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Species composition and pasture productivity of Bermudagrass-fesue-legume combinations for yearling beef steers

Ronald Lewis Mitchell

To the Graduate Council:

I am submitting herewith a dissertation written by Ronald Lewis Mitchell entitled "Species composition and pasture productivity of Bermudagrass-fesue-legume combinations for yearling beef steers." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Plant, Soil and Environmental Sciences.

Henry A. Fribourg, Major Professor

We have read this dissertation and recommend its acceptance:

J. B. McLaren, J. H. Reynolds, W. R. Backus

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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SPECIES COMPOSITION AND PASTURE PRODUCTIVITY OF BERMUDAGRASS-FESCUE-LEGUME COMBINATIONS FOR YEARLING BEEF STEERS

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

Ronald Lewis Mitchell

March 1985

DEDICATION

To Mom and Dad, for their wise counsel, love, and friendship, I humbly and lovingly dedicate this dissertation.

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"It is the land, for the land doesn't need articulateness or social grace. It needs only what you bring to it, voiceless love and wholehearted fealty."

Adapted from, *The Thorn Birds* by Colleen McCullough

ABSTRACT

A beef-steer (*Bos* sp.) grazing experiment was conducted on a Typic Hapludalfs soil. The 1.2 ha pastures were (1) Midland (*Cynodon dactylon* (L.) Pers.) + fescue (*Festuca arundinacea* Schreb.)(25) + N, (2) Midland + fescue(25) + legumes, (3) Midland + fescue(50) + legumes, (4) fescue + legumes, (5) 1/3 annual grasses + N and 2/3 fescue + legumes in separate pastures (0.4 and 0.8 ha), (6) common (*C. dactylon* var. *dactylon*) + fescue(25) + legumes, and (7) orchardgrass (*Dactylis glomerata* L.) + ladino clover (*Trifolium repens* L.). Legumes refer to overseedings of ladino clover, red clover (*T. pratense* L.) and lespedeza (*Lespedeza striata* (Thunb.) H & A). The 25 and 50 refer to the distances in cm between fescue rows at seeding. Annual grasses were a sorghum-sudangrass hybrid (*Sorghum bicolor* (L.) Moench) seeded in mid-May and rye (*Secale cereale* L.)-ryegrass (*Lolium multiflorum* L.) seeded in early September each year. Annual grass pastures received 134 kg N ha^{-1} $year^{-1}$, Midland + fescue(25) + N pastures received 290 kg N ha^{-1} $year^{-1}$. Pastures were grazed continuously. Forage growth and consumption were estimated by the cage and strip method. Yearling beef steers weighing 230 kg in the spring grazed 131 to 168 days and were weighed at 21-day intervals. Forage consumption was 62% or more of forage growth, which ranged from 6786 to 14232 kg/ha. Crude protein was well above the minimum requirement for growing steers. Neutral- and acid-detergent fiber ranged from 63 to 67%, and from 39 to 43%, respectively. Stocking rates were between 3.2 and 7.7 steer/ha. Average daily gains (ADG) were greatest on Orchardgrass + clover (869 g/day) and ranged from 478 to 821 g/day for the other

treatments. Productivity ranged between 591 animal grazing days/ha for Common + fescue(25) + legumes and 1537 for Midland + fescue(25), and ranged from 605 to 833 for the other pastures. Daily forage dry matter (DM) intake was 6.3 to 15.3 kg/steer, with conversion efficiencies of about 12 to 20 kg DM/kg gain. Beef production was 630, 474, 510, 597, 431, 392, and 545 kg/ha for treatments 1-7, respectively. The Species Composition Index (SCI) was evaluated in relation to the effects of year, season, grazing pressure, forage quality, precipitation, and air temperature on forage growth and consumption, and animal performance. It was compared to the traditional classification variable 'treatment' to describe the seven different pasture combinations. When treatment was entered into the model to explain total variation in forge growth and consumption, ADG, and beef production, R^2's of 0.15, 0.32, 0.34, and 0.36 were obtained respectively; when SCI was used, they were 0.36, 0.51, 0.53, and 0.56.

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CHAPTER I

INTRODUCTION

Grasslands are estimated to cover 30% of the world's land area (Barnard and Frankel, 1964; Stoddart et al., 1975), with some 47% of the earth's land surface suitable only for grazing domestic livestock and game animals (Williams et al., 1968). The establishment of grasslands and grazing animals among dominant life forms on earth preceded the arrival of man (Barnard and Frankel, 1964). Some 20 million years ago, during Miocene times, it is thought that grasslands were assuming an important place in the earth's vegetative cover. Many of the large grassland areas such as the plains of North America, the pampas of South America, the steppes of Asia, and the velds of Africa are thought to be climax formations determined by soil and climate.

When an appreciation of the varied qualities of the species found in natural grasslands was developed, the idea of deliberately creating swards by planting mixtures of several desirable components became obvious (Harper, 1971). Sown pastures have been utilized in almost all parts of the world for hundreds of years (Hartley, 1964). However, only a few of the over 10,000 grass species which are known to occur in nature are used as cultivated pasture plants. Approximately 40 species are utilized as important cultivated pasture grasses.

Legumes have been recognized as important in building and conserving soil fertility since the beginning of agriculture (Nutman, 1965). As early as 6000 B.C. legumes were grown by the bronze-age lake-dwellers of Central Europe and are often mentioned in the Old Testament. The first record of use of clover pastures appears to be in the early sixteenth century (Fussell, 1964; Nutman, 1965).

Recognition that legumes could be used as a source of nitrogen (N) for other plants grown in association came with an appreciation of soil fertility and the *Rhizobium* symbiosis (Barnard and Frankel, 1964; Tothill, 1978) in the late nineteenth century (Barnard and Frankel, 1964; Nutman, 1965). It was realized then that grass-legume associations were not necessarily a fortuitous circumstance, but that grass-legume associations could be created at most locations.

Today, pastures are known to require careful management to maintain the delicate balance among the components of the association, both in natural and introduced grasslands. The key to the maintenance of the proper proportions of species within a pasture has come from an understanding of the role of the grazing animal in maintenance of the circulation of essential plant nutrients, of growth habit of pasture plants and their response to frequency and intensity of defoliation and regrowth potential, of trampling effects on plants and soils, and their interactions with the environment (Kydd, 1957; Tothill, 1978).

The range vegetation of the U.S. can be broadly divided into five regions: (1) Grasslands, which contain the tall- and short-grass prairies of the Great Plains, (2) Desert shrublands, which consist of the Intermountain and Hot-Desert shrub regions, (3) Shrub Woodlands, which contain the California Chaparral, the Pinyon-Juniper region, and the mesquite shrublands of south Texas, (4) Coniferous Forests of the western U.S. which occur at high elevations all over the West, and (5) the southeastern U.S. (USDA, 1936; Grelen, 1978; W. E. McMurphy, personal communication).

The southeastern U.S. is primarily cow-calf country and is considered as potentially the most productive rangeland due to its ample precipitation (750-1500 mm/year) and relatively long growing season (200-365 days). Generally characterized by forests of *Pinus* sp., *Quercus* sp., and/or *Carya* sp. as climax vegetation, introduced species of *Festuca*, *Cynodon*, *Paspalum*, *Sorghum*, and *Trifolium* are extremely high forage producers in this area and are easily established and maintained as monocultures and/or mixtures. Many pastures containing these species are mismanaged and unproductive. Proper fertilization with N, phosphorus (P), and potassium (K) along with additions of lime for low soil pH correction can be utilized to increase productivity. Proper grazing management techniques can increase pasture utilization and maintain the proper balance of species within a pasture.

The full potential of the southeastern U.S. as a backgrounding area for beef cattle has not yet been realized. Although several innovative research workers have been aware of this potential for at least the past three decades, producer response has been slow. As world population increases and world food supplies decrease, more and more producers will realize the potential of the Southeast for producing high quality pastures for maximum growth and development of stocker cattle. However, research in this area must be intensive and extensive in order to provide alternative systems which can compete with existing land uses. That is the purpose of the research reported here. Specifically, the objectives of this experiment were to determine the effects of selected overseeding systems on beef production and pasture quality of tall fescue and/or 'Midland' or common bermudagrasses as the dominant grass in pasture mixtures with and without legumes; and to determine the effect of including selected winter and summer annual grasses in these systems and their effects on beef production as supplements to perennial grass pastures.

CHAPTER II

REVIEW OF LITERATURE

A. The Competitive Nature of Grass-Legume Associations

Donald (1963) states that competition occurs when each of two or more organisms seeks the measure it wants of any particular factor or thing and when the immediate supply of the factor or thing is below the combined demand of the organisms. He also reminds us that water, nutrients, light, oxygen, and carbon dioxide are the factors for which plants compete. Therefore, the more agnate the needs of two organisms, the more intense the contest for the factors which are in short supply. Thus intraspecific competition is more intense than interspecific competition (Dubbs, 1971; Haynes, 1980).

The natural outcome of plant competition has been termed succession (Tothill, 1978). The concept of succession is considered to be one of the cornerstones of ecological theory (Horn, 1974). Succession is a pattern of changes in the specific composition of species in a community. Generally, in natural communities, these changes occur after an extreme disturbance in the physical environment. This new niche allows for colonization of new plants and/or animals. When a community exhibits some directional, cumulative, nonrandom change it is said to be a seral community. The species involved are termed seral species (Barbour et al., 1980). During some time the changes in the community are so slow they cannot be detected, or the changes cease altogether. This late stage of succession is termed "climax." Although climax has been characterized as a constant state of specific composition, species and their relative abundance change from place to place as the physical environment changes.

Pastures, being a mixture of agricultural plants as well as being artificial and man-made, do not react as a stable diverse climax ecosystem (Haynes, 1980). Tothill (1978) describes most pasture vegetation, in contrast to natural grassland vegetation, as seral nonequilibrium species. Pastures may be in equilibrium with their environment, but only under specific management regimes. When these management regimes are altered, the pasture starts to change to some other form of vegetation. Thus the basis of pasture science is to utilize pasture management techniques to secure a balance of desired species within the pasture.

B. Establishment, Maintenance, and Productivity of Grass-Legume Associations

There are several important reasons for the inclusion of legumes in grass swards. Legumes are utilized to extend the grazing season (Hoveland, 1960; Knight, 1970; Watson and Knight, 1978), resulting in better utilization of land resources, especially for the warm-season perennial grasses (Knight, 1970). Legumes also increase forage production and quality (Knight, 1970,1971) which in turn improves animal performance as measured by average daily gain (ADG), increased conception rates and calf crop percentages (Watson and Knight, 1978). Legumes also have a unique capability to form a symbiosis with N-fixing rhizobia. Estimates of N fixation for some of the major legumes used in temperate pastures are given by LaRue and Patterson (1981), in kg N/ha, as follows: alfalfa (*Medicago sativa* L.) 148-290, white clover (*Trifolium repens* L.)

128-268, ladino clover (*T. repens* L.) 165-189, red clover (*T. pratense* L.) 17-154, subterranean clover (*T. subterraneum* L.) 21-207, crimson clover (*T. incarnatum* L.) 64, and Korean lespedeza (*Lespedeza stipulacea* Maxim.) 193. Some of the N fixed by the legumes can then be transferred to the associated grasses, increasing grass growth and quality (Hoveland, 1960; Knight, 1970, 1971).

1. Establishing Legumes in Grass Swards

The sod-seeding of legumes into grass swards has a great potential for increasing forage quality and production on land not tillable by conventional methods. In the U. S., Graber (1927,1928) was the first to report the successful establishment of a legume into a grass sward. This worker found that to successfully establish sweetclover (*Melilotus alba* Desr.) into a Kentucky bluegrass (*Poa pratensis* L.) sod, one must suppress the sod by burning, which ensures good soil-seed contact, lightly graze during the establishment year, and ensure that lime and P additions are adequate for good legume growth.

Since Graber developed these techniques for renovation (putting legumes in grass pastures) in 1927, much time and effort has gone into research of this nature. Sprague (1952) reported on the use of chemicals in conjunction with tillage as an aid to suppress grass growth for legume establishment. In applications of 29 kg/ha active ingredient (a.i.) of sodium trichloroacetate (TCA) in conjunction with disking, Sprague reported that both above- and below-ground parts of an old Kentucky bluegrass sod were completely killed. This allowed an excellent stand of seeded orchardgrass (*Dactylis glomerata* L.) and white clover to become established. This showed that not only could legumes be seeded, but improved varieties of grasses as well.

Since the work done by Sprague, several workers have utilized chemicals to suppress grass sods. Among these chemicals have been dalapon (2,2-dichloropropionic acid) (Fribourg and Safley, 1962; Taylor et al., 1964; Jeffery et al., 1978; Fribourg et al., 1978; Martin et al., 1983); glyphosate (*N*-(phosphonomethyl)glycine) (Jeffery et al., 1978; Fribourg et al., 1978; West et al., 1980; Groya and Sheaffer, 1981; Olsen et al., 1981; Sheaffer and Swanson, 1982; Vogel et al., 1983; Martin et al., 1983); and paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) (Taylor et al., 1964; Taylor et al., 1969; Jeffery et al., 1978; Fribourg et al., 1978; Olsen et al., 1981; Martin et al., 1983). These chemicals, along with disking as proposed by Graber (1928), have been utilized extensively throughout Tennessee with much success. In Kentucky, Taylor et al. (1969) successfully introduced alfalfa and ladino clover into Kentucky bluegrass sods using paraquat sprayed in 10-cm bands over the seeded row. This 10-cm band reduced grass yields by 62% and increased legume stands over those obtained in plots not sprayed with herbicide. Olsen et al. (1981) reported that glyphosate applied at 1.8 kg a.i./ha or paraquat at 0.9 kg a.i./ha suppressed growth of tall fescue for eight weeks. This allowed stands of alfalfa, birdsfoot trefoil (*Lotus corniculatus* L.), ladino clover, or red clover to become well established. These introduced legumes enhanced overall dry matter (DM) yields of the tall fescue sward up to three-fold under a hay production management system. Vogel et al. (1983) suppressed sods of orchardgrass with glyphosate at 1.7 kg a.i./ha to establish alfalfa. Using a broadcast spray, these workers completely killed the orchardgrass and obtained pure stands of alfalfa which, without irrigation, yielded 6.4 Mg/ha in the establishment year.

The amount and the distribution of precipitation received after sod-seeding of legumes has been shown to affect germination and emergence of the legume more than any other environmental variable (Taylor et al., 1969). However, more recent evidence suggests that a first-order interaction occurs between soil moisture and light (Groya and Sheaffer, 1981). In greenhouse studies, they found that when alfalfa was seeded into boxes containing Kentucky bluegrass or smooth bromegrass (*Bromus inermis* Leyss.), the alfalfa yield increased with increases in soil moisture only when the plants were not shaded. Shading significantly reduced alfalfa yields at each level of soil moisture and prevented a yield response to soil moisture. These results suggest that even though success in sod-seeding is increased by an increase in soil moisture, the reduction of light availability due to excessive shading by the companion grass must be minimized by suppressing the grass with use of herbicides and grazing.

Seeding rates of sod-seeded legumes, as well as the species selected, may be an important factor in the degree of success in sod-seeding (Sheaffer and Swanson, 1982). Studies in Minnesota to determine the effects of seeding rate, legume species and levels of grass suppression revealed that successful sod-seeding depends upon environmental conditions. At one site where moisture was limiting, increasing the seeding rate of alfalfa or red clover from 8.8 to 17.6 kg/ha significantly increased legume yield. At two other sites where moisture was not limiting, effects of increasing seeding rates depended on whether red clover or alfalfa was sod-seeded and on the competitiveness of the grass. When high levels of grass competition existed and low level of grass suppression was used (0.6 kg a.i./ha glyphosate) red clover yields were increased by increasing the seeding rate. With a high level of grass suppression (1.7 kg a.i./ha of glyphosate) increasing the seeding rate of red clover did not increase its yield. For alfalfa, increasing the seeding rates increased yield when high levels of grass competition occurred. During the year after establishment, yields for red clover were not significantly different due to seeding rate or grass suppresssion level. Alfalfa yields, on the other hand, were significantly greater for the 13.2 and 17.6 kg/ha seeding rates (2.6 and 2.5 Mg DM/ha, respectively) than the 4.4 and 8.8 kg/ha rates (1.6 and 1.6 Mg/ha, respectively). These researchers concluded that higher seeding rates increased establishment year alfalfa and red clover yields when levels of grass competition were high. During the year after establishment, however, the persistence of this effect depended upon the species. Alfalfa may benefit more from an increased seeding rate than will red clover.

Other research from Minnesota has suggested that herbicides and herbicide rates should be selected based upon the extent of grass vegetative development (Martin et al., 1983). These workers evaluated three herbicides at three rates applied to a sward of smooth bromegrass, quackgrass (*Agropyron repens* L.), and Kentucky bluegrass, all sod-seeded with alfalfa on four different planting dates. The greatest seeding year alfalfa yields were obtained with dalapon broadcast sprayed at 5.6 or 9.0 kg a.i./ha for an April seeding, and with rates of 0.8 or 1.1 kg a.i./ha of glyphosate for the late May seeding. Seedings made in June were unsatisfactory regardless of chemical or chemical rate used.

2. Influence of Grass-Legume Balance on Animal Performance

The inclusion of legumes into grass swards is well known to increase animal performance. In fact, the literature is replete with information regarding the effects of legumes on practically all kinds and classes of domesticated herbivorous animals. It is also well known that legumes are higher than grasses in crude protein (CP), P, K, magnesium (Mg), and much lower in crude fiber (CF) (NRC, 1982). Since animal performance is increased by inclusion of a legume in the diet, the question is: Is the increase in animal performance proportional to the amount of legume consumed?

Very little information is contained in the literature regarding varying proportions of legumes in the diet of beef cattle and its effect on animal performance. Only two reports were found regarding the performance of beef cattle consuming forage mixtures with varying proportions of legumes. Day et al. (1978) fed British Friesian steers ryegrass (*Lolium* sp.)-red clover silage which, on a DM basis, varied from 0 to 100% red clover. Steers were fed ad libitum and significant differences in DM intake occurred only when silages contained 25 or 50% red clover. The proportion of red clover in silage had no significant effect on animal performance, although there was a trend toward increased liveweight gain when increasing proportions of the silage were red clover. The second report is from Australia (Wolfe and Lazenby, 1979). These workers established swards of phalaris (*Phalaris tuberosa* L.) and white clover which had varying proportions of white clover in the sward, obtained by different levels of N and P. Their results were three pasture types: (1) high clover (HC) pastures, >60% white clover, (2) medium clover (MC) pastures, 25-50% white clover and, (3) low clover (LC) pastures, <20% white clover. In both years of this study the fertilizer treatments applied to each of the three pasture types produced pastures of the desired range in grass-legume balance. During the experimental period, the level of sub-lethal bloat found on HC pastures exceeded that recorded for MC pastures, which in turn exceeded the LC pastures, however, no cattle died from bloat or any other cause. The ADG of steers grazing the HC pastures was lower in early and mid-spring than those of steers on the MC and LC pastures. This depression in ADG was carried over the entire grazing season. Wolfe and Lazenby attributed this lower ADG to a reduced forage intake of steers on HC pastures as compared to MC and/or LC pastures. The reduced intake was related to a high incidence of sub-lethal bloat. Their conclusions were that it is inadvisable to graze beef cattle on pastures containing a high proportion (>50%) of legumes, at least during certain times of the year.

During the course of this review, specific evidence regarding proportion of legumes in the diet of grazing animals in the U.S. was not found. However, in a most recent paper (Fribourg et al., 1984) a very unique concept was proposed to explain variability in both animal and plant responses in grazing experiments. The authors termed their concept the Species Compositiiton Index (SCI). They utilized this SCI concept to describe more precisely the dynamic changes which occur in grass-legume associations, which in turn relate to the effects of season, grazing periods, stocking rates, CP, precipitation, and air temperature effects on forage growth and consumption, and beef production. These workers found the SCI, used as an independent variable rather than 'treatment', superior in explaining variability in their grazing experiments. By using the SCI they explained three to seven times more of the variation in forage growth and consumption, ADG, and beef production than when using 'treatment'. The greatest understanding of importance of species composition came from the dependent variables ADG and beef production. In terms of ADG, the concomitant variable 'treatment' accounted for only 4% of the total variation whereas SCI accounted for 28%. For beef production the variable 'treatment' was not considered significant in their analysis although the results, presented elsewhere (McLaren et al., 1983), indicated it ranged from 321 to 593 kg beef/ha. When the SCI was utilized, it explained 28% of the variation in beef production. The authors do bring out that the results from using SCI cannot be used in the selection of commercial pasture systems. It does highlight, however, the species composition of a pasture and its close relationship with animal performance. This unique concept clearly brings us closer to elucidating the animal-plant-soil-environment interaction.

From this discussion, the balance between grasses and legumes growing in association and the dynamic changes which occur over time can be seen to have profound influences on animal performance. The question asked previously, what proportion of legume should be in the diet of grazing animals?, remains unanswered if one is searching for numbers. However, using the high voluntary intake and nutritive value of the legumes, hopefully we can utilize them to the advantage of the animal, and hence the beef producer.

3. Major Factors Affecting Grass-Legume Balance

In the previous discussion it was brought out that the balance between grasses and legumes growing in association has a profound influence on the performance of grazing animals. With this in mind it is imperative to this discussion to consider those factors which can influence the balance between grasses and legumes. Broadly, these factors can be broken down into three separate groupings, (1) microbiological factors, (2) physiological factors, and (3) morphological factors. It should be noted that these divisions are somewhat artificial in that no one group is predominant but they all interact to give the end result in the field. For the purposes of this review, the factors to be considered will be those which have the most profound influence, as indicated by the literature, on grass-legume balance. They can be divided into (a) host plant influences and ecological considerations, (b) host plant influences on the competition between strains of *Rhizobium*, (c) N relationships in grass-legume associations, (d) foliage architecture, and (e) growth habit and defoliation.

a. Host Plant Influences and Ecological Considerations

The competition between strains of *Rhizobium* for infection of legume roots, and hence nodulation, is influenced by the host plant, the strain of *Rhizobium*, the environment, and the interactions among these factors (Date and Brockwell, 1978). The factors can be divided into (a) those factors affecting the organism in the absence of the host, as in soil or culture, and (b) those factors where the host is present and therefore an influence on the growth of *Rhizobium* and its ability to infect the host plant, especially in the presence of other strains of *Rhizobium*. For the purposes of this review only the latter factor will be discussed.

It is pertinent to this consideration of competition to briefly describe the steps involved in the formation of N fixing nodules. There are essentially four phases: (i) proliferation of *Rhizobium* in the rhizosphere and soil, (ii) infection of the host plant, (iii) initiation and development of nodules, and (iv) N fixation (Date and Brockwell, 1978). In this particular section, the primary concern will be with the first two aspects.

i. Host-Influenced Rhizobia Multiplication and Recognition

In the presence of the host, *Rhizobium* are stimulated to multiply rapidly. In work with pea seedlings (*Pisum sativum* L.), van Egeraat (1975a) found that from the time of inoculation until six hours thereafter an 81% decrease in numbers of *Rhizobium leguminosarum* occurred. This decrease in rhizobia numbers continued until 48 hours after inoculation. An increase in rhizobia numbers occurred from 48 to 72 hours. The increase of *R. leguminosarum* cells on the root surface coincided with the formation of lateral roots. At 24 hours after inoculation no lateral roots were present, but at 48 hours a few had formed and at 72 hours several had developed. Rovira (1961) reported similar results with red clover. He found the greatest number of *Rhizobium* in the soil adhering to the roots (13.9 million/gram soil) with lesser amounts of *Rhizobium* further from the root.

It is generally accepted that the stimulation of microorganism growth in the rhizosphere is the result of root exudates. Rovira (1956) found that the roots of pea seedlings excreted 22 different amino compounds during 21 days of growth. Oats (*Avena sativa* L.) were found to excrete 14 different amino compounds in the same length of time. van Egeraat (1975b) found homoserine to stimulate growth of *R. leguminosarum* but to reduce growth of *R. meliloti*, *R. trifolii*, and *R. phaseoli*. This worker suggested that homoserine, released by roots of pea seedlings, selectively stimulates the growth of *R. leguminosarum* and reduces the growth of other species of *Rhizobium* belonging to different cross-inoculation groups.

The recognition of *Rhizobium* by the host plant has been the subject of much research. Evidence has suggested a role for lectins in *Rhizobium*-legume recognition. Bohlool and Schimdt (1974) found soybean *(Glycine max* (L.) Merr.) lectin combined specifically with 22 of 25 strains of the soybean-nodulating bacterium *R. japonicum*. Dazzo and Hubbell (1975) identified the cross-reactive agents responsible for infection. The cross-reactive capsular antigen of *R. trifolii* was characterized as an acidic hetero-polysaccharide. A soluble nondialyzable substance was extracted from white clover seeds (clover lectin) and was capable of binding to the cross-reactive antigen and agglutinated only infective cells of *R. trifolii*. Lectins have been shown to exist in clover (Dazzo and Brill, 1977), alfalfa (Bhuvaneswari et al., 1977), and soybeans (Bohlool and Schmidt, 1974; Paau et al., 1981).

The infection of the root frequently occurs behind growing apices or points of emergence of lateral roots (J. Ownby, personal communication). Several cell wall degrading enzymes and growth stimulators have been proposed, and eliminated, as factors involved in the process of infection (Dart, 1974). The process(es) which occur during root hair infection are not fully understood (J. Ownby, personal communication). There are two modes of infection, reviewed by Dart (1974), that are clearly recognizable: (i) infection by binding of *Rhizobium* to the root hair, the *Rhizobium* creating an invagination of the root hair. An infection thread containing the rhizobia develops and grows into the interior of the cortex just outside of the stele, and (ii) and intercellular penetration in the junctions of lateral roots. No infection threads develop and *Rhizobium* are distributed in the nodules by cell division. This type of infection occurs in peanut (*Arachis hypogeae* L.) roots.

ii. Ecological Aspects of Legume Inoculation

The inoculation of legume seed with the proper rhizobia can be considered an exercise in applied microbiology. As discussed in the previous section, *Rhizobium* is primarily a rhizosphere organism and finds support in the rhizospheres of legumes more readily than in those of non-legumes (Rovira, 1961). At planting however, no legume rhizosphere exists. Therefore, until seedlings emerge and become established, the introduced bacteria are in competition with a well established complex of soil microorganisms and perhaps a soil environment that is physically and/or chemically unfavorable to legume establishment or to the *Rhizobium* (Date and Brockwell, 1978).

Early nodulation can be obtained through rapid colonization of the rhizosphere by reducing the mortality rate of the inoculant, raising the rate of inoculum, or decreasing the time required for seedling germination (Brockwell, 1962). The latter possibility does not offer much for exploitation due to economic constraints involved in grassland agriculture, but the other two aspects have potential for improving rhizobia survival and therefore, seedling nodulation. Date (1968) found that solid-based inoculants were far superior to liquid or freeze-dried inoculants. He found that only the lime-pelleted seed and seed inoculated with a peat slurry -provided the minimum number of rhizobia per seed. Brockwell et al. (1980) conducted 16 field experiments to determine whether inoculant applied as a liquid or in solid form separately from the seed directly into the seedbed could be utilized as an alternative for conventional methods of forage legume seeding. These researchers found that under favorable sowing conditions, no difference was found between the methods in terms of success in nodule formation, quality of nodulation, seedling establishment, or forage DM yield. However, when sowing conditions were adverse due to environmental variables, solid or liquid inoculant applied directly to the seed bed gave better nodulation and plant growth than conventional methods of inoculation. Some workers have suggested seed pelleting as a means to allow better survival of rhizobia. Pelleting subterranean clover increased nodulation over non-pelleting (Brock 1962). In this study, using DM production as a measure of promptness of nodulation, Brock found that mixing the inoculum with pelleting materials increased DM production 22% over that produced from seed with the inoculum applied on the surface of the pellet. This was in agreement with the work of Hastings and Drake (1960) who found that a soil + lime + inoculum or clay + lime + inoculum pellet had 100% of white clover plants nodulated 92 days after inoculation, whereas only 10% of the plants were nodulated when inoculum was placed outside the pellet.

Also proposed have been massive rates of inoculum. In studies with crimson clover and subterranean clover, Jenkins et al. (1954) found that 100 times the recommended rate gave significant increases in plant green weight (promptness of nodulation) over the recommended rate. Hely (1965) found that massive rates of inoculum plus a hard coating of lime on the outside of the seed significantly increased the number of recovered *R. trifolii* in the rhizosphere: numbers were 30 times greater with this combination as compared to peat inoculation plus a lime coating on the seed.

Wade et al. (1972) found that doubling the inoculum rate, lime pelleting, or soil fumigation increased annual DM yields of arrowleaf clover (*T. vesiculosum* Savi.) 1200 to 2000 kg/ha over that of the normal rate of inoculum (190 g inoculum/22.7 kg seed). Coating inoculated seeds with lime increased winter forage production by 200%. This large increase in DM production was thought to come about due to improved nodulation and seedling growth. In Texas, Waggoner et al. (1980) found that an adhesive increased nodulation efficiency in white clover. They found significant increases in DM production, nodule numbers, nodule fresh weight, and percentage CP of white clover inoculated with 600 rhizobia/seed using gum arabic as an adhesive, as compared to white clover with 600 rhizobia/seed mixed with water. No difference was noted when gum arabic was used as an adhesive on white clover when inoculated with either 600 or 3000 rhizobia/seed. In North Carolina, Green et al. (1979) reported that the use of a 10% syrup solution as an inoculant adhesive resulted in an increase of 980 kg/ha of alfalfa DM. These workers reported that by using an adhesive, the applied rates of inoculant could be increased four to 12 times the recommended rate. This would be an important advantage in establishing fall-seeded forage legumes because of the hotter and drier conditions normally encountered. Greater than normal rates of inoculum and an adhesive should be applied to legume seed to compensate for the bacteria which will be killed by adverse climatic conditions (Giddens et al., 1982).

b. Competition Between Strains of *Rhizobium* for Nodule Formation

The competitive ability of a strain of rhizobia is considered as its ability to form nodules on the roots of a host legume plant in the presence of other related strains of *Rhizobium* (Date and Brockwell, 1978). The term 'competitve ability' describes the end result of several factors, some undefined, and their interactions. The most important of these is the influence of the host plant. This influence can be expressed at several stages in the development of the symbiosis, (i) survival of the inoculant strain on the seed, (ii) colonization of the rhizosphere, and (iii) root infection and nodulation.

i. Survival of Inoculant on the Seed

Thompson (1960) determined that seeds of subterranean clover contain a thermo-stable, water-soluble antibiotic active against a strain of *Rhizobium* usually used in commercially prepared inoculum . He found that soaking seeds before inoculation reduced the inhibition but autoclaving did not. Further investigations determined that the antibiotic was associated with, and extractable from, the seed coat and not the embryo. In field experiments, Thompson (1961) used several different adhesives plus several different seed coatings resulting in a pH range of 6.5 to 9.7. At the conclusion of the experiment there was no difference in the percentage of plants with nodules on the upper 1-inch of the tap root among treatments. He concluded that the key was separation of the seed coat from the inoculum rather than the chemical composition of the pellet coating. Bowen (1961) conducted similar experiments in pots containing sterilized soil or sand. He inoculated seeds of subterranean clover and glass beads with approximately 1000 organisms per seed or bead of RTR 151 (*R. trifolii*), S&R 13 (*Xanthomonas-Flavobacterium*), or the soil and rhizosphere organism *Agrobacterium radiobacter*. After 24 hours in sand or soil, counts of viable organisms were made. There was a decline of viable numbers of the S&R 13 isolate in both sand and soil, whereas multiplication took place freely around glass beads. The RTR 151 strain multiplied on seed in sand, but much less than on glass beads. *Agrobacterium radiobacter* was not inhibited and in fact was stimulated by the seeds.

