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Forage Legume Research

Review of Literature and Recommendations for East Texas

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Summary

In the past few years increased attention has been focused on the use of legumes in forage-livestock production systems. The importance of forage legumes as a source of both high-quality forage and cheap nitrogen has been recognized anew, particularly in the southern United States where marginal land unsuited for row-crop production can be successfully utilized for pasture and/or hay. A large number of forage legume species and a wide range of genetic diversity within species provide the genetic potential for development of improved varieties. Cultural practices must also be more adequately defined through research in order to improve the dependability of forage legumes. This report reviews pertinent research findings, enumerates the major problems of forage legume production in East Texas, and presents general recommendations for future research efforts. Significant advances may be achieved through a coordinated program of genetic improvement and production-management research.

Introduction

"There is a definite need for a legume that will produce a high yield of forage, that can stand grazing and is compatible with the pasture grasses" (11). Although some progress has been made, these words written by an East Texas agronomist in 1952 convey a challenge that still confronts forage researchers. The production of legumes was widely promoted in the United States before World War II. Much attention was focused on their nitrogen fixation capability and general soil improvement properties. Various winter annual legume species were utilized as green manure crops in rotation with warm-season row crops (49). Within the past few years, the use of legumes in animal-forage grazing systems has been rediscovered. The "revival" of interest in grass-legume mixtures has resulted primarily from the high cost of nitrogen fertilizer. Legumes grown in association with grass species can supply some of the N required by the companion species. This benefit has often been overemphasized with a resulting lack of attention to the other benefits derived from legumes. Forage legumes may provide (a) high-quality forage in terms of increased amounts of protein and energy, (b) improved animal performance, (c) a lengthened grazing period, and (d) an increase in dry matter production over that of perennial grass species grown in pure stands.

Fifty percent of all beef cows in the United States are found in the South (21). Most of these animals are found on relatively small farms where the cow-calf operation supplements the part-time farmer's income. Traditionally in the United States, slaughter cattle have been fattened on feed concentrates in the feedlot. However, with the world's booming population demanding a larger portion of grain for direct human consumption, more emphasis has been given to fattening cattle entirely on pasture.

Description of Environment

Due to climatic and soil conditions, the southern United States is in a unique position to implement year-round grazing systems for ruminant animals. The lower South is generally defined as the area that lies below the 33rd parallel and east of the 100th meridian. East Texas lies in the western portion of the lower South, with the Texas-Oklahoma border located just south of the 34th parallel. The region is generally referred to as the "East Texas Pineywoods" and is bordered by the Blackland Prairie on the west and the Coastal Prairie and Gulf Coast Marsh to the south. The total area of the East Texas Pineywoods is approximately 15 million acres, ranging from rolling to hilly terrain. The soils are generally sandy, acidic, low in fertility, and have a

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low water-holding capacity. Surface soils are usually light in color and may be underlain by soils having a slightly higher percentage of clay. The area is best adapted to forage-livestock agriculture since erosion may be severe on cultivated sloping land. Upland soils cover 85 percent of the region (9).

The average frost-free growing season is 240 days. Rainfall averages 1,200 mm (47 inches) annually but is unevenly distributed, with the winter and spring months receiving the greatest amounts. Drouths can be expected to occur quite frequently during the summer months (July to September). Figure 1 illustrates the seasonality of rainfall at Overton, Texas, over a 4-year period. Summer temperatures are high but winters are characterized by relatively mild average minimum temperatures (Figure 2). Although the average annual rainfall and monthly average temperatures may seem to indicate a favorable year-round climate for growth of forage crops, Figures 1 and 2 illustrate the fact that climatic conditions may be extremely harsh during summer and fall months.

Identification of Research Needs

Coastal bermudagrass, *Cynodon dactylon* (L.) Pers., is the primary warm-season perennial grass grown in the region. It is extremely drouth-tolerant and provides a solid base around which year-round forage systems can be assimilated. Perennial legume species grown with bermudagrass would provide a higher quality forage, as well as supplying part of the nitrogen requirement of the grass. At present, annual legume species such as arrowleaf (*Trifolium vesiculosum* Savi) and crimson (*T. incarnatum* L.) clovers are used with cereal grains for winter pasture and can be overseeded on warm-season perennial grasses. Specific areas of legume research which need to be addressed include: (a) identifying a perennial legume species to improve summer forage quality; (b) adjusting the production period of winter annual legumes to provide earlier fall grazing; (c) increasing the dependability of legume crops by selecting for seedling vigor, low temperature growth, and reseeding ability; (b) identifying species and genotypes within species having improved rates of nitrogen fixation; and (e) quantifying fertility requirements and improved management techniques for various legume species.

