights of cattle were 599 and 920 lb, respectively.
**Carcass grade 11 = high good.
***Dry matter, % of daily ration.

26). Feeding a ground ear corn-protein mixture with two sorghum and corn silages did not improve gains and had minor effects on carcass grades as compared to supplementing only protein.

The wilted hay crops, producing 56-66% dry matter silages, are higher than recommended for ordinary upright silos, but these silages were of good quality. The dry matter contents and growth stages for grain crop silages were: 41.5% for corn silage in hard dent, 33.2% to 36.9% for grain sorghums in hard dough, and 33.2% dry matter for soybeans harvested in a hard dough stage (Table 26).

Data for annual silage crops harvested in 1975 show highest yields for corn, being twice more than for soybeans (Table 27). The dry matter contents of plants, when harvested for silage, were highest for corn, lowest for soybeans, grain sorghums being intermediate. The high dry matter of corn plants, as compared to the other crops when ensiled, contributes to fermentation processess that may increase silage consumption. The high dry matter content of the corn plant when ensiled is attributed to the lower water percent in ears than in stems and leaves; also, grain makes up about 50% of the dry matter in corn plants harvested for silage in a hard dent stage (Table 27 and Figure 29). For all annual silage crops, when ensiled, stems are lowest, seed organs highest, and leaves intermediate in percent dry matter (Table 27).

It is concluded that all of the rations in Table 26 are suitable for fattening cattle. Supplementing grain to the high-energy grain crop silages was not economic. It is estimated that silages from legume-grass hay crops or soybeans, to supply protein, may make up about 20% of the dry matter in corn silage rations without depressing liveweight gains. Soybeans produce low yields as compared to other row crops. This and earlier research shows that wilting hay crops to 40 to 50% dry matter silages can be preserved with little spoilage in ordinary upright silos when chopping

Table 27. The yield and dry matter content of plant components of different silage crops ensiled in 1975

Crop and growth stage	Dry matter contents of crops and plant parts when ensiled					Yield components of crops in percent of dry matter			
	Silage yield 35% DM	Whole plant	Leaf	Stem and husk	Heads, ears, or pods	Leaf	Stem and husk	Heads, ears, or pods	Grain
	tons	%	%	%	%	%	%	%	%
Corn, hard dent*	14.6	45.4	54.2	21.3	64.9	14.7	23.5	61.9	50.5
Grain sorghum hard dough - SS109A	11.1	39.8	24.1	14.8	68.2	19.4	8.8	71.8	49.2
Grain sorghum hard dough SS BR93Y	12.4	32.2	17.4	10.8	41.4	21.7	12.4	65.9	51.3
York soybean in dough stage	7.1	29.9	26.0	22.8	30.6	10.5	27.0	62.5	41.4

*Average of two varieties, DeKalb XL 66 and Pioneer 3535.

with sharp knives, filling silos quickly, and topping silos with weighted plastic covers or with heavy wet forage.

II.J.6. Conclusions

The production per animal fed various hay or silage diets, when protein is adequate, depends on the daily energy intake, which depends on the combined effects of digestibility and daily intake. With silages high in digestibility, intake improves as the dry matter of ensiled crops increases to about 40%. Thus, reducing water content, as with wilting of herbaceous forages or harvesting grain varieties of corn or sorghum in hard dough or hard dent stages, when dry matter is around 40%, usually increases silage consumption and output per animal. The higher moisture content of small grains than of grain varieties of corn and sorghum when ensiled may depress intake.

The potentials of animal products per acre from hay or silage crops are associated with the yield of the crop and the production per animal. The potential liveweight gain per acre of corn silage supplemented with a urea-protein meal mixture is more than a ton. High dry-matter silages made from grain varieties of corn and sorghum are high energy silages that require only protein and possibly mineral supplements for high animal output. Protein may be furnished by a urea-protein mixture or by feeding about 20% of the dry matter from legume-grass hay or silage or from soybean silage. Feeding larger percentages of the lower energy-high protein hay crops would depress DDMI and animal performance. The high energy grain crop silages should be reserved for responsive animals such as lactating dairy cows, young replacements, growing and fattening animals, lambs and nursing or weaned beef, and dairy calves.

Small grain and perennial grass-legume silage and hay crops are medium energy forages suitable for replacements where rapid gains are not required and for beef cows without grain supplements. For high outputs with responsive animals, silage and hay from perennial forages and small grains should be supplemented with high energy silage or with grain; protein is not usually needed with leafy forages except for milk cows. Beef cows and ewes can obtain all of their energy needs from the medium energy grass-legume or small grain conserved crops; hence grain supplements should not normally be used unless animals are sick. It may be a good plan to raise heifer and ewe replacements on grass-legume pastures and hay or hay crop silage to develop herds and flocks that become adapted to and use forages efficiently, as practiced and achieved at the Virginia Forage Research Station with the beef herd.

III. Models of Forage-Animal Systems

III.A. Characteristics of Good Systems

The principles in Sections I and II and the models of forage animal systems in this section should be modified and implemented into management systems for farms. A specific system or systems should be designed to fit the soil and environmental conditions of the farm and its different livestock enterprises, e.g., raising calves and lambs, growing replacements and feeder cattle, finishing cattle and lambs for slaughter, milk production, or raising horses. The successful livestock entrepreneur should develop an ecological aptitude to serve specific enterprises, e.g., pertinent soil, biotic, and climatic factors should be considered so that wise management choices can be made. Narrow perspectives, where important factors are ignored, multiply risk in the forage animal complex and reduce the possibilities of successful, profitable, or satisfying operations.

The land and environment determine the adaptation of plant species and varieties and are basic for obtaining high yields of good quality forage economically to supply the variable nutritional needs of animals. Markets, expertise, financial status, equipment and facilities, and dedication and enthusiasm of the grazier (farm manager) and other factors leading to efficient production should be considered when selecting an animal enterprise and a forage-animal management system(s). Feed is a costly ingredient; thus, producing large quantities of good quality forage economically is as important as good animal management. For a given environment, the normal seasonal growth and quality of forage vary within any year due to rainfall distribution and temperature. Thus, where practical, animal breeding should be cycled so that adequate nutrition for animals is furnished by the cyclic yields and quality of forage.

Favorable economic returns depend on wise compromises in management; it is economical to use high stocking rates to obtain high yields of animal products per acre, by making small sacrifices in production per animal. These goals can be reached by stocking farms at a high and near constant rate, where the amount and quality of available pasture (AP) is controlled by varying stocking rates for seasons within a farm to utilize the forage and provide the needed nutrition of animals, as discussed in section II. Also, AP must be managed to allocate needed nutrition, which varies with classes of ruminants. Farmers should set high standards by establishing goals or targets of production per animal and per land area and endeavor to reach them economically.

One unnecessary expense on most beef cattle operations is building shelters. In an experiment, winter-born heifers were raised in three ways: 1) stanchioned for 14 hours in stalls in a dairy barn during evening and morning feeding; 2) like 1, but each heifer fed in a 6 x 8 ft stall; and 3) fed the identical forage-grain mixture outside where a small forest area provided shelter. All heifers overwintered satisfactorily; however, the heifers without shelter made the best liveweight gains and had the best health conditions. In all silage evaluation experiments with steers and heifers reported earlier, animals did not have access to shelters during the day; shelters were used during the evening through morning feedings to control the rations. Systems for raising beef calves and growing and finishing cattle in this section show good animal performance without shelters.

Finally, the success of any forage-animal system depends on the grazier, a person with equal interest and expertise in managing the interplay of soils, plants, and animals.

III.B. A Forage System for Breeding Herds

While practicing July-September calving with the breeding herd at the Virginia Forage Research Station, we harvested part of the bluegrass-white clover pasture area not grazed during the flush spring season, for hay. The residue after cutting for hay was leafy; hence this area could be grazed immediately after the hay was removed to increase the grazing area and the available pasture (AP) for the summer-fall season (Figure 16). Alfalfa-grass mixtures in other fields were harvested for silage in spring; the regrowths were harvested for hay or grazed, if needed. As AP became inadequate during the late fall and winter season, the cows with nursing calves grazing in bluegrass-white clover pastures were fed limited amounts of bluegrass-clover hay. Later, when AP became nil, cows and calves were fed various kinds of hay or alfalfa-grass silage in feeders, some silage being placed in narrow rows along fences. The calves, from around 4 months old until weaning, consumed large quantities of silage. It became evident that nursing calves consumed much food in addition to milk. These observations led us to two conclusions: 1) that nursing calves needed good quality forage, and 2) that restricting feed to cows with 3- to 4- month old calves could be a good practice. Both postulations have been proved to be right and have become management principles.

III.C. A System with Perennial Grasses and Legumes

A 5-year experiment compared animal production with a) continuous grazing, and b) a grazing-silage-hay 12-months forage system as follows:

a. **Continuous Grazing** — a 3-acre bluegrass-white clover-orchardgrass pasture was grazed continuously during the April-November season. Four yearling tester cattle grazed in a pasture all season; additional grazers were added or withdrawn to utilize the pasture and to control quality and quantity of AP.

b. **12-month Forage Plan** — a 3-acre area was divided into 5 fields: bluegrass-white clover-orchardgrass rotationally grazed all season, 2) orchardgrass-ladino clover rotationally grazed all season, 3) orchardgrass-ladino clover-alfalfa for grazing in spring if needed, or for silage, thereafter rotational grazing with fields 1 and 2; and fields 4 and 5) alfalfa-orchardgrass, first growth for silage and thereafter for hay or rotational grazing when needed. The 3-acre area was stocked with 4 yearling tester cattle all season. With this model of a farm plan, the 3-acre land area was stocked at a constant rate but some of the mixtures were harvested to vary the grazing area to control AP. Thus, special mixtures in different fields suitable for flexible utilization (grazing, hay, or silage) furnished a 12-month feed supply.

The a and b plans were repeated four times; hence 16 different testers were used each year. Either heifers or steers were used for each comparison. Implants to stimulate growth were not used.

Amount of feed: Grazing started in April and ended in October or November. The 12-months feed plan furnished 180 days of grazing and enough harvested feed for 196 days, 376 days of feed per acre for a 700 lb yearling. This plan provided 72% more forage than the continuously grazed bluegrass-clover mixture. The higher production for the 12-month system is attributed to the high yields of alfalfa mixtures as compared to bluegrass pastures and to yield advantages with managed rotational as compared to controlled continuous grazing.

Liveweight gains: The daily liveweight gains of steers grazing rotationally among the five pastures averaged 1.25 lb, 10% lower than for continuous grazing. The higher gains with continuous grazing are explained by a somewhat better AP than for rotational grazing. With continuous grazing, it is necessary to accumulate some reserve pasture because of naturally occurring droughts. Also, short-leafy bluegrass-clover growth with adequate quantity of AP gives higher energy intake (DDMI) than stemmy alfalfa mixtures (Table 4).

Various systems with perennial grass legume mixtures, such as the system just described, are especially suitable for farms with hilly land that is not suitable for tillage because of potential erosion. The plan just described should be modified for the soils, environments, and livestock operations on a particular farm. The model described is suitable for cow-calf herds, raising replacements, growing stocker cattle, and ewe-lamb flocks. By supplementing with energy by purchasing grains, systems with perennials are also suitable for milk cows.

The system with perennials, described in this section, should be modified to reduce harvesting costs and shorten the feeding period by lengthening the grazing season. For example, alfalfa could have been managed to provide excellent late-fall-early winter grazing; also with judicious management it could have been used for early spring grazing (Section II). Seedings of endophyte-free tall fescue-alfalfa or other fescue-legume mixtures would furnish early spring grazing and winter grazing (Section III, E and F).

III.D. Systems with Annual and Perennial Forages

Most farms with potentially erosive soil have some land suitable for tilled crops rotated with perennial grasses and legumes. Also, with no-till cropping methods, where herbicide-treated sod or cereal crop residues give protective soil covers and enhance water infiltration, erosion can be controlled on farms with undulating topographies. Thus growing corn silage in rotation with perennial forages or double cropping with small grains could improve yield and quality of stored forage to give sharp increases in energy intake because corn silage gives high animal performance as compared to harvested perennial forages. For example, as compared to the model with perennials (III.C), a modified design with a third of the land in corn silage and two thirds in perennial grass-legume mixtures would give an additional 3000 to 4000 lb of digestible dry matter per 3-acre unit. Additionally, plans with corn silage and perennial forage make excellent systems for lactating dairy cows and fattening steers.

III.E. Twelve-Month Grazing Systems for Raising Calves

Forage systems were designed to raise beef calves efficiently with a beef herd. The cattle and forages were managed to maintain high nutrition for the nursing calves by creep grazing and hay feeding and variable nutrition of cows by controlling AP and hay feeding. Angus cows were managed to receive good nutrition during about a month before calving until about 4 months after calving. The pastures and hay were of high quality (estimated to range from 60-75% DDM for pastures and 55% DDM or TDN for hay); thus, the level of nutrition for cows was controlled by restricting the amount of pasture or hay offered, both being high in quality.

Cows and calves were wintered by feeding hay, a common farm practice, or by grazing tall fescue-red clover pastures during the fall-winter season by accumulating the growth (stockpiling) during the mid-August-November season. Hay was fed, if necessary, during brief periods with heavy snow cover or when the AP of stockpiled pasture was very low in quantity.

Cows were assigned to each system so that age, weight, and condition of cows were similar among systems. The cows stayed in a system for four successive years; some cows with health or breeding problems were replaced by other cows to retain designated stocking rates. There were 9 cows in each system with stocking rates of 1.67 and 2 acres per cow and nursing calf for some of the systems. A bull was shifted among two systems every other day during the 75-day breeding season. There were two calving periods winter (January-March calving with November 1 weaning) and fall (September-November calving with July 1 weaning) for most of the systems.

