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# TEXAS JOURNAL OF AGRICULTURE AND NATURAL RESOURCES

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## ARTICLES

# SIRATRO: A LEGUME FOR SOUTH TEXAS

**James D. Arnold and Hans Hovda**

## ABSTRACT

**The value of legumes in a forage program is well established, however; south Texas lacks a summer-growing legume for improved pasture. The objectives of this study were to determine the quality and productivity of Siratro (*Phaseolus atropurpureus* D.C.), a sub-tropical legume species, in south Texas. To determine the effects of inoculation and phosphorus fertilizer, samples were analyzed for crude protein (CP), cell wall content (CWC), and dry-matter yield (DM). Inoculation + 268 lbs/A triple-superphophate increased CP (20.2%) and DM (2,214 lbs/A) and decreased CWC (47.1%) levels. Results of this study indicate that Siratro can be grown in south Texas and has good forage quality and productivity if properly inoculated and fertilized.**

## INTRODUCTION

Legumes are economical, nutritious, and productive livestock feed. Either alone or in mixtures with grasses, legumes are important in soil conservation and provide a means of increasing forage quality with higher daily gains and higher beef production per acre. Legumes supply nitrogen to the soil through symbiosis with nitrogen fixing organisms and reduce the incidence of grass tetany because of a higher magnesium content than grass. Legumes also lengthen the grazing season, increase cow conception rates, and keeps bulls in better breeding condition (Chessmore, 1979). Because of the long humid summer in south Texas, quality summer pasture is critical if a high level of livestock production is to be maintained. Many legumes native to south Texas are not productive enough for use in pastures (T.E. Fulbright, pers. commun.) and a well adapted summer legume is needed. Siratro, a sub-tropical legume species, was selected for this project. Objectives of this study were to determine effects of phosphorus fertilizer and inoculant on dry matter yield (DM), crude protein (CP) and cell wall content (CWC) of Siratro.

## MATERIALS AND METHODS

The study was conducted on the northwest edge of the campus of Texas A&I University, Kingsville, Texas. The study area was comprised of the soil series Orelia fine sandy loam with inclusions of Willacy sandy clay loam.

Siratro was planted in randomized cells (13 x 16 ft) with a 13-ft alley between each cell in two replications. The treatments were: (1) application of 0-46-0 triple - superphosphate at 268 lbs/A, (2) inoculation of the seeds with a "cowpea-type" inoculant, (3) a combination of inoculant and triple-superphosphate at 268 lbs/A, and (4) no treatment (control). Treatments were randomly administered within each replication.

The test area was disked, floated, and each cell hand-raked to insure a clean, weed and clod-free, firm seedbed. Fertilizer was applied broadcast and hand-raked into the soil in those cells receiving fertilizer treatment. Enough cowpea inoculant to thoroughly coat the seed was applied immediately before planting where required. Planting was done in the spring and sampling was delayed until September to allow time for plant establishment.

Sampling was done at bimonthly intervals for 12 months. The samples were clipped by hand using three randomly placed 1.6 by 1.6 ft quadrates in each cell. Plants were clipped to 3.9 inches, dried in a drying room at 105°F and ground in a Wiley mill to pass through a 40-mesh screen. Samples were stored in airtight polyethylene sample bags and analyzed for DM, CP (Harris, 1970), and CWC (Van Soest and Goering, 1970). All assays were run in duplicate. Data were analyzed by analysis of variance procedures using a factorial model with interaction. Means were separated using Duncan's Multiple Range Test (Steel and Torrie, 1980).

## RESULTS AND DISCUSSION

The inoculation treatment did not significantly ($P>0.05$) increase the protein levels of Siratro above that of the control when values were averaged across sampling dates (Table 1); possibly because competition between native and introduced bacterial strains (Roa, 1976). Phosphorus fertilization significantly ($P<0.05$) increased protein above the control but not above the level of protein in the inoculated only Siratro. This indicated that phosphorus fertilizer can significantly increase the protein levels of Siratro; as has been reported in other legumes (Jones et al., 1970).

The inoculation plus phosphorus fertilizer (268 lbs/A of (0-46-0) significantly ($P<0.05$) increased the protein content of Siratro above all other treatments (Table 1). The combination of treatments apparently produce a synergistic affect, compensating for the competition of native rhizobia strains. Proper inoculation and adequate levels of phosphorus are necessary for Siratro to reach high levels of protein. The phosphorus fertilizer stimulates early nodule activity which results in earlier rhizobial production of nitrogen and consequently increased growth and development (Gates, 1970). Siratro had the lowest percent crude protein during the months of August and September (Table 2). Even at lower levels, the CP content of Siratro is well above the generally accepted threshold level of 7% for dry cows. Animal intake and rumen microorganism activity is reduced when the protein content drops below 7%. The percent of CP ranged from a low of 13.2 (control, harvested September 20) to a high of 23.2 (inoculated-fertilized, harvested July 4).

Treatment had no effect (Table 1) on the CWC of Siratro. The CWC was different ($P<0.05$) (Table 3) among dates, probably due to the physiological development of the legume through the growing season (Minson, 1976). With the exception of the December harvest there was an increase ($P<0.05$) in CWC with each succeeding harvest (Table 3). The December harvest resulted in a non-significant ($P>0.05$) drop in CWC, possibly because of a freeze (26.6°F) the day before harvest. The freeze could have lacerated the cell walls, increasing digestibility as determined by the NDF procedure.

The control (1,162 lbs/A) and phosphorus fertilized (1,262 lbs/A) Siratro DM production was higher ($P<0.05$) than the inoculated only (280 lbs/A) Siratro. The Siratro that received both inoculation and phosphorus fertilizer produced higher ($P<0.05$) yields (2,215 lbs/A) than all other treatments (Table 4).

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**Table 1. Interaction of the control, inoculated, fertilized, and inoculated-fertilized treatments on percent crude protein (CP), cell wall (CW), and dry matter (DM) (lbs/A) at the Texas A&I University Research Compound, Kingsville, Texas.**

| | TREATMENTS[1] | | | |
|---|---|---|---|---|
| Attributes: | Control | Inoculated | Fertilized | Inoculated-Fertilized |
| Crude Protein | 16.6a | 17.5ab | 18.8b | 20.2c |
| Cell Wall | 48.5a | 47.7a | 47.0a | 47.1a |
| Dry Matter | 1162b | 780c | 1262b | 2215a |

[1]All values followed by the same letter in the same row are not significantly different at ($P<0.05$) level of probability. Values are averages across all sampling dates.

**Table 2. Percent protein (CP) of Siratro as affected by treatment at the Texas A&I University Research Compound, Kingsville, Texas.**

| | Harvest Dates | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | 9/9 | 9/23 | 11/23 | 12/9 | 7/4 | 7/18 | 8/1 | 8/15 | 9/5 | 9/20 |
| | % Crude Protein[1] | | | | | | | | | |
| Control | 17.4 | 17.4 | 20.9 | 21.4 | 17.3 | 15.2 | 13.8 | 14.9 | 14.2 | 13.2 |
| | b | b | a | a | b | c | de | d | de | e |
| Inoc.[2] | 15.6 | 16.2 | 20.8 | 21.0 | 19.8 | 18.2 | 16.6 | 15.8 | 14.5 | 14.2 |
| | cd | c | a | a | a | b | c | c | de | de |
| Fert.[3] | 19.9 | 18.1 | 19.8 | 22.3 | 20.2 | 20.2 | 18.2 | 16.9 | 16.6 | 15.7 |
| | c | d | c | a | b | b | d | e | e | e |
| Inoc.- | 19.3 | 20.9 | 21.0 | 22.3 | 23.2 | 21.2 | 18.6 | 19.5 | 19.4 | 16.9 |
| Fert.[4] | cd | bc | bc | ab | a | bc | d | cd | cd | e |

[1]Means in the same row followed by the same letter are not significantly different at ($P<0.05$) level of probability.

[2]Inoculated. [3]Fertilized. [4]Inoculated-fertilized.

The control plots produced more ($P<0.05$) DM than the inoculated only plots (Table 4). Rao (1976), working with **Arachis hypogea**, indicated that inoculation with **Rhizobia** alone sometimes decreases yields. This may result from competition between the introduced strain of **Rhizobia** and the native strains already present in the soil. This competition reduces the effectiveness of the **Rhizobia** and consequently nodule formation and nitrogen fixation.

The phosphorus fertilizer did not ($P>0.05$) increase DM (1,262 lbs/A) over the control (1,162 lbs/A). However, the inoculated plus phosphorus fertilizer increased ($P<0.05$) DM production to 2,215 lbs/A. Phosphorus is important in the nutrition of nodulated legumes. If phosphorus is limiting, the addition of phosphorus fertilizer can do more to improve DM production than inoculation (Roa, 1976). This appears to be the case with Siratro. Siratro needs both inoculation and adequate phosphorus to reach its production potential in south Texas.

**Table 3. Cell wall percentage (CWC) of Siratro as affected by treatments at the Texas A&I University Research Compound, Kingsville, Texas.**

| | Harvest Dates | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | 9/9 | 9/23 | 11/23 | 12/9 | 7/4 | 7/18 | 8/1 | 8/15 | 9/5 | 9/20 |
| | % Cell Wall[1] | | | | | | | | | |
| Control | 39.9 | 42.1 | 45.6 | 41.1 | 50.8 | 52.1 | 53.4 | 51.5 | 52.2 | 54.3 |
| | c | c | b | c | a | a | a | a | a | a |
| Inoc.[2] | 48.9 | 44.8 | 45.6 | 42.1 | 47.7 | 50.0 | 48.5 | 48.3 | 51.4 | 51.4 |
| | bc | de | d | e | c | ab | bc | bc | a | a |
| Fert.[3] | 39.3 | 43.0 | 47.3 | 44.7 | 50.7 | 52.7 | 47.2 | 47.3 | 48.4 | 49.4 |
| | g | f | d | e | b | a | d | d | cd | c |
| Inoc.- | 43.2 | 41.3 | 46.2 | 46.0 | 48.8 | 50.9 | 48.9 | 48.0 | 46.3 | 51.1 |
| Fert.[4] | d | e | c | c | b | a | b | b | c | a |

[1]Means in the same row followed by the same letter are not significantly different at ($P<0.05$) level of probability.

[2]Inoculated. [3]Fertilized. [4]Inoculated-fertilized.

**Table 4. Dry matter (DM) production (lbs/A) of Siratro as affected by treatments at the Texas A&I University Research Compound, Kingsville, Texas.**

| | Harvest Dates | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | 9/9 | 9/23 | 11/23 | 12/9 | 7/4 | 7/18 | 8/1 | 8/15 | 9/5 | 9/20 |
| | Dry Matter lbs/A[1] | | | | | | | | | |
| Control | 206 | 274 | 899 | 1,286 | 1,505 | 1,526 | 1,958 | 1,488 | 1,432 | 1,078 |
| | c | c | b | b | b | ab | a | b | b | b |
| Inoc.[2] | 708 | 787 | 654 | 1,206 | 522 | 792 | 819 | 874 | 842 | 597 |
| | a | a | a | a | a | a | a | a | a | a |
| Fert.[3] | 819 | 726 | 706 | 1,581 | 1,721 | 1,207 | 1,444 | 1,479 | 1,786 | 1,116 |
| | ab | b | b | a | a | ab | ab | ab | a | ab |
| Inoc.- | 1,685 | 2,507 | 2,426 | 1,733 | 2,190 | 2,107 | 2,359 | 2,205 | 2,217 | 1,823 |
| Fert.[4] | ab | a | a | ab | ab | ab | ab | ab | ab | ab |

[1]Means in the same row followed by the same letter are not significantly different at ($P<0.05$) level of probability.

[2]Inoculated. [3]Fertilized. [4]Inoculated-fertilized.

## CONCLUSION

These results indicate that Siratro is an excellent source of protein ranging from a low of 13.2% CP the last of September to a high of 23.2% the first of July. If the crop is inoculated with cowpea-type **Rhizobia** and adequate phosphorus is available, DM yields ranged from 1,685 lbs/A to 2,507 lbs/A.

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# RESPONSE OF YUCCA TO FIRE, HERBICIDE, AND MECHANICAL TREATMENTS

**Robert A. Masters, Kay L. Marietta, and Carlton M. Britton[1]**


## ABSTRACT

**Response of individual yucca(Yucca glauca) plants to fire, herbicide, and mechanical treatments, applied singularly and in combination, was evaluated during two consecutive growing seasons. Plant tops were removed by burning plants with a propane burner or shredding to a 6 inch stubble height. Tebuthiuron [N-(5(1,1-dimethylethyl) -1,3,4-thiadiazol-2-yl)-N,N'-dimethylurea] was applied at rates of 1 and 2 lb a.i./ac and a 1:1 mixture of picloram (4-amino-3,5,6-trichloropicolinic acid) and 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) was applied to yucca foliage at 2 lb/ac. Greatest plant mortality occurred when herbicides were applied alone, 67%, or when tebuthiuron at 2 lb/ac was applied following burning or shredding, 73 and 93%, respectively. In contrast, burning and shredding alone caused yucca mortalities of only 13 and 33%, respectively. Burned yucca, regardless of herbicide treatment, produced an average of 1.3 new shoots/plant compared to 0.3 shoots produced by unburned plants. Across all treatments, yucca weight declined 85% during the study period.**


## INTRODUCTION

Yucca (**Yucca glauca**) or small soapwood is a xerophytic shrub ranging in distribution from Arizona, east to Texas and north to North Dakota (Vines, 1960). In Texas this species reaches greatest abundance in the western half of the state and occupies over 3.5 million acres in the Rolling and High Plains (Robison, 1968). On severly degraded rangeland in the panhandle of Texas, densities of yucca often exceed 2000 plants/ac (Sosebee and Churchill, 1982). Depletion of soil water and reduction in forage production resulting from such high densities necessitate control measures be instituted to maintain or improve livestock carrying capacity.

Yucca is susceptible to basal sprays of 2,4,5-T (2,4,5-trichlorophenoxyacetic acid), silvex [2-(2,4,5-trichlorophenoxy) propanoic acid], and karbutilate [m-(3,3-dimethylureido)phenyl-**tert**-butylcarbamate] and is intermediately susceptible to foliar sprays of 2,4,5-T and silvex (Bovey, 1977). Robison (1968) found consistent control of **Y. glauca** with 2,4,5-T and silvex. Moreover, forage production on treated areas was 1830 lb/ac compared to 846 lb/ac on untreated areas. However, these effective herbicides are no longer available for use. Generally, currently available herbicides provide inadequate control of yucca. Jacoby et al. (1983) found the frequency of yucca was unchanged following the application of 1 lb a.i./ac of tebuthiuron [N-(5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl)-N,N'-dimethylurea]. As a group, **Yucca** sp., are tolerant to fire and maintain their position in plant communities after a burn (Wright and Bailey, 1982). However, following a wildfire in the desert southwest, Humphrey (1949) reported a 25% reduction in yucca. In this instance, fire-induced mortality was enhanced by drought conditions at time of the wildfire.

Effectiveness of mechanical treatments depends on whether whole plant or top removal treatments are used (Scifres, 1980). Disc plowing resulted in a 21% reduction in yucca density (Herndon, 1982). Lower than expected mortality resulted from low soil moisture which hindered ability of plow to sever and exhume rhizomes. Since yucca propagates vegetatively, top removal will not provide long-term control. Top removal, sufficient to remove apical dominance, will likely increase yucca density by stimulating shoot growth from rhizomes.

Top removal combined with herbicide treatment improves control of a number of undesirable brush species in South Texas beyond that of treatments applied alone (Scifres et al.,1983). Similarly, top removal followed by herbicide application may enhance yucca control. The objective of this study was to determine the efficacy of fire, herbicides, and shredding alone and in combination for yucca control.

## MATERIALS AND METHODS

The study site was located in Terry County, 3 mi north of Brownfield, Texas. Soil on the site is classified as an Amarillo loamy fine sand (Aridic Paleustalf). Slope ranges from 0 to 3%. Prior to 1976, the site was cultivated. In 1976 weeping lovegrass(**Eragrostis curvula**) and alfalfa (**Medicago sativa**) were planted on the site. Yucca and catclaw mimosa (**Mimosa biuncifera**) were the most abundant shrubs on the site.

The study was initiated in April 1983 to evaluate the response of yucca to 12 combinations of herbicide, fire, and shredding treatments. Each treatment combination was imposed on 15 plants. The fire treatment was conducted on April 15, 1983 using an individual propane plant-burner (Britton and Wright, 1979). To ensure uniformity of the burn treatment, propane pressures of 5.5 psi for 1 min followed by 1 psi for 15 sec were used. Fire temperatures at the soil surface simulated by these pressures were similar to that generated by combustion of a fine fuel load of 5400 lb/ac (Wright et al., 1976). At this time, additional plants were clipped to a 6 inch stubble height to simulate shredding.

On April 20, 1983, when yucca was at the pre-bloom phenological stage, pelleted tebuthiuron (20% a.i.) was applied to a 1-yd$^2$ area around burned, shredded, and intact plants at rates of 1 and 2 lb/ac. On June 3, 1983, when intact yucca were at the bloom growth stage, a 1:1 mixture of picloram (4-amino-3,5,6-trichloropicolinic acid) and 2,4,5-T was applied to foliage of burned, shredded, and intact yucca at 2 lb/ac in a water:oil emulsion carrier using a hand operated sprayer.

Before treatment, plant height, canopy diameter, and number of new shoots were recorded. A new shoot was defined as aerial plant growth arising from within 1-yd$^2$ around treated plants. Similar measurements and plant mortality determinations were made September 29, 1983 and October 9, 1984. A plant was considered dead if leaves originating from the parent plant were chlorotic on more than 50% of their leaf

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surfaces and shoots from basal buds were not evident.

Topgrowth of plants clipped during the shredding treatment, April 15, 1983, and at the last sampling period, October 9, 1984, was collected, oven dried and weighed. At the final sampling date five plants from each treatment combination were harvested. Plant weights were used to develop predictive equations with plant volume as the independent variable and weight as the dependent variable. The formula for a cylinder was used with canopy diameter, average length of two perpendicular directions, as the cylinder diameter and plant height as height of the cylinder. Weight estimates obtained at study initiation and termination were compared to determine changes in above-ground plant weight during the experiment.

The experiment was designed in a completely random manner with individual plants as replications. Plant mortality by treatment was compared using Chi-square analysis ($P < 0.05$). All possible combinations of pairs of treatments were compared. Number of new shoots per plant were compared using Duncan's multiple range test ($P < 0.05$) (Steele and Torrie, 1980). Pre- and post-treatment plant weights were predicted using regression analysis and compared using Student's t-test ($P < 0.05$).

## RESULTS AND DISCUSSION

Precipitation was 1.3 and 3.4 inches below the long-term average of 18 inches in 1983 and 1984, respectively. Although total precipitation during 1983 was greater than 1984, 1.7 inches more rainfall occurred from May to August 1984 than during that period in 1983. Rainfall, 0.7 inches, sufficient to move tebuthiuron into the soil profile occurred the day after application.

Greatest plant mortality resulted from combined top removal, either by burning or shredding, followed by application of tebuthiuron at 2 lb/ac (Table 1). Mortality of burned and shredded plants treated with 2 lb/ac of tebuthiuron was 73 and 93%, respectively. In contrast, mortality of burned and shredded plants treated with tebuthiuron at 1 lb/ac was only 13%. Mortality of burned and shredded plants was lower than plants treated only with herbicides. Burned and shredded plant mortality averaged 21% as compared to 67% for plants treated only with herbicides.

High mortality of untreated plants and those treated with tebuthiuron at 1 lb/ac may be linked to high infestation of these plants with fungal pathogens. Based on visual observations made at the final plant evaluation date, more plant pathogens were found on leaves of unburned and unshredded plants when compared to burned and shredded plants. The three most prominent pathogens on leaf surfaces were fungi from the genera **Hysterographium**, **Kellermania**, and **Torula**. These pathogens are phytophagous and may produce toxins which inhibit plant growth. Removal of older leaves and replacement with new shoots may account for differential pathogen infestation among plants which had topgrowth removed and those which did not. Older leaves are often more susceptible to pathogen penetration and infestation than younger leaves (Royle, 1976).

An unusually wet fall in 1983 may have contributed to the apparent increase in fungal pathogen infestation. Of the total precipitation received during 1983, 48% occurred during a 5-day period in October. Resultant cool, moist environmental conditions may have enhanced fungal growth and subsequent pathogen infestation of yucca. Cool, moist enviromental conditions induced by excessive precipitation were cited as increasing levels of snowmold fungus (**Typhula** sp.) infestation on mountain big sagebrush (**Artemisia tridentata** var. **vaseyana**) (Sturges, 1986).

An antagonistic relationship may have existed between tebuthiuron and the herbicide mixture, picloram +2,4,5-T. Mortality of burned plants treated with a combination of tebuthiuron and picloram + 2,4,5-T was 33% as compared to a 73% mortality of burned plants treated with 2 lb/ac of tebuthiuron. Possibly the hormone-like activity of picloram + 2,4,5-T altered plant metabolism to the extent that phytotoxicity of tebuthiuron was reduced.

**Table 1. Mortality and number of new yucca shoots on a site near Brownfield, Texas 18 months after fire, herbicide, and shredding treatments.**

| Treatment[1] | Total mortality[2] % | New shoots[3] (No./plant) |
|---|---|---|
| Untreated | 40 ab | 0.1 a |
| F | 13 a | 1.5 de |
| F + T (1) | 13 a | 1.8 e |
| F + T (2) | 73 c | 0.8 abcd |
| F + T (2) + P (2) | 33 a | 1.2 cde |
| F + P (2) | 20 a | 1.1 bcde |
| S | 33 a | 0.6 abc |
| S + T (1) | 13 a | 0.3 ab |
| S + T (2) | 93 c | 0 a |
| T (1) | 67 bc | 0.2 a |
| T (2) | 67 bc | 0.5 abc |
| P (2) | 67 bc | 0.2 a |

[1]Treatment abbreviations follow: F = fire, T = tebuthiuron, P = picloram + 2,4,5-T, and S = shred. Numbers in parenthesis indicate rate of herbicide applied expressed as active ingredient, i.e. (1) = 1 lb/ac and (2) = 2 lb/ac.

[2]Means followed by the same letter are not significantly different at the 0.05 level of probability according to Chi-square analysis.

[3]Mean number of new shoots followed by the same letter are not significantly different at the 0.05 level of probability according to Duncan's Multiple Range Test.

**Table 2. Yucca weight estimates and reduction in plant weight from beginning to end of experiment conducted near Brownfield, Texas from April 1983 to October 1984[1]**

| Treatment[2] | Plant weight[3] (g/plant) April 1983 (Pre-treatment) Mean | Plant weight[3] (g/plant) Oct. 1984 (Post-treatment) Mean | Weight reduction %) |
|---|---|---|---|
| Untreated | 366 a | 106 b | 71 |
| F | 285 a | 44 b | 85 |
| F + T (1) | 407 a | 73 b | 82 |
| F + T (2) | 394 a | 32 b | 92 |
| F + T (2)+ P (2) | 364 a | 43 b | 88 |
| T + P (2) | 269 a | 45 b | 83 |
| S | 348 a | 64 b | 82 |
| S + T (1) | 325 a | 101 b | 69 |
| S + T (2) | 269 a | 3 b | 99 |
| T (1) | 348 a | 14 b | 96 |
| T (2) | 394 a | 17 b | 96 |
| P (2) | 289 a | 79 b | 73 |

[1]Means within a treatment are significantly different at the 0.05 level of probability according to Student's t-test.

[2]Treatment abbreviations follow: F = fire, T = tebuthiuron, P = picloram + 2,4,5-T, and S = shred. Numbers in parenthesis indicate rate of herbicide applied expressed as active ingredient, i.e. (1) = 1 lb/ac and (2) = 2 lb/ac.

[3]Predictive equations developed from plant weights are:

Pre-treatment: $Y = 0.00074x + 31.195$, $R^2 = 0.80$

Post-treatment: $Y = 0.00054x + 3.552$, $R^2 = 0.78$

Lower mortality of burned and picloram + 2,4,5-T treated plants compared to plants treated only with picloram + 2,4,5-T may result from difference in plant maturity at time of herbicide application. At this time only 13% of burned plants were at the early bloom growth stage as compared to 40% of the unburned plants. Scifres (1980) indicated yucca was most susceptible to foliar application of 2,4,5-T or silvex at this growth stage.

Burned plants and burned plants treated with 1 lb/ac of tebuthiuron produced more new shoots by the end of the experiment than untreated, shredded, and herbicide-treated plants (Table 1). Change in status of apical dominance may account for difference in shoot numbers between burned and shredded plants. Apparently, top removal by shredding did not remove apical dominance. In contrast, fire-induced mainstem damage removed apical dominance, stimulating shoot production from buds on rhizomes. On average, burned plants, regardless of herbicide treatment, produced 1.3 new shoots/plant while only 0.3 shoots were produced by unburned plants. In comparsion to other burned plants, low number of shoots produced by burned plants treated with tebuthiuron at 2 lb/ac resulted from high mortality caused by the herbicide.

Within treatment, yucca weight declined significantly during the experiment (Table 2). Across all treatments, plant weight declined an average of 85%. Weight reduction associated with untreated plants reflect the high mortality which may be partially attributable to high levels of fungal pathogen infestation. Based on low mortality of burned and shredded plants, except those treated with 2 lb/ac of tebuthiuron, decline in plant weights resulted from plant top removal at the beginning of the experiment.

## CONCLUSION

Burning or shredding combined with application of 2 lb/ac of tebuthiuron caused the greatest yucca mortality. Lowest mortality and greatest number of resprouts were produced after burning or burning coupled with application of 1 lb/ac of tebuthiuron. Based on mortality and number of resprouts fire rejuventated individual yucca plants. Removal of older shoots by fire facilitated production of new shoots from rhizomes.

Impact of fungal pathogens on plant mortality can only be speculated and not conclusively demonstrated by this study. However, high mortality of untreated or plants treated with tebuthiuron at 1 lb/ac when compared to burned or shredded plants suggest another factor, possibly fungal pathogens, may have contributed to the observed mortality. Additional information on relative phytotoxicity of the various pathogens is needed. Once the most virulent species are identified, their populations might be augmented to a level sufficient to enhance yucca control.

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# PRELIMINARY STUDY ON SEXUAL BEHAVIOR OF SOCIALLY DOMINANT AND SUBORDINATE BOARS IN A SEMINATURAL ENVIRONMENT

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## ABSTRACT

**The objective of this preliminary study was to determine whether domestic pig social dominance confers later reproductive success. Two seminatural environments were established with a feeder, shaded pond, shelter and 2 acres of ground cover with alfalfa. Four prepuberal (2 males and 2 females) "resident" pigs were placed on the fields after the post-weaning dominance order was established. Pigs on one field showed a very stable dominance order, while the other field's dominance order was more volatile. Later, additional estrous gilts were brought to each field to determine which boar(s) bred each gilt. Boars shared estrous gilts, that is, both boars on each field bred estrous gilts. Fathership of litters from resident gilts was also shared by both boars on each field. Certain males which were socially dominant mounted estrous gilts more frequently. But all boars shared breedings of estrous gilts and paternity of litters.**

## INTRODUCTION

A central theory of ethology is that social dominance confers reproductive success (Poole, 1985). It is not known to what degree social dominance impacts typical swine farm conception rates (of 70 to 90 percent). Furthermore, domestication may have altered any natural relationship between dominance and reproductive success. Little or no research has been conducted, with domestic pigs, asking questions central to issues of ethology. A better understanding of mechanisms controlling behavior may lead to greater reproductive performance on swine farms.

The objective of this study was to determine if social dominance attained prior to puberty confers later reproductive success. This research was conducted primarily in a large semi-natural enviroment.

## METHODS

**Animals.** Two Duroc (red) boars, two Yorkshire by Landrace (white) boars, and four Yorkshire by Landrace (white) gilts were the primary subjects. Two groups of four pigs were established indoors after weaning at 28 days of age. Table 1 indicates the identification, sex of the pigs, and their birth and weaning weights.

Pigs were moved to the field at about nine weeks of age. They were fed a sorghum-soybean meal diet ad libitum from a three hole self-feeder. Pigs on each field also had access to 2 acres of planted alfalfa. Three months later the feeders were removed and one daily meal of 2 kg per head and native alfalfa were the available feed sources.

**TABLE 1. DEMOGRAPHIC DATA FOR EXPERIMENTAL PIGS**

| Identification | Sex | Pen | Field | Birth weight,lb | Weaned weight,lb |
|---|---|---|---|---|---|
| Orange tag | gilt | C[a] | East | 3.5 | 15.1 |
| Yellow tag | gilt | C | East | 4.6 | 18.3 |
| White | boar | C | East | 4.8 | 20.4 |
| Red | boar | C | East | 4.0 | 17.9 |
| Orange tag | gilt | D[b] | West | 4.7 | 19.9 |
| Yellow tag | gilt | D | West | 4.5 | 17.9 |
| White | boar | D | West | 3.8 | 18.0 |
| Red | boar | D | West | 3.9 | 18.6 |

[a] These pigs later put on east field.
[b] These pigs later put on west field.

When resident pigs were five to six months old, the red boar on the west field injured a leg. This slight impairment may have reinforced his social position.

**Social Dominance.** The groups were formed when pigs were 5 weeks old and marked with coded eartags for identification. At this time, they were placed in a 4 by 4 foot pen indoors with a 5 hole feeder and nipple waterer. Behavior was video recorded for the first 72 hours they were together. Data were collected from video records to establish a social order based on aggressive attacks, and submission. At five months of age pigs were observed once per week for four weeks to confirm that the earlier-determined dominance was maintained. Aggression was defined as boars or gilts alternating bites and pushes. Most attacks were among males. Submission was defined as any pig receiving attack but not retaliating. These behaviors were more fully described by McGlone (1985).

**Reproductive Success.** Pigs were allowed to live together, breed and eventually give birth. Because of sire colors, the offspring could be examined to determine which boar(s) sired the litter. However, actual numbers of pigs per litter by each sire could not be determined.

