# PROCEEDINGS OF THE 33RD SOUTHERN PASTURE AND FORAGE CROP IMPROVEMENT CONFERENCE

Mississippi State University
Mississippi State, Mississippi

April 19-22, 1976

Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE
December 1976

This publication is available from
Homer D. Wells
Agricultural Research Service
Tifton, GA 31794

CONTENTS

3001

# BREEDING FOR IMPROVED FORAGE QUALITY IN TALL FESCUE

By R. C. Buckner, L. P. Bush, J. A. Boling, L. Bull,
P. B. Burrus, II, and D. G. Ely[1/]

Tall fescue is a perennial semi-rhizomatous bunchgrass adapted to a wide range of climatic conditions. It grows best and is the predominant cool-season grass in the transition zone that separates the northern and southern region of the United States. It is estimated that tall fescue occupies between 7.0 and 14 million hectares (17 to 35 million acres) in pure and mixed stands in this transition zone. Although tall fescue has many excellent qualities as a pasture grass, forage quality of the grass is somewhat of a problem.

A high quality forage is one with the greatest possible concentration of utilizable nutrients in a form highly acceptable to animals. Criteria used to determine forage quality include the contents of crude protein, crude fiber, lignin, soluble carbohydrates, mineral elements, digestibility, acceptability, and intake of the forage by livestock. Contributing factors which govern quality of tall fescue appear to be age of leaves, fertility of the soil in which it is grown, season of the year, and genetic variation.

Although tall fescue appears to be of relatively high quality when compared to other cool-season grasses, many investigations have shown extremely variable results of animal performance (8, 13). Average daily gains of cattle were superior in some tests and inferior in others. Erratic performance is most often noticed in summer, especially during July, August, and September.

Intergeneric and interspecific hybridization of the *Lolium* and *Festuca* species is being utilized in an effort to transfer the forage quality of annual and perennial ryegrass and of giant fescue to tall fescue while maintaining the excellent agronomic qualitites of tall fescue. The hybrids are completely male-sterile and largely female-sterile. Meiotically stable and fertile hybrids have been obtained at the 2n=42 chromosome level of tall fescue, and additional hybrids are being studied with varying degrees of stability and fertility with 2n=56 and 84 chromosome numbers. Once fertility is achieved in the hybrids, they are screened for various agronomic and forage quality characreristics in an effort to develop varieties with superior agronomic and nutritional qualities.

Kenhy tall fescue (2n=42 chromosomes) derived from 2n=56 chromosome amphiploids of annual ryegrass x tall fescue hybrids, is the first tall fescue variety to be derived from the ryegrass-tall fescue breeding program. It has proven from tests in 21 states to be widely adapted, and is superior for agronomic characters and for many forage quality characteristics to the present commercially available named varieties.

---

1/ ARS, USDA, and University of Kentucky, Lexington.

Tall fescue compares favorably with other grasses in in vitro digestibility. However, it is not consumed as well by cattle, and intake during the summer is more variable than with other grasses (6, 9). Therefore, although in vitro digestibility is an effective measure of forage quality in many cool-season grasses, it does not seem so for tall fescue. Forage palatability appears to be the first limiting factor. In grazing seasons when poor animal performance does occur, it is most frequent during late summer.

Research efforts have identified the seasonal accumulation pattern of the alkaloid, perloline, to be indirectly associated with tall fescue forage quality and to directly affect animal performance (4, 5). Consequently, heritability studies, conducted in ryegrass-tall fescue hybrids previously selected for improved quality, showed that perloline content was highly heritable, and that it was controlled by a few major genes with a high degree of dominance for low perloline (3, 7). The high heritability of perloline indicates that rapid progress should be made in developing breeding materials with low perloline content and possibly for the whole class of compounds grouped as alkaloids.

Palatability and digestibility are important components of forage quality. Moisture content at harvest has been shown to be highly correlated with palatability and digestibility of forages (1, 11). Steer gains on range grasses were associated more highly with the percentage moisture than with any other factor (10). Annual ryegrass x tall fescue amphiploids (2n=56 chromosomes) had higher moisture content, dry matter digestibility and palatability than tall fescue cultivars (2n=42) (2). Kenhy tall fescue was found to have significantly lower stomatal frequency and percentage leaf-roll during summer drought stress than Kentucky 31. Miskin, et al. (12) have shown stomatal frequency in barley to be heritable and that decreased stomatal frequency decreased transpiration but did not alter photosynthesis. Since Kenhy had 12 per cent higher dry matter yields than Kentucky 31, apparently photosynthetic rates were not altered in Kenhy. Broad-sense heritability values of 0.62 have been obtained for moisture content in ryegrass x tall fescue and in tall x gaint fescue hybrids. Percent leaf roll (a measure of wilting) is negatively correlated with moisture content and frequency and size of stomates is inversely related to moisture content in these materials. However, it is not known whether stomata frequency is correlated with increased moisture content of ryegrass x tall fescue and tall x giant fescue hybrids. Recent data suggest that genetic differences exist in moisture content and stomata frequency of these hybrid materials and that breeding lines and cultivars can be developed with greater digestibility and palatability based on moisture content.

Voluntary intake is positively associated with higher relative proportions of soluble carbohydrates and hemicelluloses and negatively related to the more insoluble fiber content of the cell wall. An increase in chromosome number is usually accompanied by an increase in cell size and an increase in cell content to cell wall ratio. Sullivan (14) found that an increase in chromosome number of perennial ryegrass was frequently associated with an increase in soluble cell constituents which would increase the digestibility of forage. Annual ryegrass x tall fescue (2n=56) and tall x giant fescue amphiploids (2n=84) have higher digestibility and palatability than ryegrass-tall fescue hybrids (2n=42) or tall fescue cultivars. Preliminary analysis of 2n=42, 56, and chromosome hybrids has shown theat the neutral detergent fiber fraction is lower in the higher polidy levels indicating a change in cell content to cell wall ratio. Thus, increased chromosome number of the hybrid amphiploids has resulted in increased cell size, water content, and soluble cell content to cell wall ratio. Therefore, rapid progress should be realized by incorpora-

ting these parameters into genetic materials to achieve improved forage quality and consequently, improved animal performance.

## LITERATURE CITED


(1) Archibald, J. G., Bennett, E., and Ritchie, W. S.
1943. The composition and palatability of some common grasses. J. Agric. Res. 66: 341-347.

(2) Buckner, R. C., Todd, J. R., Burrus, P. B., II, and Barnes, R. F.
1967. Chemical composition, palatability, and digestibility of rye-grass-tall fescue hybrids, 'Kenwell' and 'Ky. 31' tall fescue varieties. Agron. J. 59: 345-349.

(3) Buckner, R. C., Bush, L. P., and Burrus, P. B., II.
1973. Variability and heritability of perloline in Festuca sp., Lolium sp., and Lolium-Festuca hybrids. Crop Sci. 13: 666-669.

(4) Bush, L. P. and Buckner, R. C.
1973. Tall fescue toxicity. In Antiquality components of forages. Crop Sci. Soc. Amer. Special Publication No. 4, p. 99-112.

(5) Boling, J. A., Bush, L. P., Buckner, R. C., Pendlum, L. C. Burrus, P. B., Yates, S. G., Rogovin, S. P., and Tookey, H. L.
1975. Nutrient digestibility and metabolism in lambs fed added perloline. J. Anim. Sci. 40: 972-976.

(6) Bryan, W. B., Wedin, W. F., and Vetter, R. L.
1970. Evaluation of reed canarygrass and tall fescue as spring-summer, and fall-saved pasture. Agron. J. 62 (1): 75-80.

(7) Cornelius, P., Buckner, R. C., Bush, L. P., and Burrus, P. B., II.
1974. Inheritance of perloline content in Lolium multiflorum L. x Festuca arundinacea Schreb. hybrids. Crop Sci. 14: 896-898.

(8) Jacobson, D. R, Carr, S. B., Hatton, R. H., Buckner, R. C., Graden, A. P., Dowden, D. R., and Miller, Wm M.
1970. Growth, physiological responses, and evidence of toxicity in yearling dairy cattle grazing grasses. J. Dairy Sci. 53: 575-587.

(9) Martz, F. A., Asay, K. H., and Worthington, R. T.
1970. Preliminary rept. Plant-animal factors associated with voluntary intake of tall fescue, Festuca arundinacea Schreb. Mo. Agr. Exp. Sta. Res. Rept., pp. 63-70.

(10) McIlvain, E. H. and Shoop, M. C.
1966. Relationship of moisture content and cultural practices to forage quality of range grasses. Agron. Abst. p. 42.

(11) Meredith, W. R.
1964. The use of dry matter percentage at time of harvest in the evaluation of forage digestibility and intake. Diss. Abst. 24: 3486-3487.

(12) Miskin, K. E., Rassmusson, D. C., and Moss, D. N.
1972. Inheritance and physiological effects of stomatal frequency in barley. Crop Sci. 12: 780-784.

(13) Mott, G. D., Kaiser, C. J., Peterson, R. C., Peterson, Randall, Jr., and Rhykered, C. L.
1971. Supplemental feeding of steers on Festuca arundinacea Schreb. Pastures fertilized at three levels of nitrogen. Agron. J. 63: 751-754.

(14) Sullivan, J. T.
1944. Further comparisons of plants with different chromosome members in respect to chemical composition. J. Amer. Soc. Agron. 36: 537-543.

2001

# BREEDING FOR IMPROVED FORAGE QUALITY IN SERICEA LESPEDEZA

By E. D. Donnelly 1/

Sericea lespedeza, Lespedeza cuneata (Dumont) G. Don, is a perennial, summer legume well adapted to the climate and soils of the southeastern USA. It generally is recognized as being low in palatability and nutritive value. A breeding program was begun in 1950 to improve this crop. Earlier researchers showed that sericea was high in tannin and thought that tannin and coarse stems contributed to its relatively low quality.

Rabbits consumed more fine-stemmed sericea than coarse-stemmed (2). Fine-stemmed sericea contained more total digestible nutrients, crude fiber, and nitrogen-free extract than the coarse and the digestibility of these constituents was greater in the fine-stemmed forage. In a "free choice" grazing study, using cattle and spaced plants, fine-stemmed plants and low-tannin plants were most heavily grazed (1). As an initial step in improving sericea, the fine-stemmed but normal or high-tannin variety 'Serala' was developed (3). In a grazing study it was shown to be a satisfactory pasture for beef cattle in the Piedmont area of Alabama (7).

Low-tannin sericea plants were found to be higher in digestible dry matter (DDM) than high tannin plants as indicated by the in vivo nylon bag method (4, 5).

In another study steers weighing approximately 250 kg were grazed on high- and low-tannin sericea (6). The $Cr_2O_3$-chromogens technique was used. Crude protein for both types was higher than 16% during three 28-day grazing periods from May through mid-September. Steers on low-tannin forage consumed less dry matter per day than did steers on high-tannin forage. Even so, there was no difference in daily DDM intake between the two forages. The higher digestibility of low-tannin forage was sufficient to overcome lower intake of this forage. Chromogens estimated DDM was higher for low-tannin forage than for high-tannin. This was substantiated by a lower crude protein percentage of feces from cattle on low-tannin forage than from cattle on high-tannin sericea. Feces from cattle on high-tannin sericea contained 22% more crude protein than did that from cattle on low-tannin forage. Also, feces from steers on low-tannin forage was higher in percent in vitro digestibility than that from steers on high-tannin forage. Data showed that dry matter and crude protein of low-tannin sericea were more highly digestible than that in high-tannin sericea.

---

1/ Professor, Department of Agronomy and Soils, Auburn University Agricultural Experiment Station, Auburn, Alabama.

King, et al. (8) studied cow-calf performance on pastures of two normal or high-tannin sericea varieties, a low-tannin experimental sericea line, and bahiagrass. The average adjusted 270-day weaning weight of calves on low-tannin sericea was equal to that on bahiagrass that received 168 kilograms of nitrogen per hectare annually. Weight gain of cows did not differ among pastures.

A foliar disease identified as Rhizoctonia is severe on low-tannin sericea during prolonged periods of hot, humid weather. Selection for resistance has produced lines that appear promising. Performance of these lines under field conditions will determine whether or not a low-tannin sericea variety can be released in the near future.

## LITERATURE CITED


(1) Donnelly, E. D.
1954. Some factors that affect palatability in sericea lespedeza, L. cuneata. Agron. J. 46: 96-97.

(2) _____, and Hawkins, G. E.
1959. The effects of stem type on some feeding qualities of sericea lespedeza, L. cuneata as indicated in a digestion trial with rabbits. Agron. J. 51: 293-294.

(3) _____.
1965. Serala sericea. Crop Sci. 5: 605.

(4) _____, and Anthony, W. B.
1969. Relationship of tannin, dry matter digestibility and crude protein in sericea lespedeza. Crop Sci. 9: 361-362.

(5) _____, and _____.
1970. Effect of genotype and tannin on dry matter digestibility in sericea lespedeza. Crop Sci. 10: 200-202.

(6) _____, _____, and Langford, J. W.
1971. Nutritive relationships in low-and high-tannin sericea lespedeza under grazing. Agron. J. 63: 749-751.

(7) Hoveland, C. S., Anthony, W. B., Harris, R. R., Mayton, E. L., and Burgess, H. E.
1969. Serala sericea, Coastal bermuda, Goar tall fescue grazing for beef cows and calves in Alabama's Piedmont. Auburn Univ. Agr. Exp. Sta. Bull. 388. pp. 14.

(8) King. C. C., Anthony, W. B., McCormick, R. F., Jr., and Glaze, Fred T.
1975. Cow-calf performance on low-and normal-tannin sericea (Lespedeza cuneata). Abst. Sou. Assoc. of Agr. Scientists. p. 4.

2001

# BREEDING FOR FORAGE QUALITY IN WARM SEASON GRASSES[1]

By Wayne W. Hanna[2]

Yield has been one of the most important consideration in breeding forages. High production costs and more demand on land use have increased the emphasis on yield. However, as profit margins narrow and there is demand for higher quality forages to put more finish on animals, we need to emphasize maximizing yield of metabolizable energy. Quality includes more than dry matter digestibility. It involves palatability, intake, and efficient use in the digestion process. Although quality of a forage can be largely controlled through management, much progress can also be made through breeding.

## Dry-Matter Digestibility

Until the advent of *in vitro* dry matter digestibility (IVDMD) or organic matter digestibility (IVOMD) techniques, there was no rapid way to measure dry matter digestibility of breeding lines, varieties and/or hybrids. These techniques have made it possible to screen large populations for variability in dry matter digestibility.

Dry matter digestibility (DMD) has been the most popular method used to estimate forage quality. Of the various methods used to determine DMD, the *in vitro*, two-stage Tilley and Terry technique with various modifications is probably the most widely used. This method gives quick results that correlate well with animal performance.

---

1/ Cooperative investigations of the ARS, USDA, and the University of Georgia, College of Agriculture Experiment Stations, Coastal Plain Station, Tifton, Ga.

2/ Research Geneticist, ARS, USDA, and the University of Georgia, College of Agriculture Experiment Stations, Coastal Plain Station, Tifton, Ga.

At Tifton, Dr. Warren Monson routinely runs 175 duplicate samples a week. It takes about 6 minutes per sample to grind and complete the two stage analysis. Large numbers of samples can be screened quickly which is important in a breeding program.

Duble, Lancaster, and Holt (7) showed that average daily gain of grazing steers correlated well (r = 0.78) with the IVDMD of six tropical grasses. Burton, Hart, and Lowery (2) showed that 'Coastcross 1' bermudagrass was 12% more digestible than 'Coastal', and it gave 30% better daily gains and total animal gain per hectare than Coastal did. Both grasses produce the same amount of dry matter per hectare. The increased quality of Coastcross 1 was due to both higher forage intake and higher digestible energy. This study emphasizes how a small increase in DMD (one component of quality) can significantly increase animal production per hectare. It also emphasized the importance that must be placed on quality.

The potential for improving DMD in warm-season species is encouraging. Variation for this component, which is necessary in a plant breeding program has been observed in many species as summarized by Moore and Mott (14). Some species such as Cynodon dactylon have been shown to have genotypes that vary in DMD by as much as 26 percentage units. DMD in bermudagrass has been shown to be heritable and controlled by multiple factors with little or no dominance (Burton and Monson, 4). The occurrence of plants in the world collection with DMDs of 70% indicate that possibilities still exist for improving this quality-component in bermudagrass. However, problems do exist. The introductions with the highest DMD also lack winter hardiness and carry high levels of prussic acid glucocide. DMD variation under genetic control has also been observed at Tifton for pearl millet and bahiagrass (Burton and Monson - personal communication) indicating that breeding can improve DMD in these species.

Through telephone contact with a number of breeders of warm-season grasses in the South, I found that all were using DMD as an estimate of quality. K. Quesenberry (Florida), S. Schank (Florida), and R. Smith (Florida) said they were screening both hybrids and introductions of Hemarthria, Digitaria, and Panicum maximum, respectively, for DMD.

Quesenberry expressed a concern that they may need an early screening of hybrids for grazing pressure tolerance, indicating that the most highly digestible Hemarthria lines may not be persistant. In a test in Brazil, Schank, Day, and Lucas (19) reported that the best digitgrass hybrids among 29 entries yielded the most dry matter and were the highest in DMD. E. C. Holt (Texas) said that he was able to increase DMD of Panicum coloratum by 5% with two cycles of maternal-line recurrent selection. P. Voigt (Texas) reported that high DMD was the weakest characteristic of winter-hardy weeping lovegrass and that he saw very little variation for this quality component. He felt that the less winter-hardy genotypes might show more variation. C. Taliaferro (Oklahoma) is using the IVDMD method to screen old world bluestem introductions and various bermudagrass introductions and hybrids for higher quality genotypes.

## Cell Wall Digestibility

In their review of structural inhibitors of quality in tropical grasses, Moore and Mott (14) state that "the major factors limiting intake and digestibility are those associated with rate and extent of forage degradation by microbial and physical factors in the rumen, primarily cell wall constituents and extent of lignification."

Cell walls may be divided into two fractions: a) a digestible cell wall fraction with potential digestibility near 100% and b) an undigestible fraction with a digestibility near 0% (Moore, Golding, and Barnes, 15). This emphasizes that cell wall estimates may not always be accurate for estimating digestible cell wall. Fortunately, the correlation coefficient for DMD and cell-wall digestibility is high for most warm-season species studied: 0.95 for *Cenchrus ciliaris* (Lovelace, et al, 12) and 0.99 for *Cynodon dactylon* and *Digitaria decumbens* (Weller and Moore - Unpublished data, 1972). Hanna and Monson (unpublished data, 1975) have found that when comparing high- and low-IVDMD bermudagrass genotypes, the high-IVDMD genotypes had a lower percentage of cell wall with a high soluble fraction and a higher percent digestible cell wall. These and other studies indicate that digestible cell wall is one of the most important components of organic matter digestion. If two forages are equally digestible, then the one with the higher rates of cell content to digestible cell wall should have the higher intake (Moore and Mott, 14) and should result in production of the most animal product. This observation does not account for any mechanical factor such as cuticle or cell arrangements.

## Lignin

Lignin is another anti-quality component that is responsible for incomplete digestion of cellulose and hemicellulose (Van Soest, 22). The discovery of the brown-midrib mutants in *Sorghum*, which reduce lignin by up to 45%, increase IVDMD by 12% and increase digestibility of fiber by 17 percentage units (Porter, Lechtenburg, and Axtell, 17), hold exciting potential for improving the quality of forage sorghums and sorghum-sudangrass hybrids. At Tifton we are incorporating the genes controlling brown midrib into some experimental sorghum-sudangrass hybrid lines. If these brown-midrib mutants improve quality of forage sorghum as much as we anticipate, a major effort to find or induce similar types of mutants in other grass species may be well worth the effort.

## Silica

Grass is also known to metabolize silica, which decreases the digestibility of structural carbohydrates (Van Soest and Jones, 21). Van Soest (22) states that "there is much we do not know about silicon metabolism in plants." The genetic variability and range of variability for this characteristic must be

studied.

## Dwarfs

One of the simpliest ways to increase forage quality is to incorporate simply inherited genetic characteristics which improve quality into existing improved varieties. The dwarf ($d_2$) gene has been successfully incorporated into pearl millet, Pennisetum americanum, thereby reducing height by one half, increasing amount of leaf by 50%, and producing only 78% as much dry matter per hectare as its near isogenic tall counterpart. Although the dwarf produced only 85% as many steer days of grazing as the tall millet, animals on the dwarf millet made 20% better daily gains with steer gains per hectare being equal for both millets (Burton et al, 3). Research by Johnson et al (11) has shown that 318 kg dairy heifers grazing dwarf 'Tifleaf 1' pearl millet gained 0.84 kg per day for 56 days at a stocking rate of 7.5 animals per hectare. This was a significantly higher gain than that obtained on the tall 'Gahi 1' or 'Gahi 3' pearl millet included in the same test.

## Day Length Sensitivity

'Short day' plants fail to flower when daylight exceeds a certain number of hours. This flowering response to day length can be a tremendous asset because the forage remains vegetative, maintaining a higher quality forage produced uniformly for a longer period of time. The mechanism is usually under genetic control and intermediates that would flower and produce seed before frost can be developed from day length sensitive x day neutral $F_1$ hybrids. Another way of using day length sensitivity (DLS) to advantage would be to produce intermediate DLS parents with different DLS genes. These intermediate DLS parents could theoretically be used to produce hybrids that would remain vegetative until frost. At Tifton we are in the process of testing these methods of using DLS to produce quality forage.

## Interspecifics

Interspecific hybrids may be a way of producing quality forages or improving the quality of widely used forages through the transfer of desirable genetic characteristics. Hybrids of pearl millet, P. americanum x napier, P. purpureum are immune to rust, are sterile, remain vegetative until frost, and produce high quality forage. Hybrid seed can be easily produced, the hybrids act as perennials and can be vegetatively propagated. Interspecific hybrids can also be developed to improve quality in other species.

## Pest Resistance

The availability of quality forage depends to a large degree on genetic pest resistance. Pest resistance imparts many plus factors such as longevity,

drought tolerance, dependability, palatability, etc. to a forage. It can determine how much quality forage is produced or whether a species can survive in an area. Many genes conditioning pest resistance already exist. Some may be in non-economic types or in related species but they can be transferred. If resistance to a specific pest is not found, it may be induced with mutagens.

## Cuticle and Waxes

Leaf and stem surfaces, as they affect rumen microbe penetration and rate of digestion is a relatively new area of research that promises to significantly contribute to improving forage quality. Many of these mechanical effects on quality are masked when the samples are ground for the IVDMD process. As breeders, we need to be constantly aware that these surface effects do exist and make an attempt to measure their effects.

Cuticle and bloom (powdery waxes) have been shown to impede penetration of rumen microbes through the leaf surface (Monson, Powell, and Burton, 13; Hanna, Monson, and Burton, 9). Leaf sections of bloomless sorghum lost 31% more dry matter per unit time than did its near isogenic bloom counterpart, because rumen microbes penetrated more rapidly through the surface of bloomless leaves. This tendency should result in higher intake and increased animal performance. Steers (205 kg) fed bloomless silage made significantly higher gains than those fed silage from bloom plants (Cummins and Sudweeks, 6). Recently, Peiretti, Weibel, and Starks (16) have shown that greenbugs exhibit a nonpreference for bloomless plants. In palatability studies at Tifton, Georgia, cattle repeatedly preferred trichomeless (a single gene recessive mutation) pearl millet. Studies show that the trichomeless mutant is digested more slowly than trichomed millet. Additional research is needed to determine if its reduced digestion rate is offset by its increased palatability and drought tolerance and whether the leaf surface may be genetically altered to increase penetration by rumen microbes.

Many of these surface characteristics are relatively simply inherited and can be easily manipulated in a breeding program.

## Morphological Characteristics

Variation in cell arrangements, amount of cutinized and lignified cell walls, and rate and extent of tissue degradation has been observed in a number of warm-season species (Hanna, Monson, and Burton, 8; Akin, 1). Histological studies on stems have shown that increased vascular bundle areas (Schank, Klock, and Moore, 18) and formation of lignified bands in stems (Hanna, Monson, and Burton, 10) are inversely related to dry matter disappearance. We are only beginning to understand how some of the morphological characteristics may affect forage quality (rate of digestion, intake, extent of digestion, etc.). Much more work needs to be done on the genetic control of these morphological characteristics within different species and on their effect on forage quality.

## Nitrogen Fixation

Nitrogen fixation by grass (Smith et al., 20) is a new discovery that, if developed to a workable stage on a field basis, could do much for improving quality of warm season grasses. Variation in nitrogen fixing capabilities has been observed among genotypes of various species, indicating a potential for genetic improvement.

## Physiology

Increased demand for high quality forage and increased production costs demand that plant breeders begin investigating genetic variability for photosynthetic efficiency and energy storage.

## Breeding Methods

It is possible to use any of a number of breeding techniques and eventually accomplish one's breeding objective. However, ever increasing demands for food necessitate that plant breeders accomplish their objective in the shortest possible time. This demand means that breeders must constantly improve existing breeding techniques or develop new procedures. An example of a new breeding technique is recurrent restricted phenotypic selection (modified mass selection), which has increased forage yield of Pensacola bahiagrass 17.7% in four cycles (Burton, 5).

## Summary

The quality of warm season grasses can be improved through breeding. Plant breeders must thoroughly evaluate all germplasm in domestic and world gene pools and be alert to any and all components that could affect quality. Breeders should remember that a small increase in quality may result in a large increase in animal performance.

Forage quality is affected by a number of components. DMD, which is highly correlated to digestible cell wall, is one component. Emphasis on DMD has made a significant contribution to improving forage quality because of the variability for DMD within species and the accuracy and rapidity with which this component can be measured. Much more work needs to be done in this area. Other areas to consider for improving forage quality through breeding are genetic variability for lignin, silica, plant height, day length sensitivity, pest resistance, plant-surface characteristics, plant anatomy and morphology, nitrogen fixation, photosynthetic efficiency, and energy storage. Additional areas that can contribute to improving forage quality are interspecific hybridization and new breeding procedures.

## LITERATURE CITED


1. Akin, Danny Earl. 1973. Ultrastructure of grass leaves related to rumen microbial degradation. Ph.D. Dissertation, University of Georgia, 81 pages.
2. Burton, G. W., Richard H. Hart, and R. S. Lowery. 1967. Improving forage quality in bermudagrass by breeding. Crop Sci. 7:329-332.
3. Burton, Glenn W., W. G. Monson, J. C. Johnson, Jr., R. S. Lowery, H. D. Chapman, and W. H. Marchant. 1969. Effect of the $d_2$ gene on forage yield and quality of pearl millet. Agron. J. 61:607-612.
4. Burton, Glenn W., and Warren G. Monson. 1972. Inheritance of dry matter digestibility in bermudagrass, Cynodon dactylon (L.) Pers. Crop Sci. 12:375-378.
5. Burton, Glenn W. 1974. Recurrent restricted phenotypic selection increases forage yield of Pensacola bahiagrass. Crop Sci. 14:831-835.
6. Cummins, D. G., and E. M. Sudweeks. 1975. Comparative quality of bloom and bloomless sorghum silage determined by steer feeding trials. Agron. Abstracts. p. 105.
7. Duble, R. L., J. A. Lancaster, and E. C. Holt. 1971. Forage characteristic limiting animal performance on warm-season perennial grasses. Agron. J. 63:795-798.
8. Hanna, Wayne W., Warren G. Monson, and G. W. Burton. 1973. Histological examination of fresh forage leaves after in vitro digestion. Crop Sci. 13:98-102.
9. Hanna, Wayne W., Warren G. Monson, and Glenn W. Burton. 1974. Leaf surface effects on in vitro digestion and transpiration in isogenic lines of sorghum and pearl millet. Crop Sci. 14:837-838.
10. Hanna, Wayne W., Warren G. Monson, and Glenn W. Burton. 1976. Histological and in vitro digestion study of 1- and 4-week stem and leaves from high and low quality bermudagrass genotypes. Agron. J. 68(2): 219-222.
11. Johnson, J. C., Jr., W. C. McCormick, W. G. Monson, and G. W. Burton. 1976. Performance of dairy heifers grazing pastures of either Gahi 1, Gahi 3, or Tifleaf 1 millet. Paper presented at 73rd annual meeting of Southern Assoc. of Agri. Scientists.
12. Lovelace, D. A., E. C. Holt, W. C. Ellis, and E. C. Bashaw. 1972. Nutritive value estimates in apomictic line of Buffelgrass (Cenchrus ciliaris L.). Agron. J. 64:453-456.
13. Monson, W. G., J. B. Powell, and G. W. Burton. 1972. Digestion of fresh forage in rumen fluid. Agron. J. 64:231.
14. Moore, John E. and Gerald O. Mott. 1973. Structural inhibitors of quality in tropical grasses. In Anti-quality Components of Forage. CSSA Special Publication 4. pp. 53-98.