Materon and Weaver (1984) conducted experiments similar to Thompson's but used arrowleaf clover. They found that a thermo-stable, water-soluble compound released from autoclaved and nonautoclaved seeds of arrowleaf clover inhibited the growth of many strains of *R. trifolii*. They suggested that additional research be conducted to identify the toxic substances and determine their influence on survival of rhizobia applied to seed as an inoculant.

Fottrell et al. (1964) identified two compounds with antibiotic activity towards *R. leguminosarum*. These compounds were extracted from seeds of white clover. One of the substances was identified as myricetin (3,5,7,3',4',5',-hexahydroxyflavone) while the other compound was a mixture of tannins. Myricetin was found in extracts of seeds from white clover, strawberry clover, (*T. fragiferum* L.), crimson clover, and red clover. It was not detected in extracts from subterranean clover, but aqueous extracts from this species were highly toxic to *Rhizobium*.

Hale and Mathus (1977) found that survival of *R. trifolii* on white clover seeds could be increased either by washing the seed or by treatment of seed with phenolic absorbents such as polyvinyl pyrrolidone or activated charcoal before inoculation.

ii. Rhizosphere Colonization

In the absence of a host plant rhizobia are frequently present in the soil in relatively small numbers (Date and Brockwell, 1978). When a host plant is present, rhizobia numbers are much greater. This increase in rhizobia numbers is generally greater for those species of rhizobia having the capability to nodulate the legume present than for those species requiring some other host legume. In an investigation of 26 sites throughout New South Wales and Queensland, Hely and Brockwell (1962) found that large numbers of *R. meliloti* in the topsoil were related to the presence of annual medic (*Medicago minima* (L.) Bart.). Further evidence of host specificity comes from work by Purchase and Nutman (1957). These workers mixed *R. meliloti* and *R. trifolii* and inoculated red clover seeds. They found total numbers of bacteria in the mixture remained fairly constant throughout the experiment, however, the number of *R. trifolii* cells increased rapidly. At the end of 24 days *R. trifolii* had reached a total count equal to the bacteria in pure culture. The *R. meliloti* was not successful in suppressing the clover bacteria nor was it stimulated into multiplication by exudates from clover roots.

Although the evidence suggests that a host is somewhat specific in regard to stimulation of rhizobia, Cloonan and Vincent (1967) found no stimulation of rhizobia numbers in the rhizospheres of *Lablab purpureus*. *Rhizobium* numbers dropped 95% in the first six days in treatments inoculated with a 'normal' rate of inoculant and in treatments receiving 100 times the normal rate. Labandera and Vincent (1975) found similar results with the TA1 strain of *R. trifolii*. This strain readily nodulated subterranean or white clovers but was found to be a poor colonizer of the root surface of *T. polymorphum*.

iii. Infection and Nodulation

The host legume exercises a selective preference for strains of rhizobia which form nodules. Working with five strains of *R. trifolii* and four species of *Trifolium*, Vincent and Walters (1953) found that the proportions of strains found in the nodules were unrelated to their representation in the root's external environment and that each host exercised a specific selective effect in this regard. Robinson (1969) collected *R. trifolii* from established plants of red and subterranean clovers, then inoculated seed of red and subterranean clovers with the rhizobia collected from each of the clovers. He found that plants of either host species nodulated faster and more effectively when inoculated with rhizobia isolated from the homologous host growing in the field than did test plants inoculated with cultures from the heterologous host.

The success of a strain is strongly influenced by numerical factors. Ireland and Vincent (1968) seeded subterranean clover inoculated with from 100 to 100,000 rhizobia/seed of the strains TA1 and UNZ29, into a paspalum (*Paspalum dilatatum* Poir.)-white clover pasture which had an ineffective soil population of approximately 100,000 rhizobia/gram of soil. The success in producing effectively nodulated plants of subterranean clover increased with an increase in the number of rhizobia used as inoculum. The proportional improvement was similar for both strains, but strain UNZ29 was required at about 100 times the concentration of TA1 to provide the same proportion of effectively nodulated plants. In further experiments in the greenhouse, Ireland and Vincent (1968) varied the amounts of indigenous, ineffective rhizobia in the soil and seeded subterranean clover inoculated to provide tenfold inoculum levels from 100 to 1,000,000 rhizobia per seed. They found that increased effective nodulation of subterranean clover was obtained by increasing the size of the inoculum for any given number in the soil, and that increasing the inoculum more than offset the same proportional increase in the number of competing rhizobia in the soil. Their general conclusion was that an increase in the number of an effective strain applied to the seed had about twice the influence as the same proportional increase in the number of ineffective rhizobia in the soil.

The occurrence of natural populations of rhizobia that are competitive but are ineffective constitutes a serious practical problem of some complexity. Holland (1970) found native populations of *R.*

trifolii associated with several native species of *Trifolium* in northern California rangelands. These native rhizobia were found to nodulate subterranean clover but were ineffective N fixers with this host. In experiments to determine at what level of inoculation effective nodulation was obtained, it was found that four times the recommended rate was required to insure effective nodulation. Subterranean clover plants inoculated at this rate yielded 520 kg DM/ha; plants from sterilized seed (no inoculum) and the recommended rate of inoculum (10,000 rhizobia/seed) yielded 49 and 47 kg DM/ha, respectively. In other experiments to test the persistence of introduced strains over time, Holland (1970) inoculated subterranean clover with a commercial inoculum or strain TA1. He found second-year yields of subterranean clover inoculated with TA1 to be 76% higher than those of subterranean clover inoculated with commercial inoculum. This indicated that the strain TA1 was able to persist over the summer period and produce effective nodules the second year on plants resulting from seed set the previous year. This is in contrast to work done by Dudman and Brockwell (1968). These researchers examined the persistence of two strains of *R. trifolii* (TA1 and UNZ29) applied as commercial peat inoculant to clover seed in a number of locations in Australia. They found that of the 456 isolates examined, 243 or 53.3% were identified as inoculum, strain TA1 or UNZ29. At one site, inoculum was recovered from nodules 30 months after sowing, but at another, the inoculum had dissappeared in 18 months. At the latter site, 14 months after sowing, the inoculum had fallen from 76% recovery to 0% in the same plant generation.

Not only do particular species of clover agglutinate certain rhizobia to infect them, Russell and Jones (1975) reported that cultivars of red and white clovers differed in their agglutination of rhizobia strains. The workers used three white clover cultivars ('S100','Kersey', and 'Pajberg'), and three red clover cultivars ('S123','S151', and 'Drewitts'), with each clover cultivar subjected to three inoculation treatments. Two of these were pure strain inoculation of strain 7a or strain A121111, and the third consisted of inoculation with a 50:50 ratio of the aforementioned strains. These workers found that of the three white clover cultivars, only S100 showed an overall selection response. Out of 405 nodules examined, 255 nodules contained strain 7a with the remainder containing strain A121111. The red clover cultivars behaved somewhat differently from the white clover cultivars, although both strains were considered effective with red clover. Drewitts red clover selected strain A121111 over 7a, S123 selected strain 7a and S151 had no preference for either strain. Gaur and Lowther (1982) evaluated five strains of *R. trifolii* for competitive ability and persistence as inoculum for white clover in a soil which had a naturalized population of rhizobia at two inculation levels, with and without lime pelleting. It was found that of the five strains tested, strain 2163 was by far the most competitive at sowing as well as 15 months after sowing. Regardless of inoculation or pelleting treatment, 53% of the nodules of white clover inoculated with strain 2163 contained that strain, whereas only 35-39% of the nodules of white clover inoculated with the other strains contained those specific strains of rhizobia six months after sowing. The differences obtained in competition between strains and their persistence was also evident in clover growth 15 months after sowing. White clover inoculated with strain 2163 produced 2870 kg DM/ha; white clover inoculated with strain 4144, the least competitive and persistent strain, produced only 2290 kg DM/ha. These results show that effective strains of rhizobia not only differ in their ability to nodulate the host, but also influence growth of the legume. In the United Kingdom, inoculation of white clover ('S184') with selected *R. trifolii* improved clover DM production by 1.88 t/ha in the first harvest year and 1.01 t/ha in the second harvest year (Mytton and Hughes, 1984).

From this discussion it can be seen that the relationship between root-nodule bacteria and their leguminous host is not always a beneficial one. The association can range from parasitic through ineffective to varying degrees of effectiveness. A fully effective combination requires a stable association between host and bacteria within the nodule which permits the formation of the maximum amounts of N-fixing tissue and which persists as long as possible. The performance of various clover-*Rhizobium* symbioses is difficult to predict and may differ with location. However, the literature indicates that maximal legume production is likely to require matching of plant genotypes, *Rhizobium* genotypes and environments. The factors which are important in determining the different production capabilities of specific clover-*Rhizobium* genotypes are largely unknown, but it is clear that these differences do exist.

c. Nitrogen Relationships in Grass-Legume Associations

Pasture plants obtain most of their N from either mineral N in the soil or from N fixed via the symbiosis which exists between rhizobia and the nodulated legume host (Vallis, 1978). The supply of N is considered to be a major factor influencing the interactions which occur among grass and legume plants growing in the same sward (Donald, 1963). Involved in such interactions are (i) uptake of mineral N, (ii) symbiotic fixation and (iii) transfer of N, all of which will affect grass-legume balance.

i. Uptake of Nitrogen

Nitrate (NO_3^-) is often the preferred source of N for crop growth although NH_4^+ can also be absorbed (Mengel and Kirkby, 1982). The most important difference in the uptake of these species of N is their sensitivity to pH. Uptake of NH_4^+ takes place in a neutral medium and it is depressed as pH decreases. The opposite is true for NO_3^- absorption.

It has been widely assumed that legumes obtain little or none of the available mineral N (Walker et al., 1954). There have been, however, several exceptions to this assumption. Willoughby (1954) found that subterranean clover was very competitive for N when grown in association with ryegrass (*Lolium rigidum* Gaud.) to the extent of virtual disappearance of the grass component within two or three years. From a series of experiments it became evident that applications of N or P at the onset of the season greatly enhanced legume growth and subsequently reduced the level of nutrients required for good grass growth. When N and P were applied 11 weeks after the onset of the growing season, this competition was greatly reduced. At this time clover made up only 10% of the total yield as compared to 29% for the early fertilizer applications. By the second harvest, two months later, the early applications had an approximate 50-50 mixture of grass-clover but the the late fertilizer applications resulted in a 75-25 mixture.

Davies (1964) found that in meadow fescue (*Festuca elatior* L.)-alfalfa swards, the fescue actually took up less N than when fescue was grown in a monoculture (48 vs 57 kg N uptake/ha, respectively). A decreasing trend in N uptake continued throughout the three years of the study. At the conclusion of the study, meadow fescue grown in monoculture took up 39 kg N/ha but in grass-legume mixture it took up only 13 kg N/ha. These data indicate that alfalfa was very competitive with meadow fescue for available soil N.

In pot experiments Allos and Bartholomew (1955) found that when legumes were grown in monoculture, uptake of fertilizer N was approximately 66% of that fertilizer N taken up by grasses grown in monoculture. These data suggest sufficient N from fixation is not available for maximum growth rates of the legumes.

Species differences between legumes in uptake of N has been demonstrated by several workers. Simpson (1965) found in pot experiments that white clover growing with orchardgrass was very competitive for soil N during the early stages of growth when N uptake of the orchardgrass was slight. In the same experiment subterranean clover and alfalfa did not reduce N uptake of orchardgrass. In his field experiments, Simpson (1976) showed that subterranean clover increased N yield of orchardgrass by 66% over the N yield of grass alone. Nitrogen concentrations were also increased in orchardgrass grown in swards with subterranean clover. White clover and alfalfa transferred very little of their fixed N to the orchardgrass. White clover, however, did contribute more N to orchardgrass than alfalfa, as reflected by the N yield of orchardgrass grown with the legume. Nitrogen yield of orchardgrass was increased by 40 and 22% over the no-legume control by white clover and alfalfa, respectively. These data indicate that alfalfa was by far the most competitive for mineral N of the three legumes studied. In legume monocultures Allos and Bartholomew (1955) noted large difference in N fixation of different legumes. In pot experiments, birdsfoot trefoil fixed the least amount of N (34 mg/pot) while peanuts fixed the greatest amount (333 mg/pot). Among the forage legumes, alfalfa (cv. 'Ranger') fixed the greatest amount of N (141 mg/pot).

Another factor which greatly influences the competition between grasses and legumes for nutrients is seasonal growth patterns. Willoughby (1954) found that the disappearence of ryegrass from ryegrass-subterranean clover pastures could have been due to earlier germination and growth of the legume. This earlier germination and growth created a N deficiency for the ryegrass, resulting in a clover dominant pasture for the entire grazing season. At the beginning of the growing season pastures contained a 25-75% grass-legume mixture, and by the end a 15-85% grass-legume mixture.

ii. Symbiotic Fixation

The fixation of atmospheric N by plants is a very complex biochemical process. The rate of N fixation by legumes depends upon the effectiveness of symbiosis between *Rhizobium* and host plant as well as on the environmental conditions (Nutman, 1965; Vincent, 1965; Havelka et al., 1982).

Environmental factors can influence N fixation both directly and indirectly (Vincent, 1965). The direct effects are those concerning the establishment and the functioning of the symbiosis between host plant and *Rhizobium*. The indirect effects are those dealing with growth of the plant. Many factors are involved but this section deals only with the supply of mineral N.

Nodulation. Nodule initiation and development is very complex and the influences of mineral N add to the complexity. Several aspects such as the time at which nodules appear and the number and size of nodules can be affected by mineral N (Vallis, 1978). The nodulation response depends on the level and form of N, species of legume, *Rhizobium* strain, application time, and other factors that may affect growth of the plant.

A large number of factors can be seen to affect the response of nodulation to combined N, and this response can be quite variable. The literature bears this out. Thornton (1946) found that the addition of 5 mg N/pot to Korean lespedeza significantly reduced the number of nodules/plant as compared to the control (no added N). In this same experiment, the addition of 200 mg N/pot reduced the number of soybean nodules per plant to 53 whereas the control had 60 nodules/plant. Gibson and Nutman (1960) found that KNO_3, $NaNO_3$, NH_4NO_3, and $NaNO_2$ at 20 ppm significantly delayed initial nodulation of white clover, but asparagine, urea, and $(NH_4)_2SO_4$ had no effect. Regardless of form of N, nodule number was increased above that of the control plants. In testing bacterial strains, alfalfa plants were given varying initial concentrations of NO_3-N and it was found that small amounts of added N (up to 10 ppm) increased the total number of nodules formed regardless of strain of bacteria used.

In favorable summer sowing, primary-root nodulation of cowpeas (*Vigna sinensis* Endl.) was stimulated by low concentrations of NH_4NO_3 (0 to 10 mg N/pot) but higher levels (20-150 mg N/pot) decreased nodule numbers (Pate and Dart, 1961). In the less favorable growth conditions of autumn, no stimulation was noted and all additions of N reduced the number of primary-root nodules. In the same series of experiments, Pate and Dart (1961) used two strains of bacteria, SU277.1 and SU41.237 (effective and ineffective, respectively), on barrel medic (*Medicago tribuloides* Desr.) and added increasing levels of N. They found that primary-root nodulation with the effective strain (SU277.1) was stimulated by all but the highest levels of added N (<20 mg N/pot). In the ineffective association (SU41.237) a maximum in primary-root nodulation was obtained from applications of 4 to 8 mg N/pot. Lateral-root nodules were at a maximum at the highest rates of applied N (>30 mg N/pot) with the effective strain, whereas in the ineffective association the greatest number of lateral-root nodules occurred with small amounts of added N and marked depression occurring at the higher concentrations (6-40 mg N/pot).

Dart and Mercer (1965) found the greatest number of primary-root nodules to occur when no N was supplied to cowpeas. Of the treatments receiving N, significantly more nodules were formed at the intermediate level (30 mg N). Optimum temperature for primary-root nodulation when no N was added and under full sunlight conditions was found to be 27° C with a response of 20 nodules/plant.

Dart and Wildon (1970) found that nodulation of cowpeas was decreased by immersion of leaves in solutions of KNO_3, $(NH_4)_2SO_4$, NO_3^-, or urea at all levels of N applications (1.5, 3, and 6 mg N/liter). Root applications at sowing of the same compounds at rates of 8, 24, or 72 mg N/pot also decreased nodulation. Further evidence on the effect of form of N on nodulation comes from experiments conducted by Diatloff (1967). Although high NO_3^- and NH_4^+ levels had a definite inhibitory effect on nodulation of soybean, the NO_3^- ion was found to have the greatest influence on nodulation. Nodulation was almost prevented by NO_3^- at levels close to 168 ppm N (1.5 nodule/5 plants), whereas NH_4^+ was only partially inhibitory at 224 ppm N (1 nodule/5 plants).

Nodulation has quite a variable response to mineral N. This variable response is thought to result from the confounding of different effects on the infection process and nodule development (Dart and Mercer, 1965). The effect that has been recognized is an external effect of combined N in the root medium (Tanner and Anderson, 1963). Early work on this external effect, inhibition of rhizobia invasion of roots, implicated a role for indole-3-acetic acid (IAA) (Kefford et al., 1960; Tanner and Anderson, 1963; Munns, 1968a,b). More recent evidence has suggested a role for lectins in legume-*Rhizobium* recognition (Bohlool and Schmidt, 1974) as discussed previously (see Host-Influenced Rhizobia Multiplication and Recognition). Dazzo and Brill (1978) found that either NO_3^- or NH_4^+ (16mM) completely inhibited infection and nodulation of white clover seedlings. These workers found that the binding of *R. trifolii* to root hairs and immunological levels of the plant lectin, trifoliin, on the root hair surface decreased similarly as the concentration of either NO_3^- or NH_4^+ was increased in the rooting medium. The agglutination of *R. trifolii* by trifoliin from seeds was not inhibited by any level of NO_3^- or NH_4^+ used. These results suggest that N may play important roles in regulating an early recognition process in the *Rhizobium*-legume symbiosis, namely the accumulation of high numbers of infective *R. trifolii* cells on legume root hairs.

N Fixation. The response of N fixation to level of mineral N is quite similar to that of nodulation. One might consider additions of combined N to have a direct effect on nodulation, or recognition, and an indirect influence on N fixation. Hence all the factors which influence the nodulation response also influence the fixation response.

It has been suggested that the response to applied N depends on the supply of photosynthate. In studies with white clover, Van Schreven (1959) found that concentrations of 0.5 and 1% glucose stimulated nodule formation and hence, N fixation. Pate and Dart (1961) found that applications of N to 4 day-old cowpea seedlings depressed symbiosis. In these plants it was found that fixation at the end of the growing period (6 weeks) was approximately 10% lower than the control plants and as much as 50% lower than seedlings receiving comparable doses at 10 days after germination. These workers concluded that the developing association was particularly sensitive to combined N and further suggested that perhaps a channelling of photosynthetic products into protein sythesis in the actively-growing shoots limits the amount of carbohydrate and other growth materials available for the root system and its developing nodules. Barta (1979) found that additions of 1mM N as NH_4NO_3 to birdsfoot trefoil reduced N-fixation, as measured by acetylene reduction, four weeks after cutting. Nitrogen fixation in the control treatment (no added N) had a seven-fold increase from two to four weeks after cutting. This was considered a reflection of increasing plant demand for N and increasing supply of photosynthate. Distribution of ^{14}C showed reduced amounts of photosynthate in trefoil supplemented with N. This suggested that the shoot growth of trefoil is a dominant sink for photosynthate and that accumulations of photosynthate are neither altered by N source nor by the amount supplied.

At times, additions of small amounts of N increase fixation. Diatloff (1974) found that a foliar spray of 120 ppm NH_4NO_3 almost doubled nodule fresh weight and percentage of pink nodules over those of control plants of Tinaroo glycine (*Glycine wightii* var. Tinaroo). Total N assimilated was increased by 31%. Total N assimilated was found to be positively correlated with nodule weight (r = 0.86) and percentage of pink nodules (r = 0.84). Pate and Dart (1961) found that a single dose of 10 mg N/pot increased N fixation by 31% over the controls of 10-day old cowpea seedlings. Doses of up to 30 mg N/pot at sowing also increased fixation, as well as that N applied at 7- or 14-days after germination. It appears that under suitable climatic conditions small additions of inorganic N at sowing benefit symbiosis by increasing seedling growth rate and the number, size and efficiency of the nodule complex. After nodule initiation (7-,10-, or 14-days after germination) the seedling often goes through a period of 'N-hunger' before the nodules are sufficiently developed to supply N to the plant. Dart and Mercer (1965) found that additions of 30 mg N/pot as NH_4NO_3 to cowpea increased N fixation over that obtained from the controls. This would be in agreement with the findings of Pate and Dart (1961).

The literature indicates that differences in the response of N fixation to combined N occurs among legume species. Allos and Bartholomew

(1959) found that total N fixation of several legumes was closely related to the amount of growth. Soybeans fixed the most N, followed in decreasing order by alfalfa, sweetclover, ladino clover, and birdsfoot trefoil. This was also the order of total DM production. Dart and Wildon (1970) found that N fixation by cowpea was stimulated by combined N. Additions of 90 mg N/pot as urea increased N fixation by 29% above that of controls receiving no added N. In other experiments, N fixation by cowpeas after addition of 160 mg N/pot remained greater than that of the controls. In purple vetch (*Vicia benghalensis* L.), however, the addition of combined N did not stimulate N fixation, although concentrations of applied N were similar to those applied to cowpeas. These results are consistent with the findings of Allos and Bartholomew (1959). The effect of N additions on N fixation depends on the growth rate of the plant, with the faster-growing species being more tolerant of combined N. It appears from these studies that the faster-growing species are more able to reduce the concentration of mineral N in the root medium.

Another factor which can affect the response of N fixation to level of combined N is the strain of rhizobia used to create the symbiosis. Pate and Dart (1961) found no significant differences in N fixation among purple vetch plants inoculated with four different rhizobia strains when no N was added. However, when varying amounts of N were added, the abilities to fix atmospheric N of the four associations were quite different. Strain V19 was a very efficient N fixer at high levels of added N, in fact N fixation was stimulated at all levels of combined N. The ability of strains V32 and SU133 to fix N with additions of 7.5 and 10 mg/plant of combined N was depressed. Upon final examination of the roots it was found that primary-root nodulation was inhibited in all four associations by the smallest dose of applied N (5 mg/plant). It was also found that lateral-root nodulation was sparse with strains V32 and SU331 when 7.5 or 10 mg N were added per plant, but extensive and clearly effective with strains V19 and V200. They attributed the symbiotic performance of purple vetch in the presence of high doses of combined N to the relative success or failure of the *Rhizobium* to infect the lateral roots of the host plant. They further concluded that the later infection of lateral roots took place after a large portion of the added N had been absorbed by the plant.

The growth response to small of moderate additions of combined N indicate that symbiotic fixation is often unable to supply enough N for maximum growth. Norman and Krampitz (1946) demonstrated that the soybean plant can effectively utilize more N than can be supplied symbiotically. They found that additions of 1000 mg N at sowing increased DM production by 33% over the check (no added N) whereas the same amount of N applied 24 days before harvest increased DM production by only 8%. Allos and Bartholomew (1959) in studying soybeans, alfalfa, sweetclover, ladino clover, and birdsfoot trefoil, found that the fixation process never supplied sufficient N for maximum growth. All legumes responded to additions of combined N with increased growth and N uptake and in some instances, increases in growth increased N fixation. However, when applied N exceeded that necessary for an increase in growth, the applied N replaced that N created by the fixation process. Gates and Wilson (1974) found both N and P additions increased the yield of Townsville stylo (*Stylosanthes humilius* H.B.K.). The yield of tops increased with P level up to 100 kg P/ha. At P levels of 0 to 125 kg P/ha additions of N decreased nodulation, but increased nodulation when P was added at 50 to 200 kg P/ha. It appears from this work that when a limit to growth is eliminated, symbiotic N fixation becomes less sensitive to combined N.

iii. Transfer of Nitrogen

Generally, the inclusion of a legume in a pasture mixture increases the N uptake of the grass (Vallis, 1978). The transfer of N which has been fixed symbiotically can occur by several pathways and these include soluble N-containing compounds released from living plants, animal excreta, and legume residues.

Soluble N compounds. Virtanen and Lane (1935) found that peas excreted nitrogenous compounds into the growth medium. The nitrogenous compounds were found to consist chiefly of amino acids (87-98% of the total N was amino N). In additional experiments, Virtanen et al. (1937) found that the extent of excretion rose with increasing ratio of non-legumes to legumes. They found that when two pea plants were grown with three barley (*Hordeum vulgare* L.) plants, 62.2% of the N excreted was transferred to barley whereas 40.8% of the N was transferred to four barley plants grown with two pea plants. This is in contrast with Wyss and Wilson (1941) who could not duplicate the work of Virtanen and others under the same environmental conditions. However, under certain environmental conditions, long days and low temperatures, excretion of N from the peas to barley was noted. Butler and Bathurst (1956) concluded that the excretion of N from legumes in the field is likely to be of transient or rare occurrence since their values of N excretion were relatively low for red and white clovers (100-105 ug N $plant^{-1}$ $week^{-1}$). They also concluded that if legumes excreted N compounds it would require a luxury accumulation of low molecular weight nitrogenous metabolites in the nodule. Management practices imposed upon pastures are designed to promote rapid vegetative growth which results in high utilization of nitrogenous compounds for protein synthesis.

Most pot experiments have indicated that the transfer of N from intact root systems is only a small percentage of the N fixed. Henzell (1962) found 80% of the total N fixed by alfalfa and white clover in the plant tops, the remainder being found in the sand and roots. In terms of N transference, 1.12 and 0.87% of the N fixed by white clover and alfalfa, respectively, was transferred to the companion grass, *Paspalum commersonii*. Simpson (1965,1976) noted that N transference was influenced by the species of legume. White clover competed with the associated grass in early stages of growth, but during autumn and winter N was released and transferred to the grass. Subterranean clover also competed with the grass for mineral N but upon senescence, the root system released N during summer. Alfalfa was found to act differently from white clover and subterranean clover, since it did not compete for mineral N at any stage, but instead increased the grass yield and N uptake. Vallis et al. (1967) found very little transfer of N from Townsville lucerne to Rhodesgrass (*Chloris gayana* Kunth.).

The results from pot experiments are supported by work done in the field. Little transfer of N occurs during the first year of newly established grass-legume swards (Whitehead, 1970). In establishing a white clover-ryegrass sward, Holliday and Wilman (1962) found that white clover transferred 3.4 to 7.7 kg N/ha to the ryegrass whereas total N fixed was 326 kg/ha. Bland (1967), who separated the roots of perennial ryegrass and white clover, found no significant effect on N percentage of the grass component the first two years of the study. In the third year 218 kg N/ha were harvested from grass and clover growing together, whereas only 184 kg N/ha came from the separated plots. This indicated that 34-35 kg N/ha was transferred from white clover to the associated ryegrass.

Animal excreta. The transfer of N from legumes to grasses growing in association with them through the urine and feces of the grazing animal is widely believed to be the principal process of N transfer in grazed pastures (Russell, 1973). About 75% of the N ingested by beef cattle is excreted via the urine and dung (Van Soest, 1982). The availability of N in feces and urine is quite different. The N in urine occurs as urea or amino-N and is readily available for plant and microbial uptake, but is subject to losses (Whitehead, 1970). The N in feces is in insoluble forms and its availability depends largely on the activities of insects and/or other soil fauna.

The N concentration of urine is somewhat variable, although average values agree. For cattle the range is about 0.25-1.3% with an average of 0.8% (Doak, 1952; During and McNaught, 1961; Gisiger, 1950; Petersen et al., 1956b). In cattle, the frequency of urination ranges between 8 and 12 times/day (Hancock, 1953; MacLusky, 1960; Peterson et al., 1956a) with an average volume of 1.6 liters/urination (Doak, 1952). The area covered by a volume of urine has been reported to be approximately 0.27 m^2 (Peterson et al., 1956a). If an area is covered by a 2 liter cattle urination containing 0.8% N, and is distributed over 0.27 m^2 , this would be equivalent to 576 kg N/ha (Whitehead, 1970). However, the center of the urine patch will receive a larger dose of urine than will the periphery.

The influence of a urination will extend over a greater area than that actually wetted. In North Carolina, Lotero et al. (1966) reported that the area influenced by urination was 0.86 to 1.17 m^2. The fate of the urine is influenced by both weather conditions and soil texture, and losses as ammonia are inevitable. Doak (1952) applied urine at 2 liters/10 m^2 and found that the pH of the soil surface went from 5.3 to 7.8 within four hours, reflecting ammonia volatilization. In other experiments, Doak found that 12% of the N was volatilized as ammonia gas within three days when air temperature was 21° C. Watson and Lapins (1969) found N losses from urine to exceed 50% on sandy soils.

Quantity and composition of feces varies with the diet of the animal, but the average N concentration has been reported to be 0.4% on a fresh weight basis, or 2.0-2.8% N on a DM basis (Petersen et al., 1956b). The N contained in feces is of relatively little value to the sward at the onset, and to be useful the feces must be incorporated into the soil. Estimates of the contribution made by feces to grass growth varies. Petersen et al. (1956a) reported that the area affected was only slightly greater then the area covered. MacLuskey (1960), on the other hand, found that feces affected the growth of the sward over an area about six times that actually covered.

Several workers have reported that additions of excreta depress the clover content of grass-clover pastures. Frame (1966) found that under grazing, a perennial ryegrass-white clover sward went from 30% clover to less than 10% clover in a six-month period. He attributed this to the excretal N contained in urine. In experiments to elucidate full return of excreta versus no return, Herriot and Wells (1963) reported that percentage of white clover in the full return plots decreased from 40 to 4% during the five-year study. Wheeler (1958) studied the effects of excreta on a ryegrass-white clover sward. In the first year clover percentage was reduced 9% by dung and urine applications, as compared to the control. The second year, this reduction had increased to 13%. Applications of dung only have been reported to have no significant effect on percentage of clover. Ball et al. (1979) found N fixation, determined by acetylene reduction, to be decreased by urine applications. With no urine applications, N fixation was estimated to be 80 kg/ha. In plots receiving urine at 300 kg N/ha, N fixation was reduced to 15 kg N/ha, and at the 600 kg N/ha rate it was reduced to 5 kg N/ha. This was reflected in the contribution that white clover made to total yield. Over a 53-day study period, white clover accounted for 48% of the DM yield in control plots, and only 19 and 12% in the plots receiving 300 and 600 kg N/ha as urine, respectively. Ledgard et al. (1982) noted a 21% reduction of clover in plots receiving urine as compared to control plots receiving distilled water.

