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# Palustrine Wetland Vegetative Dominance Types Along the Central Coast of Texas

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## ABSTRACT

**We studied vegetative dominance types in natural and man-made palustrine emergent wetlands in the central coast of Texas during 1991-93. Study design consisted of a stratified random sample of 64.5-ha plots. Fifty-seven dominance types were recorded. Typha *domingensis* was the most abundant dominance type throughout the winter covering over 9,000 ha. Eighty percent of the dominance types were perennials, 93% were native, and 84% were classified as warm-season growth plants. The five most abundant dominance types (i.e., *Typha domingensis, Phragmites australis, Spartina spartinae, Zizaniopsis milacea,* and *Scirpus californicus*) form thick stands of tall, robust emergents that generally make the wetlands unsuitable for wintering waterfowl.**

**KEYWORDS:** Texas Coast, wetland vegetation, palustrine wetlands

Palustrine wetlands are nontidal and tidal wetlands dominated by trees, shrubs, or persistent emergents where ocean-derived salts are <0.5 parts per thousand (ppt) (Cowardin et al., 1979). Palustrine wetlands also include wetlands lacking such vegetation but are <8 ha in area, lack active wave-formed or bedrock shoreline features, are <2 m deep at low water, and have ocean-derived salt levels <0.5 ppt (Cowardin et al., 1979). Palustrine emergent wetlands are wetlands that meet the above definition and are characterized by erect, rooted herbaceous hydrophytes excluding mosses and lichens (Cowardin et al., 1979). Persistent emergent wetlands are dominated by species that generally remain standing until the next growing season (Cowardin et al., 1979). Nonpersistent wetlands are dominated by plants that do not remain standing until the next growing season (Cowardin et al., 1979).

Palustrine emergent wetlands provide important and abundant habitat for waterfowl and other wetland wildlife (Weller and Spatcher, 1965; Murkin et al., 1982; Anderson, 1994; Anderson et al., 1996). Some emergent wetland types produce abundant food resources for waterfowl (Fredrickson and Taylor, 1982; Anderson and Smith, 1998). Wetland vegetation also provides valuable forage for livestock (Catling et al., 1994; Garza et al., 1994).

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More than 100 species of waterbirds use palustrine emergent wetlands along the coast of Texas (Anderson, 1994; Anderson et al., 1996). Coastal Texas is one of the most important wintering grounds for waterbirds in the United States (Anderson and DuBowy, 1996; Anderson et al., 1998). An estimated 3.5 million ducks and 3.3 million geese winter in the lower and middle coast region of Texas (Anderson et al., 1998). The area also provides important habitat for migrating waterfowl, including >500,000 blue-winged teal (*Anas discors L.*) (Anderson et al., 1998). Over 1.5 million other waterbirds extensively use coastal Texas wetlands during winter (Anderson et al., 1998). The central coast of Texas is especially important, harboring about 90% of wintering ducks; 80% of wintering shorebirds, rails, and waders; 90% of geese; and 60% of gulls, terns, and allies (Tacha et al., 1993; Anderson et al., 1998).

Natural and man-made palustrine emergent wetlands cover over 200,000 ha in coastal Texas (Tacha et al., 1993; Muehl et al., 1994). Despite the abundance of emergent wetlands, no data exist on the abundance of vegetative dominance types occurring in this area. Determining the amount of wetland area covered by each species is vital for describing coastal Texas wetlands.

Description and classification of vegetation provides baseline information for ecological studies concerning wildlife and vegetation management (Meyer, 1985). Baseline information on vegetation abundance provides valuable data on the current status of wetlands and for monitoring the effects of future wetland management actions or continued wetland destruction (Dahl, 1990). The purpose of this study was to document the area of palustrine emergent wetlands dominated by vegetative types in coastal Texas and discuss vegetation as it relates to waterfowl management on the Texas coast.

## MATERIALS AND METHODS

The study area includes 16 Texas counties from Corpus Christi to Galveston Bay (Anderson et al., 1996), totaling 3.6 million ha. Climate is subtropical humid with warm summers (Larkin and Bomar, 1983). Average precipitation ranges from 133 cm in the north to 87 cm in the south (National Fibers Information Center, 1987).

The study area is located primarily in the Gulf Prairie and Marsh Ecological Areas of Texas (McMahan et al., 1984). Native climax vegetation is largely tall-grass prairie, with some *Quercus stellata* Wang. savannah on upland areas (Gould, 1969). Climax vegetation in the prairie is dominated by tall bunchgrasses such as *Andropogon gerardi, Schizachyrium scoparium, Sorghastrum nutans* (L.) Nash, *Tripsacum dactyloides* (L.) L., and *Panicum* spp. L.