**Boar Dominance for Estrous Test Gilts.** When pigs were eight months of age, resident gilts appeared pregnant. Because little sexual behavior had been actually observed among resident pigs, estrous gilt tests were conducted. Estrous gilts used for sexual tests, were 6 to 7 month old crossbred gilts, weighing 200 to 220 pounds. When it was determined that they were in estrus (by testing with a mature boar), they were put on one of the fields. There were a total of nine trials. Five were completed on the west field and four on the east field. An estrous gilts was brought into each field and the following duration and frequency data were taken: mounting,

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another pig located within one body length, sniffing, touching, aggression, and time spent away from the gilt. Mounting was when a boar was positioned on top of the estrous gilt's rump, backside, or front end. The gilt could be standing, sitting or lying down (but primarily standing). Within one body length was when a focal pig was at least one body length from the estrous gilt. While being within one body length, pigs could be standing, walking, pursuing, rooting or performing any behavior. Written observations were also taken continuously. The test periods were 90 minutes.

## RESULTS

**Social Dominance**. Prepuberal social dominance data are presented in Table 2. In pen C, the dominance order was relatively stable. The red boar was dominant over the white boar. Boars were dominant over gilts. However, the two gilts in pen C were approximately equal in social dominance.

In pen D the white boar was dominant over the red boar in every social encounter. The submissive behavior shown by the white boar during the 24-48 hour period was due to his defeat by the orange tag gilt.

In pen D (what later will become the west field pigs), boars showed long durations of aggressive behavior compared with that shown in pen C. The white boar in pen C was clearly subordinate to the red boar. Thus, in pen C (later put on the east field) a clear relationship between dominance status and reproductive success could be shown (if such a relationship exists in the domestic pig). However, in pen D since the social structure was volatile among males, a clear relationship between dominance and reproductive success would be difficult to demonstrate.

**Reproductive Success**. The most critical measure of reproductive success is production and survival of offspring. All "resident" gilts gave birth, indicating that they were bred about the time they reached puberty. When planned breedings are preformed, some piglets from red sires have light red spots on their skin, while all piglets from white sires are exclusively white.

In this preliminary study each litter of piglets had some pigs with light red spots on their skin. Most piglets were all white. This indicated that both boars sired each litter. The exact number of piglets sired by each boar could not be determined in this study. Use of red females and white or red boars would have confirmed the exact numbers of piglets from each sire. Such a determination requires further study.

**TABLE 2. BEHAVIOR OF PIGS ON FIRST THREE DAYS IN PENS**

| Behavior | Post-Grouping hour | Yellow tag gilt | Orange tag gilt | White boar | Red boar |
|---|---|---|---|---|---|
| | | PEN C[a] | | | |
| Agression, minutes | 0-24 | 1.08 | 0.24 | 6.21 | 9.6 |
| | 24-48 | 0.0 | 0.0 | 2.4 | 2.58 |
| | 48-72 | 0.0 | 0.12 | 0.12 | 0.48 |
| Submission, minutes | 0-24 | 0.45 | 1.05 | 1.23 | 0.0 |
| | 24-48 | 0.0 | 0.03 | 0.03 | 0.0 |
| | 48-72 | 0.0 | 0.09 | 0.15 | 0.0 |
| | | PEN D[b] | | | |
| Aggression, minutes | 0-24 | 24.27 | 6.3 | 97.51 | 84.48 |
| | 24-48 | 55.49 | 3.0 | 24.32 | 35.52 |
| | 48.72 | 71.0 | 0.0 | 79.42 | 8.09 |
| Submission, minutes | 0-24 | 2.61 | 3.57 | 0.0 | 0.24 |
| | 24-48 | 0.69 | 1.47 | 1.14 | 0.12 |
| | 48-72 | 0.09 | 0.09 | 0.0 | 0.33 |

[a] These pigs later put on east field.
[b] These pigs later put on west field.

**Boar Dominance for Estrous Test Gilts**. Listed in Table 3 are the results from the sexual behavior tests. The boar by field interaction was significant for duration of mounting (P=.01) and tended to be significant for frequency of standing within one body length (P=.10) and frequency of sniffing (P=.08). The white boar on the east field (the socially subordinate male) showed lower sexual and investigatory sniffing behaviors. This was replicated on the west field where the red boar (socially subordinate) also showed lower levels of sexual and investigatory sniffing behaviors.

Although differences in behavior were evident due to field and boar-type (red or white), all boars were sexually active. In fact, in each estrous gilt test, both boars mounted and successfully bred the estrous gilts. Therefore, although certain boars were more or less active, both resident males attained apparent reproductive success.

**TABLE 3. MEANS, STANDARD ERRORS AND RESULTS OF ANALYSIS ON ESTROUS GILT TESTS**

| Behavior | N | RB | WB | SE | N | RB | WB | SE | B | Fi | B*F |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | East Field | | | | West Field | | | | PR > F | | |
| Mounting, D | 4 | 16.6 | 7.9998 | 2.0077 | 5 | 4.9169 | 6.5143 | 1.7706 | .07 | .01 | .01 |
| Mounting, F | 4 | 40.000 | 17.7500 | 6.3957 | 5 | 18.6750 | 13.9321 | 5.6450 | .03 | .10 | .14 |
| Within one body length, D | 4 | 16.8768 | 18.8843 | 4.9741 | 5 | 17.8942 | 26.1765 | 4.3867 | .26 | .46 | .91 |
| Within one body length, F | 4 | 133.8427 | 108.5927 | 28.2399 | 5 | 98.5283 | 149.5200 | 24.9050 | .61 | .93 | .10 |
| Sniffing, D | 4 | 14.9748 | 8.0598 | 3.5334 | 5 | 8.8884 | 9.5150 | 3.4693 | .38 | .60 | .30 |
| Sniffing, F | 4 | 175.0375 | 97.2875 | 34.5313 | 5 | 65.6485 | 101.6557 | 30.4535 | .50 | .19 | .08 |
| Touching, D | 4 | 6.5333 | 1.4886 | 1.3740 | 5 | 3.3301 | 1.3583 | 1.2118 | .01 | .29 | .23 |
| Touching, F | 4 | 94.6935 | 27.1935 | 16.5303 | 5 | 45.4345 | 26.1488 | 14.5782 | .01 | .19 | .12 |
| Agression, D | 4 | 0.06556 | 0.08550 | 0.0284 | 5 | -0.0124 | -0.0144 | 0.02500 | .72 | .01 | .67 |
| Aggression, F | 4 | 1.2083 | 1.4583 | 0.7970 | 5 | 0.4333 | 0.2333 | 0.7029 | .97 | .28 | .75 |
| Away | 4 | 34.9498 | 53.4823 | 10.1287 | 5 | 54.9821 | 46.450 | 8.9326 | .58 | .57 | .15 |

N = # of Trials
SE = Standard Error
D = Duration, minutes/90 minute test period
F = Frequency or number of times behavior was observed
RB = Red boar (Duroc)
WB = White boar (York X Landrace)
B = Boar effect
Fi = Field effect
B*F = Boar by field interaction

## DISCUSSION

Domestication may have altered the domestic pigs' sexual and social behavior. While the European Wild Boar (the ancestor of the domestic pig) male is a solitary animal (Graves, 1982), our postpuberal males lived peacefully and were commonly observed near one another. The resident females remained together. However, the two males and two females were not often observed together. Boars and gilts were together typically when resting and when the females were in estrus.

Interesting behavior was observed when the test estrous gilts were brought to the experimental pens. Resident boars showed excitement and considerable investigatory behavior in the presence of novel gilts while resident gilts showed little interest or aggression (unless test gilts came near resident gilts). Dominance was not overt. Only when a limited amount of a palatable feed was given could dominance be surmised.

The determination of social dominance when prepuberal pigs were first placed together was a critical part of our dominance determination. Observers felt uncomfortable assigning social status to pigs based on live observations of relatively peaceful pigs.

As is evident from Table 2, a clear social dominance order was formed in pen C (the east field). The red boar showed no submissive behavior during hierarchy formation. In pen D (the west field), both boars showed some submissive behavior, but the white boar eventually was considered the more dominant winner among males because he showed the least submission.

Social dominance status influenced male sexual behavior. Dominant boars mounted more often and for longer durations. However, subordinate boars also mated estrous test gilts (they just did so less often). Males shared estrous test gilts and, apparently, they shared the paternity of the litters. Perhaps if boars bred a large number of females, the increased breedings by dominant boars would result in more offspring sired by the dominant male. Therefore, the small advantage dominance confers in reproductive success may be the reason aggression-dominance behaviors remain fixed in the gene pool of the domestic pig. Further examination of this theory is needed since the number of groups of pigs used was limited. A larger number of replications may lead to more conclusive results.

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# RELATIONSHIPS BETWEEN PRIOR RAINFALL AND CURRENT BODY FAT FOR NORTHERN BOBWHITES IN SOUTH TEXAS

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## ABSTRACT

**In South Texas, heavy rainfall (≥30% of mean annual precipitation) during a 1- to 2-month period in April-September was positively correlated ($0.0031 < P < 0.0455$) with subsequent body fat levels in northern bobwhites (Colinus virginianus). Effects were observed within 2 months and persisted up to 6 months. Rainfall in February was negatively related ($r = -0.81$, $P = 0.0076$) to body fat levels in April.**

## INTRODUCTION

Rainfall patterns and amounts influence the density and productivity of gallinaceous birds throughout the Southwest. Fall and/or spring moisture appears generally important, because it is correlated with productivity in wild turkeys (**Meleagris gallopavo**) (Beasom and Pattee 1980), California quail (**Callipepla californica**) (Francis 1970, Leopold et al. 1976), Gambel's quail (**C. gambelii**) (Swank and Gallizioli 1954, Gullion 1960, Hungerford 1964), and bobwhites (D. Wilson, pers. commun.). Spring and summer rainfall also may be correlated with fall age ratios in bobwhites (Kiel 1976) and scaled quail (**C. squamata**) (Campbell et al. 1973).

Relationships between rainfall and body fat levels (BFL) of galliforms in dry regions remain unexplored. The productivity and survival of game birds may vary with body fat (Dimmick 1975, Norman and Kirkpatrick 1984). The objective of the study was to determine relationships between prior rainfall and current BFL of bobwhites in South Texas.

## STUDY AREA AND METHODS

Study areas were on ranches in Duval, Dimmit, Webb, Refugio, and Brooks counties in South Texas. Mean annual precipitation ranged from 19 to 35 inches; annual area-specific precipitation ranged from 12 to 52 inches during the study and differed by 22-113% on a given area between years (Koerth 1985). Soils were clays in the Refugio County area, deep sands in the Brooks County area, and mainly sandy loams in other areas. Birds on all areas were fed sorghum and corn from feeders or along roads during fall and winter. Gould (1975) described ecological conditions in the South Texas Plains and Koerth (1985) gave more detail on study areas.

Five to 10 bobwhites were collected monthly from January 1982 to December 1983 from each study area ($N = 863$). Whole birds less crops and crop contents were ground while frozen, dried at 158°F for 48 hours, and finely reground. Crude fat was extracted from duplicate 0.05-oz. samples for 8 hours with ether in a Goldfisch apparatus (modification of Harris [1970:2301]. If duplicates differed by >10%, additional duplicates were analyzed. The mean value of duplicates differing by < 10% was used in analyses. BFL (dry-matter basis) was calculated as 100 × (sample fat weight/sample weight).

Monthly rainfall data (U.S. Dep. Commer. 1982, 1983) were obtained from 4 stations < 7 miles and 1 station 25 miles from study areas. Eight independent variables were created from these data: rainfall totals for each of the 6 months preceding the beginning of the month tested, and totals of 3 and 5 months preceding the 6 months.

The dependent variable was a fat index defined as the mean BFL of a sample of birds collected in a specific year-month-area category. For example, if 5 birds were collected in Duval County in January 1982, their mean BFL was a dependent variable. Birds of all ages and sexes were pooled in calculation of the dependent variable because (1) we collected mature-appearing birds and mean fat levels of juveniles and adults seldom differed and (2) area-specific fat levels of males and females were similar in fall and winter (Koerth 1985). Fat levels of sexes sometimes differed in spring and summer, but this did not bias the dependent variable because males and females generally were equally represented in the samples. Sample sizes for calculations of the dependent variable were ≥ 5 in 88% of the tests.

Correlation analyses, stratified by months, were used to explore relationships between previous rainfall and current BFL. Potential sample sizes were 10 for each month (2 years × 5 areas). Actual sample sizes were smaller because of missing records at some weather stations. Because of variation in patterns and amounts of rainfall between years, we assumed that dependent variables from the same study area approximated independence.

## RESULTS AND DISCUSSION

Because we explored 96 relationships between previous rainfall and current BFL of bobwhites, we would expect 1-2 significant correlations by chance based on the average of significant **P** values obtained (Table 1). That 9 **r** values were significant ($P < 0.05$) indicates direct or indirect effects of rainfall on BFL. These results occurred despite variation imposed by time, area, land-use practices, and other factors.

Rains during April, May, September, and December were postively correlated with subsequent BFLs (Table 1). However, the December-March relationship was suspect because of a narrow range in X variables (0.2-1.8 inches). The April-July relationship was questionable for the same reason (0.3-2.3 inches) but appeared biologically reasonable, as discussed below. Rainfall appeared to affect body fat within 2 months, and effects persisted up to 6 months.

Concentrated periods (1-2 months) of heavy rain (≥30% of mean annual precipitation) preceded increased BFLs in fall and winter. This phenomenon contributed to the positive relationships between May rain and August, October, and November BFL, and between September rain and January BFL (Table 1). For example, the Duval County area received 79% of mean annual precipitation in May 1982; November body fat levels responded positively (Fig. 1). The Refugio County area received 42 and 50% of mean May rainfall in May 1982 and 1983, respectively; body fat levels in the following

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Novembers were low (8.7 and 8.5%, respectively). Mean May rainfall on the Dimmit County area is 3.4 inches; rainfall was 3.7 and 0.9 inches in 1982 and 1983, respectively. Consequently, body fat levels in November 1983 were only 64% of levels in 1982.

**Table 1. Monthly relationships between previous rainfall and current mean body fat for bobwhites in South Texas, 1982-83.**

| Season<br>Current month | N | Month of previous rainfall | r | P |
|---|---|---|---|---|
| Winter | | | | |
| Dec | 7 | Jul | -0.48 | 0.2800 |
| Jan | 8 | Sep | 0.71 | 0.0455 |
| Feb | 9 | Nov | -0.64 | 0.0608 |
| Spring | | | | |
| Mar | 9 | Dec | 0.78[a] | 0.0128 |
| Apr | 9 | Feb | -0.81 | 0.0076 |
| May | 8 | Dec | 0.46 | 0.2600 |
| Summer | | | | |
| Jun | 8 | Jan | -0.84[a] | 0.0098 |
| Jul | 7 | Apr | 0.91[a] | 0.0046 |
| Aug | 7 | May | 0.91 | 0.0046 |
| Fall | | | | |
| Sep | 7 | Aug | -0.85[a] | 0.0163 |
| Oct | 7 | May | 0.78 | 0.0377 |
| Nov | 7 | May | 0.92 | 0.0031 |

[a]Although significant, these relationships are regarded as questionable for reasons explained in the text.

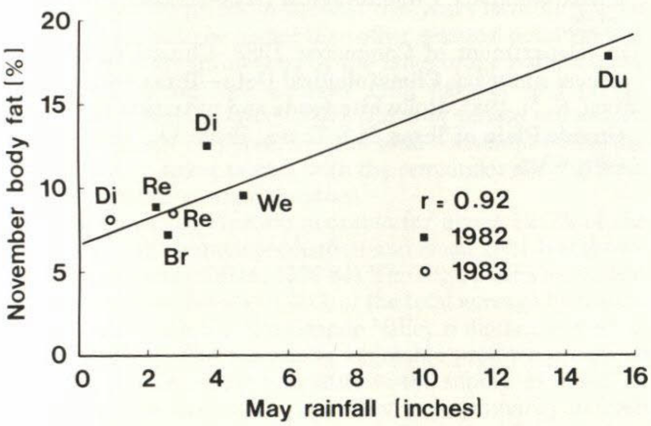


**Figure 1. The relationship between May rainfall and the following November mean body fat for bobwhites collected from 5 countries in South Texas (Di = Dimmit, Re = Refugio, We = Webb, Br = Brooks, and Du = Duval).**

We hypothesize that rainfall was postively related to BFL during April-October because of direct and indirect effects on the availability and accessibility of food and preformed water. Because of the long growing season in South Texas (> 300 days), rain at virtually any time may result in the emergence of plant sprouts. However, certain minimum levels of precipitation probably are necessary to trigger mass germination (Beatley 1974), consistent with our finding that heavy rainfall during a short period was necessary to actuate the rainfall-body fat relationships. Sprouting plants, which may appear within 2-7 days after precipitation (Gullion 1960), are a relatively rich source of nutrients (Wood 1985) and preformed water (Turner and Kramer 1980:1) in the bobwhite diet (Lehmann 1984:170, Wood 1985, Koerth et al. 1986). Widespread availability of succulent sprouts as a source of dietary water permits broader dispersal of galliforms in arid regions (Gullion 1960) and thus increases the accessibility of foods. Conversely, birds such as Gambel's quail cannot maintain body weight on a dry-seed diet during warm seasons (Gullion and Gullion 1964) and water deprivation reduces the rate of food intake in bobwhites (N. E. Koerth and F. S. Guthery, unpubl. data). Dietary water apparently is important to bobwhites in South Texas because these birds have been observed drinking surface water during July-October (Prasad and Guthery 1986); as many as 468 birds have been observed drinking at a livestock pond in 1 day (Lehmann 1984:87).

Further, the abundance of invertebrate foods varies with the succulence and diversity of herbaceous vegetation (Hurst 1972, Scriber and Slansky 1981, Healy 1985). Thus, plants that sprout and grow after rainfall provide substrate for invertebrates (Mayhew 1966), widely recognized as rich sources of preformed water and protein. Protein eaten in excess of physiological demands can be converted to fat (Sheehy 1955:161).

Lastly, heavy, concentrated rains probably had extended effects on BFL by increasing the germination, emergence, survival, and/or productivity of seed-producing plants important in the summer and fall diet of bobwhites in South Texas. These include crotons (**Croton** spp.) and panicoid grasses (**Setaria** spp., **Paspalum** spp., **Pancium** spp.) (Lehmann 1984:168, Wood 1985).

Of the 3 negative ($P < 0.05$) relationships between rainfall and BFL (Table 1), two appeared to be spurious. The January-June relationship was based on a narrow range of X variables (0-0.9 inches); it seems unlikely that negative effects of January rain would be seen after 5 months had elapsed. The August-September relationship was negative largely because of a sample from the area with clay soils. This area received 12 inches of rain in July 1983, which caused extensive flooding, the probable cause of low fat levels ($\bar{x}$ = 6.2%) of birds collected in September 1983.

The negative correlation between February rain and April BFL (Table 1) could have occurred because of increased energy demands for thermoregulation (see Case and Robel [1974]) during extended periods of cool, wet weather. February is, on average, the second coldest month in South Texas. Although bobwhites can withstand dry cold, they chill easily if feathers become damp (Stoddard 1931:55).

Our findings on potential relationships between rainfall and body fat in bobwhites pertain to a region where monthly and annual precipitation is highly variable (Tucker and Griffiths 1965), mean annual precipitation is < 26 inches, mean annual temperature exceeds 72°F, and gross lake-surface evaporation is 2-3 times higher than mean annual precipitation (Larkin and Bomar 1983). In short, the region is semiarid and moisture may be a limiting factor for many forms of wildlife. Because of the unique quail environment under which we studied, the findings may not hold in other portions of bobwhite range, such as the Midwest and Southeast. However, similar relationships may hold for other gallinaceous birds in the Southwest.

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# THE ECONOMICS OF STORING WEST TEXAS POTATOES

**Bob Davis and Norma Bojorquez[1]**

## ABSTRACT

**Growers in the West Texas area have attempted to determine whether privately owned grower storage facilities would be economically viable. This paper discusses storage goals, investment decision criteria, storage design, and investigates the costs of storing potatoes produced in the West Texas area. Results indicate that fresh market prices generally do not rise enough to cover the costs of storage in a typical year. The analysis is done using two methods, a break-even analysis and the Rister, Skees and Black storage model, and the results are consistent.**

## INTRODUCTION

The seasonal potato market has been associated with large year to year variations in production and price. A relatively small change in production tends to be accompanied by a relatively large change in price, causing prices to vary substantially from year to year and within the year, as well. Over time potato production has shown a normal inverse relationship to its own price (USDA, 1976-84). Such fluctuations have made potato production a speculative enterprise, causing most growers to face the market with considerable uncertainity. Summer potato prices in the last five years have fluctuated widely and tend to be higher than other seasonal potato prices. These prices are influenced by the fall storage potatoes, the timing of spring and summer crop harvest and potato processors' demand (Hee, 1967). Summer potato production provides almost 50 percent of the total consumption during the summer market period, with the remainder coming from spring and fall storage potatoes.

Texas potato production accounts for about 12.5% of the nation's total summer production and since 1981 has shown an upward trend (USDA, 1976-84). The High Plains has historically accounted for about 60% of the total acreage harvested in the state with the Rio Grande Valley a distant second at 14% (Table 1). The remaining vegetable producing regions in the state contribute very little to the supply, as indicated in the table. Texas potato production goes primarily to fresh markets in the midwest and the east. Recent unload data show that Texas is becoming more active in national markets and less reliant on state and nearby regional markets. However, the small proportion of Texas potato production in relation to the total quantity marketed in the summer causes potato growers to have very little, if any, influence on the market price. Consequently, they are price takers, causing production to be risky.

## THE PROBLEM

Recently, growers in the West Texas area have attempted to determine whether privately owned grower storage facilities would be economically viable. These facilities would allow producers to withhold production from the market when prices are depressed at harvest time. A major component in the decision to store potatoes for a period of time is the producer's market price in any given month of the year. The storage investment decision involves such specific considerations as:

1. Selecting facilities to provide storage of potatoes at the lowest cost while maintaining quality; and
2. Deciding how long to store the crop, which is related to when an increase in price will occur.

**Table 1. Texas Potatoes:**
**Acreage harvested by state regions 1983-84**

| | Acreage harvested | | | |
|---|---|---|---|---|
| **State regions** | **1983** | **percent** | **1984** | **percent** |
| Rio Grande Valley | 2,500 | 16.0 | 2,400 | 13.7 |
| Coastal Bend | 50 | 0.3 | 50 | 0.2 |
| San Antonio-Winter Garden | 1,000 | 6.7 | 1,150 | 6.6 |
| Upper Coast | 350 | 2.4 | 570 | 3.3 |
| Central Texas | 500 | 3.3 | 700 | 4.0 |
| East Texas | 200 | 1.4 | 330 | 1.9 |
| North Texas | 1,800 | 11.9 | 1,700 | 9.7 |
| High Plains | **8,800** | **58.0** | **10,600** | **60.6** |
| State total | 15,200 | 100.0 | 17,500 | 100.0 |

Source: USDA, 1983-84.

## STORAGE GOALS

Studies were reviewed to gain a better understanding of the physical requirements of potato storage, the factors affecting the decision of when to store, and the importance of storage in the potato industry. Several authors agree (Brennan 1959, Plissey, 1976, Cargill, 1976, and Hanes, 1969) that the main goals for potato storage are to:

1. Retain water in the tuber because profits depend on holding shrink to a minimum.
2. Hold respiration to a minimum which will both reduce weight losses and quality deterioration.
3. Hold reducing sugars to a minimum for potatoes to be processed.
4. Maintain external appearance.

When potatoes are harvested and placed in storage, they are usually held at a temperature of 50 to 60 degrees Fahrenheit (F.) at a relatively high humidity for 10 to 14 days to allow cuts and bruises to heal and to reduce subsequent losses from shrinkage and decay. Then, temperatures are reduced to 38 to 48 degrees F. for storage (unless the potatoes are to be processed, in which case temperatures are kept at 50 to 60 degrees to retard accumulation of reducing sugars). Another important factor affecting the weight loss of potatoes during storage is the relative humidity of the air used to maintain the temperature within the pile. Studies have shown that minimum weight loss occurred when the tubers were maintained at a temperature of about 45 degrees F. with air at 95% or more relative humidity. Storage temperatures 2.5 degrees F. lower

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significantly increased weight loss and also produced an unacceptable color in unblanched french fries.

## INVESTMENT DECISION CRITERIA

The farm operator, as the decision maker, must decide how long to store potatoes based on the expected economic gain. Economic gain is dependent on total storage costs and the increase in sale value. Another factor which affects economic gain is the convenience yield on inventories which is the ability to keep regular customers satisfied by meeting their orders in a timely fashion. The economic gain to the convenience yield on inventories is recognized as the premium that buyers are willing to pay in return for the assurance of a supply of consistent quality from the beginning of the season until the new crop is available. However this requires the proper storage facilities and storage management.

## STORAGE DESIGN

Von Bermuth (1964) evaluated storage designs to determine the economically optimum investment. Considering eight storage systems, his designs were based on expected temperature and relative humidity extremes resulting from weather analysis. Results indicated that the frame structure design with automatically controlled forced air ventilation and humidification provides the greatest net return to storage. The facility must have adequate insulation such that walls and ceilings should have no more heat transfer than 0.05 BTU's per square foot of surface area each hour for each degree F. difference between inside and outside temperature. The air distribution system must be capable of maintaining a uniform temperature through the potato pile. Thus, the forced air system should be capable of 0.5 cfm per cwt. during the brief period of cool down, and a sustained rate of 0.25 cfm per cwt. after cooling to the holding temperature has been accomplished. For this study, the potato storage facility selected is refrigerated with a capacity of 100,000 cwt., well insulated, and includes ventilating and humidifying systems. It is also the least cost system of the several designs considered (Cargill, 1976, Summer and Sparks, 1974, and Von Bermuth, 1964).

## STORAGE COSTS

Total costs of potato storage fall into three categories: (1) shrinkage and weight loss; (2) quality deterioration and (3) direct costs of owning and operating storage facilities. The costs of storing potatoes for this analysis have been determined by taking into account the following:

1. Cash storage costs for the period are the monthly variable costs incurred from harvest until the time when potato stocks are sold as well as continous variable and fixed facility costs associated with the acquistion of the building and storage equipment. Thus cash storage costs will change as other variable costs are increased due to increased time in storage, as represented in the following equation:

$$CS = FFC + OVC \text{ and } OVC = VC_t * T \quad (1)$$

where:
CS = cash storage costs for the period ($/cwt.).

FFC = fixed facility costs and continous variable costs ($/cwt.).

OVC = other variable costs for the period ($/cwt.).

$VC_t$ = monthly variable costs ($/cwt.).

T = number of months of storage.

2. Opportunity costs, which are the indirect costs associated with delaying sales past harvest. The interest rate reported by the Dallas Federal Reserve District for farm loans was used in the following formula to reflect the opportunity cost of capital:

$$DF = (1.0 + r), -^{T/12} \quad (2)$$

where:
DF = discount factor for the period.

r = current annual interest rate.

T = number of months of storage.

3. Costs of physical loss, which are due to losses caused by enviromental conditions during storage. The percent values for weight loss computed by Summer and Sparks (1974) were used in the calculations of these costs based on maintenance of recommended enviromental conditions for minimum weight loss. Minimum weight loss of potatoes stored from 30 to 180 days range from 0.44 to 2.28 percent.

## TEXAS POTATO PRICE PATTERN

A trend equation was developed to indicate the average movement of potato prices over time. Secondly, seasonal variations were explored using moving average prices to construct a seasonal index. Data used were monthly average potato prices received by Texas farmers as reported by the Texas Statistical Reporting Service for the period, July, 1976 to June, 1984. Monthly average prices received were estimated from monthly wholesale average potato prices at the Dallas market less transportation costs for months in which there were no published data.

## BREAK-EVEN POST-HARVEST POTATO PRICES

Post-harvest potato prices that should encourage growers to hold potatoes in storage during successive periods of time (30, 60, 90 and 180 days) were computed by adding the total storage costs for the period to the average price for the month of August.

$$PPH_t = TSC/T + PH_{to} \text{ and } TSC = CS + OC + PLC + IFSC \quad (3)$$

where:
$PPH_t$ = post-harvest potato price in month t ($/cwt.).

TSC = total storage costs for the period ($/cwt.).

$PH_{to}$ = potato price at harvest ($/cwt.).

CS = cash storage costs for the period ($/cwt.).

OC = opportunity costs for the period ($/cwt.).

PLC = physical loss costs for the period ($/cwt.).

IFSC = initial fixed storage costs ($/cwt.).

T = number of months in the storage period.

## NET RETURNS TO STORAGE

The profitability of storing potatoes for several lengths of time was computed using an equation developed by Rister, Skees, and Black (1984) in their analysis of grain sorghum storage decisions in the Texas Coastal Bend. The equation represents net returns to post-harvest sales from storage as opposed to sales at harvest.

$$NR_{tto} = ((PPH_t - CS_t) * (1 - w_t) * DF_t) - PH_{to} - IFSC \quad (4)$$

$$CS_t = CS/T \quad (5)$$

$$w_t = (\% * 0.01) \quad (6)$$

$$DF_t = (1 + r), - ^{1/12} \quad (7)$$

where:

$NR_{tto}$ = net revenues from storage in month t as opposed to sales at harvest ($/cwt.)

$w_t$ = proportional weight loss adjustment factor for month t, and all other terms are as previously defined.

## RESULTS

Estimated storage costs shown in Table 2 relate the costs of ownership and operation of a well-constructed and well-maintained 100,000 cwt. storage facility to the length of storage season. Costs are expressed per cwt. of potatoes and are estimated on a 5 percent shrinkage giving 95,000 cwt. of marketable potatoes out of storage.

Cash storage costs include continous variable costs, fixed facility costs and other variable costs. Continous variable costs represent the costs of unloading and piling the potatoes in storage as well as the cost of removal from storage. Fixed facility costs are the costs related to investment in the facility such as depreciation, taxes, insurance and interest. For the purpose of this analysis interest was 14.35 percent. Even at this relatively high interest rate, continous variable costs and fixed facility costs were only $0.48 per cwt. Other variable costs include such items as electricity for ventilation and refrigeration and the service costs of such units. Other variable costs vary according to the length of the storage period and range from $0.10 to $0.39 per cwt. as time changes from 30 to 180 days.