15. Moore, J. E., E. J. Golding, III, and R. F. Barnes. 1975. Assessment of applicability of present methods of predicting digestible energy values. Manuscript presented to Hay Marketing Task Force, Amer. Forage Grassland Council. April 28-30.
16. Peiretti, R. A., D. E. Weibel, and K. J. Starks. 1975. Some aspects of greenbug resistance in sorghum as related to "bloomless" character. Agron. Abstracts. p. 60.
17. Porter, U. S., V. L. Lechtenburg, and J. D. Axtell. 1975. Laboratory and in vitro evaluation of forage from chemically induced brown midrib mutants of Sorghum bicolor (L.) Moench. Agron. Abstracts. p. 109.
18. Schank, S. C., M. A. Klock, and J. E. Moore. 1973. Laboratory evaluation of quality in subtropical grasses. II. Genetic variation among Hemarthrias in in vitro digestion and stem morphology. Agron. J. 65:256-258.
19. Schank, S. C., John Day, Enesio Delgado de Lucas. 1976. Nitrogenase activity, nitrogen content, IVDMD, and yield of thirty tropical grasses. Tropical Agriculture (Accepted for publication).
20. Smith, Rex L., S. C. Schank, M. H. Gaskins, and D. H. Hubbell. 1975. Nitrogen fixation by grass association in Florida - a progress report. Agron. Abstracts p. 133.
21. Van Soest, P. J., and L. H. P. Jones. 1967. The effect of silica upon digestibility decline. J. Dairy Sci. 50:989.
22. Van Soest, P. J. 1968. Structural and chemical characteristics which limit the value of forages. In Forages Economics - Quality. ASA Special pub. 13. pp. 63-76.

# Present Status of Methods for Determining Forage Quality

By Hagen Lippke 1/

Interest by forage breeders in forage quality has increased greatly in recent years, apparently in response to an increase in the reliability of rapid methods for determination of quality, however that may be perceived. The *in vitro* method of Tilley and Terry (12) and its modifications (e.g., Barnes (2) Goehring and Van Soest (4)) appear to have been widely adopted. Hopefully, even better methods will be developed so that forage quality can become a primary measure in forage breeding programs.

In this paper "quality" refers solely to digestible energy intake or the closely allied parameter, digestible organic matter intake. Though the protein and mineral contents of forages are also very important, the ease and cost of supplementation of these nutrients ranks them behind energy as the primary "quality" selection component. Further, protein is rarely the first limiting nutrient in animal production so long as forages are in the vegetative state.

Digestible energy intake can obviously be separated into two major components - digestibility or extent of digestion, and intake. Figure 1 shows other factors, inside and outside the rumen, which influence these major components and must be considered when evaluating *in vitro* or other laboratory methods for estimating forage quality.

Note first the interrelationships among intake (gut fill), extent of digestion, rate of digestion, and rate of passage. With few exceptions, all are positively correlated. In the animal these are dynamic processes, influenced by both the composition of the diet and physiology of the rumen. This is in contrast to laboratory procedures, primarily *in vitro* fermentations, which impose a constant "rate of passage" or exposure to degradation, whether that be 6 hr or 6 days.

The rate of passage from the rumen is greater for high quality forages than for poor forages. Consequently, the 48-hr fermentation commonly used to estimate extent of digestion overestimates excellent forages and underestimates low quality forages. Such values may, in fact, be more accurate representations of quality than they are of extent of digestion, since intake tends to parallel digestibility and has a wider relative range. Data from the S-45 Regional Project show extremely high relationships between 6-day fermentation results and digestible energy intake. (H. Lippke and J. E. Moore, unpublished data).

---

1/ Associate Professor, Texas Agricultural Experiment Station, P. O. Box 728, Angleton, Texas 77515.

The minimum dietary protein requirement for maximum rate of digestion is approximately 7%, lower than the requirement for production. Addition of protein hydrolysates to *in vitro* fermentations effectively simulates *in vivo* supplementation of low-protain forages.

In the rumen, particle size influences both rate of digestion and rate of passage and is negatively correlated with these parameters. Again, holding "rate of passage" constant imposes an artificial situation, causing the influence of particle size (fineness of grind) on rate of digestion to be transmitted to extent of digestion. Wilkins and Minson (19) observed significant ($P<.001$) differences in cellulose digestibility between forages ground to pass either a 0.5 mm screen or a 1.0 mm screen, even after 6 days of fermentation. The difference was greatest after 1 day (6.3 percentage units) and declined to 2.5 percentage units after 6 days. Of greater significance, perhaps, is the grinding treatment x forage interaction ($P<.01$) which resulted.

The influence of particle size on rate of fermentation is, of course, a manifestation of the amount of surface area exposed to degradative processes. Hanna *et al*. (5), using specialized fermentation techniques, observed that digestion consistently began with larger, more loosely arranged cells which, because of larger inter-cellular spaces, present a much larger surface area. Obviously, forages having a higher percentage of this type of cell arrangement will be more rapidly digested. Akin and Burdick (1) made similar observations and classified a number of cool-season and tropical grasses according to their content of easily degradable tissue. Microscopic examination of plant tissues is proving to be a valuable tool in quality evaluation. Availability of the more sophisticated equipment may be a limitation, however.

The fragility of plant structure has a strong influence on forage quality through its sequential effect on particle size, rate of digestion, and intake. Laredo and Minson (7) reported a high negative correlation between forage intake and power required to grind the forage. It should be noted that most fermentation and chemical techniques totally obliterate gross structural differences among forages. Since sample grinding is inherent in almost all evaluation procedures, measurement of the power required may provide valuable additional information at relatively low cost.

In the forage fractionation system developed by Van Soest (17), cell contents, in contrast to cell wall constituents (CWC), have a uniformly high true digestibility, usually in the 92-98% range [Van Soest (18), Riewe and Lippke (9)]. Consequently, extent of digestion is determined almost entirely by the amount and digestibility of CWC. If digestibility of CWC is found to be strongly related to content of CWC or some measurable fraction of CWC, then forage fiber analyses can provide reliable estimates of digestibility [Van Soest (16), Marten *et al*. (8)]. Often though, such relationships have been applicable only within a narrow range of forages and may not even hold for the varieties within a species (H. Lippke, unpublished data). Nonetheless, a breeder may find Van Soest fiber analyses quite sufficient when dealing with certain narrow groupings of forage plants.

CWC content and composition are primarily functions of species, maturity, and method of harvest. The important point here is that care should be taken in experimental design and procedure to avoid ascribing variation to species or cultivars that is actually due to differences in maturity or drying conditions in the harvesting process. The literature is replete with reports of the detrimental effects of commonly used methods of sample drying [e.g., Schmid *et al*. (10), Van Soest (15)]. This topic has recently been reviewed by Smith (11) and shall not be pursued further here.

Lignin appears to be the primary intrinsic factor controlling extent of digestion. All available evidence strongly suggests that lignin acts as a physical barrier, preventing access by bacterial enzymes to the cellulose and hemicellulose fibers. Also, lignin may exert much influence on forage quality through its effect on gross plant sturcture. Lignin, however, has thusfar not been a useful indicator of digestibility for warm season grasses. The coefficients between lignin content and CWC digestibility frequently found within species or varieties may differ significantly. The inhibitory effect of lignin is likely only indirectly related to lignin content.

The various in vitro fermentation procedures are now used primarily as a measure of extent of digestion. Placing two or more divergent forages of known in vivo digestibility into each in vitro run provides a method for detecting run x forage interaction and a regression for adjusting observed values when "absolute" values are of interest. Rate of fermentation can also be estimated using in vitro procedures. With fermentation times of 12, 48 and 144 hr, the mathematical form

$$y = ae^{-k\,ln\,t}$$

was found to closely fit the data where y is the fraction CWC remaining after (t) hr of fermentation (H. Lippke, unpublished data). It is likely that more data points would show the form

$$y = a_1e^{-k_1t} + a_2e^{-k_2t}$$

to be more correct. In any case, this form adheres more closely to the concept of at least two fiber fractions - easily degradable, characterized by mesophyll and pholem cells, and slowly degradable, made up of epidermis and parenchymal sheath and possibly some lignified vascular cells - as proposed by Akin and Burdick (1).

Engdahl et al. (3) estimated the variance components associated with in vitro fermentation of kleingrass and buffelgrass cultivars. The estimates for "plants within cultivar" ranged from 1.8 to 2.7 (G. R. Engdahl, personal communication). Other variance component estimates coincided with those previously reported by Barnes (2).

The principal disadvantage of in vitro fermentation methods is the necessity for maintaining an inoculum donor and the amount of time required to complete the determination. However, where large numbers of samples are to be processed, cost per sample is likely to be lower than for any other meaningful analysis.

The in situ or "nylon bag" fermentation methods appear to offer no particular advantage over in vitro methods except a saving of equipment, i.e., a water bath. This is balanced against a limited capacity per animal maintained and the considerable precautions required to prevent leakage of dry matter into and out of the bags. Van Dyne and Weir (13) found that seeds punctured the nylon bags they used and caused loss of fine particles. Van Hellen (14) reported that commonly used nylon fabric allowed sufficient influx of fine particles from the rumen pool that negative fiber digestions resulted in some instances. He concluded that pore sizes of $10\mu$ or less are necessary to prevent dry matter leakage.

Jones and Hayward (6) used isolated cellulose to estimate extent of digestion. They reported that their method gave results almost equal to that of common in vitro procedures, and, of course, alleviated the need for a rumen fluid donor. A reliable supply of cellulase may be a problem, however.

In summary, the *in vitro* fermentation to determine organic matter disappearance is the best single screening method now available. It leaves much to be desired, however, when attempting to find the basis for observed differences. Additional techniques, such as microscopic examination, rate of digestion estimates, Van Soest fiber analyses, and resistance to grinding may be very helpful in this regard.

## LITERATURE CITED


(1) Akin, Danny E., and Burdick, Donald.
1975. Percentage of tissue types in tropical and temperate grass leaf blades and degradation of tissues by rumen microorganisms. Crop Sci. 15: 661-668.

(2) Barnes, R. F.
1970. Collaborative research with the two-stage *in vitro* rumen fermentation technique. Proc. Natl. Conf. Forage Qual. Evaluation and Utilization. N-1.

(3) Engdahl, Gilbert R.; Ellis, W. C.; and Holt, E. C.
1974. Digestibility of grass selections as influenced by maturity. J. Anim. Sci. 38: 214-215 (Abstract).

(4) Goering, H. K., and Van Soest, P. J.
1970. Forage fiber analyses. U.S.D.A. Handbook No. 379.

(5) Hanna, W. W.; Monson, W. G.; and Burton, G. W.
1973. Histological examination of fresh forage leaves after *in vitro* digestion. Crop Sci. 13: 98-102.

(6) Jones, D. I. H., and Hayward, Margaret V.
1973. A cellulase digestion technique for predicting the dry matter digestibility of grasses. J. Sci. Fd. Agric. 24: 1419-1426.

(7) Laredo, M. A., and Minson, D. J.
1973. The voluntary intake, digestibility, and retention time by sheep of leaf and stem fractions of five grasses. Aust. J. Agric. Res. 24: 875-888.

(8) Marten, G. C.; Goodrich, R. D.; Schmid, A. R.; Meiske, J. C.; Jordan, R. M.; and Linn, J. G.
1975. Evaluation of laboratory methods of determining quality of corn and sorghum silages: II. Chemical methods for predicting in vivo digestibility. Agron. J. 67: 247-251.

(9) Riewe, M. E., and Lippke, H.
1970. Considerations in determining the digestibility of harvested forages. Proc. Natl. Conf. Forage Qual. Evaluation and Utilization. F-1.

(10) Schmid, A. R.; Marten, G. C; and Goodrich, R. D.
1970. Influence of drying methods and temperatures on *in vitro* dry matter digestibility of corn and soghum fodder and silage. Agron. J. 62: 543-546.

(11) Smith, Dale.
1973. Influence of drying and storage conditions on nonstructural carbohydrate analysis of herbage tissue - A Review. J. Br. Grassld. Soc. 28: 129-134.

(12) Tilley, J. M. A., and Terry, R. A.
1963. A two-stage technique for *in vitro* digestion of forage crops. J. Br. Grassld. Soc. 18: 104-111.

(13) Van Dyne, G. M., and Weir, W. C.
1966. Comparison of microdigestion techniques under range and drylot conditions. J. Agric. Sci. 67: 381-387.

(14) Van Hellen, Russell William
1974. Kinetics of digestion of forage fiber components. Masters' Thesis. Texas A & M University.

(15) Van Soest, P. J.
1965. Use of detergents in analysis of fibrous feeds. III. Study of effects of heating and drying on yield of fiber and lignin in forages. Assoc. Off. Agr. Chem. J. 48: 785-790.

(16) Van Soest, P. J.
1965. Comparison of two different equations for prediction of digestibility from cell contents, cell-wall constituents, and lignin content of acid detergent fiber. J. Dairy Sci. 48: 815 (Abstract).

(17) Van Soest, P. J.
1966. Nonnutritive residues: A system of analysis for the replacement of crude fiber. Assoc. Off. Agr. Chem. J. 49: 546-551.

(18) Van Soest, P. J.
1967. Development of a comprehensive system of feed analyses and its application to forages. J. Anim Sci. 26: 119-128.

(19) Wilkins, R. J., and Minson, D. J.
1970. The effects of grinding, supplementation and incubation period on cellulose digestibility *in vitro* and its relationship with cellulose and organic matter digestibility *in vivo*. J. Agric. Sci. 74: 445-451.

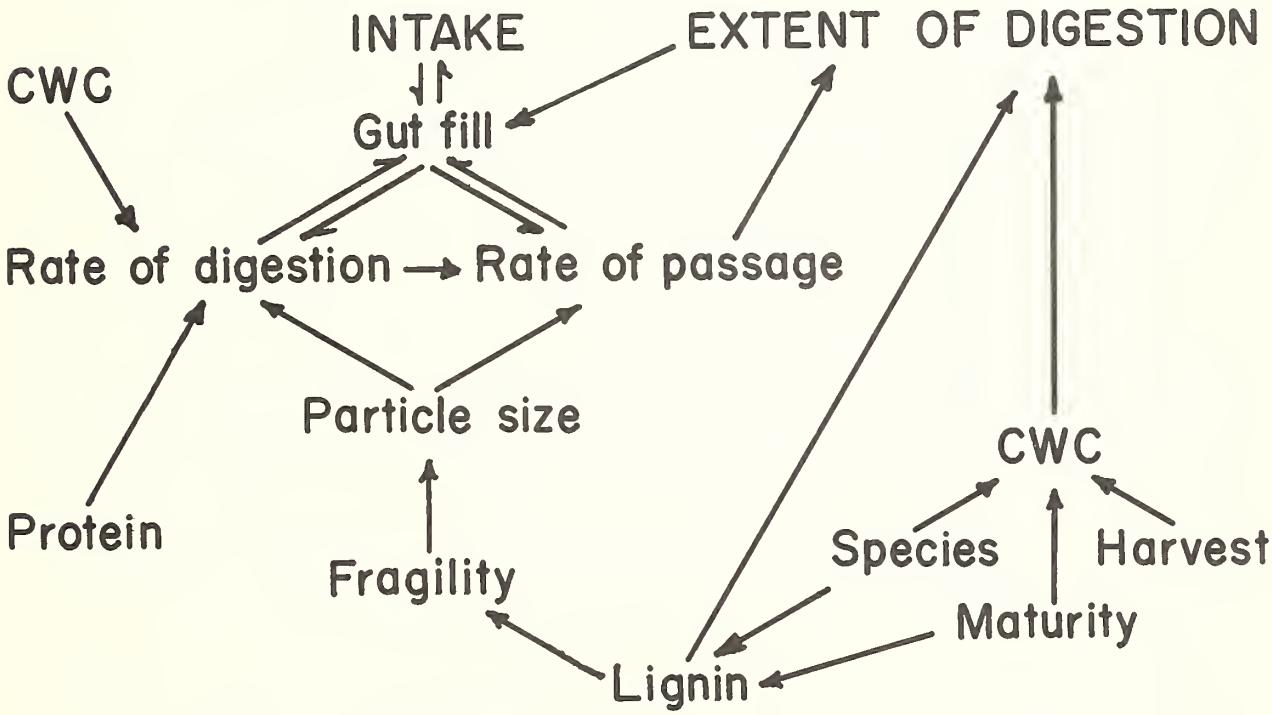


Figure 1. Interrelationships among factors influencing nutritive value of forages.

# COLCHICINE AND NITROUS OXIDE FOR DOUBLING CHROMOSOMES NUMBERS IN TRIFOLIUM SPECIES

By N. L. Taylor, M. K. Anderson and K. H. Quesenberry 1/

Colchicine has been used for doubling chromosome numbers in higher plant for many years. In most species it is quite effective but doubling rates may be low and the frequency of mixaploid tissue rather high (5). To over come the difficulty of mixaploid tissues or sectoral chimeras, Berthaut (2) treated red clover (Trifolium pratense L.) with nitrous oxide at the time of the first mitotic division of the zygote. Treatments of 6 to 10 bars atmospheric pressure for 12 to 36 hours after cross pollination produced up to 100 percent tetraploids. The optimum treatment appeared to be 6 bars atmospheric pressure (approximately 90 p.s.i.) at 24 hours after cross pollination. Production of sectoral chimeras were much less than reported with colchicine but some aneuploids were produced.

In this paper we report some of our earlier work with colchicine and compare that with nitrous-oxide treatments. Our objectives were to verify the success of Berthaut in producing tetraploids with nitrous oxide, to determine the feasibility of the treatment for other species of Trifolium and to ascertain the stability of the treated material by examination of somatic and meiotic preparations.

## MATERIALS AND METHODS

In the earlier colchicine treatments, 2 methods were used: shoot or seedling immersion and the drop or smear method. In the former, seeds of T. pratense and T. diffusum Ehrh. were sown in flats of soil and allowed to grow for 3 weeks. After the plants were removed from the soil, the roots were wrapped in wet paper towels and tops were clipped to within 2 1/2 cm of the bud. The plants were suspended roots upward in a 0.2% aqueous colchicine solution for 12 hours. The colchicine solution was not permitted to come in direct contact with the roots. A total of 900 plants were treated in each species. Following treatment, the seedlings were rinsed 3 times and left in running water overnight before being transplanted into flats of soil in a greenhouse.

---

1/ Professor of Agronomy, University of Kentucky; Associate Professor, North Dakota State University, Fargo, North Dakota (formerly Assistant Professor, University of Kentucky); and Assistant Professor, University of Florida, Gainesville, Florida (formerly D. F. Jones Graduate Fellow, University of Kentucky).

For the drop or smear method, growing points of 900 3-week-old plants of both species were smeared once daily for 6 consecutive days with a 0.2% colchicine-glycerine solution with swabs of cotton on toothpicks.

All plants received 12 hours of light in growth chambers and were divided into 3 temperatures: approximately 18, 24, and 30C, but for simplicity the results from the 3 treatments were averaged.

For nitrous oxide treatment, plants of the T. pratense cultivar 'Kenstar', T. alpestre L., and T. rubens L. were allowed to flower in a greenhouse. Heads were excised on 10 cm stems 24 hours after crossing within species and placed in vials containing a 2% aqueous sucrose solution. Vials with heads were placed in a gas-tight chamber and nitrous oxide was introduced and maintained at 6 bars atmospheric pressure. Nitrous oxide was introduced and evacuated from the chamber over a 20 to 30 minute period so as not to disrupt the plant tissues with sudden pressure changes. Approximately 25 to 50 cc of water was placed in the chamber to prevent dessication. After 24 hours, heads were removed to a dark incubator at 20 C for a seed maturation period of about 3 weeks.

Seeds from the colchicine and nitrous oxide treatments were germinated and were allowed to flower under 16-hour photoperiod in a greenhouse. A sample of pollen from each plant was examined at 100X according to the method of Hutton and Peak (3) and classified as large (Tetraploid) or small (diploid). Self seeds from heads of T. diffusum (an autogamous species) that were found to have large pollen were sown for later verification of the pollen classification. Random samples of buds and root tips of T. pratense and root tips of T. alpestre and T. rubens were collected for later cytological analyses. Root-tip chromosomes were counted by the method of Anderson et al. (1) and meiotic figures were stained by method of Snow (8).

## RESULTS AND DISCUSSION

Colchicine treatments: The shoot immersion method was more effective in producing plants with large pollen grains than the smear method (Tables 1, 2.) and was considerable less laborous. On the other hand, fewer plants survived the shoot immersion than did in the smear method of treatment so that the final percentages of plants with large pollen grains were not greatly different.

TABLE 1.--Results of treatment of T. pratense plants with colchicine.

| Method of treatment | Plants treated | Plants surviving | Plants with large pollen grains of survivors | Plants with large pollen grains of originals |
|---|---|---|---|---|
| | (No.) | (No.) | (%) | (%) |
| Immersion | 900 | 496 | 7.5 | 4.1 |
| Drop Appl. | 900 | 690 | 4.7 | 3.6 |

TABLE 2.--Results of treatment of T. diffusum plants with colchicine.

| Method of treatment | Plants treated | Plants surviving | Plants with large pollen grains of survivors | Plants with large pollen grains of originals |
|---|---|---|---|---|
| | (No.) | (No.) | (%) | (%) |
| Immersion | 900 | 260 | 9.6 | 2.8 |
| Drop Appl. | 900 | 879 | 4.5 | 4.4 |

About 15 progeny plants from each of 33 plants of T. diffusum with large pollen grains were grown (Table 3). Five produced progenies which yielded only large pollen grains, 8 produced progenies which yielded a mixture of sized and 20 produced progenies which yielded only small or normal diploid pollen. Apparently 28 of the original 33 plants were mixaploid.

A similar progeny test of colchicine-treated T. pratense was not possible because of self-incompatibility, and the amount of mixaploidy is unknown. No tetraploid red clover plants were isolated from the colchicine treatment. However, tetraplid red clover was developed later by similar methods using a self-compatible genotype.

Crosses among T. pratense plants produced 226 plants from the nitrous-oxide treatment which flowered and were classified for ploidy level based on pollen size (Table 4). The average percentage of plants with large pollen grains was 71. To verify the pollen classification, at least 10 root-tip cells from each of 136 plants were examined cytologically (Table 5). Eighty-eight percent of the original number were confirmed as tetraploids, and most of the remainder possessed aneuploid numbers of 26, 27, or 29. No sectoring was observed in the total sample of plants. Open-pollinated seed set of the euploid plants as determined at a later date was within the range for comparable tetraploids but much less than for diploid red clover (4).

TABLE 3.--Pollen size of self progenies of 33 plants of T. diffusum with large pollen grains.

| Pollen size | Plants (No.) |
|---|---|
| Only large pollen | 5 |
| Mixed pollen | 8 |
| Only small pollen | 20 |

TABLE 4.--Ploidy level of red clover plants produced after treatment with nitrous oxide at 6 bars atmospheric pressure based on pollen examination.

| Female Parent of Cross | Number of Plants 4x | 2x | Total | % 4x |
|---|---|---|---|---|
| 581 | 5 | 0 | 5 | 100 |
| 684 | 28 | 20 | 48 | 58 |
| 700 | 6 | 0 | 6 | 100 |
| 710 | 34 | 7 | 41 | 83 |
| 713 | 28 | 13 | 41 | 68 |
| 740 | 23 | 9 | 32 | 72 |
| 829 | 1 | 0 | 1 | 100 |
| 1173 | 23 | 15 | 38 | 61 |
| 1222 | 11 | 1 | 12 | 92 |
| 1224 | 1 | 1 | 2 | 50 |
| Total | 160 | 66 | 226 | 71 |

TABLE 5.--Effect of nitrous-oxide treatment on root-tip chromosome numbers in Trifolium species.

| Chromosome No. | Plants (No.) | (% of Total) |
|---|---|---|
| *T. pratense* | | |
| 14 | 3 | 2 |
| 14 or 28 | 2 | 1 |
| 26 | 1 | 1 |
| 27 | 4 | 3 |
| 28 | 119 | 88 |
| 29 | 7 | 5 |
| Total | 136 | 100 |
| *T. alpestre* | | |
| 16 | 22 | 49 |
| 31 | 1 | 2 |
| 32 | 22 | 49 |
| Total | 45 | 100 |
| *T. rubens* | | |
| 16 | 6 | 21 |
| 32 | 23 | 79 |
| Total | 29 | 100 |

Twelve plants not included in the original 226 because of lack of flowering were abnormal in appearance with wrinkled and misshapen leaves and shortened stems and petioles. One of these plants eventually flowered and produced sterile pollen. PMC's have not been examined but root-tip examination showed that the plant was octaploid, a condition which apparently exceeds the optimum ploidy level for T. pratense. This is the first report of octaploid red clover in the literature to our knowledge. Later we found that it was possible to produce octaploid T. pratense plants routinely by treatment of tetraploids with nitrous-oxide.

Meiotic analyses of 24 of the 136 plants examined somatically again verified the ploidy level as 4x (Table 6). Fewer quadrivalents and more bivalents and univalents were observed at M-1 of the tetraploids than were observed by either Schwer and Cleveland (7) or by Povilaitis and Boyles(6). Also, the percentage of lagging chromosomes (Table 6) was less than that observed at A-1 by Schwer and Cleveland in autotetraploid red clover.

TABLE 6.--Configurations observed at metaphase I and irregularities in disjunction at anaphase I in nitrous-oxide produced autotetraploid red clover.

| Plants (No.) | PMC's (No.) | Configurations at metaphase I-frequency and type | | | |
|---|---|---|---|---|---|
| | | I | II | III | IV |
| | | $\bar{x}$ Range | $\bar{x}$ Range | $\bar{x}$ Range | $\bar{x}$ Range |
| 23 | 281 | 1.22(0-10) | 10.43(6-14) | 0.13(0-3) | 1.38(0-5) |

| Plants (No.) | PMC's (No.) | Irregularities in disjunction at anaphase I | | |
|---|---|---|---|---|
| | | Lagging Chromosomes | | |
| | | Percent cells exhibiting | Range per cell | Cells with bridges |
| 22 | 268 | 25.5 | 0-7 | 4 |

Nitrous-oxide treatment of T. alpestre and T. rubens (Table 5) produced 49 and 79% tetraploids respectively. Other species doubled were T. noricum Wulf. and T. pallidum Wald. and Kit. By this time, the treatment was routine and no data on percentage tetraploids in these 2 species were collected. However, nitrous-oxide at 6 bars was toxic to T. hirtum All. and T. heldreichianum Hausen. and no tetraploids of these species have been obtained to date. Likewise autogamous annual species could not be doubled perhaps because of difficulty of timing of the first mitotic division of the zygote. Attempts to produce amphidiploids by treatment of plants after interspecific hybridization were unsuccessful.