The cows were wintered in systems on land with southerly slopes and a forest close to and along the north side of the site that gave wind protection. There was no shelter, except for a small open shed used for a few days for each cow during winter calving.

A diagram of the three forage systems, each with 15 acres for 9 cows and calves (1.67 acres per cow), appears in Figure 30.Each system had three fields arranged so calves could creep graze from any one field to either of the other two fields. The management of each forage system is described in detail at the end of this section. A brief description of the management of each system follows.

III.E.1. Forage-Animal Systems

III.E.1.1. System A: Bluegrass-White Clover and Alfalfa-Orchardgrass

For the high stocking rate of 1.67 acres per cow, an 8.25-acre bluegrass pasture was grazed continuously and also in rotation with the two 3.375-acre alfalfa-orchardgrass fields that also furnished hay for winter feed (Figure 30). The calves were allowed to creep-graze into the alfalfa-grass fields whenever the AP in bluegrass-clover pastures was judged to be too low for rapid gains of calves. The calves did not creep-graze when AP was high in any field grazed by cows and calves. The alfalfa-grass growth after two harvests of hay was usually grazed by cows and calves in summer when AP was low on bluegrass-clover pasture, and calves creep-grazed ahead of the cows when AP was low; meanwhile the bluegrass-clover pasture accumulated growth. The cows with nursing calves grazed an alfalfa-grass field to a low AP while calves creep grazed the bluegrass pasture that had accumulated a high AP; later the cows were also moved to the bluegrass pastures to rest the alfalfa-grass fields. The alfalfa-grass fields were also grazed by cows during November and December. This system could have been improved by grazing the good quality alfalfa-grass field with November-weaned calves, but this was not done because all weanlings were needed for another experiment.

With fall calving and July 1 weaning, a low AP on the bluegrass pastures often made it necessary to creep-graze the alfalfa-grass fields before and after harvesting hay in spring and early summer.

III.E.1.2. System B: Bluegrass-White Clover and Tall Fescue-Red Clover

An 8.25-acre bluegrass-white clover pasture was grazed continuously and also in rotation with the two 3.375-acre fields with a Kentucky 31 tall fescue-red clover mixture (Figure 30). One or two of the spring-early summer growths of the fescue-red clover fields were harvested for hay, depending on the AP in the bluegrass-clover pasture. The fescue-red clover fields were grazed and creep-grazed during July to Mid-August to allow AP accumulation on the bluegrass-clover pasture. In early summer, when AP in the fescue-red clover field became low, the calves creep-grazed into the other fescue-clover field or in the accumulating growth in the bluegrass pasture.

Beginning in mid-August after applying 220 lb of ammonium nitrate per acre, the fescue-red clover growth was stockpiled for winter grazing. However, nursing calves creep grazed into a fescue-red clover field with a good AP, whenever the AP in the bluegrass-clover pasture being grazed by cows was inadequate for calves. The calves creep-grazed into any fresh pasture whenever the AP in a pasture being grazed by cows could inhibit calf growth. Calves creep grazed bluegrass-clover pasture in early spring when cows were still grazing residues and new growth in the stockpiled fescue-red clover fields, an especially necessary procedure with fall calves.

With fall calving and July weaning, the calves usually creep-grazed some of spring growth in the fescue-red clover fields because the high forage

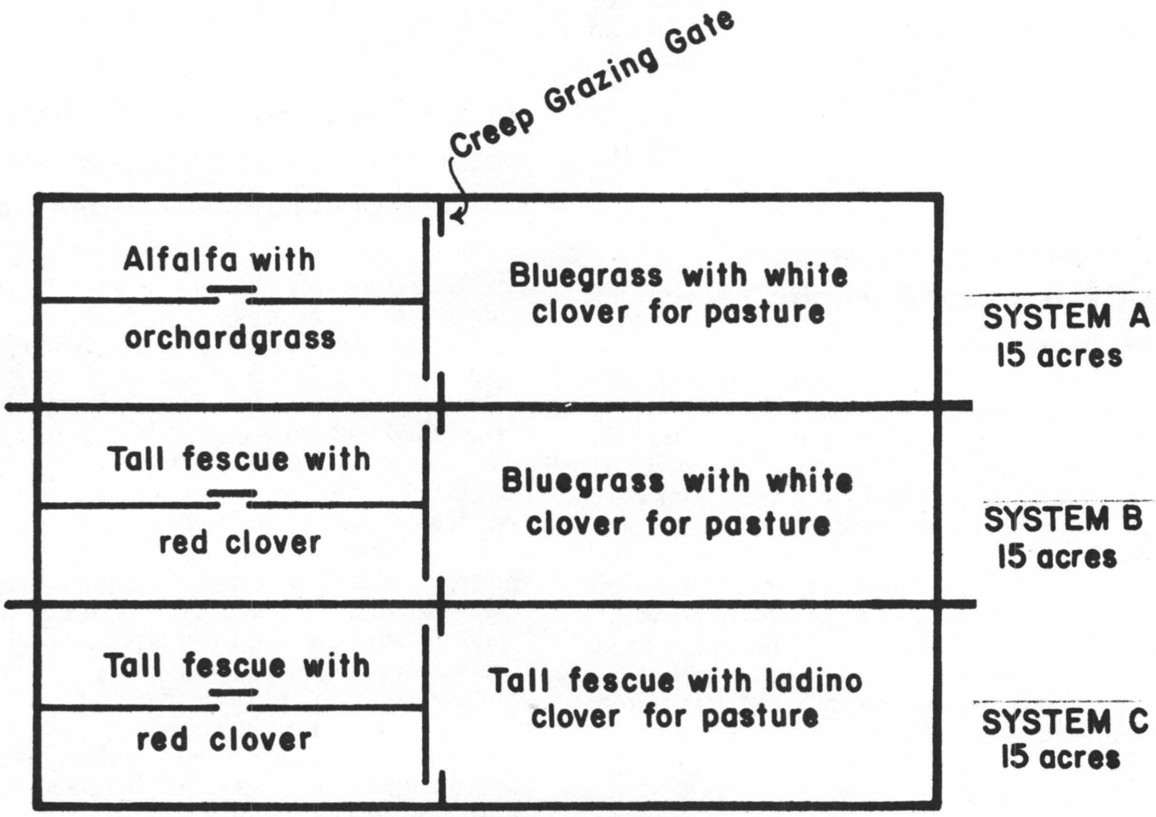


Figure 30. The plan shows three 15-acre areas divided into three fields for each of three forage systems stocked with nine cows, 1-2/3 acre per cow and calf. Similar 18-acre areas in three fields with nine cows per system gave a lower stocking rate of 2 acres per cow and calf. The largest field, 55% of the area, was used for spring to fall grazing, winter feeding of cattle with system A, and also for creep grazing. The remaining 45% of the area, divided into two fields to facilitate management, was used for grazing, creep grazing, winter grazing, and hay for systems B and C. Gates with openings for creep grazing between the three fields in each system served to rotate cows and for creep grazing by calves (creep grazing device, Figure 24).

intake of cows and 400 to 600 lb nursing calves caused a low AP on the bluegrass pasture as compared to pasture grazed by cows with winter calves.

III.E.1.3. System C: Tall Fescue with Legumes

The 8.25-acre Kentucky 31 tall fescue-ladino clover pasture was managed as the bluegrass-white clover pasture in System B (Figure 30);also the two 3.375-acre fields with the fescue-red clover mixture were managed as described for System B.

With the lower stocking rate (18 acres for 9 cows), 9.9 acres was assigned for grazing and 8.1 acres, divided into two fields, was used flexibly for hay, grazing, and creep-grazing. Management was similar to that previously described for the higher stocking rate (15 acres per 9 cow-and-calf units).The pastures were mowed only once during four years as the rather high stocking generally controlled weeds during the 4-year experiment.

III.E.2. Health of Cows and Calves

Cows and calves restricted to a given system all year, without shelter, maintained excellent health. The cows and calves developed long, dense hair coats during winter. Although temperatures declined to less than -10 F with strong winds, cows and calves, often lying down on snow and ice, appeared to be comfortable as they became adapted to the environment without shelter. The absence of shelters, and not confining cows and calves to buildings, may have avoided problems with internal parasites; excreta were distributed rather evenly over the winter-grazed fescue-clover fields. Neither the cows nor the weaned calves used for forage fattening experiments encountered parasite problems, even though parasite control treatments were not made. After the end of the experiment, fecal analyses showed that parasite populations were very low.

With around 12 inches of snow, cows and calves sought the forage through a fluffy snow and grazed the stockpiled fescue and red clover. Snow usually melted in areas next to the cow tracks, which exposed forage for grazing. During periods of either deep or crusty snow covers, strips of snow were pushed to the side with a tractor with a front-mounted steel blade.The cleared strips made it unnecessary to feed hay; cows were wintered through two successive winters on System B with 2 acres per cow and calf without feeding hay.

The cows grazing in fescue System C often appeared to walk with a mild stiffness and stood in shallow water in a creek during summer more often than cows from other systems. Both cows and calves grazing System C shed the long hair after winter more slowly than the animals grazing Systems A and B.

III.E.3. Calf Gains and Weaning Weights

When stocking at 1.67 acres per cow and calf, the average daily gains and weaning weights of winter calves were similar for System A and System B; daily gains, averaged for four years, ranged from 1.87 to 1.92 lb, and weaning weights ranged from 560 to 567 lb (Table 28). The liveweight gains and weaning weights of fall calves were similar for Systems A and B but a little lower than with winter calving. Feeding alfalfa-grass hay or grazing stockpiled fescue-clover during winter lowered the liveweight gains of fall calves as compared to spring calves that grazed and creep grazed high quality pasture at a high AP. However, the fall calves made excellent gains when grazing and creep grazing during April through June.

Restricting cows and nursing calves to tall fescue-legume mixtures (System C) depressed daily gains and weaning weights of both winter and fall calves when compared to Systems A and B (Table 28). As compared to the other systems, the fescue system C reduced the weaning weights by an average of 55 lb per calf. The cows on System C with both calving dates did not develop udders as fast before and after calving as the cows with Systems A and B. Thus, the lowest calf weights for System C may be attributed to low milk production during the early growth period of calves when nutrition from milk is most important.

Some of the systems were stocked at the lighter rate of 2 acres per cow-calf unit (Table 28). The similar average daily gains and weaning weights for the two stocking rates are attributed to maintaining a high AP and nutrition for calves via creep-grazing. Because AP was not always adequate for fall calving at the high stocking rate for Systems B and C, hay was occasionally creep-fed. Stocking rate did not influence calving percentage; thus stocking one cow-calf unit per 1.67 acres instead of 2 acres increased calf production by 21% per acre, 275 lb as compared to 333 lb of weaned calf weight per acre for the low and the high stocking rates. The low stocking rate had 20% more land per cow and calf than the higher rate.

Table 28. The daily liveweight gains and weaning weights of calves for different forage systems and stocking rates with some of the systems (4-year averages)*

Forage systems	1 cow and calf per 1-2/3 acres Daily gain	Weaning wt.	Net per acre	1 cow and calf per 2.0 acres Daily gain	Weaning wt.	Net per acre
	lb	lb	$	lb	lb	$
I. Winter (Jan-Mar) calving						
System A - Bluegrass-alfalfa	1.92	560	16	1.87	548	11
System B - Bluegrass-fescue	1.87	567	43	1.87	556	35
System C - Tall fescue	1.73	497	32	---	---	---
II. Fall (Sept-Nov) calving						
System A - Bluegrass-alfalfa	1.77	539	15	1.80	546	8
System B - Bluegrass-fescue	1.80	542	23	---	---	--
System C - Tall fescue	1.61	497	24	---	---	---

*Birthweights were included in weaning weights, but excluded in average daily gains.

III.E.4. Performance of Cows

III.E.4.1. Calving Percentages

During a 75-day breeding season one bull was assigned to two systems, each with nine cows. The procedure of shifting one bull on alternate days between the two systems probably decreased the conception rate, thereby giving less than maximum number of weaned calves as with conventional breeding. When averaging the 4-year data, the number of weaned calves did not differ for the three systems nor for stocking rates; ranging from 78 to 94%, the average weaned calving percentage was 86% for the four years. Previous to this experiment when a bull was kept with one herd, the average calving percentage was about 94%.

III.E.4.2. Liveweights of Cows

The changes in liveweight among cows (Table 29) should be interpreted as responses to planned management and control of AP for the forage-animal systems. Restricting hay or AP to cows during certain cycles of production reduces feed costs for raising beef calves. Also, because of its low cost, the spring season with its flush, high quality forage is a desirable period to pasture cows to regain weight and store fat. Restricted feeding of cows during designated cycles of their production to utilize stored fat to provide energy during slow pasture growth is economical. Managing 1100 to 1200 lb cows to lose and regain 200 to 250 lbs during yearly calving cycles is reasonable for maintaining health, achieving high conception, and weaning large calves (see Section II).

Being reflections of the management, the weights of cows for any system could have been increased or decreased by more or less forage allowance for a specific system. When stocking at the rate of 1 cow per 1.67 acres, the weights of cows for winter and fall calving were similar within each of three dates; however, cows weighed an average of 160 lb less after the winter season in April than after the grazing season in December. In July the cows weighed an average of 54 lb more than in April.When averaged for the three dates for each of the three systems,the weights per cow were similar, ranging from 1044 lb for System C to 1081 lb for System A.