One must consider, though, the nature of the experiments conducted above. The experiments were designed to measure the effect of dung and/or urine and the distribution of excreta was probably more uniform than what would be obtained under more usual conditions. Petersen et al. (1956a) estimated that at a stocking rate of 494 cow-days/ha, only 5.5% of the area would be covered by excreta during a one-year period. Hilder (1969) concluded that excreta may be of limited value in nutrient recycling due to heavy concentration of excreta in camp and shade tree areas. Wolton (1979) concluded that only at very high stocking rates, or where swards are consistently mismanaged at low stocking rates, will the grazing animal be responsible for deleterious sward changes. The rate of recovery of N in grazed pastures will depend ultimately upon the distribution of excreta (Petersen et al., 1956a; Hilder, 1969), stocking rates and management practices (Wolton, 1979), size of the nutrient pools, and the capacity of plants to absorb large amount of nutrients (Mott, 1974).

Legume residues. Very little information is available on the contribution to soil N made by the litter of grasses and legumes in cut or grazed pastures, but one can envision the large quantities of forage involved. When swards are cut and forage removed, substantial quantities of N remain in the field. Cowling (1961) estimated that 149 kg N/ha was left unharvested in the stolons and petioles of white clover. The rate of soil N accumulation under pure swards of subterranean clover was found to be 81 kg N ha^{-1} $year^{-1}$ regardless of whether swards were clipped and forage discarded, or clipped and dried forage added back to the sward, or swards were grazed (Watson and Lapins, 1964). Without a doubt, plant litter is a potential avenue for the transfer of N. However, the value of plant litter as a source of N will depend on decomposition rate, chemical composition (especially N concentration), rate and position added to the soil, and temperature and moisture conditions (Bartholomew, 1965). Watson and Lapins (1964) concluded that N volatilization from excreta and returned herbage, and reduced N fixation due to the return of N in excreta and herbage were the factors responsible for the absence of differential treatment effects. They questioned the role of the grazing animal as an agent necessary in the maintenance or buildup of soil fertility levels.

In pot experiments, Vallis and Jones (1973) found that after 32 weeks of incubation, leaves and leaf litter of *Desmodium intortum* cv. 'Greenleaf' and of *Phaseolus atropurpureus* cv. 'Siratro' had significantly increased the mineral N concentration of soil over that of control soil with no added litter. They also found a difference between the two species in their ability to contribute to soil mineral N. During the first four weeks of incubation, additions of leaves of *Phaseolus* were followed by a net mineralization of N in proportion to the amount of material added. On the other hand, leaf material of *Desmodium* reduced the concentration of mineral N to almost zero during this time. This was explained by the fact that *Desmodium* species contain tannins which protected proteins from soil microorganisms.

Yaacob and Blair (1980a) added ^{15}N-labelled soybean or *Macroptillium atropurpureum* to soil in which one, three or six previous crops of these species had been grown. Half of the pots were then seeded to Rhodesgrass, the other half left bare. Nitrogen uptake by the grass increased with the number of previous crops for both soybean and *Macroptillium*. For soybeans with one previous crop, N uptake by Rhodesgrass was 59.2 mg/pot whereas for six previous crops N uptake was 98.3 mg/pot. For grass grown in soils cropped with *Macroptillium*, these values were 91.3 and 298.2 mg N/pot, respectively. They attributed the difference to the carbon (C)-N ratio of the two species, 28.4 and 16.1 for soybean and *Macroptillium* residues, respectively. The high C-N ratio of soybean residues led to a rapid rate (mineralization>immobilization) of decomposition which resulted in production of ammonia which was lost to the atmosphere. These results show that the turnover rate from organic residues can be high and the net results of additions of plant litters depends on their nature and the soil system to which they are added. In further experiments in the greenhouse Yaacob and Blair (1980b) grew Rhodesgrass on soils previously cropped with one to six soybean or *Macroptillium* crops. They added the equivalent of 50 kg N/ha to half of the pots, the other half did not receive N. At the first harvest (14 wks) a response to applied N was obtained in all soils which had grown one to six soybean crops previously. Soils which had grown three or more *Macroptillium* crops had no significant response to applied N. This was again due to the more rapid mineralization of N in soybean than in *Macroptillium*. These workers (Yaacob and Blair, 1980a,b) emphasized the need to study rates of nutrient turnover and the dynamics of N in soil systems rather than to measure the size of resident nutrient pools.

In field studies, Vallis (1983) applied ^{15}N-labelled Siratro and Greenleaf leaf and stem materials of different N concentrations (0.5-3.8%) to the soil surface of a Rhodesgrass pasture. The recovery of ^{15}N was monitored for up to three years. Vallis found that only small proportions of ^{15}N applied via the legume materials were used for shoot growth by the Rhodesgrass over two growing seasons. With Siratro leaves applied at 6.7 g $^{15}N/m^2$, only 0.44 and 0.49 g $^{15}N/m^2$ were used for shoot growth the first and second year, respectively. This was only 3.0 and 2.3% of the total N yield in grass shoots, respectively, for the two seasons. Nitrogen uptake by Rhodesgrass shoots from Greenleaf materials was less than from Siratro. At the end of the second year, percent recovery of ^{15}N in whole plants of Rhodesgrass was not different between the two species for leaves or for stems. Recovery of ^{15}N at this time was 18 and 29%. In additional experiments Vallis found that Siratro leaf materials containing 1.35% N contributed only 1% of the total N harvested in grass shoots over a one-year period, whereas leaves and stems with 3.8 and 2.1% N, respectively contributed approximately 3%. By the end of the third year the uptake of ^{15}N supplied by the N-rich Siratro leaves (3.84% N) the cumulative recovery was 18.4% of the initial addition. In summary, Vallis concluded that rarely will more than 25% of the N in legume materials decomposing in the field become available to plants during the first one or two years, and much less each year succeeding.

The literature adheres to the classical concepts of N availability from decomposing organic materials. Nitrogen in plant materials with less than 1.0 to 1.5% N is largely immobilized in the tissues of the decomposer microflora. The N from these materials becomes available very slowly whereas in plant materials with higher N concentrations, such as in temperate-zone legumes, a part of the N is in excess of the needs for microbial growth and is released to become available for plant growth (Bartholomew, 1965).

From this discussion of N relationships in grass-legume associations, it appears that the N uptake of the grass can be influenced by the legume through two opposing processes. First, the legume may increase the supply of mineral N available to the grass. Second, it may compete with the grass for available soil N. These two processes, transfer and competition, cannot be measured separately. The net effect of these two processes is the measurable entity.

In most experiments and in all practicality, the grass benefits more from the increase in N supply than it suffers from legume competition. Therefore a net transfer of N from legume to grass occurs.

d. Architecture of Grass-Legume Canopies

Fundamental to light interception by plants is the spatial arrangement or composition of the leaf canopy, with plant height as the most important feature determining competitive ability for light (Haynes, 1980). Trenbath (1974) concluded that in competition for light, the component with its leaf area higher in the canopy is at an advantage. Plants with horizontal rather than erect leaves have a competitive advantage. In temperate pastures, the grasses are generally taller and more vigorous than the legumes grown in association with them. If the pasture is not managed properly, grasses often shade the legumes.

In grass-legume associations, light intensity decreases by absorption and reflectance down the leaf layers to the soil surface. This gradient has been termed as the "light extinction coefficient" (k) (Brown and Blaser, 1968). Values of k depend upon the growth habit and leaf structure of the plant. In a review, Brown and Blaser (1968) determined that values of the dicotyledonous species with horizontal leaves (planophile) generally lie near 1. Grasses, on the other hand, with vertically inclined leaves (erectophile) require more leafage to intercept a given amount of light. Grasses are characterized by lower k values than the clovers, in a range of 0.4-0.7.

The total area of leaves can be described by the leaf area index (LAI). This value is the ratio of area of leaf per unit area of ground surface. Two types of relationships have been found when DM production is related to LAI (Mitchell, 1970).

In the first relationship, yield increases as LAI increases, up to some optimal value, then declines. This is termed optimal LAI. Brougham (1958) found this relationship in monocultures of white clover with a LAI of 3.5. At this stage leaf formation under the canopy was equal to leaf senescence at the top of the canopy. Similar results were obtained by Davidson and Donald (1958) with subterranean clover. These workers used different densities of subterranean clover and found that DM production was at a maximum when the LAI was 4 to 5, but decreased by 30% when the LAI reached 8.7. They also found that regardless of plant density, all swards had common ceiling LAI's and DM yields by the end of the growing season. Black (1963) found that for subterranean clover both the maximal growth rate and optimal LAI increased with increased level of solar radiation, but the effect of temperature was negligible. Thus it appears that LAI of clovers increases with DM accumulation to a certain point, then DM accumulation decreases due to excessive self-shading while LAI increases.

In the second relationship, a plateau response, yield remains constant as LAI increases and is termed critical LAI (i.e. LAI continues to increase after the index at which interception of light by the canopy is complete). Brougham (1958) noted this response in ryegrass-clover swards regardless of defoliation intensity. The rate of forage growth was found to increase until complete light interception was approached, and afterward an almost constant rate of DM production was maintained. The critical LAI value was found to be 4.5. Short-rotation ryegrass (*Lolium perenne* L. X *L. multiflorum* Lam.), perennial ryegrass (*Lolium perenne* L.)

and timothy (*Phleum pratense* L.) were found to have critical LAI's of 7.1, 7.1, and 6.5, respectively. Legumes such as alfalfa have been shown to exhibit a critical LAI of 10 to 11 (Smith et al., 1964), probably due to growth habit, characterized by erectophile stems supporting planophile leaves (King and Evans, 1967).

The previous discussion has brought out that clovers generally have planophile leaves, absorb light from only a few layers of leaves, and reach optimal or critical LAI more quickly than the grasses which characteristically have erectophile leaves. Coupling the above with the facts that grasses tend to be taller and their growth rate faster, legumes are generally more prone to be shaded. In pastures, however, grazing and/or hay cutting are common practices, and the balance between associated grasses and legumes can be modified by clipping and/or grazing animals.

e. Growth Habit and Defoliation

The growth habit of pasture plants is important because it is a principal factor determining the response of a plant to defoliation. The relationships are very complex, since many factors such as soils, climate, and animal selection patterns all interact to affect the response of pasture plants to defoliation.

The grasses are one of the largest families of flowering plants (Hartley, 1964). They are present in almost all types of vegetation, including not only the prairies and steppes where they are indigenous, but also in temperate and tropical forests, deserts, and swamps. They occur on all continents, including Antarctica, and are outstanding in their ability to adapt themselves to diverse ecological conditions. The success of grasses as pasture plants is due to this wide distribution and their growth habit, which is well adapted to defoliation. In most grasses, buds from which growth arises are formed at or below the soil surface (Stoddart et al., 1975), well below the level normally reached by grazing animals or harvesting machinery. During growth of a grass, three kinds of stems are produced: (1) a vegetative stem without a culm, (2) a culmed stem which produces no inflorescence, and (3) a reproductive stem which contains an inflorescence (Stoddart et al., 1975). Vegetative stems can make up anywhere from 25 to 90% of the stems present, depending upon the species and environmental conditions. Reactions of stems to defoliation are quite different due to two factors - the position of the apical bud and the duration of meristematic activity and foliar enlargement.

Individual leaves of grasses continue to enlarge until the ligule is formed and, if defoliation occurs after ligule formation, no additional leaf growth is made. On the other hand, if defoliation occurs during ealier stages when meristematic tissue at the base of the leaf blade and sheath remain intact, then leaf growth continues (Stoddart et al., 1975).

Grasses as a group react similarly to defoliation, but individual species vary in their tolerance to repeated defoliations (Moore and Biddiscombe, 1964). Species with erect growth habit, or culmed grasses, are generally more susceptible to close defoliation than the rhizomatous or stoloniferous grasses. However, the growth habit of culmed grasses can be modified by regular defoliation. Grasses which undergo regular defoliation tend to be semi-decumbent and have a fairly large number of buds below the soil surface (Moore and Biddiscombe, 1964). Regardless of whether culmed grasses have the properties discussed above, a grazing animal removes a greater proportion of each tiller or stem of a culmed grass than from a grass with a prostrate growth habit (Haynes, 1980). Therefore more leaf area of a prostrate grass is left after defoliation to increase regrowth potential. Grasses with upright growth habits, such as orchardgrass, require more time to recover from defoliation. Frequent, repeated removal of leaf tissue of orchardgrass will result in stand deterioration (Jung and Baker, 1973). More important perhaps, is the height of cut. Frequent clipping (8 cuts/year) at a short stubble height (3.8 cm) has been found very detrimental to orchardgrass stands in Tennessee (Fribourg and Reynolds, 1968; Reynolds et al., 1971). Under seasonal continuous grazing, excellent stands of orchardgrass were maintained for at least three years (McLaren et al., 1983), but the grass was not allowed to be grazed below a height of 8 cm. Bermudagrass (*Cynodon dactylon* (L.) Pers.), on the other hand, is a highly rhizomatous/stoloniferous warm-season grass which can be defoliated frequently and still maintain excellent stands (Burton, 1973).

The suitability of legumes for grazing is determined, as with the grasses, by their growth habit. Those legumes with a rhizomatous and/or stoloniferous growth habit are not easily damaged by grazing animals, whereas those legumes with an upright growth habit can be severely damaged by grazing. The ability of a legume with an upright growth habit to persist under grazing will depend upon the position of the crown (Haynes, 1980). Most of the legumes used in temperate pastures are able to modify their growth habit after frequent defoliation. In defoliation experiments with subterranean clover, Davidson and Birch (1972) found that swards that had been clipped at weekly intervals developed a prostrate network of stolons which led to a rapid recovery of leaves following defoliation. White clover is a very important pasture legume in many parts of the temperate zone (Leffel and Gibson, 1973). The success of white clover in temperate agriculture comes from its wide diversity of growth forms. Its growth habit varies from erect, large-leaved plants from the Mediterranean area (ladino form) to the small-leaved, many-branched prostrate forms from northern Europe (kentish form) (Brougham et al., 1978). White clover also has the ability to persist either sexually, through seed production, or asexually through stolon proliferation. The red clovers have an upright growth habit. This upright growth habit can be both an advantage and a disadvantage. Red clover has an advantage over the prostrate white clover when grazing intervals are long enough to allow grasses to shade the clovers. Under continuous grazing however, white clover, because of its prostrate growth habit, can withstand frequent harvesting and recovers more quickly than red clover. Butler et al. (1959) found that under recurrent defoliation, losses of roots and nodules from white clover were more than counterbalanced by new growth, whereas red clover regrowth was very slow due to limited loss of roots and nodules. Hunt and Wagner (1963) found that clipping height had the greatest influence on grass-legume balance. Frequency of clipping, as determined by canopy height (15- and 30-cm for frequent and infrequent, respectively) was found also to influence grass legume balance. The combination of the lower cutting height (5-cm) and frequent clipping (when plants reached 15-cm) resulted in highest percentage legume component. For tall fescue (*Festuca arundinacea*

Schreb.)-ladino clover associations under frequent clipping at 5-cm, foliage was 18% ladino clover; the same association under infrequent or frequent clipping at 10-cm had only 1% clover.

Brougham et al. (1978) states that the persistence of white clover is related to its ability to adapt to changes in environmental conditions. Under heavy grazing, white clover that normally has medium-sized leaves becomes very small-leaved. Kydd (1957) reported that under a management system designed to overgraze pastures, white clover created an extensive mat of stolons bearing small leaves. In contrast, Kydd reported that under no grazing or clipping treatments, the white clover contribution went from 20% of the total DM yield to only 3% in one year. After two years, the white clover component had disappeared completely. The author noted that ladino white clover formed mats of small leaves under a seasonal continuous grazing system with yearling steers. In lax grazing areas, such as camp areas, and under portable cages, the white clover took on its large-leaved ladino form.

Different cultivars within a species may be an important consideration. Different birdsfoot trefoil cultivars reacted differently to the same type of management system. Van Keuren et al. (1968) studied the persistence of two birdsfoot trefoil cultivars, 'Empire' and 'Viking', as influenced by plant growth habit and continuous or rotational grazing. Empire is a semiprostrate variety whereas Viking has an upright growth habit. They found that after only one year of continuous grazing, Viking trefoil was almost completely eliminated from the pastures. It was not until the latter part of the third year that stands of Empire, the more prostrate cultivar, had deteriorated to the point of no trefoil contribution. Under rotational grazing, both cultivars of trefoil persisited very well throughout the entire six-year study period.

Alfalfa is a widely grown herbaceous perennial legume in the U.S. and abroad (Hanson and Barnes, 1973). It has a growth habit much different from that of the clovers. Five to 25 stems arise from a woody crown from which new stems grow when subjected to defoliation. Alfalfa loses its growing points upon defoliation because the growing points are elvated during stem elongation. Regrowth occurs from the crown, from new buds, or from buds that have begun elongation (Ellis-Davies, 1972). Alfalfa will will not persist under close, continuous defoliation (Van Keuren and Marten, 1972; Hanson and Barnes, 1973; Rohweder and Thompson, 1973) because of the nature of its regrowth and its palatablity to livestock. To maintain a desired balance of grass-alfalfa, a rotational grazing system must be employed. Mixture of grass-alfalfa should be allowed to attain a height of 20-45 cm before grazing with a rest period of 5 or 6 weeks between grazings (Van Keuren and Marten, 1972; Rohweder and Thompson, 1973).

Numerous studies have been conducted in the U.S. and abroad regarding the growth habit and defoliation of grass-legume associations. The aspects discussed above are exemplified by Dobson and coworkers (1976) who compared the yield and persistence of several legumes when grown with tall fescue. Of the legumes tested, the white clovers by far had a higher percentage legume coverage than those legumes with more upright growth habits such as the red clovers, trefoils and vetches (*Vicia* spp.). The area covered by upright legumes increased as cutting height increased from 5 to 10 cm, whereas the coverage by white clovers decreased.

Changes in grass-legume balance are much different when considering cut or grazed pastures (Jameson, 1963; Watkin and Clements, 1978). Under grazing conditions legumes tend to be dominated by the grasses because the legumes are selectively grazed by livestock. Sheep and cattle express differential selection patterns when grazing the same forage mixture (Bennett et al., 1970), with sheep being more selective than cattle (Watkin and Clements, 1978). The ability of sheep to select their diet more precisely than cattle is due to the difference in prehensile mechanisms of the two species (Church, 1976). Generally, animals will select, if possible, the clover component of grass-clover mixtures (Brougham, 1966). However, selection patterns by sheep and cattle may sometimes vary from the usual. Bedell (1968) found cattle grazing forage mixtures of perennial ryegrass-subterranean clover and tall fescue-subterranean clover preferred grass over the clover during spring and summer. During spring, sheep consistently selected more subterranean clover than either grass, but during summer selected tall fescue over the dry subterranean clover. During summer, sheep selected the dry subterranean clover over the ryegrass.

Treading damage inflicted by cattle or sheep has been reported to reduce pasture yield and influence grass-legume balance (Watkin and Clements, 1978). Both sheep (Edmond, 1963,1964,1966,1970,1974; Charles, 1979; Witschi and Michalk, 1979; Currl and Wilkin, 1981) and cattle (Edmond, 1970; Charles, 1979) can cause treading damage. Using 10 different pasture species, Edmond (1964) found that under heavy treading the most resistant grass and legume were perennial ryegrass and white clover. This agreed with earlier work conducted by Edmond (1963). It should be noted that ryegrass was found to be more resistant to treading than was the white clover, giving the grass a competitive advantage over the clover.

At this time very little is known about the different responses of grasses and legumes exposed to treading. Important factors that have been noted are the site and height of the growing point and the size of leaf (Edmond, 1966,1974), the physical strength of the leaf (Evans, 1967) and the ability of plants to assume a rhizomatous growth habit (Brougham, 1966).

It has been suggested that growth habit may affect competition for space on the soil surface (Haynes, 1980). Whether this is a competition for space or some other factors affecting plant growth is debatable and is not in the scope of this discussion. However, the growth habit of a plant does have an effect on its ability to utilize empty spaces within a pasture. Contrary to many beliefs, plants have the ability to move from one niche to another (Leith, 1960; Harper, 1971; Barbour et al., 1980). Harris and Thomas (1973) have suggested that ryegrass-white clover mixtures provide a more stable association, in terms of N economy and yield, than monocultures of ryegrass fertilized with N. The ability of the clover component to spread vegetatively by stolons into inter-ryegrass spaces maintains this efficiency. The author noted that each species within a pasture develops its own niche, and as time passes these niches change from one species to another.

It is very apparent from this discussion that growth habit and both frequency and intensity of defoliation, can affect the grass-legume balance of a pasture. Frequency and intensity of defoliation must be planned in accordance with the growth habit and regrowth characteristics of individual plants within a pasture.

4. Productivity of Grass-Legume Associations

Grasses, legumes, and combinations of the two are the major feed sources for most of the world's herbivorous animals. Since the shortage of fossil fuels has been recognized, renewed interest in leguminous plants has arisen. This is especially true in the area of grassland agriculture, due to increased production costs of N fertilizers and uncertainty of the beef market. For the purposes of this review, discussion will be limited to nonbreeding beef cattle.

Blaser et al. (1956) evaluated several grass-legume combinations over six grazing seasons. Steers grazing orchardgrass-ladino clover pastures had higher ADG's than orchardgrass fertilized with 240 kg N/ha (540 vs 486 g/day, respectively). This same trend was seen for tall fescue + ladino clover vs. tall fescue + N. Orchardgrass or tall fescue with ladino clover pastures were lower in carrying capacity than when the grasses were grown in monoculture. The data indicated that grass pastures fertilized with N had a 26% higher carrying capacity than grasses grown with ladino clover, but only a 13% advantage in liveweight gains per acre due to the increase in ADG of steers grazing grass-clover swards. The authors pointed out that stands of ladino clover were unsatisfactory for three of the six years. Had stands of ladino clover been satisfactory for all years studied, perhaps the advantage of N-fertilized grass over grass-legume pastures would not have been as great.

Van Keuren et al. (1969) evaluated Kentucky bluegrass and 'Empire' or 'Viking' birdsfoot trefoil using continuous or rotational grazing management systems with yearling steers. They found that steers grazing Empire trefoil rotationally produced significantly higher liveweight gains per hectare (289 kg/ha) than Empire or Viking trefoil grazed continuously (226 and 223 kg/ha, respectively). Kentucky bluegrass and Viking trefoil grazed rotationally averaged 20 kg/ha less beef production than Empire similarly grazed. Greatest ADG was 530 g/day for steers rotationally grazing Kentucky bluegrass-Empire trefoil. Hoveland et al. (1981) reported that ADG's of yearling steers grazing tall fescue-trefoil pastures were 42% greater than those of steers grazing tall fescue monocultures fertilized with N. Beef production was reported to be 446 kg/ha for fescue-trefoil and 419 kg/ha for fescue-N pastures. However, fescue-N pastures provided 28 more calender grazing days than fescue-trefoil and, at a higher stocking rate, 4.35 vs 3.06 steers/ha, respectively.

High et al. (1965) reported ADG's of steers grazing swards of orchardgrass-ladino clover were greater than those of steers grazing tall fescue-ladino clover (640 vs. 550 g/day, respectively). The ADG's of steers grazing orchardgrass-ladino clover pastures in the spring were no greater than those of steers grazing common bermudagrass fertilized with 112 kg N/ha (approx. 1070 g $steer^{-1}$ day^{-1}) but were larger than the ADG's of steers grazing 'Midland' bermudagrass pastures fertilized with four rates of N (0, 112, 224, and 448 kg N/ha) (Fribourg et al., 1979). During summer, however, ADG's of steers grazing swards of orchardgrass-ladino clover were over 200% greater than those of steers grazing bermudagrass.

Only Midland bermudagrass fertilized with 448 kg N/ha outproduced orchardgrass-ladino clover in beef production (705 vs. 561 kg/ha, respectively)

Steers grazing tall fescue in rotation with 'Coastal' bermudagrass produced 486 kg beef/ha, but only 384 or 394 kg beef/ha for ladino clover in combination with orchardgrass or tall fescue, respectively (Gross et al., 1966). Stands of tall fescue and Coastal bermudagrass in monoculture were reported to have been maintained relatively easily throughout the experiment. However, stand maintenance and persistence with grass-legume pastures was a serious problem. Tall fescue tended to crowd out the ladino clover; in the orchardgrass-ladino clover pastures, the grass had to be reseeded twice during the four year experiment. McLaren et al. (1983) reported 321 kg beef/ha were produced by steers grazing tall fescue-ladino clover pastures and converted 9.3 kg forage DM into 1 kg beef. Midland bermudagrass-ladino clover pastures produced a greater amount of beef/ha (400 kg/ha) but were not as efficient in converting forage to beef (11.6 kg forage DM/kg beef). Orchardgrass-ladino clover pastures had the highest ADG (826 g/day) and the best feed efficiency (8.8 kg forage/kg beef) but produced only a moderate amount of beef (416 kg/ha). Hoveland et al. (1981) reported steers grazing tall fescue-ladino clover pastures produced 640 kg beef/ha, twice as much as reported by McLaren and coworkers. However, Hoveland and coworkers had steers grazing their swards only in spring and fall, whereas McLaren et al. (1983) allowed steers to graze from 1 April through 30 August. Hoveland and coworkers reported that during their entire grazing season, ADG of steers on tall fescue-ladino clover pastures were 681 g/day whereas ADG was 454 g/day on tall fescue pastures fertilized with N.

Harris et al. (1972) compared monocultures of tall fescue or orchardgrass fertilized with N or overseeded with ladino clover to Coastal bermudagrass overseeded with vetch. Total annual beef production ranged from 326 kg/ha for steers grazing N-fertilized orchardgrass to 552 kg/ha for Coastal bermudagrass + vetch. Average daily gain of steers on tall fescue-ladino clover swards were almost 12% greater than the ADG's of steers grazing tall fescue + N pastures. Inclusion of ladino clover into orchardgrass did not improve ADG over that of orchardgrass + N, but it did increase total annual gain per hectare by 16%. Templeton et al. (1970) reported that the ADG and the final finish grade of steers grazing swards of Kentucky bluegrass-ladino clover were comparable to those of steers grazing a sequence of winter and summer annuals. Forage quality was found to be essentially equal for the two systems.

From this discussion it is evident that the inclusion of legumes increases animal performance and extends the grazing season beyond that reported for grass-only pastures. Perhaps more important is the balance between grasses and legumes in association. Many of these reports indicate increases in beef production per hectare when legumes are included in grass swards, but no improvement in ADG, whereas some others report the opposite. These results clearly bring out the need for the development of methodology to quantify the grass-legume balance for pastures and their dynamic changes over time.

C. Productivity of Mixed Cool- and Warm-Season Perennial Grass Swards

Devising forage systems to improve forage quantity and quality, and to extend the grazing season for longer periods of time, has been the subject of research for some time. In the U.S., this has been accomplished for the most part by establishing cool-season annuals, such as small grains (Elder and Murphy, 1961), or cool-season perennials, such as tall fescue (Wilkinson et al., 1968), into dormant bermudagrass sods. For the purposes of this review, discussion will be limited to mixtures of cool- and warm-season perennial species.

In the U.S., Wilkinson and coworkers (1968) were the first to report the introduction of tall fescue into dormant Coastal bermudagrass sod in northern Georgia. They had noted that producers in South Carolina and Georgia had aquired tall fescue-bermudagrass associations, evidently by accident. These workers found that tall fescue, when clipped at 5 cm, persisted and contributed about 17% of the DM production of the association with a N rate of 420 kg ha^{-1} $year^{-1}$. Higher N rates, up to 560 kg N ha^{-1} $year^{-1}$, coupled with a 10 cm clipping height, also resulted in good fescue contribution (approx. 25%) and maintained stands. In Tennessee, tall fescue seeded into Midland or common bermudagrass was reported to reduce the production of these bermudagrasses by 30 and 40%, respectively (Fribourg and Overton, 1973). The spring, summer, and fall production of tall fescue compensated for this reduction in bermudagrass yield by increasing total forage production of the association by 1.8 t DM/ha over that of Midland bermudagrass alone. In evaluating row spacings, N rates, and clipping management, Fribourg and Overton (1979) found the most uniform production each year from a bermudagrass-tall fescue sward was obtained with fescue seeded in 25 cm rows, harvested from a 10 cm height to a 5 cm stubble and fertilized with 200 kg N ha^{-1} $year^{-1}$. The combination of these two species extended the potential grazing season of the sward from five to nine or ten months per year with a 23% increase in DM production/year. McLaren et al. (1983) reported bermudagrass-tall fescue swards produced 593 kg beef/ha during a 150 day-grazing season. This was significantly greater than beef production from Midland or common bermudagrass grown in monocultures.

Bermudagrass is not the only warm-season species with which tall fescue is grown. Bahiagrass (*Paspalum notatum* Flugge) interseeded into tall fescue swards has been utilized to extend the grazing season in the lower southeastern U.S. (Hoveland et al., 1979). However, tall fescue was maintained only when high rates of N were used in conjunction with high summer stubble heights. Mitchell et al. (1984) found tall fescue interseeded in native range to extend the grazing season from five to nine months. However, fall forage production from tall fescue was very dependent on fall precipitation, and in only two out of six years did the area receive enough precipitation to generate fall fescue production. Spring fescue production was excellent in all six years but additions of P and K were required to maintain good production. Botanical composition at the end of the study showed that the vegetation was dominated by the tall-grass decreaser species, big bluestem (*Andropogon gerardi* Vitman) and indiangrass (*Sorghastrum nutans* (L.) Nash).

Workers in Maryland encountered difficulty in maintaining tall fescue or orchardgrass in Midland bermudagrass sods (Decker et al., 1974). Severe competition occurred between the cool-season species and bermudagrass during the bermudagrass growing season. This competition becomes less pronounced further south, where tall fescue is semi-dormant to dormant during bermudagrass growth.

To increase productivity and utilization of bermudagrass and tall fescue combinations, Spooner and Ray (1974) applied 269 kg N/ha in four equal installments in October, February, June and August. The grazing season was increased by 249 grazing days/ha and animal gains increased by 99 kg/ha over those obtained from bermudagrass-fescue combinations fertilized in June and August only.