It appears, therefore, that nitrous-oxide is an valuable alternative to colchicine for doubling chromosome numbers in Trifolium. Applications to which nitrous-oxide appears particularly well adapted include the cross pollinated species with high fertility. On the other hand, $F_1$'s of interspecific crosses may be difficult to double to produce amphiploids because of low seed set and the indication that nitrous-oxide treatment reduces the total amount of seed produced. Also, colchicine probably will be the better agent to use for the self-pollinated species because of the difficulty of timing for nitrous-oxide

treatment and the ease in these species of separating diploid and tetraploid tissues.

## LITERATURE CITED


(1) Anderson, M. K., Taylor, N. L., and Collins, G. B.
1972. Somatic chromosome numbers in certain Trifolium species. Canad. J. Genet. and Cytol. 14: 139-145.

(2) Berthaut, J.
1968. L'emploi du protoxyde d'ozote dans la creation de varietes autotetraploides chez le trefle violet (Trifolium pratense L.). Amelior. Plantes 18: 381-390.

(3) Hutton, E. M. and Peak, J. W.
1954. The effect of autotetraploidy in five varieties of subterraneum clover (Trifolium subterraneum L.). Aust. J. Agr. Res. 5: 356-364.

(4) Mackiewicz, T.
1965. Low seed-setting intetraploid red clover (Trifolium pratense L.) in the light of cytoembryologic analyses. Genetica Polonica 6: 5-39.

(5) Neubauer, J. and Thomas, H. L.
1966. Effects of various colchicine pH levels of seed treatment on polyploid cells and other cytological variations in root tips of red clover. Crop Sci. 6: 209-210.

(6) Povilaitis, B. and Boyles, J. W.
1956. A cytological study of autotetraploid red clover. Amer. J. Bot. 43: 169-174.

(7) Schwer, J. F. and Cleveland, R. W.
1972. Tetraploid and triploid interspecific hybrids of Trifolium pratense L., T. diffusum Ehrh., and some related species. Crop Sci. 12: 419-422.

(8) Snow, R.
1963. Alcoholic hydrochloric acid - carmine as a stain for chromosomes in squash preparations. Stain Tech. 39: 9-13.

# BREEDING ALFALFA RESISTANCE TO THE ALFALFA WEEVIL

By Thad H. Busbice [1/]

The alfalfa weevil *Hypera postica* (Gyllenhal) was discovered in the eastern USA in 1952 (7). During the next two decades this insect devastated the alfalfa crop across the south reducing acreages from 50 to 90%. None of the varieties being grown at the time appeared to contain resistance. Four hundred fifty-six alfalfa introductions were evaluated for resistance in the field and all were susceptible, although differences in degree of damage were noted (5).

In the south the weevil is mostly inactive during the summer and early fall (7). But during late fall and winter the adult female enter the field to oviposite her eggs in alfalfa stems and crown buds. During late winter and early spring the eggs hatch and young larvae begin feeding on the new alfalfa growth. By late April or early May larvae often will have defoliated the entire alfalfa field. It is this feeding by the larvae that reduces yield and stand.

Breeding alfalfa for resistance to the alfalfa weevil has followed three courses of action:

a. Selecting plants less defoliated by larvae in the field under natural infestation.

b. Selecting plants resistant to oviposition by the adult (4, 6).

c. Selecting plants with antibiotic factors that adversely affect the weevil (1, 2).

The most successful field selection has been in the Starnes strain of alfalfa (Figure 1). The varieties 'Team' and 'Arc' were bred from this strain. The Starnes strain was initiated in 1957 by C. H. Hanson [2/] who selected 66 plants with low larval damage from a large number of polycross progenies in a field near Raleigh, N. C. (3). This field had been rented from the Starnes family, thus the strain has been called the Starnes strain. Resistance has steadily increased with generations of field selection (Table 1). NCW20 will be named and released as a variety. NCW21, which shows the most resistance, differs from NCW20 only in the final selection. The 49 parental clones of NCW20 were evaluated for low larval feeding for two years in a replicated field trial. The 20 most resistant clones were combined to produce NCW21. The level

---

1/ Research Geneticist, ARS, U.S. Dept. of Agriculture, 1126 Williams Hall, N. C. State University, Raleigh, N. C. 27607.

2/ Research Agronomist, ARS, U.S. Dept. of Agriculture.

of resistance achieved in NCW20 and NCW21 may be sufficient to allow alfalfa to be grown economically without the use of insecticides.

TABLE 1.--Field evaluation of field selection for weevil resistance in the Starnes strain of alfalfa.

| Entry | Generation of selection | Defoliation by larvae measured in five experiments | | | | |
|---|---|---|---|---|---|---|
| | | A157 | A184 | A188 | A212 | A220 |
| | | % | | | | |
| Field selection for tolerance to larval defoliation | | | | | | |
| $MSH_p2$ | 1 | 49 | -- | -- | -- | -- |
| $MSH_p5$ | 4 | 36 | 34 | 45 | -- | -- |
| $MSH_p6F$ | 5 | -- | 33 | 39 | -- | -- |
| NCW20 | 6 | -- | -- | -- | 12 | 20 |
| NCW21 | 6 | -- | -- | -- | 10 | 13 |
| Check varieties | | | | | | |
| Weevlchek | -- | -- | 49 | 65 | 49 | 56 |
| Cherokee | -- | 68 | 55 | 67 | 49 | -- |
| Williamsburg | -- | 63 | 55 | -- | 62 | 55 |
| LSD .05 | | 13 | 7 | 5 | 9 | 14 |
| LSD .01 | | 18 | 10 | 7 | 12 | 19 |

Selection for resistance to oviposition by the adult female appeared to have been successful at first (4, 6). Greenhouse selection for non-preference to oviposition quickly increased resistance to oviposition, as measured in the greenhouse. But when the selected populations were grown in the field, they were just as susceptible as the checks. The germplasm NCW(64)1, which was released[3/] as being less preferred by the female for oviposition than other sources, was found to be very susceptible to larval feeding in the field (Table 2). An effort to increase the weevil resistance in the Starnes strain by greenhouse selection for non-preference to oviposition failed, as measured by field evaluation (Table 2).

Efforts to improve resistance to the alfalfa weevil by laboratory selection for antibiotic factors appears to have failed also. Three generations of laboratory selection in the Starnes strain for resistance to adult leaf feeding and larval development (3) did not increase resistance to a level higher than that already achieved by field selection (Table 3). In addition, the germplasm AWPX3, which was released [4/] as expressing antibiotic factors in the laboratory tests, was highly susceptible in the field (Table 3).

3/ Notice to plant breeders of release of alfalfa germplasm with weevil resistance, N. C. Agri. Exp. Sta. and ARS, U.S. Dept. of Agri., December 31, 1964.

4/ Notice of release of alfalfa weevil resistant germplasm AWPX3 to alfalfa breeders, ARS, U.S. Dept. of Agric., March 20, 1968.

TABLE 2.--Field evaluation of greenhouse selection for weevil resistance in the Starnes strain of alfalfa.

| Entry | Generation of selection | Defoliation by larvae measured in two experiments A188 | A200 |
|---|---|---|---|
| | | ----------% | ----------- |
| Starting population | | | |
| MSHp6F | 5 | 39 | -- |
| Greenhouse selection for oviposition non-preference from MSHp6F | | | |
| NCW19a | 6 | 45 | 41 |
| NCW19b | 7 | 44 | 47 |
| NCW19c | 8 | -- | 43 |
| Check varieties | | | |
| Weevlchek | -- | 65 | -- |
| Cherokee | -- | 67 | 75 |
| Team | -- | 44 | 50 |
| Arc | -- | -- | 32 |
| LSD .05 | | 5 | 9 |
| LSD .01 | | 7 | 13 |

TABLE 3.--Field evaluation of laboratory selection for weevil resistance in the Starnes strain of alfalfa.

| Entry | Generation of selection | Defoliation by larvae measured in four experiments A170 | A184 | A188 | A220 |
|---|---|---|---|---|---|
| | | ----------% | ---------- | ---------- | ---------- |
| Starting population | | | | | |
| MSHp5 | 4 | -- | 34 | 45 | -- |
| Laboratory selection for antibiotic factors from MSHp5 | | | | | |
| MSHp6 | 5 | -- | 35 | 46 | -- |
| MSHp7 (Team) | 6 | 41 | 33 | 44 | 32 |
| MSHp8 | 7 | -- | -- | 45 | -- |
| Check varieties | | | | | |
| Weevlchek | -- | -- | 49 | 65 | 56 |
| Cherokee | -- | 72 | 55 | 67 | -- |
| Williamsburg | -- | 80 | 55 | -- | 55 |
| Arc | -- | -- | -- | -- | 32 |
| AWPX3 | -- | 68 | 51 | -- | -- |
| LSD .05 | | 9 | 7 | 5 | 14 |
| LSD .01 | | 12 | 10 | 7 | 19 |

In summary, I have observed only one source of germplasm that has consistently shown resistance to the alfalfa weevil. This source is the Starnes strain. Field selection under natural infestation for low larval defoliation has been the only breeding method that has proven successful to date. This kind of selection can be practiced on spaced plants. Such selection has been very successful in the Starnes strain, and it may be successful in other germplasm sources as well.

## LITERATURE CITED


(1) Barnes, D. K., and Ratcliffe, R. H.
1967. Leaf disk method of testing alfalfa plants for resistance to feeding by adult alfalfa weevil and factors affecting it. J. Econ. Entomol. 60: 1561-1565.

(2) Barnes, D. K., Ratcliffe, R. H., and Hanson, C. H.
1968. Interrelationship of three laboratory screening procedures for breeding alfalfa resistant to the alfalfa weevil. Crop Sci. 9: 77-79.

(3) Barnes, D. K., Hanson, C. H., Ratcliffe, R. H., Busbice, T. H., Schillinger J. A., Buss., G. R., Campbell, W. V., Hemken, R. W. and Blickenstaff, C. C.
1970. The development and performance of Team alfalfa. Bul. ARS 34-115, U.S. Dept. of Agric.

(4) Busbice, T. H., Campbell, W. V., Rawlings, J. O., Barnes, D. K., Ratcliffe, R. H., and Hanson, C. H.
1968. Developing alfalfa resistant to alfalfa weevil oviposition. Crop Sci. 8: 762-767.

(5) Busbice, T. H., Barnes, D. K., Hanson, C. H., Hill, R. R., Jr., Campbell, W. V., Blickenstaff, C. C., and Newton, R. C.
1967. Field evaluation of alfalfa introductions for resistance to the alfalfa weevil *Hypera postica* (Gyllenhal). ARS Bul. 34-94, U.S. Dept. of Agric.

(6) Campbell, W. V. and Dudley, J. W.
1965. Differences among *Medicago* species in resistance to oviposition by the alfalfa weevil. J. Econ. Entomol. 58: 245-248.

(7) Campbell, W. V., Busbice, T. H., Falter, J. M., and Glover, J. W.
1975. Alfalfa weevil and its management in North Carolina. Tech. Bul. No. 234, N. C. Agr. Exp. Sta., Raleigh, N. C.

# SCREENING FOR RESISTANCE TO THE CLOVER HEAD WEEVIL, *HYPERA MELES* (FAB.) 1/

By C. M. Smith and W. E. Knight 2/

The clover head weevil, *Hypera meles* (F.), greatly hinders the reseeding of crimson clover, *Trifolium incarnatum* L., because of the larval damage to floral parts and developing seeds. The total crimson clover acreage in the southeastern United States has declined from an estimated 6 million acres grown in 1951 to 600,000 acres. Although cheap nitrogen fertilizer contributed to this decline, much of this decline has been attributed to *H. meles*, with reported reductions in seed yield ranging from 80 to 87%.

This paper reports: 1) Methods of screening selected inbred lines of crimson clover for resistance to damage to the seed head by larvae of *H. meles* and 2) Differences in feeding preference of *H. meles* on *Trifolium* spp.

Feeding preference of the adult clover head weevil was determined on 90 inbred lines of crimson clover (Table 1.). Significant differences were observed among inbred lines in whole plant (seedling) feeding tests in the greenhouse and in mature leaf disc tests, but not in seedling stem feeding tests in a growth chamber.

TABLE 1.--Treatment F values, coefficients of variation, and damage ranges for indicated tests of clover head weevil feeding on crimson clover.

| Test Criteria | Treatment F value | CV (%) | Damage Range |
|---|---|---|---|
| | | | Score 1-10 |
| Whole plant feeding | 1.54* | 23.5 | 1.5-4.5 |
| Stem feeding | 1.19 | 25.7 | 2.5-6.0 |
| Leaf disc feeding | | | Mg. leaf tissue consumed |
| Early maturity | 2.62** | 25.6 | 0.3-1.5 |
| Mid maturity | 5.68** | 25.4 | 0.1-0.2 |
| Late maturity | 1.77** | 44.7 | 0.1-0.2 |

*, ** Significant at the 5% and 1% levels, respectively.

1/ Cooperative investigations of the Mississippi Agricultural and Forestry Experiment Station and the Plant Science Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Mississippi State, Mississippi 39762.

2/ Graduate Research Assistant, Department of Entomology, Mississippi Agricultural and Forestry Experiment Station; and Research Agronomist, Plant Science Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Mississippi State, Mississippi, respectively.

Whole plant feeding tests yielded results similar to those obtained with leaf disc tests, but required much less labor. Correlations between leaf disc feeding and leaf pubescence were too variable and too low to be of much value in selection for weevil resistance (Smith et al., 1975a).

In leaf disc tests conducted with trifoliolates of 10 Trifolium spp. (Tab. 2), lappa, crimson, ball, and striate clovers were all significantly less fed on by H. meles than were red or white clover. Leaf feeding on the least preferred clover, striate, did not differ significantly from feeding on arrowleaf, ball, crimson, lappa, strawberry, or subterranean clover (Smith et al., 1975b).

TABLE 2.--Adult H. meles leaf disc feeding on 10 Trifolium spp.

| Trifolium spp. | Common Name | Mean mg. leaf tissue consumed |
|---|---|---|
| T. striatum | Striate clover | 0.070 a* |
| T. nigrescens | Ball clover | 0.074 ab |
| T. incarnatum | Crimson clover | 0.074 ab |
| T. lappaceum | Lappa clover | 0.075 ab |
| T. subterraneun | Subterranean clover | 0.092 abc |
| T. fragiferum | Strawberry clover | 0.096 abc |
| T. vesiculosum | Arrowleaf clover | 0.099 abc |
| T. alexandrinum | Hop clover | 0.102 bc |
| T. pratense | Red clover | 0.112 c |
| T. repens | White clover | 0.123 c |

* Means not followed by the same letter differ significantly at the 0.05 probability level as determined by Duncan's multiple range test.

Plastic chambers were built to measure clover head weevil larvae feeding damage. Excised crimson clover seed heads of 35 inbred lines were placed in the chambers and exposed to larvae of H. meles. Percent seed damage was based on number of florets with corollas removed. Seed was considered to be undamaged when the corollas were not disturbed. Significant differences existed between the least and most fed on lines among both early and late-season inbreds (Smith et al., 1975c).

Inbred lines of crimson clover were field-screened for resistance to weevil oviposition and larval feeding damage in plant nurseries established in an area of inherent weevil infestation, and supplemented with additional field-collected weevils (1 pair/2 plants), released during the period of peak oviposition. Whole plant samples were taken periodically during the clover growing season to measure eggs/stem, larvae/head, and pupae/head. Generally, numbers of eggs, larvae, and pupae increased on plants with more stems and heads. Approximately, 60% of all eggs were found in the second stem internodes, but no relationship was found between stem length, diameter, or pubescence density and oviposition. Larval feeding damage to various numbers of seedheads was compared to determine the most reliable sample size. When top and bottom halves of individual seedheads were compared, the bottom halves, which were more uniformly pollinated, were found to be more representative of insect damage. Egg, larval, and pupal data were compared to actual seed damage to determine if any of the three could predict seed damage. Pupal cases per seed head were found to be significantly correlated to percentage seed damage in two crimson clover varieties (Chief r= 0.65, 14 df; Tibbee r= 0.61, 10df) and gave the most reliable indication of seed damage (Smith et al., unpublished results).

Development of crimson clover varieties with weevil resistance could greatly improve the reseeding success of this important forage legume, and reduce or eliminate the requirement for chemical control of the clover head weevil.

## LITERATURE CITED


(1) Smith, C. M., Pitre, H. N., and Knight, W. E.
1975a. Evaluation of crimson clover for resistance to leaf feeding by the adult clover head weevil. Crop Sci. 15: 278-8.

(2) Smith, C. M., Knight, W. E., and Pitre, H. N.
1975b. Feeding preference of the clover head weevil on clovers of the genus Trifolium. J. Econ. Entomol. 68: 165-6.

(3) Smith, C. M., Pitre, H. N., and Knight, W. E.
1975c. Evaluation of crimson clover seed damage by the clover head weevil. Florida Entomol. 58: 113-6.

# SCREENING FOR SPITTLE BUG RESISTANCE IN BUFFELGRASS

By Ethan C. Holt and B. E. Conrad [1/]

A Mexican Spittle bug complex made up of two genera and five species has been moving steadily northward on the east coast of Mexico. Infestations had been observed within 50 miles of the South Texas border by 1974. Varying degrees of damage have been reported with the greatest damage occurring on improved pastures. One of the most susceptible grass species is buffelgrass (*Cenchrus ciliaris*) which occupies extensive acreages in South Texas. Because of the potential threat to improved pastures and ranges in South Texas, a cooperative monitoring and research program was started in Mexico. This report is concerned with one phase of that program.

Our phase of the program has been concerned with developing host plant resistance to the spittle bug complex. Since buffelgrass is the most important grass in South Texas, our first efforts have been with buffelgrass. Since the spittle bug complex does not occur in Texas, our efforts have been limited to work in Mexico. The primary problems encountered in this approach involve the physical movement of plant materials across international borders, the language barrier, and the development of appropriate screening or evaluation techniques. We have had excellent cooperation with Dr. Dieter Enkerlin, Director, Graduate Programs in Agriculture, Instituto Technologico y de Estudios Superiores, Monterry, N. L. Mexico, who is an Entomologist.

Monterrey is on the fringe of the northern advancement of the complex and for this reason dependence on natural infestations for screening for host plant resistance is unreliable. Monterrey Tech has a research farm south of Tampico and this location has been used for studies under natural infestations.

In mid-August, 1974, approximately 70 apomictic buffelgrass and buffelgrass x birdwoodgrass hybrids were established at Monterrey and Tampoal (South of Tampico). Each line was represented by six closely spaced seedling plants per plot in three replications. All plots became established during the fall and winter and were cut back to a uniform height in April 1975.

On July 29, 1975, at Monterrey, replication 1 was mowed to a uniform height, replication 2 plant heights were determined and 60% of the top growth removed from each plot, replication 3 was not cut in July. The number of tillers (elongated stems) was counted in each plot in replication 2 as well as the number of spittle masses present on July 29. Each plot in replication 2 was covered with a fine mesh nylon-covered frame and adult spittle bugs introduced under the cover to provide uniform infestations per tiller. Twenty-one

1/ Professor and Associate Professor, Soil and Crop Sciences Department, Texas Agricultural Experiment Station, College Station, TX 77843.

days following caging, plants in replication 2 only were cut to a uniform height and spittle masses counted. In late September the degree of top damage under cages was noted.

In June 1975, an additional 77 hybrids were established at Monterrey, Tempoal and on a private rance near Monte, Mexico in the same pattern described above. In addition, seedling plants of each hybrid were established in individual pots in the greenhouse, each pot covered with a fine mesh screen and two adult spittle bugs, one male and one female, introduced on each plant.

Field observations under uncontrolled conditions at both Tempoal and Monte detected differences in amount of top damage in 1975. However, total growth was not greatly affected. Recovery growth in 1976 will be a greater factor in determining the degree of damage and genetic differences to spittle bug damage than the appearance of the plants in 1975.

A wide range in degree of top damage under controlled infestations under cages was apparent in September, 1975 (Table 1). Six plants showed no apparent spittle bug damage while 13 plants showed complete top kill. The remaining plants showed responses between these two extremes. Uncaged plants in replication 1 and 3 showed some leaf damage with differences between genotypes but no extreme damage comparable to that found under cages.

TABLE 1.--Frequency distribution of spittle bug damage to top growth of buffelgrass hybrids, Monterrey, Mexico, 1975.

| Damage Rating | Number of Plants |
|---|---|
| No Apparent Damage | 6 |
| Slight Damage | 12 |
| Stunted, Yellow Leaves | 18 |
| Leaves Mostly Brown | 21 |
| No Green Leaves | 13 |
| Total | 70 |

The data in Table 2 represent some of the most susceptible and some of the most resistant or tolerant lines. Some lines appear to tolerate a fairly heavy load (65), while sustaining relatively little damage, others are apparently resistant in that the insects either do not increase or survive on them (49, 42), while still others are subject to severe damage (53, 62).

TABLE 2.--Insect Counts and Plant Damage Under Cages, Monterrey, Mexico, 1975.

| Line No. | No. of Nymph August | | No. of Adults August | | % Damage | |
|---|---|---|---|---|---|---|
| | 1 | 20 | 1 | 20 | Aug. 20 | Sept. 25 |
| 17 | 89 | 13 | 24 | 42 | 60 | 10 |
| 65 | 60 | 27 | 58 | 30 | 10 | 10 |
| 49 | 0 | 0 | 23 | 0 | 10 | 10 |
| 42 | 8 | 2 | 14 | 6 | 10 | 10 |
| 53 | 42 | 15 | 48 | 100 | 20 | 100 |
| 62 | 5 | 4 | 41 | 10 | 30 | 100 |

The results under cages are encouraging and suggest potential for making progress through breeding for resistance. Since only one replication could be evaluated, the study will be repeated in 1976, concentrating on plants showing the greatest tolerance. The greenhouse study was conducted on a different set of genotypes and does not serve to confirm field cage results. Differences were observed in the greenhouse but the range of responses was not as wide as observed under cages in the field.

Screening techniques require additional modifications and verification. If the greenhouse technique yields repeatable results and seedling plant resistance is related to mature plant resistance, more plants can be screened using less space, fewer insects and at less expense for experimental materials. A system is needed for evaluating more precisely the degree of yield or vigor loss from spittle bug attack in the absence of significant top kill or apparent leaf damage.

# SCREENING FORAGES FOR RESISTANCE TO ROOT PRUNING NEMATODES

By R. L. Haaland, C. S. Hoveland, and R. Rodriguez-Kabana 1/

## INTRODUCTION

Low forage production, common in the Southeastern United States, may be the result of poor stand establishment, low heat and drought tolerance, and lack of persistence. These problems are particularly evident on light textured soils common to the Coastal Plain. The cause of these problems may be root pruning nematodes that are commonly found in lighter soils.

Forage production has been increased in sorghum, (*Sorghum bicolor*), sorghum-sudangrass (*S. bicolor* x *S. sudanense*) and pearl millet (*Pennisetum typhoides*) by controlling nematodes (14). High populations of stubby root (*Trichodorus christiei*) have been associated with root damage and stand losses of 52 percent in tall fescue (*Festuca arundinacea*) and 78 percent in phalaris (*Phalaris aquatica*) (11). The application of a nematicide before planting rye (*Secale cereale*) increased autumn forage production 29 percent over a three year period (12). Several tropical forages are also damaged by plant parasitic nematodes (4, 5, 6, 7). Several nematode genera have been found in association with many different grasses and legumes (9, 15, 16, 17).

### Screening Systems

Screening techniques for nematode resistance in forage crops are limited and those that have been developed, screen for resistance to only one nematode species. Shepherd, et al. (19) described an improved method of screening vetch (*Vicia sativa*) and sericea lespedeza (*Lespedeza cuneata*) for resistance to root-knot nematodes (*Meloidogyne* spp.). Hunt et al. (13) used field inoculation techniques to screen alfalfa (*Medicago sativa*) for resistance to the root-knot nematode (*Meloidogyne hapla*). Other studies using screening systems to determine segregation for nematode resistance have been concerned with only one nematode species at the time (2, 3, 8, 10).

The philosophy of screening for resistance to one nematode species at a time is appropriate if only one species is the pathogen. However, if several nematode species are involved in the pathogenic response, working with one at a time may not be the most effective way of obtaining resistant or tolerant

---

1/ Assistant Professor and Professor of Agronomy and Soils Department, and Associate Professor, Department of Botany and Microbiology, Auburn University Agricultural Experiment Station, Auburn, Alabama.

germplasm in the initial stages of breeding for nematode resistance. Techniques used at Auburn were developed to screen seedlings for resistance or tolerance to several parasitic nematodes prevalent in Alabama soils including stubby root (Trichodorus spp.), stunt (Tylenchorhynchus spp.), spiral (Helicotylenchus spp.), lance (Pratylenchus spp.), ring (Creconemoides spp.), and dagger (Xiphenema spp.). The Auburn technique is a broad spectrum system in which seedlings of a forage species are grown in the greenhouse, on one inch centers, in soil obtained from the field. The soil used for screening must contain 10 to 15 parasitic nematodes per 50cc of soil. After six to eight weeks of growth the seedlings are dug, the roots washed and scored for vigor and namatode damage. Seedlings grown in methyl bromide treated soil serve as non-infected checks. Both grasses and legumes can be evaluated with this system.

Other microorganisms such as fungi, bacteria, and virus can interact with namatodes to cause disease symptoms on crop plants (18). This probably occurs in forage crops also. By using soil from the field (containing nematodes and other organisms) as the screening medium plants showing a tolerance reaction may be tolerant to the total soil pathogen complex. This type of host reaction would probably be governed by several genes rather than having the simpler genetic systems associated with resistance to only one pathogen (1, 8). As more information is obtained about individual pathogenic species, more refined screening and genetic techniques may be appropriate.

## Initial Screening Results

Several cool-season grasses and legumes have been evaluated in the greenhouse nematode screening program at Auburn. All grass species evaluated showed a reduction in plant height and root vigor when grown in soil infested with nematodes (Tables 1 and 2). Reed canarygrass (Phalaris arundinacea) had the least vigorous root system when grown in association with nematodes, whereas wheat had the most vigorous root system. Wheat (Triticum aestivum) tended to be more tolerant of nematodes than the other grass species. Cool-season annual species showed less reduction in plant height than perennial species with the exception of smooth bromegrass (Bromus inermis). All grass seedlings had some damage to their roots when grown in nematode infested soil. The frequency of seedling tolerant to nematode damage was low within all grass species.

TABLE 1.--Reaction of Cool-Season Perennial Grasses to Nematodes

| Species | Root Score 1/ | | Plant Height (Millimeters) | | |
|---|---|---|---|---|---|
| | +Nem 2/ | -Nem 2/ | +Nem | -Nem | Percent Reduction |
| Tall Fescue | 7.4 | 2.8 | 61 | 135 | 55 |
| Bromegrass | 7.4 | 4.1 | 73 | 112 | 35 |
| Orchardgrass | 8.0 | 4.0 | 33 | 65 | 49 |
| Phalaris | 8.0 | 4.7 | 53 | 122 | 57 |
| Ky Bluegrass | 8.0 | 3.9 | 19 | 51 | 63 |
| Reed Canary | 8.6 | 3.9 | 45 | 117 | 62 |

1/ Root Score 1 = most vigorous root system; 10 = weakest root system

2/ +Nem: Soil infested with neamtodes; all seedlings showed nematode damage.

-Nem: Soil treated with methyl bromide to kill neamtodes; no seedlings showed nematode damage.