**Table 2. Estimated storage costs for a 100,000 cwt. potato storage facility, selected time periods.**

| Cost Items | Length of Storage 30 days | 60 days | 90 days | 180 days |
|---|---|---|---|---|
| | dollars per cwt. | | | |
| Cash storage costs[1] | 0.58 | 0.62 | 0.67 | 0.87 |
| Opportunity costs | 0.04 | 0.09 | 0.13 | 0.28 |
| Physical loss costs | 0.04 | 0.06 | 0.09 | 0.20 |
| Initial fixed costs | **3.63** | **3.63** | **3.63** | **3.63** |
| Total storage costs | 4.29 | 4.40 | 4.52 | 4.98 |

[1]Cash storage costs are composed of continous variable costs and fixed facility costs of $0.48 per cwt. regardless of length of storage, and other variable costs of $0.10, $0.14, $0.19, and $0.39 for 30, 60, 90 and 180 days, respectively.

The opportunity costs include the indirect costs associated with delaying sales after harvest as interest on operating capital and interest on potato stocks and range from $0.04 to $0.28 per cwt. as time varies from 30 to 180 days.

The physical loss costs represent the percentage of weight and quality change that occur during storage. The value used in estimating the monetary costs of storage losses in this study was the price of potatoes at harvest ($8.61 per cwt.). The costs associated with each length of storage were computed by multiplying the proper percentage of physical loss for the period by the harvest price.

Initial fixed costs include the purchase value of the building, complete with ventilation and refrigeration systems, and were estimated to be $3.63 per cwt. Thus, the total storage costs for potatoes were estimated to be between $4.29 and $4.98 per cwt. as storage varies between 30 and 180 days (Table 2).

Post-harvest potato prices required to offset storage costs for specific time periods were obtained by adding total storage costs for the period to the price of potatoes at harvest time. These values are the prices required to return the same income that would be realized if the potatoes were sold at harvest rather than stored. Post-harvest prices must increase by more than 50% above the harvest price to offset storage costs and return the same profit that would have been available at harvest (Table 3).

**Table 3. Post-harvest average potato prices required to offset storage costs for selected time periods.**

| Storage period | Average harvest price | Total storage costs | Post-harvest price |
|---|---|---|---|
| | dollars per cwt. | | |
| 30 days | 8.61 | 4.39 | 12.90 |
| 60 days | 8.61 | 4.41 | 13.02 |
| 90 days | 8.61 | 4.52 | 13.13 |
| 180 days | 8.61 | 4.98 | 13.59 |

In comparing Texas potato prices over time, it is apparent that there have been only a few periods in which it would have been profitable to store potatoes. The data in Figure 1 are for the period August 1976 to July 1984, representing 96 months. In only 13 of those months, or about 1 year in 7, were prices high enough to justify storage. The cost data presented have assumed annual use of the storage facility. If it were used in some pattern other than annually, such as 1/7th of the time, actual costs of use would be higher. Thus, storage of summer potatoes produced in West Texas is infeasible if one crop must carry storage fixed costs for seven years. The outlook for the average movement in Texas potato prices is that they will move upward over time. However, the seasonal price pattern shows that post-harvest prices will generally not increase by more than 10 percent over a yearly period. It seems that expected average potato prices will not rise sufficiently to cover the costs of storage in the long run unless they are substantially higher than we have historically seen.

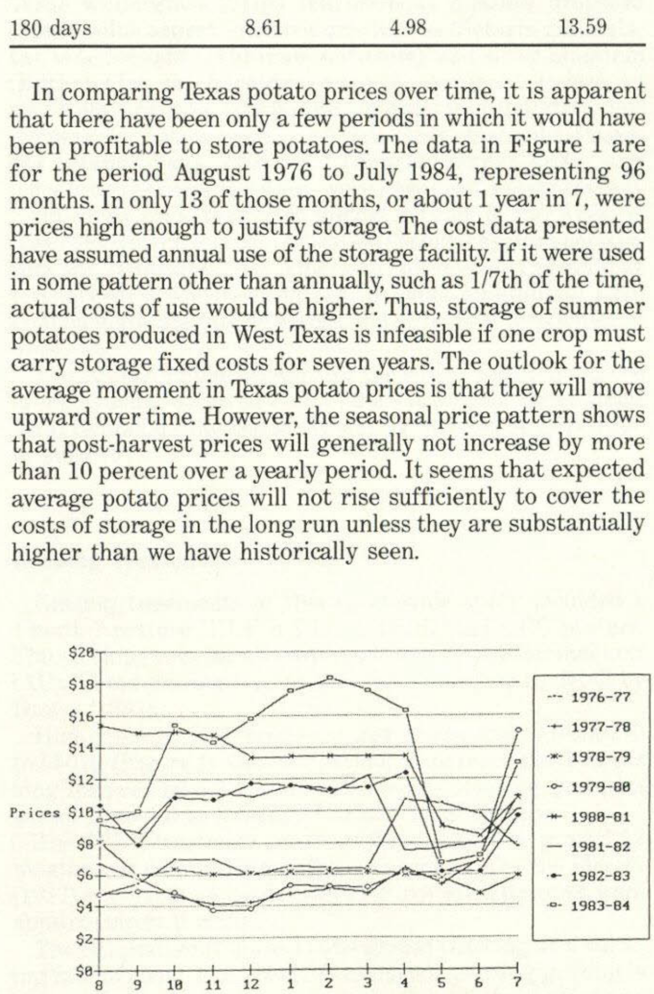


**Figure 1. West Texas Potato Prices by Month, 1976-84.**

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# EFFECT OF GRAZING MANAGEMENT ON CATTLE DIETS AND NUTRITION IN THE COASTAL PRAIRIE

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## ABSTRACT

**Cattle diets and nutrition were studied using fecal analysis and bite counts under (1) continuous, yearlong (CG), (2)4-pasture, deferred-rotation (4PDR), and (3) high-intensity, low-frequency (HILF) grazing treatments at the Welder Wildlife Foundation Refuge. Of 156 plant species consumed, only 23 provided greater than 1% each of the diet. Grasses comprised 95% of the diet, forbs 4%, and browse 1%. Four warm-season grasses, silver bluestem (Bothriochloa saccharoides), longtom (Paspalum lividum), vine mesquite (Panicum obtusum), and meadow dropseed (Sporobolus asper), comprised a large percentage of the diet in all 3 treatments. Texas wintergrass (Stipa leucotricha) was the most highly-preferred cool-season grass. Plant community, soil type, season, and rainfall had greater effects on species consumed than did grazing treatment. On HILF the diet changed from highly-preferred to less-preferred species as the grazing period progressed. The 5 most highly-preferred grasses provided adequate crude protein and calcium to meet the minimum requirements of lactating cows except during winter. All 5 were deficient in phosphorus except during spring green-up. There were no differences in forage digestibility between treatments. Forage digestibility in HILF diets showed a significant ($P < .05$) decline after the first week of a 3-week grazing period.**

## INTRODUCTION

Grazing management is often an important tool in improving overgrazed rangelands in Texas. Properly handled, grazing management improves range condition and increases stocking rates (Kothmann and Mathis, 1970). A knowledge of cattle diets and nutrition is essential for successful grazing management. A comparsion of plant species in cattle diets and their nutritional qualities on different grazing treatments would aid in indentifying key species and measuring the effect on management practices.

In 1974, the Welder Wildlife Foundation Refuge initiated a study of (1) continuous, yearlong (CG), (2) 4-pasture, deferred-rotation (4PDR), and (3) high-intensity, low-frequency (HILF) grazing treatments. Similar research was performed at Sonora (Merrill, 1957), Throckmorton (Sanders, 1975), and Uvalde (Chamrad et al., 1982), but the more severe climatic conditions of these areas do not allow the abundance or diversity of vegetation present in the Texas Coastal Prairie. No research data were available concerning cattle diets or nutrition in these 3 grazing treatments in the Coastal Prairie.

The objectives of this study were: (1) to determine seasonal species composition of cattle diets on 3 grazing treatments; (2) to determine nutrient content of major species in the cattle diet; and (3) to determine digestibility of forage in cattle diets across the 3 grazing treatments and within grazing periods in the HILF grazing treatment.

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## MATERIALS AND METHODS

### Study Area

The study was conducted on the Rob and Bessie Welder Wildlife Foundation Refuge located 8 mi. NE of Sinton, Tx. The refuge encompasses 7800 ac. The native vegetation is classified as coastal prairie grasslands interspersed with a chaparral complex. Sixteen plant communities have been indentified on the refuge (Drawe et al., 1978). At the time of this study refuge pastures were in high fair range condition.

The area has a long history of livestock use dating back to the era of the Spanish missions. Following the creation of the Welder Wildlife Foundation in 1954, refuge ranges were lightly stocked with steers and a non-systematic rotational grazing program was followed. In 1974 the steer operation was replaced with a cow-calf operation.

For this study the refuge was broadly divided into clay and sandy soils as described in Drawe et al. (1978). Clay and clay loam soils occurred primarily above the Aransas River floodplain. Victoria clay (Udic Pellustert) is the dominant series. Texas wintergrass (**Stipa leucotricha**), meadow dropseed (**Sporobolus asper**), knotroot bristlegrass (**Setaria geniculata**), vine mesquite (**Panicum obtusum**), and silver bluestem (**Bothrichloa saccharoides**) were the dominant grasses on clay soils. Longtom (**Paspalum lividum**) was abundant during periods of above average rainfall. Honey mesquite (**Prosopis glandulosa**), huisache (**Acacia farnesiana**), and blackbrush (**Acacia rigidula**) were important woody species.

On sandy soils, restricted almost entirely to the Aransas River floodplain, seacoast bluestem (**Schizachyrium scoparium** var. **littoralis**), Pan American balsamscale (**Elyonurus tripsacoides**), and rescuegrass (**Bromus unioloides**) were dominant grasses. Woody species were primarily mesquite and huisache.

The 20-year rainfall average for the refuge was 35 in. Above average rainfall occurred 7 out of the 9 years prior to the study. Total rainfall during the study was 47 in. from August 1976 to July 1977.

### Grazing Treatments

Grazing treatments of this ranch-scale study included a 1-herd, 7-pasture HILF, a 3-herd, 4PDR, and a CG pasture. The stocking rate for all treatments was 12.5 ac/animal unit (AU). These grazing treatments were described in detail by Drawe (1987).

High-intensity, low-frequency pasture size varied from 275 to 550 ac (Figure 1). Grazing periods were from 2 to 6 weeks long followed by 5.5 months deferment. Stocking densities varied from 1.5 to 3.5 ac/AU in individual pastures.

The 4PDR treatment pastures (Figure 1) were grazed 12 months and deferred 4 months, an adaptation of the Merrill (1957) system. Stocking densities for individual pastures were approximately 9 ac/AU.

The CG pasture (Figure 1) was grazed yearlong at a stocking rate of about 12.5 ac/AU. Continuous, yearling grazing is the common ranching practice in the Coastal Prairie and was considered the standard for comparison.

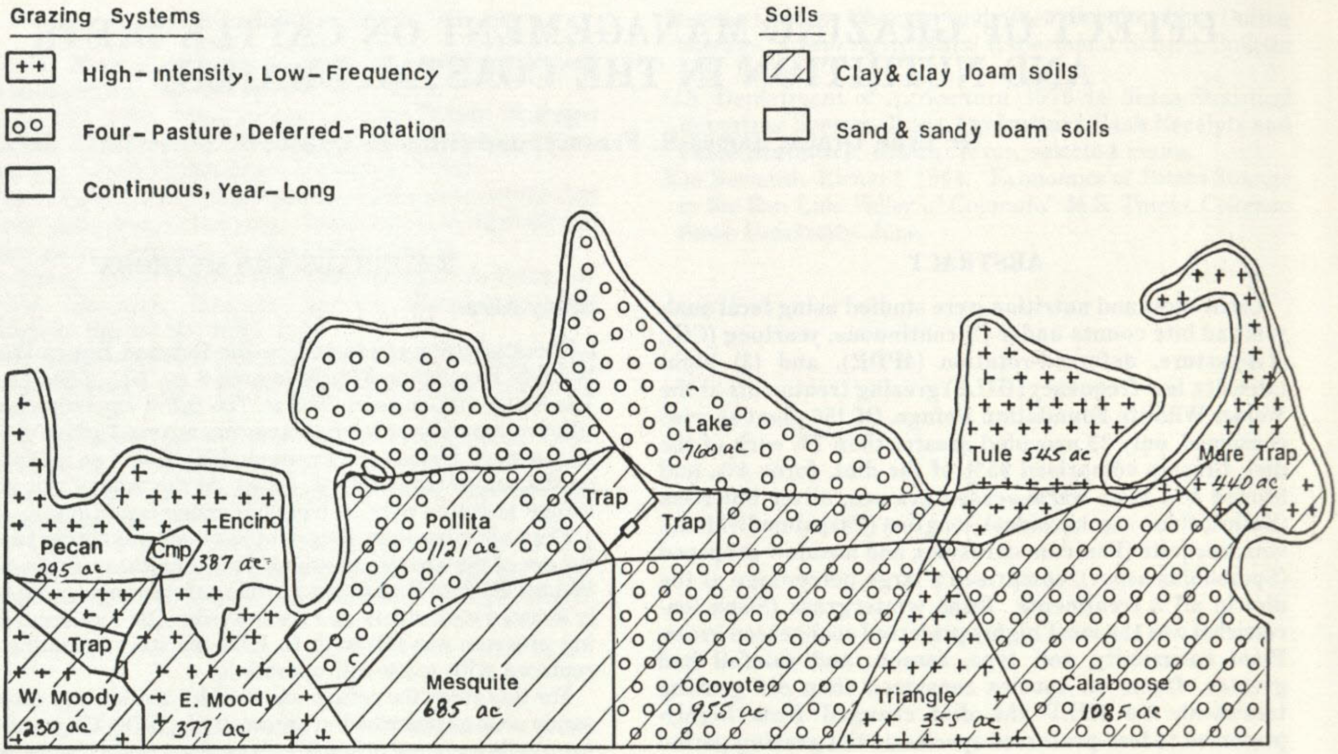

**Figure 1. Pasture units and grazing treatments of the Welder Wildlife Foundation Refuge.**

## Cattle Diets

Early during the grazing treatment comparison it was observed that cattle diets and nutrition might be playing a role in causing differences in cattle performance. Therefore, during 1976 and 1977 a study was conducted to determine cattle diets on the 3 grazing treatments. Cattle diet was determined at the beginning, middle, and end of the grazing period in all 3 treatments using both direct observation of grazing animals (Bjugstad et al. 1970) and microscopic identification of fecal material (Free et al. 1970).

## Nutrient Content of Herbage

Herbage samples of the 5 major grasses were analyzed for crude protein, calcium, and phosphorus by the Agricultural Analytical Services Laboratory at Texas A&M University. Herbage from 10 plants of each species was collected at random, composited by species monthly during 1975, 1976, and 1977, and sent to the lab for analysis. The 5 grasses included the 4 major warm-season species consumed by cattle,meadow dropseed, silver bluestem, longtom, and vine mesquite,plus the major cool season species, Texas wintergrass. Nutrient content of the herbage was compared to the nutrient requirements of beef cattle (NAS-NRC 1976) for both lactating and non-lactating cows.

## Forage Digestibility

During 1976 and 1977 hand-plucked samples were collected from species comprising greater than 10% of cattle diets at 3 critical periods during the year: (1) late January, during winter dormancy of warm-season grasses, (2) early April, during spring green-up of warm-season grasses, and (3) early July, during maximum production of warm-season grasses.**Invitro** digestibility was determined from the hand-plucked samples (Cook, 1964) using the modified Tilley and Terry (1965) method.

Weighted digestibility values for cattle diets were calculated by multiplying percent composition of each species in the diet by its percent digestibility. Digestibility data were subjected to analysis of variance, and significant mean separations were determined by Duncan's multiple range test at the 0.05 level of significance.

**Table 1. Plant species comprising more than 1% of cattle diets using the fecal analysis method in 3 grazing treatments on the Welder Wildlife Foundation Refuge. Data are averages for a full year during 1976-77.**

PS8

| Species | High-intensity, low-frequency | | Four-pasture, deferred-rotation | | Continuous, yearlong | |
|---|---|---|---|---|---|---|
| **GRASS** | $\bar{x}$ | s.d. | $\bar{x}$ | s.d. | $\bar{x}$ [1/] | s.d. |
| **Bothriochloa saccharoides** | 8.9 | 5.8 | 8.5 | 7.0 | 11.4 | 8.6 |
| **Bromus wildenowii** | 6.3 | 15.7 | 5.0 | 17.0 | ___ [2/] | ___ |
| **Buchloe dactyloides** | 1.6 | 2.3 | 1.2 | 1.6 | ___ | ___ |
| **Elymus canadensis** | 1.1 | 2.8 | ___ | ___ | ___ | ___ |
| **Elyonurus tripsacoides** | ___ | ___ | 1.1 | 2.6 | ___ | ___ |
| **Hilaria belangeri** | 1.8 | 3.0 | 3.6 | 6.0 | ___ | ___ |
| **Leersia hexandra** | 3.0 | 6.8 | 2.0 | 3.4 | ___ | ___ |
| **Panicum coloratum** | 3.3 | 6.3 | ___ | ___ | ___ | ___ |
| **Panicum obtusum** | 4.4 | 4.7 | 6.0 | 5.7 | 8.7 | 5.3 |
| **Paspalum lividum** | 7.7 | 7.2 | 11.1 | 9.8 | 12.7 | 10.8 |
| **Paspalum notatum** | ___ | ___ | 1.3 | 3.9 | ___ | ___ |
| **Paspalum plicatulum** | 6.0 | 8.7 | 1.4 | 2.7 | 1.4 | 3.6 |
| **Paspalum pubiflorum** | ___ | ___ | 1.3 | 3.9 | ___ | ___ |
| **Schizachyrium scoparium** | 7.0 | 5.9 | 5.9 | 10.22 | 2.6 | 2.8 |
| **Setaria geniculata** | 1.2 | 1.2 | 1.5 | 2.9 | 3.5 | 6.4 |
| **Spartina spartinae** | 1.3 | 2.2 | ___ | ___ | ___ | ___ |
| **Sporobolus asper** | 6.3 | 7.5 | 6.8 | 5.9 | 13.5 | 3.2 |
| **Stipa leucotricha** | 10.5 | 12.9 | 15.6 | 19.0 | 17.9 | 19.7 |
| **GRASS-LIKE** | | | | | | |
| **Carex brittoniana** | 1.2 | ___ | ___ | 2.8 | 2.8 | 3.3 |
| **FORBS** | | | | | | |
| **Lesquerella argyraea** | ___ | ___ | 1.0 | 3.1 | 1.2 | 3.4 |
| **Malvastrum aurantiacum** | ___ | ___ | ___ | ___ | 2.5 | 2.3 |
| **Rhynchosia minima** | ___ | ___ | ___ | ___ | 2.4 | 5.0 |
| Totals | 71.6 | | 73.3 | | 80.6 | |

1/ $\bar{x}$ = mean; s.d. = one standard deviation.
2/ ___ species did not occur or made up less than 1% of the diet.

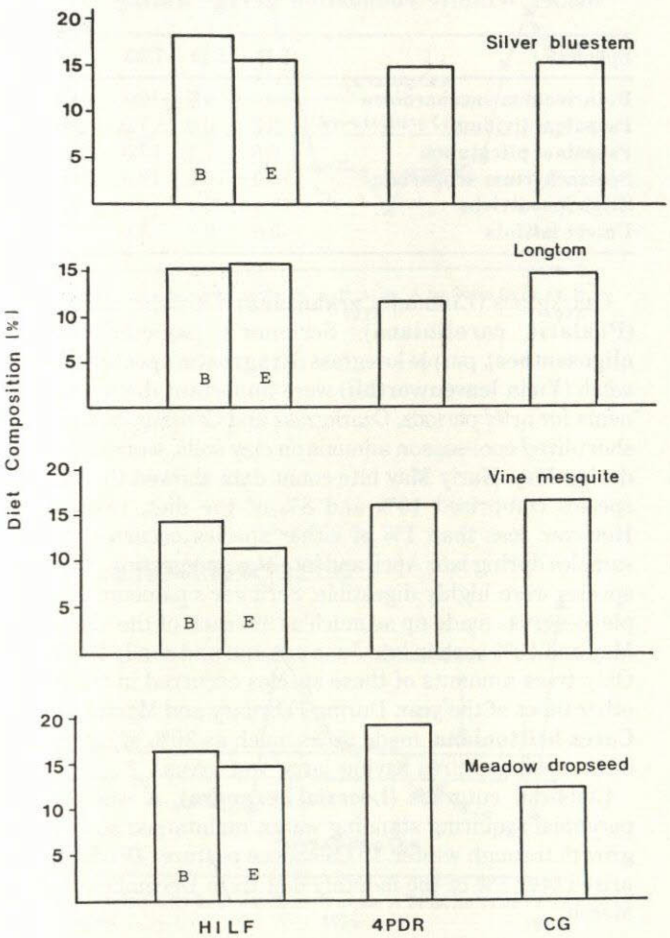


Figure 2. Diet composition of major forage species in continuous-yearlong (CG) and 4-pasture, deferred-rotation (4PDR), and the beginning (B) and end (E) of the grazing period in the high-intensity, low-frequency (HILF) systems on the Welder Wildlife Foundation Refuge. Data are averages for a 2-year period, 1975-77.

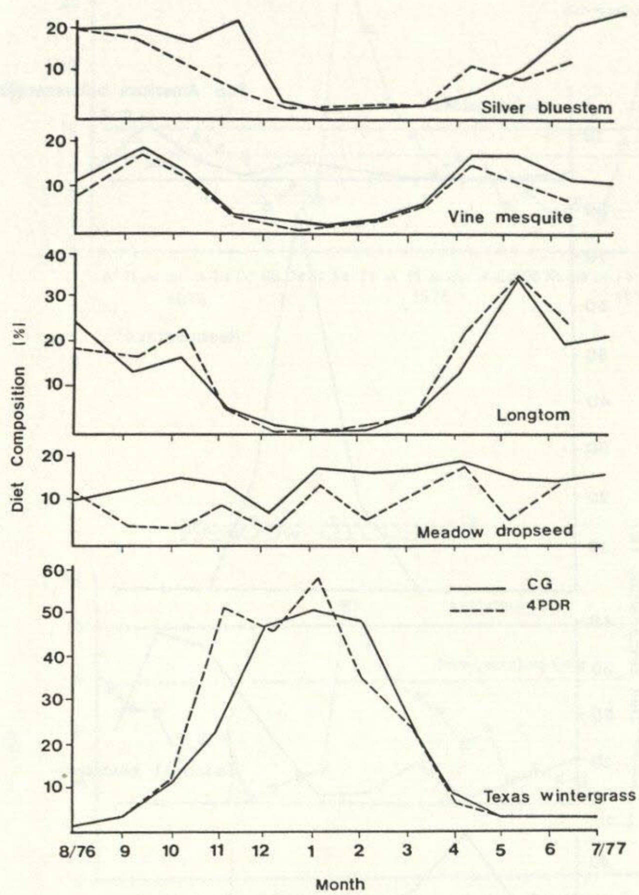


Figure 3. Seasonal trends in cattle diets for selected species on clay soil pastures in the 4-pasture, deferred rotation (4PDR) and continuous, yearlong (CG) grazing treatments on the Welder Wildlife Foundation Refuge.

## RESULTS AND DISCUSSION

### Cattle Diets

Cattle grazed 156 different species during this study, including 76 grasses, 4 grass-like species, 66 forbs, and 10 shrubs. Of these 156 species, only 23 provided greater than 1% each of the total diet (Table 1).

Average diet values were 92% and 95% for grasses, 7% and 4 % for forbs, and 1% and < 1% for shrubs from fecal analysis and bite-count methods, respectively. Comparison of forage classes in cattle diets across treatments showed only minor differences. Grasses were the most important forage class in all treatments. Forbs were eaten in greater quantity during late winter and early spring. The only measurable use of browse and mast was on live oak (**Quercus virginiana**) in winter and honey mesquite bean pods in late summer. Although it was difficult to single out major species where a variety was consumed, 4 grasses, (1) silver bluestem, (2) longtom, (3) vine mesquite, and (4) meadow dropseed, occurred in relatively high amounts in the diet throughout most of the year across all 3 treatments (Figure 2). In fact, major differences in diet appeared to be influenced as much by differences in plant communities among pastures as by treatment.

Yearlong use made determination of seasonal trends easier for the CG pasture. Deferment in the 4PDR and HILF treatments changed species composition in cattle diets because species availability varied among pastures. One 4PDR unit was grazed for 11 months during the study, allowing a more direct comparison with the CG pasture. Silver bluestem, vine mesquite, longtom, meadow dropseed, and Texas wintergrass comprised 60% of the diets on pastures with clay soil. Despite different grazing treatments, similar seasonal trends occurred for the 5 species in both pastures (Figure 3). Texas wintergrass was a larger seasonal dietary component than other species, primarily because it was the only cool-season grass available during winter.

No valid comparison was available across treatments on sandy soils. One 4PDR unit provided seasonal data over a 10-month period during the study (Figure 4). Rescuegrass increased and declined dramatically in the diet over a 2-month period during spring green-up. The complexity of plant communities in sand and sandy loam pastures resulted in a complex diet with no single species dominating for any extended period. Pan American balsamscale, Texas wintergrass, and seacoast bluestem were major dietary constituents for a time.

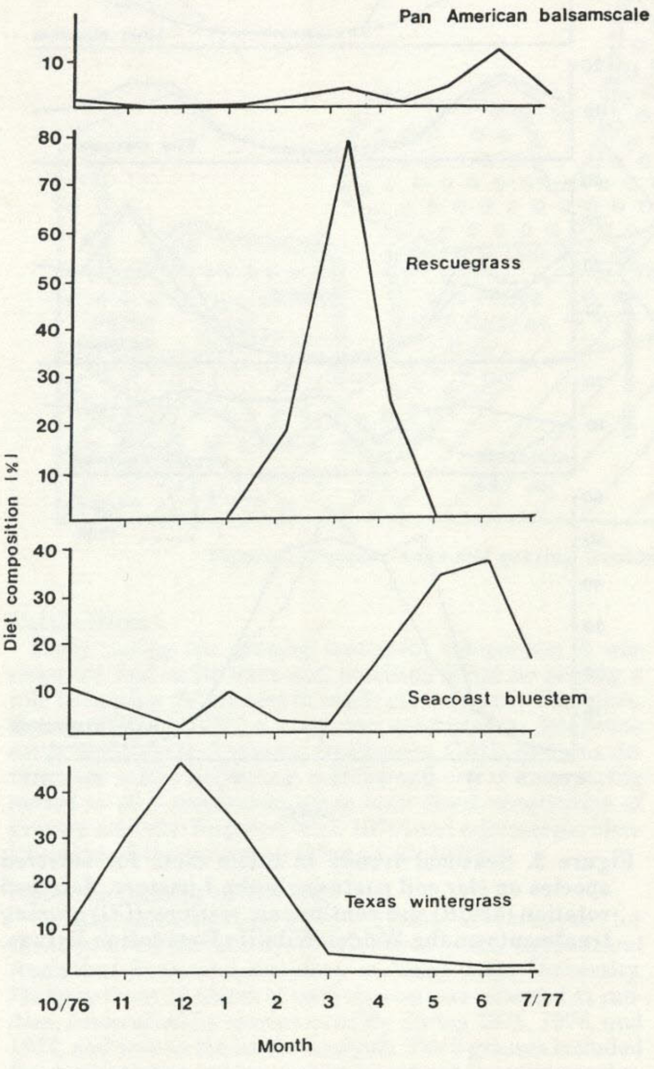


**Figure 4. Seasonal trends in cattle diets for selected species on a sandy soil pasture in the 4-pasture, deferred-rotation grazing system on the Welder Wildlife Foundation Refuge.**

Cattle diets in HILF pastures were determined at the beginning, middle, and énd of each grazing period. Diet composition changed from highly-selected species to less-preferred species as the grazing period progressed. Relative amounts of individual species in the diet rarely varied more than 15% among sampling periods.

Seasonal trends were not as easy to follow on HILF because animals were presented with different forage species each time they moved from pasture to pasture. Seasonal changes were discernable when the same pasture was grazed at different times of the year. The high stocking density of individual HILF patures increased competition among cattle for available forage. Warm-season grasses such as seacoast and silver bluestems, ungrazed in CG and 4PDR pasutres during winter, were important components in cattle diets on HILF during winter (Table 2).

**Table 2. Changes in cattle diets using the fecal analysis method at various sampling dates in Pecan Pasture of the high-intensity, low-frequency grazing system on the Welder Wildlife Foundation Refuge during 1977.**

| Species | 1/14 | 1/19 | 7/23 | 7/30 | 8/7 |
|---|---|---|---|---|---|
| Bothriochloa saccharoides | 10.1 | 4.7 | 12.3 | 8.6 | 8.2 |
| Paspalum lividum | 3.2 | 0.0 | 7.9 | 9.8 | 14.6 |
| Paspalum plicatulum | 6.5 | 7.1 | 17.3 | 16.5 | 12.6 |
| Schizachyrium scoparium | 15.0 | 16.6 | 10.9 | ·9.8 | 3.4 |
| Stipa leucotricha | 19.4 | 32.4 | 0.6 | 2.2 | 5.1 |
| Uniola latifola | 0.0 | 0.0 | 5.8 | 8.3 | 4.8 |

Ozarkgrass (**Limnodia arkansana**), Carolina canarygrass (**Phalaris caroliniana**), Scribner's panicum(**Panicum oligosanthes**), purple lovegrass (**Eragrostis spectabilis**), and vetch (**Vicia leavenworthii**) were important dietary components for brief periods. Ozarkgrass and Carolina canarygrass, short-lived cool-season annuals on clay soils, were eaten only during May. Early May bite-count data showed that these 2 species comprised 16% and 8% of the diet, respectively. However, less than 1% of either species occurred in fecal samples during late April and late May, suggesting that these species were highly digestible. Scribner's panicum and purple lovegrass made up as much as 9% each of the diet in late May and 13% each in late June on sand and sandy loam soils. Only trace amounts of these species occurred in the diet at other times of the year. During February and March, a sedge, **Carex brittoniana**, made up as much as 30% of cattle diets in clay soil pastures having large wet areas.

Clubhead cutgrass (**Leersia hexandra**), a warm-season perennial requiring standing water, maintained some green growth through winter. In Calaboose pasture (4PDR) it comprised over 8% of the monthly diet from December through March.