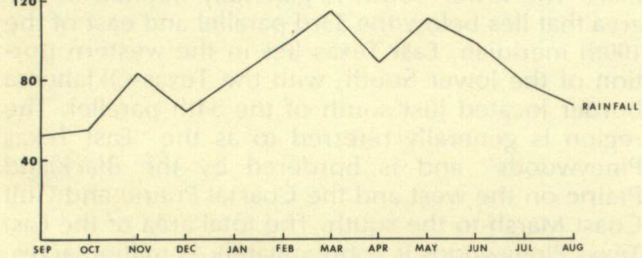

Figure 1. Seasonal rainfall distribution at Overton, Texas, 1975-1978.

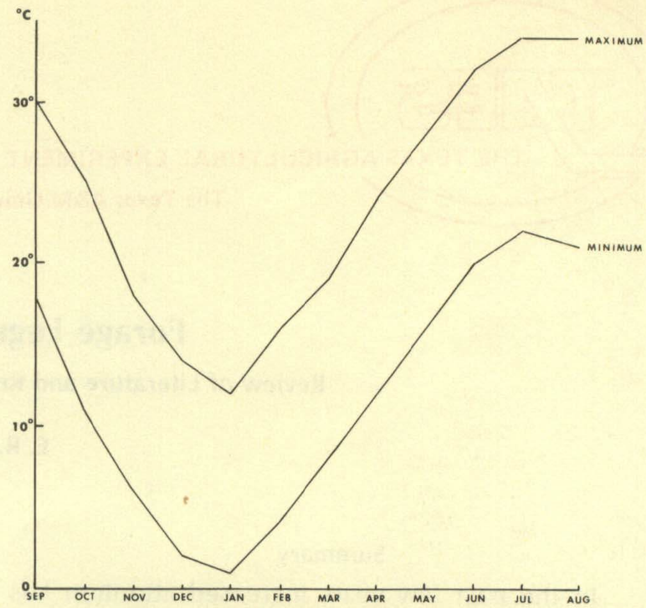

Figure 2. Average maximum and minimum monthly temperatures (°C) at Overton, Texas, 1975-1978.

The beef and dairy industries are quite important to the East Texas economy, contributing 377 million and 168 million dollars, respectively, to the total 1979 farm sales of 1.2 billion dollars (43). Some forage is marketed directly as hay ($82 million), but the primary research emphasis should be directed toward improving pasture legumes. The increased dependability of annual legumes and the development of a persistent, perennial legume for East Texas would greatly enhance the livestock industry in the region. These improvements, when incorporated into an overall, year-round forage system, are essential in achieving the goals of forage-fed beef and decreased production costs for cow-calf producers. Similarly, dairy farmers could reduce feed costs by producing rather than buying high-quality forage. Use of pasture legumes would also provide a cheaper source of N as part of the N requirement of companion grass species.

Review of Literature

The advantages and desirability of legume-grass forage mixtures over pure grass swards have been well-documented (5,6,30,39). However, legumes are grown most successfully in specific environmental niches and are generally less flexible than many grass species in their range of adaptation. Burton, in a recent review comparing legume N versus fertilizer N for warm-season grasses, concluded that forage legumes can replace fertilizer N profitably only in those situations where soils and climatic conditions are favorable (7). General problem areas encountered in the growth and utilization of forage legumes include (a) establishment, (b) lack of stand persistence in perennial species, (c) bloat, (d) animal reproductive disorders, and (3) the overall higher level of management required (55).

Alfalfa (*Medicago sativa* L.) production in the lower South has been limited, due in part to the acidic, infertile, and sandy soils found there (8). Root diseases, insects, and nematodes are also detrimental to the use of alfalfa in that region. Winter annual legume species have been widely used alone in overseeded bermudagrass pastures (33) and in mixtures with winter annual grasses seeded in a prepared seedbed (25). Perennial legumes have an obvious advantage over annuals in that stands do not have to be established from seed each year. However, annual legumes are better adapted in many areas of the lower South due to soil conditions and drouth periods that are unfavorable for many perennial species (23,27).