Soil associations are mainly Lake Charles-Edna-Bernard, Moreland-Pledger-Norwood, Victoria-Orelia-Clareville, and Harris-Veston-Galveston (Westfall, 1975). These associations generally are characterized by soils that are somewhat poorly drained, and have a surface layer of fine sandy loam above several layers of clay and sandy clay to a depth of 2 m.

The study area was divided into three strata based on physiographic regions and land practices: coastal, rice prairie, and other crop (Anderson et al., 1996; 1998). Descriptions of strata can be found in Anderson et al. (1996).

Sample selection and allocation for each strata are described in Anderson (1994) and follow Muehl et al. (1994). In 1991-92, we used map coordinates to randomly select 290 64.5-ha plots, hereafter referred to as plots, within strata. After plots were selected, trespass permission was obtained or the plot was replaced with another random plot. The coastal stratum was allocated 25 plots, rice prairie 201 plots, and other crop 64 plots. Data from 1991-92 were used in 1992-93 to reallocate and increase plots among strata according to (Kish, 1965) based on variance estimates for total waterfowl populations and wetland area (Muehl, 1994). We randomly selected 600 plots in the study area the second year; 273 in the coast, 241 in the rice prairie, and 86 in the other crop strata. All surveys for wetlands and their dominance types occurred during surveys in September, November, January, and March of both years. All plots were visited once per survey period.

The dominant vegetative type (species or co-dominants) in each wetland classified as palustrine emergent was determined by walking each wetland and determining ocularly the most frequently occurring species following the methods of Cowardin et al. (1979). A dominant plant species was the predominant species occurring in a wetland (Cain and de Oliveira Castro, 1959:29). Wetland size was determined by measuring wetland length and width and using the formula provided by Millar (1973).

Plants were identified using Godfrey and Wooten (1979; 1981) and Correll and Johnston (1979). Hatch et al. (1990) was used as the taxonomic authority. Plants were classified as to origin (native or introduced), longevity (annual or perennial), and season of growth (warm or cool season) according to Hatch et al. (1990).

Seasonal estimates of area occupied by dominance types in palustrine emergent wetlands were calculated following Muehl et al. (1994). Mean area of each dominance type within sample plots in each stratum were multiplied by the area of each stratum, and the totals were added to give study area estimates. Standard errors associated with estimates of area dominated by vegetative types were calculated following procedures for weighted pooled stratified random samples (Kish, 1965).

## RESULTS

Data from the first year (1991-92) were used to reallocate plots for the second year (1992-93) and therefore are not presented. A total of 57 species was recorded as dominance types on the palustrine emergent wetlands surveyed during 1992-93. Thirty-three genera were recorded, including six species of *Eleocharis.* An additional nine combinations of co-dominants were observed.

*Typha dominigensis* was generally the most abundant species during the four survey periods (Table 1). *Spartina spartinae* was the most abundant species ever recorded covering 12,251 ha in March. Other abundant dominance types included *Erianthus giganteus, Paspalidium geminatum, Phragmites australis, Spartina spartinae, Zizaniopsis milacea, Eleocharis quadrangulata,* and *Scirpus californicus.*

Nine species (16% of total number of species) are classified as annuals: *Leptochloa fascicularis, Polypogon monspeliensis, Cyperus odoratus, Eleocharis obtusa, E. parvula, Fimbristylis autumnalis, Polygonum pennsylvanicum, Sesbania macrocarpa,* and *Ammannia coccinea.* Two species (4%) *Polygonum hydropiper* and *P. hydropiperoides* are considered to be either annuals or perennials. The other 46 species (80%) are perennials. Area dominated by annuals totaled 2,006 ha in September, 971 ha in November, 619 ha in January, and 1,138 ha in March. Area dominated by perennials totaled 24,746 ha in September, 29,760 ha in November, 34,757 ha in January, and 54,360 ha in March.