Introduction of paspalum into perennial ryegrass swards has been proposed in Australia and New Zealand, but it has not met with much success (Harris and Lazenby, 1974). Evidently, the depressive effect of the dormant paspalum on the winter yield of perennial ryegrass has hindered the system. However, more recent evidence from New Zealand (Harris et al., 1981a,b; Percival and McClintack, 1982) has shown means to maintain these two species in the same sward. Harris and coworkers (1981a,b) found the growth rhythms of the two species were compatible under proper clipping frequencies in growth chambers. Percival and McClintack (1982) found the two species very compatible when grazed intensively in the spring to increase tillering of paspalum and grazed much less in the summer to allow tillers to express their growth potential.

Success in maintaining productivity and the desired balance between cool- and warm-season species mixed in the same sward lies in management of differences in growth rhythms and grazing.

D. Annual Grasses for Beef Production

The cool- and warm-season annual grasses provide nutritious forage utilized for pasture, green chop, silage and hay (Fribourg, 1973). The use of annual grasses as forage crops depends primarily on environmental conditions, nature and allocation of soil resources and economic considerations. Since the annual grasses can be either warm- or cool-season, discussion of these two will be separated and will be limited to biological, not economic, aspects of beef production of nonbreeding livestock.

1. Cool-Season Annual Grasses

The cool-season annual grasses used for forage production include the small grains [wheat (*Triticum aestivum* L.), rye (*Secale cereale* L.), barley, and oats] (Fribourg, 1973) and the ryegrasses [annual or Italian] (Frakes, 1973). The small grains and ryegrasses are suited to a fairly wide range of soils and cropping conditions (Fribourg, 1973) and are used throughout the southeastern U.S. to provide high quality forage in fall, winter, and spring.

The selection of species or a combination of species depends upon the goals of the individual producer. Animal preference must also be considered (Elder, 1967). Performance of steers grazing mixtures of small grains and ryegrass, as well as mixtures with clovers, has been reported to be excellent (Elder, 1960; Roark et al., 1966; Harris et al., 1971; Anthony et al., 1971; Harris et al., 1972; Bagley et al., 1984). Recent work in Louisiana (Bagley et al., 1984) evaluated rye in ryegrass-clover combinations and found mixtures containing rye increased the total amount of forage produced in December and January when forage was most limiting. Beef production for all systems, however, was about 560 kg/ha, with an ADG of about 908 g. Yearling steers in Alabama grazing cool-season annual pastures (rye-ryegrass-arrowleaf clover mixtures) were reported to have ADG's of 910 g with a total gain of 180 kg/steer (Anthony et al., 1971). Carcasses of steers slaughtered directly off pasture graded good or better. Average daily gain for yearling beef steers grazing cool-season annuals can range from 636 g/day (Elder, 1960) to 1000 g/day (Bagley et al., 1984).

The research cited above shows that the southeastern U. S. has the potential for producing quality beef using cool-season annual grass-legume pastures. However, caution should be exercised in the use of cool-season annual pastures. They are expensive to establish, at least in the upper Southeast. In the lower Southeast, where winter temperatures allow good growth, cool-season annual pastures have a greater potential for commercial beef production.

2. Warm-Season Annual Grasses

The warm-season annual grasses include members of several gramineous genera such as Sorghum and Pennisetum and range from southern Texas to Minnesota and North Dakota (Fribourg, 1973). In the U.S., sorghums used for forage include grain sorghums (*Sorghum bicolor* (L.) Moench), sorgos and grass sorghums (*S. bicolor*), and sudangrass (*S. bicolor*). Pearlmillet (*Pennisetum typhoides* (Burm.) Stapf & C.E. Hubb) has also been used in the southern U.S. (Fribourg, 1973; Walton, 1983).

The warm-season annual grasses have been thought to offer promise as pasture for yearling stocker cattle. Sorghum-sudangrass hybrids and pearlmillet have been evaluated as pastures for yearling steers in Florida (Dunavin, 1970). Average daily gain ranged from 370 g for steers grazing 'Lindsey 77F' sorghum-sudangrass to 530 g for steers grazing 'Gahi-1' pearlmillet. Steer gains per hectare were 62% greater on pearlmillet than on the two sorghum-sudangrass hybirds. In Alabama, Hoveland et al. (1971) found beef production to average about 235 kg/ha for steers grazing sorghum-sudangrass pastures without supplementation. Steers had an ADG of about 490 g.

Success in grazing pastures of the summer annuals has not been very good. High cost of planting, management difficulties (Hoveland et al., 1971) and animal health problems (Walton, 1983) overbalance their advantage of high potential carrying capacity. In fact, very little information is contained in the literature on yearling beef steer production when grazing summer annuals. Maximum ADG has been reported to be around 454 g (Patterson et al., 1961; Harris et al., 1961; Dunavin, 1970; Hoveland et al., 1971).

CHAPTER III

FORAGE GROWTH AND CONSUMPTION, AND ANIMAL PERFORMANCE

A. Introduction

Including legumes in grass swards extends the grazing season (Hoveland, 1960; Knight, 1970; Watson and Knight, 1978), increases forage production and quality (Knight, 1970, 1971), and improves land utilization and animal performance (Watson and Knight, 1978). 'Midland' bermudagrass (*Cynodon dactylon* (L.) Pers.) is well adapted to the mid-southeastern U.S. (Faix et al., 1981), responds well to N fertilization (Decker et al., 1971), overseedings of legumes, and to combinations of the two practices (Elder and Murphy, 1961; Holt and Lancaster, 1968; McLaren et al., 1983). Midland grows well in spring and summer and fills the summer production gap in beef pasture systems utilizing cool-season species (Fribourg et al., 1979). Pastures of orchardgrass (*Dactylis glomerata* L.) and ladino clover (*Trifolium repens* L.) can support 2.5 to 4.0 steer/ha from April to mid-August and produce about 500 kg beef/ha (High et al., 1965; Fribourg et al., 1979; McLaren et al. ,1983) in Tennessee. Tall fescue (*Festuca arundinacea* Schreb.) with legumes can support more animals over a longer grazing season (High et al., 1965; McLaren et al., 1983) but summer semi-dormancy and forage quality factors are less conducive to beef production (High et al., 1965).

Overseeding of legumes and tall fescue into bermudagrass sods has been suggested as a means of lengthening the grazing season and increasing forage and animal productivity (Holt and Lancaster, 1968; Wilkinson et al., 1968; Fribourg and Overton, 1973, 1979). Combinations of tall fescue and bermudagrass have produced 593 kg beef/ha over a 150-day grazing season (McLaren et al., 1983) and produced more forage per year than either species grown alone or singly in combination with clover, with stands being maintained over a four-year period.

Cool- and warm-season annual grasses can provide nutritious forage for yearling beef steers (*Bos* sp.) (Frakes, 1973; Fribourg, 1973) and are utilized throughout the southeastern U.S. Animal performance from grazing cool-season annuals has been reported to be excellent (Elder, 1960; Roark et al., 1966; Harris et al., 1971; Anthony et al., 1971; Harris et al., 1972; Bagley et al., 1984). The warm-season annuals have been utilized to some extent as pastures for beef steers (Dunavin, 1970; Hoveland et al., 1971) but their advantage of a high carrying capacity has been overbalanced by high cost of planting, management difficulties (Hoveland et al., 1971), and animal health problems (Walton, 1983). The southeastern U.S. is potentially the most productive rangeland in the conterminous 48 states (Grelen, 1978). Detailed information regarding forage quality and pasture productivity of various species and combinations that support rapid animal gains is needed for successful stocker cattle performance prior to feedlot placement.

The objectives of this study were to determine the effects of selected overseeding systems on pasture quality and beef production of tall fescue and/or Midland or common bermudagrass (*Cynodon dactylon* var. *dactylon*) pasture mixtures with and without legumes, and to determine the effect of including selected winter and summer annual grasses in these systems and their effects on beef production as supplements to perennial grass-legume pastures.

B. Materials and Methods

Beef steers were backgrounded on different pasture systems during the springs and summers of 1979, 1980, and 1981 at Ames Plantation, Grand Junction, Tennessee. Plants included in the pasture systems were Midland and common bermudagrasses, 'Kentucky 31' tall fescue, orchardgrass, rye (*Secale cereale* L.), ryegrass (*Lolium multiflorum* L.), a forage sorghum-sudangrass hybrid (*Sorghum bicolor* (L.) Moench), ladino and red clovers (*T. pratense* L.), and 'Kobe' lespedeza (*Lespedeza striata* (Thunb.) H & A). Fourteen 1.2 ha pastures were established on a Memphis silt loam soil (fine-silty, mixed, thermic, Typic Hapludalfs) and were arranged in a randomized complete block design with two replications of seven treatments. The seven pasture systems were (1) Midland + fescue(25 cm) + N, (2) Midland + fescue(25 cm) + legumes, (3) Midland + fescue(50 cm) + legumes, (4) fescue + legumes, (5) 1/3 annual grasses + N and 2/3 fescue + legumes in separate pastures (0.4 and 0.8 ha), (6) common bermudagrass + fescue(25 cm) + legumes, and (7) orchardgrass + ladino clover. Pastures containing legumes were overseeded each year with 1.7 kg/ha ladino clover and 4.5 kg/ha Kobe lespedeza in February. The 25 cm and 50 cm designations refer to the distance between fescue rows at seeding time. Fescue seed at 16 kg/ha was drilled into the Midland + fescue(25 cm) + N treatment in fall of 1974. Midland + fescue(25 cm) + legumes were interseeded with 16 kg/ha tall fescue seed in the fall of 1978. Orchardgrass + ladino clover were overseeded with 1.7 kg/ha of ladino each winter whenever ladino was less than 20% of the botanical composition in the immediately preceding June. The 1/3 annual grasses-2/3 fescue + legumes system consisted of 0.4 ha of sorghum-sudangrass hybrid seeded in mid-May and rye-ryegrass seeded in early September each year, plus 0.8 ha of fescue + legumes, in separate pastures. Annual grass pastures were topdressed with 134 kg N ha^{-1} $year^{-1}$ (NH_4NO_3) in three installments: 34 kg N/ha in early March and again in early May, and 67 kg N/ha in mid-July. Midland + fescue(25 cm) + N pastures were topdressed with 290 kg N ha^{-1} $year^{-1}$: 78 kg N ha^{-1} $year^{-1}$ in mid-March, mid-May and early July, and 67 kg N/ha in early September.

In mid-March of each year 29 kg P/ha and 56 kg K/ha were broadcast on orchardgrass + ladino clover, and on Midland and common bermudagrasses overseeded with fescue and legumes. Midland + fescue + N pastures received 24 kg P/ha and 93 kg K/ha in mid-March and an additional 15 kg P/ha and 28 kg K/ha in early September. Pastures containing fescue + legumes were fertilized with 29 kg P/ha and 56 kg K/ha in early September. Annual grass pastures received 29 kg P/ha and 56 kg K/ha in early May.

Forage growth and consumption were determined by the cage and strip method (Linehan, 1952) using one cage and one strip at random for each 0.2 ha at about 21-day intervals. The sampling mower blade was set at a stubble height of 5 cm for sods containing fescue or bermudagrass, and at 8 cm for orchardgrass. Each cage and strip forage sample was oven-dried for 72 h at 65° C and weighed. Dried forage samples from each pasture were composited for cages and strips separately and analyzed for total N by the phenolhypochlorite color reaction (Thomas et al., 1967) with a Technicon Autoanalyzer. Crude protein was estimated by multiplying N concentration by 6.25. Neutral-detergent fiber (NDF) and acid-detergent fiber (ADF) were determined with a Tecator Fiber Analysis System on composited cage and strip samples (Goering and Van Soest, 1970).

Yearling Angus beef steers were purchased each fall preceding the spring grazing season and wintered uniformly on a hay diet to gain about 300 g $head^{-1}$ day^{-1}. In spring, the steers weighed 205 to 270 kg. Averages of body weights taken on two consecutive days were used as initial and final weights. Individual weights of three tester animals per 1.2-ha pasture (five were used in the grass + N treatment) were taken at about 21-day intervals during the grazing season. A seasonal continuous grazing management system was used (Stoddart et al., 1975). Stocking rate adjustments were made by a modified put-and-take procedure which minimized the frequency of stocking rate changes within a pasture. Bermudagrass and fescue, and their respective combinations, were maintained between 5 and 8 cm high, and orchardgrass at 7 to 14 cm. Beef production for each period was calculated by multiplying the total number of animal grazing days per weighing period by the ADG of the tester steers. At no time did the steers receive supplemental feed while on pasture, but all had free access to salt, minerals, water, and artifical shade.

Least-squares procedures (SAS Institute, Inc., 1982) were used to determine the effect of the independent variables (year, season, replication, and pasture combination) and the interactions among them on the dependent variables (forage growth and consumption, average daily gain (ADG), total gain per steer, and beef production). To compare the seven different pasture combinations, the following linear contrasts were used: (1) Orchardgrass + clover vs. Others, (2) Fescue + legumes vs. 1/3

Annuals-2/3 Fescue + legumes, (3) Midland + fescue(25 cm) + legumes vs. Midland + fescue(50 cm) + legumes, (4) Fescue + legumes vs. the mean of Midland + fescue(25 cm) + legumes and Midland + fescue(50 cm) + legumes, (5) Midland + fescue(25 cm) + N vs. the mean of Mildand + fescue(25 cm) + legumes and Midland + fescue(50 cm) + legumes, and (6) Common + fescue(25 cm) + legumes vs. the mean of Midland + fescue(25 cm) + legumes and Midland + fescue(50 cm) + legumes.

C. Results and Discussion

The cumulative data per year for the three years were fitted to polynomials in order to describe treatment effects from spring to autumn (Fig. 5-10, Appendix). Quadratic polynomials were used whenever the partial regression coefficients associated with the cubic effects were not significant. Cubic polynomials were the highest degree of polynomial used. The R^2 values obtained for cumulative forage growth and consumption ranged from 0.89 to 0.98. These values are similar to those obtained in a previous study at this location (McLaren et al., 1983), with the exception of those for Orchardgrass + clover. In this study, R^2 values for models fitted to forage growth and consumption for Orchardgrass + clover were 0.96 and 0.95, respectively, but in the previous study, R^2 values were 0.76. The greater R^2 values for forage growth and consumption may have been due to increased managerial abilities of the experimenters or perhaps to more favorable environmental conditions. The R^2 values for models fitted to animal gains ranged from 0.90 to 0.95, and for beef/ha from 0.91 to 0.99.

1. The Grazing Season

The introduction of fescue in bermudagrass sods in 1979 resulted in earlier growth similar to that observed in a previous study (McLaren et al., 1983). Midland + fescue(25 cm), Fescue + legumes and the 1/3 Annuals-2/3 Fescue + legumes pastures had the longest average grazing season (Table 1). The grazing seasons for Midland-fescue-legume combinations were about 15 days less than the aforementioned pasture systems because of a delay in the spring. This delay perhaps reflected the lower N status of the pastures with clover than those with N, and the shading effects of dormant bermudagrass sods on fescue growth. This situation was particularly evident in Common + fescue(25 cm) + legume pastures, where spring grazing was delayed an additional week as compared to Midland sods containing fescue and legumes, probably due to the denser sods formed by common bermudagrass than by Midland. Orchardgrass + clover pastures had the shortest grazing season because height did not reach 7 cm until almost a month after the other pastures and because of dormancy induced by hot, dry weather. This situation was particularly severe during the late spring and summer of 1980 when grazing lasted only 105 days due to below-normal precipitation (142 mm less than normal) and well above-normal temperatures (Fig. 1). These adverse conditions also affected the other pasture systems by reducing the length of the grazing season by two to three weeks. In contrast, 1979 temperatures were slightly below normal and precipitation 332 mm above normal. In 1981, precipitation was slightly above normal (49 mm) and temperatures were close to normal conditions. Under these conditions of abundant moisture, legume stands were excellent.

Table 1. Mean forage growth, consumption, and crude protein (CP), neutral-(NDF) and acid-detergent (ADF) fiber concentrations of, animal performance and production on, seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee.

[illegible]							
Final weight, kg/steer	352††	337	341	307‡‡	358	356	338
Gain, kg/steer	118††	101	101	80‡‡	138	112	98
Daily gain, g/steer	740††	650	652	478‡‡	821	869	662
Grazing, consumption, and beef production							
Animal grazing days/ha	607#	777	833	1537	768	605	591
Forage dry matter intake, kg $steer^{-1}$ day^{-1}	15.3#¶¶	8.2	6.3	7.2	9.3	9.9	9.9
Conversion efficiency, kg/kg gain	20.4#¶¶	13.2	9.8	15.5	11.8	11.8	15.4
Beef production, kg/ha	431#	474	510	630	597	545	392

† Sorghum-sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

‡ 25 cm and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

§ 25 cm refers to the distance between fescue rows at seeding in fall 1974.

¶ 78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

Mean of two replications for each of three years.

††Mean of three tester steers in each of two replications for each of three years, except ‡‡ five tester steers.

§§Weighted mean based on available forage dry matter.

¶¶High values for this treatment due to much lesser utilization of summer annuals than of forage in other treatments.

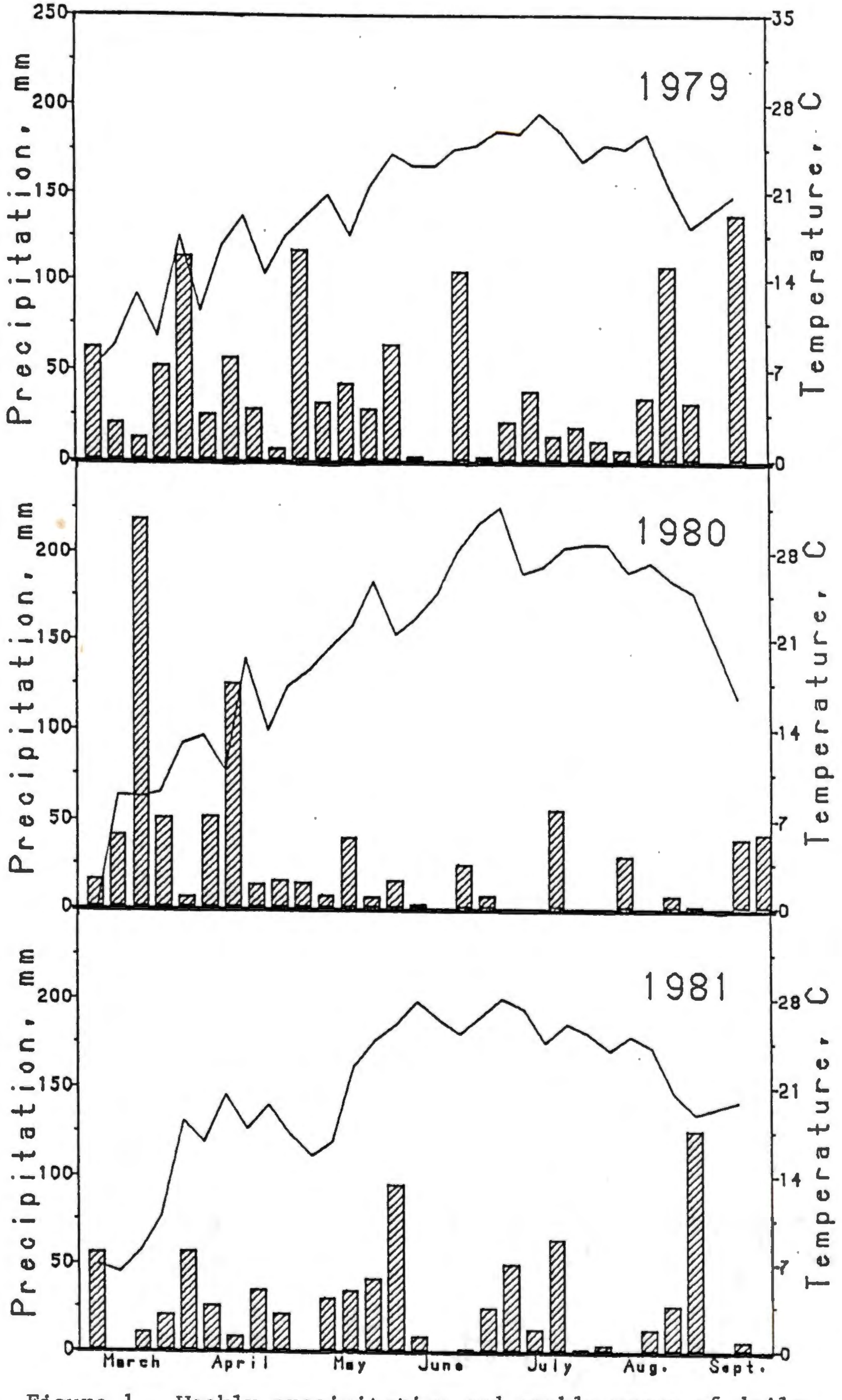

Figure 1. Weekly precipitation and weekly means of daily air temperatures during the 1979-1981 grazing seasons.

Since one of the three years was much hotter and drier than normal, one had near normal temperatures with precipitation slightly above normal, and the third had below normal temperatures and above normal precipitation, only the combined data for all years will be presented here (Table 1). More detailed data are presented elsewhere (Tables 5-21, Appendix).

2. Forage Growth and Consumption

Midland + fescue(25 cm) pastures produced more forage than any other pasture combination, 51% more in spring and 46% more for the entire grazing season than Midland-fescue-legume combinations (Table 1). These results confirm observations made previously at this location (McLaren et al., 1983) although forage growth was almost twice the amount reported earlier.

Forage consumption per hectare, an estimate of dry matter (DM) intake, from each pasture system ranged from 72% of growth to 84% for all treatments except for the 1/3 Annuals-2/3 Fescue + legumes which was 62%. Forage consumption was not different among treatments with the exception of Midland + fescue(25 cm) vs. the average of comparable Midland-fescue-legume combinations (Table 2). Consumption efficiency of Fescue + legumes was 12% greater than that of 1/3 Annuals-2/3 Fescue + legumes. It was not considered feasible to utilize all the forage produced on the 0.4-ha annual grasses, but rather it was deemed more appropriate to maintain the 0.8-ha Fescue + legumes in a vegetative stage by grazing this pasture combination below a height of 8 cm. Winter annuals (rye and ryegrass) were generally dominated by rye (Table 20,

Table 2. Results of planned F tests for seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee

	Dependent Variable				
Linear contrast	Forage growth kg/ha	Forage consumption, kg/ha	ADG, g/steer	Gain, kg/steer	Beef production kg/ha
Orchardgrass + clover vs. Others	*	N.S.	*	N.S.	N.S.
Fescue + legumes vs. Annuals (0.4 ha)† - Fescue + legumes (0.8 ha)	*	N.S.	*	*	*
Midland + fescue (25 cm)‡ + legumes vs. Midland + fescue (50 cm)‡ + legumes	N.S.	N.S.	N.S.	N.S.	N.S.
Fescue + legumes vs. mean of Midland + fescue (25 cm)‡ + legumes and Midland + fescue (50 cm)‡ + legumes	N.S.	N.S.	*	*	*
Midland + fescue (25 cm)§¶ + N vs. mean of Midland + fescue (25 cm)‡ + legumes and Midland + fescue (50 cm)‡ + legumes	*	*	*	*	*
Common + fescue (25 cm)‡ + legumes vs. mean of Midland + fescue (25 cm)‡ + legumes and Midland + fescue (50 cm)‡ + legumes	N.S.	N.S.	N.S.	N.S.	N.S.

† Sorghum-sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

‡ 25 cm and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

§ 25 cm refers to the distance between fescue rows at seeding in fall 1974.

¶ 78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

Appendix), hence grazing was discontinued about two weeks before planting of the sorghum-sudangrass hybrid. The winter annuals were excellent forage producers and growth was generally easy to utilize. However, summer production for the sorghum-sudangrass hybrid, although excellent, was extremely difficult to utilize. Since hay harvesting was not a management practice, much of this growth was wasted.

The two Midland pastures overseeded with fescue in 25- or 50-cm rows and with legumes produced about the same amount of forage; this is in agreement with observations made from agronomic plot experiments in the same geographic region (Fribourg and Overton, 1973, 1979). This same trend was noted between the average of these two pasture systems and Common + fescue(25 cm) + legumes. Forage quality, as expressed by concentrations of CP, NDF, and ADF, was essentially the same for the three pasture systems.

Forage growths of Fescue + legumes and the average of the two Midlands overseeded with fescue and legumes were similar for the spring grazing season, although for the latter pasture systems the grazing season was 10 days shorter. This delay in initial grazing can probably be attributed to the competitive nature of the dormant bermudagrass. The dormant bermudagrass could have prevented soil temperatures from rising enough to induce tall fescue growth. Over the entire grazing season, Fescue + legumes produced more forage than Midland overseeded with fescue and legumes, but only 16% more. This is in contrast with previous reports from this location which found that Midland + clover produced one third more total forage than Fescue + clover (McLaren et al., 1983). This may indicate that bermudagrass-fescue combinations may be limited in their production potential when overseeded with legumes and no topdressings of N fertilizer are used.

Total forage growth during the spring grazing season was similar for the two Midlands overseeded with fescue and legumes, Fescue + legumes, Orchardgrass + clover, and Common + fescue(25 cm) + legumes, but spring growth of orchardgrass delayed initial grazing from one week to almost a month after grazing of the other pasture combinations had started. Orchardgrass + clover had the lowest forage production of all pasture combinations in the study, but the highest consumption efficiency (84%). Forage quality was essentially equal for the pasture combinations, as indicated by CP concentrations which were well above the minimum requirements for a 250 to 320 kg steer gaining 700 g/day (NRC, 1984). This indicates that sods were maintained in a mostly vegetative state throughout the grazing season and legume stands were good. However, digestible protein may hve differed greatly among the pasture combinations, especially when contrasting treatments with legumes and the one with N fertilization. Acid-detergent fiber concentrations were the same for all pasture combinations, with the exception of the 1/3 Annuals-2/3 Fescue + legumes which was several percentage points higher than the other treatments (43 vs. 39%). This increase in ADF was due to the sorghum-sudangrass hybrid used during the summer season. Neutral-detergent fiber concentrations were fairly uniform across pasture combinations, with Orchardgrass + clover being lowest (60%). However, inclusion of bermudagrass into tall fescue swards slightly increased NDF concentration (63 vs. 65%).

3. Stocking Rates

Average stocking rate across all years for the entire grazing season ranged from 3.2 steer/ha for 1/3 Annuals-2/3 Fescue + legumes and Common + fescue(25 cm) + legumes to 7.7 steer/ha for Midland + fescue(25 cm) (Table 1). This range is about the same as the range from a previous study at this location (McLaren et al., 1983). This similar range of stocking rate coupled with the greater forage growth in this study explains the lower consumption efficiencies found in this study as compared to the previous one. The stocking rate on the 1/3 Annuals-2/3 Fescue + legumes system had to be limited by the 0.8-ha of fescue-legumes. This explains why some of the sorghum-sudangrass hybrid was not used.

Stocking rate for each pasture was set at the beginning of each 21-day period with the objectives of (1) maintaining the species of the pasture in vegetative stages of growth and (2) facilitating maximum utilization of forage produced by the individual pastures. In general, these objectives were met, but stocking rate was influenced by several factors, primarily soil moisture conditions and weather conditions most likely to occur in the forthcoming 21-day period. Factors also considered were forage growth and species composition of individual pastures. Generally, changes consisted of no more than two or three animals per pasture, and often no changes were made. Stocking rate on Midland + fescue(25 cm) in this study was about the same as for the previous study (McLaren et al., 1983) (7.7 vs. 7.3 steer/ha, respectively). However, forage growth in this study was almost twice as great as in the previous study. This explains the 77% consumption of available forage found in this study as compared to the 95% previously reported for the same pastures. In 1979, an overall average of 4.0 steer/ha was used with a range of 2.4 to 7.9 steer/ha for individual treatments. During the extremely droughty 1980 grazing season, average stocking rate was 4.0 steer/ha; for 1981 overall average stocking rate was 4.6 steer/ha. Although average stocking rates for each year were about the same, during 1980 stocking rate on a per period basis was extremely variable (Table 13, Appendix). During that year stocking rate was set during the spring when precipitation was well above normal conditions (Fig. 1). As the season progressed and precipitation became more limiting, steers were completely removed from experimental pastures for one 21-day period for most of the pasture combinations. Grazing of Orchardgrass + clover pastures was terminated on 10 June.

4. Pasture Productivity

Pasture productivity ranged from 591 grazing days/ha for Common + fescue(25 cm) + legumes to 1537 for Midland + fescue(25 cm). The small number of grazing days for Common + fescue (25cm) + legumes was a function of both the relatively low stocking rates and the delay in initial grazing date in the spring. Orchardgrass + clover pastures were slightly higher in grazing days/ha than Common + fescue(25 cm) + legumes, (605 vs. 591 grazing days/ha, respectively), and about equal to 1/3 Annuals-2/3 Fescue + legumes pasture combination. Midland + fescue(25 cm) combinations produced 42% more grazing days/ha than the Midland pastures overseeded with fescue and legumes. This was a function of the greater stocking rate and longer grazing season of Midland + fescue(25 cm). Fescue + legumes produced 161 grazing days/ha more than 1/3 Annuals-2/3 Fescue + legumes.

This observation, along with data from the previous study regarding 0.4-ha Midland plus 0.8-ha Fescue (McLaren et al., 1983), emphasizes that supplemental pastures are very difficult to utilize to their full potential when hay-making is not a management practice in beef backgrounding programs. The use of Midland instead of common bermudagrass in bermudagrass-fescue-legume combinations increased grazing days/ha by 27%, whereas only a 5% gain was obtained from inclusion of fescue-legumes into Midland swards as compared to Fescue + legumes alone.

5. Animal Gains

Steers gained an average of 696 g $steer^{-1}$ day^{-1} over the 3-year 155-day average grazing season. Steers grazing 1/3 Annuals-2/3 Fescue + legumes gained more, and those steers grazing Fescue + legumes and Orchardgrass + clover considerably more, than this average. The other four pasture combinations resulted in lesser gains ranging from 478 to 662 g $steer^{-1}$ day^{-1}. The smallest gains were associated with Midland + fescue(25 cm), which produced the largest number of grazing days/ha. These results are in agreement with previous findings using these same pastures (McLaren et al., 1983). The inclusion of legumes into Midland-fescue swards resulted in 27% larger ADG's for the entire grazing season over those from steers grazing Midland-fescue swards. The inclusion of legumes in grass swards has been held responsible for larger animal gains than when they are absent (Watson and Knight, 1978; McLaren et al., 1983). Steers grazing Orchardgrass + clover pastures had an ADG of 869 g $steer^{-1}$ day^{-1}, a gain which is in close agreement with previous studies at this location (Fribourg et al., 1979; McLaren et al., 1983).

Animal gains on Fescue + legumes were greater than those associated with 1/3 Annuals-2/3 Fescue + legumes during the entire grazing season. This same trend was seen during the spring grazing season, but was somewhat less pronounced. Average daily gains of steers grazing the three combinations of bermudagrass overseeded with fescue and legumes were the same.