Relatively little is known about a large number of forage legume genera, and species within genera, in terms of potential for agronomic improvement (3). A wide range of germplasm material should be evaluated to determine the adaptation and potential of various species for the East Texas area. Several of the currently grown annual legume species and cultivars have been developed by selection and direct seed increase from the original plant introduction (1,4,26,29,36,38). Texas has 304 native legume species and 44 introduced species, which grow as weeds along roadsides and in other areas (57). However, the use of native legumes in rangeland areas was studied in Oklahoma, and researchers concluded that their reseeding ability was too poor for them to be of value (31). Results of experiments to identify forage legume genotypes tolerant to suboptimal soil and climatic conditions are encouraging (2,16,41,42). Screening germplasm for tolerance to low levels of soil fertility, low soil pH, and low management inputs may be initially frustrating for the researcher but highly successful in the long run.

A 1977 survey found that forage legume selection and/or breeding programs were being conducted in all Southeastern states expect Texas and Tennessee (35). Over the last several years, three forage legume species have been improved and released as cultivars for specific areas in Texas (1,10,29).Cultivar/species tests on various forage legumes have been conducted sporadically in Texas for many years (11,12). Recent tests have been conducted in the Gulf Coast area (17,18,19) and also on the sandy soils of upper East Texas (20). These tests show white clover (*T. repens* L.) to be a well-adapted perennial on the heavy, poorly drained soils while arrowleaf and subterranean (*T. subterrnaeum* L.) annual clovers grow well in both areas. Subterranean clover has not been widely used in the area but has several advantageous qualities, including tolerance of acidic soils and reliable reseeding under continuous grazing (48). Additional information is needed on the adaptation and potential of these and other species on sandy, low pH soils, and on the differences between cultivars within species for use in a long-term breeding program.

Forage legume breeding programs have generally been directed toward improving seedling vigor, improving reseeding ability in annual species, increasing stand persistence in perennials, increasing yield, adjusting the time and/or length of the production period, and improving pest resistance. Seedling vigor and seed size have been shown to be highly correlated (13). However, differences in vigor between seedlings from seed of the same size have also been observed. Townsend and Wilson (56) suggested the use of various correlated growth characteristics as a basis for selection to improve seedling vigor in cicer milkvetch (*Astragalus cicer* L.). High soil temperatures and dry conditions normally present in East Texas during September and October dictate a breeding effort to improve seedling vigor. Early establishment and adequate growth is desirable to provide forage for grazing at an earlier date. Selection for improved seedling vigor and increased growth rate can be used to shorten the time between seedling and the presence of available forage for grazing. Reseeding ability is very important in maintaining annual legumes in perennial grass sods. Two components of reseeding ability are seed production (22,52) and the proportion of hard seeds produced (59). Both of these traits lend themselves to selection and subsequent genetic improvement.

Stand persistence, yield, and pest resistance are other traits to be considered in a forage legume breeding program. Acceptable perennial species must withstand drouth conditions during summer months while producing adequate forage. Both quality and quantity should be considered in improving yields of forage legumes. Animal performance is the best overall indicator of forage yield and quality but is difficult to measure. Alfalfa provides high-quality hay forage but has not been successfully exploited in the lower South except on widely scattered alluvual soils (8). A developing area of research has given rise to the possibility of breeding for N fixation rate in alfalfa (15), and the techniques developed for alfalfa might be used in other legume species to improve N fixation potential. Improved cultivars and/or species must also have adequate resistance to insects and diseases. Nematodes cause significant economic losses in many legume species, and development of resistant types has long been a major objective in alfalfa improvement (28).

Forage legume breeding programs in the United States have relied heavily on plant materials introduced from other countries as a source of germplasm. Various breeding methods are utilized depending on the species, mode of pollination, and generation interval. Natural selection, mass selection, recurrent selection, and inbreeding followed by hybridization have been utilized in annual clover breeding (34). Several crimson clover cultivars were developed as a result of natural selection for hard seed (37). Recurrent restricted phenotypic selection is currently being used in the development of new cultivars of arrowleaf clover (46). Interspecific hybridization (14,51) and cell-tissue culture (47) are relatively new techniques that have been used with only a limited number of species but appear to hold great promise for the future.