## Nutrient Content of Herbage

Crude protein values for Texas wintergrass and vine mesquite were mostly adequate for non-lactating cows from April through September 1975 (Figure 5). Vine mesquite provided adequate crude protein March through August 1976 and March 1977. For lactating cows, the 4 warm-season species provided adequate protein only during April and May 1975, March through June 1976, and March 1977. Texas wintergrass held up well for non-lactating cows throughout 1975, through March 1976, and during December through March 1977. It provided adequate crude protein for lactating cows during the winter of both years. Several other grasses were tested throughout the 2 years under both burned and unburned conditions, and some outstanding values can be reported. During February 1976, burned Pan American balsamscale had 17.6% crude protein. In January 1976, unburned rescuegrass had 17.9% crude protein, and March 1977 rescuegrass had 17.0% crude protein. In February and March 1977, unburned switchgrass (**Panicum virgatum**) had 15.3% and 14.7% crude protien, respectively.

Calcium content was adequate for non-lactating cows during both years in all 5 grasses except meadow dropseed during May through December 1976 (Figure 6). Calcium content for vine mesquite was above the requirement for lactating cows throughout the 2 years (Figure 4). Among other species tested, most showed adequate calcium, except one or 2 species during months in late summer and early fall.

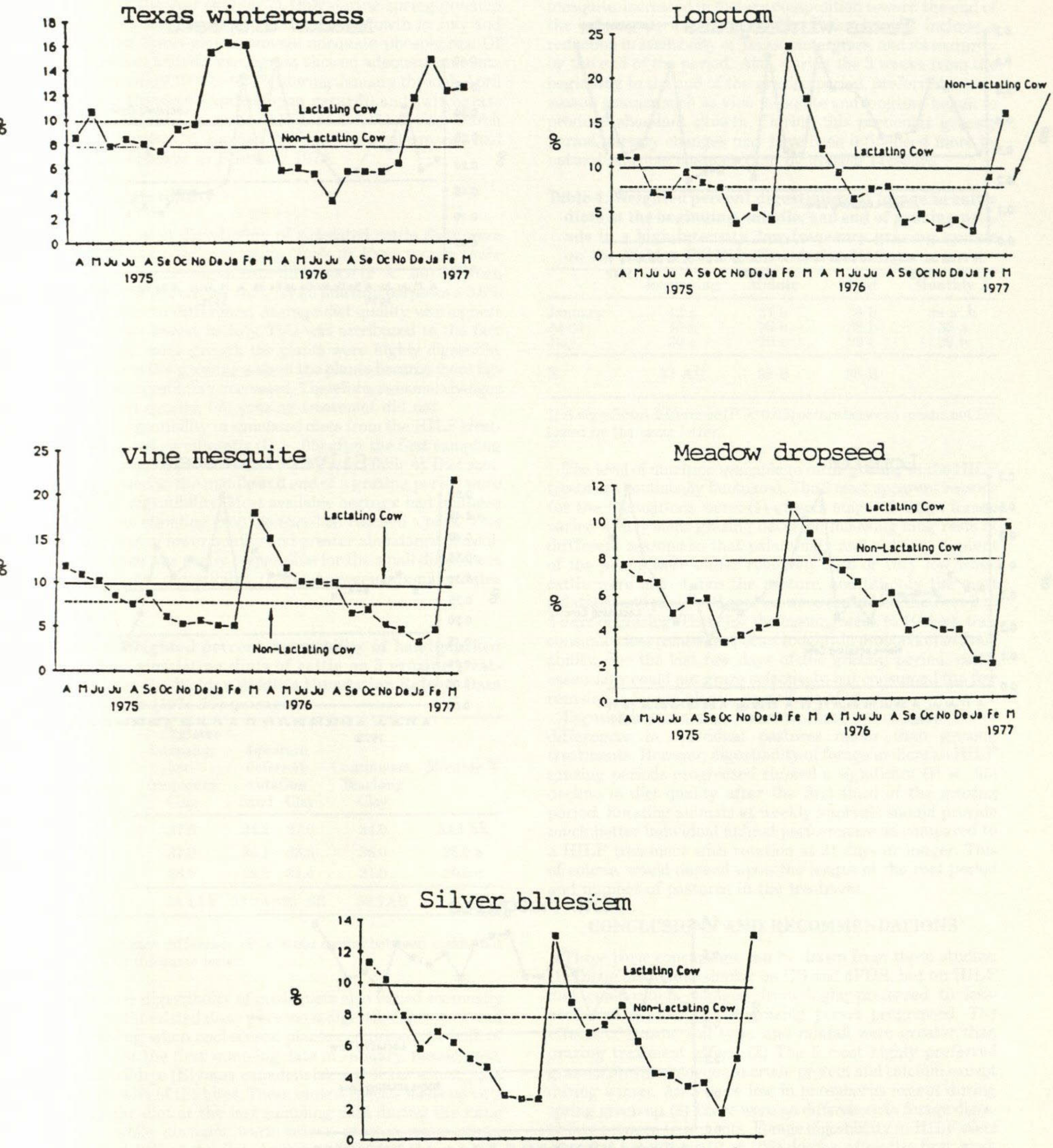


**Figure 5. Percent crude protein content of 5 major grasses in cattle diets on the Welder Wildlife Foundation Refuge, 1975-77, compared to NRS-NRC (1976) standards for lactating and non-lactating cows.**

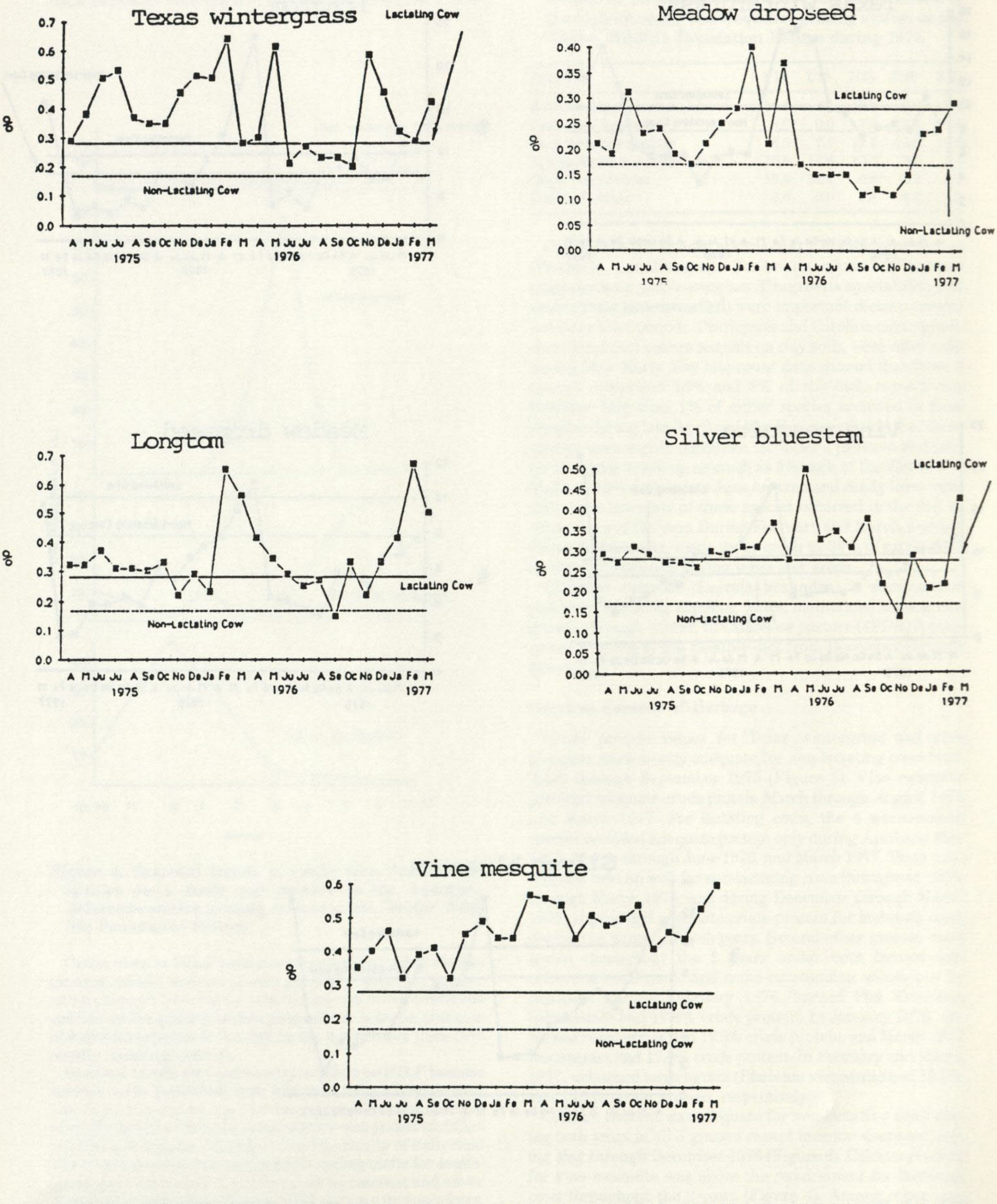


**Figure 6. Percent calcium content of 5 major grasses in cattle diets on the Welder Wildlife Foundation Refuge, 1975-77, compared to NRS-NRC (1976) standards for lactating and non-lactating cows.**

Phosphorus content was deficient in all 5 species tested during most of the year (Figure 7). Only during spring greenup in February and March and during lush growth in July and August did these plants provide adequate phosphorus. Of other species tested, rescuegrass showed adequate amounts of phosphorus (0.19% to 0.37%) during January through April 1976. Big bluestem (**Andropogon gerardi**) and switchgrass showed adequate amounts (0.18% to 0.45%) during March through April 1976. Burned Pan American balsamscale had 0.51% phosphorus in February 1976.

### Forage Digestibility

Differences in digestibility of simulated cattle diets were very small between treatments (Table 3). Even though there was a statistically significant difference ($P < .05$) between HILF and 4PDR on clay soils, for all practical purposes a 3.6% difference is no difference. Average diet quality was highest in April and lowest in July. This was attributed to the fact that during early growth the plants were highly digestible, than later in the growing season the plants became more lignified and digestibility decreased. Therefore, seasonal changes altered diet quality, but grazing treatment did not.

Forage digestibility in simulated diets from the HILF treatment declined significantly ($P > .05$) after the first sampling date in a grazing period except during July (Table 4). Diet samples collected at the middle and end of a grazing period were similar in digestibility. Most available herbage had matured in July, and standing crop biomass had reached a peak. This combination of lower quality and greater abundance of available herbage was partly responsible for the small differences in dry matter digestibility (DMD) between sampling dates during July.

**Table 3. Weighted percent digestibility of hand-plucked samples simulating diets of cattle on 3 grazing treatments on the Welder Wildlife Foundation Refuge. Data are 2-year (1976-77) averages.**

| Collection Date | High-intensity, low-**frequency** Clay | 4-pasture, deferred-**rotation** Sand | Clay | Continuous, **Yearlong** Clay | Monthly $\overline{X}$ |
|---|---|---|---|---|---|
| January | 37.0 | 34.2 | 27.0 | 34.0 | 33.1 b1/ |
| April | 37.8 | 36.1 | 33.8 | 36.0 | 25.9 a |
| July | 28.5 | 29.2 | 31.4 | 31.0 | 30.0 c |
| System $\bar{x}$ | 34.4A1/ | 33.2AB | 30 .8B | 33.7AB | |

1/ A significant difference ($P < 0.05$) occurs between means not followed by the same letter.

Dry matter digestibility of cattle diets also varied seasonally (Table 4). Simulated diets were most digestible in winter and early spring when cool-season plants comprised the bulk of the diet. At the first sampling date in January, rescuegrass, Canada wildrye (**Elymus canadensis**), and Texas wintergrass made up 95% of the bites. These same 3 species made up only 44% of the diet at the last sampling date during the same period, while dormant warm-season grasses made up an additional 42% of the diet. As expected, DMD declined with this dietary change in species composition.

Dry matter digestibility also dropped in April diets with respect to time in the grazing period. Texas wintergrass, the only cool-season grass utilized in this period, made up 32%, 21%, and 6% of the diet, respectively, during early, middle, and late sampling dates. Meadow dropseed dropped from 17% of the diet early, to 8% mid, and 8% late in the grazing period. Other warm-season grasses, primarily longtom and vine mesquite, increased in dietary composition toward the end of the grazing period. Reasons for these changes include a reduction in availability of Texas wintergrass, and its maturity by the end of the period. Also, during the 3 weeks from the beginning to the end of the grazing period, preferred warm-season grasses such as vine mesquite and longtom began to produce abundant growth. During this particular grazing period, dietary changes may have been influenced more by natural seasonal changes than by grazing pressure.

**Table 4. Weighted percent digestibility of forage in cattle diets at the beginning, middle, and end of grazing periods in a high-intensity, low-frequency grazing system on the Welder Wildlife Foundation Refuge.**

| | Beginning | Middle | End | Monthly $\overline{X}$ |
|---|---|---|---|---|
| January | 42 a | 37 b | 38 b | 39 a 1/ |
| April | 40 a | 38 b | 38 b | 39 a |
| July | 30 c | 29 c | 29 c | 29 b |
| X | 37 A1/ | 35 B | 35 B | |

1/ A significant difference ($P < 0.05$) occurs between means not followed by the same letter.

The level of nutrition available to cattle grazing in the HILF treatment continually fluctuated. The 2 most apparent reasons for the fluctuations were: (1) growth stage of range forage varied widely since grazing occurred following long rests at diffferent seasons so that palatability and nutrient content of the plants were either relatively high or very low when cattle were moved into the pasture, and (2) only the most palatable and preferred species were consumed the first 2 to 3 days of grazing. Then, for the ensuing week to 10 days, they consumed less palatable species roughly in proportion to availability. For the last few days of the grazing period, cattle essentially could not graze selectively, but consumed the few remaining forage plants, regardless of species.

Digestibility of forage in cattle diets was a reflection of differences in individual pastures rather than grazing treatments. However, digestibility of forage in diets as HILF grazing periods progressed showed a significant ($P < .05$) decline in diet quality after the first third of the grazing period. Rotating animals at weekly intervals should provide much better individual animal performance as compared to a HILF treatment with rotation at 21 days or longer. This of course, would depend upon the length of the rest period and number of pastures in the treatment.

## CONCLUSIONS AND RECOMMENDATIONS

Three basic conclusions can be drawn from these studies: (1) Cattle diets were similar on CG and 4PDR, but on HILF diet composition changed from highly-preferred to less-preferred species as the grazing period progressed. The effects of season, soil type, and rainfall were greater than grazing treatment effect. (2) The 5 most highly preferred grasses provided adequate crude protein and calcium except during winter. All 5 were low in phosphorus except during spring green-up. (3) There were no differences in forage digestibility between treatments. Forage digestibility in HILF diets showed a significant ($P < .05$) decline after the first week of a 3-week grazing period.

Results of the Welder Wildlife Refuge HILF grazing treatments work have raised some of the same questions posed by Kelton (1978), i.e., that Texas grazing schemes have used 3- to 4-week grazing periods which are too long for peak animal performance. Jackson (1964) pointed out the importance of moving cattle to the next grazing unit before graz-

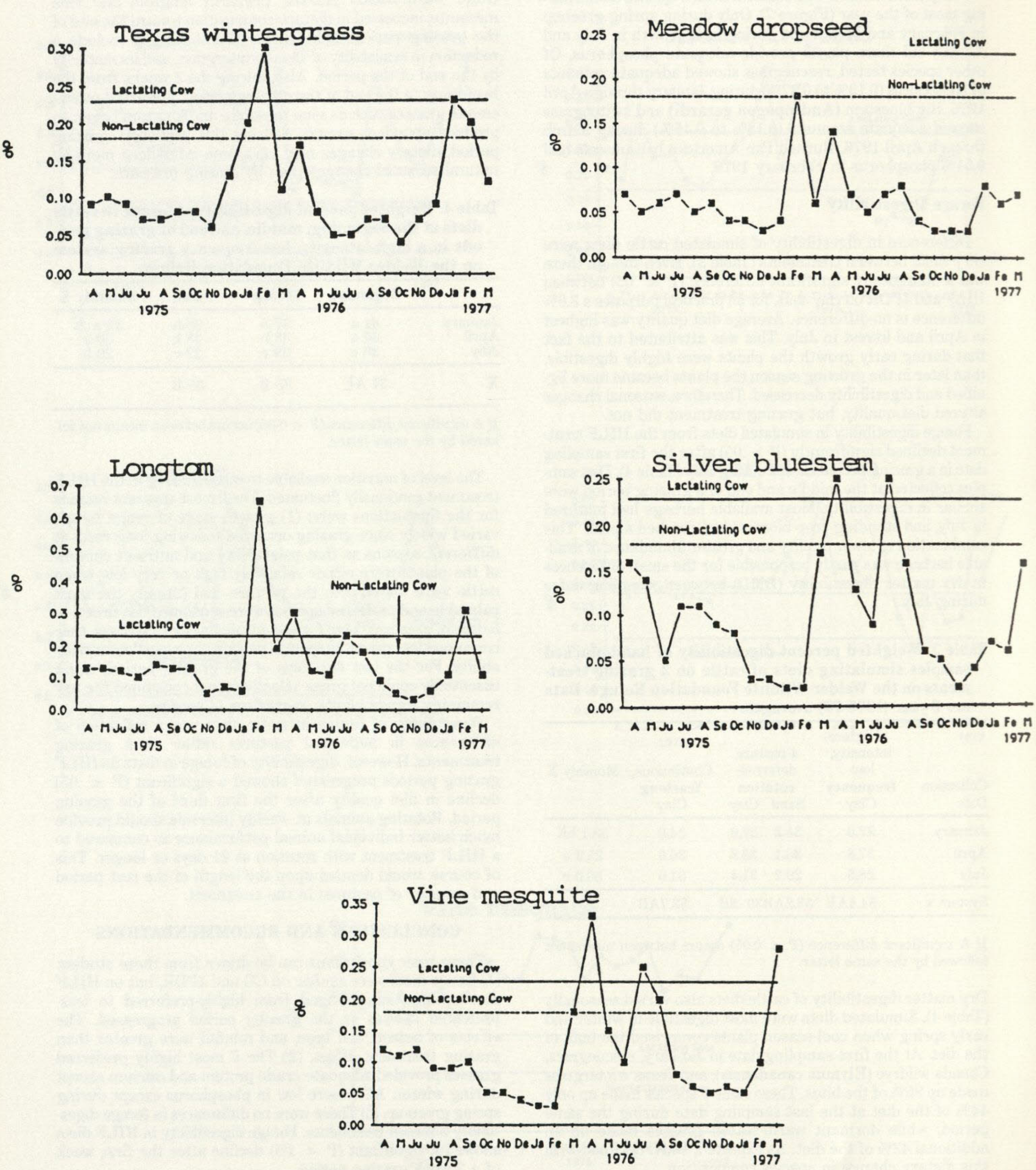


**Figure 7. Percent phosphorus content of 5 major grasses in cattle diets on the Welder Widlife Foundation Refuge, 1975-77, compared to NRS-NRC (1976) standards for standards for lactating and non-lactating cows.**

ing stress causes loss of production. Reardon (personal communication) found it impossible to maintain animal production using a 21-day grazing period with a 1-herd, 6-pasture scheme in the northwestern Rio Grande Plain. Although the Welder Refuge study was conducted under higher rainfall and better growing conditions than on the Rio Grande Plain, we have continued our evaluations long enough that our data also indicate lowered animal performance with "Texas style" HILF grazing (Drawe 1987). Our studies indicate that a 1-week grazing period might be preferable.

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# FACTORS INFLUENCING THE PRICES OF MARKET CATTLE IN SOUTH TEXAS

**Denis E. Hale, Donald M. Nixon and Margaret E. Land[1]**

## ABSTRACT

**The purpose of this study was to see what factors influenced the price of market cattle in South Texas. Feeder and slaughter cattle were examined, and the factors proposed to have an influence on these cattle were type, sex, weight, buyer, condition, grade, horns, market and area.**

**The results showed that, of the nine variables proposed, sex, grade and weight had the most significant influence on the price paid for market cattle in South Texas. Condition and presence of horns was revealed as being significant in influencing market cattle prices.**

**On the basis of this study it is recommended that (1) dehorning and castration of male calves become a regular practice, (2) condition of the cattle should be examined before marketing, (3) a grading system for feeder cattle should be instituted and (4) the optimum weights at which to sell cattle should be investigated.**

## REVIEW OF LITERATURE

The average cattle producer in the state of Texas does not have enough volume of cattle to sell directly to feedlots (Walters, 1965). Therefore, the majority of producers sell their feeder cattle through local auctions. Generally, the market at the feeder calf level is close to being purely competitive and so is subject to a broader price variability than are the more monopolistically competitive slaughter and wholesale markets (Franzmann and Walker, 1972).

"Many factors influence the price producers receive for their cattle, and if these factors can be identified and substantiated then a marketing strategy can be formulated." (Hayenga and Hacklander, 1971). Price analysis is used to relate the behavior pattern of price to variables (Tomek and Robinson, 1972). One of the major factors that influence the price received for feeder and slaughter cattle is the weight of the cattle (Breimyer, 1961 and Ward, 1976). Also selling cattle by their sex is an important marketing consideration (Dahl and Hammond, 1977). Hayenga and Hacklander (1971), suggested that the price received for live cattle changed in relation to grade and condition. Dahl and Hammond (1977) stated in their study that most buyers wanted choice and good grade slaughter cattle and that the buyers wanted feeder cattle that were in medium condition.

"Cattle cycles have been observed since the late 1800's. Over the period, cycles have averaged 12 years in length, but earlier cycles were longer than later ones. Each cycle is divided in two phases: (1) the accumulation phase, and (2) the liquidation phase" (McCoy, 1978). Lower prices start occurring and cattle producers begin to reduce the size of their breeding herd. This situation adds more to total production and causes prices to falter even more. An additional factor that influences the cattle cycle is the availability of feed.

Price cycles are usually the inverse of supply cycles. As the supply of cattle increases price tends to decline. Franzmann (1967) reported that, "On the average the adjusted price paid decreased $2.35 per cwt. as the industry progressed from a peak to a trough in the cycle. Conversely, when the industry went from a trough to a peak, price increased by $2.35 per cwt." By being aware what part of the cycle in which a study is being conducted, price analysis can be carried out in coordination with other information collected at different times during the cattle cycle. Prices of market cattle are usually high in the first phase (accumulation) of a cycle because there is confidence that the price will be high when the cattle are sold, and the price of fed cattle is so much higher than feed cost, only a small margin between buying and selling prices for the market cattle is necessary for profit (Breimyer, 1955). This study was conducted during a time period when market cattle prices were high and most experts expected the price of fed cattle to remain high for at least a year.

## MATERIALS AND METHODS

The goal of this study was to determine which factors influence the price of feeder and slaughter cattle. The independent variables used were type, sex, weight, buyer, condition, grade, horns, market and area. Four South Texas auctions and three terminal markets were studied. Data was collected at these markets for a three year period. Data was collected bi-weekly at each market on a bi-monthly basis. One hundred head of cattle were observed at each market during each observation period. The number of cattle observed during the three year period totaled 25,200 head.

The type of cattle were either feeder or slaughter. Five sex categories were established: bull, cow, steer, heifer and calf. Weight was also broken down into five categories by scale readings:

(1) 300 pounds
(2) 301-500 pounds
(3) 501-700 pounds
(4) 701-1000 pounds
(5) 1000 + pounds

The buyer was either a farmer, feedlot operator, dealer, older buyer or packer buyer. Condition scores were 1 (best condition), through 3 (worst condition). The grades of the cattle were choice through canner. The presence or absence of horns was decided at both the feeder calf and slaughter calf stage. The market was either terminal or auction and the area was either north, central or south.

The analytical technique used in this study may be described as the general linear regression model incorporating dummy variables in the regression equation. It was desired to determine whether the covariates (independent variables, X's) had a significant influence on price (Y). Regresssion analysis shows the linear relationship between the independent variables (X's) and the dependent variable (Y).

The regression model used can be stated algebraically as follows:

$$P = a + T_i + S_j + W_k + B_1 + Cd_m + G_n + H_o + M_p + A_q + e \quad (1)$$

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where:

P = price, a quantitative dependent variable
a = intercept term
$T_i$ = type $i = 1,2.$
$S_j$ = sex $j = 1,2 \ldots, 5.$
$W_k$ = weight $k = 1,2 \ldots, 5.$
$B_1$ = buyer $1 = 1,2 \ldots, 5.$
$Cd_m$ = condition $m = 1,2,3.$
$G_n$ = grade $n = 1,2, \ldots, 6.$
$H_o$ = horns $o = 1,2.$
$M_p$ = market $p = 1,2.$
$A_q$ = area $q = 1,2,3.$
e = error term

The subsidiary hypotheses were of the form:

$$P = f(T_i, S_j, \ldots\ldots, A_q) \quad (2)$$

where:

$(T_i, S_j, \ldots, A_q)$ denotes the variables specified in (1) and took on the values 1 or 0, depending on whether or not the variable was included. The use of dummy variables in regression analysis is used to quantify variables that are not otherwise non-quantifiable (Morgan and Sonqist, 1963). The essence of the technique involves assigning a dummy variable to all categories of a characteristic except one. Since this variable takes a value of 1 if the individual observed belongs to the category and 0 if not, it is called a dummy variable.

Tests of significance of the regression equations were based on their F statistics, while tests of significance of the individual coefficients were based on their t values. In making comparsions between intra-group coefficients the t test was employed by comparing the difference between the coefficients and the standard error of this difference. In all cases a positive test at the 0.05 level was regarded as significant.

## RESULTS AND DISCUSSION

In general, there was a highly significant relationship between price and each of the independent variables. A comparsion between feeder and slaughter cattle shows a higher multiple correlation coefficient for slaughter cattle than for feeder cattle as shown in Table 1.

**Table 1. Multiple correlation coefficients for slaughter, feeder and entire sample of cattle.**

| Slaughter | Feeder | Whole Sample |
|---|---|---|
| .9446 | .8053 | .8936 |

The variables hypothesized to influence both feeder and slaughter cattle prices most were sex, grade, and weight. In all cases, more highly significant results were obtained for slaughter than for feeder cattle.

Feeder steers and calves were above average price by \$2.23 and \$1.84 per 100 pounds, respectively. These coefficients were significantly different from zero but not from each other. Feeder bulls were significantly higher than average by \$0.63 per 100 pounds but significantly lower than steers and calves. Cows and heifers were significantly lower than average by \$41.17 and \$0.53 per 100 pounds, respectively. The same relationship held for slaughter cattle and for the whole sample, the coefficients differing only in magnitudes which is shown in Table 2. These results reflect the established preference pattern of consumers for different types of beef.

As noted in Table 3, prices showed a marked decline as weight increased above 300 lbs for both feeder and slaughter cattle.

For slaughter cattle, prices decreased as weight increased up to 501 to 600 pounds, stabilized with further increases in weight, and then declined sharply for animals weighing over 1000 pounds. The data in Table 3 suggests that an optimum weight for selling both feeder and slaughter cattle exists.

**Table 2. Regression coefficient and standard errors for the variable sex.**

| Group Variable | Specific Variable | Symbol | Feeder | Slaughter | Whole Sample |
|---|---|---|---|---|---|
| | | | Regression Coefficients (Standard Error) | | |
| Sex | Bull | $C_1$ | 0.63(0.16)* | 0.71(0.41) | 0.74(0.11) |
| | Cow | $C_2$ | -4.17(0.13) | -4.38(0.07) | -4.25(0.07) |
| | Steer | $C_3$ | 2.23(0.08) | 2.26(0.08) | 2.26(0.06) |
| | Heifer | $C_4$ | -0.53(0.09) | -0.43(0.08) | -0.40(0.06) |
| | Calf | $C_5$ | 1.84(0.24) | 1.95(0.20) | 1.65(0.15) |
| Intercept | Term | | 17.04 | 17.29 | 17.04 |

*The standard errors of the regression coefficients are in parentheses.

**Table 3. Regression coefficients and standard error for the variable weight.**

| Group Variable | Specific Variable | Symbol | Feeder | Slaughter | Whole Sample |
|---|---|---|---|---|---|
| | | | Regression Coefficients (Standard Error) | | |
| Weight | 300 | $W_1$ | 1.46(0.24)** | 1.28(0.21) | 1.52(0.16) |
| | 301-500 | $W_2$ | 0.29(0.10) | -0.48(0.14) | 0.12a(0.09) |
| | 501-700 | $W_3$ | -0.54(0.10) | -0.55(0.12) | -0.59(0.06) |
| | 701-1000 | $W_4$ | -0.61(0.10) | -0.13a(0.10)* | -0.56(0.06) |
| | 1000+ | $W_5$ | -0.59(0.30) | -0.22a(0.30) | -0.49(0.20) |
| Intercept | Term | | 17.04 | 17.29 | 17.04 |

* Coefficients with an **a** were not significantly different from zero.
** The standard errors of the regression coefficients are in parentheses.

It will be noted in Table 4, that for feeder cattle the coefficient for packer buyers was negative but not significantly different from zero. The coefficients for all other buyers were significantly different from zero. The analysis for feeder cattle held true for the whole sample. Dealers were consistently low in their bidding and competition among buyers of slaughter cattle was high (Table 4).

**Table 4. Regression coefficients and standard errors for the varible buyer.**

| Group Variable | Specific Variable | Symbol | Feeder | Slaughter | Whole Sample |
|---|---|---|---|---|---|
| | | | Regression Coefficients (Standard Error) | | |
| Buyer | Farmer | $B_1$ | 0.28(0.11)** | 0.31a(0.31) | 0.29(0.08) |
| | Feedlot Operator | $B_2$ | -0.30(0.10) | -0.23a(0.21) | -0.34(0.07) |
| | Dealer | $B_3$ | -0.25(0.08) | -0.25(0.11) | -0.32(0.10) |
| | Order Buyer | $B_4$ | 0.45(0.09) | -0.01a(0.12) | 0.21(0.06) |
| | Packer Buyer | $B_5$ | -0.18a(0.19)* | 0.19a(0.41) | 0.16a(0.15) |
| Intercept | Term | | 17.04 | 17.29 | 17.04 |

* Coefficients with an **a** were not significantly different from zero.
** The standard errors of the regresssion coefficients are in parentheses.

Results recorded in Table 5 indicate that condition 1 feeders were discounted $0.24 per 100 pounds, but condition 3 feeders received a premium of $0.22 per 100 pounds, a significant difference between the two groups and from zero. The whole sample showed a discount for condition 2 and 3 cattle. The data in Table 5 indicate that a feeder can put the condition on an animal cheaper himself, than having to put a conditioned animal through the market.