6. Beef Production

Midland + fescue(25 cm) pastures produced the more beef (630 kg/ha) than any other pasture combination. Although ADG of steers on this treatment was less than those of steers on Midland overseeded with fescue and legumes, the larger beef production was due to the greater stocking rate and the longer grazing season. The combination of annuals and Fescue + legumes in separate pastures produced 168 kg beef/ha less than an equal area containing Fescue + legumes. Although stocking rates were similar for the two pasture combinations, the annual grasses could not be used to their potential due to the limitations set by the area of the Fescue + legumes. Fescue + legumes patures in this study produced 46% more beef/ha than fescue-clover pastures utilized in a previous study at this location (McLaren et al., 1983). This can be explained by the longer grazing season in this study as compared to the previous one (168 vs. 136 days) and perhaps the inclusion of the warm-season legume, 'Kobe' lespedeza.

Fescue + legumes produced 105 kg/ha more beef than Midland-fescue-legumes combinations. The larger beef production from these pastures resulted from larger individual animal gains, a longer grazing season, and higher stocking rates on Fescue + legume pasture combinations than on Midland-fescue-legume pastures.

Common bermudagrass overseeded with fescue and legumes produced 100 kg less beef/ha than pastures containing Midland, although this difference was not significant (Table 2). Steers grazing Orchardgrass + clover pastures, due to high individual animal gains, produced more beef than steers grazing pastures of 1/3 Annuals-2/3 Fescue + legumes or bermudagrass-fescue-legume combinations.

7. Estimated Forage Dry Matter Intake

Forage DM intake ranged from 6.3 kg $steer^{-1}$ day^{-1} to 9.9 kg for steers grazing Orchardgrass + clover or Common + fescue(25 cm) + legumes. These results are in close agreement with previous studies (Fribourg et al., 1979; McLaren et al., 1983). The steers grazing 1/3 Annuals-2/3 Fescue + legumes had an estimated forage DM intake of 15.3 kg $steer^{-1}$ day^{-1}. This large value resulted from the inadequate use of the summer annuals and probably does not reflect what might have occurred had the summer annuals been managed as a separate pasture. This also led to the large conversion efficiency of 20.4 kg DM/kg gain for this treatment. The other six pasture combinations ranged in conversion efficiency between 9.8 and 15.5 kg DM/kg gain. Steers grazing Midland-fescue-legume combinations or steers grazing Fescue + legumes had similar conversion efficiencies. Steers grazing Midland + fescue(25 cm) or Common + fescue(25 cm) + legumes had conversion efficiencies of 15.5 and 15.4 kg DM/kg gain. These were among the lowest conversion efficiencies from the pasture combinations studied. Daily forage DM intake and conversion efficiency by steers grazing Midland + fescue(25 cm) were similar to values obtained from this treatment previously (McLaren et al., 1983).

D. General Discussion and Management Implications

Forage production, animal performance, and pasture productivity from Orchardgrass + clover, Fescue + legumes, and Midland + fescue(25 cm) were greater than those measured earlier in the region (High et al., 1965; Fribourg et al., 1979; McLaren et al., 1983). This increased performance of forage plants and animals may have been due to more favorable climatic conditions, longer grazing seasons, or an increase in the ability of experimenters to manage animals and pastures. Previously at this location, Midland-fescue pastures had a lesser productivity than that reported here (1190 vs. 1537 grazing days/ha), but about the same ADG. Consequently beef production was about the same (593 vs. 630 kg/ha). Orchardgrass + clover pastures produced more forage in the present study than in earlier studies; ADG, beef production and forage quality were almost identical.

The inclusion of legumes in Midland-fescue swards resulted in ADG's 27% greater than those of steers grazing Midland-fescue swards fertilized with moderate (290 kg N/ha) amounts of N. However, beef production and pasture productivity were several-fold less from the legume-overseeded pastures than from the N-fertilized pasture combinations. The benefit from the overseedings of legumes into Midland sods in a previous study (McLaren et al., 1983) was not realized in this study when considering Midland-fescue combinations. No differences in forage growth and consumption or animal performance were noted between Common or Midland sods overseeded with fescue and legumes. These results agree with previous work at this location where Common or Midland bermudagrasses were grown alone and fertilized with low rates of N (112 kg/ha) (Fribourg et al., 1979).

Utilizing different pastures in a forage system to provide early spring to fall grazing for stocker steers did not perform well. Utilization of the 0.4-ha of cool-season annuals was relatively high (Tables 6 and 7, Appendix); however, summer forage production by the sorghum-sudangrass hybrid, although very high, could not be utilized well and was extremely difficult to maintain in a vegetative stage. Similar observations were made (Hoveland et al., 1971) when grazing pastures of summer annual grasses. The inclusion of cool-season annuals did not provide spring forage any earlier than Fescue + legume pastures. Early summer grazing was not available while the sorghum-sudangrass hybrid was becoming established. It could be argued that the 0.4-ha was too large relative to the 0.8-ha of Fescue + legumes. Nevertheless, and regardless of pasture size, grazing of summer annuals cannot be considered profitable without the options of hay, silage, or green chop production. This would allow animals access to sorghum-sudangrass when vegetative, and permit animal removal when selective grazing of leaf blades occurs. Hay, silage, or green chop production then could be practiced with the forage produced being stored for winter use or fed back to the animals on that pasture. This system would also allow producers a greater flexibility in meeting animal nutritional requirements with on-the-farm forages. This flexibility comes about at the expense of beef production.

Legumes were successfully established and maintained in bermudagrass-fescue sods, but control of potentially excessive grass heights was essential in order to maintain 20 to 40% legumes in the stands. Inoculation with the proper *Rhizobium*, the correct rate of inoculum (Wade et al., 1972), use of an adhesive (Waggoner et al., 1980), and proper fertilization with P and K (Hunt and Wagner, 1963b) have been shown to play important roles in maintaining the desired balance between grasses and legumes. Ladino clover and 'Kobe' lespedeza persisted very well under the seasonal continuous grazing management imposed upon the pastures. Red clover, however, did not persist well under the constant, close defoliation regimes set by the modified put-and-take system. This was to be expected, since the upright growth habit of red clover does not allow it to withstand close, continuous defoliation (Butler et al., 1959; Rohweder and Thompson, 1973). Red clover did contribute a great deal in early spring as steers went onto pastures, but generally declined to 0-3% by the end of the spring grazing season. Ladino clover assumed its normal prostrate growth habit, but very close to the soil surface, and appeared small-leaved throughout the pastures (Brougham et al., 1978). Lespedeza also was very small under the grazing management used. Winter overseedings were necessary to maintain the desired balance between grass and legume components of the swards.

Pastures of tall fescue are quite common throughout the mid-South and the inclusion of legumes in fescue swards can provide excellent pasture during spring and autumn, but semi-dormancy during the summer has been reported less conducive to beef production (High et al., 1965; Burns et al., 1973). However, the results presented here indicate that Fescue +

legumes produced 100 kg more beef/ha than Midland-fescue-legume combinations. It appears that the limiting factor in Midland-fescue-legume combinations are N and/or poor quality of Midland in summer, and that interspecific competition is more intense in Midland-fescue-legume swards than in fescue-legume swards. It may be worthwhile to apply small amounts of N in early spring when temperatures allow fescue growth, or increase the legume component of the sward, or the N-fixing tissue, by using massive rates of inoculum (Jenkins et al., 1954; Hely, 1965) or lime pelleting of legume seeds (Wade et al., 1972) to increase nodulation; or to increase the competitive ability of improved *Rhizobium* strains over those that are indigenous or those that have been previously used as inoculum (Ireland and Vincent, 1968; Mytton and Hughes, 1984). In a previous study, Midland-ladino clover associations produced 25% more beef/ha than Fescue-ladino clover associations (McLaren et al., 1983) over a March to September grazing season. Beef production from Common + fescue(25 cm) + legumes was about the same in this study as beef production from Midland-ladino clover swards in previous reports (McLaren et al., 1983). Midland-fescue-legume combinations produced about 100 kg/ha more beef than Midland-ladino clover swards from the previous study but about 100 kg/ha less than Fescue + legumes in the current study. Producers who desire to background beef steers during these months might find one pasture of Midland with legumes and one of fescue with legumes of greater value in terms of beef production and management alternatives than a single pasture of bermudagrass-fescue-legumes.

CHAPTER IV

EXPLAINING VARIABILITY IN STEER GRAZING EXPERIMENTS:

AN EVALUATION AND VALIDATION OF THE SPECIES COMPOSITION INDEX

A. Introduction

Grazing experiments are difficult and expensive to conduct but are the infrastructure of research programs in the evaluation of forage crops. Data obtained can be reduced to one or two small tables leaving investigators frustrated because reasons for effects and consequences are not easily explored or explained. The difficulties are confounded with the inherent variability in such experiments - among animals, soils and topography, and pasture plants. Insufficient replication of experimental units (pastures), numbers of sampling units (animals), and uncontrollable variability often render statistical tests insensitive (Petersen and Lucas, 1960).

Species which comprise swards change dynamically with time. These changes can influence forage production and animal performance (Wolfe and Lazenby, 1979; Fribourg et al., 1984). Representing these dynamic changes by treatment labels such as "fescue (*Festuca* sp.) + clover (*Trifolium* sp.)" or "bermudagrass (*Cynodon* sp.) + clover" is a gross simplification of what occurs in the field. Previous research at this location has led to the development of the Species Composition Index (SCI) (Fribourg et al., 1984). This concept describes concisely the dynamic changes which occur in species composition of pastures within an experimental treatment. The SCI was found to be superior to the variate 'treatment' in explaining variability in forage growth and consumption, average daily gain (ADG) and beef production, both as a concomitant variate and in conjunction with the models developed.

In a beef backgrounding experiment, forage growth and consumption, and animal gains and production were measured concurrently with several environmental, plant, and animal characteristics (Chapter III). The intent of this chapter is to present an evaluation and validation of the SCI as a tool for explaining as much total variability in steer grazing experiments as possible.

B. Materials and Methods

A beef-steer backgrounding experiment, with seven pasture systems in a randomized complete block design with two replications, was conducted with a seasonal continuous grazing management system (Stoddart et al., 1975). Stocking rate changes were made by a modified put-and-take procedure which minimized the frequency of stocking rate changes within a pasture. Plants studied included 'Midland' bermudagrass (*C. dactylon* (L.) Pers.), common bermudagrass (*C. dactylon* var. *dactylon* L.), ladino clover (*T. repens* L.), red clover (*T. pratense* L.), 'Kobe' lespedeza (*Lespedeza striata* (Thunb.) H & A), tall fescue (*F. arundinacea* Schreb.), orchardgrass (*Dactylis glomerata* L.), rye (*Secale cereale* L.), ryegrass (*Lolium multiflorum* L.), and a forage sorghum-sudangrass hybrid (*Sorghum bicolor* (L.) Moench).

The 1.2 ha pastures were (1) Midland + fescue(25 cm) + N, (2) Midland + fescue(25 cm) + legumes, (3) Midland + fescue(50 cm) + legumes, (4) fescue + legumes, (5) 1/3 annual grasses + N and 2/3 fescue + legumes in separate pastures (0.4 and 0.8 ha), (6) common bermudagrass + fescue(25 cm) + legumes, and (7) orchardgrass + ladino clover. Detailed methods, forage growth and consumption, and animal performance have been discussed in Chapter III. Forage growth and consumption were estimated by the cage and strip procedure (Linehan, 1952) with samples being taken at about 21-day intervals during the spring (March to late June) and summer (late June to September). Botanical composition of pastures was estimated at about 21-day intervals by two or three trained independent observers, with each observer estimating ground cover and botanical composition.

At each observation date, several variables were measured for each pasture: (a) dry matter forage yield from cages and (b) strips; (c) visual estimates of the contribution of each forage species to the stand and composition of each pasture; (d) height of each species in each pasture; (e) number of days per period; (f) daily precipitation and (g) mean air temperature; and (h) stocking rate. Forage samples from cages and strips were analyzed for (i) crude protein (CP), (j) neutral- (NDF), and (k) acid-detergent (ADF) fiber concentrations. From these measurements, (l) forage growth and (m) consumption (estimated dry matter intake) were calculated (Chapter III). Animal weights were measured at approximately 21-day intervals. Occasionally periods were as short as 16 days or lasted more than one month. From the tester steer weights and the number of animals on pasture (testers + extras) during each grazing period, variables calculated were: (n) number of grazing days/grazing period; (o) average daily gain (ADG); (p) beef gain/ha; and (q) total beef production/ha.

The SCI characterizes each pasture on each rating day by a vector which combines the contribution of each species within a pasture. Frequency class groups for the botanical composition percentages were established for each of the perennial grasses studied (Table 3), and one for the legumes. The annual grasses (rye, ryegrass and sorghum-sudangrass) were not included in the SCI vector.

As described by Fribourg et al. (1984), the SCI for each individual date is a vector constituted by an element for each species present in sufficient quantity to be considered in the botanical composition of the individual pastures. In this study each vector had five elements. In addition to representing the botanical composition, the SCI included the treatment number. This was accomplished by a horizontal concatenation of the vector representing the botanical composition and the treatment number. The purpose of the concatenation was to represent not only the botanical composition of a sward on a particular rating day, but also to include the differing managements imposed upon a pasture by being associated with a particular treatment. For example, a pasture with 43% fescue and 57% bermudagrass would be described with an SCI of [0,0,50,58.5] when occurring in treatment 5 (Midland + fescue(25 cm) + N). The same species composition in treatment 2, Midland + fescue(50 cm) + legumes, would have an SCI of [0,0,50,58.2]. The frequency classes within each species have somewhat different boundaries than those in the previous study. The reason for these different classes is that the distribution of observed botanical composition percentages was different and an attempt was made to keep the number of observations in each class as equal from class to class as possible.

Table 3. Derivation of vector elements used in creating the Species Composition Index (SCI).

First SCI element: orchardgrass		Second SCI element: legumes		Third SCI element: fescue		Fourth SCI element: bermudagrass	
Frequency class	SCI	Frequency class	SCI	Frequency class	SCI	Frequency class	SCI
% botanical composition							
0–39	20	0–14	7	0–14	7	0–19	10
40–69	50	15–29	22	15–39	27	20–35	28
≥70	80	30–49	40	40–59	50	36–49	42
		≥50	60	60–69	65	50–65	58
				≥70	80	≥66	70

The total number of combinations is quite large, however, the restrictions imposed by the nature of the treatments in the experiment limited the number of possible meaningful combinations. In fact, 103 SCI vectors occurred, over twice the number which occurred in the previous study. This was due to the greater species diversification found in this study. In the previous study several treatments considered monocultures of grass species which consistently produced SCI values in the same frequency class (Fribourg et al., 1984), with a maximum of two species occurring in a single pasture on a single rating day. In this study, no monoculture was studied. The SCI was considered to be a discrete classification variable with 103 possible values, each one characteristic of a specific botanical composition. Since the seven treatment names do not reflect the dynamic changes which occur in sward botanical composition, the use of the classification variable SCI was compared to the classification variable treatment in the analysis.

As in the previous study, to evaluate the effectiveness of the SCI procedure and of treatment labels, univariate multiple regression second-order equations were developed for forage growth and consumption, ADG, and beef production (SAS Institute, Inc., 1982). The SCI vector for each observation time was coupled with the other variables measured for that specific time period. The total number of observations was 342. Concomitant variables were arranged in an order which made biological sense, or which first considered those variates which were easier or cheaper to obtain than others, i.e. year, season, days/period were entered before forage chemical analyses. Concomitant variables were retained in the models for subsequent analyses when the partial regression coefficient associated with a variable was significant at P $\geq$ 0.10. The percentage of the total variability associated in the model with each concomitant variate was calculated from the sequential sum of squares of the final model. Main effects only were used, although the inclusion of interactions might have led to larger coefficients of determination but also would lead to greater difficulty in interpretation of results. Fixed effects were assumed, therefore all errors were pooled in a residual term.

C. Results and Discussion

1. Forage Species Occurrence

Fescue + legumes pastures had large clover occurrence percentages in 1979 and 1980 (Fig. 2A and 2B). The content declined in 1981 but clover presence was still substantial and 10% or less on only a few occasions. In Orchardgrass + clover pastures the clover content was stable and substantial in 1979 and 1980, but had decreased to about 20% in 1981 (Fig. 2C). Legume percentages in bermudagrass-fescue-legume combinations remained constant between 20 and 40% (Fig. 3A, 3B, 3C). Upon occasion legume percentages were as high as 60% or as low as 10%. There was slightly more bermudagrass than fescue in 1979 and 1980 in bermudagrass-fescue-legume combinations (Fig. 4A, 4B, 4C). They were about equal in 1981. In Midland + fescue(25 cm) + N pastures the percentages of bermudagrass and fescue were about the same for the three years (Fig. 4D). The occurrence of frequencies along the diagonal illustrates the change from fescue dominance in spring to bermudagrass dominance in summer.

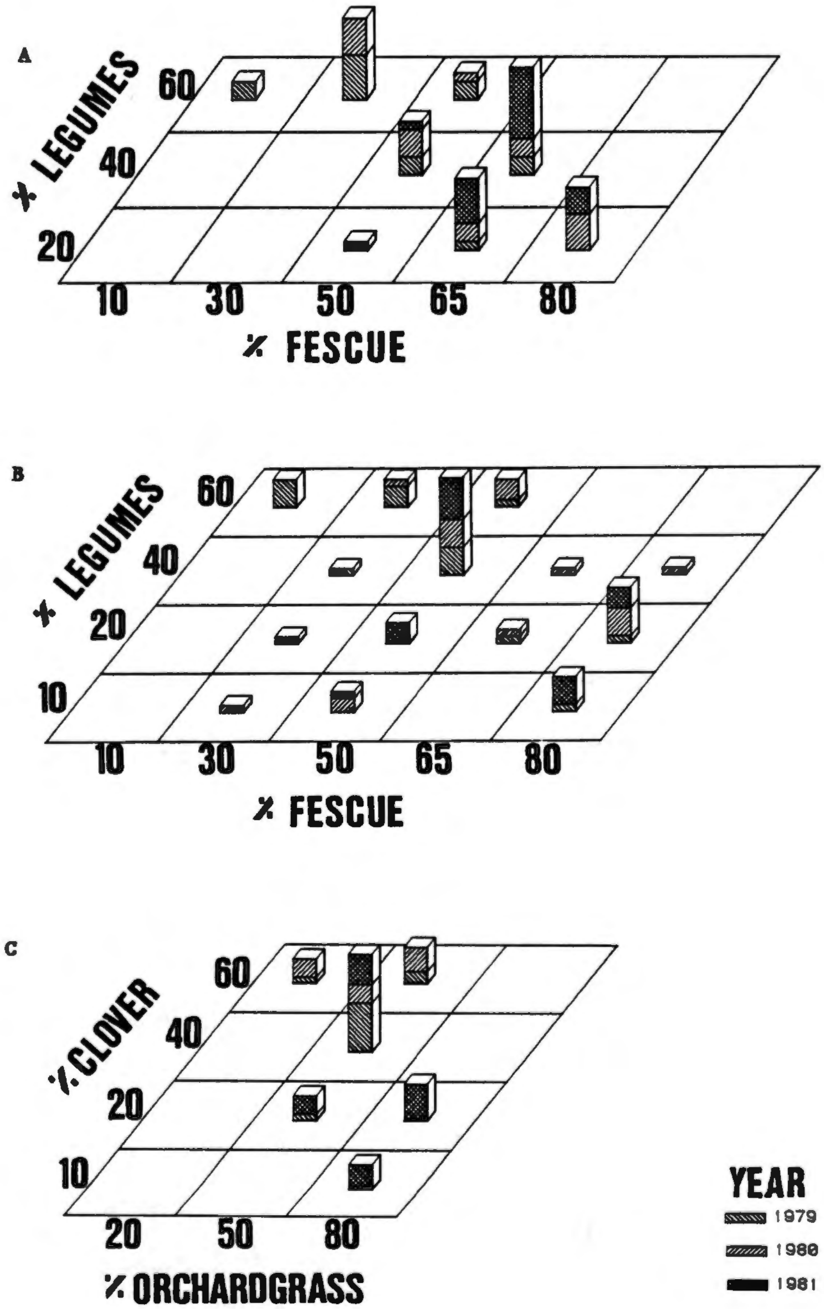

Figure 2. Relative frequency of botanical components in pastures rated at about 21-day intervals on 26 occasions during the 1979-1981 grazing seasons at Ames Plantation, Tennessee: A. Fescue + legumes(0.8 ha); B. Fescue + legumes(1.2 ha); C. Orchardgrass + clover.

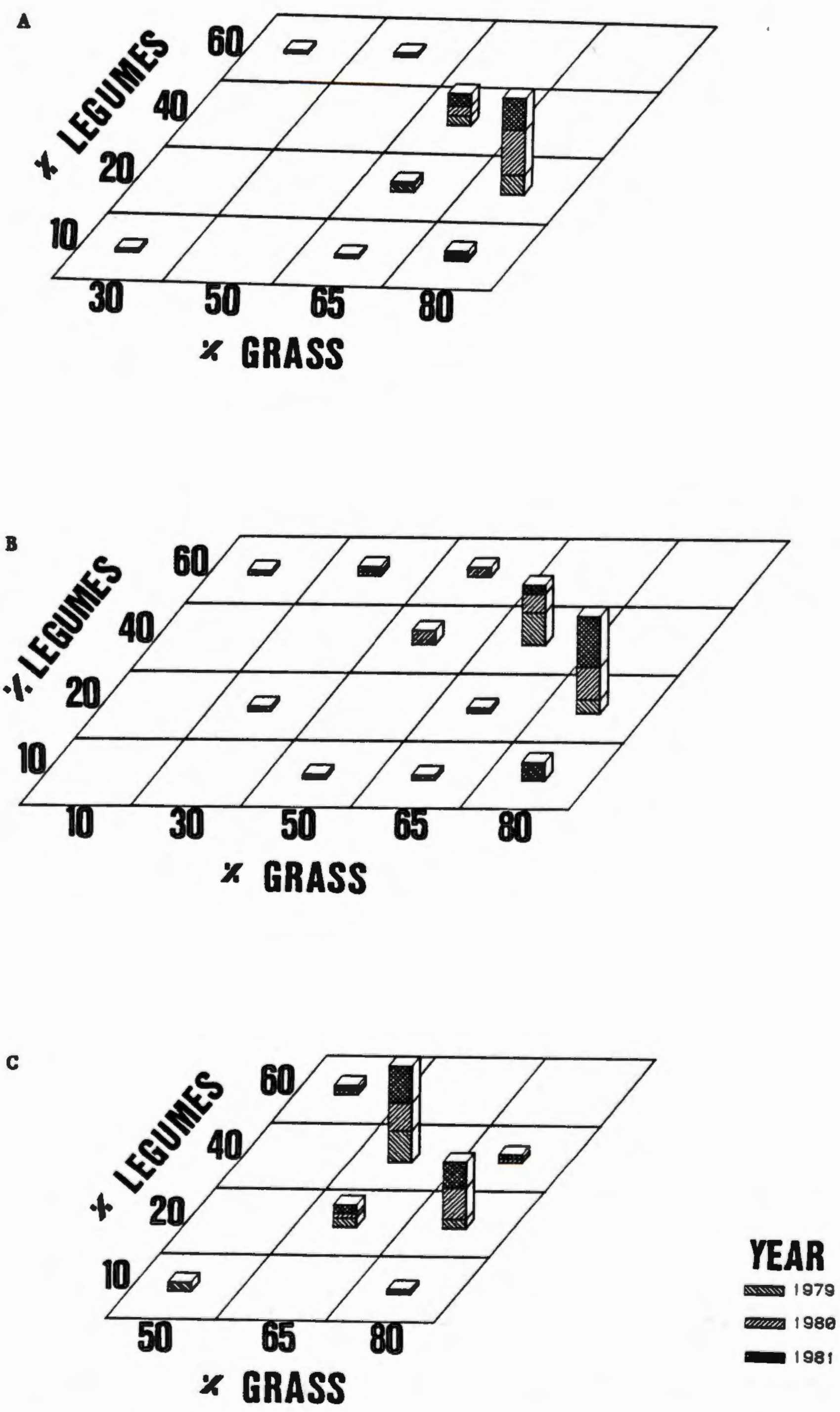

Figure 3. Relative frequency of grasses and legumes in bermudagrass-fescue-legume combinations rated at about 21-day intervals during the 1979-1981 grazing seasons at Ames Plantation, Tennessee: A. Midland + fescue(25 cm) + legumes; B. Midland + fescue(50 cm) + legumes; C. Common + fescue(25 cm) + legumes.

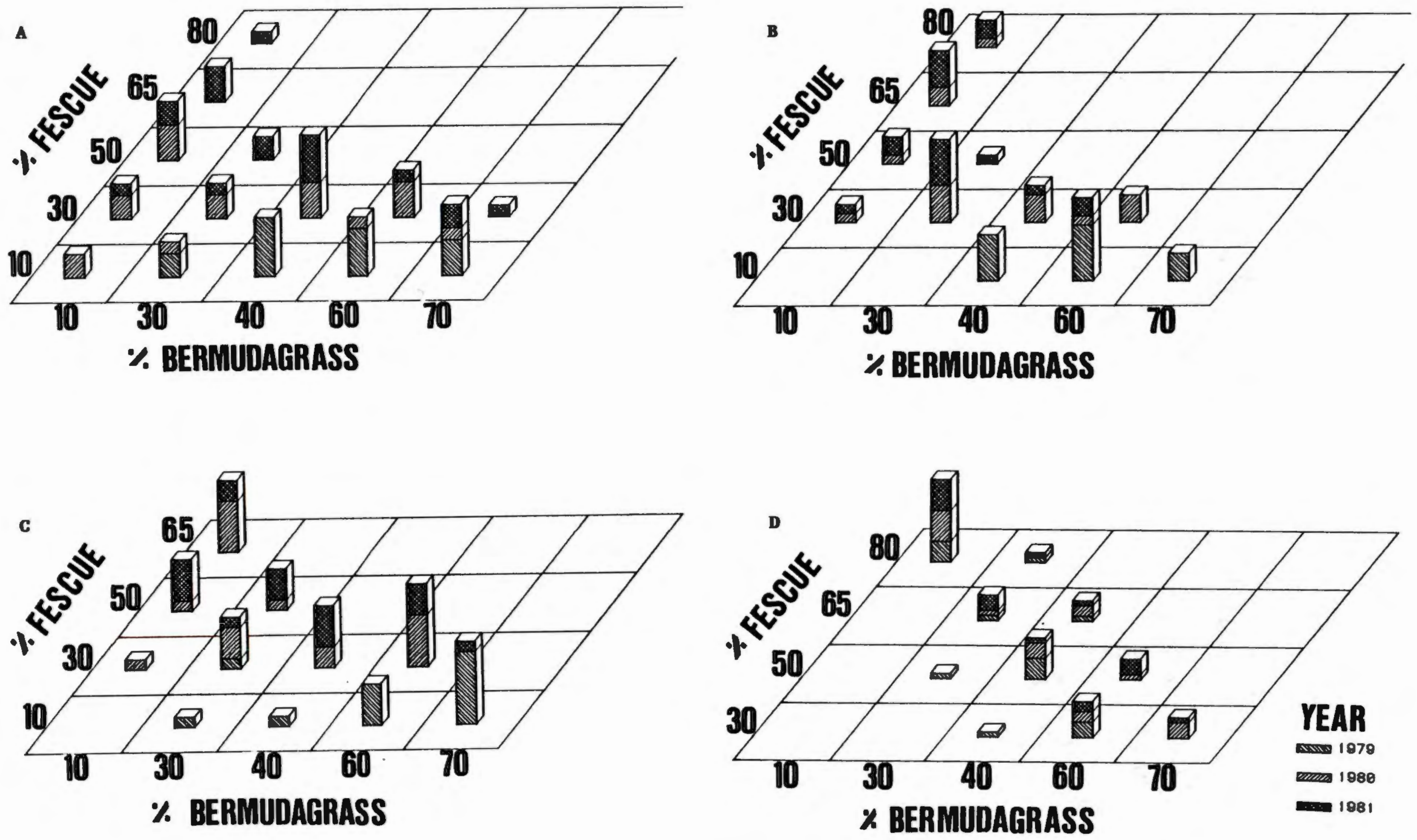

Figure 4. Relative frequency of bermudagrass and fescue in pastures rated at about 21-day intervals on 26 occasions during the 1979-1981 grazing seasons at Ames Plantation, Tennessee: A. Common + fescue(25 cm) + legumes; B. Midland + fescue(50 cm) + legumes; C. Midland + fescue(25 cm) + legumes; D. Midland + fescue(25 cm) + N.

2. Forage Growth

Variability in forage growth was associated with variability in precipitation and ADF. Year, season (spring or summer), grazing days/period, CP, NDF, and temperature were not significant variates (Table 4). When SCI was used in the model, it accounted for over three times as much variability as when treatments was used. Acid-detergent fiber explained slightly more of the total variation when treatments was used than when SCI was used. Precipitation contributed about the same to each model.

Although ADF did not make a large contribution in explaining total variability, it does reflect that height of pasture growth was carefully controlled within the predefined height criteria by a modified put-and-take system (Chapter III). Under these conditions all plants in a pasture were maintained in a vegetative stage of growth, except where recent animal excreta arrested grazing. This could be considered a better indication of forage maturity than the other quality factors measured.

3. Forage Consumption

Forage consumption was related mostly to grazing days/ha, which indicates that stocking rate had a profound influence on consumption of available forage. As in the case of forage growth, ADF of forage was a significant variate, indicating that forage maturity was a factor in consumption, but did not make a large contribution. Forage consumption was also related to year, and was the only dependent variable where year was retained in the model. This may reflect unobserved changes in the sward as the stands aged. Season was also related to forage consumption,

Table 4. Comparison of the Species Composition Index (SCI) and the treatment labels procedures in evaluating forage growth and consumption, average daily gain (ADG), and beef production of seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee

	Concomitant variables										
Dependent variable	Treatment	SCI	Year	Season (spring or summer)	Grazing days/ period	Crude protein in forage during period	Neutral-detergent fiber in forage during period	Acid-detergent fiber in forage during period	Precipitation during period	Mean temperature for period	R^2
	ΔR^2										
Using SCI to describe pasture conditions:											
Forage growth	NA†	0.343*						0.010*	0.011*		0.364
Forage consumption	NA	0.333*	0.018*	0.024*	0.106*			0.029*			0.510
ADG	NA	0.306*		0.017*	0.047*	0.134*				0.023*	0.527
Beef production	NA	0.285*		0.033*	0.173*	0.042*	0.015*			0.008*	0.556
Using treatments to describe pasture conditions											
Forage growth	0.102*	NA						0.040*	0.012*		0.154
Forage consumption	0.058*	NA	0.016*	0.037*	0.164*			0.040*			0.315
ADG	0.032*	NA		0.042*	0.067*	0.171*				0.029*	0.341
Beef production	0.020*	NA		0.041*	0.222*	0.056*	0.018*			0.007*	0.364

* Significant, $\alpha = 0.10$, blank spaces indicate acceptance of null hypothesis at $\alpha = 0.10$

† NA = Not applicable

reflecting different forage consumption in spring and summer. Crude protein, NDF, precipitation, and temperature were not significant. When SCI was used, it accounted for almost six times as much variability as treatments. Grazing days/ha and SCI were very important in reflecting the different consumptions of forage in the many different pasture conditions to which the steers were exposed.