During the April-November grazing season, the cows developed good body conditions; daily liveweight gains of cows ranged from 0.32 to 1.17 lb, except that the winter-calving cows on the fescue-legume System C did not gain weight during the April-June period; however, later, during the July-November season, daily gains of cows for winter and fall calving averaged 0.79 lb (Table 29). With System C (all fescue-legumes), the low gains of winter-calving cows during the April-June period were caused by low nutrition from forced close grazing of fescue (low AP) to encourage clover growth. Later, because pastures were not mowed, the excess stemmy fescue growth along with a reduction of ladino clover with winter calves and cows caused low quality of AP. Fall calving cows made good gains during April through June because the high herbage consumption by cows during spring and their large calves utilized the growth to maintain a good balance

Table 29. The average liveweights and daily gains or losses of cows at various seasons when stocked at 1.67 acres per cow and calf (4-year averages)

Forage systems	Seasonal periods: December-March, Winter calving	December-March, Fall calving	April-June, Winter calving	April-June, Fall calving	July-November, Winter calving	July-November, Fall calving
	Daily gain or losses, lb per cow					
System A Bluegrass-alfalfa	-1.40	-1.13	+0.46	+0.76	+0.71	+0.77
System B Bluegrass-fescue	-1.43	-1.24	+1.17	+1.00	+0.73	+0.32
System C Fescue	-1.34	-1.25	-0.02	+0.77	+0.88	+0.70
	Liveweights of cows, lb					
	December		April		July	
System A Bluegrass-alfalfa	1199	1146	1035	985	1072	1050
System B Bluegrass-fescue	1123	1141	967	983	1029	1072
System C Fescue	1129	1147	978	981	979	1049

of leafy fescue and ladino clover. During spring with fall calving and July 1 weaning, the fescue-ladino clover or bluegrass-white clover pastures in the systems were leafy and short; however, the lower feed requirements of spring calves than fall calves caused spotted grazing and accumulations of stemmy grass growth during flush pasture growth in spring.

III.E.5. Winter vs. Fall Calving

III.E.5.1. Cows

It was simpler to manage calving during fall than in the winter season; however, feed management was simpler with winter calving. Better quality and more forage per cow is needed for fall than for winter calving. Shelters during calving are not needed with fall calving. Winter forage management for fall calving with stockpiled fescue systems was simplified by reserving an area for creep grazing under an electric wire in one of the stockpiled fescue-clover fields. Forage needs of animals are more directly associated with forage growth distribution with fall than with winter calving, pasture growth and feed needs being highest in spring. With winter calving some of the spring growth in System C was wasted and the ungrazed grass *per se* reduced forage quality and also depressed clover by light competition. Fall as compared to winter calving cows, especially after calving, were generally in a better weight condition in December because they were in late lactation or dry during most of the growing season; thus a higher AP than for winter calving cows caused them to be quite fat.

III.E.5.2. Calves

Winter as compared to fall calves had higher suckling gains, heavier weaning weights, and better hair coat bloom. Many fall calves, especially those on fescue (System C), had rough hair coats often retained until the yearling age. Fall calves made good gains until three months after calving but later winter gains were low, averaging 1.37 to 1.51 lb per day. Calves can compensate for low winter gains while grazing the next spring; however, with low winter gains there was not enough time for compensatory gains before July weaning. To attain optimum high weaning weights, it appears that fall calves should gain about 1.5 lb daily during winter. Fall calving could have advantages over spring (March-April) calving, delayed to escape cold temperatures and winds. Such spring calves would be rather light for feeder calf sales and could be marketed in July a year later.

Fall calving should not be considered unless forage quality and forage-herd management favor calf growth during the December-April period. For optimum over-wintering and weaning weight, fall calving should be completed by mid-November.

Placing cows and calves in a pasture, applying little or no management, and accepting the production results is an out-of-date practice. The principles established for managing and controlling AP with forage-animal systems in this section should be studied and implemented. Thus details on management of animals and forages for different systems to improve the proficiency of the grazier are given at the end of this section.

III.E.6. Profit, Other Attributes, and Conclusions

The land area needed per cow and calf will vary with soils, fertility status, forage mixtures, climate; and management expertise. Stocking at 1.67 acres per cow and calf gave better economic returns than stocking at the 2-acre rate because 21% more calf per acre was produced at the highest stocking rate (275 and 333 lb for low and high stocking). Economic returns (system averaged) were about 37% higher with the high as compared to the low stocking rate (Table 28). The best economic returns per acre occurred with System B, bluegrass pasture and fescue-red clover with spring calving. Utilizing the fescue-red clover mixture flexibly for grazing, creep grazing, hay, and stockpiling for winter grazing was less costly than maintaining and utilizing the alfalfa-orchardgrass mixture flexibly in conjunction with bluegrass pasture (System A). Thus, System A gave the lowest economic returns. System C, fescue-ladino clover plus fescue-red clover used flexibly, requires less land area per cow and calf than System B, but the depressed gains and weaning weights of calves counteracted the advantage of a higher carrying capacity (yield). With a given system, net returns were higher with winter than with fall calving (Table 28). Using managements to maintain 40-50% legumes in fescue and using tall fescue free of fungus endophytes would probably make System C most profitable.

A given forage system based on the growth of mixtures in the system must be managed to capitalize on merits of each mixture in the system. The forage must be utilized by animals where nutrition is controlled by allocating the AP to responsive ruminants to achieve high returns and profits. Basing management on rigid calendar dates or computers *per se* will not realize the potentials of a system. Computer models can give useful projections, but the manager must make valid decisions to judge AP and control nutrition and utilization. For example, in System B the bluegrass-white clover pasture has a shorter growth season of lower herbage yields than the fescue-ladino clover in System C. Thus the fescue pasture in System C must be grazed earlier and later in the season before shifting cattle to stockpiled fescue to capitalize on its inherent advantage as compared to bluegrass pasture in System B.

High and near maximum gains of calves are attainable when cows and calves graze together at a low stocking rate that maintains a high AP. However, such low stocking reduces potential profitability because of wasted forage and low conversion efficiency in terms of calf yield per acre. On the other hand, high stocking rates and maintenance of adequate amounts of a high quality AP for calves via creep grazing while cows are stressed at certain production cycles does not depress calf gains and enforces good forage utilization. Conversion efficiency of forage to calf production and profit was improved via heavy stocking in four ways:

1. little forage was wasted,
2. losing weight, around 1.3 lb daily during winter, the winter calving cows used body fat as part of the needed energy during the winter season when feeding costs are high and restored fat during the low-cost grazing season;
3. health, longevity, and reproductivity of cows was maintained; and
4. high stocking gives high calf production per acre without reducing calf gains by providing a high AP (quality and quantity) with creep grazing.

Not providing shelter for animals is an economic benefit and probably reduces parasite and disease problems with calves and cows. Also, in the absence of shelter and with limited shade, animal excreta were distributed quite uniformly over the fields. Recycling animal excreta can reduce fertilizer costs and increase forage production. Vigorous tall fescue growth in spring in response to animal excreta on the winter-grazed stockpiled fescue fields was evident.

Three fields were adequate to realize the benefits from controlled management. Additional fields would facilitate management and increase production of animal products per acre but increase fencing and other costs. Controlling the quality of AP and its allocation to limit or supply the nutritional needs of different ruminants for profit is more important than the number of fields for profitable animal production.

The creep grazing procedure simplifies weaning of calves. The cows and calves have become adapted to being separated. When the creep grazing gap is closed to keep cows and calves in adjacent fields animals "nose each other" through the fence and remain contented.

III.E.7. Details on Managing Systems

III.E.7.1. Forage System A

One bluegrass-white clover pasture, 55% of the area, plus two fields in an alfalfa-orchardgrass mixture, 45% of the area, are shown in Figure 30. Bluegrass pastures were grazed from early April until late October or November, whenever AP became inadequate. The cows, wintered on the bluegrass pastures without shelter, were fed alfalfa-grass hay from the system. These alfalfa-grass fields were managed flexibly: usually two spring cuttings for hay, with the third and fourth growths for summer grazing when the AP of bluegrass pasture is low, and for creep grazing at any date. For example, the fall calves even creep grazed into the alfalfa-grass fields during late winter and early spring when AP of bluegrass pasture was low. During the midsummer-autumn season with low AP of bluegrass pastures, the winter calves got excellent forage by creep grazing into the alfalfa-grass fields.

The winter calving cows, wintered on the bluegrass pastures, were restricted to 12 to 14 lb of good quality alfalfa-orchardgrass hay until calving began and then were increased to about 21 to 22 lb daily. The cows with fall calves were fed 21 to 22 lb hay daily, and calves were fed the best alfalfa-grass hay (15 to 20% protein in creep feeders at 15% more than eaten). For calves about 3-1/2 months old, growth depends primarily on food other than milk. Thus restricted feeding of hay to cows and liberal feeding of calves improved the conversion efficiency of forage to calf production. Hay feeding of cows was usually started in early December after grazing the alfalfa-grass fields, when bluegrass AP became inadequate. It was necessary to start feeding hay 7 to 10 days earlier for the high as compared to low stocking rate.

III.E.7.2. Forage System B

One bluegrass-white clover pasture, 55% of the area, plus two fields of a red clover-Kentucky 31 tall fescue mixture, 45% of the area, are shown in Figure 30. The fescue-red clover fields were used flexibly for hay, grazing, creep grazing, and accumulating forage (stockpiling) for winter grazing.All or some of the fescue was used for hay in spring, depending on the AP of the bluegrass pasture. For example, it was planned to harvest both of the fescue-red clover fields once for hay; however, during years with a dry spring at the high stocking rate with fall calving, the spring growth in one field was grazed because of low AP for bluegrass pastures. Also with the low stocking rate and winter calving, one or both of the fescue-clover fields were used for a second cutting of hay during years with favorable moisture and a high AP on bluegrass pasture. Thus, the fescue fields were used to control AP by adjusting the stocking rates needed for grazing within a system. The fescue-red clover fields were grazed during July to mid-August while the bluegrass pasture was rested to accumulate growth to extend the late summer-fall grazing season. By mid-August after close grazing, fescue-red clover fields were fertilized with 75 lb N per acre to stockpile growth for late fall and winter grazing. Close grazing to remove dead and old leaves about to die improved the quality of the stockpiled fescue and red clover. Generally about two tons of dry matter, 10 to 16% protein (dry basis), were stockpiled per acre by mid-November. Fall or winter calves in their respective systems creep grazed into the fescue-clover pastures at any period of low AP when cows and calves were grazing bluegrass-clover pasture.

The tall accumulated growth with stockpiling and winter grazing reduced the stand of fescue tillers as compared with spring-summer grazing. Such a sparse sod reduced competition from fescue to enhance re-establishing red clover. Because clover-grass mixtures give better animal performance than grass, red clover was encouraged by drilling seed into the soil with a grain drill during March after the first year. Herbicides were not needed because close grazing controlled grass competition.

Fall calving: After fall (September-November) calving was almost finished on short bluegrass pastures, the cows and calves were moved to one of the stockpiled fescue-clover fields with an AP high in quality to improve nutrition and milk flow. The field with the most red clover was grazed first because freezing temperatures cause clover leaves to die and fall, whereas fescue stays green with little deterioration of quality until midwinter.

During heavy snow cover, snow was pushed aside in strips with a tractor-mounted snow blade. Cows and calves grazed and rested in these strips. Hay from the system was fed to cows and calves when snow was too deep for grazing or when the stockpiled growth became exhausted. Calves were fed hay from the system in creep feeders to exclude cows.

During the winter while stockpiled fescue-red clover was being grazed, nutrition and growth of fall calves was improved by creep grazing in three ways:

1. the first grazed stockpiled field with a closely grazed 2-inch sod allowed absorption of sunlight (radiant energy) causing regrowth of high quality young fescue during late winter for creep grazing,
2. allowing calves to creep graze ahead of cows, and,
3. reserving enough stockpiled forage for creep grazing (high AP) during the winter, which is better in quality than hay feeding.

By March the low-quality creep-grazed residue was grazed by cows, and calves creep grazed young fescue regrowth in the fescue-red clover field that had been grazed first in late fall.

Fall calves, weaned on July 1, gain rapidly while grazing bluegrass-white clover pasture with their dams during the flush spring growth of high quality pasture, without creep grazing. However, when the AP in bluegrass pastures became inadequate, the calves creep-grazed into the fescue-red clover field with the most clover. When the AP on bluegrass pasture was too low for the cows, the cows were shifted to the fescue-clover field grazed by the calves. When the AP became low, the calves creep grazed into the second fescue-red clover field or back to the bluegrass-clover pasture.

Winter calving: With winter calving and November 1 weaning, creep grazing into the fescue-clover fields was practiced at any period during the spring-fall season when bluegrass AP was too low to maintain high calf-growth rates. When AP became low while cows and calves grazed bluegrass pasture, the calves creep grazed tall fescue-clover (Field A either before or after harvesting hay). When the AP on the bluegrass pastures became very low, the cows were also moved to Field A. After a declining AP was judged to inhibit calf gains, the calves creep-grazed into the other fescue-red clover field (Field B) to assure a high AP of leafy grass and clover. After the cows grazed Field A to a 2-inch sod, they were switched to Field B, which was being creep grazed. As cows and calves grazed together and AP declined, the calves creep grazed the rested bluegrass-white clover pasture with an accumulating high AP. The cows were switched back to the bluegrass pasture, depending on AP, after either Field A or B was grazed closely. Whenever the AP of bluegrass pasture became low, especially by late September, the winter-born calves creep grazed the stockpiled fescue-red clover pasture with the most growth and best clover (either Field A or B). During some years, creep grazing reduced the yield of stockpiled fescue-red clover for winter grazing by as much as a ton per acre. However, it is economical to sacrifice yield of stockpiled fescue and clover to maintain high calf gains and weaning weights.