**Table 5. Regression coefficients and standard errors for the variable condition.**

| Group Variable | Specific Variable | Symbol | Regression Coefficients (Standard Error) Feeder | Slaughter | Whole Sample |
|---|---|---|---|---|---|
| Condition | 1 | $Cd_1$ | -0.24(0.07)** | -0.36(0.05) | -0.27(0.05) |
| | 2 | $Cd_2$ | 0.02a(0.06)* | 0.17(0.04) | 0.11(0.04) |
| | 3 | $Cd_3$ | 0.22(0.09) | 0.19(0.07) | 0.16(0.06) |
| Intercept | Term | | 17.04 | 17.29 | 17.04 |

* Coefficients with an **a** were not significantly different from zero.
** The standard errors of the regression coefficients are in parentheses.

Feeders were graded into three categories: choice, good and standard (Table 6). Buyers paid a premium for choice, good and slaughter cattle and discounted for utility, cutter and canner cattle. Between choice grades and canners there was a difference of $5.24 per 100 pounds. Though the differences between successive grades were not uniform, they were significant. The results in Table 6 implied that the USDA's grading system for slaughter and feeder cattle was effective in reflecting the retail meat values of the animals, thus encouraging the production of better grades.

**Table 6. Regression coefficients and standard errors for the variable grade.**

| Group Variable | Specific Variable | Symbol | Regression Coefficients (Standard Error) Feeder | Slaughter | Whole Sample |
|---|---|---|---|---|---|
| Grade | Choice | $G_1$ | 1.84(0.05)* | 2.64(0.08) | 2.74(0.07) |
| | Good | $G_2$ | 0.39(0.05) | 1.39(0.06) | 0.95(0.08) |
| | Standard | $G_3$ | -2.21(0.08) | 0.48(0.07) | 1.44(0.09) |
| | Utility | $G_4$ | | -0.83(0.08) | -0.64(0.07) |
| | Cutter | $G_5$ | | -1.08(0.19) | -1.49(0.24) |
| | Canner | $G_6$ | | -2.60(0.24) | -3.01(0.28) |

* The standard errors of the regression coefficients are in parentheses.

As noted in Table 7 for better types and for the whole sample, the coefficients for horns were not significantly different from zero. There was a significant difference of $0.16 per 100 pounds between horned and dehorned slaughter cattle. This price differential implies that the presence of horns depressed prices for slaughter cattle.

A fact also noted in Table 7 was that feeder prices were $0.18 per 100 pounds higher at auctions than at terminals, but slaughter cattle prices were $0.24 per 100 pounds higher at terminals than at auctions. These results support the theory that auction markets have a special advantage in handling feeder livestock and indicate a similar relationship for terminals in the case of slaughter cattle. Area had no significant influence on feeder cattle prices; the coefficients were not significantly different from zero (Table 7). Prices in the southern area were not significantly large to warrant a shift in supplies from one area to another (Table 7).

**Table 7. Regression coefficients and standard errors for the variable horns, market and area.**

| Group Variable | Specific Variable | Symbol | Regression Coefficients (Standard Error) Feeder | Slaughter | Whole Sample |
|---|---|---|---|---|---|
| Horns | Present | $H_1$ | -0.03a(0.05)** | -0.08(0.04) | -0.06a(0.03) |
| | Absent | $H_2$ | 0.03a(0.05) | 0.08a(0.04) | 0.06a(0.03) |
| Market | Terminal | $M_1$ | -0.09a(0.05) | 0.12(0.03) | 0.01a(0.03) |
| | Auction | $M_2$ | 0.09a(0.05) | -0.12(0.03) | -0.01a(0.03) |
| Area | North | $A_1$ | 0.10a(0.06) | 0.12(0.04) | 0.08(0.04) |
| | Central | $A_2$ | 0.01a(0.08) | -0.18(0.06) | -0.08a(0.05) |
| | South | $A_3$ | -0.09a(0.10) | 0.06a(0.08) | 0.00a(0.06) |
| Intercept | Term | | 17.04 | 17.29 | 17.04 |

* Coefficients with an **a** were not significantly different from zero.
** The standard errors of the regression coefficients are in parentheses.

Finally, the type of cattle was regressed on the whole sample and Table 8 illustrates the results; feeders brought approximately a dollar more than slaughter cattle.

**Table 8. Regression coefficients and standard errors for the variable type.**

| Group Variable | Specific Variable | Symbol | Regression Coefficients (Standard Error) Whole Sample |
|---|---|---|---|
| Type | Feeder | $T_1$ | 0.99(0.05)* |
| | Slaughter | $T_2$ | -0.99(0.05) |
| Intercept | Term | | 17.04 |

* The standard errors of the regression coefficients are in parentheses.

Through the use of dummy variables in regression analyses the influence of certain qualitative variables were estimated. The results show that the hypothesized variables were important in explaining variation in cattle prices-80 percent in feeder cattle prices, 94 percent in slaughter cattle prices and 89 percent for the whole sample. Results indicated that the markets for feeder and slaughter cattle were some different.

## SUMMARY

The grading system for slaughter cattle and that used in the study for feeders reflected the retail meat value of the animals and should be effective in encouraging the production of better grades. Prices tended to decrease as live weights increased and a condition 1 depressed prices for both types of cattle. Condition 3 feeder cattle and condition 2 and 3 slaughter cattle received a premium while condition 2 feeders brought average prices.

The presence of horns also influenced price adversely. Therefore, producers stood to gain if they sold condition 3 feeder cattle and condition 2 or 3 slaughter cattle that had been dehorned. The conversion of bull calves into steers could also result in higher prices per pound to the farmer. The price differences between areas were not sufficiently

large enough to warrant a shift in supplies from one area to another.

On the basis of this study it is recommended that (1) dehorning and castration of male calves should become a regular farm practice, (2) producers should pay attention to the condition of the animals at the time of sale, (3) a grading system for feeder cattle should be instituted and the optimum weights at which to sell feeder and slaughter cattle should be investigated, (4) in this area, producers with small volumes should sell feeders at auctions and slaughter cattle at the terminal market.

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# CHEMICAL CONTROL OF MESQUITE, CREOSOTEBUSH, AND CATCLAW MIMOSA WITH TEBUTHIURON AND SUBSEQUENT GRASS PRODUCTION

**James T. Nelson and Charles Vick**


## ABSTRACT

**Mortality of mesquite, catclaw mimosa and creosotebush treated with 1.5 lbs. ai/ac of tebuthiuron in April of 1984, and resulting grass production was determined on a draw site and a gravelly site in south Brewster County, Texas. Brush mortality 3 years post-treatment on the draw site was 10% for mesquite, 55% for creosotebush (Larrea tridentata DC.) and 75% for catclaw mimosa (Mimosa biuncifera Benth.). Mortality on the gravelly site was 0% for mesquite (Prosopis glandulosa Torr.), 94% for creosotebush and 100% for catclaw mimosa. Grass production was increased more on the gravelly site (960 lbs/ac on the treated area vs. 161 lbs/ac on the untreated) than on the draw site (509 lbs/ac on the treated area vs. 133 lbs/ac on the untreated control). Forb production was decreased on both treated sites. The lesser degree of grass response on the draw site was attributed to lack of mesquite control on that site.**


## INTRODUCTION

Brush treatment with herbicides has been a part of range improvement systems for more than 25 years (Scifres et al. 1977). Dense stands of brush reduce forage production and restrict movement of livestock (Smith and Rechenthinn, 1964).

Tebuthiuron is an effective control agent for creosotebush, tarbush (**Flourensia cernua** DC.) and mesquite in the southwest (Jacoby et al., 1982; Ibarra and Morton, 1984; Herbel et al., 1985). Increases in grass production following brush control with tebuthiuron have been shown on sand-shinnery oak (**Quercus havardii** Rydb.) (Jones and Pettit, 1984), and application of tebuthiuron may also increase crude protein content of forage grasses and subsequent grazing perference of grasses by cattle (Masters and Scifres, 1984).

Tebuthiuron is a substituted urea compound originated by Elanco Products Company under the Division of Eli Lilly and Company in 1972. It is readily absorbed through the root system with moisture and inhibits photosynthesis. Once in the woody plant it takes 2-3 years to complete the control cycle. At the time of this study, it was marketed in pelleted form under the trade name "Graslan" (presently marketed as "Spike").

This study was conducted to determine (1) mortality of shrub species treated with pelleted tebuthiuron and (2) the resulting grass production on two sites in south Brewster County, Texas.

## MATERIALS AND METHODS

The study areas were approximately 16 miles south of Marathon, Texas, in a desert grassland/desert shrub community dominated by creosotebush, mesquite and catclaw mimosa. Research plots were in a draw range site and in a gravelly range site. Sand dropseed (**Sporobolus cryptandrus** Torr.), whiplash papusgrass (**Pappophorum mucronulatum** Nees.), and burrograss (**Scleropogon brevifolius** Phil.) were the dominant grasses on the draw site and red grama (**Bouteloua trifida** Thurb.) was the dominant grass on the gravelly site. The draw soil was a Bigetty silty loam (classified as a fine, silty, mixed thermic Cumulic Haplustoll) while that of the gravelly site was a Monterosa gravelly loam (classified as a loamy-skeletal, mixed thermic, shallow Ustollic Paleorthid). Mean annual precipitation for the area is about 12 inches. Actual precipitation measured at the study area was 14.87 inches in 1984; 19.32 in 1985; 22.96 in 1986; and 9.77 inches from January through July 1987.

Tebuthiuron was applied aerially to approximately 80 acres of draw and 40 acres of gravelly sites at the rate of 1.5 lbs. active ingredient per acre (20% pellets) on April 8, 1984. These sites along with adjacent non-treated control areas of approximately the same size were protected from grazing from 1984 through the summer of 1987. Grass production was determined in September 1986 by clipping to ground level randomly placed 5 ft.$^2$ quadrats in each of the treated and untreated areas. Stein's 2-stage method (Steel and Torrie, 1980) was used to determine necessary number of plots - 45 on each treated and 80 on each untreated area. Herbaceous material was oven-dried at 54°C for 24 hours. Brush mortality was determined by counting live and dead plants in 5 ft. by 100 ft. belt transects (9 in each draw area, 6 in each gravelly area). Chi square analysis was applied to brush mortality data while forage production was subject to paired t-test analysis (Little & Hills, 1978). Since treatments were not replicated inferences reported are restricted to the study area.

## RESULTS AND DISCUSSION

Mean mortality of brush species in the treated draw site was 10% for mesquite -$Chi^2$ (1, N = 43) = .95, **p** < .50; 55% mortality for creosotebush -$Chi^2$ (1, N = 35) = 12.16, **p** <.001; and 75% for catclaw mimosa -$Chi^2$ (1, N = 86) = 27.85, **p** <.001 (Table 1). Mesquite was apparently resistant to tebuthiuron at the rate applied in the draw site. Tebuthiuron label recommendations are higher for mesquite than for catclaw mimosa or creosotebush, indicating a recognized resistance of that species to the chemical. Higher rates of tebuthiuron are necessary for mesquite in finer textured soils since the herbicide is tied up by clay-sized soil particles and the amount of chemical available to be taken up by the root system is reduced (Herbel et al. 1985).

Mortality rates on the treated gravelly sites were 100% for catclaw mimosa -$Chi^2$ (1, N = 63) = 49.64 **p** <.001; and 94% for creosotebush -$Chi^2$ (1, N = 186) = 170.61 **p** <.001 (Table 1). A single mesquite (live) was found on the treated gravelly site and none were present on the untreated site (thus statistical comparsion was not possible). Tebuthiuron at 1.5 lbs ai/ac was more effective on catclaw mimosa and creosotebush on the coarse textured gravelly site than on the fine textured draw site.

Authors are Associate Professor and Graduate Student respectively, Range Animal Science Center, Sul Ross State University, Alpine, Texas.

**Table 1. Mortality of Mesquite, Catclaw Mimosa and Creosotebush, July 1987, on plots treated with 1.5 lbs/ac tebuthiuron, Brewster County, Texas.**

| Species | Draw Site Percent Mortality Treated | Draw Site Percent Mortality Untreated | Gravelly Site Percent Mortality Treated | Gravelly Site Percent Mortality Untreated |
|---|---|---|---|---|
| Mesquite | 10% | 0% | 0% | No mesquite |
| Catclaw mimosa | 75%* | 0% | 100%* | 0% |
| Creosotebush | 55%* | 0% | 94%* | 0% |

* Mortality level significant at $p < .001$.

Grass production was 133.4 lbs/ac on the untreated draw site compared to 509.4 lbs/ac on the treated draw ($p < .01$). Grass production was 161 lbs/ac on the untreated gravelly site compared to 960 lbs/ac on the treated area ($p < .001$). Forb production was lower on both treated sites ($p < .001$) (Table 2). Grass and forb production were similar on both untreated sites, and the response to treatment was greater on the gravelly site (a 6-fold increase) than on the draw site (a 3.8-fold increase). One would expect more response on the presumably more productive draw site. However, there was a greater abundance of mesquite on the draw site which was relatively resistant to tebuthiuron at the rate applied.

**Table 2. Grass and forb production, October 1986, on plots treated with 1.5 lbs ai/ac tebuthiuron, Brewster County, Texas.**

| Class | Draw Site Pounds/Acre Treated | Draw Site Pounds/Acre Untreated | Gravelly Site Pounds/Acre Treated | Gravelly Site Pounds/Acre Untreated |
|---|---|---|---|---|
| Grasses | 509.4* | 133.4* | 960.0** | 161.0** |
| Forbs | 0.0 | 11.3** | 0.0 | 11.7** |
| Total: | 509.4* | 144.7* | 960.0** | 173.3** |

*Significant difference at $p < .01$ within a site.
**Significant difference at $p < .001$ within a site.

## CONCLUSION

Tebuthiuron at 1.5 lbs ai/ac was more effective in eliminating catclaw mimosa and creosotebush than mesquite, and was more effective on the former two species on the gravelly site than on the draw site. The natural lack of mesquite on the gravelly site resulted in a greater response of grasses to control of catclaw mimosa and creosotebush on that site than on the draw site where remaining mesquite apparently continued to depress grass production.

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# DISKING OF IMPROVED RANGELAND TO INCREASE WILDFLIFE FOOD PLANTS

**Nurdin and Timothy E. Fulbright**[1]


## ABSTRACT

**This study was conducted to determine effects of 3 intensities of soil disturbance by disking on abundance of wildlife food plants in improved rangeland. No disking (control) and 1, 2, and 3 passes with an 11-foot offset disk were replicated in improved pastures dominated by either Rhodesgrass (*Chloris gayana*), buffelgrass (*Cenchrus ciliaris*), or Kleberg bluestem (*Dichanthium annulatum*). Plots were disked in May 1984. At 1, 2, 4, 10, 15, and 17 months after disking, percent canopy cover of perennial grasses on plots disked with 3 passes was lower than that on control plots. Percent canopy cover of annual forbs was higher on plots disked with 3 passes 7 and 10 months after treatment. Disking did not affect the growth of annual grasses, perennial forbs, and shrubs. We recommend disking with 3 passes to increase abundance of annual forbs and reduce perennial grasses in improved rangeland.**


## INTRODUCTION

Large areas of rangeland in south Texas are dominated by introduced forage grasses. Rhodesgrass (*Chloris gayana*), buffelgrass (*Cenchrus ciliaris*), and Kleberg bluestem (*Dichanthium annulatum*) are commonly planted in the region. Planting monocultures of these grasses reduces quality of rangeland for wildlife habitat. These grasses outcompete and reduce the abundance of native wildlife food plants (Lehmann, 1985). Seeds of these exotics are not consumed by game birds such as bobwhite quail (*Colinus viginianus*) (Lehmann, 1985). Moreover, thick stands of exotic grasses make habitat unsuitable for quail impeding travel (Guthery, 1986). Although white-tailed deer (*Odocoileus virginianus*) eat fresh, succulent growth (Meyer, 1982), grasses normally compose a small percentage of deer diets in south Texas (Arnold, 1976).

Improving rangeland dominated by introduced grasses for wildlife habitat is an important consideration since income for commercial hunting exceeds income from livestock on many south Texas ranches (Fulbright and Beasom, 1986). Disking rangeland may increase the abundance of plants eaten by several wildlife species (Webb and Guthery, 1983). The response of plants to disking varies with plant species composition, range site and condition, and the degree of soil disturbance. This study was conducted to determine the degree of soil disturbance by disking needed to increase wildlife food plants in rangeland dominated by introduced grasses.

## STUDY AREA

The study was conducted in 3 pastures of the Texas A&I University Farm about 3 miles north of Kingsville, Kleberg County, Texas. The pastures were dominated vegetatively by either Rhodesgrass, buffelgrass, or Kleberg bluestem. Soil in the Rhodesgrass pasture was Clareville clay loam, classified as a fine, mixed hyperthermic Pachic Argiustoll. Orelia fine sandy loam, classified as a mixed, hyperthermic Typic Ocraqualf was present in the buffelgrass pasture. The soil in the Kleberg bluestem pasture was Willacy fine sandy loam classified as a mixed, hyperthermic Udic Argiustoll. Elevation is about 65 feet above sea level. The climate is subtropical and average rainfall is about 25 inches. Precipitation for 1984 and 1985 is presented in Figure 1.

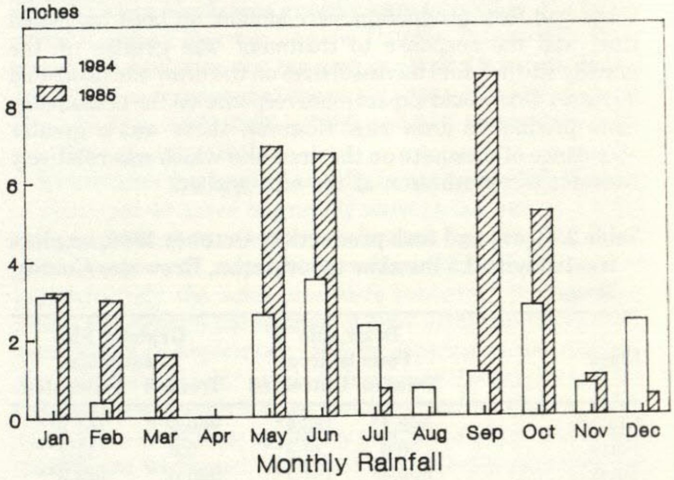


**Figure 1. Monthly rainfall (inches) during 1984 and 1985 at the Texas A&I University Farm, Kingsville, Texas.**

## MATERIAL AND METHODS

A randomized complete-block experimental design with pastures as blocks was used in the study. Treatments consisted of 0, 1, 2, or 3 passes with an 11-foot-wide offset disk pulled by a farm tractor. Each treatment was randomly assigned to a 15- by 120- foot plot in each pasture. Plots were disked on 25 May 1984. Depth of disk penetration ranged from 3 to 6 inches. Plots were separated by 3-foot buffers and deer and livestock were excluded by an electric fence.

Two permanent 100-foot transects were randomly located in each treatment and control plot. Thirty 0.66-by 1.64-foot sample plots were placed along the right side of each transect at 3-foot intervals. Percent canopy cover of vegetation was estimated before disking, monthly during the first 7 months after disking, and bimonthly during the following 9 months.

Vegetation canopy cover data were tabulated and then classified for statistical analysis into annual and perennial grasses, annual and perennial forbs, and shrubs. Horsetail Conyza (**Conyza canadensis**), an annual forb, was analyzed separately because of its abundance. Analysis of variance (SAS 1982) was used to compare the treatment effects, and Tukey's test was used at the 0.05 level of probability to identify significantly different means for each sampling date.

## RESULTS AND DISCUSSION

Canopy cover of vegetation was similar (**P** >0.05) among treatment plots before disking (Figs. 2-7). One, 2, and 3 passes reduced canopy cover by 35, 71, and 80%, respectively.

Percent canopy cover of annual grasses, horsetail Conyza,

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perennial forbs, and shrubs was similar (P >0.05) among treatments on all sampling dates (Figs. 2-5). The percent canopy cover of perennial grasses on plots disked with 3 passes was lower than that of controls 1 (June 1984), 2 (July 1984), 4 (September 1984), and 10 (March 1985) months after disking, but was similar to that on plots disked with 2 passes (Fig. 6). Fifteen months after disking (August 1985), percent canopy cover of perennial grasses on plots disked with 3 passes was lower than on plots disked with other treatments and controls. Seventeen months (October 1985) after disking, canopy cover on plots disked with 3 passes was lower than controls and 1 pass, but was similar (P > 0.05) to that on plots disked with 2 passes. Percent canopy cover of perennial grasses on all other sampling dates was similar (P >0.05) among treatments and control plots.

Disking with 1 or 2 passes did not affect canopy cover of annual forbs (Fig. 7). In December 1984 and March 1985, the percent canopy cover of annual forbs on plots disked 3 passes was higher than that on controls, but was similar to that on plots disked with 1 or 2 passes. Annual forbs on 3-pass plots that are important wildlife food plants included tallow weed (**Plantago hookeriana**), **Verbena runyonii**, evening primrose (**Oenothera** sp.), yellow woodsorrel (**Oxalis dillenii**), and annual lazy daisy (**Aphanosthepus kidderi**) (Martin and Nelson, 1951; Buckner and Landers, 1979). Arnold (1976) found that annual lazy daisy and tallow weed composed 6.10 and 0.13% by weight of white-tailed deer diets, respectively. Meyer (1985) reported that yellow woodsorrel was an important white-tailed deer food, especially during the spring (February-March). Wood (1985) found that yellow woodsorrel composed 2.7 to 7.9% by weight of northern bobwhite diets.

The reduction in perennial grass cover resulting from disking with 3 passes may benefit bobwhite quail. The birds need fairly open land for feeding and movement on the ground (Lehmann, 1985; Guthery, 1986). Canopy cover of perennial grasses on strips disked with 3 passes increased to 50% in October 1985, thus disking reduces cover only temporarily. To maintain reduced cover of introduced grasses and increase annual forbs, disking with 3 passes probably should be repeated at 2-3 year intervals.

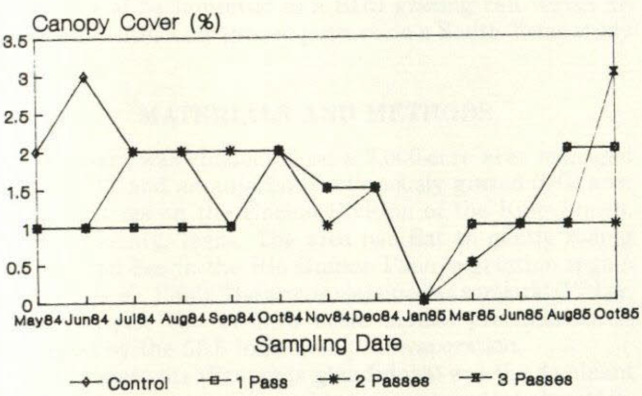


**Figure 2. Mean canopy cover (%) of annual grasses during 1984 and 1985 on controls and plots disked in May 1984 with 1, 2, or 3 passes. There were no significant (P >0.05) differences among treatments on all sampling dates.**

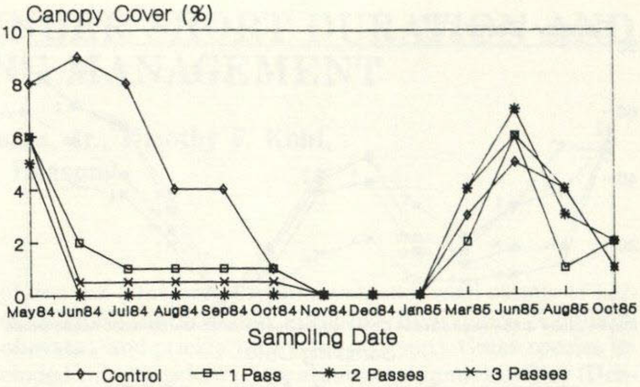


**Figure 3. Mean canopy cover (%) of horsetail Conyza during 1984 and 1985 on controls and plots disked in May 1984 with 1, 2, Or 3 passes. There were no significant (P >0.05) differences among treatments on all sampling dates.**

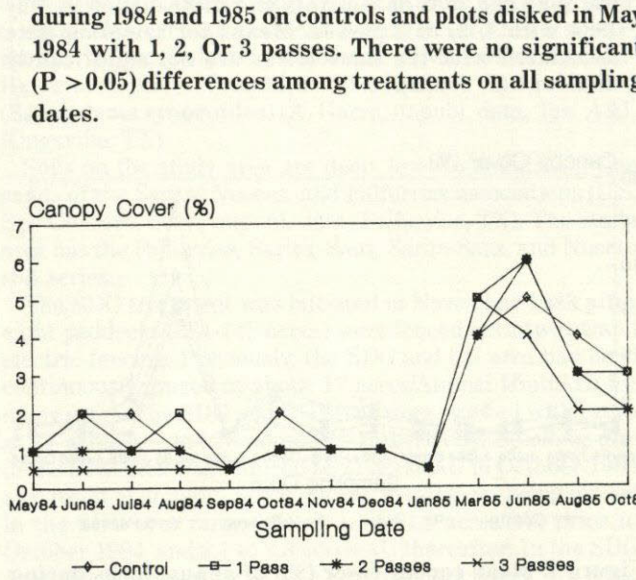


**Figure 4. Mean canopy cover (%) of perennial forbs during 1984 and 1985 on controls and plots disked in May 1984 with 1, 2, or 3 passes. There were no significant (P >0.05) differences among treatments on all sampling dates.**

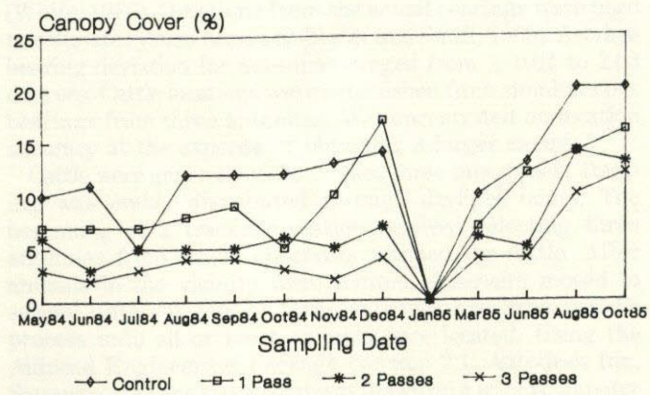


**Figure 5. Mean canopy cover (%) of shrubs during 1984 and 1985 on controls and plots disked in May 1984 with 1, 2, or 3 passes. There were no significant (P >0.05) differences among treatments on all sampling dates.**

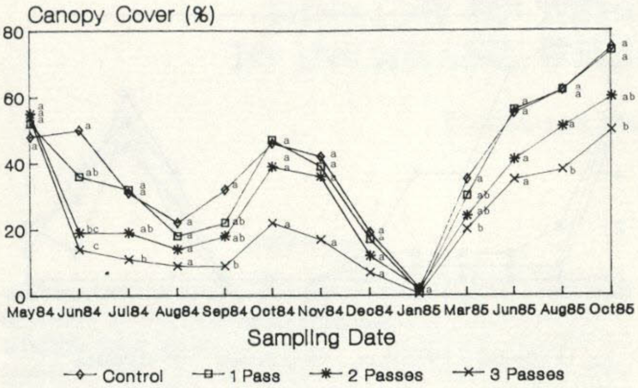


**Figure 6. Mean canopy cover (%) of perennial grasses during 1984 and 1985 on controls and plots disked in May 1984 with 1, 2, or 3 passes. Means for sampling date associated with the same letter are not significantly different (P >0.05).**

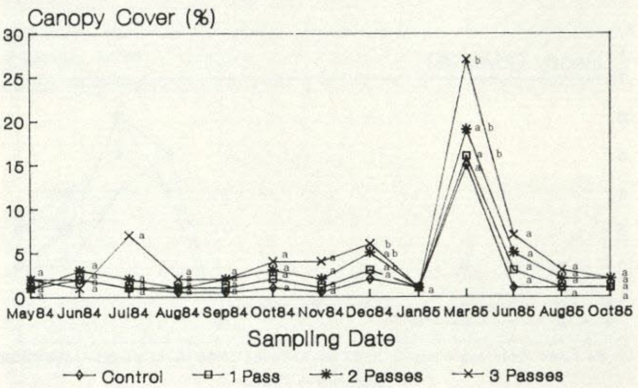


**Figure 7. Mean canopy cover (%) of annual forbs during 1984 and 1985 on controls and plots disked in May 1984 with 1, 2, or 3 passes. Means for a sampling date associated with the same letter are not significantly different (P >0.05).**

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# SITE PREFERENCE BY CATTLE UNDER SHORT DURATION AND CONTINUOUS GRAZING MANAGEMENT

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## ABSTRACT

**Cattle locations were monitored by radio tracking on a South Texas study area to determine if site utilization was more uniform under short-duration versus continuous grazing management. Site variables compared with the distribution of cattle locations were vegetation type, soil series, and distance to water. Use of vegetation type was more uniform under short duration grazing. However, cattle showed more selection for soil series and distance to water under short duration as compared to continuous grazing. Thus the bulk of the evidence did not support a hypothesis of more uniform site utilization by cattle under short duration grazing management.**

## INTRODUCTION

Short duration cattle grazing has been increasing in the southwestern U.S. (Westmoreland et al., 1981; Allison, 1983; Moseley, 1983). This type of grazing management typically involves a single herd of cattle rotated through eight or more paddocks. Cattle are moved to a new paddock every few days, resulting in periods of grazing deferral of from 45-60 days per paddock. The most controversial hypothesis connected with short duration grazing (SDG) is that stocking rate can be increased over that which is ordinary with conventional grazing management. Heitschmidt and Walker (1983:148) speculated that: "By utilizing short duration grazing and thus increasing stocking density, livestock distribution will be enhanced which will improve the ability of livestock to search all areas of a pasture and more effectively utilize all available forage. In addition, grazing pressure will become more uniform throughout the pasture and thus control of the frequency and severity of defoliation of all plants will be enhanced."

In the present study, we tested the hypothesis that cattle distribution in relation to vegetation type, water, and soil series would be improved in a SDG grazing cell versus an adjacent continously grazed pasture on a South Texas study area.