4. Animal Gains

Grazing days/ha, season, CP, and temperature were associated with variability in ADG. Year, NDF, and ADF were not significant variates. When SCI was used in the model, it accounted for almost ten times as much variability as when treatments was used. Crude protein helped explain slightly more of the total variation when treatments was used than when SCI was utilized. Crude protein and ADG are often considered the best measures of forage quality. Grazing days ha^{-1} $period^{-1}$ is a combination of stocking rate and number of days/period (Petersen and Lucas, 1968). As reported previously (Petersen et al., 1965; Fribourg et al., 1984), stocking rate, expressed as grazing days ha^{-1} $period^{-1}$, had a significant effect on ADG. Grazing days ha^{-1} $period^{-1}$ was assumed to be a valid expression in this study because results were conditioned by the animal-forage management systems used (Chapter III), since the objectives were to maintain the species within a pasture in vegetative stages of growth using predefined height criteria, with stocking rate determined primarily by soil moisture, weather conditions most likely to occur in the next 21-day period, and forage availability. Therefore, any advantage or disadvantage resulting from grazing days/ha was a consequence of the state of an individual pasture.

Season and temperature were significant variates affecting ADG. Air temperature has a strong influence on animal performance (NRC, 1981) which is altered by wind, precipitation, humidity, and radiation. These variables and their relative contribution emphasize the decreases in ADG noted from spring to summer.

5. Beef Production

Season, temperature, grazing days/ha, and CP were important in explaining variability in beef production, just as they were in accounting for variations in ADG. Neutral-detergent fiber concentration was also a significant variate, reflecting to a certain degree forage consumption. Since NDF represents plant cell walls and the structural volume of feed, the removal of digestible and soluble contents from this structure does not diminish its effective volume, termed the "hotel effect" (Van Soest, 1982). The relief of rumen fill is accomplished through reduction in particle size by rumination and microbial action, hence it appears that beef production may have been limited by rumen fill.

Treatment was significant in explaining beef production, indicating a better ability of managers to manipulate pastures and animals in differing environments. However, when SCI was used in the model it accounted for seven times more variability than when treatments was used.

6. General Discussion

In this study, as in the previous one (Fribourg et al., 1984), the SCI concept appears to be a useful tool in describing dynamically changing sward composition in introduced pasture situations. The SCI was superior to the discrete variate treatments in explaining variability in both experiments. The frequency classes for each species were easily adjusted, thus increasing or decreasing the number of vectors created. However, the greater number of vectors in this study did not seem to affect the overall sensitivity. In the first study (Fribourg et al., 1984), 48 SCI vectors explained greater amounts of total variation in forage growth and consumption, and ADG, than that reported here where 103 SCI vectors were used. In fact, models developed previously which included the SCI (Fribourg et al., 1984) explained 3, 1, and 15% more of the total variation in forage growth and consumption, and ADG, respectively, than comparable models developed here. The model developed for beef production in this study explained 1% more total variation than the previously developed model. However, the contribution of the SCI as a concomitant variable in the current models explained 13, 12, 3, and 4% more variation in forage growth and consumption, ADG, and beef production, respectively, than the previous SCI. This indicates that the larger number of vectors used in this study increased the contribution of variance explained by the SCI, but overall sensitivity is dependent upon the significant concomitant variables.

Further application of the SCI concept in rangeland evaluations or other management and ground cover studies is unknown at this time, but appears to show some promise where a practical, abbreviated means of quantifying ground covers is needed.

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APPENDIX

Table 5. Yearly forage growth and consumption, forage crude protein (CP), neutral- (NDF) and acid-detergent (ADF) fiber concentrations, initial grazing dates and grazing seasons for seven different pasture combinations during 1979-1981 at Ames Plantation, Tennessee.

Variable	Year	Annuals (0.4 ha)†- Fescue + legumes (0.8 ha)			Midland + fescue (50 cm)‡ + legumes	Midland + fescue (25 cm)‡ + legumes	Midland + fescue (25 cm)§¶	Fescue + legumes	Orchardgrass + clover	Common + fescue (25 cm)‡ + legumes
		Pasture Combinations								
Initial grazing date	1979			19 March#	26 April	26 April	19 March	19 March	16 May	26 April
	1980			18 March	18 March	18 March	18 March	18 March	08 April	08 April
	1981			09 March	09 March	09 March	09 March	09 March	09 March	09 March
	Mean			15 March	28 March	28 March	15 March	15 March	11 April	04 April
Length of spring grazing season, days	1979			98#	60	60	98	98	40	60
	1980			126	126	126	126	126	105	105
	1981			114	114	114	114	114	114	114
	Mean			113††	100	100	113	113	86	93
Length of grazing season, days	1979			169#	131	131	169	169	111	131
	1980			137	158	158	158	158	105	137
	1981			177	177	177	177	177	177	177
	Mean			161††	155	155	168	168	131	148
		Annuals	Fescue + legumes	Total						
Forage growth, kg/ha	1979	11884††	3722‡‡	15606§§	7581§§	6473	12446	7762	4525	9418
	1980	7025	5896	12921	8375	6420	15002	7773	5557	7358
	1981	7351	6699	14050	9452	7465	15249	11633	12734	7071
	Mean	8753	5439	14192	8469	6786	14232	9056	7605	7949
Forage consumption, kg/ha	1979	4453†	2286‡‡	6739§§	5803§§	4452	9965	5872	3549	6931
	1980	5087	4296	9383	4987	4816	9906	5691	4197	4509
	1981	5175	5027	10202	8149	5801	12918	10056	11461	5821
	Mean	4905	3870	8775	6313	5023	10929	7206	6402	5753
				Weighted total						
Weighted forage crude protein, %	1979	11.2¶¶	14.2##	11.0†††	12.4†††	11.6	14.0	14.3	14.9	12.8
	1980	13.0	17.6	15.2	16.3	15.8	14.2	17.5	20.5	15.2
	1981	14.8	13.4	13.8	11.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Weighted forage neutral-detergent fiber, %	1979	70¶¶	63##	70†††	71†††	73	70	66	64	74
	1980	61	54	58	56	60	64	58	49	61
	1981	58	63	61	66	63	66	66	67	62
	Mean	63	60	63	64	65	67	63	60	66
Weighted forage acid-detergent fiber, %	1979	51¶¶	35##	47†††	40†††	39	37	42	38	40
	1980	42	37	39	40	41	42	37	35	39
	1981	41	41	41	38	37	37	39	44	38
	Mean	44	37	42	39	39	39	39	39	39

† Sorghum-sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

‡ 25 cm and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

§ 25 cm refers to the distance between fescue rows at seeding in fall 1974.

¶ 78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

Mean of two replications for each of three years.

†† Mean of two cage samples in each of two replications.

‡‡ Mean of four cage samples in each of two replications.

§§ Mean of six cage samples in each of two replications.

¶¶ Weighted mean of two cage samples in each of two replications, based on forage dry matter growth.

Weighted mean of four cage samples in each of two replications, based on forage dry matter growth.

††† Weighted mean of six cage samples in each of two replications, based on forage dry matter growth.

Table 6. Forage growth for periods ending at specified dates for seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee

Year	Sampling date	Season	Annuals (0.4 ha)†-Fescue + legumes (0.8 ha)			Midland + fescue (50 cm)‡ + legumes	Midland + fescue (25 cm)‡ + legumes	Midland + fescue (25 cm)§¶	Fescue + legumes	Orchardgrass + clover	Common + fescue (25 cm)‡ + legumes
			kg/ha								
			Annuals	Fescue+ legumes	Wt. Tot.						
1979	20 March	Spring	0[#]	0[††]	0[‡‡]	----	----	0	0	----	----
	27 April	Spring	2611	0	2611	0[‡‡]	0	3794	484	----	0
	17 May	Spring	----	142	142	881	264	476	708	0	435
	05 June	Spring	----	490	490	396	209	966	477	522	831
	26 June	Summer	0	558	558	732	932	825	183	817	462
	17 July	Summer	1842	801	2643	1151	904	1471	789	978	1515
	07 Aug.	Summer	----	295	295	1152	1273	840	1983	715	1621
	05 Sept.	Summer	----	----	----	1491	870	1593	1248	517	2067
1980	18 March	Spring	0	0	0	0	0	0	0	----	----
	08 April	Spring	1363	395	1758	302	309	1588	745	0	0
	28 April	Spring	112	1244	1356	561	376	1595	1236	1082	736
	19 May	Spring	0	638	638	789	1071	1632	827	1002	983
	10 June	Spring	0	1155	1155	1738	1021	1281	1378	1068	1159
	01 July	Summer	3612	865	4477	1334	1278	1778	954	1045	1042
	23 July	Summer	----	----	----	0	0	0	0	----	0
	13 Aug.	Summer	0	0	0	263	760	2032	552	----	588
	29 Aug.	Summer	----	----	----	----	----	----	----	----	----
1981	10 March	Spring	0	0	0	0	0	0	0	0	0
	08 April	Spring	550	610	1160	672	314	1356	704	996	221
	27 April	Spring	----	490	490	712	181	2186	821	853	606
	17 May	Spring	----	550	550	497	734	1060	906	1124	497
	12 June	Spring	0	1595	1595	1146	948	1648	1015	2062	635
	02 July	Summer	----	124	124	1140	508	970	1108	1781	668
	22 July	Summer	4625	338	4963	1268	839	2148	1765	1002	1257
	11 Aug.	Summer	----	332	332	1450	1854	2254	1699	1536	1936
	03 Sept.	Summer	----	988	988	1264	425	1297	2037	2106	----

† Sorghum-sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

‡ 25 cm and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

§ 25 cm refers to the distance between fescue rows at seeding in fall 1974.

¶ 78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

Mean of two cage samples in each of two replications.

†† Mean of four cage samples in each of two replications.

‡‡ Mean of six cage samples in each of two replications.

Table 7. Forage consumption for periods ending at specified dates for seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee.

Year	Sampling date	Season	Pasture combinations: Annuals (0.4 ha)†- Fescue + legumes (0.8 ha)			Midland + fescue (50 cm)‡ + legumes	Midland + fescue (25 cm)‡ + legumes	Midland + fescue (25 cm)§¶	Fescue + legumes	Orchardgrass + clover	Common + fescue (25 cm)‡ + legumes
			kg/ha								
			Annuals	Fescue+ legumes	Wt. Tot.						
1979	20 March	Spring	710#	----††	710‡‡	----	----	202	314	----	----
	27 April	Spring	3456	567	4023	784‡‡	659	6084	397	----	276
	17 May	Spring	----	389	389	698	----	----	799	852	508
	05 June	Spring	----	399	399	290	510	905	500	440	1066
	26 June	Summer	2065	530	2595	874	780	485	696	716	738
	17 July	Summer	1324	1245	2569	1503	1058	1975	1187	1050	1652
	07 Aug.	Summer	----	592	592	1476	2219	1777	2437	945	2379
	05 Sept.	Summer	4330	----	4330	1956	1247	1019	1432	522	2801
1980	18 March	Spring	654	833	1487	1317	449	1655	574	----	
	08 April	Spring	1260	253	1513	----	128	1236	933	1797	1128
	28 April	Spring	566	1361	1927	853	510	1390	1577	343	291
	19 May	Spring	----	825	825	1451	1438	1534	970	683	1241
	10 June	Spring	981	897	1878	2211	1257	2456	1165	1666	1688
	01 July	Summer	3564	1155	4719	1087	1300	1534	946	1068	787
	23 July	Summer	----	----	----	776	696	1661	617	----	526
	13 Aug.	Summer	----	431	431	679	641	2498	666	----	737
	29 Aug.	Summer	----	142	142	----	1	1039	326	----	960
1981	10 March	Spring	614	793	1407	396	494	1366	494	896	415
	08 April	Spring	1858	542	2400	901	433	1292	981	1536	223
	27 April	Spring	----	1770	1770	758	659	2130	1196	1037	572
	17 May	Spring	----	367	367	805	423	800	981	1451	447
	12 June	Spring	853	1108	1961	1294	1006	2209	813	1310	1095
	02 July	Summer	0	100	100	1345	925	1329	1454	1948	1300
	22 July	Summer	4027	530	4557	1725	695	2613	1332	1324	1040
	11 Aug.	Summer	0	678	678	1120	2139	2118	2031	1284	1980
	03 Sept.	Summer	0	811	811	1108	690	1393	2352	1948	----

† Sorghum-sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

‡ 25 cm and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

§ 25 cm refers to the distance between fescue rows at seeding in fall 1974.

¶ 78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

\# Mean of two cage samples in each of two replications.

†† Mean of four cage samples in each of two replications.

‡‡ Mean of six cage samples in each of two replications.

Table 8. Crude protein (CP) concentrations of forage consumed by steers grazing seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee.

			Pasture combinations								
Year	Sampling date	Season	Annuals (0.4 ha)†-Fescue + legumes (0.8 ha)			Midland + fescue (50 cm)‡ + legumes	Midland + fescue (25 cm)‡ + legumes	Midland + fescue (25 cm)§¶	Fescue + legumes	Orchardgrass + clover	Common + fescue (25 cm)‡ + legumes
			% CP								
			Annuals	Fescue+ legume	Wt. Tot.						

† [illegible] sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

‡ 25 cm and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

§ 25 cm refers to the distance between fescue rows at seeding in fall 1974.

¶ 78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

Composite of two cages in each of two replications.

†† Composite of four cages in each of two replications.

‡‡ Weighted mean of cage samples, based on dry matter growth.

§§ Composite of six cage samples in each of two replications.

	01 July	Summer	71	58	67	51	59	68	56	--	63
	23 July	Summer	--	--	--	--	--	--	--	--	--
	13 Aug.	Summer	--	--	--	69	67	71	67	--	68
	29 Aug.	Summer	--	--	--	--	--	--	--	--	--
1981	10 March	Spring	--	--	--	--	--	--	--	--	--
	08 April	Spring	54	51	53	54	51	57	55	57	58
	27 April	Spring	--	60	60	63	59	63	65	58	65
	17 May	Spring	--	65	65	65	59	65	68	71	63
	12 June	Spring	--	67	67	61	60	63	64	69	60
	02 July	Summer	--	65	65	66	62	64	73	73	65
	22 July	Summer	62	58	61	69	63	68	65	67	61
	11 Aug.	Summer	--	60	60	69	68	69	64	67	63
	03 Sept.	Summer	--	61	66	70	70	70	70	69	69

† Sorghum-sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

‡ 25 cm and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

§ 25 cm refers to the distance between fescue rows at seeding in fall 1974.

¶ 78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

Composite of two cages in each of two replications.

†† Composite of four cages in each of two replications.

‡‡ Weighted mean of cage samples, based on dry matter growth.

§§ Composite of six cage samples in each of two replications.

	19 May	Spring	--	35	35	45	44	38	38	36	42
	10 June	Spring	--	37	37	39	39	37	39	35	39
	01 July	Summer	49	40	47	38	39	38	37	35	39
	23 July	Summer	--	--	--	--	--	--	--	--	--
	13 Aug.	Summer	--	--	--	--	41	39	37	--	41
	29 Aug.	Summer	--	--	--	--	--	--	--	--	--
1981	10 March	Spring	--	--	--	--	--	--	--	--	--
	08 April	Spring	35	34	35	32	29	33	33	34	34
	27 April	Spring	--	38	38	38	36	37	39	39	38
	17 May	Spring	--	40	40	39	37	39	43	49	38
	12 June	Spring	--	43	43	39	37	37	38	45	38
	02 July	Summer	--	40	40	39	38	37	40	48	39
	22 July	Summer	47	36	44	37	38	37	38	44	38
	11 Aug.	Summer	--	36	36	37	37	38	36	43	37
	03 Sept.	Summer	--	50	50	39	39	38	40	45	39

† Sorghum-sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

‡ 25 cm and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

§ 25 cm refers to the distance between fescue rows at seeding in fall 1974.

¶ 78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

Composite of two cages in each of two replications.

†† Composite of four cages in each of two replications.

‡‡ Weighted mean of cage samples, based on dry matter growth.

§§ Composite of six cage samples in each of two replications.

Table 11. Number of days per sampling period at specified dates for seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee.

Year	Sampling date	Season	Annuals (0.4 ha)†- Fescue + legumes (0.8 ha)		Midland + fescue (50 cm)‡ + legumes	Midland + fescue (25 cm)‡ + legumes	Midland + fescue (25 cm)§¶	Fescue + legumes	Orchardgrass + clover	Common + fescue (25 cm)‡ + legumes
			days							
			Annuals	Fescue + legumes						
1979	20 March	Spring	0	0	--	--	0	0	--	--
	27 April	Spring	38	38	0	0	38	38	--	0
	17 May	Spring	--	20	20	20	20	20	0	20
	05 June	Spring	--	19	19	19	19	19	19	19
	26 June	Summer	0	21	21	21	21	21	21	21
	17 July	Summer	21	21	21	21	21	21	21	21
	07 Aug.	Summer	--	21	21	21	21	21	21	21
	05 Sept.	Summer	--	29	29	29	29	29	29	29
1980	18 March	Spring	0	0	0	0	0	0	--	--
	08 April	Spring	21	21	21	21	21	21	0	0
	28 April	Spring	20	20	20	20	20	20	20	20
	19 May	Spring	--	21	21	21	21	21	21	21
	10 June	Spring	0	22	22	22	22	22	22	22
	01 July	Summer	21	21	21	21	21	21	21	21
	23 July	Summer	--	--	0	0	0	0	--	0
	13 Aug.	Summer	0	0	21	21	21	21	--	21
	29 Aug.	Summer	16	16	16	16	16	16	--	16
1981	10 March	Spring	0	0	0	0	0	0	0	0
	08 April	Spring	29	29	29	29	29	29	29	29
	27 April	Spring	--	19	19	19	19	19	19	19
	17 May	Spring	--	20	20	20	20	20	20	20
	12 June	Spring	0	26	26	26	26	26	26	26
	02 July	Summer	20	20	20	20	20	20	20	20
	22 July	Summer	20	20	20	20	20	20	20	20
	11 Aug.	Summer	--	20	20	20	20	20	20	20
	03 Sept.	Summer	--	23	23	23	23	23	23	23

† Sorghum-sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

‡ 25 cm and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

§ 25 cm refers to the distance between fescue rows at seeding in fall 1974.

¶ 78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

Table 12. Yearly animal performance and pasture productivity of seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee.

		Pasture combinations						
Variable	Year	Annuals (0.4 ha)†- Fescue + legumes (0.8 ha)	Midland + fescue (50 cm)‡ + legumes	Midland + fescue (25 cm)‡ + legumes	Midland + fescue (25 cm)§¶	Fescue + legumes	Orchardgrass + clover	Common + fescue (25 cm)‡ + legumes
Stocking rate, steers/ha	1979	2.4#	4.0	4.5	7.9	3.1	2.8	3.2
	1980	2.9	3.2	3.3	6.0	3.9	5.5	3.2
Daily forage dry matter intake kg/steer/day	1979	14.2#	9.2	6.3	6.6	9.5	9.3	13.1
	1980	20.1	7.7	7.3	8.3	7.4	7.3	7.9
	1981	11.7	7.9	5.3	6.8	10.9	13.2	8.7
	Mean	15.3	8.2	6.3	7.2	9.3	9.9	9.9
Conversion efficiency, kg/kg gain	1979	19.8#	16.0	10.9	13.8	9.2	10.4	21.8
	1980	24.0	9.3	8.5	17.4	9.6	8.3	11.2
	1981	17.3	14.4	10.0	15.4	16.7	16.8	13.3
	Mean	20.4	13.2	9.8	15.5	11.8	11.8	15.4
Beef production, kg/ha	1979	349#	361	443	675	591	339	600
	1980	436	574	602	501	689	705	410
	1981	507	486	484	713	511	590	454
	Mean	431	474	510	630	597	545	392

† Sorghum-sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

‡ 25 cm and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

§ 25 cm refers to the distance between fescue rows at seeding in fall 1974.

¶ 78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

Mean of two replications.

†† Mean of three tester steers in each of two replications, except ‡‡ five tester steers.

Table 13. Stocking rates for periods ending on specified dates for seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee.

Year	Sampling date	Season	Annuals (0.4 ha)†-Fescue + legumes (0.8 ha)	Midland + fescue (50 cm)‡ + legumes	Midland + fescue (25 cm)‡ + legumes	Midland + fescue (25 cm)§¶	Fescue + legumes	Orchardgrass + clover	Common + fescue (25 cm)‡ + legumes
			steer/ha						
1979	20 March	Spring	0.0#	---	---	0.0	0.0	---	---
	27 April	Spring	2.7	0.0	0.0	6.3	2.0	---	0.0
	17 May	Spring	3.2	5.3	8.1	11.0	3.5	0.0	2.5
	05 June	Spring	3.0	3.9	4.6	12.1	3.3	3.9	2.3
	26 June	Summer	2.2	3.8	4.3	9.4	2.4	3.9	2.1
	17 July	Summer	3.1	4.6	4.7	9.7	3.4	4.1	4.3
	07 Aug.	Summer	2.4	5.1	4.7	7.1	4.7	2.4	5.1
	05 Sept.	Summer	2.3	5.2	4.7	7.6	5.7	2.4	5.6
1980	18 March	Spring	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	08 April	Spring	2.2	1.8	2.2	3.7	2.2	8.4	3.5
	28 April	Spring	4.8	2.8	2.8	11.7	6.3	10.6	4.0
	19 May	Spring	3.4	4.9	4.1	9.0	6.4	4.1	5.5
	10 June	Spring	7.4	6.8	6.6	8.6	10.4	4.4	5.3
	01 July	Summer	2.5	5.8	5.8	7.9	3.9	---	0.0
	23 July	Summer	---	0.0	0.0	0.0	0.0	---	0.0
	13 Aug.	Summer	0.0	2.9	3.7	4.9	2.9	---	3.3
	29 Aug.	Summer	2.6	3.7	4.3	8.4	3.2	---	3.9
1981	10 March	Spring	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	08 April	Spring	3.3	3.3	3.1	5.4	2.6	3.3	3.2
	27 April	Spring	3.1	5.5	5.5	9.4	3.9	3.5	4.7
	17 May	Spring	5.4	4.7	7.0	11.6	5.0	5.8	4.0
	12 June	Spring	5.5	5.5	7.1	11.9	5.9	7.5	2.3
	02 July	Summer	5.6	6.7	7.0	11.8	5.9	5.4	3.6
	22 July	Summer	5.5	6.7	7.0	11.8	5.9	4.3	4.3
	11 Aug.	Summer	4.8	7.4	7.4	11.8	5.9	4.3	3.5
	03 Sept.	Summer	4.8	5.9	5.9	9.6	5.1	3.1	3.7

† Sorghum-sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

‡ 25 cm and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

§ 25 cm refers to the distance between fescue rows at seeding in fall 1974.

¶ 78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

Mean of two replications for each of three years.

Table 14. Steer gains for periods ending on specified dates for seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee

Year	Sampling date	Season	Annuals (0.4 ha)†-Fescue + legumes (0.8 ha)	Midland + fescue (50 cm)‡ + legumes	Midland + fescue (25 cm)‡ + legumes	Midland + fescue (25 cm)§¶	Fescue + legumes	Orchardgrass + clover	Common + fescue (25 cm)‡ + legumes
			kg/steer						
1979	20 March	Spring	0#	--	--	0††	0	--	--
	27 April	Spring	29	0	0	35	69	--	0
	17 May	Spring	25	12	19	5	21	0	3
	05 June	Spring	8	11	7	9	9	18	8
	26 June	Summer	8	10	9	3	11	10	20
	17 July	Summer	13	14	4	3	22	25	22
	07 Aug.	Summer	13	10	15	10	11	17	15
	05 Sept.	Summer	25	18	22	16	30	30	10
1980	18 March	Spring	0	0	0	0	0	--	--
	08 April	Spring	33	25	11	20	9	0	0
	28 April	Spring	7	7	16	-1	11	14	15
	19 May	Spring	39	37	40	24	43	37	34
	10 June	Spring	24	30	28	17	19	20	27
	01 July	Summer	17	18	21	6	19	23	5
	23 July	Summer	--	--	--	--	--	--	11
	13 Aug.	Summer	0	12	20	11	17	--	17
	29 Aug.	Summer	-5	-6	-3	-3	-1	--	-10
1981	10 March	Spring	0	0	0	0	0	0	0
	08 April	Spring	60	47	38	46	44	64	41
	27 April	Spring	12	13	7	1	17	27	16
	17 May	Spring	17	16	18	11	22	6	17
	12 June	Spring	6	3	9	5	3	1	9
	02 July	Summer	13	13	9	17	12	10	12
	22 July	Summer	-9	3	-1	-5	0	4	14
	11 Aug.	Summer	17	0	5	1	1	6	-5
	03 Sept.	Summer	3	6	5	7	15	23	11

† Sorghum-sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

‡ 25 cm and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

§ 25 cm refers to the distance between fescue rows at seeding in fall 1974.

¶ 78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

Mean of three tester steers in each of two replications for each of three years, except †† five tester steers.

Table 15. Average daily gain (ADG) of steers for periods ending on specified dates for seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee.

			Pasture combinations						
Year	Sampling date	Season	Annuals (0.4 ha)†-Fescue + legumes (0.8 ha)	Midland + fescue (50 cm)‡ + legumes	Midland + fescue (25 cm)‡ + legumes	Midland + fescue (25 cm)§¶	Fescue + legumes	Orchardgrass + clover	Common + fescue (25 cm)‡ + legumes
			g/steer						
1979	20 March	Spring	0#	---	---	0††	0	---	---
	27 April	Spring	776	0	0	950	1873	---	0
	17 May	Spring	1247	624	964	265	1077	0	132
	05 June	Spring	411	575	345	477	477	953	444
	26 June	Summer	378	454	416	151	548	491	983
	17 July	Summer	612	648	180	144	1026	1134	990
	07 Aug.	Summer	617	497	736	458	517	796	696
	05 Sept.	Summer	882	630	756	540	1044	1026	360
1980	18 March	Spring	0	0	0	0	0	---	---
	08 April	Spring	1584	1206	504	950	414	0	0
	28 April	Spring	340	359	813	-57	548	718	756
	19 May	Spring	1836	1764	1908	1145	2034	1764	1638
	10 June	Spring	1082	1375	1289	763	859	911	1220
	01 July	Summer	792	864	1008	281	882	1098	252
	23 July	Summer	---	0	0	0	0	---	0
	13 Aug.	Summer	0	554	972	508	810	---	810
	29 Aug.	Summer	-298	-387	-203	-207	-90	---	-666
1981	10 March	Spring	0	0	0	0	0	0	0
	08 April	Spring	2079	1634	1336	1599	1544	2217	1417
	27 April	Spring	630	639	396	63	911	1422	846
	17 May	Spring	842	584	893	559	1093	292	859
	12 June	Spring	234	126	360	205	126	54	360
	02 July	Summer	630	648	450	853	612	522	594
	22 July	Summer	-468	144	-54	-227	0	198	720
	11 Aug.	Summer	846	-18	270	32	54	324	-234
	03 Sept.	Summer	144	288	234	356	756	1170	576

† Sorghum-sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

‡ 25 cm and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

§ 25 cm refers to the distance between fescue rows at seeding in fall 1974.

¶ 78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

Mean of three tester steers in each of two replications, except †† five tester steers.

Table 16. Grazing days per hectare for periods ending on specified dates for seven different pasture combinations during the 1979-1981 grazing season at Ames Plantation, Tennessee.

			Pasture combinations						
Year	Sampling date	Season	Annuals (0.4 ha)†- Fescue + legumes (0.8 ha)	Midland + fescue (50 cm)‡ + legumes	Midland + fescue (25 cm)‡ + legumes	Midland + fescue (25 cm)§¶	Fescue + legumes	Orchardgrass + clover	Common + fescue (25 cm)‡ + legumes
			grazing days/ha						
1979	20 March	Spring	0#	---	---	0	0	---	---
	27 April	Spring	107	0	0	247	76	---	0
	17 May	Spring	68	110	170	231	75	0	52
	05 June	Spring	61	78	95	242	65	78	47
	26 June	Summer	49	84	94	208	53	86	47
	17 July	Summer	68	101	104	215	74	91	95
	07 Aug.	Summer	52	113	104	156	103	52	112
	05 Sept.	Summer	70	156	140	228	170	72	179
1980	18 March	Spring	0	0	0	0	0	---	---
	08 April	Spring	47	38	46	78	47	0	0
	28 April	Spring	97	57	56	234	127	169	70
	19 May	Spring	72	102	86	189	135	223	84
	10 June	Spring	162	149	146	189	229	90	121
	01 July	Summer	52	121	121	166	82	91	111
	23 July	Summer	---	0	0	0	0	---	0
	13 Aug.	Summer	0	61	78	104	61	---	69
	29 Aug.	Summer	42	59	70	134	52	---	62
1981	10 March	Spring	0	0	0	0	0	0	0
	08 April	Spring	99	105	91	164	79	99	97
	27 April	Spring	63	110	110	188	78	70	94
	17 May	Spring	113	100	147	245	106	121	83
	12 June	Spring	150	150	193	321	158	203	63
	02 July	Summer	118	140	148	247	124	114	75
	22 July	Summer	115	140	148	247	124	91	91
	11 Aug.	Summer	102	157	156	247	124	91	73
	03 Sept.	Summer	115	141	141	231	124	75	91

† Sorghum-sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

‡ 25 cm and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

§ 25 cm refers to the distance between fescue rows at seeding in fall 1974.

¶ 78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

Mean of two replications for each of three years.

Table 17. Beef production for periods ending on specified dates for seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee

Year	Sampling date	Season	Pasture combinations: Annuals (0.4 ha)†–Fescue + legumes (0.8 ha)	Midland + fescue (50 cm)‡ + legumes	Midland + fescue (25 cm)‡ + legumes	Midland + fescue (25 cm)§¶	Fescue + legumes	Orchardgrass + clover	Common + fescue (25 cm)‡ + legumes
			kg/ha						
1979	20 March	Spring	0#	---	---	0††	0	---	---
	27 April	Spring	83	0	0	235	147	---	0
	17 May	Spring	86	65	169	63	79	0	7
	05 June	Spring	26	45	33	114	31	74	21
	26 June	Summer	19	38	39	26	29	42	46
	17 July	Summer	41	66	19	34	76	107	96
	07 Aug.	Summer	32	52	77	78	53	41	77
	05 Sept.	Summer	62	95	107	124	175	74	63
1980	18 March	Spring	0	0	0	0	0	---	0
	08 April	Spring	74	48	23	74	19	0	54
	28 April	Spring	33	20	45	-13	68	123	138
	19 May	Spring	132	180	162	220	275	396	148
	10 June	Spring	168	204	180	142	197	87	28
	01 July	Summer	41	98	122	45	72	100	29
	23 July	Summer	---	---	---	---	---	---	---
	13 Aug.	Summer	0	34	76	51	49	---	56
	29 Aug.	Summer	-13	-31	-12	-29	-3	---	-42
1981	10 March	Spring	0	0	0	0	0	0	0
	08 April	Spring	206	164	125	261	123	218	137
	27 April	Spring	39	75	43	12	71	96	79
	17 May	Spring	95	65	130	137	113	39	71
	12 June	Spring	35	19	62	57	20	11	23
	02 July	Summer	75	89	64	211	78	59	44
	22 July	Summer	-54	20	-18	-63	0	23	65
	11 Aug.	Summer	94	-3	42	7	4	36	-19
	03 Sept.	Summer	17	57	35	91	101	108	53

† Sorghum-sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

‡ 25 cm and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

§ 25 cm refers to the distance between fescue rows at seeding in fall 1974.