Management of forage legumes is extremely critical for their successful production and utilization. An adequate fertilization program is a prerequisite for maximum production and efficient utilization of legumes in a forage-beef cattle operation. Acidic soils and low levels of soil phosphorus are two obstacles to increased use of forage legumes in East Texas (50) that can be overcome with present technology. However, only limited research information is available on cool-season legumes with regard to efficient and successful techniques of stand establishment, interactions between legume species and soil factors (i.e., fertility and pH), grazing management, and nitrogen fertilization of bermudagrass pastures overseeded with legumes (24,32,44). Previous work at The Texas Agricultural Experiment Station at Overton has shown that annual clover-ryegrass (*Lolium multiflorum* Lam.) mixtures overseeded on Coastal bermudagrass can extend the productive period of the pasture 150 to 180 days annually (45). An inoculation study demonstrated that the use of a sticking agent and up to three times the normal rate of inoculum promotes the effective nodulation of legume seedlings (40). A similar experiment conducted in Southeast Texas on white clover provides data that clearly show the importance of using a sticking agent to improve field survival of rhizobia (58). Cultural practices need to be more closely defined through experimentation so as to improve the dependability of forage legumes for producers. Research is lacking on the feasibility of irrigating forage legumes that have a high cash value, such as alfalfa. The location of a significant dairy industry in Northeast Texas provides a ready market for alfalfa or other high-quality hay and might allow for its profitable production using supplemental irrigation.

A preliminary evaluation of 523 plant introductions in the *Trifolium* genus has been conducted at Overton (53). Seed were harvested from 52 plant introductions that appeared to have the greatest agronomic potential based on observations made during the first growing season. These lines were evaluated in the field during 1978-79, and genotypes within the following three species appear to have some merit for future testing and development: *T. dasyurum, T. diffusum,* and *T. hirtum* All. (54). Evaluation of additional *Trifolium* germplasm, only recently made available, is needed as well as continued evaluation of material currently under test. Germplasm of other "exotic" legume genera and species should also be evaluated for adaptation and potential use in a comprehensive breeding program. It is evident that reseeding annual forage legumes have a significant role to play in forage systems for East Texas (25). However, the search continues for an adequate perennial legume. Perennial species are currently availabe that are generally adapted to environmental conditions in East Texas (3). However, problems of palatability, toxicity, low productivity, and compatibility with perennial grasses render them agronomically unsuitable in their present state. The challenge of improving forage legumes will be met only by a coordinated program of germplasm evaluation, genetic improvement, and management research.

Research Priorities and Approaches

Initial emphasis in the forage legume research program should be given to evaluation of genetically diverse germplasm with a breeding program evolving as the most promising, adapted species are identified. Cultural practices also need to be more closely defined in order to improve the dependability of forage legumes. To solve these problems, cooperation across scientific disciplines is required, especially in the areas of plant breeding, soil fertility, microbiology, and forage management. Specific research priorities and approaches designed to meet the challenge are presented in outline form below.

I. **Priority 1:** Collection and evaluation of germplasm of both annual and perennial forage legume species for adaptation and agronomic potential.
   - A. Planned Approach
     1. Preliminary evaluation in small plots for
        - a. Rate of emergence
        - b. Stand
        - c. Length of production period
        - d. Winter growth
        - e. Pest resistance
        - f. Reseeding ability (hard-seededness/embryo dormancy)
     2. Rating of introduced species against adapted species
     3. Cultivar trials for adapted annual clovers

II. **Priority 2:** Selection among and within annual legume species for the following characteristics — early fall growth, low temperature growth without loss of winter-hardiness, pest resistance, reseeding ability, response to grazing, and nitrogen fixation rate.

A. Planned Approach

1. Greenhouse and growth chamber experiments (controlled environment) to compare genotypes for response to temperature and moisture stress
2. Initial field evaluation in small plots and spaced-plant nurseries
3. Evaluation of initial selections under grazing in replicated plots

III. **Priority 3:** Determination of improved cultural practices for efficient production and utilization of adapted forage legume species.

A. Planned Approach

1. Evaluation of methods for overseeding legumes into perennial grass sods
2. Determination of fertilizer requirements of legume-grass pastures
   a. N requirement
   b. Fertilizer placement for establishment of legumes
3. Detemination of more effective methods of legume inoculation
   a. Amount of inoculum required
   b. Importance of adhesives and lime-pelleting

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