## MATERIALS AND METHODS

The study was conducted on a 3,000-acre area managed under SDG and an adjacent continuously grazed (CG) area of 6,000 acres on the Encino Division of the King Ranch, Brooks County, Texas. The area has flat to gently rolling terrian and lies in the Rio Grande Plain vegetation region (Frances et al., 1966). The area is classified as semiarid (Visher, 1954) because the 24 inch mean annual precipitation is exceeded by the 58.5 inch open-pan evaporation.

Honey mesquite (**Prosopis glandulosa**) was the dominant woody vegetation on the study area, with scattered mottes of live oak (**Quercus virginianus**), and small stands of hercules club (**Zanthoxylum clava-herculis**), brazil (**Condalia obovata**), and prickly pear (**Opuntia** spp.). Grass species included thin paspalum (**Paspalum setaceum**), sandbur (**Denchrun incertus**), seacoast bluestem (**Schizachrium scoparium** var. **littoralis**), threeawns (**Aristida** spp.), and Texas grass (**Vascyochloa multinervosa**). Important forbs included sunflowers (**Helianthus** spp.), crotons (**Croton** spp.), dayflower (**Commelina erecta**), camphor weed (**Heterotheca subaxilaris**), milkpea (**Galactia canescens**), ragwort (**Senecio ridelli**), scratch daisy (**Croptilon divaricatum**), and milkweed (**Sarcostema cynocoides**) (A. Garza, unpubl. data, Tex. A&I, Kingsville, TX).

Soils on the study area are deep, level to undulating fine sands of the Sarita, Nueces, and Falfurrias associations (U.S. Soil Conserv. Serv., unpubl. data, Falfurrias, TX). The study area has the Falfurrias, Sarita, Sauz, Sarita-Sauz, and Nueces soil series.

The SDG treatment was initiated in November 1983 after eight paddocks (284-445 acres) were fenced with two-strand electric fencing. Previously, the SDG and CG area had been continuously grazed at about 17 acres/Animal Unit(AU) for many years. The SDG and CG areas were stocked with cattle at 11 acres/AU and 18 acres/AU, respectively. Stocking rate in the SDG area was reduced to 21 acres/AU in October 1984 as a result of drought. Stock density in paddocks being grazed in the SDG area ranged from 1.1 to 1.8 acres/AU, prior to October 1984, and 2.1 to 3.3 acres/AU thereafter. In the SDG area, cattle were rotated to a new paddock every 4-7 days.

Cattle distribution was determined between 15 February 1984 and 10 January 1985 by radio tracking six cows in each of the two grazing treatments. Radio transmitters were attached to a collar carried by each animal. Bearings to instrumented cattle were taken with radio receivers hooked to permanent null antennas arranged in a pentagonal configuration (White, 1985) in the SDG area, and a triangle in the CG area. Each antenna was tested for accuracy by taking 10 bearings from six to ten known beacon locations (White, 1985). Devations from the actual bearings were used to estimate system accuracy (Tester and Siniff, 1965). Average bearing deviation for antennas ranged from $\pm$ 0.61 to 2.03 degrees. Cattle locations were established from simultaneous bearings from three antennas. We concentrated on location accuracy at the expense of obtaining a larger sample.

Cattle were generally radio-tracked three times/week. Tracking was evenly distributed through daylight hours. The beginning of a tracking session involved selecting three antennas from which observers scanned for cattle. After animals in the vicinity were located, observers moved to several different sets of three antennas and repeated the process until all or most animals were located. Using the Autocad Engineering Package (version 2.1, Autodesk Inc., Sausalito, CA), the study area was drawn on a micro computer and overlaid with a grid of 10 acre blocks. The triangulation software program developed by White (1985) was used to determine grid coordinates from individual bearings and to exclude erroneous bearings. Thus cattle locations were assigned to grid blocks on the study area.

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Each grid block was also categorized by the vegetation type and soil series covering the largest percentage of the block, and by distance to the nearest water. Vegetation types were mesquite, cordgrass, mesquite-prairie, prairie, oak motte, and oak regrowth. Soil series were Falfurrias, Sarita-Sauz, Sauz, Sarita, and Nueces. Distances to water were considered in 400-yard intervals. Aerial photographs and soil maps were used to categorize blocks.

Null hypotheses that cattle locations were distributed in proportion to the number of SDG or CG grid blocks containing each vegetation type, soil series, or water-distance interval were tested by Chi-square analysis at **P** = 0.10 (Nue et al., 1974). If a null hypothesis was rejected, a further test was conducted at **P** = 0.10 to determine if the range area in question was preferred or avoided by cattle.

## RESULTS AND DISCUSSION

Locations per cow averaged 73 (range 64-85) in the SDG area and 37 (range 27-43) in the CG area.

Cattle used vegetation types in relation to their occurrance in the SDG area but avoided the mesquite, oak motte, and cordgrass types in the CG area (Table 1). This pattern was in agreement with the hypothesis of Heitschmidt and Walker (1983). However, more selection was shown in the SDG area for soil series (Table 2) and distance to water (Table 3), as compared to the CG area.

**Table 1. Preference for vegetation types by cattle radio-tracked in a short-duration grazing cell and adjacent continuously grazed pasture, King Ranch, Brooks County, Texas.**

| | Short duration | | | Continuous | | |
|---|---|---|---|---|---|---|
| Vegetation types | % available | % use | Preference[a] | % available | % use | Preference[a] |
| Mesquite prairie | 0.15 | 0.16 | None | 0.12 | 0.16 | None |
| Mesquite | 0.17 | 0.20 | None | 0.03 | 0.01 | Avoid |
| Prairie | 0.60 | 0.56 | None | 0.63 | 0.70 | None |
| Oak motte | 0.05 | 0.05 | None | 0.04 | 0.01 | Avoid |
| Cordgrass | 0.03 | 0.02 | None | 0.07 | 0.02 | Avoid |
| Oak regrow | 0.01 | 0.01 | None | 0.13 | 0.11 | None |

[a]Neu et al. (1974), **P** < 0.10.

**Table 2. Preference for soil series by cattle radio-tracked in a short-duration grazing cell and adjacent continuously grazed pasture, King Ranch, Brooks County, Texas.**

| | Short duration | | | Continuous | | |
|---|---|---|---|---|---|---|
| Soil series | % available | % use | Preference[a] | available | % use | Preference[a] |
| Falfurrias | 0.33 | 0.27 | Avoid | 0.27 | 0.19 | Avoid |
| Sarita-Sauz | 0.35 | 0.43 | Prefer | Not present | | |
| Sauz | 0.03 | 0.00 | Avoid | Not present | | |
| Sarita | 0.27 | 0.29 | None | 0.49 | 0.51 | None |
| Nueces | 0.03 | 0.01 | Avoid | 0.24 | 0.31 | None |

[a]Neu et al. 1974, **P** < 0.10.

In the SDG area, the Sarita-Sauz series was preferred, the Sarita was used in relation to occurrance, and all others were avoided. In the CG area, the Falfurrias series was avoided and all others used in relation to occurrance. The different pattern of preference for vegetation type versus soil series is surprizing since the two are usually correlated. Much of the study area was root plowed about fifteen years ago and vegetation types may still be influenced more by this disturbance than by underlying soil series.

**Table 3. Preference for distance (yds) from water by cattle radio-tracked in a short-duration grazing cell and adjacent continuously grazed pasture, King Ranch, Brooks County, Texas.**

| | Short duration | | | Continuous | | |
|---|---|---|---|---|---|---|
| Distance to water | % available | % use | Preference[a] | % available | % use | Preference[a] |
| < 400 | 0.04 | 0.13 | Prefer | 0.06 | 0.07 | None |
| 400-800 | 0.13 | 0.21 | Prefer | 0.19 | 0.18 | None |
| 801-1200 | 0.21 | 0.20 | None | 0.26 | 0.30 | None |
| 1201-1600 | 0.29 | 0.17 | Avoid | 0.26 | 0.31 | None |
| 1601-2000 | 0.18 | 0.20 | None | 0.16 | 0.14 | None |
| 2001-2400 | 0.10 | 0.07 | None | 0.05 | 0.00 | Avoid |
| >2400 | 0.05 | 0.02 | Avoid | 0.02 | 0.01 | None |

[a]Nue et al. (1974), P < 0.10.

Distance from water influenced cattle perference for site more in the SDG area as compared to the CG area. In the SDG area, the only available water was at the cell center. Cattle in the SDG area spent much more time within 800 yards of water than was the case in the CG area. There was a trend in both grazing treatments to avoid areas at extreme distance from water.

Thus, in this study, the bulk of the evidence did not support the hypothesis that cattle used the SDG area more uniformly. If anything, there was more selection for site in SDG as compared to CG. Caution should be employed in extending these results, however. This was a single, unreplicated study. Furthermore, the study was conducted in a drought, which could have influenced results. Finally, SDG grazing decisions depend considerably on the individual manager and it is difficult, if not impossible, to standardize this variable between sites where SDG is practiced.

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# SIMPLIFIED SHORT-RUN PRICE FORECASTING MODELS FOR WHEAT AND CORN

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## ABSTRACT

**Models were developed which are simple enough for use by farmers and rural elevators in short-term price forecasting. The models express annual U.S. wheat and corn prices as a function of world stocks and projected levels of world production and consumption. The wheat model had a 6.6% average error in annul prices over the 12 years of data and the corn model averaged 1.2% error over 11 years of data. The models predicted 1986/87 prices to increase 6% for wheat and decrease 20% for corn using U.S.D.A. projections of production and consumption as of August, 1986. Price responsiveness indicators were also examined.**


## INTRODUCTION

Prices of agricultural commodities are volatile when compared to many other economic goods. The price volatility exists both within and among years. For example, between 1970 and1985, average annual variation in corn prices was 17% or$.44/bu. (USDA, Ag. Statistics, 1985). Agricultural commodities are also volatile over short periods of time. The price of corn in 1982 and the price of wheat in 1976 changed more than 30% in less than 12 months (Chicago Board of Trade, 1984). The average within-year price variation on wheat between 1974 and 1983 was 25.4% or $.87/bu. (Chicago Board of Trade, 1984).

Price uncertainty in agricultural commodities is a persistent problem for producers and merchants of the commodities and producers and purchsers rarely have price forecasting tools which are readily adaptable to their management systems. Producers typically must make price sensitive production decisions before they plant a crop with little indication of price levels at the time of harvest. Producers and merchants may also lose revenue through poorly timed marketing decisions because of lack of accurate price expectations.

Economics literature provides numerous price forecasting models for agricultural commodities, but they consist primarily of complex structural long-run models. For example, Roy and Ireland (1975) developed a simultaneous equations model to forecast annual U.S. sorghum prices with a set of supply and demand relationships for determining market prices. Paddock (1985) used the same general approach to forecast quarterly and annual wheat prices. Johnson et al. (1986) likewise employed a multi-sector econometric model to forecast annual prices for corn and wheat. These types of forecasting tools are productive for policy analysis and long-range price projections but have limited application for short-term (within-year) price forecasts. In addition, they require extensive knowledge of econometric modeling and computers, which few business managers possess.

If producers and merchants had a simplified price forecasting model for commodities, such as corn and wheat, they might improve the profitability of their production and marketing decisions. They need a method for price forecasting that is accurate, but it should also be simple enough to use easily. The objective of this study was therefore to develop a short-run (up to one year) price forecasting model for corn and wheat that is readily usable by producers and merchants to complement the general price forecasts available from various public and private agencies.

## METHODS AND PROCEDURES

The steps involved in the analysis included: (a) developing price forecasting models for wheat and corn based on economic principles, (b) collecting data and estimating coefficients in the models, and (c) testing, analyzing and evaluating the models.

### Models

Wheat and corn prices are established by interaction of demand and supply forces. Supply relationships are established primarily by cost factors and supply is shifted by forces such as weather, government programs, and alternative uses of production resources. The demands for corn and wheat, in domestic and export markets, are shifted by changes in population, incomes, values and quantities of other products in which corn is an input, prices of competing products, and consumer tastes and preferences (in both domestic and export markets).

These relatively complex relationships may be captured in simpler relationships between price and indicators of production, consumption, and inventory or stock levels. For example, when demand for wheat decreases (supply constant), price decreases and stocks in storage rise. When supply of wheat decreases, price increases and stocks decline. When consumption increases, other things constant, prices are bid up, etc. The relationship between price and each of these factors is expected to be non-linear because prices are more sensitive to small changes in demand or supply forces when stocks, production, and consumption are small and less sensitive when they are large.

For this study, U.S. prices of wheat and corn were expressed as functions of world stocks, utilization (consumption plus losses) and production of the respective grains because the U.S. market reflects global conditions in the corn and wheat markets for the period analyzed. For example:

$$Pw = f(Sw, Uw, PDw)$$
$$Pc = g(Sc, Uc, PDc)$$

where: Pw,Pc = price of wheat and corn, respectively
Sw,Sc = stock levels of wheat and corn, respectively
Uw,Uc = utilization levels of wheat and corn
PDw,PDc = production levels of wheat and corn

In order to capture the expected nonlinear relationships the natural logarithms of variables were used in the model, abbreviated by the symbol "ln".

Various combinations of the dependent price variable evaluated included annual U.S. average corn and wheat prices in

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nominal terms and adjusted for inflation by using various price indexes (adjusted prices), and the natural log of adjusted prices.

Combinations of independent variables tested in the models included ending stock levels, beginning stock levels, production levels, utilization levels, and ratios such as beginning stocks divided by production and beginning stocks divided by utilization, and stocks, utilization, and production lagged one year. These variables were examined at world and U.S. levels. The natural logs of these variables were also evaluated.

The model was estimated by Ordinary Least Squares regression analysis. The estimated models were evaluated statistically by examining R-squared values for the estimated equations, statistical significance of the explanatory variable coefficients and theoretical consistency of coefficient signs. Theory suggests that production and stock variables should have negative coefficient signs while the utilization coefficient sign should be postive. After selecting the best statistical models, forecasted prices were compared with the actual prices.

Responsiveness of price with respect to each variable was evaluated. Price flexibility with repect to each variable shows the percentage change in price associated with a one percent change in the variable. For example, price flexibility of stocks was calculated as $(\partial P/\partial S)(S/P)$ where S and P are mean values of stocks and price, respectively. This procedure was followed for both corn and wheat models.

### Data

For both corn and wheat, no data were collected prior to the year 1974. In 1973 and 1974 significant structural changes occurred in international grain markets. Including data prior to 1974 might decrease the accuracy of a model designed to forecast current prices.

Data were collected for corn and wheat on a crop marketing year basis. Marketing years were October/September for corn and June/July for wheat. This means, for example, that in the 1974/75 year for corn the data were for the year October 1974 through September 1975. For the 1980-81 year for wheat the data were for the year July 1980 through June 1981.

The price data collected were crop marketing year asking prices at Rotterdam for 30-day delivery, as shown by Hamburg Mercantile Exchange. Prices were quoted for U.S. no. 2 Northern Spring wheat at 14% moisture. For corn the prices were for U.S. no. 3 Yellow corn.

It was not certain whether the estimation models should use nominal or real prices, so a number of price indexes were collected so that the price could be adjusted. The indexes collected and their sources included (a) the GNP implicit price deflator and the index of prices received by farmers (U.S.D.A., June 1985) and (b) the world non-fuel commodity price index, the world food price index and the agricultural raw products price index (International Monetary Fund, 1986). These price indexes were converted from a calendar year to a marketing year basis by multiplying the price index of the first year by the percentage of the crop that fell into that year and then adding it to the percentage of the price index for the next year that fell in the that marketing year. The price indexes were all converted to a base year of 1985/86.

For both wheat and corn, world production levels, total world utilization levels, and ending world stock levels were in millions of metric tons and were collected for the marketing years 1974/75 through 1985/86 (U.S.D.A., Sept. 1980, July 1982, Dec. 1984, Sept. 1986). U.S. production, utilization and ending stock levels and net trade levels (exports minus imports) were also collected (U.S.D.A., 1985).

## FINDINGS

Several model forms were evaluated. Beginning stock levels were better predictors of prices than were ending stocks in all cases. Ratio variables such as stock levels as a percentage of production and stock levels as a percentage of utilization were also less effective than separated variables. U.S. data did not yield results as reliable as the world data.

### Wheat

The best (semi-log) model for wheat used the nominal (unadjusted) price as the dependent variable. The equation selected for estimating wheat prices was:

$$Pw = \underset{(-2.55)}{-1004.0} - \underset{(-3.61)}{177.04(\ln SBw)} + \underset{(3.96)}{936.83(\ln Uw)} - \underset{(-3.55)}{610.43(\ln PDw)} \quad (1)$$

where Pw = average marketing nominal price of wheat in Rotterdam U.S. dollars per metric ton.

SBw = world marketing year beginning stocks of wheat, millions of metric tons.

Uw = world marketing year utilization of wheat millions of metric tons.

PDw = world marketing year production of wheat, millions of metric tons.

ln = natural logarithm.

The coefficient t-values are in paratheses below the estimated parameters. All parameter estimates were statistically significant at the .01 significance level. The $R^2$ for the estimated equation was .674, indicating that the model explained 67.4% of the variation in wheat prices over the 12-year period (1974/75-1985/86). The average percentage error for the wheat price equation over the 12-year peroid was 6.6%; i.e., the actual price average being 6.6% above or below the price predicted by the equation.

One measure of price responsiveness, the partial derivative of price with respect to each explanatory variable, measures the change in price resulting from a one unit change in the variable. The partial derivative for the stock utilization, and production variables were $\partial Pw/\partial SBw$ = (-177.04/SBw), $\partial Pw/\partial Uw$ = (936.83/Uw), and $\partial Pw/\partial PDw$ = (610.48/PDw), respectively. At different levels of production, utilization and stocks the price responsiveness is different. Price responiveness measured at "low", "high", and mean level of the variables responsiveness are shown in Table 1. At the mean value for SBw = 88.9, a change (increase) in world beginning stocks of one million metric tons causes wheat prices to change (decrease) by $1.99 per metric ton. At the mean value for Uw = 433, a one million metric ton change (increase) in utilization causes a $2.16 per metric ton change (increase) in the price of wheat. At the mean value of PDw = 439, a one million metric ton change (increase) in the level of production causes a $1.39 per metric ton change (decrease) in the price of wheat.

The price flexibilities, the percentage change in price from a one percent change in explanatory variable, measured at the means of the variables are also shown in Table 1 at the low, high and mean values for the twelve years of data. The price flexibility at the mean for the stock variable is = Pw/ SBw (mean SBw/mean Pw) = -1.99 (88.9/174.62) = -1.01. This indicates that for a one percent change (increase) in the beginning world stock level, the price of wheat will change (decrease) by 1.01%. The price flexibilities of utilization and production were calculated similarly.

The indicators of price flexibility show that wheat prices are most sensitive to changes in world utilization, next to changes in production, and least sensitive to change in stocks, other things constant. Price is more sensitive to changes in all three variables at lower prices.

**Table 1. Measures of Price Responsiveness for Wheat.**

| Variable (X) | Levels of Variables (Xi) | Corresponding Price[1] | ( ∂Pw/ ∂Xi) | Price Flexi-bility |
|---|---|---|---|---|
| | million metric tons | - - $/metric ton - - | | % |
| Stocks | 63.7 (low) | 233.63 | -2.78 | - .76 |
| | 88.9 (mean) | 174.62 | -1.99 | -1.01 |
| | 125.7 (high) | 113.30 | -1.41 | -1.56 |
| Utilization | 367 (low) | 19.69 | 2.55 | 47.52 |
| | 433 (mean) | 174.62 | 2.16 | 5.36 |
| | 495 (high) | 299.99 | 1.89 | 3.12 |
| Production | 357 (low) | 300.83 | -1.71 | -2.03 |
| | 439 (mean) | 174.62 | -1.39 | -3.49 |
| | 511 (high) | 81.91 | -1.19 | -7.42 |

[1]Assuming other variables at mean levels.

### Corn

The best-fit corn model (semi-log) used an adjusted price, the natural log of the price divided by the GNP deflator, as the dependent variable. The independent variables for the corn model were the beginning world stock level, world utilization and world production. For the corn model the data were for the 1975/76 crop year (ending stock levels for the 1973/74 crop were not available) through 1985/86. The corn price equation chosen as the best for prediction purposes was:

$$\ln Pc' = \underset{(15.88)}{6.05565} - \underset{(-2.66)}{.00604\ SBc} + \underset{(1.67)}{.00366\ Uc} - \underset{(-3.68)}{.00509\ PDc} \quad (2)$$

where: Pc' = average marketing year price of corn in Rotterdam, U.S. dollars per metric ton, adjusted for inflation by dividing by the U.S. GNP deflator (1985-86 = 100).

SBc = beginning world marketing year stocks of corn, millions of metric tons.

Uc = world marketing year utilization of corn, millions of metric tons.

PDc = world marketing year production of corn, millions of metric tons.

ln = natural logarithm

The t-values in paratheses below estimated parameters indicate that the estimated stock coefficient is significant at the .02 level, the production coefficient significant at the .01 level, and the utilization coefficient significant at the .07 level. The model $R^2$ was .822. The average annual percent error for the model was 1.2%.

Levels of corn price responsiveness at mean, low and high observed values for the variables are listed in Table 2. The partial derivative of the stock variable at the mean with respect to price, $\partial Pc'/\partial SBc$ = - .00604(Pc'), is - .00604 (168.09) = -1.02. This indicates that at mean levels of production and use, for every one million metric ton change (increase) in beginning world stocks the price of corn will change (decrease) by $1.02 per metric ton. At the mean world production of corn, a one million metric ton change (increase) in corn consumption changes (increases) the price of corn by $.62 per metric ton. The price of corn appears to be most flexible to changes in stocks. For the stock variable the price flexibility at the mean is $\partial Pc'/\partial SBc\ (SBc/Pc')$ where SBc and Pc' are taken at their mean values; -1.02 (53.9/168.09) = - .33%. This indicates that for a one percent change (increase) in the world stock levels of corn the price of corn will change (decrease) by .33% at the mean. The other price flexibilities in Table 2 were calculated similarly.

**Table 2. Measures of Price Responsiveness for Corn.**

| Variable (X) | Levels of Variables (Xi) | Corresponding Price[1] | ( ∂ Pc/ ∂ Xi) | Price Flexi-bility |
|---|---|---|---|---|
| | million metric tons | - - $/metric ton - - | | % |
| Stocks | 28.6 (low) | 195.85 | -1.18 | - .17 |
| | 53.9 (mean) | 168.09 | -1.02 | - .33 |
| | 106.6 (high) | 122.27 | .74 | - .65 |
| Utilization | 326 (low) | 130.58 | .48 | 1.20 |
| | 395 (mean) | 168.09 | .62 | 1.46 |
| | 437 (high) | 196.03 | .72 | 1.61 |
| Production | 328 (low) | 247.12 | -1.26 | -1.67 |
| | 403 (mean) | 168.09 | - .86 | -2.06 |
| | 482 (high) | 112.44 | .57 | -2.44 |

[1]Assuming other variables at mean levels.

## USING THE MODELS

To use the models for short-run prediction purposes, projected current-year production and utilization levels are needed. The Foreign Agricultural Service, U.S.D.A. publishes estimated world production and utilization levels for both wheat and corn for the current and upcoming crop years. Use of the models for forecasting prices is illustrated below.

For forecasting the 1986/87 marketing year prices for wheat and corn the models used the following estimates from U.S.D.A. (Sept. 1986) in equations (1) and (2):

| Variables | Wheat | Corn |
|---|---|---|
| | - mil. of metric tons - | |
| BEGINNING STOCKS (SB) | 123.5 | 121.4 |
| UTILIZATION (U) | 505.9 | 444.0 |
| PRODUCTION (PD) | 505.6 | 477.0 |

For wheat, Pw = -1004.0 - 177.04 (ln 123.5) + 936.83 (ln 505.9) - 610.43 (ln 505.6) = $175.97 per metric ton. Thus, as of September, 1986, the model would have suggested a marketing year price of $175.97 per metric ton for 1986/87, a 5.6% increase from the $166.68 price for 1985/86. However, with 1986/87 estimates of stock, production, and use levels as of August, 1987, the model estimate was $153.18 per ton. These compare to an actual price of $135.40 per ton (U.S.D.A., Aug. 1987).

For corn, ln Pc' = 6.05565 - .00604 (121.4) + .00366 (444) 1986/87 GNP deflator increase of 2% (U.S.D.A., June 1985), then estimated Pc becomes $91.79 (1.02) = $93.63. Forecasts as of August, 1987 gave a price estimate of Pc = $89.62. The actual Pc for the first 9 months of the 1986/87 marketing year was $75.57.

## SUMMARY AND CONCLUSIONS

Many variables affect prices of agricultural commodities and no model can forecast prices without error. The models developed in this study consider major supply and demand factors in estimating prices of wheat and corn. They are simple enough to be usable without sophisticated computer equipment, e.g., Lotus 1-2-3 (Lotus Development Corp.), and needed data are published on a regular basis and are readily accessible. Larger, more complex models could have been estimated that might have been more accurate, but they would have been more difficult to use.

The models are sufficiently reliable to facilitate general forward planning decisions by producers, agribusiness firms and merchants who need a basis for price expectations six to nine months in advance. The wheat model averaged 6.6% error when the model was used to predict the prices for the last 12 crop years. The largest error was 22.9% in 1977/78. The corn model was slightly more accurate, averaging only 1.2% error over the last 11 crop years. The error in the models should be considered when using the models to forecast prices. Forecasted prices for 1986/87 using the USDA world production and use estimates as of August, 1986, were about $94 per metric ton for corn, down 20% from the 1985/86 price, and about $176 per metric ton for wheat, 6% above the 1985/86 price. The prices obtained from the models should be looked at as a general level of prices for the next crop year, not as an exact forecasted price for any one date. Consequently, forecasted prices might be expanded to a range of plus or minus seven or eight percent.

The price flexibilities obtained from the models indicate that the price of corn is less responsive to changes in stock levels than is the price of wheat. The price of wheat is more responsive (has higher absolute value of price flexibilities) to production and utilization than the price of corn. The price of wheat is most responsive to changes in the utilization of wheat and least responsive to changes in stocks of wheat. The price of corn is most responsive to changes in the production levels of corn and least responsive to changes in stock levels of corn.

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# EFFECTS OF BRUSH PILE BURNING ON SOIL NUTRIENTS AND MICROBES IN THE EDWARDS PLATEAU OF TEXAS

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## ABSTRACT

**On the Edwards Plateau of Texas, Juniperus Ashei piles can occupy as much as 15% of the pasture land and therefore decrease stocking rates. These brush piles are often removed by high intensity fires. Revegetation of burned areas is a very slow process taking several years to occur. A study was undertaken to determine the effect of brush pile burning on soil nutrients and microbes. After burning, the amount of soil nutrients either remained the same or increased. The microbial population was reduced.**

## INTRODUCTION

On the Edwards Plateau of Texas, range managers use bulldozers equipped with chain drags and other implements to clear stands of cedar, **Juniperus Ashei** Buchh. Once uprooted, individual cedar trees are stacked in large brush piles. These brush piles can cover 15% of the pastureland, and therefore decrease stocking rates (Kerr Wildlife Management Area, unpublished data). Range managers remove them with high intensity fires.

Studies of brush pile burns have been conducted in southeastern Utah. Buckhouse and Gifford (1976a,b) investigated sediment production and infiltration rates, and analyzed the chemical composition of overland flow. Gifford (1981) found that debris pile burning had a greater effect on soils under burned debris piles than in adjoining grassland. He reported that the first year after burning there is a significant increase in electrical conductivity, phosphorus, potassium, percent nitrogen, and percent organic carbon to a depth of 4.0 in.

No studies of the effect of brush pile burning on the edaphic enviroment have been conducted in Texas. Therefore, a study was initiated to determine the effects of brush pile burning on soil microbes and on soil pH, total carbon, total nitrogen, phosphorus, potassium, calcium, magnesium, zinc, iron, manganese, copper, and sodium to a depth of 1.0 in.

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## MATERIALS AND METHODS

### Study Area

The study was conducted in Buck Pasture on the Kerr Wildlife Management Area (KWMA), Kerr County, Texas. KWMA, a 6500 ac. facility of the Texas Parks & Wildlife Department enclosed entirely by an 8-ft. deer-proof fence, is centrally located on the Edwards Plateau at an elevation of 1899 to 2201 ft. It consists of 15 pastures and ten 96-ac. research plots. The topography is rolling hills. Mean annual temperature is64°F with a January average of 48°F and a July average of 80°F (Hunter, 1983). The plant community was described by Hunter (1983) and Cross (1984).

The soil series of Buck Pasture is Eckrant (Lithic Haplustoll); the range site is Low Stoney Hill. Soils beneath brush piles are clay textured with Cation Exchange Capacities (CEC) of 38 meq/100 g. (CEC was determined by the method developed in 1977 by Polemio and Rhodes). Soil pH was measured as a 1:2, soil:water suspension. In 1972, most of the cedar (**Juniperus Ashei**) and other brush in this pasture was cleared by chaining and stacked into piles by bulldozers. Five brush piles of various sizes were selected in 1983; they exhibited minimal decomposition (Table 1). The piles were burned during Spring 1983 on 23 Feb., 2, 30, and 31 Mar., and 15 Apr. Relative humidity, air temperature, and wind speed were recorded at the time of brush pile burning (Table 2).

### Temperature and Heat Production Measurements

Soil temperatures of the brush piles were measured using pairs of thermocouples. One of each pair was placed at the soil surface and the other at a depth of 1 in. In each sample pile, 1 pair of thermocouples was placed in the center and 1 pair at each cardinal position within the pile area. Temperature readings were taken every 2 min. for 5 h. Initial temperature readings were taken immediately after ignition.

Total heat production of each brush pile was determined using water-can fire analogs described by George (1969) and Gifford (1981). Four cans were placed within each brush pile area, 1 adjacent to each surface thermocouple. An additional can was placed outside of the pile to determine water loss by evaporation. Calculations to determine total heat production were based on Gifford (1981).

### Soil Collection and Analyses

Samples were collected before burns, immediately after burns, and one year later. Litter was removed before sampling and samples were taken to 2.5 in. depths under each brush pile and in adjacent grassland sites. Samples were placed in paper sacks, air-dried and analyzed at Southwest Texas State University and the Extension Soil Testing Lab at Texas A&M University, College Station, Texas.

Total carbon was determined by wet combustion with chromic acid (Allison, 1982). Total nitrogen was determined by the micro-Kjeldahl method described by Bremner (1982). Acetanilide (T.H.A.M.) was used as a check of recovery of organic nitrogen. Samples were digested by block digestion, and a LabConCo distillation apparatus was used to distill the digested soil samples.