TABLE 2.--Reaction of Cool-Season Annual Grasses to Nematodes.

| Species | Root Score[1] | | Plant Height (Millimeters) | | |
|---|---|---|---|---|---|
| | +Nem[2] | -Nem[2] | +Nem | -Nem | Percent Reduction |
| Wheat | 5.5 | 2.8 | 110 | 181 | 39 |
| Rye | 7.3 | 3.5 | 117 | 174 | 33 |
| Ryegrass | 7.1 | 3.0 | 92 | 152 | 39 |

1/ Root Score: 1 = most vigorous root system; 10 = weakest root system
2/ +Nem: Soil infested with nematodes; all seedlings showed nematode damage.
-Nem: Soil treated with methyl bromide to kill nematodes; no seedlings showed nematode damage.

Leaf number was measured in addition to plant height and root vigor in the grasses; however, leaf number and plant height were poorly correlated with root vigor. The best method for selecting tolerant individuals was by close observation of root vigor and root pruning as compared to seedlings that had not been attacked by nematodes.

Cool-season legumes, both annual and perennial, had reduced root vigor and plant height when grown in association with nematodes (Tables 3 and 4). In addition, the annual legumes, crimson (*Trifolium incarnatum*) and arrowleaf clover (*T. vesiculosum*) showed a striking reduction in leaf number when attacked by nematodes. Red clover (*T. pratense*) had slightly less root vigor than ladino clover (*T. repens*) or alfalfa (*Medicago sativa*) in both nematode infested and non-infested soils. Arrowleaf clover showed less reduction in root vigor and plant height but more reduction in leaf number than crimson clover when attacked by nematodes.

TABLE 3.--Reaction of Cool-Season Perennial Legumes to Nematodes.

| Species | Root Score[1] | | Plant Height (Millimeters) | | |
|---|---|---|---|---|---|
| | +Nem[2] | -Nem[2] | +Nem | -Nem | Percent Reduction |
| 'Regal' Ladino Clover | 5.3 | 1.8 | 41 | 72 | 43 |
| 'Kenland' Red Clover | 6.0 | 3.3 | 53 | 78 | 32 |
| 'Florida 66' Alfalfa | 5.3 | 2.0 | 40 | 57 | 30 |

1/ Root Score: 1 = most vigorous root system; 10 = weakest root system
2/ +Nem: Soil infested with nematodes.
-Nem: Soil treated with methyl bromide to kill nematodes.

TABLE 4.--Reaction of Cool-Season Annual Legumes to Nematodes.

| Species | Root Score[1/] | | Plant Height (mm) | | | Leaf Number | | |
|---|---|---|---|---|---|---|---|---|
| | +Nem[2/] | -Nem[2/] | +Nem | -Nem | Percent Reduction | +Nem | -Nem | Percent Reduction |
| 'Autauga' Crimson Clover | 5.0 | 3.0 | 46 | 67 | 31 | 9.9 | 15.4 | 36 |
| 'Yuchi' Arrowleaf Clover | 4.1 | 3.0 | 54 | 67 | 19 | 8.1 | 15.4 | 47 |

1/ Root Score: 1 = most vigorous root system; 10 = weakest root system
2/ +Nem: Soil infested with nematodes.
-Nem: Soil treated with methyl bromide to kill nematodes.

An additional characterization of root damage by nematodes was added to the legume root scores. The roots were grouped as susceptible if pruning was severe, moderately susceptible if pruning was moderate and apparently resistant if no sign of pruning was evident. Perennial legumes had a high percentage of susceptible plants with two ladino and two red clover plants classed as moderately susceptible (Table 5). None of the perennial legumes had plants classified as apparently resistant. Annual legumes contained a higher percentage of moderately susceptible plants than perennials. In addition, crimson clover contained one apparently resistant plant out of 57 examined and arrowleaf contained three apparently resistant plants out of 59 examined (Table 6).

TABLE 5.--Nematode Symptomology Reaction of Three Cool-Season Perennial Legumes.

| Species | Susceptible[1/] | Moderately Susceptible[1/] | Apparently Resistant[1/] |
|---|---|---|---|
| | Number of Plants | | |
| 'Regal' Ladino Clover | 58 | 2 | 0 |
| 'Kenland' Red Clover | 48 | 2 | 0 |
| 'Florida 66' Alfalfa | 48 | 0 | 0 |

1/ Susceptible: Roots showed extensive pruning by nematodes.
Moderately Susceptible: Roots showed moderate pruning (perhaps an indication of tolerance).
Apparently Resistant: Roots showed no visible signs of root pruning.

TABLE 6.--Nematode Symptomology Reaction of Cool-Season Annual Legumes.

| Species | Susceptible 1/ | Moderately Susceptible 1/ | Apparently Resistant 1/ |
|---|---|---|---|
| | Number of Plants | | |
| 'Autauga' Crimson Clover | 44 | 12 | 1 |
| 'Yuchi' Arrowleaf Clover | 40 | 16 | 3 |

1/ Susceptible: Roots showed extensive pruning by nematodes
Moderately Susceptible: Roots showed moderate pruning (perhaps an indication of tolerance).
Apparently Resistant: Roots showed no visible signs of root pruning.

## CONCLUSION

Several thousand tall fescue and phalaris seedlings have been screened for nematode resistance at Auburn University. The most tolerant and the most susceptible seedlings have been selected and established in the field for intercrossing to determine if the nematode tolerance observed is a heritable trait. If it is heritable and if seeding tolerance will hold up as mature plant tolerance, nematode resistant varieties could be developed. Nematode resistant varieties would probably improve forage production in the Southeast and perhaps extend the range of adaptation of some of the cool-season species that currently cannot be grown on the Coastal Plains soils.

## LITERATURE CITED


(1) Adamson, W. C., Donnelly, E. D., Minton, N. A., and Miller, J. D.
1974. Inheritance of resistance to Meloidogyne hapla in Lespedeza cuneata. The Jour. of Her. 65: 365-368.

(2) Bain, D. C.
1959. Selection for resistance to root knot of white and red clover. Plant Dis. Reptr. 43: 318-322.

(3) Bingefors, S.
1956. Inheritance of resistance to stem nematodes in red clover. Nematologica 1: 102-108.

(4) Boyd, F. T. and Perry, V. G.
1969. The effect of sting nematodes on the establishements, yield, and growth of forage grasses on Florida soils. Proc. Soil and Crop Sci. Soc. of Fla. 29: 288-300.

(5) Boyd, F. T. and Perry, V. G.
1970. Effect of seasonal temperatures and certain cultural treatments on sting nematodes in forage grass. Prod. Soil and Crop Sci. Soc. of Fla. 30: 360-365.

(6) Boyd, F. T. and Dicksan, D. W.
1971. Plant-parasistic nematodes: Occurrence in Florida, sensitivity to temperature, and effect on tropical forage yields. Proc. Soil and Crop Sci. of Fla. 31: 267-268.

(7) Boyd, F. T., Schroder, V. N., and Perry, V. G.
1972. Interation of nematodes and soil temperature on growth of three tropical grasses. Agron. J. 64: 497-500.

(8) Cook, R.
1974. Nature and inheritance of nematode resistance in cereals. J. Nematol. 6: 165-174.

(9) Eriksson, K. B.
1972. Nematode diseases of pasture legumes and turf grasses. In: J. M. Webster (ed.) Economic Nematology. Academic Press, N. Y.

(10) Hare, W. W.
1965. The inheritance of resistance of plants to nematodes. Phytopathy. 55: 1162-1167.

(11) Hoveland, C. S., Rodriguez-Kabana, R., and Berry, C. D.
1975. Phalaris and tall fescue forage production as affected by nematodes in the field. Agron. J. 67: 714-717.

(12) Hoveland, C. S., Rodriguez-Kanaba, R., Starling, J. G., and Bannon, J. S.
1976. Cool season annual pasture mixtures as affected by autumn irrigation and nematicide in the Wiregrass area. Auburn University (Ala.) Agr. Exp. Sta. Cir. 228.

(13) Hunt, O. J., Peaden, R. N., Faulkner, L. R., Griffin, G. D., and Jensen, H. J.
1969. Development of resistance to root-knot nematode (Meloidogyne hapla Chitwood) in alfalfa (Medicago sativa L.) Crop Sci. 9: 624-627.

(14) Johnson, A. W., and Burton, G. W.
1973. Comparison of millet and sorghum-sudangrass hybrids grown in untreated soil and soil treated with two nematicides. J. Nematology 5: 54-59.

(15) Kort, J.
1972. Nematode diseases of cereals of temperate climates. In: J. M. Webster (ed.) Economic Nematology. Academic Press. N. Y.

(16) McGlohon, N. E., Sasser, J. M., and Sherwood, R. T.
1961. Investigations of plant-parasitic nematodes associated with forage crops in North Carolina. N. C. Tech. Bul. 148: 1-39.

(17) Minton, N. A. and Donnelly, E. D.
1971. Reaction of field-grown sericea lespedeza to selected Meloidogyne spp. J. Nematology 3: 369-373.

(18) Powell, N. T.
1971. Interaction of plant parasitic nematodes with other disease carrying agents. In: B. M. Zuckerman (ed.) Plant Parasitic Nematodes. Academic Press. N. Y.

(19) Sheperd, R. L., Minton, N. A., and Donnelly, E. D.
1965. An improved method of screening plants for root-knot resistance. Twenty-second Southern Pasture and Forage Crop Improvement Conference. Nashville, Tenn.

# RHIZOBIA SELECTION FOR FORAGE LEGUMES 1/

By Joe C. Burton 2/

Leguminous plants are valued as forage crops because of their ability to work symbiotically with nodule bacteria (Rhizobium sp.) and use the free nitrogen ($N_2$) of the atmosphere. Maximization of forage production depends upon improved host genotypes, wise use of highly effective rhizobia and prudent management. Indeed, these are the objectives of this conference.

It seems unusual, but the genus, Rhizobium, encompasses the nodule bacteria for the more than 12,000 species of leguminous plants in about 600 genera. The Rhizobium genus is divided into seven species, but only six have names. Differentiation of species is based on ability to produce nodules on particular host plants rather than morphological or cultural characteristics of the bacteria or capacity to fix $N_2$. While nodulation is a prerequisite for $N_2$ fixation, it is no assurance of it.

Differentiation of rhizobia into species was discontinued more than three decades ago because of the ever increasing reports of non-reciprocal reactions between plants within a cross-inoculation group and because of the objection to using host response as a taxonomic character. It is common practice now to designate isolates of rhizobia by the name of the parent host when there is no species name.

## Nitrogen Fixation

The prime objective in inoculating legume seeds is to assure the presence of highly effective strains of rhizobia to nodulate the host plant and provide abundant nitrogen. Nitrogen fixing ability can be determined only by putting the bacteria and plant together under a favorable environment and measuring growth in a nitrogen-poor substrate. Rhizobium strains which provide abundant N in association with one host may nodulate another without providing any N. This is true with species and with cultivars although differences between cultivars are generally of lower magnitude.

---

1/ Contribution from Research Dept., The Nitragin Co., Milwaukee, Wis. 53209

2/ Vice-President, Research and Development

TABLE 1.--Leguminous Forage Plants Nodulated by Rhizobium (species or variety).

A. Rhizobium meliloti: Alfalfa, (Medicago sativa, L.) Sweet clovers, (Melilotus sp.) Bur clover annuals, (Medicago sp.) Fenugreek, (Trigonella foenum-graecum).
B. Rhizobium trifolii: (Trifolium sp.) Clovers.
C. Rhizobium leguminosarum: Peas, (Pisum sp.) Vetches, (Vicia sp.) Grasspea, (Lathyrus sp.) Lentils, (Lens sp.).
D. Rhizobium lupini: Lupine and Serradella.
E. Rhizobium japonicum: Glycine max., (G. soja).
F. Cowpea Rhizobia: Cowpeas, (Vigna sp.) (Lespedeza sp.) Beggarweed, (Desmodium sp.) (Crotalaria sp.) Alyceclover, (Alysicarpus vaginalis) hyacinth bean, (Lablab sp.) Stylo, (Stylosanthes sp.) Peanut, (Arachis sp.) Siratro, (Phaseolus atropurpureus) Partridge pea, (Cassia fasciculata) (Glycine wightii).
G. Lotus Rhizobia: Birdsfoot trefoil, (Lotus corniculatus) Big trefoil, (Lotus pedunculatus), Prairie trefoil, (Lotus Americanus) Canary clover, (Dorycnium sp.).
H. Crownvetch Rhizobia: Crownvetch, (Coronilla varia) Sainfoin, (Onobrychis sativa) Prairie clover, (Petalostemum sp.).
I. Lotononis Rhizobia: (Lotononis bainesii) (Lotononis angolensis).
J. Milkvetch Rhizobia: (Astragalus sp) milkvetches and loco weeds.

Certain patterns of response are noteworthy. For example - rhizobia isolated from alfalfa are very likely to be ineffective on bur clover and other annual medics (2). This indicates a possible long-time host-plant influence on the chemistry or enzymes of the microsymbiont.

A similar situation occurs in the Lotus group. Rhizobia effective on birdsfoot, L. corniculatus, are generally ineffective on Big trefoil, Lotus pedunculatus, and vice versa. Other species of trefoil likewise give effective response to either the birdsfoot rhizobia or the Big trefoil rhizobia, but not to both. Birdsfoot and Big trefoil rhizobia should not be combined in a composite inoculum.

Rhizobium trifolii is supposed to nodulate all true clovers. However, several Trifolium species native to Africa are not nodulated by rhizobia which are highly effective on American or European clovers. Also, there is a high degree of specificity among Trifolium species grown in the U. S. T. ambiguum M. Bieb adapted to high altitudes requires different rhizobia from that adapted to lower elevations. In inoculating clover, it is very important that the inoculum contain only rhizobia highly effective on the particular clover. The diverse clover reactions to inoculation were discussed in 1975 (1).

Rhizobium leguminosarum nodulates four genera of legumes: Lathyrus, Lens, Pisum and Vicia species, but host specificity is very marked. Rhizobium strains effective on the pea Pisum sativum, are generally ineffective on the fababean Vicia faba (Burton unpublished results). Gunn (5) has studied 36 species of Vicia in North America. Growth of spring or common vetch Vicia sativa is benefitted little by rhizobia which work very effectively with peas, P. sativum, hairy vetch V. villosa and wollypod vetch V. dasycarpa. V. acutifolia does not fix $N_2$ with any of the common strains of R. leguminosarum. Further study is needed to select the most effective strains of rhizobia for this group of plants.

The majority of summer forage legumes are nodulated by the "cowpea" variety of nodule bacteria. Included in this group are forage cowpeas, the many species of lespedeza, alyceclover, velvet bean, greenleaf and silver leaf desmodia, peanuts, partridge pea, crotalaria, jointvetch, and many other species. Nodules are usually present on the roots of these plants wherever they are grown, but little is known concerning the amount of $N_2$ fixed. Certain host species are highly specific and the probability of their being effectively nodulated is very low. Because the plants are nodulated, agronomists often think that inoculation is unnecessary. However, the prospect of increasing $N_2$ fixation and yield by proper inoculation with selected highly efficient strains of nodule bacteria appears good. Further study is needed, particularly of the possible adverse effect native ineffective rhizobia can have on legume growth.

## Unusual Rhizobia-Legume Associations

In dividing leguminous plants into cross-inoculation groups, Fred, Baldwin, and McCoy (4) placed crownvetch Coronilla varia and sainfoin, Onobrychis sativa into two cross-inoculation groups. However, more recent studies by Van Schreven (6) and also in our laboratory, have shown that these two genera of plants are effectively nodulated by the same strains of rhizobia. Another legume indigenous to the Midwest, prairieclover Petalostemum sp., is effectively nodulated by rhizobia which nodulate crownvetch and sainfoin and should be included in the same group (unpublished results, Nitragin Laboratory).

The milkvetches have received considerable attention as forage crops in Northwestern U. S. (3). The rhizobia for the milkvetches are considered distinct from those of other leguminous species. Yet, the rhizobia isolated from Astragalus often nodulate various leguminous species. Also, there are many species of Astragalus which do not nodulate. This should not be surprising in light of the great number of Astragalus species and diverse areas where they grow.

## Competitiveness, an Important Quality of Rhizobia Strains

Competitiveness may be defined as the ability of a certain rhizobial strain to nodulate its host when one or several other strains capable of nodulating that particular host plant are also present in the rhizosphere. Too little attention has been given to competitiveness in selection of rhizobia for forage legumes. Field tests for rhizobial effectiveness are generally more dependable than greenhouse or growth chamber tests possibly because they provide a measure of competitiveness.

Competitiveness in rhizobia can be measured in pot cultures using serological methods or simply by mixing an inoculum of highly infective non-beneficial rhizobia in the soil or sand prior to planting seeds inoculated with the test *Rhizobium*. The latter method permits direct measurement of benefit without involvement in time-consuming serology and nodule counts. With clover, two or three nodules produced by a highly effective strain can provide all the N needed for good growth and offset the bad effects of hundreds of ineffective nodules on the roots. Nodule numbers are determined by many factors other than infectiveness.

Since so many of our summer forage legumes are susceptible to nodulation by the cowpea type of rhizobia, there is a good possibility that production by many of these legumes could be substantially increased by prudent use of large inocula of highly effective competitive strains of nodule bacteria.

## CONCLUSIONS

Maximum benefit from forage legumes depends upon selection of the best available host genotype for the soil and climate, prudent use of the most effective rhizobia available and good management. Rhizobia need to be tested both for $N_2$ fixing ability on the specific host and for compatibility with indigenous microorganisms.

Pastures containing good mixtures of grass and legumes are more nutritious and productive than nitrogen fertilized grasses. Effective nodulation and good management help to maintain the proper balance between grasses and legumes. The new techniques in sod seeding make thorough inoculation more important than ever. Large inocula of highly effective rhizobia enable the young legume to get off to a fast start and cope more successfully both with the grass and the weeds if present.

## LITERATURE CITED


(1) Burton, J. C.
1975. Advances in Rhizobium specificity and its significance to forage legume breeding. Proc. 32nd Annual Southern Pasture and Forage Crop Improvement Conference (SPFCIC).

(2) _____, and Erdman, L. W.
1940. A division of the alfalfa cross-inoculation group correlating efficiency in nitrogen fixation with source of Rhizobium meliloti. J. Am. Soc. Agron. 32:439-450.

(3) Carlton, A. E., Austin, R. D., Stroh, J. R., Wiesner, L. E., and Schutz, J. G.
1971. Cicer milkvetch (Astragalus cicer L.) seed germination, scarification and field emergence studies. Mont. Agr. Exp. Sta. Bull. 655.

(4) Fred, E. B., Baldwin, I. L., and McCoy, E.
1932. Root nodule bacteria and leguminous plants. Studies in Science No. 5 Univ. of Wisconsin Press, Madison, p. 343.

(5) Gunn, C. R.
1971. Seeds of native and naturalized vetches of North America. USDA Agriculture Handbook No. 392.

(6) Van Schreven, D. A.
1972. Note on the specificity of the rhizobia of crownvetch and sainfoin. Plant and Soil 36:325-330.

# ESTABLISHMENT AND MAINTENANCE OF LEGUMES IN WARM SEASON GRASS SWARDS

By C. S. Hoveland 1/

Warm season perennial grasses are the main pasture species for beef brood cows and calves in the Lower South. Bermudagrass (Cynodon dactylon (L.) Pers.) is the most widespread while bahiagrass (Paspalum notatum Flugge) is the dominant species in the southern portions of Mississippi, Alabama, and Georgia, and the northern portion of northern Florida. Dallisgrass (Paspalum dilitatum Poir.) is most important in the Alabama-Mississippi Black Belt and the Gulf Coast of Texas and Louisiana. In peninsular Florida, digitgrass (Digitaria decumbens Stent) is also an important species.

Although the species vary from one area to another of the Lower South, these pastures have a common problem. Legumes are generally sparse or absent in these swards.

Why is it desirable to overseed clover or other legumes on warm season perennial grass sods? There are at least three reasons for establishing legumes: (1) Extend the productive season when the grass sods are dormant. (2) Improve forage quality and animal performance. (3) Supply nitrogen by biological fixation.

A major problem with legumes is that they are often not dependable forage producers in warm season perennial grass sods. Ladino or intermediate white clover (Trifolium repens L.) is generally not successful in bahiagrass except on wet flatwoods soils. A similar situation exists with white clover in bermudagrass except on wet bottomland. White clover has been more successful in dallisgrass pastures but even here, clover stands often do not persist more than two or three years. On flatwoods soils in Florida, well-managed white clover - digitgrass pastures have been quite productive.

In addition to intermediate white or ladino clover, a number of other species have been or are being grown in the Lower South on warm season perennial grass sods: arrowleaf clover (Trifolium versiculosum Savi), ball clover (T. nigrescens Viv.), crimson clover (T. incarnatum L.), persian clover (T. resupinatum L.), subterranean clover (T. subterraneum L.), hairy vetch (Vicia villosa Roth).

Overseeding cool season annual legumes on warm season perennial grass sods has not been dependable for a variety of reasons: (1) Inadequate soil moisture. (2) Crickets in the sod destroy clover seedlings. (3) Excess grass residue. (4) Unsatisfactory nodulation. (5) Soil acidity and low fertility. (6) Diseases and nematodes. (7) Planting unscarified seed. (8) Planting at the wrong time.

---

1/ Professor, Agronomy and Soils Department, Auburn University, Auburn, Ala. 36830.

Inadequate autumn moisture is often blamed for clover failures on warm season grass sods. Autumn rainfall differs markedly from one area of the Southeast to another as shown in the table:

| Location | Percent of years with October and November rainfall below 4 in. (2 in. per month) |
|---|---|
| Huntsville (northern Ala.) | 16 |
| Rock Mill (Piedmont of east Ala.) | 29 |
| Fairhope (Gulf Coast of southwestern Ala. | 26 |
| Dothan (southeastern Ala.) | 52 |
| Tifton (southern Georgia) | 57 |

Generally, autumn rainfall needed for successful legume establishment (a minimum of 2 inches in each of the months of October and November) is most dependable in the northern and western portions of the southeastern U. S. Autumn rainfall is least dependable in the extreme southeastern part of the region. Overseeding should be delayed until warm season grass growth ceases at frost. Chemical growth suppressants such as glyphosate appear promising to reduce grass competition and allow establishment of legumes in the sod during September when rainfall is greater.

Striped field crickets (Nemobius fasciatus) can destroy clover seedlings in sod during autumn. Application of diazinon during this period can control this pest and allow seedlings to become established successfully.

Excess sod residue may prevent establishment of small-seeded clovers in autumn. Close grazing or mowing in autumn can improve clover stands and produce earlier forage production in winter.

A serious problem in successful clover production on grass sods is unsatisfactory nodulation. Exposure of inoculum to heat at the soil surface can kill most of the rhizobia. Pelleting of clover seed with gum arabic or methyl cellulose will protect the inoculum for several weeks and improve nodulation. Commercial pelleting materials are now available for use by farmers.

Many grass sods have not been limed or fertilized for many years. Clover seedlings are especially sensitive to low soil pH and low P and K. Clover failures or poor growth can often be overcome by following soil test recommendations for lime and fertilizer.

Diseases such as Sclerotinia trifoliorum during warm wet winter periods can destroy clover stands. Close grazing can reduce the problem. Clovers are susceptible to other diseases such as Fusarium oxysporium. Recently, arrowleaf clover stands in Alabama and Mississippi have been severely damaged by this organism. Nematodes can also be a serious problem on clovers. Grass sods generally have high populations of nematodes and this may sharply reduce productivity of clovers.

Several species such as arrowleaf clover have extremely hard seed. When farmers plant unscarified clover seed having a hard seed content of 70 to 80%, poor stands result. Therefore, it is imperative that hard seeded species be scarified before planting in order to obtain satisfactory stands.

Another problem that occurs more frequently than it should is planting at the wrong time. Overseeding clover on grass sods in midwinter or spring generally results in stand failure or very low production.

Many farmers successfully grow cool season annual clovers on warm season perennial grass sods. Their success generally depends on good management: (1) Liming and fertilizing according to soil test recommendations. (2) Planting inoculated scarified seed at the right time. (3) Mowing or grazing excess grass growth to reduce competition. (4) Application of insecticide to control crickets.

# History and Concept of Grassland Renovation in Kentucky

Timothy H. Taylor, William C. Templeton, Jr.,

and Edward M. Smith[1/]

## Abstract

The importance of legumes in grassland plant communities has been well established by the University of Kentucky during this century. Research on principles and practices of introducing forage legumes into grass-dominant fields without the destruction of the grass have been conducted during more than two decades. From this research have come recommendations to farmers on needs and methods of grassland renovation. Studies of natural reseeding of birdsfoot trefoil and bigflower vetch have demonstrated the feasibility of this technique for maintaining these legumes in grasslands. Research was conducted on the use of minimum tillage and herbicides in grassland renovation, resulting in the design and construction of a prototype field machine to plant legumes into grass sods in one pass over the field. The prototype renovator has been used since 1967 as a regular tool for experimental plantings. In late 1973 one of the farm machinery companies bought certain patent rights of the renovator from the University of Kentucky Research Foundation and developed a commercial machine which became available to farmers in the Spring of 1976. Currently, extension county-renovation trials and renovation experiments on the station farm are being conducted with the aim of furthering our knowledge of establishing, using, and maintaining legumes in grasslands.

Early Work -- The contribution of legumes to pasture and hay production was established in the 1920's and 1930's in Kentucky by Professor E. N. Fergus, P. E. Karraker, and George Roberts (1, 2, 5 and 6). Their research indicated that the presence of legumes in grass pastures or grass hayfields increased total dry-matter production, improved the vigor of the grass sod, reduced weed growth, and increased protein and mineral concentrations of the forage. One study showed that well-nodulated legumes added considerable amounts of biologically-fixed N to the plant-soil system. Professor Fergus showed in field trials that clover stands could be established, improved, and maintained by "top-seeding" under suitable grazing and/or clipping, liming, and fertilizing practices.

Release of 'Kentucky 31' Tall Fescue -- In the mid-1940's, 'Kentucky 31' tall fescue was released by the Experiment Station and a large number of acres was sown for seed. An incredible seed bonanza followed. The seed boom ran its course, and by the early 1950's many of the seed fields were being used for grazing. During the decade from 1945 to 1955, fescue acreage in Kentucky and her neighboring states went from a few thousand to a few million acres. Extension personnel, research workers, and farmers soon realized that older, pure tall fescue was not high-quality feed, especially

1/Professor of Crop Ecology, Professor of Pasture Management, and Associate Professor Farm Machinery, respectively, University of Kentucky, Lexington, Kentucky 40506.

as pasturage during the summer months. One of the first tall fescue renovation experiments, done in 1952, showed that legumes could be introduced into the old sod fields under certain management practices (4).

Financial Support and Renovation Research -- The dry summers of 1953 and 1954 in Kentucky reduced, and in many cases eliminated, legume stands in tall-fescue fields. Fortunately, in 1954 the Kentucky General Assembly appropriated $100,000.00 to be used for pasture research and forage extension programs. Already, Drs. E. N. Fergus and R. C. Buckner had initiated a breeding program for the improvement of tall fescue. It was recognized that grassland-renovation research was needed. The special appropriation made this possible, and it was initiated in 1954 and 1955 by W. C. Templeton, Jr. and T. H. Taylor, as one way of upgrading grass pastures and grass hay fields. The main objective of the research was to develop successful methods of introducing and growing legumes in association with grass.

From the beginning, it was assumed that legumes could only be successfully introduced into and maintained in established cool-season grasses if attention and management were directed toward the well-being of the legume, instead of the grass. This assumption has not been validated by innumerable experiences in Kentucky and many other regions of the world where cool-season grasses are used.

Employing on-the-farm tools and machines, the Kentucky researchers conducted eight renovation experiments in established tall-fescue and Kentucky-bluegrass fields. These research findings were put into farmer recommendations in the late 1950's (13, 14, 15).