¶ 78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

Mean of three tester steers in each of two replications for each of three years, except †† five tester steers.

Table 18. Steer weights on individual dates for seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee

Year	Weighing date	Season	Annuals (0.4 ha)†- Fescue + legumes (0.8 ha)	Midland + fescue (50 cm)‡ + legumes	Midland + fescue (25 cm)‡ + legumes	Midland + fescue (25 cm)§¶	Fescue + legumes	Orchardgrass + clover	Common + fescue (25 cm)‡ + legumes
			kg/steer						
1979	20 March	Spring	230#	---	---	233††	237	---	---
	26 April	Spring	259	253	264	268	278	---	248
	16 May	Spring	284	265	283	273	299	267	251
	08 June	Spring	293	278	291	284	310	289	261
	28 June	Summer	300	287	299	287	321	299	280
	20 July	Summer	313	301	303	290	342	323	301
	08 Aug.	Summer	325	310	317	299	352	338	314
	29 Aug.	Summer	343	323	332	310	374	359	321
1980	18 March	Spring	231	220	226	228	230	---	---
	07 April	Spring	264	246	237	248	240	247	248
	28 April	Spring	271	253	253	247	251	262	264
	20 May	Spring	310	290	293	271	293	299	298
	10 June	Spring	333	320	322	289	312	319	325
	01 July	Summer	---	338	343	294	331	342	330
	22 July	Summer	350	345	346	296	338	---	341
	12 Aug.	Summer	362	357	365	307	355	---	358
	03 Sept.	Summer	357	351	363	304	353	---	348
1981	10 March	Spring	230	233	230	221	222	227	224
	07 April	Spring	288	279	268	262	265	279	262
	28 April	Spring	302	293	276	263	284	309	280
	20 May	Spring	320	306	296	276	308	315	299
	10 June	Spring	325	308	303	280	311	317	306
	01 July	Summer	338	322	312	298	323	327	318
	22 July	Summer	328	325	311	293	323	332	333
	12 Aug.	Summer	346	324	317	294	324	338	329
	02 Sept.	Summer	349	330	322	301	340	363	341

† Sorghum-sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

‡ 25 cm and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

§ 25 cm refers to the distance between fescue rows at seeding in fall 1974.

¶ 78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

Mean of three tester steers in each of two replications, except †† five tester steers.

Table 19. Number of days per weighing period for seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee

			Pasture combinations						
Year	Weighing date	Season	Annuals (0.4 ha)†-Fescue + legumes (0.8 ha)	Midland + fescue (50 cm)‡ + legumes	Midland + fescue (25 cm)‡ + legumes	Midland + fescue (25 cm)§¶	Fescue + legumes	Orchardgrass + clover	Common + fescue (25 cm)‡ + legumes
			days						
1979	20 March	Spring	0	--	--	--	0	--	
	26 April	Spring	37	0	0	0	37	--	0
	16 May	Spring	20	20	20	20	20	0	20
	08 June	Spring	23	23	23	23	23	23	23
	28 June	Summer	20	20	20	20	20	20	20
	20 July	Summer	22	22	22	22	22	22	22
	08 Aug.	Summer	19	19	19	19	19	19	19
	29 Aug.	Summer	21	21	21	21	21	21	21
1980	18 March	Spring	0	0	0	0	0	--	0
	07 April	Spring	20	20	20	20	20	0	20
	28 April	Spring	21	21	21	21	21	21	21
	20 May	Spring	22	22	22	22	22	22	22
	10 June	Spring	21	21	21	21	21	21	21
	01 July	Summer	21	21	21	21	21	21	21
	22 July	Summer	--	0	0	0	0	--	0
	12 Aug.	Summer	0	21	21	21	21	--	21
	03 Sept.	Summer	22	22	22	22	22	--	22
1981	10 March	Spring	0	0	0	0	0	0	0
	07 April	Spring	28	28	28	28	28	28	28
	28 April	Spring	21	21	21	21	21	21	21
	20 May	Spring	22	22	22	22	22	22	22
	10 June	Spring	21	21	21	21	21	21	21
	01 July	Summer	21	21	21	21	21	21	21
	22 July	Summer	21	21	21	21	21	21	21
	12 Aug.	Summer	21	21	21	21	21	21	21
	02 Sept.	Summer	21	21	21	21	21	21	21

† Sorghum-sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

‡ 25 cm and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

§ 25 cm refers to the distance between fescue rows at seeding in fall 1974.

¶ 78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

Table 20. Species composition of individual pasture combinations during the 1979-1981 grazing season at Ames Plantation, Tennessee

Date	Orchardgrass	Legumes	Fescue	Bermudagrass	Weeds	Rye	Ryegrass	Sorghum-sudangrass	SCI†
Pasture combination 1 - Annuals‡ (0.4 ha) - Fescue + legumes (0.8 ha) Rep 1									
1979 20 March	0	0	0	0	0	100	0	---	1111.1
27 April	0	35	60	0	5	100	0	---	1341.1
17 May	0	45	50	0	5	---	--	---	1331.1
05 June	0	45	45	0	10	---	--	---	1331.1
26 June	0	55	40	0	5	---	--	100	1431.1
17 July	0	60	25	0	15	---	--	100	1421.1
07 Aug.	0	60	35	0	7	---	--	98	1421.1
05 Sept.	0	60	20	0	20	---	--	100	1421.1
1980 18 March	0	25	73	0	2	90	10	---	1251.1
08 April	0	30	67	0	3	90	10	---	1341.1
28 April	0	44	53	0	3	80	20	---	1331.1
19 May	0	59	40	0	1	---	--	---	1431.1
10 June	0	60	35	4	3	---	18	80	1421.1
01 July	0	48	52	0	17	---	63	20	1331.1
23 July	-	--	--	--	--	---	--	---	---
13 Aug.	0	25	65	10	0	---	--	0	1241.1
29 Aug.	0	25	60	15	0	---	--	0	1241.1
1981 10 March	0	25	65	0	10	35	65	---	1241.1
08 April	0	30	65	0	7	23	75	---	1341.1
27 April	0	30	63	0	7	---	--	---	1341.1
17 May	0	30	65	0	5	---	--	---	1341.1
12 June	0	43	50	5	2	0	50	50	1331.1
02 July	0	28	60	10	2	0	40	60	1241.1
22 July	0	25	65	0	25	---	--	85	1241.1
11 Aug.	0	15	80	0	5	---	--	0	1251.1
03 Sept.	0	20	65	15	0	---	--	0	1241.1

Table 20 (continued)

Date	Orchardgrass	Legumes	Fescue	Bermudagrass	Weeds	Rye	Ryegrass	Sorghum-sudangrass	SCI†
Pasture combination 1 - Annuals‡ (0.4 ha) - Fescue + legumes (0.8 ha) Rep 2									
1979 20 March	0	0	0	0	0	100	0	---	1111.1
27 April	0	20	65	0	15	100	0	---	1241.1
17 May	0	33	65	0	2	---	--	---	1341.1
05 June	0	55	40	0	5	---	--	---	1431.1
26 June	0	60	25	0	16	---	--	99	1421.1
17 July	0	50	20	0	30	---	--	100	1421.1
07 Aug.	0	65	10	0	40	---	--	85	1411.1
05 Sept.	0	65	10	0	25	---	--	100	1411.1
1980 18 March	0	25	72	0	3	90	10	---	1251.1
08 April	0	30	67	0	3	90	10	---	1341.1
28 April	0	70	20	0	10	80	20	---	1421.1
19 May	0	65	33	0	2	---	--	---	1421.1
10 June	0	65	30	0	10	0	20	75	1421.1
01 July	0	30	54	6	22	0	68	20	1331.1
23 July	-	--	--	--	--	---	--	---	---
13 Aug.	0	20	72	8	0	---	--	0	1251.1
29 Aug.	0	20	70	10	0	---	--	0	1251.1
1981 10 March	0	25	55	0	20	45	55	---	1231.1
08 April	0	25	60	0	20	30	65	---	1241.1
27 April	0	35	60	0	5	---	--	---	1341.1
17 May	0	30	68	0	2	---	--	---	1341.1
12 June	0	30	65	0	5	0	25	75	1341.1
02 July	0	36	62	0	2	0	20	80	1341.1
22 July	0	35	63	0	42	---	--	60	1341.1
11 Aug.	0	15	80	0	5	---	--	0	1251.1
03 Sept.	0	22	77	0	1	---	--	0	1251.1

Table 20 (continued)

Date		Orchardgrass	Legumes	Fescue	Bermudagrass	Weeds	Rye	Ryegrass	Sorghum-sudangrass	SCI†
Pasture combination 2 - Midland + fescue (50 cm)§ + legumes Rep 1										
1979	20 March	-	--	--	--	--	---	--	---	---
	27 April	0	15	7	25	53	0	0	0	1212.2
	17 May	0	12	8	30	50	0	0	0	1112.2
	05 June	0	30	10	45	15	0	0	0	1313.2
	26 June	0	31	4	60	5	0	0	0	1314.2
	17 July	0	35	7	55	3	0	0	0	1314.2
	07 Aug.	0	35	10	45	10	0	0	0	1313.2
	05 Sept.	0	33	8	46	13	0	0	0	1313.2
1980	18 March	0	45	52	3	0	0	0	0	1331.2
	08 April	0	40	45	5	10	0	0	0	1331.2
	28 April	0	70	5	5	20	0	0	0	1411.2
	19 May	0	43	42	5	10	0	0	0	1331.2
	10 June	0	45	28	25	2	0	0	0	1322.2
	01 July	0	39	25	36	0	0	0	0	1323.2
	23 July	0	18	30	52	0	0	0	0	1224.2
	13 Aug.	0	24	30	46	0	0	0	0	1223.2
	29 Aug.	0	22	33	45	0	0	0	0	1223.2
1981	10 March	0	35	50	0	15	0	0	0	1331.2
	08 April	0	30	60	8	2	0	0	0	1341.2
	27 April	0	10	85	5	0	0	0	0	1151.2
	17 May	0	20	68	12	0	0	0	0	1241.2
	12 June	0	25	58	15	2	0	0	0	1231.2
	02 July	0	24	32	43	1	0	0	0	1223.2
	22 July	0	20	30	50	0	0	0	0	1223.2
	11 Aug.	0	10	15	75	0	0	0	0	1115.2
	03 Sept.	0	25	31	40	4	0	0	0	1223.2

Table 20 (continued)

Date	Orchardgrass	Legumes	Fescue	Bermudagrass	Weeds	Rye	Ryegrass	Sorghum-sudangrass	SCI†
Pasture combination 2 - Midland + fescue (50 cm)§ + legumes Rep 2									
1979 20 March	-	--	--	--	--	---	--	---	---
27 April	0	10	0	50	40	0	0	0	1113.2
17 May	0	25	10	55	10	0	0	0	1214.2
05 June	0	40	5	45	10	0	0	0	1313.2
26 June	0	17	2	73	8	0	0	0	1215.2
17 July	0	18	4	68	10	0	0	0	1215.2
07 Aug.	0	30	0	65	5	0	0	0	1314.2
05 Sept.	0	25	0	72	3	0	0	0	1215.2
1980 18 March	0	45	37	8	10	0	0	0	1321.2
08 April	0	45	35	10	10	0	0	0	1321.2
28 April	0	75	0	15	10	0	0	0	1411.2
19 May	0	60	16	22	2	0	0	0	1422.2
10 June	0	56	13	29	2	0	0	0	1412.2
01 July	0	20	20	59	1	0	0	0	1224.2
23 July	0	20	25	55	0	0	0	0	1224.2
13 Aug.	0	15	15	70	0	0	0	0	1215.2
29 Aug.	0	20	15	65	0	0	0	0	1214.2
1981 10 March	0	55	35	0	10	0	0	0	1421.2
08 April	0	25	65	8	2	0	0	0	1241.2
27 April	0	20	45	30	5	0	0	0	1232.2
17 May	0	15	50	35	0	0	0	0	1232.2
12 June	0	20	35	35	10	0	0	0	1222.2
02 July	0	19	30	43	8	0	0	0	1223.2
22 July	0	18	20	60	2	0	0	0	1224.2
11 Aug.	0	7	5	85	3	0	0	0	1115.2
03 Sept.	0	8	20	69	3	0	0	0	1125.2

Table 20 (continued)

Date	Orchardgrass	Legumes	Fescue	Bermudagrass	Weeds	Rye	Ryegrass	Sorghum-sudangrass	SCI†
Pasture combination 3 - Midland + fescue (25 cm)§ + legumes Rep 1									
1979 20 March	-	--	--	--	--	---	--	---	---
27 April	0	5	3	20	72	0	0	0	1112.3
17 May	0	32	35	30	3	0	0	0	1322.3
05 June	0	27	0	70	3	0	0	0	1215.3
26 June	0	20	2	75	3	0	0	0	1215.3
17 July	0	18	5	73	4	0	0	0	1215.3
07 Aug.	0	30	0	65	5	0	0	0	1314.3
05 Sept.	0	32	0	59	9	0	0	0	1314.3
1980 18 March	0	27	65	8	0	0	0	0	1241.3
08 April	0	25	65	10	0	0	0	0	1241.3
28 April	0	60	20	15	5	0	0	0	1421.3
19 May	0	43	43	12	2	0	0	0	1331.3
10 June	0	40	35	23	2	0	0	0	1322.3
01 July	0	32	30	32	6	0	0	0	1322.3
23 July	0	15	30	55	0	0	0	0	1224.3
13 Aug.	0	18	32	50	0	0	0	0	1223.3
29 Aug.	0	20	28	52	0	0	0	0	1224.3
1981 10 March	0	50	45	0	5	0	0	0	1431.3
08 April	0	25	65	5	5	0	0	0	1241.3
27 April	0	35	52	10	3	0	0	0	1331.3
17 May	0	35	50	12	3	0	0	0	1331.3
12 June	0	23	40	35	2	0	0	0	1232.3
02 July	0	24	35	40	1	0	0	0	1223.3
22 July	0	20	30	50	0	0	0	0	1223.3
11 Aug.	0	10	25	65	0	0	0	0	1124.3
03 Sept.	0	16	24	50	10	0	0	0	1223.3

Table 20 (continued)

Date	Orchardgrass	Legumes	Fescue	Bermudagrass	Weeds	Rye	Ryegrass	Sorghum-sudangrass	SCI†
Pasture combination 3 - Midland + fescue (25 cm)§ + legumes Rep 2									
1979 20 March	-	--	--	--	--	---	--	---	---
27 April	0	2	2	56	40	0	0	0	1114.3
17 May	0	19	8	50	23	0	0	0	1213.3
05 June	0	20	0	70	10	0	0	0	1215.3
26 June	0	15	0	80	5	0	0	0	1215.3
17 July	0	12	3	82	3	0	0	0	1115.3
07 Aug.	0	20	0	65	15	0	0	0	1214.3
05 Sept.	0	20	0	75	5	0	0	0	1215.3
1980 18 March	0	25	67	4	4	0	0	0	1241.3
08 April	0	25	65	5	5	0	0	0	1241.3
28 April	0	25	65	10	0	0	0	0	1241.3
19 May	0	21	50	29	0	0	0	0	1232.3
10 June	0	23	38	35	4	0	0	0	1222.3
01 July	0	22	20	58	0	0	0	0	1224.3
23 July	0	20	30	50	0	0	0	0	1223.3
13 Aug.	0	15	25	60	0	0	0	0	1224.3
29 Aug.	0	25	23	63	0	0	0	0	1224.3
1981 10 March	0	35	55	0	10	0	0	0	1331.3
08 April	0	25	65	8	2	0	0	0	1241.3
27 April	0	25	53	20	2	0	0	0	1232.3
17 May	0	23	56	20	1	0	0	0	1232.3
12 June	0	30	35	30	5	0	0	0	1322.3
02 July	0	28	31	38	3	0	0	0	1223.3
22 July	0	22	25	53	0	0	0	0	1224.3
11 Aug.	0	10	15	70	5	0	0	0	1115.3
03 Sept.	0	20	25	53	2	0	0	0	1224.3

Table 20 (continued)

Date	Orchardgrass	Legumes	Fescue	Bermudagrass	Weeds	Rye	Ryegrass	Sorghum-sudangrass	SCI†
Pasture combination 4 - Midland + fescue (25 cm)¶# Rep 1									
1979 20 March	0	5	70	0	25	0	0	0	1151.4
27 April	0	0	52	24	24	0	0	0	1132.4
17 May	0	0	80	17	3	0	0	0	1151.4
05 June	0	5	50	45	0	0	0	0	1133.4
26 June	0	0	45	50	5	0	0	0	1133.4
17 July	0	0	52	43	5	0	0	0	1133.4
07 Aug.	0	0	35	60	5	0	0	0	1124.4
05 Sept.	0	0	30	65	5	0	0	0	1124.4
1980 18 March	0	0	95	5	0	0	0	0	1151.4
08 April	0	0	95	5	0	0	0	0	1151.4
28 April	0	3	85	10	2	0	0	0	1151.4
19 May	0	4	63	30	3	0	0	0	1142.4
10 June	0	2	60	36	2	0	0	0	1143.4
01 July	0	2	48	50	0	0	0	0	1133.4
23 July	0	0	40	60	0	0	0	0	1134.4
13 Aug.	0	0	35	65	0	0	0	0	1124.4
29 Aug.	0	0	30	70	0	0	0	0	1125.4
1981 10 March	0	0	90	0	10	0	0	0	1151.4
08 April	0	0	90	5	5	0	0	0	1151.4
27 April	0	0	90	10	0	0	0	0	1151.4
17 May	0	0	85	15	0	0	0	0	1151.4
12 June	0	0	70	28	2	0	0	0	1152.4
02 July	0	0	64	35	1	0	0	0	1142.4
22 July	0	0	60	35	5	0	0	0	1142.4
11 Aug.	0	0	45	55	0	0	0	0	1134.4
03 Sept.	0	0	40	56	4	0	0	0	1134.4

Table 20 (continued)

Date	Orchardgrass	Legumes	Fescue	Bermudagrass	Weeds	Rye	Ryegrass	Sorghum-sudangrass	SCI†
Pasture combination 4 - Midland + fescue (25 cm)¶# Rep 2									
1979 20 March	0	0	75	0	25	0	0	0	1151.4
27 April	0	0	70	15	15	0	0	0	1151.4
17 May	0	0	75	20	5	0	0	0	1152.4
05 June	0	0	67	29	4	0	0	0	1142.4
26 June	0	0	60	38	2	0	0	0	1143.4
17 July	0	0	55	39	6	0	0	0	1133.4
07 Aug.	0	0	35	50	15	0	0	0	1123.4
05 Sept.	0	0	35	57	8	0	0	0	1124.4
1980 18 March	0	0	94	3	3	0	0	0	1151.4
08 April	0	0	94	3	3	0	0	0	1151.4
28 April	0	15	75	10	0	0	0	0	1251.4
19 May	0	0	60	39	1	0	0	0	1143.4
10 June	0	0	54	45	1	0	0	0	1133.4
01 July	0	0	53	45	2	0	0	0	1133.4
23 July	0	0	35	65	0	0	0	0	1124.4
13 Aug.	0	0	20	80	0	0	0	0	1125.4
29 Aug.	0	0	20	80	0	0	0	0	1125.4
1981 10 March	0	0	85	0	15	0	0	0	1151.4
08 April	0	0	93	5	2	0	0	0	1151.4
27 April	0	0	69	30	1	0	0	0	1142.4
17 May	0	0	60	40	0	0	0	0	1143.4
12 June	0	0	50	45	5	0	0	0	1133.4
02 July	0	0	40	55	5	0	0	0	1134.4
22 July	0	0	35	63	2	0	0	0	1124.4
11 Aug.	0	0	30	65	5	0	0	0	1124.4
03 Sept.	0	0	22	70	8	0	0	0	1125.4

Table 20 (continued)

Date	Orchardgrass	Legumes	Fescue	Bermudagrass	Weeds	Rye	Ryegrass	Sorghum-sudangrass	SCI[†]
Pasture combination 5 - Fescue + legumes Rep 1									
1979 20 March	0	10	70	0	20	0	0	0	1151.5
27 April	0	25	60	0	15	0	0	0	1241.5
17 May	0	45	52	0	3	0	0	0	1331.5
05 June	0	48	50	0	2	0	0	0	1331.5
26 June	0	50	45	0	5	0	0	0	1431.5
17 July	0	55	38	0	7	0	0	0	1421.5
07 Aug.	0	78	12	0	10	0	0	0	1411.5
05 Sept.	0	80	14	0	6	0	0	0	1411.5
1980 18 March	0	25	75	0	0	0	0	0	1251.5
08 April	0	25	73	0	2	0	0	0	1251.5
28 April	0	30	70	0	0	0	0	0	1351.5
19 May	0	47	52	0	1	0	0	0	1331.5
10 June	0	49	50	0	1	0	0	0	1331.5
01 July	0	36	62	0	2	0	0	0	1341.5
23 July	0	25	65	10	0	0	0	0	1241.5
13 Aug.	0	20	75	5	0	0	0	0	1251.5
29 Aug.	0	20	75	5	0	0	0	0	1251.5
1981 10 March	0	10	80	0	10	0	0	0	1151.5
08 April	0	12	85	0	3	0	0	0	1151.5
27 April	0	10	87	0	3	0	0	0	1151.5
17 May	0	12	85	0	3	0	0	0	1151.5
12 June	0	32	55	10	3	0	0	0	1331.5
02 July	0	33	57	8	2	0	0	0	1331.5
22 July	0	18	75	0	7	0	0	0	1251.5
11 Aug.	0	20	75	0	5	0	0	0	1251.5
03 Sept.	0	20	75	5	0	0	0	0	1251.5

Table 20 (continued)

Date	Orchardgrass	Legumes	Fescue	Bermudagrass	Weeds	Rye	Ryegrass	Sorghum-sudangrass	SCI†
Pasture combination 5 - Fescue + legumes			Rep 2						
1979 20 March	0	15	70	0	15	0	0	0	1251.5
27 April	0	30	45	0	25	0	0	0	1331.5
17 May	0	40	50	0	10	0	0	0	1331.5
05 June	0	55	38	5	2	0	0	0	1421.5
26 June	0	45	35	0	10	10	0	0	1321.5
17 July	0	65	28	0	7	0	0	0	1421.5
07 Aug.	0	70	10	0	20	0	0	0	1411.5
05 Sept.	0	72	10	0	18	0	0	0	1411.5
1980 18 March	0	54	40	1	1	0	0	0	1431.5
08 April	0	55	40	2	3	0	0	0	1431.5
28 April	0	60	30	5	5	0	0	0	1421.5
19 May	0	48	49	2	1	0	0	0	1331.5
10 June	0	53	45	0	2	0	0	0	1431.5
01 July	0	40	48	10	2	0	0	0	1331.5
23 July	0	0	20	80	0	0	0	0	1125.5
13 Aug.	0	14	50	35	1	0	0	0	1132.5
29 Aug.	0	14	50	35	1	0	0	0	1132.5
1981 10 March	0	35	55	0	10	0	0	0	1331.5
08 April	0	30	50	0	20	0	0	0	1331.5
27 April	0	30	47	20	3	0	0	0	1332.5
17 May	0	35	55	0	10	0	0	0	1331.5
12 June	0	23	45	27	5	0	0	0	1232.5
02 July	0	28	35	34	3	0	0	0	1222.5
22 July	0	15	56	0	29	0	0	0	1231.5
11 Aug.	0	5	55	0	40	0	0	0	1131.5
03 Sept.	0	15	40	45	0	0	0	0	1233.5

Table 20 (continued)

Date	Orchardgrass	Legumes	Fescue	Bermudagrass	Weeds	Rye	Ryegrass	Sorghum-sudangrass	SCI†
Pasture combination 6 - Orchardgrass + clover Rep 1									
1979 20 March	-	--	--	--	--	---	--	---	---
27 April	-	--	--	--	--	---	--	---	---
17 May	50	20	0	0	30	0	0	0	2211.6
05 June	40	40	0	0	20	0	0	0	2311.6
26 June	45	55	0	0	0	0	0	0	2411.6
17 July	55	40	0	0	5	0	0	0	2311.6
07 Aug.	45	45	0	0	10	0	0	0	2311.6
05 Sept.	40	46	0	0	14	0	0	0	2311.6
1980 18 March	--	--	--	--	--	---	--	---	---
08 April	35	65	0	0	0	0	0	0	1411.6
28 April	25	75	0	0	0	0	0	0	1411.6
19 May	50	50	0	0	0	0	0	0	2411.6
10 June	60	40	0	0	0	0	0	0	2311.6
01 July	43	54	0	0	3	0	0	0	2411.6
23 July	--	--	--	--	--	---	--	---	---
13 Aug.	--	--	--	--	--	---	--	---	---
29 Aug.	--	--	--	--	--	---	--	---	---
1981 10 March	40	45	0	0	15	0	0	0	2311.6
08 April	75	23	0	0	2	0	0	0	3211.6
27 April	60	35	0	0	5	0	0	0	2311.6
17 May	75	25	0	0	0	0	0	0	3211.6
12 June	70	25	0	0	5	0	0	0	3211.6
02 July	65	35	0	0	0	0	0	0	2311.6
22 July	65	32	0	0	3	0	0	0	2311.6
11 Aug.	75	15	0	0	10	0	0	0	3211.6
03 Sept.	68	20	0	5	7	0	0	0	2211.6

Table 20 (continued)

Date	Orchardgrass	Legumes	Fescue	Bermudagrass	Weeds	Rye	Ryegrass	Sorghum-sudangrass	SCI†
Pasture combination 6 - Orchardgrass + clover Rep 2									
1979 20 March	--	--	--	--	--	---	--	---	---
27 April	--	--	--	--	--	---	--	---	---
17 May	45	30	0	0	25	0	0	0	2311.6
05 June	45	40	0	0	15	0	0	0	2311.6
26 June	47	48	0	0	5	0	0	0	2311.6
17 July	48	45	0	0	7	0	0	0	2311.6
07 Aug.	40	55	0	0	5	0	0	0	2411.6
05 Sept.	35	55	0	0	10	0	0	0	1411.6
1980 18 March	--	--	--	--	--	---	--	---	---
08 April	43	55	0	0	2	0	0	0	2411.6
28 April	30	65	0	0	5	0	0	0	1411.6
19 May	60	39	0	0	1	0	0	0	2311.6
10 June	41	58	0	0	1	0	0	0	2411.6
01 July	50	45	0	0	5	0	0	0	2311.6
23 July	--	--	--	--	--	---	--	---	---
13 Aug.	--	--	--	--	--	---	--	---	---
29 Aug.	--	--	--	--	--	---	--	---	---
1981 10 March	65	25	0	0	10	0	0	0	2211.6
08 April	85	11	0	0	4	0	0	0	3111.6
27 April	90	7	0	0	3	0	0	0	3111.6
17 May	90	8	0	0	2	0	0	0	3111.6
12 June	70	25	0	0	5	0	0	0	3211.6
02 July	66	30	0	0	4	0	0	0	2311.6
22 July	75	20	0	0	5	0	0	0	3211.6
11 Aug.	70	5	0	0	25	0	0	0	3111.6
03 Sept.	62	20	0	0	18	0	0	0	2211.6

Table 20 (continued)

Date	Orchardgrass	Legumes	Fescue	Bermudagrass	Weeds	Rye	Ryegrass	Sorghum-sudangrass	SCI†
Pasture combination 7 - Common + fescue (25 cm)§ + legumes Rep 1									
1979 20 March	-	--	--	--	--	---	--	---	---
27 April	0	5	0	45	50	0	0	0	1113.7
17 May	0	25	5	50	20	0	0	0	1213.7
05 June	0	32	0	58	10	0	0	0	1314.7
26 June	0	25	0	70	5	0	0	0	1215.7
17 July	0	47	0	50	3	0	0	0	1313.7
07 Aug.	0	35	0	60	5	0	0	0	1314.7
05 Sept.	0	36	0	61	3	0	0	0	1314.7
1980 18 March	-	--	--	--	--	---	--	---	---
08 April	0	20	70	5	5	0	0	0	1251.7
28 April	0	35	45	10	10	0	0	0	1331.7
19 May	0	55	35	8	2	0	0	0	1421.7
10 June	0	43	30	25	2	0	0	0	1322.7
01 July	0	30	15	52	3	0	0	0	1314.7
23 July	0	25	25	50	0	0	0	0	1223.7
13 Aug.	0	18	20	62	0	0	0	0	1224.7
29 Aug.	0	20	20	60	0	0	0	0	1224.7
1981 10 March	0	25	60	0	15	0	0	0	1241.7
08 April	0	15	75	5	5	0	0	0	1251.7
27 April	0	20	65	5	10	0	0	0	1241.7
17 May	0	21	68	7	4	0	0	0	1241.7
12 June	0	22	45	25	8	0	0	0	1232.7
02 July	0	34	35	25	6	0	0	0	1322.7
22 July	0	40	25	32	3	0	0	0	1322.7
11 Aug.	0	30	15	55	0	0	0	0	1314.7
03 Sept.	0	26	25	46	3	0	0	0	1223.7

Table 20 (continued)

Date	Orchardgrass	Legumes	Fescue	Bermudagrass	Weeds	Rye	Ryegrass	Sorghum-sudangrass	SCI†
Pasture combination 7 - Common + fescue (25 cm)§ + legumes Rep 2									
1979 20 March	-	--	--	--	--	---	--	---	---
27 April	0	5	0	40	55	0	0	0	1113.7
17 May	0	25	5	50	20	0	0	0	1213.7
05 June	0	30	0	60	10	0	0	0	1314.7
26 June	0	13	0	80	7	0	0	0	1115.7
17 July	0	25	0	70	5	0	0	0	1215.7
07 Aug.	0	35	0	60	5	0	0	0	1314.7
05 Sept.	0	34	0	62	4	0	0	0	1314.7
1980 18 March	-	--	--	--	--	---	--	---	---
08 April	0	25	60	5	10	0	0	0	1241.7
28 April	0	25	60	10	5	0	0	0	1241.7
19 May	0	42	31	25	2	0	0	0	1322.7
10 June	0	45	28	25	2	0	0	0	1322.7
01 July	0	30	25	40	5	0	0	0	1323.7
23 July	0	30	35	35	0	0	0	0	1322.7
13 Aug.	0	22	25	53	0	0	0	0	1224.7
29 Aug.	0	25	25	50	0	0	0	0	1223.7
1981 10 March	0	30	50	0	20	0	0	0	1331.7
08 April	0	20	70	5	5	0	0	0	1251.7
27 April	0	35	53	5	7	0	0	0	1331.7
17 May	0	30	60	8	2	0	0	0	1341.7
12 June	0	55	25	15	5	0	0	0	1421.7
02 July	0	28	34	33	5	0	0	0	1222.7
22 July	0	44	23	31	2	0	0	0	1322.7
11 Aug.	0	35	8	57	0	0	0	0	1314.7
03 Sept.	0	35	26	35	4	0	0	0	1322.7

Table 20 (continued)

† (Orchardgrass frequency class * 1000) + (legumes frequency class * 100) + (fescue frequency class * 10) + (bermudagrass frequency class) + (Treatment number * 0.1).