Exchangeable potassium, sodium, calcium, and magnesium were analyzed by the ammonium acetate method (Thomas, 1982). Phosphorus was analyzed according to the method described by Olsen and Sommers (1982) where the Weak Bray extractant (0.025 N HCL + 0.03 N $NH_4F$) was used in a 50:1 solution/soil ratio. Zinc, iron, manganese and copper were extracted with DTPA (Linsay and Norvell, 1978).

**Microbe Analysis**

Samples were taken from beneath 5 brush piles and from grassland adjacent to the piles. Brush-pile samples were collected immediately before and after burning; grassland samples were collected before pile ignition. Four sub-samples each from each brush pile and adjacent grassland were mixed in paper bags and refrigerated. Percent moisture was determined from separate samples collected immediately before and after burning (Baccus, 1984).

A plate-count method was used to determine microbial populations (Allen, 1951). A sterile medium was inoculated with saline dilution of the soil samples and poured into Petri plates. After five days of incubation at 86°F, microbial colonies were counted.

## RESULTS AND DISCUSSION

**Temperature and Heat Production**

Brush pile 2, one of the smallest in volume (28.5 $yd^3$) and fuel density, had the highest surface soil temperature (833°F). The highest subsurface soil temperature was recorded for brush pile 5, which was one of the largest in size and highest in density (Table 1). Gifford (1981) reported a mean high temperature of 550°F at 1.0-in. soil depth beneath a pinyon-juniper pile. Brush pile 3 had median values of both volume and fuel density. Its soil surface temperature (684 to 932°F) had greater variation than the subsurface temperature (185 to 239°F).

The smallest brush pile, brush pile 4, with a volume of 27.2 $yd^3$ and a medium fuel density, had the highest energy release rate (Table 1). Gifford (1981) measured total energy expended at 46 locations within a burned pinyon-juniper debris site in Utah. In his study, one of the burned debris piles, composed of ">6 trees", released 1,126,900 to >1,598,400 calories. In the present study, brush pile 3, a medium-size pile, had an energy release rate of 464,692 +/- 337,311 cal./h. or a total energy release of 2,323,460 calories (Table 1).

**Table 1. Physical description, burn temperature, and approximate energy release rates of brush piles (CI = 95%).**

| Brush Pile No | Volume ($Yd^3$) | Density of Fuel | Temperature Surface | 1.0 in Depth (°F) | Energy Release Rate (cal./h.) |
|---|---|---|---|---|---|
| 1 | 134 | Low | 626±293 | 223±108 | 387,339±226,693 |
| 2 | 29 | Low | 833±171 | 174±52 | 351,870±113,251 |
| 3 | 39 | Medium | 808±156 | 212±59 | 464,692±337,311 |
| 4 | 27 | Medium | 649±120 | 172±70 | 695,542±953,424 |
| 5 | 129 | High | 714±70 | 291±223 | 461,098±232,239 |

**Total Carbon**

Neuenschwander et al. (1974) reported that soil organic carbon in tobosagrass (**Hilaria mutica** Benth.) communities increased after a March burn and returned to normal levels within 6 years. Ueckert et al. (1978) reported a significant increase in soil organic carbon within 2 months after a burn in the upper 1.5 in. of soil. They suggested the increase was the result of surface cracking of clay soil, resulting from low precipitation, that promoted the incorporation of unburned charcoal, ash and residual litter into the soil surface layers. Gifford (1981) reported a significant increase in organic carbon at 1.0-2.0, 2.0-3.0, and 3.0-4.0 in. soil depths on burned debris sites. He did note, however, a small yet significant, decrease in organic carbon at the 0-1.0 in. soil depth. In the present study, burning did not significantly decrease total carbon under the brush piles. Before burning, perhaps due to litter from the brush piles, soils beneath these piles contained significantly higher percentages of total carbon than grassland soils (Table 3). The decrease in total carbon beneath brush piles after burning may indicate a loss of organic carbon by combustion.

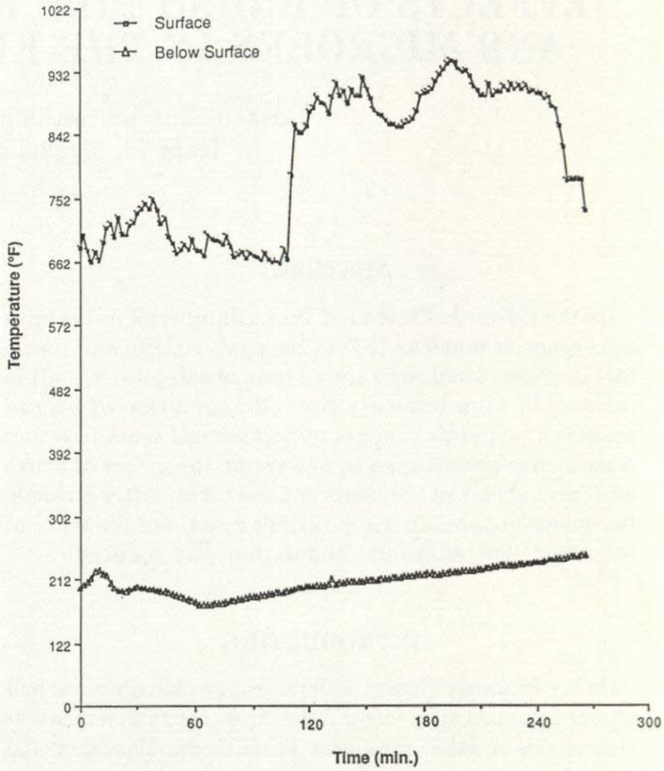


**Figure 1. Soil temperatures at surface and 1.0-in. depth in a 1983 spring burn of brush pile no. 3 at Kerr Wildlife Management Area.**

**Table 2. Weather data of 5 brush pile burns. Data ranges are based on observations taken every hour for a period of 5 hours for every burn.**

| Date of Burn | Brush Pile No. | Relative Humidity (%) | Ambient Temperature (°F) | Wind Speed (Mi/Hr) | Wind Direction |
|---|---|---|---|---|---|
| 23 Feb 83 | 1 | 28 - 37 | 66 - 75 | ---- | ---- |
| 02 Mar 83 | 3 | 29 - 54 | 71 - 79 | 0 - 14 | S |
| 30 Mar 83 | 4 | 35 - 45 | 64 - 79 | 0 - 10 | N - NW |
| 31 Mar 83 | 2 | 19 - 54 | 72 - 91 | 0 - 14 | SE - SW |
| 15 Apr 83 | 5 | 9 - 16 | 63 - 81 | 0 - 8 | SE - NE |

----denotes no observations.

**Nutrients**

**Total nitrogen**. Increased total nitrogen and nitrate-nitrogen after burning have been observed in Virginia, Montana, and Utah (Christensen, 1976, Nimir and Payne, 1978, and Gifford, 1981). Sharrow and Wright (1977) reported a decrease in total nitrogen at 1.0-2.0 and 2.0-5.0 in. soil depths in burned tobosagrass communities near Colorado City, Texas. Buckhouse and Gifford (1976b) observed no significant differences in soil nitrate-nitrogen after chaining or grazing and burning. In the present study there were no significant differences in total nitrogen between grassland and brush pile soils before or after burning (Table 3).

**Phosphorus**. Buckhouse and Gifford (1976b) observed a significant increase in phosphorus following burning in the debris-in-place treatment. Gifford (1981) reported a significant increase in phophorus in debris and grassland sites one year after burning. Phosphorus also increased significantly under brush piles after burning in this study. Brush pile soils contained significantly higher amounts of phophorus than grassland soils one year after burning indicating cedar litter is a good source of this element.

**Potassium**. Buckhouse and Gifford (1976b) observed a significant increase in potassium on a debris-in-place site in southeastern Utah. This increase persisted a full year after burning. Ueckert et al. (1978) reported significant increases in potassium levels in the upper 1.0-in. of soil in a mesquite-tobosagrass community after burning. Gifford (1981) reported a significant increase in potassium for two years after burning in both debris piles and adjacent grassland sites. However, after one year, the increase in potassium was more pronounced in debris pile soils than grassland soils. Differences the second year were less noticeable. In the present study, soil potassium in brush pile soils did not change significantly immediately after burning, but did have a significant increase one year later. However, there were no significant differences in potassium between grassland and brush pile soils one year after burning.

**Calcium, Magnesium, Zinc, Iron, and Maganese**. Buckhouse and Gifford (1976b) studied the effects of grazing and debris burning on pinyon-juniper sites in Utah. They found significant yearly variations in calcium levels, but no significant differences between treatments. Christensen (1976) studied short-term effects of mowing and burning on soil nutrients in two vegetational types in Big Meadows, Shenandoah National Park, Virginia. Significant increases in potassium, calcium, and magnesium occurred in the burn treatment; there were no detectable changes in these nutrients in the mowed treatment. There were also no detectable changes in these nutrients in the present study.

**Copper**. In brush pile soils, copper increased significantly immediately after burning. One year after the burn, the amount of copper in brush pile soils remained significantly higher than before burning.

**Sodium**. Buckhouse and Gifford (1976b) reported significant yearly fluctuations in sodium concentrations after separate treatments of debris burning and grazing in southeastern Utah. They found no differences in sodium concentrations between treatments. Ueckert et al. (1978) reported an increase in sodium after burning tobosagrass communities but detected no differences between burned and unburned plots. The present study parallels Ueckert et al. (1978) in that sodium increased one year after burning in both grassland and brush pile soils, but no significant differences were noted between grassland and brush pile soils.

### Soil Bacteria and Actinomycetes

Burning greatly reduced the number of soil bacteria and actinomycetes under brush piles. Before the burn, brush pile soils contained 2.6 +/- 0.5 X $10^6$ microbes per gram of soil. Immediately after the burn the number of microbes was 0.37 +/-0.9 X $10^6$ microbes per gram of soil. Grassland soils contained 2.4 +/-0.5 X $10^6$ microbes per gram of soil. The percent moisture in soil under brush piles was 25.1 +/-8.7 before burning and 11.7 +/-9.7 immediately after burning. The high heat from burns not only severly dried soils but also exposed those initially beneath brush piles to drying conditions.

**Table 3. Soil nutrients to a depth of 1 in. (CI = 95%).**

| Nutrient | Grassland: Before the burn | Grassland: One Year After the burn | Under Brush Piles: Before the burn | Under Brush Piles: Immediately Aftertheburn | Under Brush Piles: One Year After the burn |
|---|---|---|---|---|---|
| Total C (%) | 8.0 ± 2.2 | ---- | 10.9 ± 1.60 | 9.4 ± 1.4 | ---- |
| Total N (%) | 0.53 ± 0.09 | 0.54 ± 0.23 | 0.68 ± 0.13 | 0.62 ± 0.07 | 0.56 ± 0.07 |
| Phosphorus (ppm) | 10.0 ± 18.2 | 28.0 ± 18.2 | 16.0 ± 4.8 | 40.0 ± 14.7 | 85.0 ± 22.2 |
| Potassium (ppm) | 478 ± 69.2 | 497 ± 78.2 | 470 ± 69.3 | 469 ± 54.5 | 606 ± 95.0 |
| Calcium ($\times 10^3$ ppm) | 29.3 ± 10.2 | 38.0 ± 19.5 | 31.2 ± 16.5 | 30.2 ± 13.4 | 37.3 ± 13.9 |
| Magnesium ($\times 10^2$ ppm) | 9.7 ± 3.0 | 10.7 ± 1.50 | 8.36 ± 2.30 | 8.36 ± 2.60 | 10.0 ± 2.50 |
| Zinc (ppm) | 0.93 ± 0.12 | 1.04 ± 0.52 | 1.43 ± 0.24 | 1.44 ± 0.27 | 1.21 ± 0.34 |
| Iron (ppm) | 6.94 ± 0.71 | 6.57 ± 1.30 | 8.13 ± 1.50 | 7.69 ± 0.52 | 7.00 ± 1.10 |
| Manganese (ppm) | 9.54 ± 0.87 | 10.0 ± 0.00 | 10.0 ± 0.0 | 10.0 ± 0.0 | 10.0 ± 0.0 |
| Copper (ppm) | 0.26 ± 0.06 | 0.31 ± 0.03 | 0.32 ± 0.08 | 0.73 ± 0.19 | 0.53 ± 0.09 |
| Sodium (ppm) | 103 ± 5.70 | 126 ± 0.30 | 110 ± 10.0 | 112 ± 7.90 | 134 ± 9.60 |
| pH | 7.90 ± 0.09 | 7.90 ± 0.09 | 7.80 ± 0.08 | 7.80 ± 0.08 | 7.80 ± 0.08 |

----denotes no observations.

## CONCLUSIONS

Revegetation of cedar piles after burning is a very slow process and takes several years to occur. Results from this and other studies indicate that after burning, the amount of soil nutrients either remains the same or increases. Thus, nutrients cannot be limiting the re-establishment of vegetation in burned sites. Other factors such as destruction of the seed bank by the high intensity burns or lack of seedling establishment in the resultant rapidly drying soil conditions may be responsible for prolonging revegetation.

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# RUMINAL FIBER VALUE OF COTTON LINTERS AND EFFECT ON DIGESTIBILITY AND FEEDLOT PERFORMANCE BY LAMBS

**M.D. Miller[1], C.R. Richardson[1], D.B. McCarthy[1], L.D. Bunting[1] and D.F. Buddingh[2]**


## ABSTRACT

**Two experiments, with growing sheep, were conducted to determine the effects of feeding cotton linters (CL) on digestibility and feedlot performance and hematological, pathological and histopathological variables. Experiment 1. Five growing lambs were used in a digestibility and nitrogen (N) balance study. Treatments consisted of control (basal diet) with 25% cottonseed hulls (CSH) and four diets composed of 60% control plus 40% roughage. The 40% roughage of the four diets consisted of CSH or three different mixtures of CL and CSH in the ratios of 1 part CL plus 5 parts CSH (1 + 5 mix), 2 parts CL + 5 parts CSH (2 + 5 mix) and 3 parts CL + 5 parts CSH (3 + 5 mix). Lambs consuming 1 + 5 mix, 2 + 5 mix, 3 + 5 mix or CSH alone exhibited similar N retention, percent N intake retained, dry matter digestibility (DMD) and organic matter digestibility (OMD). Lambs fed the control diet, as would be expected, resulted in greater ($P < .01$) values for the four variables studied than lambs on other treatments. Experiment 2. Seventy-two growing-finishing lambs were provided a sorghum based supplement (.75 kg. daily) plus roughage ad libitum to determine the effect on intake, gains and feed efficiency. Roughage sources were: A) corn silage; B) CSH; C) 1 + 5 mix and D) 2 + 5 mix. Lambs consuming the CL + CSH mixtures demonstrated average daily gains (ADG) and feed efficiency (F/G) similar to those consuming corn silage or CSH. However, lambs on corn silage had lower ($P < .05$) average daily feed (ADF) consumptions than any of the other treatments. Similar ADF values were observed for lambs on the CSH and 1 + 5 mix treatments. However, lower ($P < .05$) ADF consumption was observed for the 2 + 5 mix compared to the CSH group but similar to the 1 + 5 mix. Blood samples were taken from five randomly selected lambs on each treatment. Analysis showed no treatment differences for hemoglobin (Hb), percent packed cell volume (PCV), red blood cells (RBC), total leucocytes (WBC), differential leucocytes, plasma alkaline phosphatase (PAP) or plasma glutamic oxaloacetic transaminase (GOT). These data would tend to suggest that CL can be used as a partial substitute of the roughage (CSH) without affecting any of the variables evaluated in these experiments.**


## INTRODUCTION

Roughages are feedstuffs consisting of bulky and coarse particles of plants or plant parts. These materials are termed fibrous (containing over 18% crude fiber) and are composed of hard to digest carbohydrates, mainly cellulose and lignin (Ensminger and Olentine, 1978). The cell walls of plant materials, which are comprised essentially of hemicellulose, cellulose, lignin and protein, supply varying nutritional availablities to the ruminant (Van Soest, 1967). Baker and Harris (1947) reported lignin to be a physical barrier between the more digestible cellulose and cellulolytic microorganisms.

Many different types or sources of roughages have been used in ruminants to maintain proper rumen function. However, animal performance results have been quite variable and many attempts have been made, by different treatment methods and chemical reagents, to improve the digestibility of those feedstuffs considered less digestible, such as cotton gin trash and various crop residues (Klopfenstein, 1978; Arndt and Richardson, 1982). Chemical treatment usually improves digestibility of roughage by solublizing hemicellulose, and increasing the rate and extent of cellulose and hemicellulose digestion (Klopfenstein, 1978). Lignin content is generally not reduced by chemical treatment (Klopfenstein et al., 1972) but rather the increase in digestibility is attributed to breaking bonds between lignin and other carbohydrates.

Cotton linters (CL), the short fibers removed from cottonseed as the first step in processing, are used for making a variety of chemical and non-chemical products. Current uses of CL are for mattress material, ammunition and marginally for livestock, the use of which was pioneered in feedyards on the high plains. Jones et al. (1976) reported energy digestibility of CL for ruminants to be 47%, yielding 1850 kilocalories per kg. of dry matter. Several researchers have indicated CL are comprised primarily of pure cellulose and contain very little hemicellulose or pectin (Schubert et al., 1973 and 1976; Orr, 1977). Several experiments indicate cotton fibers are almost completely solublized by rumen microorganisms **in vitro** (Hale et al. 1969; Millet et al., 1975).

The following experiments were conducted to determine the effects of feeding CL on: 1) digestibility of dry matter, organic matter and nitrogen (N) utilization; 2) average daily feed consumption (ADF), average daily gain (ADG) and feed efficiency (F/G); 3) its value as a roughage source (substitute) and 4) on hematological, pathological and histopathological variables when fed to lambs during a 120-day period.

## EXPERIMENTAL PROCEDURE

Dilute sulfuric acid delinting of cottonseed (processed for planting) was engineered to produced large quantities of seed for commerical cotton producers (Cotton Incorporated, 1976). The cotton linters used in these studies were obtained by this new delinting method.

Experiment 1. Five growing wether lambs were individually housed in metabolism crates in a thermostatically controlled environment. Lambs were shorn and treated for internal parasites prior to the study. Clean fresh water was available ad libitum.

A complete diet was fed in which CL was used as a partial substitute for CSH. The control (basal) diet is shown in Table 1. Treatments differed in levels of CSH and CL-CSH mixtures. Treatments were: A) 100% control; B) 60% control + 40% CSH; C); D) and E) contained 60% control plus the following CL-CSH mixtures; 1 part CL-5 parts CSH, 2 parts CL-5 parts CSH and 3 parts CL-5 parts CSH, respectively. Standard total collection procedures for determining consumption and digestibility were used for feeding, excreta collection and chemical

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analysis of feed, feces and urine (AOAC, 1975). Criteria of evaluation were dry matter digestibility (DMD), organic matter digestibility (OMD), N retention and percent N retained.

**Table 1. Composition of Basal Diet and Feedlot Lamb Supplement**

| | Percentages* | |
|---|---|---|
| Ingredient | Basal Diet, Exp. 1 | Feedlot Lamb Supplement, Exp. 2 |
| Cottonseed hulls | 25.00 | -- |
| Ground sorghum | 62.40 | 72.25 |
| Soybean Meal | 7.10 | 25.00 |
| Molasses | 3.00 | -- |
| Dicalcium Phosphate | 2.00 | 2.00 |
| Salt | 0.50 | -- |
| Trace Mineralized Salt | -- | 0.50 |
| Sodium Sulfate | -- | 0.25 |
| Vitamin A + | 1,506 | 4,455 |
| Vitamin D + | 440 | 1,100 |
| Vitamin E + | 33 | 240 |

*Dry matter basis
+IU/kg, International units/kilogram

A 5 x 5 latin square design was used with total collection of feces and urine. Each period consisted of a 10-day adaption followed by a 7-day collection period. One way analysis of variance and least significant differences were used to determine treatment responses (Steel and Torrie, 1960).

Experiment 2. Seventy-two growing-finishing lambs (31 kg) were used in a 120-day feeding study. Prior to initiation of the experiment, lambs were treated against internal parasites with one and one-half Tramisol ® bolus and received a 2.5 cc injection of Clostridium perfringens type C and D bacterin toxoid for prevention of enterotoxemia and a 2.5 cc injection of tylosin. Lambs were allowed a 14 day adjustment period to the control diet. Housing was provided in a building open to the south. Lambs were randomly assigned to the three replications of each treatment with six lambs per replication. Clean fresh water was provided ad libitum.

Lambs were provided once daily a .75 kg allotment of a sorhgum based concentrate supplement (Table 1). Roughage sources, provided ad libitum, were: corn silage, CSH, 1 part CL and 5 parts CSH (1 + 5 mix) and 2 parts CL and 5 parts CSH (2 + 5 mix), respectively for treatments A,B,C and D.

Five lambs were randomly selected from each treatment before slaughter for use in blood analyses. Blood samples were collected via jugular puncture using vacutainer collection tubes containing EDTA as an anti-coagulant. Analyses conducted on the blood samples included plasma alkaline phosphatase (PAP) and glutamic oxaloacetic transaminase (GOT), hemoglobin (Hb), packed cell volume (PVC), red blood cells (RBC), total leucocytes (WBC) and differential leucocytes. Differential leucocytes were determined by the coulter counter method. Spectrophotometry was used to determine Hb. The microhematocrit method was used to determine PCV. Red blood cells (RBC) and WBC were determined using a hemocytometer and a microscope (Seiverd, 1964).

An accredited veterinary pathologist observed at time of slaughter, the spleen, brain, heart, thyroid, salivay glands, adrenal glands, bladder and lungs for any abnormalities. Tissue samples of each of these organs were taken and microscopic cross-sectional analysis performed.

A complete randomized design was used. One-way analysis of variance and least significant differences were used to test for treatment differences (Steele and Torrie, 1960). Criteria for evaluation were average daily gain (ADG), average daily feed (ADF) consumption, roughage valuę and hematological, pathological and histopathological examination of the lambs.

## RESULTS AND DISCUSSION

Experiment 1. Results of the digestibility and N balance studies are shown in Table 2. Nitrogen (N) retention and percent N intake for lambs consuming the CL-CSH mixtures were similar to lambs consuming the CSH as roughage. Lambs consuming the control diet exhibited greater ($P < .01$) N retention and percent N intake retained than all other treatments.

Dry matter digestibility (DMD) and OMD were parallele for all treatments. The CSH diet and all CL-CSH mixtures were similiar in digestibilities. Lambs on the control diet demonstrated higher ($P < .01$) digestibilities than CSH and CL-CSH mixtures as was expected. The digestibilities reported for the complete diets used in this experiment were indicative of the high in vitro digestibility of CL reported by Hale et al. (1969) and Millet et al. (1975). These data indicate that CL could be a valuable substitute for CSH as a feedstuff for growing lambs.

Experiment 2. Lamb performance data from the growing-finishing experiment are shown in Table 3. Lambs consuming both CL-CSH mixtures had similiar ADG, and F/G as compared to corn silage and CSH treatments. Lambs consuming the corn silage treatment had lower ($P < .05$) ADF consumption than lambs on the three other treatments. Significantly, less ($P < .05$) of the 2 + 5 mix was consumed than the CSH treatment. Similar ADF consumptions were observed for the 1 + 5 mix and CSH treatments as well as the 1 + 5 mix and 2 + 5 mixtures exhibiting similar results.

Blood data are presented in Table 4. Lambs consuming either the 1 + 5 mix or 2 + 5 mix did not exhibit any significant differences in any of the blood variables tested. Futhermore, no abnormalities were noted from visual appraisal of organs at time of slaughter or after microscopic examination of cross-sectional tissue samples.

Only a small amount of literature is available on the animal use of CL. However, in vitro data (Hale et al., 1969; Millet et al., 1975; Jones et al., 1976) parallels the data reported in this study. Under these experimental feedlot conditions CL obtained by the dilute sulfuric acid process served as an equal substitute for a portion of the roughage (CSH or corn silage) in growing-finishing lambs diets. Equivalent values, for N utilization and digestibility of DM and OM, were also noted when lamb diets containing CSH were partially substituted with CL. Furthermore, substitution of 11.4% of the roughage in lamb diets with CL resulted in equal performance.

**Table 2. Intake and Apparent Digestibilities Experiment 1.**

| | Treatments | | | | |
|---|---|---|---|---|---|
| ITEM | A<br>Control | B<br>40%<br>CSH | C<br>40%<br>1+5 | D<br>40%<br>2+5 mix | E<br>40%<br>3+5 mix |
| Dry Matter intake (g/day) | 700 | 700 | 700 | 700 | 700 |
| N retention (g/day) | 4.3$^{a}$±1.11 | 1.2$^{b}$± .72 | 1.7$^{b}$± .81 | 2.0$^{b}$± .90 | 1.8$^{b}$± .57 |
| Percent N intake retained | 36.8$^{a}$±2.62 | 14.4 $^{b}$±.98 | 18.7$^{b}$±1.34 | 21.9$^{b}$±1.41 | 19.1$^{b}$±1.37 |
| Digestibility (%) dry matter | 76.4$^{a}$±4.21 | 59.9$^{b}$±1.47 | 66.2$^{b}$±2.22 | 65.4$^{b}$±2.07 | 65.4$^{b}$±1.94 |
| Organic matter | 77.9$^{a}$±6.02 | 60.6$^{b}$±3.21 | 67.0$^{b}$±4.19 | 65.9$^{b}$±4.11 | 64.9$^{b}$±3.73 |

$^{a,b}$Means within a row followed by different superscripts are different (P<.01).
[1]Means ± SE for n = 3.

**Table 3. Intake and Performance of Growing-Finishing Lambs, Experiment 2.**

| | Treatments | | | |
|---|---|---|---|---|
| Criteria | A<br>Corn<br>silage | B<br>Cottonseed<br>Hulls | C<br>1+5 mix | D<br>2+5 mix |
| No. Lambs | 18 | 18 | 18 | 18 |
| Initial wt (kg) | 30.3 | 30.6 | 30.6 | 30.8 |
| Final wt (kg) | 45.30 | 47.5 | 47.0 | 45.7 |
| Days of feed | 120 | 120 | 120 | 120 |
| Average daily feed (kg/day) | 1.0 $^{a}$± .003 | 1.9 $^{c}$± .02 | 1.8$^{b,c}$ ± .03 | 1.7 $^{b}$± .06 |
| Average daily gain (kg/day) | .13 $^{a}$± .002 | .14 $^{a}$± .007 | .14 $^{a}$± .003 | .12 $^{a}$± .002 |
| Feed efficiency (F/G) | 5.2 $^{a}$± .78 | 8.2 $^{a}$± .85 | 7.7 $^{a}$± 1.40 | 7.5 $^{a}$± 2.06 |

$^{a,b,c}$Means within a row followed by different superscripts are different (P<.05).
[1]Means ± SE for n = 3.

**Table 4. Analyses on Blood Variables, Experiment 2.**

| | Treatments* | | | |
|---|---|---|---|---|
| ITEM | A | B | C | D |
| Alkaline phosphatase, IU/1 | 199 ±32.53 | 177.2 ±16.46 | 215.6 ±16.46 | 241.2 ±31.32 |
| Glutamic oxaloacetic transaminase,IU/1 | 69.4 ± 7.82 | 51.8 ± 2.65 | 62.0 ± 4.30 | 71.8 ± 7.41 |
| Red blood cells, million/mm$^3$ | 8.57 ± .492 | 10.76 ± 1.025 | 9.47 ± .434 | 10.41 ± .553 |
| Total leucocytes, thousand/mm$^3$ | 7.72 ± 1.022 | 7.12 ± .857 | 8.28 ± 1.37 | 7.84 ± 1.109 |
| Hemoglobin, g/100ml | 11.06 ± .252 | 11.36 ± .264 | 11.36 ± .264 | 11.2 ± .405 |
| Packed cell volume, % | 40.2 ± .80 | 42.4 ± 1.66 | 43.0 ± 1.816 | 42.8 ± 2.29 |
| Polymorpho-nuclear, % | 31.0 ± 5.88 | 31.6 ±13.18 | 19.2 ± 1.88 | 24.8 ± 5.57 |
| Lymphocytic,% | 66.2 ± 5.68 | 50.8 ±18.28 | 75.4 ± 1.435 | 73.0 ± 5.07 |
| Eosinophils, % | 1.8 ± .916 | .6 ± .4 | 4.8 ± 1.772 | 1.6 ± .6 |
| Monocytic, % | 1.0 ± .447 | 17.2 ±15.71 | .8 ± .374 | .6 ± .245 |

*No differences (P > .05).
+Mean ±SE for n = 5.

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# RESPONSE OF WW-517 OLD WORLD BLUESTEM TO FERTILIZATION, WATERING, AND CLIPPING

**Robert A. Masters and Carlton M. Britton**


## ABSTRACT

**An experiment (TUBE) was conducted to evaluate the effect of two levels of fertilizer, two levels of watering, and clipping on dry matter (DM) and crude protein yield, water use efficiency (WUE), and end of season root weights of WW-517 Old World Bluestem (OWB) (Bothriochloa intermedia var. indica) established in plastic tubes buried in the soil. A second experiment (MICROPLOT) evaluated dry matter and crude protein yield of OWB, in 2.7 ft² plots within a two year old grass stand, at two levels of fertilizer and five clipping regimes. In the TUBE experiment, fertilization had no effect on leaf yields, but the wet-clipped treatment increased leaf yields 40% compared to dry-unclipped plants. Level of fertilizer applied did influence OWB stem, top-growth (aboveground portion less stubble), and aboveground yields. The wet-fertilized-clipped treatment increased top-growth and above ground yields by 54 and 49% when compared to dry-unfertilized-unclipped plants. Frequency of watering, unlike fertilization or clipping, did not significantly influence OWB WUE. Water use efficiency of OWB, averaged across watering regimes, was 1.2 and 0.7 g DM/L water for fertilized-clipped and unfertilized-unclipped plants, respectively. Leaf crude protein yield of wet-fertilized plants was at least 35% greater than other treatments. End of season root weights increased with frequency of watering, but declined with fertilization and clipping. In the MICROPLOT experiment, leaf, top-growth, and crude protein yields were enhanced by fertilization and clipping. Results from this study indicate fertilization coupled with clipping at proper intervals increased aboveground plant yield and nutritive value. Response to these treatments was further enhanced with addition of water. In contrast, root weights were reduced following fertilization and clipping. Reduction in root weights, likely decreased the volume of soil from which plants could extract water and nutrients and may ultimately have an adverse affect on plant vigor.**


## INTRODUCTION

As a group, Old World bluestems are endemic to mid eastern countries. They possess the $C_4$ carbon assimilation pathway (Downton 1975) and most reproduce apomictically (Harlan et al. 1964). These grasses were first introduced into the United States in 1917 for use as improved forage plants and for soil stabilization purposes. Old World bluestems have significantly contributed to beef production in the Southern Great Plains because they are superior to native North American bluestems in production, persistence under grazing, and response to fertilization (Sims and Dewald 1982).