Recommendations for Establishing Legumes in Sods of Cool-Season Grasses

1. Graze or clip the old sod closely before renovation.
2. Apply needed lime, phosphorus, and potash. Don't apply nitrogen.
3. Disk sufficiently to disturb 40 to 60% of the vegetation.
4. Sow adapted legumes at the proper time and at or near recommended rates for pure-stand seedings. Use certified seed if possible. Be sure that the legume seeds are properly inoculated with the right nitrogen-fixing bacteria at time of seeding.
5. Keep the grass short by judicious grazing or clipping during the early establishment of the legume seedlings. Thereafter, direct management toward the well-being of the legume in the mixture.
6. Control harmful grass-legume insects as needed.

Kentucky's Definition of Renovation -- The grassland research and extension personnel at Kentucky have developed a working definition of renovation which is as follows (3): "Grassland renovation is the improvement of pasture and hay fields by partial destruction of the sod, plus liming, fertilizing, and seeding as may be required to establish or re-establish desirable forage plants without an intervening crop. In Kentucky, this improvement has been primarily through the seeding of legumes such as clovers and alfalfa into grass sods." The "partial destruction" implies that it isn't necessary to plow and fit a seedbed for legumes, but that minimum tillage might provide adequate preparation.

Renovation Taken to the Farmers -- Beginning in the late 1950's, the Extension Forage Specialist, Warren C. Thompson, took the renovation recommendations (13 and 21) to the farmers by way of the county agent, through radio, television, newspapers, farm magazines, field demonstrations, and farmer meetings. For example, in 1963 there were 300 renovation demonstrations in Kentucky. The number of grass acres renovated annually went

from approximately 17,000 in 1958 to some 750,000 acres in 1970 and currently is thought to be approximately 500,000 acres.

Grazing Trial on Renovated Sods -- From 1962 through 1966 a steer-grazing experiment was conducted on renovated Kentucky-bluegrass pastures (17). Renovated bluegrass-alfalfa pastures gave 40% more grazing during the 5-year trial than did renovated bluegrass-white clover. In the latter years of the trial bluegrass-alfalfa was as productive as winter rye followed by sudangrass or sudan-sorghum hybrids with a total-N application of 300 lbs per acre each year.

Researchers Take Another Look at Renovation -- The researchers had developed techniques of up-grading perennial cool-season grass sods by introducing legumes with on-the-farm tools and, with recommendations for renovation in the hands of the extension workers and farmers, it would appear that the researchers had finished their work. But the number of tractor trips over the land to complete a renovation job, plus the uneven, rough surface of treated fields, and the amount of volunteer legumes observed on some of the experiments motivated the researchers to examine in greater depth the physical and biological aspects of renovation.

Stand-establishment results observed in the 1950's on well-managed check plots, plots that were tilled but not seeded, and those which were disked lightly and seeded, indicated that light tillage might be adequate. The volunteering of red clover, white clover, and lespedeza from seed in the soil on the no-seed plots suggested that legume stands might be maintained through natural reseeding. It was decided that more research studies were required and that they should be of two kinds: (1) to find management systems that would permit natural reseeding of legumes in grass-dominant pastures and hay fields, and (2) to study the use of minimum tillage, seed coverage, and herbicides for legume establishment in grass sods.

Natural Reseeding Studies -- Natural reseeding experiments were conducted in the 1960's and early 1970's (16, 18, 19, and 20). These studies focused on birdsfoot trefoil and bigflower vetch. Results clearly show that good birdsfoot trefoil stands may be maintained with bluegrass under grazing and clipping conditions through periodic natural reseeding. The second growth trefoil can be stockpiled and permitted to set and shatter seed every second or third year. The stockpiled legume-grass forage is utilized as pasture or as hay in late July or early August. Bigflower vetch, a winter annual, is managed to utilize the spring crop as early pasturage or as hay. The second crop is allowed to set and shatter seed. Once an adequate reservoir of seed is in the soil satisfactory vetch stands can be regenerated for a year, or perhaps two, without intervening seed production. Management systems that insure natural reseeding of legumes in permanent grass sods are of great significance on rough, hill land.

Minimum Tillage and Herbicide Studies -- To determine the usefulness of minimum tillage and herbicides in establishing legumes in grass sods, the agronomy department and the agricultural engineering department developed cooperative research projects. It was thought that grassland renovation, with its many bio-engineering aspects, was a field which required interdisciplinary effort.

From 1964 through 1968, eleven field trials were conducted on establishment of legumes in grass sods (7, 9, 10, 11, and 12). Results from these studies showed that minimum tillage and precision seed placement enhanced stand establishment. In some instances, banding a grass herbicide over the

seeded row improved legume stands. Placing alfalfa seed 1/2-inch or white clover seed 1/4-inch below the soil surface was found to be the most consistent controllable factor contributing to successful establishment. Stands were equal or superior on the minimum-tilled plots, i.e., strips tilled 1/4-inch wide and 3/4-inch deep, to those receiving other treatments. Tillage for these experiments was accomplished with a power-driven blade that floats in a vertical plane to follow the land surface.

Prototype Renovator Developed -- Based on success with minimum tillage, the agricultural engineers, in 1967, designed and built a prototype field machine that would till, seed, cultipack, and apply herbicide in one pass over a grass field. From 1967 to 1972, the custom-built renovator went through several model changes in the agricultural engineering shop, and was used throughout the 5-year period as a regular tool for experimental plantings (8). Birdsfoot trefoil was successfully sown into old Kentucky bluegrass sod. Winter rye, red clover, bigflower vetch, and tall fescue were established in bermudagrass sod; red clover, alfalfa, and bigflower vetch were successfully planted into tall fescue and Kentucky bluegrass sods.

Farm Machinery Companies -- During the period of 1954 to mid-1972, farm machinery companies showed little or no interest in grassland-renovation work at the farmer, extension, or research level in Kentucky. However, in 1972 one of the major farm machinery industries, Deere and Company, became interested in the University's prototype grassland renovator and, as a result, contributed financial and technical assistance to further develop the machine. In late 1973 Deere and Company bought the patent rights covering the University prototype renovator (22).

Prototype Renovators and Conventional Renovation Compared -- Two significant events occurred at the end of 1973: Warren C. Thompson retired from the Extension Service and J. Kenneth Evans was appointed Forage Extension Specialist. Mr. Evans had worked with the research group during the late 1950's and early 1960's and had served as an Extension Agronomist from 1961 to 1974.

Through the leadership of Smith and Evans, the University prototype renovator and a John Deere prototype, based on the University machine, were compared with conventional renovation in 1974 in nine counties at sixteen locations. The main objectives of these experiments were: (1) to compare the machines with conventional renovation in respect to clover stands obtained and time and energy required to renovate; (2) to observe machine wear over a wide range of field-soil conditions; (3) to educate extension workers and farmers concerning potentials, and pitfalls, in introducing legumes into grassy pastures and hay fields. In 1975 eight experiments were conducted in eight counties with the same objectives as the 1974 experiments except that herbicide effects were studied also. Results from these experiments showed that the Deere and University prototypes performed similarly, and legume stands obtained through the use of these machines were as good as those resulting from conventional renovation. Other significant findings were the fuel consumption and time required to renovate an acre. Renovation with conventional tools consumed 4.76 times more fuel and the prototype renovators could renovate six acres while one acre was renovated using conventional tools (unpublished data, University of Kentucky).

Renovation Research on Station Farm -- Further renovation-research studies of tall fescue and Kentucky bluegrass were initiated in 1974, with the main objectives being: (1) to compare seeding rates of red clover and alfalfa employing minimum-tillage and herbicide techniques, and (2) to compare the productivity of pure-grass swards receiving N fertilizer with grass-legume associations. Results show that: (1) the use of herbicides to establish red clover into tall-fescue or Kentucky-bluegrass sods showed little positive advantage over no herbicide; however, alfalfa establishment was improved in some instances by herbicides, and (2) sward production during the establishment year was similar on plots seeded with 9 lb/A of red clover seed and those dressed with 178 lb N/A. Sward-production data of the 1974 trial in 1975 show that: (1) the use of herbicides did not improve yields, and (2) the 5-lb alfalfa seeding-rate plots were similar in yield to pure-grass plots receiving 178 lb N/A, but the 3 lb red clover plots were higher yielding than the grass-N plots (Results of Res. in 1975, 88th Ann. Rept. Ky. Agr. Exp. Sta. In Press, 1976).

A Commercial Renovator Becomes Available -- On September 15, 1975 Deere and Company announced in a news release that they would have on the market in 1976 a new John Deere "1500 Powr-Till Seeder" (Bucher et al., 1975. John Deere 1500 Powr-Till Seeder. ASAE. In Press). A limited number of these machines became available to farmers during late winter and early spring of 1976.

## LITERATURE CITED


(1) Fergus, E. N.
1935. The place of legumes in pasture production. Jour. Amer. Soc. Agron. 27:367-373.

(2) Effects of legumes on bluegrass. 1939. Ky. Agr. Exp. Sta. 52nd Ann. Rept., P. 15.

(3) Evans, J. K., G. Lacefield, T. H. Taylor, W. C. Templeton, Jr., and E. M. Smith.
1976. Renovating grass fields. Univ. Ky. Ext. Serv. AGR-26.

(4) Jurado-Blanco, Bernardo.
1952. Effect of clipping and tillage on the emergence and establishment of some legume species in Ky. 31 fescue pastures. M.S. Thesis, U. of Ky. library.

(5) Karraker, P. E.
1925. Note on the increase growth of bluegrass from associated growth of sweet clover. Jour. Amer. Soc. Agron. 17:813-814.

(6) Roberts, George.
1937. Legumes in cropping systems. Ky. Agr. Exp. Sta. Bul. 374.

(7) Smith, E. M., T. H. Taylor and S. W. Smith.
1968. Devices for small plot experiments in grassland renovation research. Transactions ASAE 11:54-56.

(8) _____, T. H. Taylor, J. H. Cassada and W. C. Templeton, Jr.
1973. Experimental grassland renovator. Agron. Jour. 65:506-508.

(9) _____, B. P. Verma and T. H. Taylor.
1967. Energy required to operate a disk furrower in Kentucky bluegrass sod. Transactions ASAE 10:333-336.

(10) Taylor, T. H., J. M. England, R. E. Powell, J. F. Freeman, C. K. Kline and W. C. Templeton, Jr.
1964. Establishment of legumes in old Poa pratensis L. sod by use of paraquat and strip-tillage for seedbed preparation. Proc. 7th British Weed Cont. Conf. 2:792-802.

(11) _____, J. S. Foote, J. H. Snyder, E. M. Smith and W. C. Templeton, Jr.
1972. Legume seedling stands resulting from winter and spring sowings in Kentucky bluegrass (Poa pratensis L.). Agron. Jour. 64:535-538.

(12) _____, E. M. Smith and W. C. Templeton, Jr.
1969. Use of minimum tillage and herbicide for establishing legumes in Kentucky bluegrass (Poa pratensis L.) swards. Agron. Jour. 61:761-766.

(13) _____, W. C. Templeton, Jr., E. N. Fergus and W. N. McMakin.
1958. Renovation of Pastures. Univ. Ky. Agr. Ext. Serv. Leaflet 210.

(14) _____, W. C. Templeton, Jr., and W. N. McMakin.
1959. Improve grass pastures by growing more legumes. Better Crops with Plant Food. XLIII (No. 1): 32-38.

(15) _____, W. C. Templeton, Jr., W. N. McMakin and W. H. West.
1956. Establishment of legumes in seven-year-old fescue sod. Ky. Farm and Home Sci. (No. 1) 2:10-11.

(16) _____, W. C. Templeton, Jr., and J. W. Wyles.
1973. Management effects on persistence and productivity of birdsfoot trefoil (Lotus corniculatus L.). Agron. J. 65:646-648.

(17) Templeton, W. C., Jr., C. F. Buck and N. W. Bradley.
1970. Renovated Kentucky bluegrass and supplementary pastures for steers. Ky. Agr. Exp. Sta. Bul. 709.

(18) _____, and D. W. Wattenbarger. 1967. Persistence of birdsfoot trefoil under pasture conditions. Agron. J. 59:385-386.

(19) _____, and T. H. Taylor.
1975. Performance of bigflower vetch seeded into bermudagrass and tall fescue swards. Agron. J. 67:709-712.

(20) _____, _____, J. W. Wyles.
1976. Seed production and stand regeneration of bigflower vetch (Vicia grandiflora Var. Ritaibeliana W. Koch, grown with cool-season forage grasses). Agron. J. 68 (No. 2 March-April). In Press.

(21) Thompson, W. C., T. H. Taylor and W. C. Templeton, Jr.
1965. Renovating grass fields. Univ. Ky. Agr. Ext. Serv. Leaflet 277.

(22) Tillage apparatus and blade therefore-- An invention by E. M. Smith, T. H. Taylor, and J. H. Cassada. Patent Application No. 427, 912. Dec. 12, 1973.

# MULTIPLE ASSIGNMENT TESTER ANIMALS FOR PASTURE-ANIMAL SYSTEMS

By A. G. Matches[1/]

The material covered by this paper has been published in the Agronomy Journal, Matches, A. G., F. A. Martz, and G. B. Thompson. 1974. Multiple assignment tester animals for pasture-animal systems. Agron. J. 66:719-722.
Reprints are available from:

Dr. A. G. Matches
Research Agronomist
Department of Agronomy
216 Waters Hall
University of Missouri-Columbia
Columbia, MO 65201

---

[1/] Research Agronomist, North Central Region, Agricultural Research Service, U. S. Department of Agriculture, and Professor Department of Agronomy, University of Missouri, Columbia, MO 65201.

# NITROGEN FIXATION BY GRASSES IN THE FIELD

BY

S. C. Schank, Rex Smith, K. H. Quesenberry and J. H. Bouton[1/]

## INTRODUCTION

A research team was organized early in 1975 within the Institute of Food and Agricultural Sciences to investigate biological nitrogen-fixation by associative grass-bacteria systems. USDA contributed significant funds and personnel to augment the research effort, and in November 1975 a small research contract with USAID was signed to supplement the project. The inter-departmental group at Florida is coordinated by Dean S. H. West, Assistant Dean for Research of IFAS. In addition to the four agronomists named as authors of this field research report, the team includes M. H. Gaskins, plant physiologist USDA-ARS, D. H. Hubbell, Soils microbiologist, and three staff members from the Microbiology department, M. E. Tyler, J. R. Milam, and Dennis Duggan.

Preliminary reports and reviews of literature on grass-bacteria nitrogen fixation were presented by Schank (5) and Smith et. al. (7) at the Proceedings of the 33rd Southern Pasture and Forage Crop Improvement Conference (Forage breeder's work group) held at Longview, Texas in May 1975.

Additional data can now be added to the preliminary reports which indicated that the phenomenon of biological nitrogen fixation by grasses does take place (1, 2, 4, 6, 8, 9). The system, however, is not well understood. Establishment of the association has been erratic and unpredictable.

For this reason, during the spring and summer of 1975, extensive field and greenhouse experiments were conducted using *Spirillum lipoferum* inoculum on a wide variety of grass species. The strain of *Spirillum* used is designated 'Strain 13$^{t}$' (3) and has recently been placed in the American Type Culture Collection, 12301 Parklawn Drive, Rockville, Maryland. General results from these tests on corn, sorghum, pearl millet, guineagrass, digitgrass and other forage grasses were summarized for an international symposium on biological nitrogen fixation (8).

1. Corn, sorghum and millet have high nitrogen fixing potential relative to other grasses.
2. Inoculated pearl millet and guineagrass yielded significantly more than uninoculated plots.
3. Some nitrogen fertilizer is needed to enhance the biological N-fixation.

---

1/ Professor, Associate Professor, Assistant Professor and Research Associate, IFAS, University of Florida, Gainesville.

4. Florida soils have some strains of bacteria similar to Spirillum.
5. Spirillum bacteria enter the root, as confirmed by labelling with fluorescent antibodies

## MATERIALS AND METHODS

Nine genotypes in four genera (Digitaria, Panicum, Pennisetum, and Cenchrus) were grown in a factorialized combination with inoculated or uninoculated plots and four levels of nitrogen fertilizer during the summer of 1975 at the Agronomy Farm, Gainesville, Florida. The Pennisetum, Cenchrus and Panicum experiments had eight replications and the Digitaria experiment six.

Liquid culture of S. lipoferum (Sp 13t) from Dobereiner (3) were grown in 10 liter batches in a fermenter using N free medium with 0.5% malate as the energy source. The cultures were aerated with 5% $O_2$ - 95% $N_2$ at 30°C. A temperature of 40°C was used when more rapid growth was desired. Application was made in aqueous solution to the inoculated plots at about 8 X $10^6$ cells/m of row and watered into the soil by sprinkler irrigation immediately after application. Uninoculated plots received malate medium without bacteria. Nitrogen fixing activity was measured on root samples at intervals by the acetylene reduction method as modified by Dobereiner and Day (3). Yield data was collected at regular intervals and nitrogen analysis of plant material and soils is being determined using the Tecnicon Auto Analyzer. Cytological examination of the roots was accomplished using a cryostat and toluidine blue staining procedures and flourescent antibody (10).

## RESULTS

We have been able to reconstitute Spirillum-grass systems by means of inoculation capable of fixing economically important amounts of nitrogen.

In field studies we have obtained significant yield increases from pearl millet plots inoculated with Sp 13t (Figure 1). The yield data were surprising as we expected more advantage from nitrogen fixation at the lower N rates. Inoculation produced higher yields at 40 and 80 kg N/ha with significance at 5% and 2%, respectively. The inoculated 40 kg treatment yielded about the same as uninoculated 80 kg, a 40 kg advantage for inoculation of about 1/2 kg/ha/day for the 70 day growing period. The yield means from the eight replications of pearl millet, P-37, are given in metric tons per hectare:

| N fert | Inoculated | Control |
|---|---|---|
| 0 | 4.75 | 5.30 |
| 20 | 5.82 | 6.07 |
| 40 | 7.35 | 6.04 |
| 80 | 9.14 | 7.88 |

Panicum maximum, guineagrass PM-199, showed yields significantly higher (5% level) at the 30 and 60 kg N/ha rate (Figure 2). No yield advantage was demonstrated at 120 kg N/ha. Yield of PM-199 in metric tons/ha for two harvests follows:

| N fert | Inoculated | Control |
|---|---|---|
| 0 | 9.96 | 10.75 |
| 30 | 15.55 | 13.46 |
| 60 | 17.61 | 15.56 |
| 120 | 20.02 | 19.47 |

The 'Transvala' digitgrass experiment was harvested four times (at six-week intervals) during the year with the final harvest completed October 9, 1975. Data are not complete from either this or the buffelgrass inoculation experiment. However, cytological examination of buffelgrass roots revealed that both *Spirillum* shaped and rod-shaped bacteria were present in root cortical cells. The *Spirillum* reacted with Sp 13t antibody in fluorescent antibody studies and the smaller rod-shaped bacteria did not interact (10). This is strong evidence that we have a sensitive test to detect and separate bacteria which invade the root. This is also good evidence that an associative symbiosis exists between plant and bacteria. An intimate association such as this could provide the efficient transfer of carbohydrate from plant to the bacteria necessary for efficient fixation and also of fixed nitrogen from bacteria to the plant.

A summary of our field work shows some interesting relationships. See Table below:

| | | ACETYLENE REDUCTION nm/(g x hr) | | |
|---|---|---|---|---|
| SPECIES | NO. OF LINES | RANGE | % LINES ABOVE 50 | % LINES ABOVE 100 |
| *Zea mays* | 63 | 0-377 | 28 | 21 |
| *Sorghum* sp. | 51 | 0-1934 | 88 | 69 |
| *Pennisetum americanum* | 5 | 0-522 | 60 | 40 |
| *Chloris guyana* | 36 | 0-180 | 17 | 5 |
| *Cenchrus ciliaris* | 3 | 0-163 | 33 | 33 |
| *Panicum maximum* | 7 | 0-115 | 29 | 14 |
| *Digitaria* sp. | 21 | 0-32 | 0 | 0 |
| *Paspalum notatum* | 3 | 0-16 | 0 | 0 |
| *Hemarthria altissima* | 15 | 0-16 | 0 | 0 |

Sorghum, millet and corn have been most active in acetylene reduction response. *Chloris* and *Panicum* were the only forage grasses responding significantly. This points out the Sp 13t and our indigenous organisms are more efficient on sorghum, corn and millet. We have found and isolated some *Spirillum*-like organisms from our Florida soils.

More work needs to be done to characterize and identify these N-fixing bacteria-grass systems. Our objectives are to develop systems that can be managed so that the farmers in the world can harness this cheap and efficient nitrogen source.

## LITERATURE CITED

(1) Bulow, J. F. W. von and Dobereiner, J.
1975. Potential of Nitrogen fixation in maize genotypes in Brazil. Proc. Nat. Acad. Sci. 72: 2389-2393.

(2) Day, J. M., Neves, M. C. P. and Dobereiner, J.
1975. Nitrogen fixation on the roots of tropical forage grasses. Soil Biol. Biochem. 7: 107-112.

(3) Dobereiner, J. and Day, J. M.
1974. Associative symbiosis in tropical grasses: Characterization of microorganisms and di-nitrogen fixing sites. Intern. Symp. $N_2$-fixation-Interdisciplinary discussion. Pullman, Washington. (In Press)

(4) Schank, S. C., Day, J., Abrantes, G. T. V., and Dobereiner, J.
1975. Growth characteristics, nitrogenase activity and yield of two cultivars of Digitaria decumbens ('Transvala' and 'Pangola') digitgrass in Brazil. Abstracts Southern Branch Amer. Soc. Agron. 2: 12.

(5) Schank, S. C.
1975. Digitaria genotypes evaluated in Brazil for nitrogenase activity, yield and IVOMD. Proc. 33rd Southern Pasture and Forage Crop Improvement Conference, Longview, Texas. May 1975.

(6) Smith, Rex L., Gaskins, M. H., Schank, S. C. and Hubbell, D. H.
1975. Nitrogen fixation by a tropical grass-bacteria association in Florida. Abstracts Southern Branch Amer. Soc. Agron. 2:12.

(7) Smith, Rex L., Gaskins, M. H. Schank, S. C., and Hubbell, D. H.
1975. Grass-bacteria nitrogen fixation in Florida - preliminary results. Proc. 33rd Southern Pasture and Forage Crop Improvement Conference, Longview, Texas. May 1975.

(8) Smith, Rex L., Bouton, Joseph H., Schank, S. C., and Quesenberry, K. H.
1975. Yield increases of tropical grain and forage grasses after inoculation with Spirillum lipoferum in Florida. International Institute of Tropical Agriculture, Ibadan, Nigeria, Conference entitled "Biological Nitrogen Fixation in Farming Systems of the Humid Tropics". 20-23 October 1975.

(9) Watanabe, I.
1975. Non-symbiotic nitrogen fixation in rice and rice paddies. International Institute of Tropical Agriculture, Ibadan, Nigeria, Conference entitled "Biological Nitrogen Fixation in Farming Systems of the Humid Tropics", 20-23 October 1975.

(10) Weiser, G. C., Schank, S. C., Smith, Rex L.
1976. Location of nitrogen fixing bacteria in tropical forage grass roots. (In preparation).

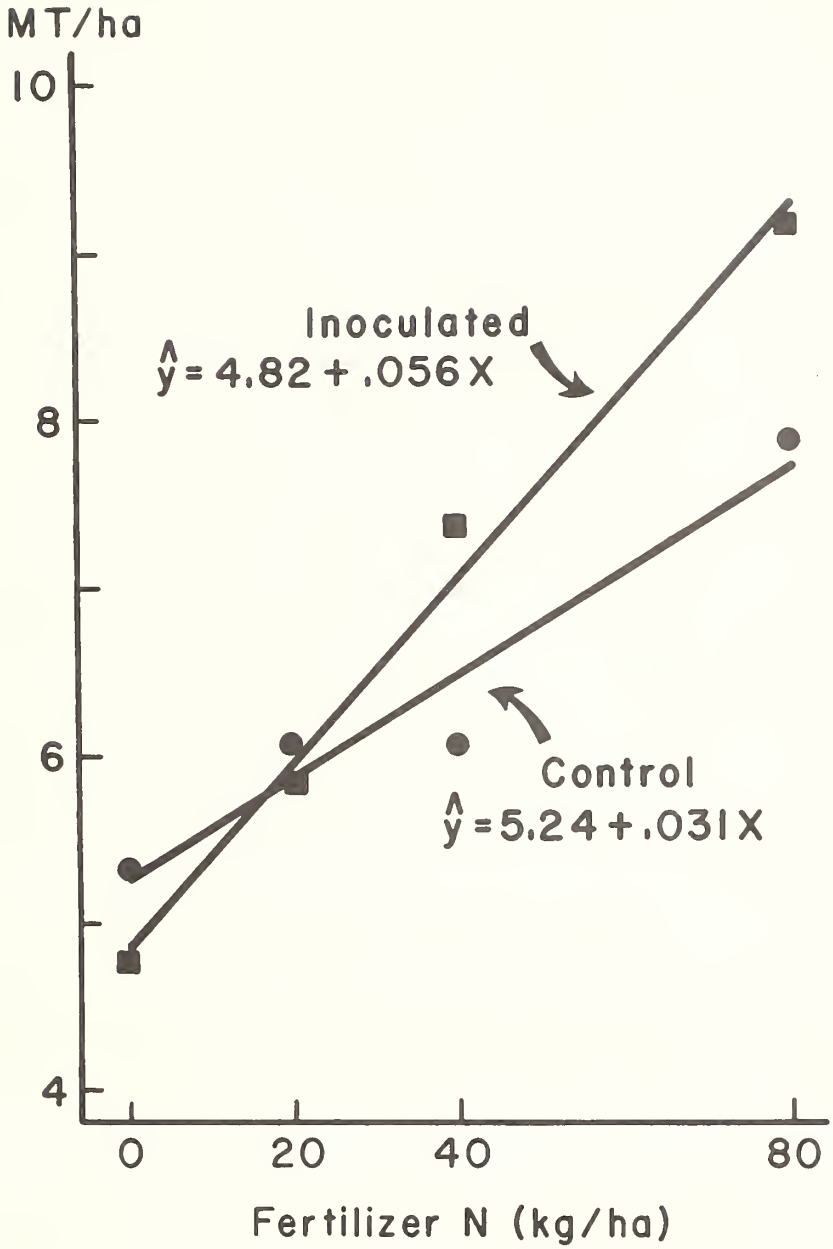


Figure 1. Dry matter forage yields of pearl millet inoculated with Spirillum lipoferum compared to uninoculated plots. Four fertilizer rates were superimposed over inoculation treatments. The regression equations are also given. Significant (P = 0.025) yield increases due to inoculation were obtained at the 40 through 80 kg N/ha fertilization rates.