‡ Sorghum-sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

§ 25 cm and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

¶ 25 cm ryers to the distance between fescue rows at seeding in fall 1974.

78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

Table 21. Coefficients of least square regression equations for forage growth and consumption, gain, beef production, grazing days, and stocking rates for seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee

		Partial regression coefficients†				
		b_0	b_1	b_2	b_3	R^2
Dependent variable	Pasture combination					
Forage growth, kg/ha	Annuals (0.4 ha)‡-Fescue + legumes (0.8 ha)	-3887.22	67.6224	0.02802564		0.95
	Midland + fescue (50 cm)§ + legumes	-3031.31	34.0111	0.05645988		0.97
	Midland + fescue (25 cm)§ + legumes	-1220.09	6.3068	0.11824350		0.96
	Midland + fescue (25 cm)¶††	-4568.84	75.6029	0.00699665		0.97
	Fescue + legumes	-1461.06	16.3111	0.10806441		0.95
	Orchardgrass + clover	-6308.69	70.9226	-0.03750894		0.96
	Common + fescue (25 cm)§ + legumes	331.85	-15.8783	0.19477904		0.95
Forage consumption, kg/ha	Annuals (0.4 ha)‡-Fescue + legumes (0.8 ha)	-4224.21	53.7285	0.00652557		0.89
	Midland + fescue (50 cm)§ + legumes	-2826.25	25.1019	0.05212194		0.95
	Midland + fescue (25 cm)§ + legumes	-1810.46	11.2624	0.07172243		0.96
	Midland + fescue (25 cm)¶††	-5951.47	83.5658	-0.05953524		0.97
	Fescue + legumes	-1769.36	18.4486	0.07822949		0.91
	Orchardgrass + clover	-7058.03	66.0490	-0.02455807		0.95
	Common + fescue (25 cm)§ + legumes	- 980.53	- 0.6946	0.11870524		0.93
Gain, kg/steer	Annuals (0.4 ha)‡-Fescue + legumes (0.8 ha)	- 111.26	1.7982	-0.00358054		0.93
	Midland + fescue (50 cm)§ + legumes	- 118.48	1.6409	-0.00304675		0.91
	Midland + fescue (25 cm)§ + legumes	- 114.65	1.5271	-0.00265302		0.90
	Midland + fescue (25 cm)¶††	- 70.93	1.1658	-0.00228341		0.94
	Fescue + legumes	- 106.97	1.6908	-0.00288775		0.93
	Orchardgrass + clover	- 109.02	1.4120	-0.00208179		0.90
	Common + fescue (25 cm)§	- 116.59	1.4783	-0.00242074		0.95

Table 21 (continued)

		Partial regression coefficients†				
		b_o	b_1	b_2	b_3	R^2
Beef production, kg/ha	Annuals (0.4 ha)‡-Fescue + legumes (0.8 ha)	- 447.43	6.8405	-0.01340408		0.91
	Midland + fescue (50 cm)§ + legumes	- 548.86	7.1223	-0.01195583		0.91
	Midland + fescue (25 cm)§ + legumes	- 543.44	6.9378	-0.01087069		0.96
	Midland + fescue (25 cm)¶††	- 564.79	8.5948	-0.01533545		0.87
	Fescue + legumes	- 471.72	6.6785	-0.00964219		0.80
	Orchardgrass + clover	- 670.31	8.9449	-0.00168052		0.93
	Common + fescue (25 cm)§ + legumes	- 442.93	5.4970	-0.00845076		0.92
Grazing days, days/ha	Annuals (0.4 ha)‡-Fescue + legumes (0.8 ha)	- 413.62	5.4307	-0.00507383		0.92
	Midland + fescue (50 cm)§ + legumes	- 409.20	4.0562	0.00330709		0.97
	Midland + fescue (25 cm)§ + legumes	- 475.31	5.0073	0.00152593		0.96
	Midland + fescue (25 cm)¶††	- 786.09	9.7643	-0.00089347		0.97
	Fescue + legumes	- 375.78	4.3470	0.00141891		0.95
	Orchardgrass + clover	- 811.14	9.1174	-0.01229975		0.97
	Common + fescue (25 cm)§ + legumes	- 309.91	2.9492	0.00283837		0.99
Stocking rate, steer/ha	Annuals (0.4)‡-Fescue + legumes (0.8 ha)	- 20.61	0.4210	-0.00227530	0.0000038728758	0.69
	Midland + fescue (50 cm)§ + legumes	- 18.33	0.3562	-0.00178455	0.0000029377030	0.62
	Midland + fescue (25 cm)§ + legumes	- 22.45	0.4377	-0.00222068	0.0000036244582	0.64
	Midland + fescue (25 cm)¶††	- 52.57	1.0894	-0.00608194	0.0000010803461	0.76
	Fescue + legumes	- 27.79	0.5632	-0.00320253	0.0000058432452	0.51
	Orchardgrass + clover	- 21.79	0.4209	-0.00208765	0.0000032122551	0.48
	Common + fescue (25 cm)§ + legumes	- 15.46	0.3233	-0.00183986	0.0000034802771	0.34

† Dependent variable = $b_o + b_1 * \text{Julian day} + b_2 * (\text{Julian day})^2 + b_3 * (\text{Julian day})^3$.

‡ Sorghum-sudangrass hybrid seeded in mid-May; rye-ryegrass seeded in early September. 34 kg N/ha in early March and in early May, and 67 kg N/ha in mid-June.

§ 25 and 50 cm refer to the distance between fescue rows at seeding in fall 1978.

¶ 25 cm refers to the distance between fescue rows at seeding in fall 1974.

†† 78 kg N/ha in mid-March, in mid-May and in early July, and 67 kg N/ha in September.

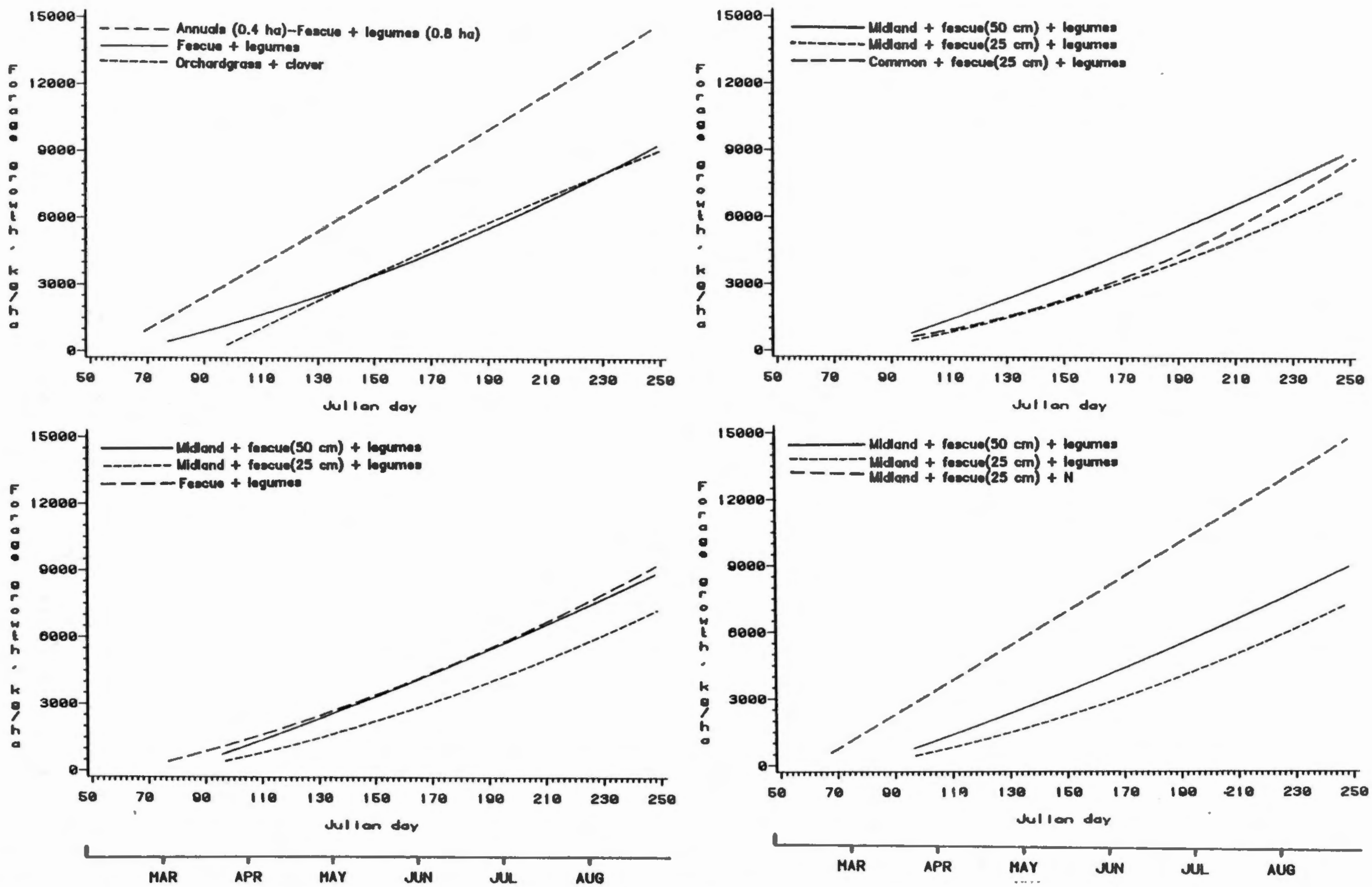

Figure 5. Cumulative forage growth for seven different pasture combinations during the 1979–1981 grazing seasons at Ames Plantation, Tennessee.

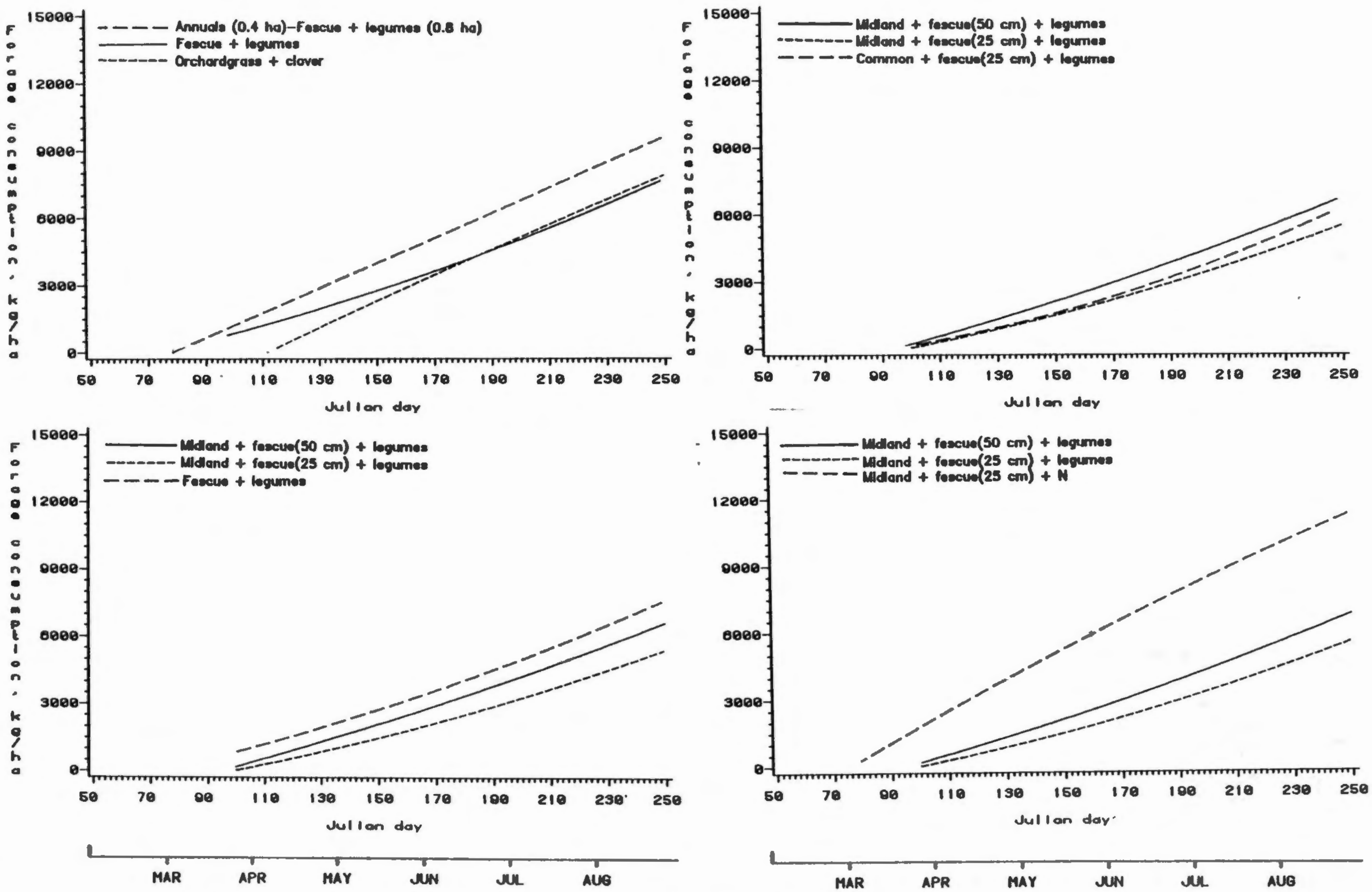

Figure 6. Cumulative forage consumption for seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee.

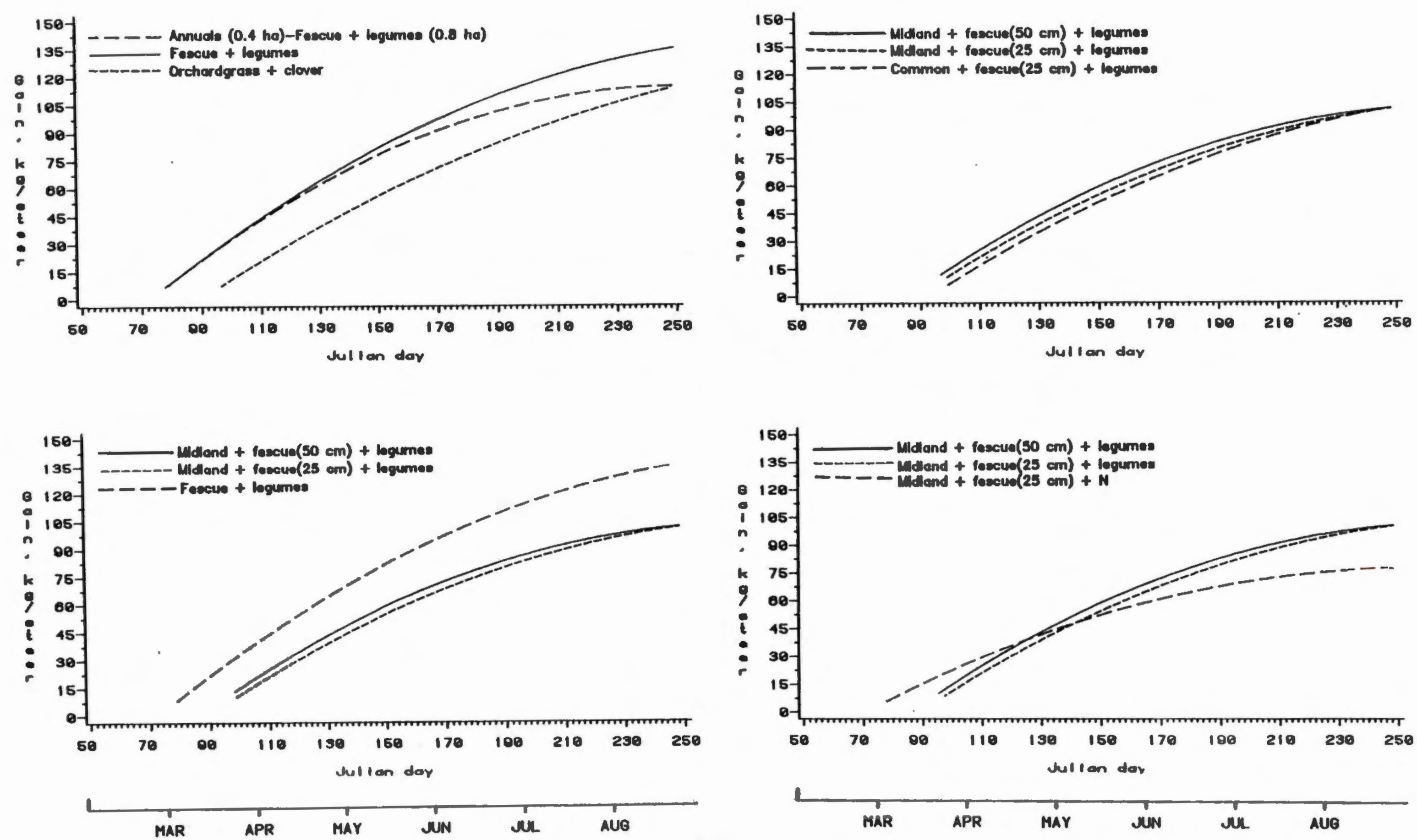

Figure 7. Cumulative steer gain for seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee.

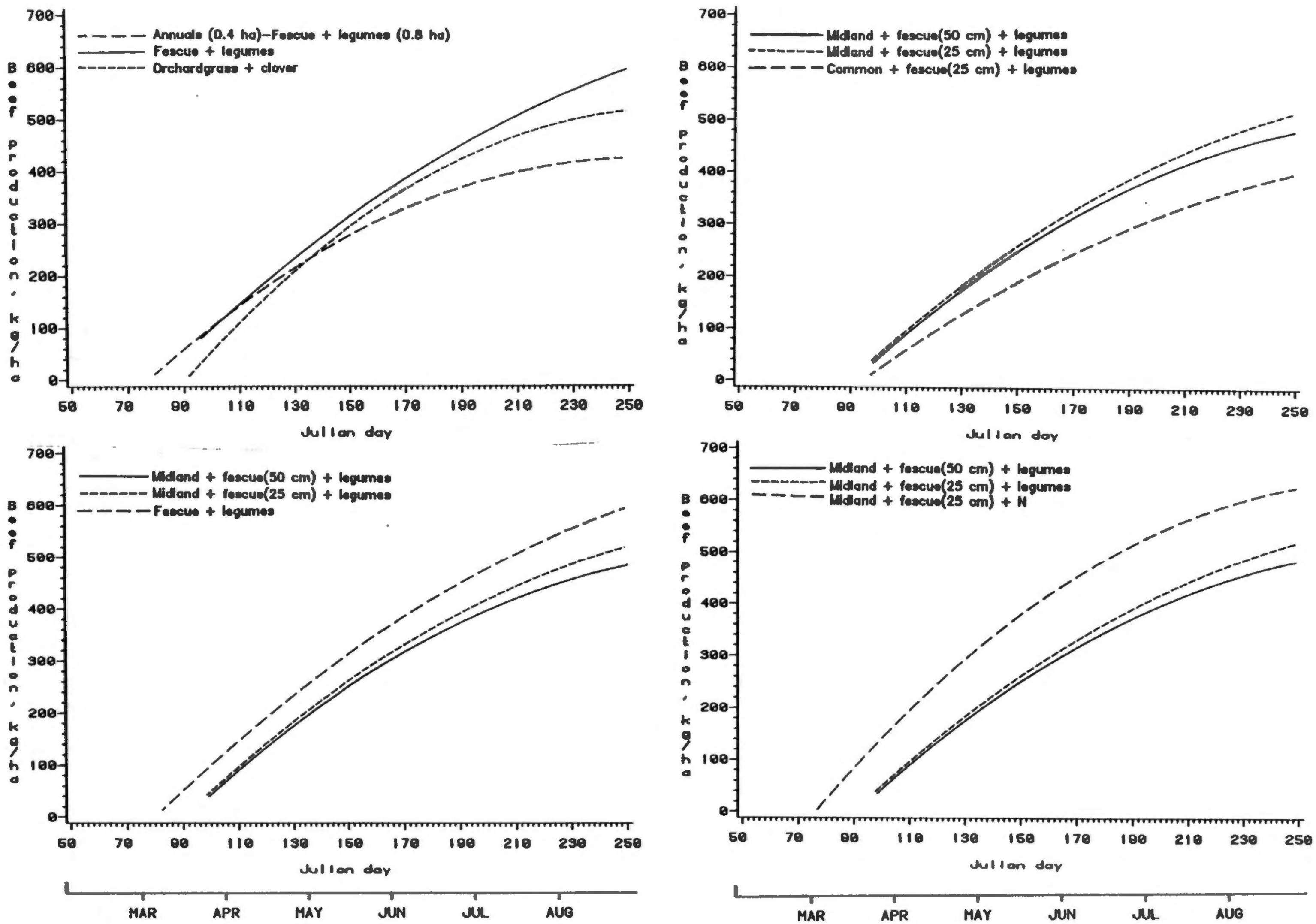

Figure 8. Cumulative beef production for seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee.

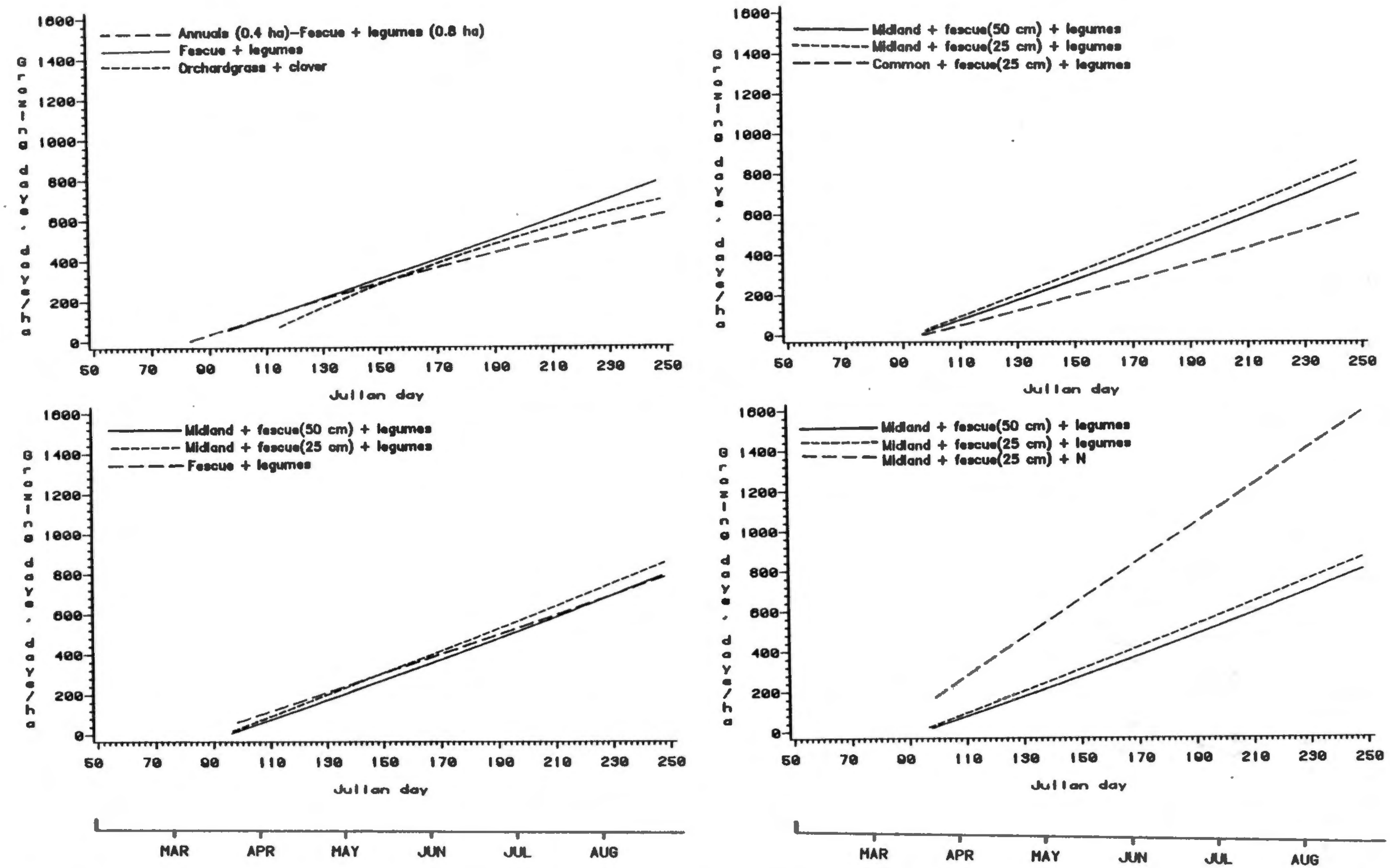

Figure 9. Cumulative grazing days for seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee.

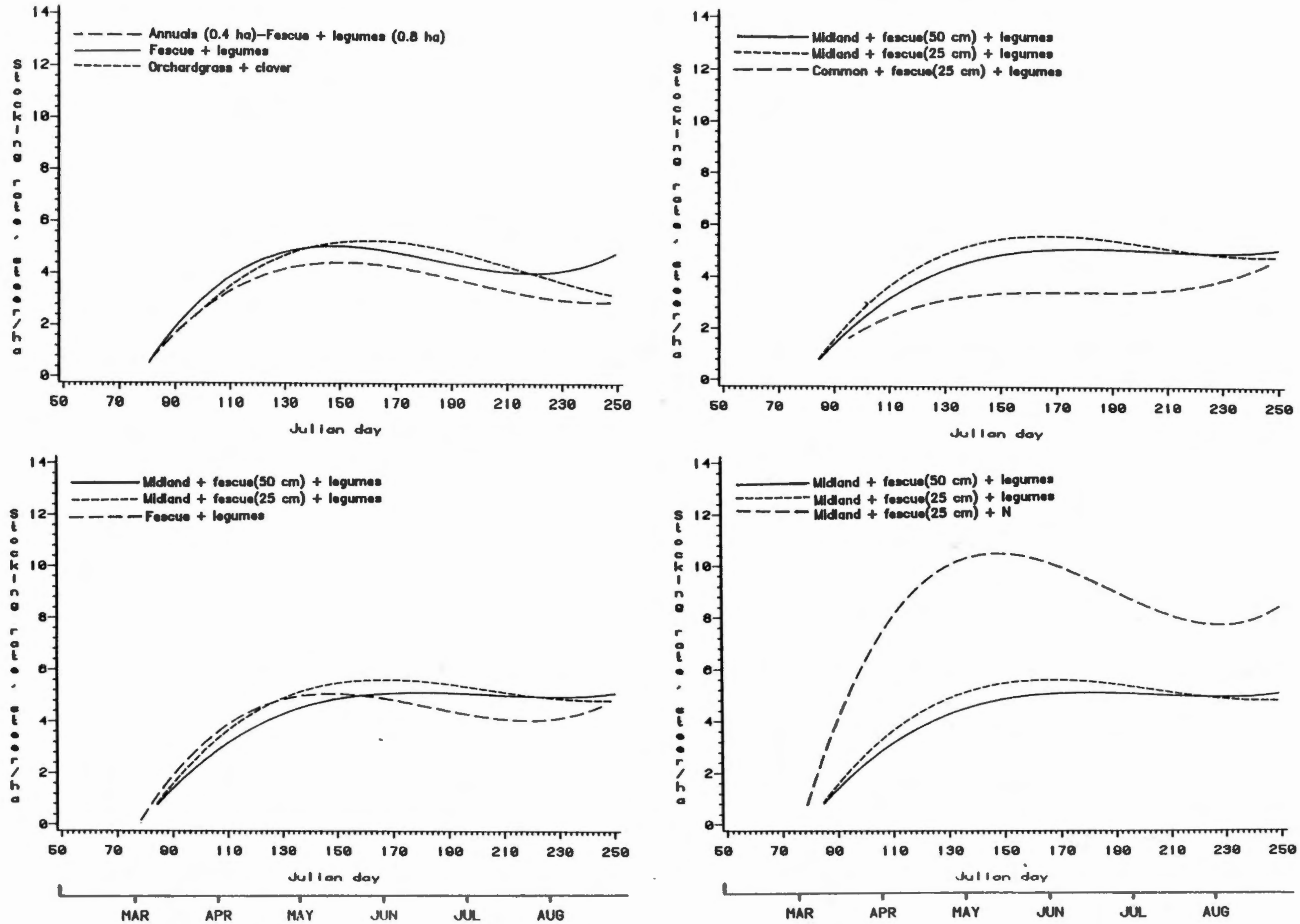

Figure 10. Stocking rate for seven different pasture combinations during the 1979-1981 grazing seasons at Ames Plantation, Tennessee.

VITA

Ronald Lewis Mitchell was born in Ardmore, Oklahoma on July 14, 1957 to Mr. and Mrs. William C. Mitchell, Jr. He was reared on a south-central Oklahoma ranch near Overbrook, Oklahoma. He attended primary and secondary schools in Ardmore, Oklahoma and was graduated from Ardmore High School in May 1975. The following August he entered Murray State College, Tishomingo, Oklahoma and received an Associate of Science degree in Agriculture in May 1977. The following fall he entered Oklahoma State University and completed the Bachelor of Science degree in Agronomy in May 1979. In June 1979 he accepted a Graduate Research Assistantship at Oklahoma State University to begin studies toward a Master's degree in Agronomy. This degree was awarded in May 1981.

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The author is a member of Phi Kappa Phi, Alpha Zeta, Gamma Sigma Delta, Phi Theta Kappa, American Society of Agronomy, Crop Science Society of America, American Forage and Grassland Council, Society for Range Management, American Society of Animal Science, and the National Cattlemen's Association. Mr. Mitchell will be employed by the Louisiana Agricultural Experiment Station as an Assistant Professor of Agronomy at the Northeast Research Station at St. Joseph and its Macon Ridge Branch at Winnsboro. His primary responsibilities will be research in forage crop production and management, and beef cattle production.