Creep-grazing gaps into adjacent pastures may stay open until weaning because calves creep graze only when the AP in pastures grazed by cows and calves becomes low. Thus calves ascertain when AP is inadequate. To reduce hay feeding in the late winter-early spring season, all three fields in System B were grazed to provide enough AP during this slow-growth period. When bluegrass-clover AP and its growth rate in spring were adequate, the cows were restricted to bluegrass pasture to rest the fescue-red clover fields for an early June cutting of hay. It is very important to plan and to manage for adequate amounts of high quality AP for creep grazing under heavy stocking where cows graze pastures with a low AP.

III.E.7.3. Forage System C: A Fescue System

System C consists of one fescue-ladino clover pasture, 55% of the area, and two fields of a fescue-red clover mixture, 45% of the area (Figure 30). The fescue-ladino clover pasture was managed as the bluegrass-clover pasture in System B; however, the better forage growth and longer grazing season of fescue-clover than bluegrass-clover pasture caused less creep grazing and grazing of the fescue-red clover fields. The fescue-red clover fields were utilized flexibly as for the mixture in System B.

The dates for creep-grazing or grazing an adjacent field with cows were independent for each system and were based on AP.

Note that each system was stocked at a constant rate, but stocking rates within systems were varied and controlled as designated by AP to allocate the needed nutrition to cows and calves.

III.F. Growing and Fattening Systems

III.F.1. Growing and Fattening Systems with High Energy Silage

Grain varieties of corn ensiled in a hard dent stage with a urea-protein meal supplement, without feeding additional grain, is an excellent high energy silage for growing and fattening cattle to choice carcass grades (Section II.J). Thus, a simple system for farms with land suitable for cropping is dry lot feeding of corn silage with protein to any young cattle, such as weanlings (Section III.E) or older feeder cattle at any season. Corn silage can be implemented into fattening systems in various ways; for example, after the flush, high quality pasture season, cattle could be fattened on a corn-silage pasture ration, as grazing cattle need not be fed protein. Another alternative is a short feeding period at the end of the grazing season, as for some systems in this section. An alternative fattening ration is about 80% corn silage and 20% of a legume-grass hay or silage.

Grain sorghum silage, without grain, may replace corn silage in a fattening ration. However, for high daily gains, small grain silages must be supplemented with energy such as from ground shelled corn (Section II.J).

III.F.2. Growing and Fattening with Forage Systems

Three simple grass-legume mixtures were managed flexibly to provide forage throughout the year. The cattle growing and fattening forage systems were designed for year-around grazing by rotating cattle among mixtures, using stockpiled fescue for winter grazing. Grain was fed with some of the grazing methods and cattle were finished by feeding corn silage after mid October for some systems. The forage-animal systems were planned to have fat cattle for market at four periods each year. Producing desirable carcasses for slaughter in a short animal life cycle primarily on forage diets was a goal.

Weanling steer calves, born in winter and weaned in November (from Section III.E), and yearling steers grazed together. Grazing for all steers began in mid-November with alfalfa-orchardgrass and/or winter grazing Kentucky 31 tall fescue-red clover pastures until April. Subsequent grazing with other mixtures ended in July for yearling steers or the next October for weanling steers. A woven-wire fence invaded by a woody vine (honeysuckle) on the north side of all pastures was a wind shelter; there were no buildings.

Perennial grass-legume mixtures in different fields were control grazed as follows:

a. Kentucky 31 fescue-red clover was grazed during winter (November-April), cut for hay in June, then grazed and/or cut for hay until early August. Nitrogen at 80 lb per acre was applied in early August to accumulate (stockpile) growth for winter grazing. Close grazing or cutting for hay in August removed old leaves and dead growth to improve forage quality for winter grazing.

b. Bluegrass-white clover pastures were grazed when AP in spring became adequate, steers being switched from fescue pastures. Steers were rotated among bluegrass-clover, fescue-clover, and alfalfa-orchardgrass mixtures during spring until October.

c. For the alfalfa-orchardgrass mixture, the first two growths were harvested for hay; the summer and autumn growths were grazed or cut for hay, depending on the AP of bluegrass-white clover pasture. After freezing temperatures, the autumn regrowth of the alfalfa-orchardgrass mixture was grazed before grazing stockpiled fescue.

The three mixtures in different fields (with subdivision fences) were grazed in a controlled sequence based on AP to furnish grazing for the entire year. Growth not needed for grazing was harvested for hay. Hay harvesting was minimized and all-year grazing stressed. Grazing was controlled to provide a high quality and quantity AP for high intake to encourage good gains and growth of steers. A dependable AP was maintained by controlled rotational grazing; areas for grazing were varied to maintain a desirable AP. Excess growth was harvested for hay and fed during winter when there was a low AP or during snow cover. The system was stocked to allow one hay crop for the fescue-red clover and two hay crops per year for the alfalfa-grass mixture.

Seven animal-forage management treatments included four periods for selling steers for slaughter. Yearling steers were managed in three ways:

1. Slaughtered in May — supplemented with grain @ 1% of liveweight while grazing stockpiled fescue red clover from mid November until April and then switched to bluegrass-white clover pasture. About 85% of the AP was consumed.
2. Slaughtered in July — first grazed fescue-red clover until April and then first grazed bluegrass-white clover, consuming about 60% of the AP.
3. Slaughtered in July — supplemented with grain @ 0.5% of liveweight until May and then increased to 1% of liveweight. Stockpiled fescue-red-clover was grazed until April when steers were switched to bluegrass white clover. About 85% of the AP was consumed with controlled rotational grazing.

Weanling steers were grazed among three mixtures during November to mid-October as described earlier. The four forage-growing-fattening systems are described below.

4. Steers first grazed all mixtures in a controlled sequence, designated by consumption of about 60% of the AP, from November to October the next year when half the steers were slaughtered. The rest of the steers were fed a corn silage-protein ration until reaching high-good carcass grade.
5. Same as (4) but supplemented with ground shelled corn @ 0.5% of liveweight. All steers were slaughtered in October.
6. Steers grazed rotationally among all mixtures, being controlled to consume about 85% of the AP. In October half the steers were slaughtered and the remaining steers were fed a corn silage-protein ration until reaching a high-good carcass grade.
7. Forage system like (6) but steers were fed grain @ 0.5% of liveweight until May and then at 1%. All steers were slaughtered in October.

III.F.2.1. Liveweight Gains with Winter Grazing

The 2-year average daily liveweight gains of first grazing weanling steers consuming about 60% of the AP from stockpiled fescue-red clover gained an average of 1.37 lb daily during 154 days in winter; whole plant grazers consuming about 85% of the AP gained 1.24 lb per day. When the gains of steers with and without grain were averaged, the first grazing steers gained 0.25 lb more per day than whole plant grazers (Table 30). For yearling steers grazing stockpiled fescue-clover during winter, steers fed grain @ 0.5 and 1.0% of liveweight with whole plant grazing gained 1.65 and 1.74 lb daily, respectively. Similar steers without grain gained an average of 1.43 lb daily with first grazing. During 154 days of winter grazing in the first year (1976-77), yearling first-grazing steers, without grain, gained 1.79 lb daily; steers fed grain at 1% of liveweight gained 2.93 lb daily. The weanling steers also gained more during the first than the second year. The lower daily liveweight gains during the second as compared to the first year may be attributed to adverse weather and longer periods for feeding hay during the second year; also, there was less clover in the mixture during the second year. During the first winter grazing season, it was necessary to feed hay because of snow for about 20 days in January. During the second year hay was fed over longer periods because of snow and a low AP. Because stockpiled fescue is usually better in quality than hay, hay feeding reduces liveweight gain. The gains of the first-grazing steers could have been improved by grazing less than 60% of the AP.

III.F.2.2. Gains and Carcass Data for Yearling Steers

After yearling steers fed grain at 1.0% of liveweight were switched to graze bluegrass-white clover until May when slaughtered, their liveweight gains averaged 2.41 lb daily. Gains during 180 days from November to May averaged 1.87 lb daily. Liveweights increased from 632 to 970 lb when slaughtered; carcass grades were satisfactory, averaging high-good (Table 31).

Yearling steers first grazing 243 days from November to July, when slaughtered, gained 1.44 lb daily; with initial weights of 639 and final weights of 999 lb, carcass grades averaged high-standard (Table 31). A third group of yearling steers was fed grain at 0.5% liveweight until May when grain was increased to 1% until they were

Table 30. Daily liveweight gains of weanling and yearling steers grazing stockpiled Kentucky 31 tall fescue-red clover during winter (2-year averages at Middleburg)

Kind of grazing*	Supplemented ground corn as % of liveweight	Daily liveweight gain, lb — Days after Nov. 18: 1 to 56	57 to 112	113 to 154	Average 154 days
		Yearling steers			
First grazing	0	1.49	1.53	1.21	1.43
Whole plant	0.5%	1.65	1.65	1.70	1.65
Whole plant	1.0%	1.82	2.00	1.61	1.74
		Weanling steers			
First grazing	0 0%	1.04	1.68	1.19	1.37
First grazing	0.5%	1.71	1.81	1.95	1.81
Whole plant	0 0%	0.85	1.59	1.10	1.24
Whole plant	0.5%	1.02	1.60	1.86	1.44

*First grazers consumed about 60% of the AP and whole plant rotational grazers consumed about 85% of the APs for ordinary rotational grazing.

Table 31. Daily liveweight gains, liveweights, slaughter dates, and carcass grades of yearling steers at various seasons when grazing different mixtures with different managements during November to May or July (2-year averages at Middleburg)

Grazing* and Grain Supplement	Daily liveweight gain, lb** Winter	Spring	Spring-Summer	Average all seasons	Liveweight, lb Initial	Final	Carcass grade	Slaughter date
First no grain	1.43	2.34	0.92	1.44	639	999	High standard	July
Rotational Grain, 0.5% liveweight, then 1% in May	1.65	2.45	1.59	1.71	625	1047	Medium good	July
Rotational grain @ 1% of livewt.	1.74	2.41	---	1.87	632	970	High good	May

*Pasture sources were: winter = stockpiled tall fescue-red clover; spring = bluegrass-white clover; spring-summer = bluegrass-white clover, alfalfa-orchardgrass and tall fescue-red clover.
**First grazers were rotated after consuming about 60% of AP; about 85% of the AP was consumed with rotational grazing.

slaughtered in July. During 243 days of whole plant, controlled rotational grazing of stockpiled fescue-clover and then bluegrass-clover, daily liveweight gains averaged 1.71 lb. Initial weights of steers averaged 625 lb, and final weights were 1047 lb, resulting in medium-good carcass grades (Table 31). Grain supplements improved liveweights, carcass grades, and dollar value of carcasses and reduced the grazing periods needed to produce desirable carcasses.

III.F.2.3. Gains and Carcass Quality of Weanling Steers

Weanling steer calves, grazing stockpiled fescue-red clover from mid-November until April, were switched to bluegrass and then rotated among the three forage mixtures in the system to provide an AP of adequate quality and quantity until October. The weanling steers were either slaughtered in October or fed a corn silage fattening ration to attain a high-good carcass grade. Steers managed as first grazers for high intake gained 1.31 lb daily for the 329-day grazing season (Table 32). The carcass grades averaged medium-good, a very satisfactory lean beef carcass produced with controlled grazing. Gains of weanling steers with controlled whole plant rotational grazing among three mixtures were lower than for first grazers and carcass grades were also lower, averaging low-good. With first grazing and feeding grain at 0.5% of the liveweight of weanling steers, daily liveweight gains for two years averaged 1.62 lb and carcass grades were excellent, averaging low-choice. Initial and final liveweights of steers were 569 and 1102 lb, respectively. Similar steers with controlled whole plant rotational grazing and with corn supplemented at 0.5% of liveweight until May and then increased to 1% until October, gained 1.54 lb daily and produced high-good carcass grades (Table 32).

Based on experiments described in Section II, first grazing as compared to controlled rotational grazing should improve liveweight gains by about 40%. In these experiments first grazing for the November to October season increased gains by only 9%. It is possible that first grazing of stockpiled fescue and clover does not improve animal performance as much as for the spring-fall season. However, yearlings gained 1.74 lb daily during 154 days during the first year. During the growing season, where about 60% of AP was consumed, the unutilized AP residues after repeated first grazing caused accumulations of old and dead forage that depressed quality of AP. Using cows as last grazers to consume the low quality ungrazed residues in a system with first grazing steers, would have improved the quality of AP for high intake and performance of steers.

Table 32. Liveweight gains, liveweights, slaughter dates, and carcass grades of weanling steers at various seasons when grazing different mixtures with different managements during November to mid-October (2-year averages at Middleburg)

Grazing* and grain Supplement	Daily liveweight gain, lb: Winter	Spring	Summer-Autumn: May-mid-July	July-mid-Oct	Average all seasons	Liveweight, lb: Initial	Final	Carcass grade	Slaughter date
First no grain	1.37	1.46	0.86	1.49	1.31	562	990	Medium good	Mid** October
First grain @ .05% livewt.	1.81	2.28	2.15	1.20	1.62	569	1102	Low choice	Mid October
Rotational no grain	1.21	2.63	0.86	0.90	1.21	560	960	Low good	Mid** October
Rotational grain @ 5% then @ 1% of livewt. in May	1.44	2.12	1.68	1.49	1.54	552	1060	High good	Mid October

*Pasture sources were: winter = stockpiled tall fescue-red clover; spring = bluegrass-white clover; spring-summer = bluegrass-white clover, alfalfa-orchardgrass and tall fescue-red clover.
First grazers were rotated after consuming about 60% of AP; about 85% of the AP was consumed with rotational grazing.
**After mid-October, half the steers were fed a corn silage-protein meal fattening ration for a short period to reach high good carcass grade.

Consuming 60% of the AP in these experiments as compared to 50% of the AP in other experiments (Section II.H.3) caused lower DDMI and gain.