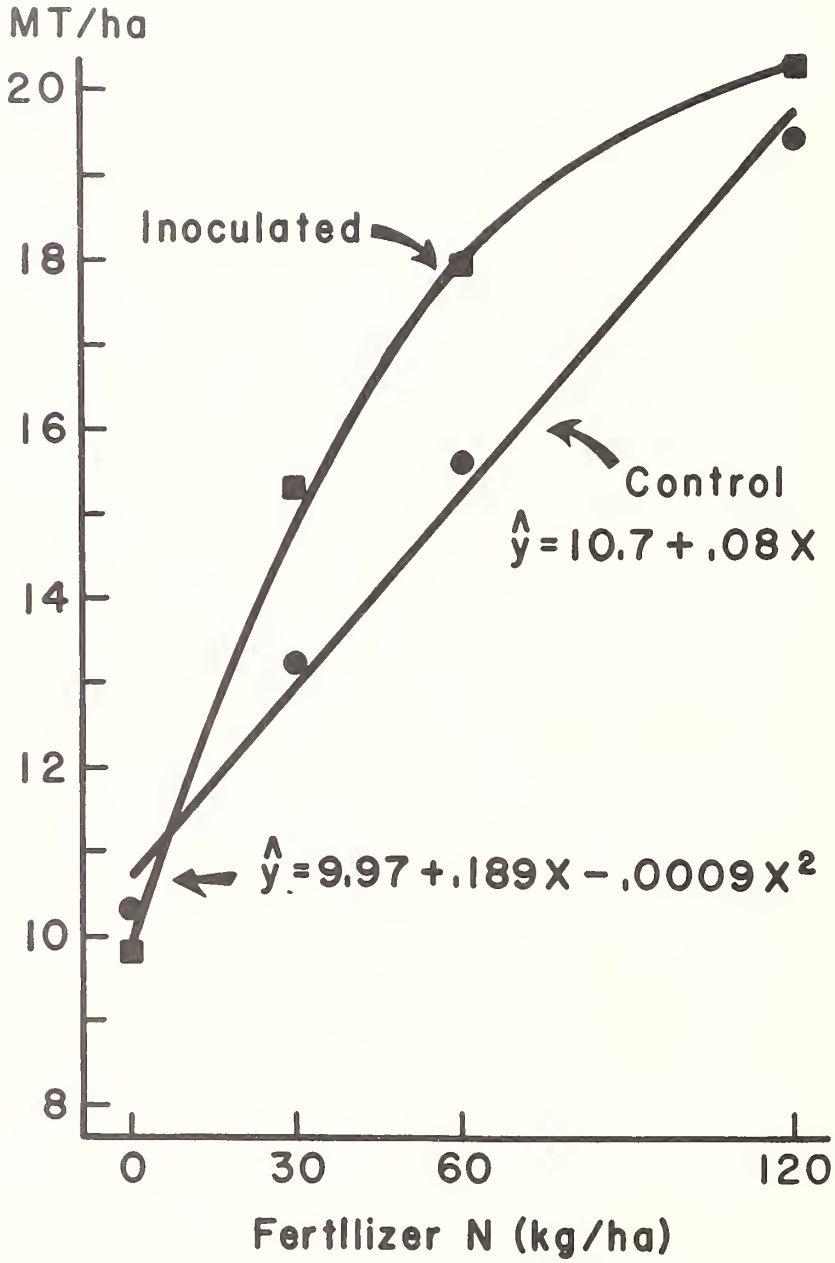


Figure 2. Dry matter forage yields of guineagrass inoculated with Spirillum lipoferum compared to uninoculated plots. Four fertilizer rates were superimposed over inoculation treatments. Data presented is total forage produced from two harvests. Significant yield increases (P = 0.05) due to inoculation were obtained at the 30 through 60 kg N/ha rates.

# CHEMICAL AND BIOLOGICAL FACTORS AFFECTING THE RATE AND EXTENT OF FORAGE DIGESTIBILITY

F. E. Barton II, D. E. Akin and D. Burdick
Field Crop Marketing and Utilization Laboratory
ARS, USDA, RRC, Athens, GA 30604

Two major advances in instrumentation facilitated a more in depth study of the ultrastructure of cell walls as related to digestibility. They are the commercial introduction of the Scanning Electron Microscope (SEM) in 1966 and the - Fourier Transform - pulsed Carbon-13 Nuclear Magnetic Resonance (FT-$^{13}$C NMR) spectrometer in 1970. The SEM allows us to view the plant cell wall with a greater magnification and resolution than possible with the light microscope (LM) and with a depth of focus unachievable by the transmission electron microscope (TEM). Thus, the SEM complements the TEM and the LM and permits a more complete interpretation of the structural relationship of tissues in the plant cell wall. The $^{13}$C-NMR spectrometer permits the structural elucidation of complex molecules isolated from the plant cell wall. These two instruments together with gas and liquid chromatography and various laboratory wet chemical analyses have been used to investigate chemical and biological factors which affect the digestibility of forages.

Two grass species, Coastal bermudagrass (*Cynodon dactylon* (L.) Pers.) (CBG) and Kentucky-31 tall fescue (*Festuca arundinacea* Schreb.) (Ky-31), were extensively used in these studies. However, other tropical and temperate grasses were used for comparison.

The Weende proximate analysis has been used for over a century to evaluate forage quality. The improved Van Soest procedures have been used for over 10 years (1, 2, 3). Although these procedures along with the Tilley-Terry (4) *in vitro* technique have yielded valuable data relating forage composition and digestibility to animal performance, there still exists the need to define specifically the chemical and structural basis for observed differences in forage nutritive value. Accordingly, our efforts have been directed towards qualitatively identifying these plant structural features which correspond to a particular chemical determination, in order to better understand how plant composition and structure are related to forage digestibility. Table 1 shows data on composition and *in vitro* dry matter disappearance (IVDMD) for certain tropical and temperate grasses investigated in our laboratory (6). For all species the IVDMD at four-weeks of age was somewhat similar. These samples were harvested at an immature stage during the summer and, therefore, do not reflect the lower digestibility of tropical grasses reported by Minson and McLeod (7).

The data in Table 1 reflect similar trends as those in the literature with respect to forage digestibility (5). Although lignin content was not significantly different ($p > 0.01$) between tropical and temperate species (4.9% vs 4.3%, respectively), as the quantity of lignin increased, digestion decreased. Lignin content was highly correlated to IVDMD in simple ($r = -0.74$) and multiple ($r^2 = 0.80$) linear regression analyses. The tropical grasses contained more neutral detergent fiber (NDF) than the temperate species, which agrees with data by Van Soest (8) and others (5). Another difference in composition between tropical and temperate grasses was that tropical species contained more hemicellulose (tropical 30 to 35%, vs temperate 22 to 27%).

In Table 2 data are presented on the component sugars in forage hemicellulose determined as their alditol acetates. Neutral detergent fiber and holocellulose represent empirical fractions that contain hemicellulose. By con-

trasting the relative amounts of each component sugar in these fractions to that of the isolated hemicellulose fraction it can be seen that there are marked compositional differences. For example, for both bermudagrasses and Ky-31 tall fescue the arabinose content decreased in the delignified holocellulose compared to the lignified NDF. Also there is a marked difference in the arabinose content of the hemicellulose isolated from the bermudagrass and Ky-31 tall fescue. Thus the apparent composition of hemicellulose (in situ) in these forage fractions changed depending upon the method of isolation or delignification. The data also indicate that lignin is closely associated with forage hemicellulose, since delignification alters the percentage of component sugars. Morrison (9) has shown that certain xyloarabans were removed only after delignification and that the hemicelluloses most easily removed before delignification for tropical grasses were the xyloglucans. The tropical bermudagrass contained appreciable amounts of glucose (7.7-10.61% in NDF and 11.4-15.8 in holocellulose) compared to fescue which contained 1% or less. Thus with the exception of isolated hemicellulose the tropical bermudagrasses contained a glucan fraction which was not found in the temperate fescue.

Table 1. Percent Compositional Analysis of Grasses[a]

| Grass | IVDMD[b] | Crude Protein | NDF[c] | ADF[d] | Hemi-cell-ulose | PML[e] |
|---|---|---|---|---|---|---|
| Coastal-4 week | 66.1 | 19.2 | 61.0 | 29.1 | 31.8 | 4.1 |
| Coastal-8 week | 50.4 | 11.0 | 71.2 | 40.0 | 31.2 | 6.0 |
| Coastcross-4 week | 66.1 | 18.7 | 60.0 | 31.9 | 28.1 | 3.5 |
| Coastcross-8 week | 54.9 | 13.9 | 62.9 | 39.0 | 23.9 | 5.5 |
| Bahia-4 week | 59.6 | 15.7 | 71.0 | 35.7 | 35.3 | 3.4 |
| Bahia-8 week | 53.2 | 9.2 | 67.5 | 35.0 | 32.5 | 5.3 |
| Pangola-4 week | 54.5 | 7.0 | 69.4 | 41.7 | 22.7 | 6.3 |
| Pangola-8 week | 48.6 | 5.9 | 67.0 | 29.5 | 37.6 | 4.8 |
| Kenhy-4 week | 65.6 | 13.2 | 58.2 | 33.6 | 24.7 | 3.2 |
| Ken-Blue-4 week | 58.1 | 15.5 | 54.0 | 30.6 | 23.5 | 4.3 |
| Brome-4 week | 64.2 | 14.3 | 56.2 | 34.3 | 21.9 | 4.8 |
| Orchard-4 week | 62.8 | 14.8 | 57.9 | 33.3 | 24.6 | 4.1 |
| Kentucky-31-4 233k | 62.7 | 14.2 | 48.4 | 31.4 | 25.5 | 3.4 |
| Timothy-4 week | 66.8 | 13.4 | 55.6 | 34.7 | 20.9 | 4.1 |

[a]F. E. Barton II, et al, 1976. J. Animal Sci. 43:504 (6)

[b]IVDMD = In Vitro Dry Matter Digestibility

[c]NDF = Neutral Detergent Fiber

[d]ADF = Acid Detergent Fiber

[e]PML = Permanganate Lignin

Data such as that in Tables 1 and 2 do not provide information on how and at what rates forage tissues are digested. Direct observation of the tissues are needed. The SEM has been very useful for observing digested forage tissue. Akin et al. (11), using SEM, have shown differential rates of tissue removal from samples of CBG and Ky-31 incubated with rumen bacteria (Table 1,2 Fig.5 and 6 in (11)).These studies revealed that mesophyll tissue is the most rapidly

Table 2. Comparison of Percent Component Sugars in the Hemicellulose[a]

| | NDF (Lignified) | | | Holocellulose(Delignified) | | | Hemicellulose | |
|---|---|---|---|---|---|---|---|---|
| Sugar | CBG[b] | CX-1[c] | Ky-31[d] | CBG[b] | CX-1[c] | Ky-31[d] | CX-1[c] | Ky-31[d] |
| Rha | tr | tr | 0.6 | -- | -- | -- | tr | 0.1 |
| Ara | 18.9 | 16.8 | 22.2 | 12.1 | 10.1 | 17.0 | 38.1 | 16.7 |
| Xyl | 72.0 | 70.2 | 71.9 | 76.0 | 73.0 | 81.5 | 45.8 | 67.7 |
| Man | tr | tr | -- | -- | -- | -- | 1.3 | -- |
| Gal | 2.1 | 2.8 | 4.0 | 1.0 | 1.9 | 0.9 | 3.5 | 3.4 |
| Glc | 7.7 | 10.6 | 1.3 | 11.4 | 15.8 | 0.5 | 11.0 | 12.1 |

[a]Hydrolyzed from NDF, Holocellulose and Isolated Hemicellulose

[b]CBG = Coastal bermudagrass

[c]CX-1 = Coastcross-1 bermudagrass

[d]Ky-31 = Kentucky-31 Tall fescue

digested plant tissue. Also, that it is more rapidly digested in Ky-31 than CBG at 24 hr. In CBG the bundle sheath resisited early digestion, but was digested after 72 hr. At the end of 72 hr incubation, only lignified tissue and epidermis remained in both species.

The SEM techniques have been combined with analytical determinations to further examine the plant cell wall. Since the digestibility of the outer bundle sheath differed for CBG and Ky-31, the tissues corresponding to acid and neutral detergent fiber of these grasses were examined. Empirical analyses have yielded the percentages of dry matter removed or left, but have given no information about the effect of these analytical procedures on the specific tissue types. Akin, et al. (10) used the SEM to botanically examine the fibrous residues of grasses extracted with neutral and acid detergent reagents. Their study (see Fig. 2, 3, 9 and 10 in (10)) showed a differential response for CBG and (Ky-31 to extraction by acid detergent fiber reagent. The extent of tissue removed from Ky-31 after 60 min in acid detergent fiber reagent exceeded degradation of leaf sections incubated with rumen microorganisms for 72 hr. For CBG, however, some digestible tissue remianed after 60 min acid detergent fiber extraction.

It has been shown that the tropical forages contains more vascular tissue (12), and that the outer bundle sheath is slowly digested and resists ADF treatment. Lignin also has been shown to be a factor in the low digestibility of the cell wall (5, 6, 8, 9). If lignin was removed from the cell wall, what effect would it's removal have on the availability of previously lignified tissues for *in vitro* digestion?

Leaf sections of CBG and Ky-31 treated with NDF reagent were essentially the plant cell wall material in an undegraded form (although there was some collapse in Ky-31). When NDF treated leaf sections were delignified with potassium permanganate analogous to the procedure of Van Soest (3), there was separation of inner from outer bundle sheaths. The sclerenchyma also was beginning to be separated into individual cells in both Ky-31 and CBG, and some mesophyll was removed in Ky-31. All the tissues were preserved to the extent that digestion by rumen microorganisms could be followed.

Sections of NDF and permanganate treated NDF, CBG and Ky-31 leaves were incubated with rumen microorganisms and samples periodically. After 1 hr the

fescue NDF showed some digestion of mesophyll while both delignified samples, particularly CBG, showed extensive digestion of mesophyll, parenchyma bundle sheath and sclerenchyma. After 4 hr the delignified NDF sections showed more extensive digestion (by virtue of the depth of digestion as revealed by SEM) and further separation of cells. After 20 hr, only isolated, large vascular bundles with some sclerenchyma cells remained. Control delignified sections were incubated in McDougall's buffer alone for the same period. These controls showed that all tissues were present and that no digestion of cell wall tissues occurred.

Compositional analyses of CBG and Ky-31 and their respective hybrids Coastcross-1 bermudagrass (CX-1) and Kenhy fescue (KHY) showed that when the NDF was delignified, approximately 17% dry matter was removed (Table 3). Gas chromatographic analyses of hydrolyzed NDF and delignified NDF showed that plant hemicelluloses (in particular arabinose containing polysaccharides) were removed with lignin from the NDF (Barton, unpublished data). The possible linking of lignin to the hemicellulose side chains through arabinoxylans has been reported (9). Permanganate treatment of NDF leaf sections removed digestible tissue from the temperate grass. The digestibilities of the grasses and the isolated fibrous fractions are shown in Table 4. The digestibilities of the grasses and NDF's were similar but those of the delignified NDF's were about 15 percentage units higher, with the digestibilities of CBG and CX-1 higher than that of the fescues.

The rate of digestion of the delignified NDF's from four grasses as plotted in Figure 1 was much faster than that of the whole grasses. The half life for digestion of all four delignified NDF samples was about 20 hr. After 4 hr, digestibility of the tropical grasses was almost twice that for the

Table 3. Percent Compositional Analysis of Grasses and Permanganate Treated NDF

| Grass | NDF | ADF | PML | NDFPML[a] |
|---|---|---|---|---|
| Kentucky-31-4 week | 58.4 | 31.4 | 3.4 | 17.5 |
| Kenhy-4 week | 48.2 | 33.6 | 3.7 | 17.2 |
| Coastal-4 week | 61.0 | 29.1 | 4.1 | 17.3 |
| Coastcross-1-4 week | 60.0 | 31.9 | 3.5 | 17.4 |

[a]NDF PML is the % dry matter removed by the $KMnO_4$ treatment of NDF

Table 4. Percent IVDMD of Grass and Isolated Fibrous Fractions

| Sample | Grass | NDF | NDFPMLT[a] |
|---|---|---|---|
| Kentucky-31-4 week | 64.2 | 63.1 | 77.0 |
| Kenhy-4 week | 67.7 | 64.5 | 77.8 |
| Coastal-4 week | 66.8 | 63.5 | 79.8 |
| Coastcross-1 4 week | 66.1 | 65.0 | 80.6 |

[a]NDFPMLT = The % of the residue remaining from the permanganate treated NDF.

temperate grasses indicating a difference in the initial rates; yet, after 12 hr the rates were parallel. The 4-hr digestibility also indicated that delignification removed digestible tissues from the fescue since it was less digested initially but not from the bermudagrass.

Results of this study showed that tropical and temperate grasses responded

differently to delignification. Treatment with permanganate affected both the rate and extent of digestion of the delignified as well as nonlignified tissue. The vascular bundle, though delignified, was still undigested; and delignification appeared to have removed a portion of the hemicellulose. Data obtained further indicated that the rate of digestion was not controlled entirely by the extent or percentage of lignification but that there were other inherent differences in the forage cell walls of both species.

Plant maturity has been shown to affect digestibility (13, 14). Akin et al. (15) examined the blade, sheath and stem of top, middle and bottom portions of CBG, cut at 5.5 month's regrowth for chemical composition, sites of lignification and percent tissue types as related to digestiblity. Essentially, no difference in digestibility was found in the blades with maturity despite a drop in crude protein of 3% from top to bottom blade. With increased maturity, sheath and stem showed the greatest decrease in digestibility. The amounts of ADF and lignin increased. Also, chlorine sulfite-positive type lignin was found in only the middle and bottom portions of sheath and stem. Chlorine-sulfite has been used as a specific stain for syringyl lignins (16). Accordingly, the presence of chlorine sulfite-positive lignification of parenchyma cells in older sheaths and stems may be related to decreases in digestibility.

More data are needed relating digestibility to specific structural features. Such questions as "Is lignin covalently bonded to plant polysaccharides?" and "Where and to what extent does polysaccharide structure differ by tissue type and species?" need to be examined. Carbon-13 NMR has been used as a tool for structural analysis of complex molecules. Preliminary results of $^{13}$C-NMR spectra showed that more c-methyl groups were present in Ky-31 than in CBG, and that grass lignins contained a larger amount of carbohydrate compared to wood. Studies are underway to characterize the carbohydrate portion and identify more of the spectral lines which are different among species.

Some of the more salient factors associated with the rate and extent of digestibility for tropical and temperate grasses as revealed by studies are:

1. Tropical grasses contain more hemicellulose than temperate grasses.
2. Immature summer-grown tropical forages are as digestible *in vitro* as immature summer grown temperate forages.
3. Coastal bermudagrass contains more parenchyma bundle sheath which is more slowly degraded by rumen microorganisms than that in Ky-31.
4. The ADF in CBG and Ky-31 differes anatomically.
5. Lignin is highly negatively correlated with digestibility, but:
   (a) Oxidation with $KMnO_4$ to delignify NDF increases the rate and extent of digestion of all tissues, lignified and nonlignified in the palnt cell wall.
   (b) The delignified vascular bundles still resist digestion by rumen microorganisms in both species.
   (c) During the maturation of CBG, lignification increases mostly in the sheath and stem.
   (d) There are differences in the chemical structure of lignin-carbohydrate complexes as shown by $^{13}$C-NMR spectroscopy for CBG and Ky-31 which may be related to differences in digestibility by rumen microorganisms.

## LITERATURE CITED

(1) Van Soest, P. J.
1963. Use of detergents in the analysis of fibrous feeds. II.

A rapid method for the determination of fiber and lignin. J. Assn. Official Agri. Chem. 46:829.

(2) _____, and Wine, R. H.
1967. Use of detergents in the analysis of fibrous feeds IV. Determination of plant cell wall constituents. J. Assn. Official Agri. Chem. 50:50.

(3) _____, and Wine, R. H.
1968. Determination of lignin and cellulose in acid detergent fiber with permanganate. J. Assn. Official Agri. Chem. 51:780.

(4) Tilley, J. M. A. and Terry, R. A.
1963. A two-stage technique for the *in vitro* digestion of forage crops. J. Brit. Grassld. Soc. 18:104.

(5) Moore, J. E. and Mott, G. O.
1973. Structural inhibitors of quality of tropical grasses. pp. 53-98. In A. G. Matches (ed.) Anti-quality components of forages. CSSA Spec. Pub. No. 4, Crop. Scie. Soc. Am., Madison, Wis.

(6) Barton, F. E., II, Amos, H. E., Burdick, D., Wilson, R. L.
1976. The relationship of chemical analysis to *in vitro* digestibility for selected tropical and temperate grasses. J. Anim. Sci. 43:504.

(7) Minson, D. J. and McLeod, M. N.
1970. The digestibility of temperate and tropical grasses. Proceedings 11th Int. Grassld. Congr. (St. Lucia, Queensland, Australia) 719.

(8) Van Soest, P. J.
1973. The uniformity and nutritive availability of cellulose. Fed. Proc. 32:1804.

(9) Morrison, I. M.
1974. Structural investigation on the lignin carbohydrate complexes of *Lolium perenne*. Biochem. J. 139:197.

(10) Akin, D. E., Barton, F. E., II and Burdick, D.
1975. Scanning electron microscopy of Coastal bermudagrass and Kentucky-31 Tall fescue extracted with neutral and acid detergents. J. Agric. Food Chem. 23:924.

(11) Akin, D. E., Amos, H. E., Barton, F. E., II and Burdick, D.
1973. Rumen microbial degradation of grass tissue revealed by scanning electron microscopy. Agron. J. 65:825.

(12) _____, Burdick.
1975. Percentage of tissue types in tropical and temperate grass leaf blades and degradation by rumen microorganisms. Crop. Sci. 15: 661.

(13) Utley, P. R., Lowrey, R. S., Marchant, W. H., Hellwig, R. E., Butler, J. L., and McCormick, W. C.

1971. Comparative feeding value of pelleted Pesacola bahiagrass, Coastal bermudagrass, and Coastcross-1 bermudagrass harvested at four and eight weeks of age. J. Anim. Sci. 33:147.

(14) Danley, M. M. and Vetter, R. L.
1973. Changes in carbohydrate and nitrogen fractions and digestibility of forages: maturity and insiling. J. Anim. Sci. 37:994.

(15) Akin, D. E., Robinson, E. L., Barton, F. E., II, and Himmelsbach, D. S.
1976. Changes with maturity in anatomy, histochemistry, chemistry and tissue digestibility of bermudagrass plant parts. J. Agric. and Food Chem. 23: (In Press).

(16) Higuchi, T.
1957. Biochemical studies of lignin formation. I. Physiol. Plant. 10: 356.

(17) Morrison, I. M.
1973. Isolation and analysis of lignin-carbohydrate complexes from Lolium Mutiflorums. Phytochem. 12:2979.

(18) Nimz, H and Ludemann, H. D.
1974. $^{13}$C-Kernresonanzspektren von lignin-5. Die Makromolekulare Chemie. 175:2577 and references therein.

(19) _____, Ebel, J. and Brisebach, H.
1975. On the structure of lignin from soybean cell suspension cultures Z. Naturforsch. Sect. C. Biosci. 30:442.

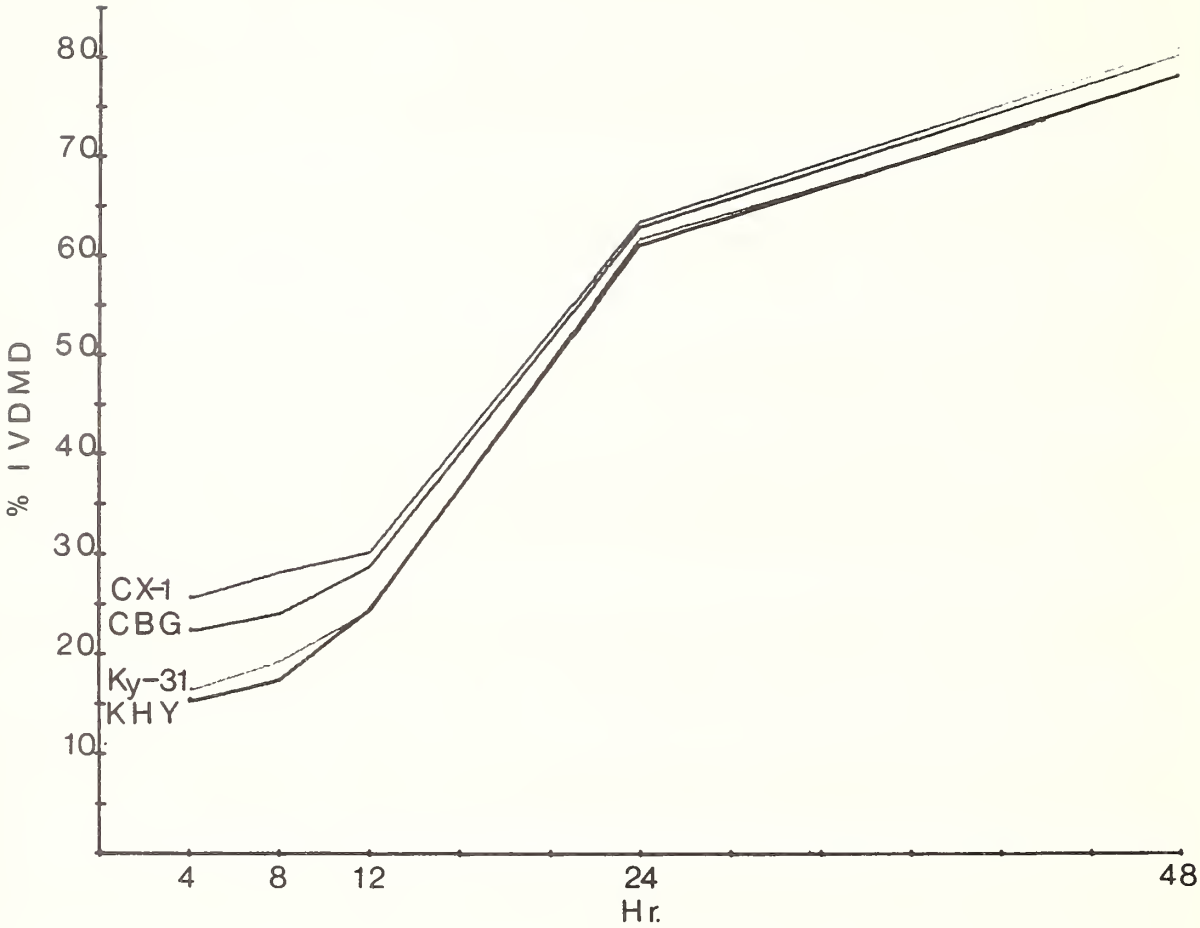


Figure 1. A plot of the percent IVDMD vs. time in hours for the digestion of permanganate treated neutral detergent fiber from four grasses.

# SILAGE FINISHING SYSTEMS FOR CATTLE[1/]

L. A. Carver and J. M. Anderson[2/]

## INTRODUCTION

The Mississippi Delta area has the necessary resources for a total beef cattle system: (1) cow-calf programs, (2) stocker programs, and (3) feeder programs. However, most of the land is suitable for row crop production; consequently more beef per acre can be produced at a lower feed cost per unit of gain where feed is grown under cultivation, harvested at the peak of its production, stored and fed in dry lots (3, 5).[3/]

Row-crop production, being seasonal in nature, leaves some resources underutilized during certain periods of the year. During the months of July, August and December through March labor requirements on typical row-crop farms are relatively low. Labor on an hourly or part-time basis is becoming increasingly difficult to obtain. If labor is to be available during peak requirement periods, it must be employed on a full-time basis. Beef cattle production in conjunction with a row-crop farm operation tends to equalize labor requirements during the year. This provides a possible alternative for labor that would otherwise be unused.

Information presented here is from research conducted at the Delta Branch Experiment Station utilizing high energy silages to produce slaughter beef. In order to fully understand the situation, some background information is needed. First, we are concerned with the production of slaughter beef which will grade high Good or above. Secondly, the systems were developed for the farmer-feeder with the idea of maximizing net returns per acre of total land resources. Thirdly, the economic data developed in conjunction with past experiments were generated during a time when the economy was not in the turmoil we have seen the past three years. No effort has been made to update the tables which were extracted from earlier publications. As part of my concluding remarks, some implications which the current economic situation may have on various beef cattle finishing programs are considered.