WW-517 Old World bluestem (**Bothriochloa intermedia** var. **indica**) is a selection from blends of genetically diverse bluestems with morphological similarities from Pakistan and Afghanistan (Sims and Dewald 1982). Sims et al. (1983) found animal performance on WW-517 comparable to WW-Spar, a released variety of Old World bluestem.

Forage yield, crude protein content, and water use efficiency can be enhanced by fertilization, irrigation, and defoliation (Wight and Black 1979; McMurphy et al. 1975; Smika et al. 1965; Jameson 1963). In Oklahoma, Caucasian bluestem (**Bothriochloa caucasia**) production increased 2000 and 1350 lb/ac during a wet and dry year following fertilization with 55 lb N/ac (Berg and Coyne 1983). The response of WW-517 Old World bluestem to fertilization, watering, and clipping must be understood to properly manage the species. With proper coordination of these treatments, plant yield, crude protein content, and water use efficiency can be enhanced. The objective of this study was to evaluate the effect of fertilization, watering, and clipping on aboveground, root, and crude protein yield, and water use efficiency of WW-517 Old World bluestem.

## METHODS

To accomplish the objective of this study, TUBE and MICROPLOT experiments were conducted. In the TUBE experiment, WW-517 Old World bluestem plants were grown in plastic tubes buried in a field environment. As a result, response of aboveground and root portions of plants to fertilization, watering, and clipping could be evaluated. The MICROPLOT experiment was undertaken to determine the response of OWB; top-growth (aboveground plant portion less the stubble) to fertilization and clipping in a field environment.

### TUBE Experiment

During the fall of 1981, 342 Visten plastic tubes (12 inches diameter X 24 inches length), sealed at one end, containing 90 lb of Amarillo fine sandy loam soil (fine, loamy, mixed, thermic Aridic Paleustalf), were placed in holes. Tubes were secured in the soil with the open ends exposed. On 4 June 1982, approximately 25 caryopses of WW-517 Old World bluestem (OWB) were planted in each of 342 tubes. At the four leaf growth stage, seedlings were thinned to four per tube. Plants were uniformily watered every 14 days throughout the summer and early fall of 1982.

On 28 April 1983 OWB plants within the tubes were clipped to a 3-inch stubble height. At this time 20 tubes containing OWB were excavated and soil washed from the plant roots. This preliminary harvest provided information on aboveground and root portions prior to treatment application.

On 29 April 1983, 168 randomly selected tubes were fertilized each with 3.8 g $NH_4NO_3$ and 3.0 g $KH_2PO_4$ (comparable to broadcast fertilizer application rate of 65-30-40 lb N-P-K/ac). Watering started on 12 May and ended 1 November 1983. Ninety-eight of the fertilized tubes (F) and 84 unfertilized tubes (UF) were watered to field capacity once every seven days (WET) while remaining tubes were watered to field capacity at 14 day intervals (DRY). As a result of the limited volume of soil within the plastic tubes all plants were watered during the experiment.

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Soil samples were collected from four tubes per treatment combination 24 hours prior to watering, oven dried at 220°F, and weighed. An average water content of the four samples was obtained and amount of water applied to each tube was determined by comparing the average water content of the soil within the tubes with a water retention curve delineated for the soil. A pressure plate apparatus as described by Richards (1947) was used to determine water retention values for the soil. To lessen impact of soil removal during the study only two cores (10 inches length × 0.75 inch diameter were taken from any tube. In addition, oven dried loamy sand soil, passed through a 0.5 mm mesh screen, replaced soil removed during sampling.

Clipping treatments took place between 17 May and 15 September 1983. Half the OWB within each fertilization by watering treatment combination were clipped to a 3-inch stubble height when regrowth height reached 12 inches. To obtain an estimate of cumulative yield all plants were clipped to a 3-inch stubble height on 15 March 1984. At each clipping date aboveground plant portions were oven dried at 140°F for 48 hours. After drying, top-growth samples were separated into leaves (leaf sheath and blade) and stems then weighed. Leaf and stem tissue were then ground in a Wiley Mill. Crude protein content (CP) of these tissues was determined using the microkjeldahl procedure for nitrogen determination (N) (CP = % N × 6.25) (A.O.A.C. 1960).

At each top-growth harvest 14 plants per fertilization and watering treatment were excavated from the field. Seven of the excavated plants had been clipped according to previously specified clipping criteria. Remaining plants were not clipped until the date of excavation. Thus, a comparison between periodically clipped (C) and unclipped (UC) plants was possible. Soil was washed from plant roots within the excavated tubes. To reduce root loss, soil was washed through two, 0.5 mm mesh screens. Washed plants were oven dried, separated into aboveground and root portions, and weighed.

Immediately before excavation, gravimetric soil samples were taken from each tube. Soil water content of excavated tubes were used to estimate plant water use from the beginning of the growing season to time of excavation. Water use efficiency was calculated by dividing top-growth dry matter weight by amount of water added to tubes during the growing season minus amount of water present in the soil at time of harvest. When precipitation occurred on the study site it was assumed that it fell uniformly on all plants, regardless of treatment. Precipitation amounts were added to amount of water added during watering events and this combined total was used in calculating WUE. Precipitation data are presented in Figure 1A.

To obtain estimates of cumulative plant dry matter, crude protein yield, and top-growth water use efficiency for the growing season, seven plants (plants were the experimental units) per fertilization, watering, and clipping treatment combination were randomly selected and were not excavated until the final harvest date, 15 March 1984. Remaining plants were relegated to excavation following top-growth harvest.

## MICROPLOT Experiment

On 21 May 1982, a 2.5 ac field near Brownfield, Texas was seeded with WW-517 Old World bluestem at a rate of 2 lb PLS/ac. The soil on the Brownfield study site was an Amarillo loamy fine sand (fine, loamy, mixed, thermic Aridic Paleustalf). On 17 March 1984 the site was burned to remove standing dead plant material. On 20 April 1984 ten, 30 × 30 ft plots were established in the grass stand at the study site. Five plots were randomly selected and fertilized at a rate of 55-27-36 lb N-P-K/ac.

Five clipping treatments were conducted between 1 June and 15 September 1984 and on 9 March 1985. In May 1984 25, 2.7 ft$^2$ plots (microplots) were located within fertilized and unfertilized plots within the grass stand. The five clipping treatments were randomly assigned to five microplots located in each fertilized or unfertilized plot. The first treatment (D1) involved clipping five previously unclipped microplots on 9 March 1985. The second treatment (D2) consisted of clipping five microplots at 45 day intervals from 1 June to 30 August 1984 and on 9 March 1985. WW-517 Old World bluestem undergoing clipping treatments D1 and D2 were harvested to 3-inch stubble heights. The final three clipping treatments involved clipping OWB within five microplots each to either a 3-inch (D3) (same clipping criteria used in the TUBE experiment), 2-inch (D4), or 4-inch (D5) stubble height when regrowth height reached 12 inches. Plants undergoing clipping treatments D3, D4, and D5 were clipped from 1 June 1984 to 15 September 1984 and on 9 March 1985. Harvested top-growth from microplots was oven dried, separated into leaf and stem portions, and weighed. Crude protein content of plant tissues was determined as mentioned previously. Precipitation data are presented in Figure 1B.

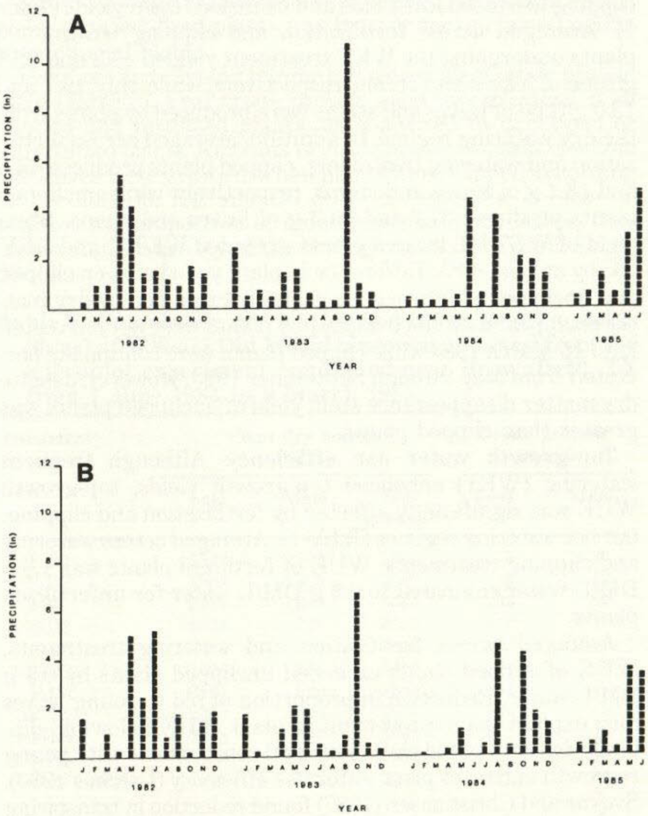


**Figure 1. Monthly precipitation (in) occurring on the Lubbock (A) and Brownfield study sites (B) from 1982 through 1985.**

### Data Analyses

The TUBE experiment was arranged as a $2^3$ factorial in a completely random design with seven replications per treatment combination. The MICROPLOT experiment was a randomized complete block arranged as a split plot with fertilization as the main plot effect and clipping treatment as the subplot effect with five replications per treatment combination. Since plants were clipped according to morphological criteria and not at specific time intervals-standard statistical procedures could not be used to compare plant responses during the growing season. However, because final harvests for all plants, regardless of clipping treatment, occurred on 15 March 1984 in the TUBE experiment and 9 March1985 in the MICROPLOT experiment cumulative dry matter yield and crude protein content of the grasses in both experiments and cumulative water use efficiency and end of season root weights of plants in the TUBE experiment were evaluated using analysis of variance procedures appropriate for the respective experimental designs. Treatment means were compared at the 0.05 level of probability using Tukey's w-procedure (Ott 1977).

## RESULTS AND DISCUSSION

### TUBE Experiment

**Top-growth yield**. Fertilization, unlike watering and clipping regimes, had no significant effect on cumulative leaf dry matter yields (Table 1). In contrast, cumulative stem and top-growth dry matter yields were significantly affected by fertilization, watering, and clipping. Averaged across watering and clipping treatments, fertilized plant stem yield was 19.0 g/tube compared to 13.7 g/tube for unfertilized plants.

The WET treatment increased leaf and stem yields while clipping increased leaf yields and decreased stem yields (Table 1). Averaged across fertilization and clipping treatments, plants undergoing the WET treatment yielded 43.3 and 29.1 g/tube of leaves and stems, respectively, while only 19.7 and 13.0 g/tube of leaves and stems were produced by plants from the dry watering regime. In addition, averaged across fertilization and watering treatments, clipped plants produced 44.6 and 13.4 g of leaves and stems, respectively, while unclipped plants produced 27.7 and 19.3 g of leaves and stems. Stem yield of WET-UC treated plants exceeded WET-C, and DRY-UC by at least 40%. Difference in plant yield between clipped and unclipped plants may be partially explained by dry matter disappearance since unclipped plants were not harvested until 15 March 1984 while clipped plants were continually harvested from May through September 1983. However, despite dry matter disappearance stem yield of unclipped plants was greater than clipped plants.

**Top-growth water use efficiency**. Although frequent watering (WET) enhanced top-growth yields, top-growth WUE was significantly affected by fertilization and clipping, but not watering regimes (Table 1). Averaged across watering and clipping treatments, WUE of fertilized plants was 1.0 g DM/L water compared to 0.8 g DM/L water for unfertilized plants.

Averaged across fertilization and watering treatments, WUE of clipped plants exceeded unclipped plants by 0.3 g DM/L water. Reduction in proportion of old to young leaves may explain the improvement in plant WUE following clipping. Removal of old leaf tissue and replacement with young regrowth enhances plant water use efficiency (Larcher 1980). Svejcar and Christiansen (1987) found reduction in transpiring surface of Caucasian Old World bluestem by heavy grazing reduced water loss and enhanced plant water potential. Moreover, adequate water was available for a longer period of time on heavily grazed areas.

**Crude protein yield**. Leaf and stem crude protein yield was greatest for WET-F-C-treated plants (Table 1). Fertilized and clipped plants, watered at seven-day intervals, contained 30, 34, and 53% greater amounts of crude protein than WET-UF-C, DRY-F-C, and DRY-UF-C, respectively. Regardless of fertilization or watering regime, unclipped plants yielded less crude protein than clipped plants.

Contribution of stems to crude protein pool within the plant was minor. Averaged across all treatments, leaves accounted for 88% of the crude protein yielded by the combined leaf and stem fractions. Typically, nutritive value of leaves far exceeds that of stems, regardless of stage of plant maturity (Kalmbalcher 1983; Beaty and Engel 1980).

**Aboveground plant and root weights**. By March, 11 months after treatment initiation, WET-treated plants had produced 30% more aboveground plant dry matter than plants watered at 14-day intervals, regardless of fertilization or clipping treatment (Table 2). Clipping fertilized plants, regardless of watering regime, increased yield by more than 20% as compared to unclipped fertilized plants. In contrast, clipping had no effect on yield of unfertilized OWB, within a watering regime.

**Table 1. Cumulative dry matter (DM) and crude protein yield and top-growth water use efficiency (WUE) of WW-517 Old World bluestem obtained from the tube experiment conducted near Lubbock, TX from 17 May 1983 to 15 March 1984.**

| Treatment[1] | | Plant dry matter (g/tube) | | | WUE of top-growth (g DM/L water) | Crude protein (g/tube) | |
|---|---|---|---|---|---|---|---|
| | | Leaf | Stem | Top-growth[2] | | Leaf | Stem |
| **WET** | | | | | | | |
| F-C | | 59.1 | 21.4 | 84.2 | 1.3 | 7.6 | 0.7 |
| F-UC | | 28.9 | 25.9 | 55.5 | 0.8 | 1.9 | 0.7 |
| UF-C | | 52.3 | 8.6 | 63.1 | 0.9 | 4.9 | 0.2 |
| UF-UC | | 32.8 | 22.9 | 56.2 | 0.8 | 1.4 | 0.6 |
| **DRY** | | | | | | | |
| F-C | | 37.0 | 13.8 | 52.8 | 1.1 | 3.5 | 0.4 |
| F-UC | | 24.9 | 14.7 | 40.5 | 0.9 | 1.8 | 0.4 |
| UF-C | | 30.0 | 9.6 | 42.7 | 1.0 | 4.3 | 0.3 |
| UF-UC | | 24.4 | 13.7 | 38.7 | 0.7 | 1.6 | 0.4 |
| Tukey (0.05)[3] | | NS | NS | NS | 0.2 | 1.2 | 0.2 |
| | | **Analyses of variance[4]** | | | | | |
| **Source** | **df** | | | | | | |
| Replication | 6 | NS | NS | NS | NS | NS | NS |
| (F)ertilize | 1 | NS | ** | ** | ** | ** | ** |
| (W)ater | 1 | ** | ** | ** | NS | ** | ** |
| (C)lip | 1 | ** | ** | ** | ** | ** | ** |
| F X W | 1 | NS | * | NS | NS | ** | ** |
| F X C | 1 | * | ** | ** | NS | NS | ** |
| W X C | 1 | ** | ** | * | NS | ** | * |
| F X W X C | 1 | NS | NS | NS | * | ** | * |
| Error | 42 | 55.8 | 15.8 | 76.7 | 0.02 | 0.5 | 0.01 |

[1]Treatments are, WET = watered every seven days, DRY = watered every 14 days, F = fertilized (equivalent to broadcast application of 65-30-40 lb N-P-K/ac, UF = unfertilized, C = clipped to a 3 inch stubble height when regrowth reached 12 inches, and UC = unclipped.

[2]Top-growth is aboveground plant portion less the stubble.

[3]Critical values for comparison of treatment means obtained using Tukey's w-Procedure where $\alpha = 0.05$ and df = 40. NS is not significant.

[4]** and * indicate significance at the 0.01 and 0.05 levels.

Based on main treatment effects, end of season root weights were increased by the WET watering regime and decreased by fertilization and clipping (Table 2). Average across treatments root weights of fertilized and unfertilized plants were 28.7 and 40.0 g/tube, WET and DRY treatments were 41.0 and 24.7 g/tube, and clipped and unclipped plants were 29.2 and 36.5 g/tube.

Adverse response of OWB roots to clipping in this study is similar to decline in Caucasian and WW-Spar Old World bluestem root biomass following severe defoliation and subsequent aboveground plant regrowth observed by Coyne and Bradford (1986). Crider (1955) found defoliation reduced root weight of selected grasses and degree of decrease was proportional to amount of foliage removed. Little bluestem roots harvested from an ungrazed portion of a pasture weighed 2.5 and 15.5 times more than root samples taken from moderately and heavily grazed areas within the pasture (Weaver 1950). Clipping-induced reduction in OWB root weight could have an adverse effect on plant productivity.

Extrapolation of these result to a defoliated plant in a pasture environment, unencumbered by a plastic tube as in this study, would equate to a decrease in soil volume exploited by the roots, reducing plant access to nutrients and water. Total quantity of water available to the plant increases with volume of soil occupied by its roots (Taylor and Klepper 1978). White and Brown (1972) found the ability of green needlegrass (**Stipa viridula**) to extract water from deeper than 35 inches in the soil profile was decreased because of reduced root penetration caused by clipping.

**Table 2. Cumulative aboveground plant and end of season root weight and root:aboveground ratio of WW-517 Old World bluestem obtained from the tube experiment conducted near Lubbock, TX from 17 May 1983 to 15 March 1984.**

| Treatment[1] | | Aboveground plant weight (g/tube) | Root weight (g/tube) | Root: aboveground ratio |
|---|---|---|---|---|
| WET | | | | |
| F-C | | 132.4 | 29.8 | 0.22 |
| F-UC | | 96.9 | 39.6 | 0.40 |
| UF-C | | 107.7 | 38.2 | 0.35 |
| UF-UC | | 101.7 | 56.4 | 0.56 |
| Dry | | | | |
| F-C | | 86.7 | 20.5 | 0.23 |
| F-UC | | 68.5 | 25.1 | 0.37 |
| UF-C | | 81.2 | 28.2 | 0.35 |
| UF-UC | | 67.3 | 25.1 | 0.37 |
| Tukey (0.05)[2] | | 18.1 | 10.5 | 0.11 |
| | | Analyses of variance[3] | | |
| Source | df | | | |
| Replication | 6 | NS | NS | NS |
| (F)ertilize | 1 | * | ** | ** |
| (W)ater | 1 | ** | ** | ** |
| (C)lip | 1 | ** | ** | ** |
| F X W | 1 | NS | ** | * |
| F X C | 1 | * | NS | NS |
| W X C | 1 | NS | ** | ** |
| F X W X C | 1 | * | * | * |
| Error | 42 | 112.1 | 37.6 | 0.004 |

[1]Treatments are, WET = watered every seven days, DRY = watered every 14 days, F = fertilized (equivalent to broadcast application of 65-30-40 lb N-P-K/ac, UF = unfertilized, C = clipped to a 3 inch stubble height when regrowth reached 12 inches, and UC = unclipped.
[2]Critical values for comparison of treatment means obtained using Tukey's w-Procedure where $\alpha = 0.05$ and df = 40. NS is not significant.
[3]** and * indicate significance at the 0.01 and 0.05 levels.

Pattern of OWB root weight changes over time differed between clipping treatment (Fig. 2). OWB responded to clipping by producing aboveground growth at expense of root growth. Root weights of clipped OWB increased initially from mid-May to mid-June followed by a decline through mid- to late-July then increased through March. The period of root decline corresponded with growth of aboveground portions. In contrast, with the exception of fertilized and WET-treated plants, root weights of unclipped plants increased throughout the study period. Rate of increase of root and aboveground plant weight of clipped and WET-treated plants from early June to mid-July was -0.02 and 1.4 g/day/tube for fertilized plants and -0.3 and 0.9 g/day/tube for unfertilized plants. At the same time, root and aboveground plant weight of unclipped plants, watered every seven days, increased 0.3 and 1.3 g/day/tube for fertilized and 0.2 and 0.7 g/day/tube for unfertlized plants. Decrease in root weight and increase in aboveground weight following clipping may result from reallocation of carbon assimilates from roots to shoots. This assimilation reallocation enables the plant to reestablish predefoliation root:shoot ratios (Ryle and Powell 1975; Detling et al. 1979).

With the exception of DRY-UF-treated plants, the proportion of root to aboveground yield was consistently greater in unclipped than clipped plants. By March 1984, root: aboveground yield ratio of fertilized and clipped, WET- and DRY-treated plants was only 0.22 and 0.23, respectively, while ratio of fertilized and unclipped plants was 0.40 and 0.37 for WET- and DRY-treated plants, respectively (Table 2). This evidence indicated clipped OWB was unable to regain predefoliation root:shoot ratios, comparable to unclipped plants prior to dormancy.

## MICROPLOT Experiment

Leaf and top-growth weight of fertilized OWB was greatest for plants that were clipped every 45 days to a 3-inch stubble height (Table 3). Stems comprised 50% of top-growth of unclipped plants and 34% of top-growth of plants clipped at 45 day intervals. In contrast, only about 10% of the harvested top-growth of plants clipped according to regrowth height criteria (D3, D4, and D5 treatments) were composed of stems.

Unfertilized OWB responded differently to clipping than fertilized plants (Table 3). Top-growth weight of unfertilized OWB did not differ, regardless of clipping treatment. Stem yield of unfertilized plants was greater for unclipped plants than clipped plants.

Fertilizer and clipping regime influenced plant crude protein yield (Table 3). Leaf crude protein yield was greatest in all clipped and fertilized plants, as compared to unclipped or unfertilized plants. Amounts of crude protein contained within the leaves were greatest when plants were clipped according to the D2, D3, D4, and D5 criteria. Generally, defoliation reduces the proportion of older, less nutritious leaves, thus increasing the quality of the herbage mass (Beaty and Engle 1980).

**Table 3. Cumulative dry matter and crude protein yields (lb/ac) of WW-517 Old World bluestem obtained from the microplot experiment conducted near Brownfield, TX from 1 June 1984 to 9 March 1985.**

| Treatment[1] | | Plant dry matter (lb/ac) | | | Crude protein (lb/ac) | |
|---|---|---|---|---|---|---|
| | | Leaf | Stem | Top-growth[2] | Leaf | Stem |
| F-D1 | | 2532 | 2363 | 5006 | 110 | 25 |
| UF-UC | | 1963 | 1568 | 3547 | 55 | 12 |
| F-C | | 3977 | 1892 | 5666 | 333 | 60 |
| UF-D2 | | 2052 | 728 | 3100 | 142 | 12 |
| F-D3 | | 3725 | 595 | 4617 | 427 | 18 |
| UF-D3 | | 1534 | 648 | 2319 | 94 | 8 |
| F-D4 | | 2801 | 503 | 3304 | 284 | 11 |
| UF-D4 | | 2318 | 630 | 2977 | 146 | 5 |
| F-D5 | | 2998 | 380 | 3549 | 372 | 16 |
| UF-D5 | | 1163 | 646 | 2052 | 72 | 9 |
| Tukey (0.05)[3] | | 1210 | 732 | 2030 | 125 | 28 |
| | | Analyses of variance[4] | | | | |
| Source | df | | | | | |
| Replication | 4 | NS | NS | NS | NS | NS |
| (F)ertilize | 1 | ** | ** | ** | ** | ** |
| Error a | 4 | 592615 | 112334 | 887547 | 7727 | 207 |
| (C)lip | 4 | ** | ** | ** | ** | ** |
| F X W | 4 | ** | ** | * | ** | ** |
| Error b | 32 | 348265 | 127477 | 980671 | 3752 | 176 |

[1]Treatments are, F = fertilized (55-27-36 lb N-P-K/ac), UF = unfertilized, D1 = clipped 9 March 1985 to 3 inch stubble height, D2 = clipped at 45 day intervals from 1 June 1984 to 30 August 1984 and on 9 March 1985, D3 = clipped to 3-inch stubble height when regrowth height reached 12 inches, D4 = clipped to 2-inch stubble height when regrowth reached 12 inches, and D5 = clipped to 4-inch stubble height when regrowth reached 12 inches.
[2]Top-growth is aboveground plant portion less the stubble.
[3]Critical values for comparison of treatment means obtained using Tukey's w-Procedure where $\alpha = 0.05$ and df = 16. NS is not significant.
[4]** and * indicate significance at the 0.01 and 0.05 levels.

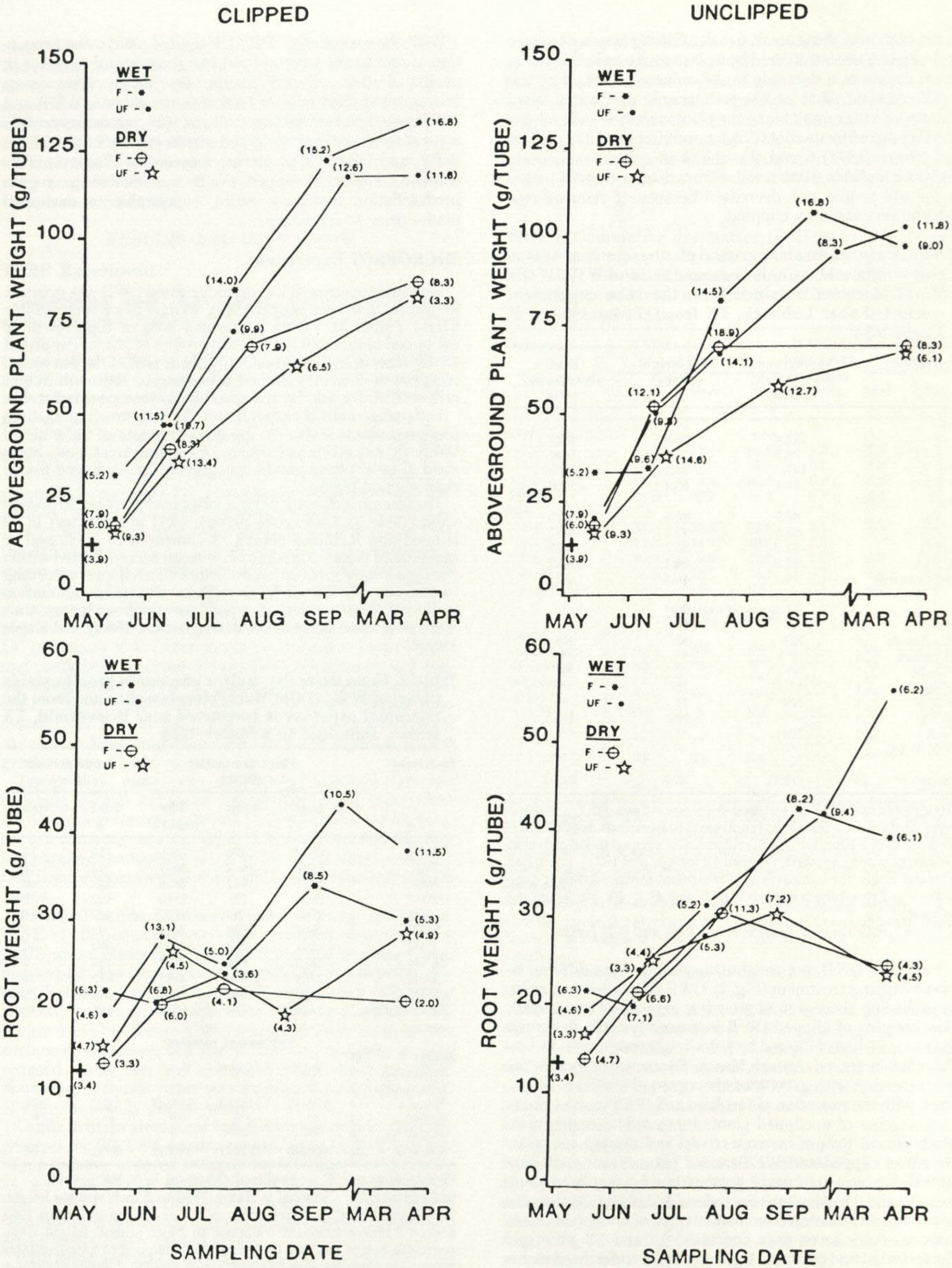


**Figure 2. Aboveground and root weights (g/tube) of clipped (clipped to 3-inch stubble height when regrowth height reached 12 inches) and unclipped WW-517 Old World bluestem from the TUBE experiment conducted near Lubbock, Texas. WET = watered every seven days, DRY = watered every 14 days, F = fertilized (equivalent to broadcast application of 65-30-40 lb N-P-K/ac), and UF = unfertilized. The + denotes pretreatment means. Numbers within parenthesis represent standard deviation of associated treatment mean.**

Stems produced by plants clipped according to D2 (clipped at 45-day intervals) criteria contained significantly greater amounts of crude protein than other fertilized plants. This greater amount was attributed to increased stem yield rather than a greater concentration of nitrogen within the stem tissue (data not shown).

## CONCLUSION

Comparison between the TUBE and MICROPLOT experiments is difficult because of differences in plant environments. In the TUBE experiment plants were established in plastic tubes and therefore, did not compete with other plants for nutrients, water, or light, unlike plants in the MICROPLOT experiment. However, despite difference in magnitude of response, fertilizer and clipping increased yield of aboveground plant portion and crude protein of plant tissue in both experiments. Moreover, clipping reduced amount of stems in top-growth plant portions, thus maintaining plants in a vegetative condition of higher nutritive quality. Results from this study indicate fertilization coupled with clipping at proper intervals enhanced plant growth and nutritive value and magnitude of plant response to these treatments was further enhanced by water supplementation. In contrast, fertilization and clipping reduced root weights. Root biomass reduction could restrict plant access to soil water and nutrients and ultimately decrease plant productivity.

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