The responses from supplementing ground shelled corn are thought to be low. Mixing salt and grain to control grain intake caused large day-to-day differences in grain intake and likely depressed animal gains. The variable grain intake was probably caused by large variations in temperature and moisture during winter that influenced water intake and interacted with the intake of the grain-salt mixture.

Nevertheless, the data with weanling and yearling steers, with and without grain supplements, in forage management systems with different mixtures has set forth principles that may be implemented for profitable operations. The simple forage systems for year-round grazing with little hay harvesting and feeding should be modified and implemented into systems for specific farms. For example, stockpiled fescue with clover declines in quality as repeated freezing and thawing cracks leaves, causing leaching of nonstructural carbohydrates and declining digestibilities. Thus, delaying grain feeding until about January would augment fescue-clover intake and cause consumption of the stockpiled fescue during its peak quality period and would improve animal gains because grain would be fed after the quality and quantity of the fescue has declined. Pasture forage quality peaks during the flush spring-early summer season and declines during summer. Thus, with October or November slaughtering, grain feeding might be delayed until mid summer when quality and growth of pastures declines. Heifers supplemented with grain and slaughtered in summer might be used in systems with steers to reduce stocking rates after the flush pasture season. Also, changing the seasonal stocking rate in a system, where weanling steers are managed for October slaughter and older steers for spring or early summer slaughter, agrees with seasonal pasture growth and quality (Figure 16). Supplementary grain in summer is equivalent to reducing the stocking rate to increase AP. Feeding grain at 1% of liveweight is similar to a 50% reduction in stocking.

Corn silage supplemented with protein, used with two grazing systems for short feeding periods to finish steers to good to choice carcass grades after mid-October, is an excellent fattening ration (Section II.J). Corn silage-protein meal rations could be fed in a system to fatten cattle after they graze the flush high quality spring-early summer forage or at the end of the grazing season.

III.G. Integrating Calf-Raising with Growing Cattle

Farmers by themselves and with help from professionals should apply the principles set forth in this publication to design potentially profitable forage animal systems for implementation on a specific farm. Based on these principles, we suggest and exemplify a potentially profitable system for integrating forage-animal management to raise beef calves and concurrently grow the weaned calves for replacements, feeder, and/or fat cattle. The proposed system is planned for farms with soils and topographies not suitable for row crops.

III.G.1. Principles for Designing Systems

Principles for designing this proposed system and the other systems discussed in Sections II and III are summarized below.

1. Use simple grass-legume mixtures adapted to soils on a farm in different fields to develop a dependable supply of high quality forage for year-around forage feed by managing the mixtures flexibly for grazing, hay, and/or silage.
2. Employ fertilizer and utilization methods to maintain legumes. Legumes improve animal performance and reduce costs of producing high quality forage.
3. Obtain the best varieties of forage and grain cereals to be harvested for silage or grain.
4. Employ and control forage mixtures and managements to attain year-round grazing to minimize equipment, harvesting, and feeding costs.
5. Utilize the forage, maintain leafy growth, and harvest in a leafy growth stage, these factors being especially important for the flush and best quality forage in the spring season that is often wasted.
6. Use high stocking for a farm or system made possible by controlling AP by varying the stocking rate achieved by harvesting or grazing more or less forage in the system or farm or selling cattle after the spring flush growth.
7. Vary and control AP to furnish the nutrition needed by classes of ruminants and for cycles of production to achieve efficient conversion of forage to animal products.
8. Minimize or avoid using animal shelters for beef herds.
9. Do not feed protein, grain, or high energy silage to beef cows and their nursing calves nor to replacements.
10. Energy (not protein) may be supplemented to cattle to be slaughtered to shorten the grazing period and to produce desirable carcasses more rapidly.
11. Practice managements that recycle animal excreta to improve forage production at reduced fertilizer costs.
12. Cycle breeding so that the number and nutritional needs of animals on a farm coincide with seasonal forage production and quality.
13. Practice rigid culling such as selling animals vulnerable to health problems and cows that are not pregnant 3 months after calving to maintain nearly 100% conception.
14. Observe pastures and animals daily to make reliable predictions on forage growth and expected AP to provide for the nutritional needs of animals.
15. For this proposed system, the achievement of the grazier in soil, plant, and animal management is to be measured by profits, associated with a 95% calf crop weaned at one-half the weight of their mother and producing 270 lb of calf and 200 lb of liveweight from weanlings per acre each year.

III.G.2. Proposed System

There is to be year-round grazing and minimum harvesting of forage as described for systems A and B (Section III.E). Cows will be bred for winter or spring calving with October weaning, selling them in June to July as feeder, replacement, and/or slaughter cattle. Hence, stocking will be lower in summer, when there is a high probability of slower forage growth than for the spring season. The date(s) of selling the weanlings as yearlings can be flexible depending on the present and predicted AP. Heavy stocking in spring is coordinated with flush growth of high quality AP.

Weanlings require high nutrition. A high stocking rate will be used without sacrificing liveweight gains of weanlings by allocating a high AP via first grazing; cows are to be last grazers consuming the residues. In case AP does not provide adequate nutrition for nursing calves and weanlings, second cutting alfalfa-grass or red clover-grass hay harvested in bud stage will be fed in winter.

The nutrition of cows varies with cycle of production and may be provided by controlling AP and quantity of hay fed when snow cover prevents grazing or when there is a short supply of stockpiled fescue-clover pasture (Section III.E).

Controlled rotational grazing, with the first grazing weanlings, will begin with a high and end with a medium-plus AP; with last grazing cows, grazing will begin with a medium-plus and end in a low AP. Stated in another way, weanlings require less pasture than nursing cows; hence, when cows are to be rotated to the next pasture because of a low AP, the weanlings will have grazed only about a third of the AP. Thus cows, before and after calving, will have good nutrition while grazing the residue left by weanlings. Selling the weanlings in the spring-early summer season will reduce the stocking rate to furnish high nutrition with creep grazing for the nursing winter calves.

III.G.3. Forage Mixtures and Management

For the proposed system it is assumed that fields and forage mixtures are: 1) and 2) a large field of natural bluegrass-white clover pasture to be subdivided into two pastures, (3) an alfalfa-orchardgrass mixture, (4) an endophyte-infected tall fescue with ladino and red clover, and 5) an unproductive orchardgrass-red clover field that was seeded to an endophyte-free tall fescue with red and ladino clovers. These fields of varying acres may be subdivided with simple electric fences or an electric wire to facilitate first and last rotational grazing and creep grazing. Based on fertilizer history and soil tests, soil amendments have been applied to maintain productive legumes. Grazing and harvesting managements will favor maintenance of legumes, encourage rapid regrowths after utilization, and compromise yield and quality of forage mixtures to maintain plants as discussed in Section II. Forage-animal management will be similar to that for III.E, Systems A and B, except that first grazing with weanlings and last grazing with cows will be integrated into the system.

The weanlings (winter calves weaned in October) will first graze the forage mixtures in the following sequence: alfalfa-grass during late October and November, stockpiled fescue-red clover during November to mid-April, spring growth of alfalfa-grass and bluegrass-white clover during April to early May; and bluegrass-white clover and fescue-red clover mixtures during April to July. High quality hay harvested in a bud stage will be fed to weanlings during periods of snow cover or whenever a low quantity or quality of AP does not supply adequate nutrition for the weanlings. The cows will be last grazers, grazing residues left by weanlings. Hay will be fed to cows whenever AP is inadequate. Creep grazing is dated to replace first grazing, beginning in mid-spring, as weanlings are sold.

Bluegrass-white clover pastures will be first and last grazed whenever AP is adequate, except during the fall-early winter season. After calves are weaned, the dry cows will be fed restricted amounts of first cutting alfalfa grass hay, as AP of bluegrass pastures becomes inadequate. After the weanlings are sold in late spring, creep grazing will be managed as discussed in Section III.E, Systems A and B.

The fescue-clover fields are to be stockpiled for winter grazing and also grazed during spring to mid-August. In years of exceptional growth with excess AP, one or both of the fescue fields may be harvested for hay in June.

The first two growths of alfalfa-orchardgrass will be harvested for hay; the second growth is to be cut when alfalfa is in a bud stage to produce a high quality hay for weanlings and nursing calves, fed during low AP periods. In April for 4 to 6 weeks, when AP is low, weanlings will graze the alfalfa-grass field that is to be cut later for hay (Section II). To control rotational grazing of the third and fourth growths of alfalfa with grass, an electric wire will allow calves to pass under it to creep graze. Creep and last grazing combined is to last about 10 days in a subdivided field. When alfalfa regrowth becomes semi-dormant because of low temperature after mid October, weanlings will continuously first graze (no subdivisions) the alfalfa-grass mixture until AP restricts growth of weanlings. The cows will graze the residue.

III.G.4. Flexibility and Alternatives

There are many alternatives. For example, the weanlings may be supplemented with grain to produce fat slaughter cattle (Section III.F). Calves could creep graze concurrently with the first grazing weanlings. The later procedure could be used if weanlings are not sold after the flush pasture growth period. Decisions on supplementing energy grains and dates of selling weanlings should be flexible and concurrently allied with prices of feeder and fat cattle and the predicted AP.

Other mixtures that are already on a farm may be used in a system. For example, bluegrass pastures, not suitable in southeastern Virginia, would be replaced by clover mixtures with orchardgrass or tall fescue. The proposed system would function when all fields are in tall fescue as described in III.E, but only if legumes are maintained in fescue. Where fescue is the primary grass component, each pasture should be sampled to ascertain the degree of endophyte infection (see Section II.D.3). If the endophyte infection is high, as it is likely to be, the tall fescue can be killed with an herbicide such as glyphosate after grazing during spring and then planted to corn and sod-seeded to an endophyte-free variety of tall fescue with clover after the corn is harvested. Costs could be distributed by destroying one field of tall fescue yearly. The economic aspects for eradicating endophyte-infected tall fescue grown with and without clover depend on comparative animal production of near endophyte-free and infected tall fescue grown with and without clover. Research data on animal performance of pastures with low and high fungus infection for Virginia environments are not yet available.

The number of pastures depends on the system and the concurrent management of the pastures and animals. Fences and their maintenance along with providing water and shade in each field are costly. Hence, the number of pastures should be kept to a minimum, even though controlled grazing is simplified with many subdivisions.

Raising the October-weaned calves and selling them after they have grazed the flush high quality pasture the next year could be profitable. This practice reduces harvesting costs and keeps the best pasture from being wasted in spring. A good system is one that is profitable, and profitability does not depend on the number of pastures, *per se*. It is important for a system to have a strong outside boundary fence; an electric wire may be used for some of the subdivisions.

III.H. Forage Systems for Dairy Cattle

It is a common practice for dairy farmers to use dry lot feeding for replacements and especially for milking herds managed for high production per cow. Year-round dry lot feeding of dairy cattle is not a panacea; however, dry lot feeding is the best economic system for soil and climate environments that maintain high yield crops, if intensive tillage does not deplete soil fertility and pollute nearby areas through soil erosion and excreta effluents. Acre yields of crops such as corn and small grains for silage and alfalfa are much higher than for pastures. However, the yield advantages of crops are usually overestimated because crops are grown on more productive soils than are pastures. Dry lot feeding *per se* augments capital outlay and operation costs. When the high milk production level per cow is coupled with such added costs as decreased longevity of cows, veterinary fees, feed ingredients, and additional interest and capital expenses, alternatives to solely dry lot feeding may be more profitable on many dairy farms.

Dry lot feeding of milk cows and replacements has been promoted by a false concept that pastures are inferior in nutrition as compared to dry lot feed. Data in Section II show that pastures with grasses and legumes of temperate origin, managed to maintain leafy growth and an adequate amount of available pasture (AP), are equal to or superior in nutrition to many dry lot feeds. Thus an experiment was planned comparing milk production with dry lot and pasture feeding to obtain information to develop alternative economical forage-feeding systems for dairy farms with various soils, environments, and facilities. Data in Table 4 show much higher milk yields per cow grazing pasture than for dry lot feeding of leafy alfalfa-grass hay, with or without low concentrate supplementation.

III.H.1. Milk Production with Pasture, Dry Lot, and Pasture-Dry Lot Systems

The pasture for two experiments was a mixture of orchardgrass, bluegrass, ladino clover, and white and red clover. Because of unsatisfactory clover stands, a mixture of red and ladino clovers was drilled into the sod in bands sprayed with paraquat in March to reduce grass competition while clovers became established. The pasture was divided into four fields for rotational grazing and managed to maintain leafy forage and to control AP; cows were moved to a fresh field before a low AP depressed milk production. Milk production and AP were observed daily to determine appropriate times for moving cows to a fresh pasture (Figures 20, 21, and 23). The clover generally made up less than 30% of the AP; a higher clover content would likely have improved yields and quality of pasture. All pastures had some tall fescue which was rarely grazed. The four pastures had drinking water but no shade; hence a fifth field with shade, to be grazed during hot sunny days, was added during the second grazing season.

Because some of the lactating cows were involved in other experiments or demonstrations, grazing by cows was delayed until May. Heifers were used during the April season to graze and control the AP. Thus, during several weeks of the early growth with the best quality pasture that stimulates animal production along with favorable cool temperatures for lactating cows, the best quality pasture was not used to measure milk production (Figure 16). The duration of the trial each year was generally 16 weeks. Except where indicated, there were 8 to 16 cows per treatment each year. The dry lot feed was corn silage (sometimes barley silage) and ground corn with a supplement (Table 33) to meet Nutrition Research Council requirements for high-producing milk cows.