## RESULTS AND DISCUSSION

Yearling Finishing Programs. The efficiency with which beef cattle convert pounds of feed to pounds of gain is greatest for a high concentrate ration because of the spreading of fixed and maintenance costs over more pounds of gain. However, this measure may not be an adequate expression of efficiency of beef production for a Mississippi farmer under present and future conditions.

---

1/ Paper for presentation at Southern Pasture and Forage Crop Improvement Conference on April 22, 1976, at Mississippi State, Mississippi.

2/ Assistant Animal Scientist and former Agricultural Economist, Delta Branch, Mississippi Agricultural and Forestry Experiment Station, Stoneville, MS 38776.

3/ Underlined numbers in parentheses refer to "Literature Cited" at the end of this paper.

First, the expression of efficiency most meaningful to the farmer-feeder is conversion of land resources to pounds of saleable beef because his business is to maximize returns from his natural resource -- land. When the problem is approached from this point of view, and alternative beef production capabilities include both corn and corn silage, corn silage will be produced at maximum rates. This is true because 50% more beef per acre can be produced by harvesting the corn plant as silage rather than grain. The ruminant is relatively inefficient in converting high concentrate feeds to meat when compared to non-ruminants. As population and resultant demands for cereal grains increase, this relative inefficiency becomes more significant. The unique digestive system of the ruminant is designed to utilize cellulose and is very efficient in converting this constitutent into meat. Any long term plans for utilizing beef animals to produce food for human consumption must take this factor into consideration.

The following three feeding systems for yearling steer cattle have been considered in our research studies: (1) high energy corn silage, (2) high energy grain sorghum silage, and (3) high energy oat-wheat silage followed by high energy corn silage.

A 2-year average of feedlot performance for steers fed high energy urea treated corn silage is presented in Table 1. These steers were permitted to graze Coastal bermudagrass pasture 140 days prior to being placed on silage. The cattle were fed corn silage that yielded an average of approximately 14 tons per acre containing 37% dry matter and an average of 120 bushels of grain. Ten pounds of urea and 10 pounds of limestone were added per ton at the time of ensiling. These results are representative of those obtained in a number of experiments with yearling cattle fed silage following Coastal bermudagrass grazing. A daily gain of 2.69 pounds is excellent for a silage ration and will return 1559 pounds of beef per acre for ensiled material.

Table 1. Feedlot Performance of Steers Fed High Energy Corn Silage, 2-Year Average. Stoneville, MS.

| Item | Amount |
|---|---|
| Length of feeding period, days | 134 |
| Number of steers | 24 |
| Initial weight, lb | 691 |
| Final weight, lb | 1050 |
| ADG, lb | 2.69 |
| Feed consumption, lb DM | |
| per day | 18.4 |
| per pound of gain | 6.8 |
| Feed cost/lb gain, cents | 6.1 |
| Beef produced per acre, lb | 1559 |

Source: Pund, William A. 1969.

The 2-year average of carcass characteristics for these steers fed high energy corn silage is shown in Table 2. These data represent the findings of a number of feeding trials conducted throughout the last 12 to 14 years. About 80% of the cattle fed high energy corn silage have achieved a slaughter grade of low Choice, when fed to an estimated live grade of low Choice.

Table 2. Carcass Characteristics of Steers Fed High Energy Corn Silage, 2-Year Average. Stoneville, MS.

| Item | Amount |
|---|---|
| Carcass weight, lb | 597 |
| Dressing percent | 56.8 |
| Conformation score 1/ | 12.5 |
| Marbling score 2/ | 5.0 |
| USDA grade 1/ | 11.8 |
| Yield grade 3/ | 2.9 |

Source: Pund, William A. 1969.

1/ high Good = 11; low Choice = 12; Choice = 13.
2/ small = 5; modest = 6.
3/ Calculated percent boneless trimmed round, rib, loin, and chuck; 2 = 52.3%; 3 = 50.0%.

The second system utilized high energy grain sorghum silage for finishing yearling steers. One of the primary reasons for considering grain sorghum is that this crop can be grown on clay soils in the Delta area of Mississippi. In contrast, utilization of corn as a ration ingredient for beef cattle is limited in our area because corn competes with cotton for the sandy loam soils.

In a feeding trial evaluating System 2, cattle were fed a non-bird resistant variety of grain sorghum harvested as silage by cutting the sorghum approximately 15 inches above the ground or 30 inches below the top of the grain head. This silage was supplemented with 10 pounds of urea and 10 pounds of limestone per ton of silage at ensiling. The silage was rolled just prior to feeding. Over a 112-day feeding period yearling steers gained 2.42 pounds per day when the sole ration component was high energy grain sorghum silage. These steers required 7.9 pounds of silage dry matter for each pound of gain. This resulted in a production of about 756 pounds of beef per acre with a total feed cost of 11.3 cents per pound of gain. One disadvantage of this feeding program is the relatively low total yields produced utilizing the grain sorghum varieties which have been available in the Delta area up until this time. Carcass grades averaged high Good (11.1) or somewhat lower than we have observed with finishing programs based strictly on high energy corn silage.

Feedlot space and supporting facilities have generally been utilized very inefficiently in southern feedlots (7). This is especially true in farm feedlots where some types of silage are a major ration component. An excellent opportunity exists for improving the utilization of feedlot space and equipment by refilling silos with high quality silages at different times during the year. Oat-wheat silage harvested in the spring would allow a two crop per season silage program.

The third finishing system for yearling steers involved two phases. In the first phase, yearling steers were fed oat-wheat silage for a relatively short feeding period (Table 3). This program produced 529 pounds of beef per acre of silage with feed costs of 7.6 cents per pound of gain. An average yield of 5.7 tons of 40% dry matter silage per acre was obtained. One advantage of this system is that this material can be produced on the clay soils and reduces the competition for sandy or mixed soils used for cotton production.

Table 3. Feedlot Performance of Steers Fed High Energy Oat-Wheat Silage, Stoneville, MS.

| Item | Amount |
|---|---|
| Length of feeding period, days | 46 |
| Number of steers | 14 |
| Initial weight, lb | 714 |
| Final weight, lb | 803 |
| ADG, lb | 1.93 |
| Feed consumed/lb gain, lb DM | |
| Silage | 8.07 |
| Supplement | .32 |
| Feed cost/lb gain, cents | 7.58 |
| Beef produced/acre, lb | 529 |

Source: Pund, William A. 1970.

In the second phase, the oat-wheat silage was followed by a 90-day feeding period on high energy corn silage. Results of this feeding period are shown in Table 4. Feed costs totaled 11.6 cents per pound of gain. Carcass data are shown in Table 5.

Table 4. Feedlot Performance of Steers Fed High Energy Corn Silage Following Oat-Wheat Silage, Stoneville, MS.

| Item | Amount |
|---|---|
| Length of feeding period, days | 90 |
| Initial weight, lb | 803 |
| Final weight, lb | 981 |
| ADG, lb | 1.97 |
| Feed consumed/lb gain, lb DM | |
| Silage | 8.52 |
| Supplement | .38 |
| Feed cost/lb gain, cents | 11.60 |
| Beef produced per acre, lb | 1063 |

Source: Pund, William A. 1970.

Table 5. Carcass Characteristics of Steers Fed Oat-Wheat and Corn Silage, Stoneville, MS.

| Item | Amount |
|---|---|
| Carcass weight, lb | 549 |
| Dressing percent | 56.0 |
| Marbling score 1/ | 5.50 |
| USDA Carcass grade 2/ | 12.38 |
| Fat thickness, inches | .58 |
| Yield grade 3/ | 3.70 |

Source: Pund, William A. 1970.

1/ small = 5; modest = 6.
2/ low Choice = 12; Choice = 13.
3/ Calculated percent boneless trimmed round, rib, loin and chuck; 3 = 50.0%; 4 = 47.7%.

Weanling Calf Finishing Programs. After examining several years of results utilizing yearling steers in finishing programs, we observed one significant disadvantage in using this type of cattle. They are not readily available in our area. We found that about 600,000 head of weanling cattle were being shipped from Mississippi to other areas for finishing (2). Therefore, a research project was initiated to evaluate various feeding programs for growing and finishing weanling steers and heifers utilizing Mississippi produced forages and feedstuffs (1).

In the fall of 1969, 1970, and 1971 weanling Hereford steers and heifers averaging 428 and 400 pounds, respectively, were placed on 3 finishing systems: (1) high energy corn silage fed during the growing and finishing phase (309 days); (2) intermediate sorghum silage (160 days) followed by high energy corn silage (209 days) to slaughter; and (3) intermediate sorghum silage (160 days) followed by Coastal bermudagrass pasture (140 days) and then finished on high energy corn silage (160 days).

The results of these finishing systems are shown in Table 6. Generally, as the concentration of nutrients decreased, the length of the finishing period increased. This increased the length of time a given amount of operating capital was required for cattle and feed purchases.

Table 6. Animal Performance, Cost of Gain, and Land Resource Requirements for Three Beef Finishing Systems for Weanling Steers and Heifers, 3-Year Average, Stoneville, MS.

| Item | Feeding System 1 | 2 | 3 |
|---|---|---|---|
| Initial weight, lb | 413[a] | 415[a] | 415[a] |
| Number of animals | 47 | 48 | 46 |
| Length of feeding period, days | 309 | 366 | 462 |
| Final weight, lb | 936 | 949 | 994 |
| ADG, lb | 1.69[a] | 1.45[a] | 1.25[a] |
| Feed & pasture costs, cents/lb | 8.1[ac] | 7.5[b] | 7.8[bc] |
| Total costs, cents/lb | 22.3[a] | 21.6[b] | 22.4[a] |
| Land required/animal, acres | | | |
| Sandy & mixed soils | .38[b] | .28[a] | .24[a] |
| Heavy clay soils | .00[a] | .17[b] | .60[c] |

Source: Anderson, J. M. et al. 1975.

[abc] Values on the same line with the same superscript are not significantly different.

Feed and pasture costs per pound of gain were lowest for System 2 (intermediate sorghum silage followed by high energy corn silage). This system also had the lowest total costs per pound of gain, 21.6 cents. In addition, System 2 required less of the sandy and mixed soil resources and replaced it with a relatively small amount of clay soils.

Table 7 contains the average carcass characteristics by system over the 3-year period of this experiment. Cattle on System 3 (intermediate sorghum silage followed by Coastal bermudagrass asture and finished on high energy corn silage) graded slightly higher than the other systems. All carcasses produced were acceptable to the trade, averaging slightly under low Choice.

Table 7. Carcass Characteristics for Three Beef Finishing Systems for Weanling Steers and Heifers, 3-Year Average, Stoneville, MS.

| Item | Feeding System 1 | 2 | 3 |
|---|---|---|---|
| Carcass weight, lb | 548[a] | 541[a] | 562[a] |
| Dressing percent | 60.4[a] | 58.7[ab] | 58.2[b] |
| Conformation score 1/ | 12.8[ab] | 12.6[b] | 13.2[a] |
| Marbling score 2/ | 5.3[a] | 5.1[a] | 4.9[a] |
| USDA grade 1/ | 11.8[a] | 11.7[a] | 12.2[a] |
| Fat thickness, inch | .59[ab] | .63[a] | .57[b] |
| Yield grade 3/ | 3.42[a] | 3.42[a] | 3.11[a] |

Source: Anderson, J. M. et al. 1975.

1/ high Good = 11; low Choice = 12; Choice = 13.
2/ slight = 4; small = 5; modest = 6.
3/ Calculated percent boneless trimmed round, rib, loin, and chuck; 3 = 50.0%; 4 = 47.7%.

[ab] Values on the same line with the same superscript are not significantly different.

Buying and selling margins favored heifers, but not sufficiently to offset lower conversion of feedstuffs to beef. Heifers had higher daily gains than steers when they were placed on a system such as System 3 involving a longer growing period prior to the finishing phase.

Table 8 contains the net returns to management for 1969-1973. Price relationships were such that the greatest net return to management per head was from System 2 followed by System 3 and then System 1. However, System 1 produced the greatest net return per acre followed closely by System 2. Returns per acre were substantially lower for System 3. An underlying assumption of this analysis was that System 2 would make the most efficient year-round use of a fixed feedlot facility.

Table 8. Purchase Price and Net Returns to Management for Three Beef Finishing Systems for Weanling Steers and Heifers, 3-Year Average, Stoneville, MS.

| Item | Feeding System 1 | 2 | 3 |
|---|---|---|---|
| Purchase price, $/100 lb | 33.64[a] | 33.64[a] | 33.64[a] |
| Selling price, $/100 lb | 31.56[a] | 31.44[a] | 31.48[a] |
| Net returns to management | | | |
| $/animal | 28.25[a] | 32.36[a] | 30.84[a] |
| $/acre | 77.95[a] | 75.90[a] | 36.84[b] |

Source: Anderson, J. M. et al. 1975.

[ab] Values on the same line with the same superscript are not significantly different.

Current Economic Conditions. It is appropriate to consider these various finishing programs in view of our current economic situation. Immediately we recognize that we have to increase both variable and fixed costs associated with the cost of the basic food input utilized in feeding beef cattle. Since corn silage is the basic feed ingredient used in System 1 for weanling calves, let us consider this system in the context of current economic conditions.

Over three years, steers fed high energy corn silage (System 1) produced 1475 pounds of beef per acre. At the time of this writing, corn was priced at about $2.70 per bushel (8). Had the silage been harvested as grain, it would have yielded approximately 110 bushels per acre for a current value of $297 per acre. Using the economic concept of opportunity costs to price the corn silage, the 1475 pounds of beef would have cost about 20.1 cents per pound for the feed alone. In addition, it is necessary to underwrite the non-feed costs involved in a feedlot operation. Previously these costs had been estimated at 14.2 cents per pound of gain. Based on the consumer price index, prices have increased an average of 38% since the determination of non-feed costs were made (9, 10). Therefore, non-feed costs per pound of gain are now estimated to be 19.6 cents, or a total of 39.7 cents for each pound of gain. This is the amount of money a beef cattle feeder would have to receive with a zero buying and selling margin to break even on his feeding operation.

Now compare the relative position of producers in the Delta areas of Mississippi to those feeding rations based strictly on grain as an energy source. At $2.70 per bushel, corn is costing 4.82 cents per pound and it generally requires about 8 pounds of corn per pound of gain or a total feed cost of 38.5 cents per pound of gain. These feedlot operators must then underwrite the non-feed cost items. Consequently, I believe this segment of the beef cattle industry has some relative advantages in our area, even in a time of stress on profits.

## CONCLUSION

The production of high Good to low Choice slaughter beef is going to increase in the Mississippi Delta; and on land suitable for corn production, no other feed crop grown can equal corn silage in pounds of digestible energy or pounds of beef produced per acre of crop fed. We feel that these systems, when properly employed with good management practices, will give a reasonable return to the investment required to implement them. The choice of a particular system would depend upon the land resources available, initial cost of investment equipment and facilities and how such a system would fit into the whole farm operation.

## LITERATURE CITED

1. Anderson, J. M., W. A. Pund, E. G. Morrison, and R. W. Rogers. 1975. Beef finishing programs for weanling calves. MAFES Bulletin 811.
2. Mississippi Crop and Livestock Reporting Service. 1973. Mississippi Farm Report. Issue No. 237.
3. Pund, William A. 1969. Silage feeding tests in the Delta. Miss. Farm Res. 32(4):2.
4. Pund, William A. 1969. Sulfur supplemented to high energy urea treated corn silage for feedlot steers. MAFES Information Sheet 1063.

5. Pund, William A. 1970. Spring and fall silage programs tested in the Delta. Miss. Farm Res. 33(4).
6. Pund, William A. 1970. Finishing yearling steers with high energy grain sorghum silage. MAFES Bulletin 780.
7. Pund, William A. 1970. Finishing yearling steers with oat-wheat silage followed by corn silage. MAFES Information Sheet 1104.
8. U.S. Dept. Agriculture, Agricultural Marketing Service, Grain Division. 1976. Grain Market News 24(12). Independence, Mo.
9. U.S. Dept. Agriculture, Economic Research Service, Economic and Statistical Analysis Division. 1970. Demand and price situation DPS-124. Washington, D.C.
10. U.S. Dept. Agriculture, Economic Research Service, Economic and Statistical Analysis Division. 1975. Agriculture Outlook. Washington, D.C.

# FORAGE SYSTEMS FOR LACTATING DAIRY COWS[1/]

By

L. B. Daniels,[2/] A. E. Spooner[3/] and C. J. Flynn[4/]
University of Arkansas, Fayetteville 72701

The cost of producing milk has continued to increase over the past few years and predictions are that it will continue to increase. This increase in cost of producing milk has been due to several factors. However, the increased cost of grain and other feed supplements has been the primary cause, since feed costs account for over 50 percent of the cost of producing milk.

One way to offset this increasing cost of producing milk is by home production and utilization of high quality forages. High quality forages should serve as the base of the diet of a dairy cow, with grain added only to supplement the nutrients of the forage to provide for a desired milk production.

## Factors Which Influence Forage Intake in Lactating Dairy Cows

Several factors (genetic, environment, age, diseases, nutrition, etc.) influence milk production of lactating dairy cows. However, one important factor which influences milk production is the level of Dry Matter (DM) intake. High producing dairy cows (30 + Kg milk/day) usually cannot consume enough DM to support milk production at a high level. Therefore, high producers must utilize body stores or reserves for energy. Thus, factors which influence DM intake have a marked influence on utilization of forages by lactating dairy cows.

Many factors influence the DM intake of lactating dairy cows. McCullough (3) reported that DM intake is influenced by body weight, milk production, cow individuality, climatic effects, ration characteristics, palatibility and ration balance. Colburn (2) summarized data from a number of experiments on DM intake of lactating dairy cows on various roughage programs. His conclusions were: (1) cows will consume more DM on all hay programs than on all silage programs; (2)when the roughage to concentrate ratio averaged near 50/50, cows fed concentrates and silage separately in the conventional manner consumed total DM at 2.8 percent of body weight vs. 3.3 percent for cows fed a complete ration composed of corn silage and concentrates. Coppock *et al*. (1) observed that cows which were group fed consumed 7.0 percent more DM than cows fed individually.

---

1/ Published with the approval of the Director of the Arkansas Agricultural Experiment Station.

2/ Department of Animal Sciences
3/ Department of Agronomy
4/ Livestock and Forestry Station

DM intake is influenced curvilenearly by digestibility. Maximum digestibility of total ration should be between 65 and 68 percent. Thus, both high or low digestibility may exert adverse influence on DM intake.

Ration density (weight per volume) plays a key role in DM intake. Most dairymen have overcome this by adding 35-55 percent grain to the total ration. However, as the forage level of the diet increases, ration density is of more importance.

DM intake is greatly influenced by the crude fiber level of the forage. Optimum crude fiber level of the total diet appear to be in the range of 14 to 17 percent (6). Therefore, forage quality is of most importance in the dairy operation.

Forage systems used by most dairymen consist of several basic types. They are (1) permanent pastures and hay, (2) permanent pasture and silage, (3) temporary pasture and silage; (4) temporary pasture and hay; (5) dry-lot silage; and (6) a combination of these.

Pasture forage has been the basic ingredient in most dairy rations. However, the popularity of pastures has declined due to a number of reasons. Some of the causes has been attributed to (1) the inability of high producing cows to consume enough DM; (2) quality of forage; (3) lack of yield of energy; and (4) confinement of dairy cattle. Yet, many areas of the country, including Arkansas and much of the Southeast, pasture forage is the most profitable crop due to soil types, topography, rainfall and other environmental factors.

Research was conducted at our Livestock and Forestry Branch Station during 1973 to 1975 to evaluate forage systems for lactating dairy cows. The systems included (1) Elbon rye, Gulf ryegrass and Yuchi arrowleaf clover; (2) Boone orchardgrass and Regal white clover; and (3) sorghum-sudan hybrids.

Eighteen Jersey and 12 Holstein cows were used each year for each treatment. Grain was fed at the rate of 1 kg per 3 kg of milk. All pastures were rotational grazed. Milk production was recorded daily.

## Rye, Ryegrass and Arrowleaf clover

Approximately 79 kg of Elbon rye, 23 of Gulf ryegrass and 9.0 kg of Yuchi arrowleaf clover per hectare were seeded on September 1 of each year. Three hundred-thirty five kg of 10-20-10 per hectare was applied at seeding and the pasture was maintained with 335 kg per hectare of ammonium nitrate. Milk yield data for the two years is given in Table 1. Good milk production was obtained during both years with returns over forage and grain costs being slightly greater during 1973-74 than those in 1974-75. The level of milk production suggests that this combination of forages produced a pasture of excellent quality and cow days per hectare indicates good forage production. Some problems were encountered with the cows bogging during early spring due to wet weather. This problem may be corrected by sod-seeding these combinations in a bermuda sod. Spooner and Huneycutt (5) have obtained good yields of small grains when sod-seeded into bermuda sod.

## Orchardgrass and Regal White Clover

Approximately 25 kg of Boone orchardgrass and 3.4 kg Regal white clover per hectare was seeded in early September. Three hundred thirty five kg of 10-20-10 was applied per hectare at seeding, and the pasture was maintained with 335 kg per hectare of ammonium nitrate. The milk production data and returns per hectare over forage and grain cost are given in Table 2. Orchard-

grass-white clover pasture is an excellent quality pasture for lactating dairy cows. Good returns per hectare were obtained. The longevity of the pasture was good as evidence by the cow days per hectare.

## Sorghum-Sudan hybrids

Twenty eight kg of sorghum-sudan hybrid were seeded per hectare on May 1. The milk production and returns over forage and grain costs are given in Table 3. Excellent production and returns were obtained. These data suggest that sorghum-sudan hybrids fit well into a dairyman's pasture program. Spooner and Huneycutt (4) have obtained good yield from sod-seeding of sorghum-sudan hybrids into fescue sod.

These data suggest that a combination of forage systems is needed to have a good quality forage program for the dairyman. Mixed varieties and species of forages offer near year-round grazing for dairymen in the Southeast.

TABLE 1.--Milk production of cows while grazing Rye, Ryegrass and Arrowleaf clover and returns above specified costs for grain and forage.

| Year and Measure | Cow days per hectare | Jerseys | Holsteins |
|---|---|---|---|
| 1973-74 | | | |
| Kg milk/cow/day | | | |
| Fall | 79.04 | 12.27 | 19.00 |
| Spring | 213.65 | 16.86 | 29.41 |
| 100 kg milk/hectare | - | 45.71 | 75.62 |
| Income ($19.80/100 kg) | - | 904.98 | 1497.19 |
| Grain Cost/hectare | - | 242.33 | 302.98 |
| Forage Cost/hectare 1/ | - | 216.12 | 216.12 |
| Income over Spec. Cost/hectare | - | 446.53 | 978.13 |
| 1974-75 | | | |
| Kg milk/cow/day | | | |
| Fall | 103.74 | 17.59 | 21.14 |
| Spring | 150.67 | 15.00 | 25.68 |
| 100 kg milk/hectare | - | 40.84 | 60.63 |
| Income ($19.80/100 kg) | - | 808.63 | 1200.47 |
| Grain Cost/hectare | - | 210.64 | 263.30 |
| Forage Cost/hectare 1/ | - | 216.12 | 216.12 |
| Income over Spec. Cost/hectare | - | 381.96 | 720.99 |

1/ Cost of seed per hectare per year: 78.6 kg Elbon rye at $0.33/kg; 22.5 kg Gulf ryegrass at $0.42/kg; 9.0 kg Yuchi arrowleaf clover at $5.28 kg, for a total of $82.90, plus $133.38 per hectare for fertilizer.

TABLE 2.--Milk production of cows while grazing Orchardgrass and white clover and returns above specified costs for grain and forage.

| Year and Measure | Cow days per hectare | Jerseys | Holsteins |
|---|---|---|---|
| 1973-74 | | | |
| Kg milk/cow/day | | | |
| Fall | 76.57 | 14.09 | 16.41 |
| Spring | 180.05 | 16.95 | 27.91 |
| 100 kg milk/hectare | - | 41.17 | 63.07 |
| Income ($19.80/100 kg) | - | 815.16 | 1248.78 |
| Grain Cost/hectare | - | 210.59 | 263.30 |
| Forage Cost/hectare 1/ | - | 194.07 | 194.07 |
| Income over Spec. Cost/hectare | - | 410.41 | 789.04 |
| 1974-75 | | | |
| Kg milk/cow/day | | | |
| Fall | 123.50 | 14.36 | 20.14 |
| Spring | 199.82 | 14.36 | 22.55 |
| 100 kg milk/hectare | - | 48.33 | 69.90 |
| Income ($19.80/100 kg) | - | 957.00 | 1384.02 |
| Grain Cost/hectare | - | 267.10 | 334.56 |
| Forage Cost/hectare 1/ | - | 133.38 | 133.38 |
| Income over Spec. Cost/hectare | - | 555.92 | 856.67 |

1/ Seed costs per hectare (for 1973-74 only): 28 kg Boone Orchardgrass at $1.32 Kg; 3.4 KG Regal white clover at $7.02 Kg, for a total of $60.82, plus $133.38 per hectare per year for fertilizer.

TABLE 3.--Milk production of cows while grazing Sorghum-Sudan hybrids and returns above specified costs.

| Year and Measure | Cow days per hectare | Jerseys | Holsteins |
|---|---|---|---|
| 1974 | 298.62 | | |
| Kg milk/cow/day | - | 13.50 | 24.27 |
| 100 Kg milk/hectare | - | 40.34 | 72.49 |
| Income ($19.80/100 Kg) | - | 798.73 | 1435.39 |
| Grain Cost/hectare | - | 247.25 | 309.07 |
| Forage Cost/hectare 1/ | - | 156.84 | 156.84 |
| Income over Spec. Cost/hectare | - | 349.63 | 969.47 |
| 1975 | 269.70 | | |
| Kg milk/cow/day | - | 15.18 | 22.14 |
| 100 Kg milk/hectare | - | 40.97 | 59.74 |
| Income ($19.80/100 Kg) | - | 811.21 | 1182.86 |
| Grain Cost/hectare | - | 223.84 | 279.16 |
| Forage Cost/hectare 1/ | - | 156.84 | 156.84 |
| Income over Spec. Cost/hectare | - | 430.99 | 746.85 |

1/ Seed costs per hectare per year: 28 kg hybrid suday at $0.84/kg= 23.52 plus $133.38 per hectare per year for fertilizer.

## LITERATURE CITED


(1) Coppock, C. E., Noller, C. H., and Wolfe, S. A.
1974. Effect of forage concentrate ration in complete feeds fed ad libitum on energy intake in relation to requirements by dairy cows. J. Dairy Sci., 57: 1371.

(2) Colburn, M. W.
1973. Proc. 33rd Annual Meeting AF or A Nutr. Council. p. 21.

(3) McCullough, M. E.
1973. Optimum feeding of dairy animals. 2nd Ed. University of Georgia Press, Athens, Ga.

(4) Spooner, A. E. and Huneycutt, H. J.
1975. The effects of row spacings, fertilizer, and paraquat on the yields of hybrid sudangrass, silage sorghum, grain sorghum interseeded into a tall fescue sod. Unpub. data.

(5) Spooner, A. E. and Huneycutt, H. J.
1976. Small grains interseeded into a bermudagrass sod. Unpub. data.

(6) Stallcup, O. T.
1975. Factors affecting feed intake in lactating dairy cows. Proc. Arkansas Nutr. Conf., p. 101.

# GRAZING STUDIES IN MISSOURI

Arthur G. Matches[1/]

## INTRODUCTION[2/]

Four grazing experiments are in progress as a cooperative research effort between the University of Missouri and the U. S. Department of Agriculture, Agricultural Research Service. These are team research projects involving participation from two or more departments; participating departments include Agricultural Economics, Agricultural Engineering, Agronomy, Animal Husbandry, Biochemistry and Dairy Husbandry. Two grazing trials are located in southwest Missouri on the University's Southwest Center, one at the Agronomy Research Center near Columbia and one at the Forage Systems Research Center Near Linneus in north central Missouri. I will discuss the purpose and experimental details of each experiment. Since all of these trials are still in progress, only highlights of research findings will be presented.