Dry lot-fed Holstein lactating cows, beyond maximum milk production, were selected in groups of 3 cows and randomized to three treatments so that cows were similar in production and other characteristics for each of three forage systems. The cows in dry lot were assigned directly to pasture without feed

Table 33. Milk production and its composition from cows on pasture, dry lot, and exchanged between pasture and dry lot (3-year averages at Blacksburg)

Milk yield and composition	Cow groups		
	A - Pasture*	B - Dry lot**	C - Exchange***
Milk, daily	55.2 lb	55.9 lb	55.5 lb
Fat content	3.19%	3.57%	3.40%
Solids-not fat	8.38%	9.92%	8.62%
Protein content	3.11%	3.01%	3.18%
Protein and solids - not fat - 2 yr. average			

*A supplement (96% ground corn, 3% calcium phosphate, and 1% iodized salt) was fed free choice the first year and at a total of 16 lb per cow the next two years; half of the supplement was fed before each of two daily milkings.
**The dry lot cows were fed a complete mixed ration of 55% corn silage (sometimes barley silage), 16.2% ground corn, and 28.8% supplement (all dry basis) to meet the NRC requirements for milk cows. The crude protein and crude fiber units were 14.6 and 19.7, respectively. The supplement, percent dry basis, consisted of the following: 75.75 soybean meal, 2 pellet binder, 5.75 wheat, 2.5 distillers grain, 3.0 wet molasses, 1.25 dry molasses, 3.5 calcium phosphate, 2.5 limestone, 1.75 salt, 0.75 sodim sulfate, 0.75 magnesium oxide, and 0.5 each vitamins A and D.
***Exchange cows were usually restricted to pasture for two weeks, followed by dry lot feeding for two weeeks.

adjustment periods. The three systems were (Table 33): (A) switched from dry lot to pasture and supplemented with a ground corn-mineral mixture, (B) continuously in dry lot, and (C) exchanged from dry lot to pasture for two weeks and back to dry lot for about 2 weeks with the cycle repeated for the grazing season.

During three grazing seasons milk, 4% fat, per cow was similar for the three forage systems, but milk was 0.38% lower in fat for cows on pasture as compared to those in dry lot (Table 33). The milk fat from exchange cows was also higher than that for cows restricted to pasture. Solids, not fat, were lower in milk for cows on pasture but protein contents were similar for the three treatments. Shifting the diet from dry lot with a complex supplement to pasture supplemented with a ground corn-mineral mixture did not alter daily milk production per cow. Even during spring, when some cows produced around 80 lb milk daily, switching cows directly from dry lot to pasture did not alter milk production per cow significantly.

The effects of the three forage systems showed that body condition was best for dry lot cows and lowest for cows restricted to pasture. At the end of one grazing season when cows were weighed, the cows on pasture weighed 1346 lb as compared to 1481 lb for dry lot cows.

III.H.2. Grain Supplements for Cows on Pasture and Milk Production

The high rate of feeding the ground corn-mineral mixture probably reduced pasture and fiber intake, causing a reduction in fat content of milk. Thus cows grazing good pasture were fed 8, 12, or 16 lb of a corn-mineral mix daily. Milk production, 4% fat, per cow differed, being 51.5, 52.4, and 54.6 lb per cow per day for the respective rates of 8, 12, and 16 lb of corn mixtures. Fat content, 3.52%, was highest for the low rate of feeding corn, and lowest, 3.23%, in milk of cows with the high rate of supplementing grain (Table 34). Milk protein percent was similar for the three rates of feeding the corn-mineral mixture.

The reduction in fat content of milk from cows on pasture as compared to dry lot can be nullified by reducing grain supplements that caused small sacrifices in milk production per cow. Because of milk fat surpluses, it is unfortunate that tradition maintains price gradients based on milk fat.

Table 34. Milk yield and its fat content as influenced by rate of feeding a corn supplement to cows on pasture (2-year averages at Blacksburg)*

	Corn-mineral mixture lb daily per cow**		
	8	12	16
Milk/day	51.5	52.4	54.6
Fat, %	3.52	3.30	3.23
Protein, %	3.15	3.10	3.16

*There were 4 cows per treatment each year.
**Mixture - 96% ground corn, 3% calcium phosphate, and 1% iodized salt.

III.H.3. Integrating Dry Lot Feeding and Grazing

The information on the value of pastures for milk production to modify dry-lot feeding, and other results, should be implemented to reduce operation costs and improve net profits on some dairy farms. The fact that the diet of high-producing milk cows can be shifted abruptly from dry lot feed to pasture supplemented with corn and back to dry lot without reducing milk yield per cow suggests economic alternatives to dry lot feeding. Contrary to accepted opinions, the milk production data show that rumen flora function efficiently with changing diets; hence forage feeds can be altered to use systems of dry lot and grazing combinations without sacrificing milk yield. For many dairy farms, due to soil and topography, some of the land area is suitable only for perennial forage plants and other areas may be cropped intensively. The pastures are often not utilized, and potentially excellent forage is allowed to grow to maturity and is wasted. On many farms where sods are necessary to control erosion, high-producing cows should be switched to pasture during the flush growth of the spring-early summer period, when leafy grass-clover mixtures are 70 to 78% digestible. Pastures with species of temperate origin, managed to provide a high AP, cause high DDM (energy) intake and enough protein to produce more than a 100 lb of milk daily per cow. Leafy grass-legume mixtures, without nitrogen fertilizer, can be excellent low-cost forage, high in minerals, protein, vitamins, and digestible energy. Also, high-producing cows grazing such forage require only a corn-mineral supplement as compared to more costly supplements with dry lot feeding.

With a dry lot-grazing forage system the cows should be managed flexibly. After grazing during the flush spring-early summer growth for 50 to 100 days, depending on AP, all or some of the cows could be switched back to dry lot. Depending on the size of the grazing area and pasture needed by replacements and dry cows, lactating milk cows would be managed flexibly to utilize pastures or returned to dry lot during summer and fall. The success of incorporating grazing into dry lot feeding systems depends on maintaining the quality and quantity of AP (Figures 3, 4, 5, 6, 16, 17, 19, and 28; Tables 3, 4, and 33). A controlled and high AP is directly related to a high daily intake of forage and high nutrition, and is attainable with controlled continuous or controlled rotational grazing.

Implementing first grazing into a forage system could improve milk production per cow and/or reduce supplementary feeding as compared to the results in Tables 33 and 34 obtained with controlled rotational grazing. With controlled rotational grazing cows not supplemented with energy and grazing about 50% of the AP, first grazers produced 24 to 55% more milk than did cows grazing the remaining 50% AP (last grazers). With a first grazing-milk production system to achieve and maintain high milk production with minimum supplementation, the highest producing cows would be first grazers (Figures 21, 22, 23, and 25; Tables 9, 10, and 11); dry cows, cows being "dried off," or replacements would serve as last grazers.

Forage systems for milk production and growing replacements on dairy farms with little or no land suitable for intensive cropping may develop systems with simple mixtures of grasses and legumes managed flexibly for hay, silage, and grazing. The models described in III.C and III.D can be modified and adapted to dairy farms. A suitable forage system with perennial plants for milk cows requires managing to maintain high yields to supply high nutrition — obtainable with leafy legume-grass mixtures, leafy growth of stored forages, and controlled AP's (Figure 28).

When grazing pastures all season with milk cows, grain supplements should be increased as the season advances because quality and quantity of pasture decline with season.

III.I. Pastures and Forage Systems for Horses

Forage is the primary diet component for horses. Pastures are major contributors to health, conception, and performance of horses. Forage from pastures is more nutritious than hay, being higher in digestibility and ingested energy, amino acids and protein, minerals, and certain vitamins. Also, pastures as exercise areas augment the physical condition of horses, especially for developing colts and fillies. Fortunately, with the climate coupled with altered soil environments in Virginia and the Middle Atlantic Humid Region, plants may provide grazable forage all year. Forage accumulated during the fall season furnishes winter grazing. Pastures made up of plants of temperate origin are more nutritious than plants such as bermudagrass, of semi-tropical or tropical origin. In southeastern Virginia, with warm summers accompanied by drought and over-grazing, cool-season plants decline while common bermudagrass weeds and crabgrass (a nutritious weed) invade and suppress cool-season plants.

Pastures with persistent and productive grass-clover mixtures depend on three concurrent management principles: (a) soil amendments to reduce acidity and give good fertility, (b) adapted species and varieties of plants for micro-climates and soils on a farm, and (c) controlled grazing management. Soil analyses to ascertain lime and fertilizer amendments and information on adapted varieties of grasses and legumes may be obtained from state extension services and from commercial sources.

As compared to cattle and sheep, there is little information on nutrition of horses. However, principles on growing and managing forage plants and mixtures to provide high or needed nutrition and high performance of ruminants (cattle and sheep) unquestionably apply to horses, which have a caecum as an organ aiding digestion. Digestibility and consumption values of forages ascertained with cattle undoubtedly apply to horses. For example, horses and cattle selectively graze young grasses and legumes that are around 75% digestible (dry matter basis) and ignore mature stemmy growths that are low in digestibility. Both cattle and horses find tall fescue unpalatable, leaving fescue more or less ungrazed when it is a contaminant in pastures with bluegrass or orchardgrass. Clover in a grass mixture stimulates productivity of cattle and sheep as compared to grass pastures; this principle likely applies to horses. High pasture intake stimulates performance of animals; cattle apparently have a little higher daily consumption per unit of liveweight than horses. Horses, grazing short leafy pasture that stimulates intake, consume pasture dry matter equal to about 2% of their liveweight daily. This consumption is equivalent to about 10% of their liveweight as green matter, or about 100 lb of green pasture daily for a 1000 lb horse.

Nutrition for horses, as for ruminants, is influenced by controlled pasture management. For example, controlled grazing should provide young leafy grass growth with some clover and adequate amounts of available pasture (AP) to encourage a high intake of highly digestible pasture herbage to give high conversion efficiencies of forage to growth, work, or milk production of mares (Figures 3, 4, 5, 6, 20, and 28). Also, utilization methods with cattle apply directly to managing pastures and hay crops for horses. Hence, understanding the principles in Section II is basic to controlled pasture management for good nutrition for horses. The nutritional requirements of horses undoubtedly vary, requirements of growing fillies and colts being higher than for mares (Figure 28). **Controlling the quality and quantity of available AP to supply the nutritional needs of various horses is vitally important, unless horses obtain their nutritional needs from supplementary feed** (Figure 28).

III.I.1. Plants and Mixtures for Pastures for Horses

Varieties of only two perennial grasses of temperate zone origin, tall fescue and Kentucky bluegrass, maintain dense sods and good production indefinitely under good management in Virginia. Bluegrass is not suitable for Eastern Virginia and Southern Piedmont. Kentucky 31 and other adapted varieties of tall fescue thrive in all areas of Virginia with good management. Orchardgrass, widely adapted, is short lived in Southeastern and Southern Piedmont Virginia; in cooler Virginia it persists for 3 to 10 years. Tall fescue is better adapted than other cool-season grasses because it persists under a wider range of soil and climatic environments. Fescue persists on dry or poorly drained soils, and with lower acidity and fertility than other cool-season grasses; it also persists with warmer temperatures and is disease- and insect-resistant. Bluegrass is more persistent with continuous grazing than tall fescue and orchardgrass because it is difficult to defoliate as compared to taller grasses (Figure 8). Because of good nutritional value and persistence, bluegrass is the best grass for horse pastures in Northern Piedmont and west of the Blue Ridge. Tall fescue invades bluegrass pastures by seed; then established plants spread laterally by tillers and short rhizomes, to subdue bluegrass. The succession of tall fescue depresses bluegrass by light competition because fescue is not grazed. Tall fescue should not be used in mixtures with other grasses; mowing when seedheads start to appear will stall invasion of plants from seed.

Tall fescue seed of all varieties, unless indicated, may be infected with a fungus endophyte. All tall fescue pastures or plants invading into pastures are likely infected with an endophyte (Section II.D.3); hence, fescue pastures should not be grazed by horses, or should be grazed with caution and an awareness of probable fescue toxicity which may cause problems with reproduction and lactation of mares. The presence of clover with endophyte-infested tall fescue may or may not depress potentially harmful effects, as with cattle. If fescue pastures are to be established, endophyte-free varieties should be used. Seed certified to be free of the endophyte is scarce but will be available. Tall fescue pastures can be sampled to ascertain the degree of infection with endophyte (Section II.D.3). At Rokeby Farm, bluegrass-white clover pastures with as much as 20% of the area in tall fescue have not caused problems with thoroughbred horses; however, the fescue is rarely grazed.

Perennial grasses like orchardgrass, Clair timothy, or improved varieties of perennial ryegrass may be used in mixtures with bluegrass and white clover in Northern Piedmont and mountainous Virginia. These grasses with good seedling vigor shorten the establishing period of pasture in mixtures with bluegrass and white clover (Section II.D.4).

Bermudagrasses are well adapted to southeastern Virginia. Common bermudagrass grows during the short, warm summer season; it is a prolific seeder, and seedlings spread rapidly by stems in and above the soil that form tillers and roots (Figure 8). Summer nitrogen fertilization or 10-10-10 fertilizer has produced dense sods and high yields of volunteer bermudagrass on a sandy soil at the Warsaw Research Station in Eastern Virginia. Hybrid bermudagrasses such as Midland and Coastal do not produce viable seed; these varieties are adapted to Southeastern Virginia and are established by planting live vegetative materials. The bermudagrasses grow at warm summer temperatures and furnish grazing for about 4 months.

Winter annual small grain varieties of rye, wheat, or barley may be used for temporary winter grazing or in new seeding mixtures to obtain soil cover quickly for erosion control. Rye makes more growth during cold temperatures than any perennial or annual grass; it is of excellent quality when leafy. Adapted legumes for Virginia are white, red, and ladino clovers, alfalfa, and annual lespedezas (Korean or Kobe varieties for summer grazing). Ladino clover may be used in all areas of Virginia, but ladino is not tolerant of continuous and close grazing; also ladino clover herbage is apparently injured by freezing more readily than the shorter white clovers. For horse pastures, short varieties of white clover such as Nolan and Louisiana S-1 are probably the best seed sources to be grown with bluegrass.