## PASTURE SYSTEMS - SOUTHWEST CENTER

### Purpose of Experiment

Cool-season forages such as tall fescue, orchardgrass, and bromegrass produce an abundance of forage during the spring and autumn, but their summer production (mid-June to September) is usually very low. In Missouri, it is not unusual for cattle to lose weight when grazing the cool-season grasses during July and August. The purpose of this research is to develop pasture systems for nearly year-long grazing. Particular attention is being given to bridging the summer gap in pasture availability.

### Experimental Details and Results (2,3,4,5,7,8)

Clipping trials we conducted from 1964 through 1967 indicated that several warm-season grasses have excellent possibilities for bridging the summer gap in pasture availability. Caucasian bluestem and 'Blackwell' switchgrass appeared the most promising of eight warm-season grasses tested. Nearly 90% of the total grazeable growth of Caucasian bluestem was available after mid-June. Switchgrass was earlier with approximately 40-60% of its total production occurring after mid-June.

In cooperation with the Dairy Husbandry Department of the University of Missouri-Columbia, Phase I, pasture system grazing experiments were established at the Southwest Center during 1968 and 1969. Individuals responsible for this research are F. A. Martz, Dairy Husbandry and A. G. Matches, USDA ARS and Agronomy. Based on results from the earlier small-plot

---

1/ Research Agronomist, Agricultural Research Service, U. S. Department of Agriculture and Professor of Agronomy, University of Missouri, Columbia, MO

2/ Underlined numbers in parenthesis refer to "Literature Cited", at the end of this paper.

experiments, we selected caucasian bluestem and 'Blackwell' switchgrass for inclusion as the perennial warm-season grasses and 'Gahi-1' pearl millet as an annual warm-season grass for summer grazing. In these replicated plantings, 10 pasture systems were evaluated under grazing (Table 1). Nine systems consisted of cool-season and warm-season grass components. They include tall fescue, orchardgrass and smooth bromegrass for spring and autumn grazing and the three warm-season grasses for summer grazing. These forage components were planted in separate pastures and not as a mixture. A tenth system consisted of two pastures of tall fescue, one on which grazing began in the spring and the other which was cut for hay in May, round-baled and the regrowth plus round bales grazed during the summer slump plus a second grazing of regrowth in late autumn.

Results for the 10 systems are given in Table 1.

TABLE 1.--Average grazing results from pasture system trials at the Southwest Center, averaged over 1970 and 1971.

| | | Test Animal Performance | | | |
|---|---|---|---|---|---|
| | Calendar Days of Grazing | Gain/A lb. | Animal Days/A | ADG lb. | Gain/ Tester lb. |
| Fescue-All-Season | 244 | 304 | 216 | 1.40 | 340 |
| Fescue-Millet | 210 | 290 | 218 | 1.34 | 294 |
| Fescue-Caucasian Bluestem | 210 | 271 | 221 | 1.23 | 265 |
| Fescue-Switchgrass | 210 | 232 | 189 | 1.23 | 268 |
| Orchardgrass-Millet | 202 | 264 | 194 | 1.36 | 272 |
| Orchardgrass-Caucasian Bluestem | 202 | 216 | 218 | 0.99 | 192 |
| Orchardgrass-Switchgrass | 202 | 185 | 174 | 1.06 | 196 |
| Brome-Millet | 202 | 226 | 184 | 1.23 | 246 |
| Brome-Caucasian Bluestem | 202 | 254 | 212 | 1.20 | 240 |
| Brome-Switchgrass | 202 | 209 | 168 | 1.24 | 247 |

We believe these and other results obtained in past grazing experiments show several good alternatives for bridging the summer slump in pasture production. Summer annual forages such as pearl millet, sudangrass, sorghum-sudangrass or sudangrass hybrids will provide good summer grazing. However, they must be seeded every year and should be seeded only where soil erosion is not a problem. If haying equipment is available and haying does not interfere with other farming operations, then some pastures of the cool-season grasses such as tall fescue and orchardgrass could be round baled for summer grazing. A third alternative is to pasture perennial warm-season grasses such as switchgrass and caucasian bluestem for grazing during the summer slump period.

Phase II of the pasture systems began in 1974. The design of Phase II was based on results from the completion of Phase I system trials as discussed above.

Pasture systems consist of tall fescue for spring and autumn grazing and perennial summer grasses (switchgrass and caucasian bluestem) for summer grazing. Also, pastures of tall fescue cut for hay in May and round baled are grazed (regrowth + round bales) during the summer slump and again in late autumn. The above fescue pastures receive an annual application of 75 lb N/A in February and 50 lb N/A in August. The warm-season grasses receive 60 lb N/A in May.

In the autumn of 1973, two additional fescue pastures per replication, which include a legume, were seeded. 'Victoria' alfalfa (a new pasture type alfalfa) was seeded in the fescue pastures intended for spring and autumn grazing and 'Kenstar' red clover was seeded in the fescue pastures intended for summer and late autumn grazing. These pastures will not be fertilized with nitrogen. All pastures are fertilized with 60 lb $P_2O_5$ and 60 lb $K_2O$ per acre in February.

The four pasture systems are:

1. Tall fescue - 'Blackwell' switchgrass
2. Tall fescue - Caucasian bluestem
3. Nitrogen fertilizer tall fescue - nitrogen fertilized tall fescue round baled plus regrowth.
4. Tall fescue and red clover - tall fescue and alfalfa round-baled plus regrowth.

Separate pastures of each forage or management are matched in each system so as to have system components in phase throughout the grazing season. All systems are replicated three times and pasture size varies from 2 to 3 acres.

Pastures are grazed by yearling Holstein heifers or steers. Tester animals remain on the same system throughout the season. The desired degree of defoliation (differs according to forage species) is maintained by put-and-take animals. Shrunk cattle weights are obtained each 14 days or when cattle are shifted to a new paddock (3-paddock rotational grazing used) or a different component of the system. Estimates of forage availability are determined from mower-strip samplings of pasture when cattle are turned into a fresh paddock or into a different component of the system. Since components of each system are managed to be in phase with one another (not always possible in Phase I) data on yield of animal gain per acre will be more precise than was possible to obtain in Phase I.

## Results for 1974

Results for the first season of grazing Phase II experiments are very preliminary. During 1974, grazing began on April 10 and recording of animal performance terminated on November 19 for a total of 223 calendar days of grazing. All tall fescue pastures were also grazed from November 19 to December 5; however, fescue hay was fed due to snow and ice cover during part of this period.

Since legumes were not yet fully established, alfalfa in particular was only lightly grazed during 1974 and not cut as hay. Neither alfalfa nor red clover were grazed during a hot and dry period from July 29 to August 28 (30 days). During this period, cattle were confined to a reserve area and fed tall fescue hay. Computation of results for the fescue + legumes system includes the period of confined feeding.

At the start of summer grazing, round-baled fescue pastures averaged, on a dry weight per acre basis, 1372 lb of hay plus 1288 lb of regrowth. Round-baled pastures were also grazed again from October 22 to November 19 (28 days).

Season-long grazing results are given in Table 2. Noteworthy is the high average daily gain of 1.69 lb on the fescue + legumes system even when 30 days of hay feeding was included in season-long computations. If the hay feeding Period is excluded, average daily gain while on the fescue + legume pastures was 1.80 lb. These results show the benefit of increased ADG from seeding a legume into pastures of tall fescue. Secondly, production costs are lower because nitrogen fertilizer is not generally applied to pastures that have good stands of legumes.

TABLE 2.--Grazing results from Phase II of the pasture system trials at the Southwest Center during 1974.

| | 1974 Grazing Season (April 10-Nov. 19) | | | | |
|---|---|---|---|---|---|
| Pasture System | Animal Days/A | AU Days/A[1/] | Average Daily Gain (lb) | Gain/A (lb) | Gain/Tester (lb) |
| Fescue-Fescue Baled | 233 | 209 | 1.46 | 341 | 326 |
| Fescue + Legumes[2/] | 169 | 155 | 1.69 | 285 | 377 |
| Fescue - Caucasian Bluestem | 248 | 211 | 1.33 | 331 | 299 |
| Fescue - Switchgrass | 192 | 171 | 1.39 | 268 | 311 |
| Average | 211 | 186 | 1.47 | 306 | 321 |
| L.S.D. .05 | 17 | 13 | 0.17 | 40 | 40 |
| C.V. (%) | 4.0 | 3.6 | 6.2 | 6.5 | 6.1 |

1/ AU Days/A = Animal Unit Days per Acre where a 1000-pound animal equals one animal unit (AU).

2/ Average botanical composition of the legume pastures:
51% fescue - 49% alfalfa
60% fescue - 40% red clover

The relative low gain per acre on the fescue + legumes system may be attributed to lower animal days of grazing. Since these pastures were rested for 30 days to give alfalfa a better opportunity to become fully established, total animal days of grazing were less than from other pasture systems.

Average daily gains for nonlegume systems were not significantly different. Gains per acre were highest from the fescue-fescue round-bale and fescue-caucasian bluestem systems. Both of these systems had over 209 animal unit days of grazing as compared to 171 days for the fescue-switchgrass system.

Nonlegume systems in 1974 yielded gains per acre and average daily gains equivalent to those obtained over three seasons of grazing the Phase I experiments. Based on these and similar grazing research conducted at the Agronomy Research Center near Columbia, we believe that with proper planning, pasture systems can be developed to bridge the summer slump on most Missouri farms. Certain legumes and warm-season perennial grasses may require two or more years before they are into full production. Therefore, it must be emphasized that action to develop season-long pasture systems must be performed well in advance of the need for summer pasture.

## ADVANCED EVALUATION OF FORAGES - SOUTHWEST CENTER

### Purpose of Experiment

To evaluate tall fescue strains derived from grass breeding programs for animal productivity under grazing conditions.

To identify and determine the interrelationship of the factors associated with cattle performance on tall fescue.

### Experimental Details and Results (1)

This is a cooperative investigation among F. A. Martz, Dairy Husbandry; D. A. Sleper, Agronomy; G. B. Garner, Biochemistry; and A. G. Matches, USDA ARS and Agronomy.

The most serious disadvantage associated with grass breeding programs has been the inability to evaluate breeding lines for animal productivity. Considerable progress in improvement has been made in traits such as disease resistance, winter hardiness, drought hardiness and to some extent forage yield. However, a lack of basic information regarding the complexities of forage quality have limited progress in this regard. The development of the *In Vitro* fermentation procedures has been of much value and we are presently using these techniques; however, we are still far from understanding the basis for genetic variability among forages in animal performance. Until more complete information is available, it is imperative that we incorporate actual animal data into our selection index.

We propose to use laboratory methods to measure quality during the early stages of each breeding cycle, followed by grazing data on the more select strains. An interdisciplinary approach is needed to explain why differences in animal performance occur. This information would not only be of value to the plant breeder in developing more effective selection criteria, but would also enable us to make more realistic decisions in pasture management.

Grazing and confined feeding trials will be conducted with different tall fescue varieties and strains to determine the interrelationships of forage-quality components with animal performance. Quality components of main concern are: intake, rate of passage, caloric density, digestibility (in vivo and in vitro), chemical composition (cell wall constituents, carbohydrates and perloline), forage availability and morphology of growth.

Initially, 'Kentucky-31', 'Kenmont', 'Fawn', and 'I-96' cultivars of tall fescue and 'Kenhy' a Lolium-Festuca hybrid are being evaluated under grazing. These cultivars represent a broad genetic base similar to what might be encountered in the evaluation of advanced strains from the grass breeding program. The first two years of experimentation will represent a pilot run to establish the criteria for the rapid evaluation of animal response in future strain testing.

Plantings of the above cultivars were made in 1 acre pastures on October 4-5, 1972, at the University of Missouri Southwest Center. The experimental design is a randomized complete block with three replications.

Pastures were initially grazed during the 1974 grazing season. Grazing periods of hopefully 40 days or more are being used in separate evaluations made during the spring, mid-summer and autumn. Between periods of evaluation, cattle are held in reserve pastures of the same cultivars grazed on experiment. During an evaluation period, all pastures are stocked at the same grazing pressure (same amount of forage available per animal) and each pasture is grazed by 2 or 3 tester animals. A tester animal remains on the same cultivar the entire season. If available, yearling half-sib steers or heifers of the Hereford or Angus breed are used as tester animals. Equal grazing pressure is maintained by adjusting the size of pasture area grazed in accordance to the amount of feed available. During an evaluation period, cattle are turned into a fresh paddock each week.

Cages and mower-strips are used to determine forage available. Sampling is done weekly and forage samples are saved and processed for laboratory analysis. Cage and uncaged sampling techniques are used to estimate animal intake on pasture. Since irrigation facilities are available to insure adequate soil moisture throughout the grazing season, it is possible to complete three experimental runs per season. The first grazing cycle began on April 18, 1974.

Average daily gain for the 1974 and 1975 seasons are shown in Table 3. 'Kenhy' and 'I-96', overall, appear superior to 'Kentucky-31' tall fescue. Laboratory and herbage sampling data are still being processed; when completed, we hope reasons for differences in animal gains can be explained.

TABLE 3.--Average daily gains of cattle from the advanced evaluation of forages at the Southwest Center

| Variety of Fescue | Average Daily Gains - lbs (Shrunk wt.) 1974 Grazing Periods | | | |
|---|---|---|---|---|
| | Spring**** | Summer** | Fall* | Full** Season |
| Kenhy | 1.58 | 0.66 | 1.01 | 1.11 |
| Kenmont | 0.85 | 0.62 | 0.80 | 0.77 |
| I-96 | 1.52 | 0.76 | 1.10 | 1.16 |
| Fawn | 0.90 | 1.06 | 0.89 | 0.94 |
| Ky-31 | 0.93 | 0.51 | 0.96 | 0.83 |
| Days of Grazing | 42 | 48 | 49 | 139 |

| Variety of Fescue | 1975 Grazing Periods | | | |
|---|---|---|---|---|
| | Spring*** | Summer* | Fall* | Full** Season |
| Kenhy | 1.68 | 0.79 | 1.37 | 1.33 |
| Kenmont | 1.36 | 0.53 | 0.83 | 0.96 |
| I-96 | 1.62 | 0.30 | 1.45 | 1.18 |
| Fawn | 1.20 | 0.23 | 0.92 | 0.83 |
| Ky-31 | 1.33 | 0.26 | 0.79 | 0.85 |
| Days of Grazing | 45 | 49 | 35 | 129 |

* Significant at the .20 level
** Significant at the .10 level
*** Significant at the .05 level
**** Significant at the .01 level

## PASTURE SYSTEMS WITH TALL FESCUE - AGRONOMY RESEARCH CENTER

### Purpose of Experiment

To estimate the optimum rate of stocking in terms of animal response and pasture output under two schemes of managing tall fescue as pasture systems.

### Experimental Details and Results (6)

This is cooperative research involving G. B. Thompson and Jack L. Clark, Animal Husbandry; C. J. Nelson, Agronomy; and A. G. Matches, USDA ARS and Agronomy.

Estimates of tall fescue grown in Missouri range between 4 to 5 million acres. Compared to the combined total for all the orchardgrass, bromegrass, and timothy, of approximately 1 million acres, tall fescue represents an extremely important position in Missouri grassland production.

The influence of rate of stocking on animal and pasture production is well documented in the literature. However, little research has been conducted with tall fescue to define the optimum rate of stocking for maximizing either performance per animal or yield of animal product per acre. Literature and CRIS reports suggest that most stocking rate trials with fescue have dealt with a single system of grazing management (continuous or rotational grazing). Rate of stocking information is lacking in respect to managing tall fescue in pasture systems designed to improve summer production and extend the grazing season.

Tall fescue pastures are being grazed at three rates of stocking. Fescue is managed as (a) single pastures continuously grazed the entire season and (b) fescue systems involving pastures for spring and autumn grazing, and fescue cut for hay and round baled for summer and late autumn grazing. Detailed measurements of the sward include (a) forage availability, (b) forage quality, and (c) morphological and physiological responses of fescue to severity of grazing. The University of Missouri Whole Body Counter which measures potassium-40 of the animal is being used to predict body composition (fat free body weight, percent fat, percent protein) of tester animals from the different stocking rate and fescue management treatments.

Rates of stocking selected (Table 4) were based on the carrying capacity of pastures observed over the past five years at the Agronomy Research Center. The medium rate represents a stocking intensity that could be expected to provide the most optimum quantity and quality of forage throughout the grazing season based on past experience. Within phases of grazing, pastures will be continuously grazed. Cattle weights following 14-16 hours of fasting without feed or water are obtained at approximately 21-day intervals throughout the grazing season.

TABLE 4.--Agronomy Research Center Grazing Trial - 1974

| | Treatments and Stocking Rates | | |
|---|---|---|---|
| Continuous Systems | | | |
| Stocking Rate | Low | Med. | High |
| Animals/Acre | 0.75 | 1.0 | 1.5 |
| Animals/Pasture | 3 | 3 | 3 |
| Acres/Pasture | 4 | 3 | 2 |
| Fescue Baled System (Total system of 6 acres) | | | |
| Stocking Rate | Low | Med. | High |
| Animals/Acre | 1.0 | 1.5 | 2.0 |
| Animals/Pasture | 6 | 9 | 12 |
| Acres/Pasture (3+3) | 6 | 6 | 6 |

During 1974, all pastures received a May application of 75-60-90 per acre plus an additional 40 pounds of nitrogen on September 7.

Results for 1974 (the first year of grazing) must be considered preliminary since pastures have not been grazed over enough seasons to exhibit carry-over effects of the different stocking rates and management practices on the response of tall fescue. Some differences in growth were noted for the various treatments in the spring of 1975.

Pastures were grazed by Hereford calves and short yearlings from April 23 to November 20, 1974, for a total of 211 calendar days of grazing. In addition, mature beef cows were grazed from November 1974 to February 21, 1975, to clean up forage residue remaining, particularly in the low stocking-rate pastures. The low stocking-rate treatments for the continuously grazed and system pastures averaged 112 and 150 cow days of additional grazing, respectively.

Cattle and pasture data for the 1974 grazing season are presented in Table 5. Continuously grazed pastures, regardless of the stocking rate, had an average daily gain per head (ADG) of 1 pound. With the pasture-round-bale system, ADG decreased from 1.0 to 0.57 pounds as stocking rate was increased from 1 to 2 head/acre. Highest gains per acre were obtained with the 1.5 head/acre stocking rate in both the continuously grazed and pasture system treatments.

TABLE 5.--Preliminary results from the Bradford Farm grazing trials 1974[1/,2/]

| | Continuous Grazing | | |
|---|---|---|---|
| Rate of Stocking/A | 0.75 | 1.0 | 1.5 |
| ADG (lb) | 1.07 | 0.95 | 0.96 |
| Animal Days/A | 158 | 211 | 316 |
| Gain/A (lb) | 169 | 201 | 306 |
| Gain/Animal (lb) | 225 | 201 | 204 |

| | Pasture - Round-Bale System | | |
|---|---|---|---|
| Rate of Stocking/A | 1.0 | 1.5 | 2.0 |
| ADG (lb) | 1.0 | 0.85 | 0.57 |
| Animal Days/A | 211 | 316 | 422 |
| Gain/A (lb) | 211 | 268 | 242 |
| Gain/Animal (lb) | 211 | 179 | 121 |

1/ Grazed from April 23 to November 20, 1974, for 211 calendar days of grazing.

2/ Shrunk weight basis for gain.

TABLE 6.--Cattle average daily gains by grazing periods (shrunk weight basis)

| 1974 Grazing Periods | No. of Days | Average Daily Gain - lbs: Continuous Grazing 0.75 | 1.0 | 1.5 | Pasture-Round-Bale System[1/] 1.0 | 1.5 | 2.0 | Period Average |
|---|---|---|---|---|---|---|---|---|
| (1) 4/23-5/15 | 22 | 3.1 | 2.9 | 3.2 | 2.7 | 2.5 | 2.4 | 2.8 |
| (2) 5/15-6/5 | 21 | 0.3 | 0.6 | 0.2 | 0.4 | 0.2 | 0.1 | 0.3 |
| (3) 6/5-6/26 | 21 | 0.5 | 0.5 | 1.2 | 1.0 | 0.5 | 0.1 | 0.6 |
| (4) 6/26-7/10 | 14 | -0.4 | -0.1 | -0.1 | -0.6 | -0.8 | -0.6 | -0.4 |
| (5) 7/10-7/31 | 21 | 1.2 | 1.0 | 0.6 | 1.2 | 1.5 | 0.9 | 1.1 |
| (6) 7/31-8/21 | 21 | -0.6 | -0.5 | -0.9 | -0.4 | -0.3 | -0.2 | -0.5 |
| (7) 8/21-9/17 | 27 | 0.8 | 1.0 | 0.8 | 1.0 | 0.6 | 0.3 | 0.8 |
| (8) 9/17-10/16 | 29 | 1.7 | 1.4 | 1.6 | 1.6 | 1.2 | 0.7 | 1.4 |
| (9) 10/16-11/20 | 35 | 1.8 | 1.1 | 1.3 | 1.2 | 1.2 | 0.9 | 1.2 |

1/ Cattle grazed pastures with round bales during grazing periods 5, 6, 7 and 9.

Average daily gains were highest in the early spring (4/23-5/15) and again in late autumn (9/17-11/20) as shown in Table 6. Cattle gains from May 15 to September 17 generally were low or even negative. The lack of a great difference in animal performance under continuous grazing vs. rotational grazing within the pasture-round-bale system was unexpected. We hope laboratory analyses of forage samples for forage quality components will aid in the interpretation of the grazing results for 1974.

## FORAGE UTILIZATION SYSTEMS FOR BEEF COW-CALF PRODUCTION FORAGE SYSTEMS RESEARCH CENTER

### Purpose of Experiment

To evaluate alternative forage production and utilization systems in beef cow-calf production as influenced by nitrogen fertilization, calving season, supplemental feeding and forage handling.

### Experimental Details and Results (9)

This research is directed and conducted by the following team of scientists: H. D. Currence, Agricultural Engineering; G. B. Thompson, Animal Husbandry, V. E. Jacobs, Agricultural Economics; H. N. Wheaton, Agronomy Extension; A. G. Matches, USDA ARS and Agronomy; J. Stricker, FSRC Superintendent; C. L. Mottesheard, Livestock Specialist; and F. A. Martz, Forage-Livestock Research Coordinator.

Cow-calf grazing research is being conducted at the University of Missouri's Forage Systems Research Center located near Linneus, Missouri. Year-long grazing of tall fescue-ladino clover pastures fertilized with three levels of nitrogen, spring and fall calving, and two levels of creep feeding are under investigation. Treatment combinations are shown in Table 7. All treatments are replicated twice. This experiment involves 144 tester cows, a total of 250 cows and replacement heifers, and 196 acres per calving system for a total of 392 acres of experimental pastures.

Grazing of experimental pastures began in the winter of 1972. Experimentation with the spring calving systems was completed with the winter grazing of 1975-76. These results are presently being prepared for journal publication. Basically, the results show that nitrogen fertilization increased the carrying capacity of pastures but resulted in low calf daily gains, lower conception percentages for cows, and lower calf gains per acre.

## ACKNOWLEDGEMENTS

Special appreciation is given to Mr. J. B. Tevis, USDA ARS Agricultural Technician, Columbia; to Marion Mitchell, Agronomy Research Associate and to Stanley Bell, Dairy Research Associate at the Southwest Center; and to D. Jacobs, Herdsman at the Forage Systems Research Center, for their assistance in conducting these grazing experiments.

TABLE 7.--Treatment combinations in the beef cow-calf systems trials at the Forage Systems Research Center.

I. Spring Calving System

Breed: Begin May (80 days)
Wean: 7½ - 9½ months age (November 1)

Calve: February, March and April
Number of testers: 72

A. Winter Pasture

| N Levels | Pasture Size (A) |
|---|---|
| $N_1$ | 12 |
| $N_2$ | 12 |
| $N_3$ | 12 |

Graze November 15-May 1, 12 tester cows per pasture

B. Summer Pasture

| N and Creep Levels | Pasture Size (A) |
|---|---|
| $N_1C_1$ | 12 |
| $N_1C_2$ | 12 |
| $N_2C_1$ | 10 |
| $N_2C_2$ | 10 |
| $N_3C_1$ | 9 |
| $N_3C_2$ | 9 |

Graze May-November 15
6 tester cows/Pasture

II. Fall Calving System

Breed: Begin November 15 (80 days)
Wean: 8-10 months age (July 1)

Calve: September, October and November
Number of testers: 72

A. Winter Pasture

| N Levels | Pasture Size (A) |
|---|---|
| $N_1C_1$ | 6 |
| $N_1C_2$ | 6 |
| $N_2C_1$ | 6 |
| $N_2C_2$ | 6 |
| $N_3C_1$ | 6 |
| $N_3C_2$ | 6 |

Graze November 15-May 1
6 tester cows/pasture

B. Summer Pasture

| N Levels | Pasture Size (A) |
|---|---|
| $N_1$ | 24 |
| $N_2$ | 20 |
| $N_3$ | 18 |

Graze May 1-November 15
12 tester cows/pasture

Nitrogen levels (split applications)

$N_1$ = no nitrogen
$N_2$ = 100 lb N/A (60 & 40 lbs)
$N_3$ = 200 lb N/A (120 & 80 lbs)

## LITERATURE CITED


(1) Martz, F. A., S. Bell, M. Mitchell, A. G. Matches and D. A. Sleper. 1975. Advanced fescue evaluation studies - a team research project. In University of Missouri-Columbia Agricultural Experiment Station Special Report 177. pp. 12-17.

(2) Matches, A. G., S. Bell, M. Mitchell and F. A. Martz. 1975. Pasture systems for season-long grazing. In University of Missouri-Columbia Agricultural Experiment Station Special Report 177. pp. 9-11.

(3) _____, F. A. Martz, Stanley Bell and Marion Mitchell. 1973. Pasture systems for season-long grazing. In 1973 Research Reports, University of Missouri Southwest Missouri Center, pp. 9-12.

(4) _____, _____, _____ and _____. 1971. Pasture systems for season-long grazing. In 1971 Research Reports, University of Missouri Southwest Missouri Center, pp. 16-18.

(5) _____, _____, and R. Thomas Wormington. 1968. Pasture grazing trials. In 1968 Research Reports, University of Missouri Southwest Missouri Center. pp. 13-16.

(6) _____, J. B. Tevis, G. B. Thompson and J. L. Clark 1975. Rate of stocking and management for pasture systems of tall fescue. In 1975 Agronomy Day Report. University of Missouri-Columbia. pp. 10-14.

(7) _____, G. B. Thompson and F. A. Martz. 1975. Post-establishment harvesting and management systems of forages. In No-Tillage Forage Symposium. October 15-16, 1975. Ohio State University and Ohio Agricultural Research and Development Center. pp. 111-135.

(8) Rountree, Billie H., Arthur G. Matches and F. A. Martz. 1974. Season too long for your grass pastures? Then use several grasses in several pastures. Crops & Soils. 26:7-10.

(9) Stricker, J. A., V. E. Jacobs, G. B. Thompson, F. A. Martz, A. G. Matches, H. N. Wheaton, H. D. Currence and C. L. Mottesheard. 1976. Field Day Report, Forage Systems Research Center, University of Missouri-Columbia, College of Agriculture. 36 pp.


* 1977-GPO-1750-S/771-040/14

U. S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
SOUTHERN REGION
P. O. BOX 53326
NEW ORLEANS, LOUISIANA 70153

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
U. S. DEPARTMENT OF
AGRICULTURE
AGR 101

U.S.MAIL