The natural white clover that regenerates from seeds in soils develops persistent stands, and is likely the best variety. White clover seeds in soils stay viable for more than 20 years; some seeds germinate yearly in spring and fall after exposure to cool temperature-moist soil conditions followed by warm temperatures. Thus, under good fertility and close grazing during fall and spring for seedling survival, germinating seeds augment white clover stands in all areas of Virginia but especially in Northern Piedmont and mountainous regions. Based on this principle, used at Rokeby Farm in Northern Piedmont, good stands of white clover have been maintained without reseeding for 35 years.

A mixture for establishing pastures in Northern Piedmont and Mountainous Virginia is: Kentucky bluegrass, a 50/50 mixture of common Kentucky bluegrass and another variety recommended for turf at 15 lb per acre; white clover at 1-3 lb per acre; and perennial ryegrass or orchardgrass at 3 lb per acre. Clair timothy at 3 to 5 lb per acre may be added to the mixture.

The best dates for seeding are late February to mid April or during late August to late September. Orchardgrass or perennial ryegrass is added to shorten the period for establishing a cover to reduce the chances for erosion and to provide grazing sooner than for bluegrass. Grazing should reduce the height of these vigorous grasses so bluegrass and white clover are not depressed by shade.

Mixtures for the warm Piedmont Region and Eastern Virginia are: orchardgrass at 12-15 lb per acre with white or ladino clover at 1-3 lb per acre or an endophyte-free variety of tall fescue at 12-15 lb per acre with white or ladino clover at 1-3 lb per acre. The latter mixture is more persistent under both good and adverse conditions.

Bermudagrass pastures may be developed from natural invasion of common bermudagrass from seed and liberal nitrogen applications in late spring in the warm southern and eastern parts of Virginia. Hybrid bermudagrasses may be established with sprigs. Bermudagrasses persist under close grazing. The short grazing season can be lengthened by seeding small grains and annual ryegrass in dormant bermudagrass sods.

III.I.2. Grazing Management

Pastures grazed all year by horses are damaged by compaction from stamping while resting, and running and galloping also injure sods. Grazing and exercising when soils are wet or after thawing cause severe soil compaction, which depresses root depth and plant growth. Light stocking, as with thoroughbred horses, and the variable pasture growth rates in seasons cause spotted grazing and undesirable shifts in plant components of pastures.

During the flush growth period from April to midsummer, good bluegrass-clover pastures produce enough forage for an average of two 700 lb yearling cattle per acre and about one 700 lb yearling during the summer-fall season (Figures 16, 17, and 19). Based on pasture consumption by cattle, the rate of pasture growth averages about 178 lb of green forage (32 lb of dry matter) per acre per day during the spring-early summer season and about one half of these amounts during the summer-autumn season. To control quality by utilizing the available pasture (AP), fields would have to be stocked with about two 800 lb horses per acre during spring and one horse per acre in summer. However, such heavy stocking is not recommended with thoroughbred horses. Without supplementary feed, a horse consumes dry matter equal to about 2% of its liveweight daily.

Light stocking, coupled with inherent selective grazing by horses, causes repeated grazing of already closely grazed areas (spot grazing). These spots do not get a "rest" from grazing because of their high palatability and nutrition as compared to the taller ungrazed accumulating growth. The closely grazed spots shift to mostly white clover (Figure 13) and even bare soil during dry and high temperature periods. The ungrazed areas shift to tall growth with seed stems by mid-spring (Figures 12 and 15).

Possible low pasture intake with close spotted grazing by horses may increase as the grazing season advances because pasture growth rate in summer declines to about 50% of spring growth. Thus, closely grazed spots that may furnish adequate AP during flush spring season do not provide needed AP for high nutrition during periods of slow growth (Figures 16 and 20). Also, as young horses grow, the season advances and they need more forage. Closely grazed spots depress pasture growth in two ways. The overgrazed plants do not grow rapidly because of low leaf areas and low nonstructural carbohydrates (Figures 8, 10, and 11), and because of adverse microclimates.

When bluegrass or other cool-season grasses begin to grow stems in spring, growth is very rapid; hence it is necessary to add cattle at a high stocking rate of up to 40 cattle per acre to consume young stems quickly while they are palatable and nutritious (Figures 3, 4, and 5). When grazed below the bud, stem tillers die; hence, all regrowth is leafy and can be accumulated for later grazing (Figure 12). Grazing close during the spring season, when moisture is usually adequate, encourages clover. When these stemmy growths of temperate grasses that appear in spring are not grazed and are allowed to mature, as with severe undergrazing, massive accumulations of stemmy growths imbedded with dead and moldy leaves and stems become an unpalatable and worthless roughage. These dead materials intercept most of the light; the low radiant energy causes sparse stands of etiolated vegetative tillers that grow slowly or often die because of diseases. The dead ungrazed materials finally form a thick surface mulch that inhibits new growth. It is difficult to rectify this problem; perhaps the best solution is prolonged heavy stocking with 40 to 50 beef cows per acre to force consumption of the dead material containing some sparse green tillers. Bad, or a lack of, management allows the occurrence of over- and undergrazing which harms plants and causes low nutrition for horses.

The person charged with the responsibilities of raising horses should be a grazier with a good conception of AP as interrelated to nutrition of horses (Figure 28) and of maintaining quality and growth of AP (Section II). A grazier must appraise AP *in situ*, expected pasture growth, and expected pasture consumption by horses and cattle daily to decide on the number of cattle grazers to add or withdraw. A common fault of graziers is to underestimate the high growth rates of pastures during the early spring-summer season. Bluegrass-clover pastures produce about two thirds of the total yield in the first third of the year. Grazing should begin early with reasonably heavy stocking in anticipation of flush growth. Undergrazing during spring amplifies later management problems.

Growth of pastures usually increases during the cool early autumn. Hence, cattle may be used to graze old pasture canopies rather closely in September to accumulate new young leaves that are cold tolerant, ideal for winter grazing by horses.

III.I.2.1. Continuous Grazing

Bluegrass-white clover pastures persist under continuous grazing with good management in Northern Piedmont and mountainous Virginia. Large pastures with light stocking reduce probabilities of injury and encourage physical conditioning of developing colts and fillies; hence bluegrass-white clover pastures grazed continuously all year or part of a year are practical, especially for thoroughbred farms. Maintaining soil fertility for bluegrass-white clover pastures, and light stocking with continuous grazing all year by horses and intermittent grazing with cattle plus infrequent mowing, have maintained high yields and good sods with about 25% white clover for about 35 years without reseeding at Rokeby Farm. Cattle serve as "grazing tools" to maintain a desirable quality and quantity AP for horses; cattle performance while grazing excess forage in horse pastures is not pertinent.

Grazing should be controlled to maintain short-leafy AP, averaging about 2 to 3 inches in height, with canopy heights ranging from about 0.75 to 6 inches within a bluegrass-white clover pasture. Maintaining about 25% white clover is achieved by close and reasonably uniform grazing during spring and fall. To avoid competition for AP between horses and cattle, cattle and horses should graze together primarily during the flush growth period in April to early summer. Pastures should be slightly understocked with cattle while horses and cattle graze together; mob grazing, around 20 cattle per acre, being used for a few days to graze to the desired AP during the spring season. Grazing with cattle could reduce intake by horses for a few days, but rapid growth to ample amounts of an excellent quality AP more than compensates for a possible low forage AP and low intake by horses for a short period. Mob grazing is used primarily during the cool and moist spring season when rapid growth of pasture is usually dependable and predictable.

A guide to plan and manage stocking rates with horses and steer grazers depends on expected daily growth rate of pasture and daily consumption. For example, a 20-acre bluegrass-white clover pasture stocked with ten 800 lb horses produces about 644 lb dry matter or 3580 lb green matter daily during spring. Ten horses consume about 160 lb dry matter daily, leaving a surplus of 484 lb pasture dry matter or 2680 lb green forage in the 20-acre pasture each day. To consume surplus forage to maintain a desirable AP, the 20-acre pasture would require about 30 steers averaging 700 lb in weight along with the horses. However, to assure high nutrition with an adequate AP for horses, pastures should be understocked; about 10 cattle should graze with the horses in early spring (Figure 16), and the number of cattle should be gradually increased to about 25 by mid-spring. Mob grazing with additional cattle at around 14-day intervals for a few days will control and maintain a desirable AP. Reducing an excess to a short AP during a brief period of mob grazing with cattle is not likely to depress pasture intake by horses because horses select short pasture and because there are about 3580 lb of green regrowth daily in a 20-acre pasture. These varying stocking rates designated by a controlled AP are based on the average pasture growth rate for the spring-early summer season; AP and stocking rates increase until mid-spring and then decline (Figure 16).

Stocking only with horses, which allows an average of 2690 lbs green forage to accumulate daily in a 20-acre field, leads to parasitic and saprophytic plant diseases, invasion of weeds, low clover content, and low nutrition for horses. Mowing will not restore a desirable AP because mowers do not mow close enough to give a short and firm sod conducive to white clover. Also, clippings accumulate, mold, and interfere with grazing. However, if cattle are not available or are not used to consume surplus forage, mowing at about 10 day intervals will avoid reproductive growth and maintain leafy grass, but mowing does not control spotted grazing. Unless mowed forage is raked and hauled away, the massive accumulation of decaying mowed forage interferes with grazing and pasture growth.

A good alternative to restore desirable pasture canopies of severely undergrazed pastures, when cattle are not available, is to mow closely and harvest a hay crop while horses remain in a pasture. Field mowers do not cut low enough to remove the short bluegrass and white clover leaves. Hence, with light stocking of horses, an adequate AP is invariably present during and after harvesting a hay crop during the spring season.

With continuous grazing with light stocking of thoroughbreds, injury to pasture by horses congregating in one spot can be reduced by separating areas for shelter, water and salt, and shade. Also, if possible, a bluegrass pasture with developing bare soil areas should be rested from grazing by horses for several months. While horses graze in another pasture, a desirable AP can be restored by intermittent mob grazing with cattle. Rest periods would reduce internal parasite problems.

III.I.2.2. Rotational Grazing

The best yields, persistence, and plant components of taller plants such as tall fescue or orchardgrass with ladino clover occur with controlled rotational grazing among four or more pastures. However, pastures with these plants may be grazed continuously during flush growth in spring to early summer followed by rotational grazing for the summer-fall season. Continuous grazing should be controlled by intermittent mob grazing with cattle for a few days to maintain average canopy heights of 3.5 to 5 inches for orchardgrass and 2.5 to 4 inches for tall fescue. Tall fescue is more tolerant of close and continuous grazing than is orchardgrass (Figure 8 and Table 6).

Plant survival and yields of such taller plants are improved by rotational grazing among four or more fields, allowing short grazing periods of 3 to 12 days followed by long rest periods of 15 to 30 days for plants to recover (Section II). Grazing and rest periods should be much shorter during rapid growth in spring than during slow growth in summer. It is not necessary to use rotational grazing to maintain bluegrass-white clover.

Rotational grazing does not solve problems with variable growth during the year. If animals are not available to consume the flush growth in spring, the alternative is to reduce the grazing area by harvesting some of the fields for hay. During very slow growth, low AP in early spring, it is desirable to graze all fields concurrently; shutting off field by field as flush growth appears, until horses graze in one field. This procedure establishes staggered growths for the sequence of rotational grazing. To control and utilize the flush spring growth, one or more fields may be harvested for hay. With orchardgrass or tall fescue with clover in separate fields, growth in a field may be reserved for summer, fall, or winter grazing. In mid-spring it is important to manage grazing and harvesting to utilize grasses to obtain early and leafy regrowths before they grow to stemmy stages (Figures 5 and 12). After seed head production in spring, the leafy regrowths may be accumulated for deferred grazing in summer or fall. During winter, restricting horses to small fields with rotational grazing is likely to deter pasture growth because of tracking and soil compaction. An alternative is to restrict horses and damage to one pasture during winter.

With limited pasture as with many horses, intermittent or restricted daily grazing could be implemented with two fields. One field would be an exercise lot, the other field could be grazed by allowing a short-fill period daily. With controlled intermittent grazing, pasture persistence and yield would be better than with continuous grazing for plants like orchardgrass. Rotational grazing is not a panacea; grazing must be controlled. Incorporating rotational grazing with forage systems has desirable potentials on farms where rotating horses among small paddocks is not likely to cause injuries.

III.I.3. Forage Systems for Horses

Rather than using one mixture for rotational grazing, it appears practical to use two or more mixtures with special utilization and management in different fields to develop a forage system for horses. The principles for developing forage systems described for cattle apply directly and indirectly to forage systems for horses. As with cattle, management of mixtures to furnish leafy grass-legume forage, with a quality and quantity of AP that will supply the nutritional needs of various horses, is of paramount value (Figure 28). As compared to one mixture, a shift of diets among plant species in leafy stages that are highly palatable and nutritious is not likely to be inferior for horses. Endophyte-free tall fescue will be used in a proposed system, even though information on palatability and nutrition is not available. When it is necessary to renovate poor pasture, seeding mixtures might be chosen to initiate forage systems for horses. Utilization management should improve the length of the grazing season and the persistence of pastures while controlling AP, and could even furnish hay. It is easier to control grazing with 20 than with 4 pastures; however, 4-pasture systems, thought to be practical on some farms with horses, are used as examples.

Systems for Southeastern and Southern Piedmont Virginia

System 1

Pastures 1 and 2. Orchardgrass with white and red clovers
Pasture 3. Tall fescue (endophyte free) and white clover
Pasture 4. Tall fescue (endophyte free) and white and red clover

During late winter and early spring, fields 1 and 2 will be grazed in rotation with other fields. As the season advances, depending on AP, one or both fields 1 and 2 will be harvested for hay. These fields will be grazed rotationally with other fields for the rest of the season. Field 4 will be rotationally grazed until mid-September when nitrogen is applied to accumulate growth for November-March grazing. After rest in spring to recover from prolonged grazing, field 4 will be grazed rotationally with other fields. Field 3 will be rotationally grazed all year; close grazing by November to encourage light (radiant energy) penetration may stimulate growth for late winter grazing.

System 2

Pastures 1 and 2. Bermudagrass with white clover will be sod seeded to cereal rye and annual ryegrass in late September or early October after bermudagrass has been grazed closely, and when it is dormant. These fields will furnish summer, late fall, and winter-spring grazing.

Pasture 3. Orchardgrass with white and red clovers. This pasture will furnish excellent grazing during the spring season; after rest, it will furnish summer grazing in rotation with other fields. If there is excess growth, this mixture will be harvested for hay.

Pasture 4. Tall fescue (endophyte free) with white and ladino clovers. This mixture is to be grazed during late spring until September, when nitrogen fertilizer is applied to accumulate growth (stockpile) for fall and winter grazing. After prolonged continuous grazing during winter and early spring, the field will be rested until growth justifies grazing it in rotation with the other fields.

Variations of these models may be used to plan other systems.

System for Northern and Mountainous Virginia

System 3

Pastures 1 and 2. Bluegrass and white clover in two fields will furnish needed forage for grazing during spring.

Pasture 3. Clair timothy with alfalfa or red clover. This field will be used for 1 or 2 hay harvests in the spring-summer season and then grazed rotationally with other fields during summer and fall.

Pasture 4. Tall fescue (endophyte free) with ladino and red clover. This field will be grazed or harvested for hay in late spring, depending on AP, and then grazed in rotation with the other fields until August when nitrogen fertilizer is applied. The stockpiled growth will be grazed during fall and winter. In the event of low rainfall and a low AP, this pasture would be grazed at any period.

These systems should generate ideas for designing forage systems for various horse or horse and cattle farms.

III.I.4. Improving Pastures

Many pastures grazed by horses are unproductive because of a sparse plant cover, weed invasion, and slow growth; the low productivity may be caused by low soil fertility, unadapted plants, and/or bad grazing management. Pastures can be improved by seeding and soil amendments with or without soil tillage and with or without herbicides. Pastures with a sparse cover of stoloniferous or rhizomatous plants, such as white clover or bluegrass, may be regenerated by good fertilization and grazing management, as these plants spread rapidly under favorable environments.

III.I.4.1. Tillage to Improve Pastures

When a soil is highly acid (pH 5.3 or lower) and low in phosphorus, it should be plowed after about half of the lime needed is applied, to reduce acidity to a pH of about 6.4. The remaining lime and phosphorus alone or in a fertilizer mixture should be applied after plowing and mixed with the surface 3-5 inches of soil. This procedure is necessary because surface applications of lime move into soils slowly, around 0.3 inch per year; surface-applied phosphates remain chemically fixed near soil surfaces. Incorporating lime and phosphate into soils low in phosphorus and high in acidity will improve rooting depth and availability of nutrients and water to improve total and seasonal yields and maintenance of plants.

A herbicide such as glyphosate should be used before plowing if the area is infested with objectionable perennial grasses such as tall fescue, bermudagrass, or perennial weeds. At Rokeby Farm several bluegrass pastures, where tall fescue had invaded, were sprayed with glyphosate and then sod seeded to an early corn that was harvested for silage in late August. The soil was plowed, fertilized, and limed as indicated by soil tests, and seeded with a mixture of two varieties of bluegrass, perennial ryegrass, and white clover. September-early October seedings furnished good grazing free of tall fescue the next year.

In bluegrass or other pastures where tall fescue is invading, the scattered plants should be killed by spot spraying with paraquat or glyphosate when growth is active. Spraying with paraquat in October is more lethal to tall fescue than is spraying in mid spring. Tall fescue plants should be killed when they first appear; plants spread rapidly because fescue is not grazed and is widely adapted. Grazing should cease during spraying. All safety precautions must be observed when herbicides are used.

III.I.4.2. Sod Seeding

To improve pastures by fertilizing and seeding without plowing or disking depends on seedling survival and rate of growth. Competition for light (shading) and water, even in a sparse plant cover, may cause death of seedlings. Thus, broadleaf weeds may be killed with 2-4D, and grasses may be depressed or killed with paraquat. Lime and fertilizer should be applied based on soil tests. Seed and fertilizer may be applied separately or concurrently with a sod seeder. Seed and triple-superphosphate may be applied in contact through a spout since this phosphate stimulates seedling growth. Other phosphates and fertilizer in contact with seeds destroy seedlings due to desiccation and burning. Placing seeds at uniform and desirable depths (an inch or less for tall fescue, ryegrass, orchardgrass, and red clover and one-half inch for bluegrass and white clover) with sod seeders improves probabilities of getting good stands.

An alternative is to apply lime, fertilizer, and herbicides as needed, disk lightly, and then broadcast seed and press seeds into contact with soils with a roller. Grass seeds require good moisture for several days to germinate; hence incorporating seed into the soil improves germination and seedling growth (Section II.D.4).

For pastures with good stands of grass but little clover, incorporating clover seeds also improves germination and stands; with good moisture, white and red clovers germinate in about a day and may be surface broadcast in the February-March season. Seeding on frozen soils with surface undulations gives natural seed coverage to augment germination. Sods must be grazed closely to reduce competition among plants and to promote growth of legume seedlings.

IV. SUMMARY AND CONCLUSIONS

This book is an interpretive summary of principles for planning and managing forage-animal systems to feed cattle, sheep, and/or horses on farms that vary in soil, climatic, and biotic environments. Person(s) managing farms with ruminants or horses should be graziers, having technical knowledge, interest, enthusiasm, and practical expertise in managing the interplaying soil, plant, and animal factors in a given environment for potentially profitable and enjoyable operations. Managing the available pasture (AP) to maintain grasses and legumes for year-round grazing, where yields and quality of forage are wisely compromised for different plants to supply the nutrition of various classes of ruminants and horses achieved by controlled stocking, is paramount for successful livestock operations. A desirable AP obtained by controlled stocking controls animal nutrition to compromise production per animal and per acre for profitability. There is not an optimum AP nor an optimum stocking rate, because AP depends on the nutritional requirements of ruminants that vary with cycles of production. It is necessary to stock farms or systems at a near constant rate; however, a desired AP is maintained by controlled stocking, i.e. by varying the land area being grazed or harvested within a farm.

Except for first grazing and creep grazing, any grazing or utilization method can give the highest yield of animal products per animal or per land area depending on AP, growth stage, and degree of utilization. Constant stocking biases the quality and quantity of AP and of animal production data. The AP principle explains the potential production of animal products with methods of grazing. Special grazing techniques allocate high nutrition to responsive ruminants. For example, the technique of first grazers with rotational grazing provides high nutrition for high-producing milk cows.

Calves, 4 to 8 months old, restricted to milk from beef cows, gain only 0.33 lb daily as compared to 2 lb daily for nursing creep-fed calves. Creep grazing provides a high AP and gives high calf liveweight gains, even when a low AP restricts forage intake of nursing cows. Managing to maintain a medium to low AP for beef cows (obtained by high stocking) while calves creep-graze results in high calf liveweight gains per acre and per animal. Growth responses of nursing calves from creep grazing or creep feeding occur only when the feed intake of calves grazing with cows is restricted by quality or quantity of AP or other feed.

Developing forage-animal management systems with year-round grazing and a minimum of feeding, where the grazier controls AP by concurrent management of the plants and animals, is more important than the number of inclosures used in a system. With controlled grazing the yield of forage and animal products per acre is better with rotational than with continuous grazing. However, potential yield advantages from added enclosures depend on the morphology of plants and yield potentials in a given environment. Rotating animals among pastures at set dates or hours as compared to controlling AP can be harmful to plants and animals and may nullify beneficial effects from controlled rotational grazing.

Research data are given for systems with beef and dairy cattle. Systems for horses are based on experiences, demonstrations, and applying principles given in this publication. The proposed system, III. G, "integrating calf-raising with growing cattle," summarizes the principles to be applied in order to design potentially profitable animal-forage management systems. A primary objective of this book is to present organized information for use by farmers, students, teachers, and service and research personnel to develop systems better than our exhibits and to advance the grazier concept to enjoy and to improve animal production.

Implementing the AP principle to obtain animal data for any new development in the pasture-animal complex (variety, soil amendment, species, etc.) simplifies experiments, reduces research costs and augments the reliability of the data. Experiments with three constant stocking rates (no AP control) to evaluate a variable plus additional pastures for replications are extremely costly and result in data that are often invalid because the yield-quality-persistence-physiology-morphology complex of plants and AP as related to animal nutrition are ignored. Exhibits on simplifying grazing experiments to obtain valid data are given. Controlling AP by adding or withdrawing grazers in experiments simulates decreasing or increasing the land area grazed, respectively, the latter procedure being used on farms with a constant number of animals to control AP.

Controlling quality and quantity of AP by management has given reliable animal data with a broad array of plants and grazing methods. The principles in this book apply broadly and are adapted even to tropical pastures. Beginning in 1937 with Napiergrass (*Pennisetum purpureum* Schumach) in a 5-pasture rotational grazing experiment, AP was managed as follows: "Grazing was initiated when the grass reached a height of approximately 3 feet. Steers were added or withdrawn so the forage in one paddock would be consumed in 5 to 8 days" (*J. Am. Soc. Agron.* 34, 1942 and *Fla. Agric. Exp. Sta. Bull.* 453, 1948). Varying the lengths of the grazing and resting periods controlled the quantity and quality of AP and the length of regrowth for plant persistence. Knowing that leaves promote animal performance, stemmy residues were left ungrazed to generate new leaves and good yields for the next grazing cycle. Best results were obtained in 1938 when steers gained 1.73 lb daily and produced 430 lb liveweight per acre with about 100 lb N per acre. In another experiment beginning in 1940 (*Soil Sci. Soc. Am. Proc.* 8, 1943), animal production from fertilized carpetgrass (*Axonopus compressus* (Swartz) Beauv.) was compared with carpetgrass-white clover pasture. The tester-grazer method of adding and withdrawing animals to utilize AP and control its quality and quantity was used as described in this publication; gains per steer and per acre during two years were 18% and 415% higher for the grass-clover than for the grass pasture.

Implementing the AP principle will be put off by procrastinating because exact AP values are not known and because visual estimates for ascertaining AP are erroneously thought to be subjective and unreliable. To find an exact AP value would require a staff of technicians where molesting the vegetation and animals could have negative effects. However, in the pasture-plant-animal complex it is not possible to obtain exact quantitative nor qualitative values of AP; AP is dynamic, shifting hourly and daily as rates of growth of grasses and legumes within a pasture and rates of animal consumption vary. AP allocations to ruminants and horses need to be relatively correct. Even if there were an absolute AP, in practice the absolute AP could not be obtained nor maintained. Although AP can be quantified by parameters such as dry matter above the soil (dead matter excluded), height measurements, leaf area units, or estimates with mechanical devices, we obtained reliable and repeatable animal performance by AP estimates based on height and density of canopies as they were grazed. Such evaluations must be made frequently and often several times daily as AP declines toward the end of rotational or intensive grazing when a low AP depresses animal production. Farmers do not have time to obtain so-called exact estimates of AP; by dedication and experience they will find AP estimates suitably precise. The progressive grazier with a positive attitude can become a proficient manager of AP to improve and advance plant and animal production. AP is based on the land area being grazed, a concept which simplifies its use. The number of animals per unit of land area influences AP, depending on the rate of forage disappearance (consumption) and the rate of forage growth. The AP values for a given species or mixture for different ruminants and horses for cycles of production can be ascertained with experience, from controlled grazing experiments, and from plant and animal observations.

The management and AP principles in this book apply internationally, as they have been used in many countries with a broad array of vegetation and animals to comprehend and advance forage and animal production.

Virginia's Agricultural Experiment Stations

1—Blacksburg
Virginia Tech, Main Station
Dairy, Poultry, and all other topics

2—Steeles Tavern
Shenandoah Valley Agricultural Experiment Station
Beef, Forages, Fruit, Insect and Pest Control, Sheep

3—Orange
Northern Piedmont Agricultural Experiment Station
Alfalfa, Corn, Crops, Small Grains

4—Winchester
Winchester Agricultural Experiment Station
Fruit, Insect and Pest Control

5—Middleburg
Middleburg Agricultural Experiment Station
Beef, Forages

6—Warsaw
Eastern Virginia Agricultural Experiment Station
Field Crops, Insect and Pest Control

7—Holland Station, Suffolk
Tidewater Agricultural Experiment Station
Corn, Peanuts, Pest Control, Small Grains, Soybeans, Swine

8—Blackstone
Southern Piedmont Agricultural Experiment Station
Forages, Horticulture Crops, Small Grains, Tobacco, Turfgrass

9—Critz
Reynolds Homestead Agricultural Experiment Station
Aquaculture, Forestry, Wildlife

10—Glade Spring
Southwest Virginia Agricultural
Experiment Station
Beef, Burley Tobacco, Sheep

11—Hampton
Virginia Seafood Agricultural Experiment Station
Seafood

12—Virginia Beach
Hampton Roads Agricultural Experiment Station
Ornamentals, Vegetables, Insect and Pest Control

13—Painter
Eastern Shore Agricultural Experiment Station
Fruit, Field Crops, Herbs, Insect and Pest Control, Vegetables