Fifty-three species (93%) are native to the study area. Four species (7%) are not native to the area: *Polypogon monspeliensis, Sorghum halepense, Rumex crispus,* and *Alternanthera philoxeroides.* Area dominated by introduced species totaled 2,418 ha in September, 683 ha in November, 545 ha in January, and 391 ha in March. Area dominat-

Table 1. Total estimated area (ha) and standard errors (SE)$^{\dagger}$ of palustrine emergent wetland vegetation in the Texas midcoast region during September and November 1992 and January and March 1993 wetland surveys.

| Species | September | | November | | January | | March | |
|---|---|---|---|---|---|---|---|---|
| | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE |
| *Typha angustifolia* L. | 0 | 0 | 0 | 0 | 81 | 64 | 0 | 0 |
| *Typha domingensis* Pers. | 9,186 | 4,948 | 10,369 | 4,885 | 10,847 | 5,197 | 12,192 | 5,152 |
| *Typha latifolia* L. | 93 | 85 | 0 | 0 | 12 | 9 | 15 | 12 |
| *Sagittaria latifolia* Willd. | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| *Sagittaria longiloba* Engelm. | 57 | 57 | 0 | 0 | 0 | 0 | 41 | 25 |
| *Sagittaria platyphylla* (Engelm.) J. G. Smith | 286 | 286 | 0 | 0 | 0 | 0 | 1,050 | 1,050 |
| *Andropogon gerardii* Vitman | 0 | 0 | 170 | 170 | 0 | 0 | 0 | 0 |
| *Andropogon glomeratus* (Walt.) B.S.P. | 0 | 0 | 0 | 0 | 275 | 196 | 277 | 198 |
| *Distichlis spicata* (L.) Greene | 0 | 0 | 32 | 32 | 39 | 33 | 561 | 513 |
| *Erianthus giganteus* (Walt.) F. T. Hubbard | 0 | 0 | 1,752 | 1,752 | 1,752 | 1,752 | 2,858 | 2,858 |
| *Leersia oryzoides* (L.) Sw. | 15 | 15 | 3 | 3 | 3 | 3 | 0 | 0 |
| *Leptochloa fascicularis* (Lam.) Gray | 201 | 185 | 528 | 367 | 187 | 153 | 66 | 66 |
| *Panicum virgatum* L. | 0 | 0 | 86 | 49 | 1 | 1 | 662 | 524 |
| *Paspalidium geminatum* (Forssk.) Stapf | 28 | 28 | 652 | 414 | 2,534 | 1,341 | 4,105 | 2,843 |
| *Paspalum distichum* L. | 1,078 | 1,078 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 1. Continued.

| Species | September | | November | | January | | March | |
|---|---|---|---|---|---|---|---|---|
| | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE |
| *Paspalum lividum* Trin. | 123 | 123 | 54 | 38 | 36 | 36 | 0 | 0 |
| *Paspalum vaginatum* Sw. | 0 | 0 | 0 | 0 | 288 | 288 | 0 | 0 |
| *Phragmites australis* (Cav.) Trin. | 1,328 | 979 | 1,160 | 1,136 | 1,548 | 1,179 | 2,293 | 1,323 |
| *Polypogon monspeliensis* (L.) Desf. | 1,752 | 1,752 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Schizachyrium scoparium* (Michx.) Nash | 0 | 0 | 91 | 69 | 0 | 0 | 0 | 0 |
| *Sorghum halepense* (L.) Pers. | 0 | 0 | 1 | 1 | 9 | 6 | 0 | 0 |
| *Spartina spartinae* (Trin.) Merr. | 0 | 0 | 2,499 | 1,897 | 2,932 | 1,898 | 12,251 | 7,143 |
| *Zizaniopsis milacea* (Michx.) Doell and Aschers | 8,433 | 5,433 | 8,433 | 5,433 | 6,953 | 5,236 | 8,433 | 5,433 |
| *Carex brittoniana* Bailey | 1,051 | 896 | 166 | 166 | 169 | 169 | 0 | 0 |
| *Carex longii* Mack. | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 33 |
| *Carex muhlenbergii* Schkuhr. | 0 | 0 | 0 | 0 | 0 | 0 | 56 | 37 |
| *Cladium jamaicense* Crantz. | 0 | 0 | 47 | 38 | 1,613 | 1,482 | 0 | 0 |
| *Cyperus acuminatus* Torr. and Hook. | 0 | 0 | 0 | 0 | 0 | 0 | 174 | 174 |
| *Cyperus odoratus* L. | 50 | 44 | 19 | 19 | 19 | 19 | 0 | 0 |
| *Eleocharis acicularis* (L.) Roem. and Schult. | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |

Table 1. Continued.

| Species | September | | November | | January | | March | |
|---|---|---|---|---|---|---|---|---|
| | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE |
| *Eleocharis austrotexana* M. C. Johnst. | 59 | 59 | 16 | 16 | 0 | 0 | 95 | 92 |
| *Eleocharis obtusa* (Willd.) Schult. | 0 | 0 | 11 | 11 | 43 | 43 | 11 | 11 |
| *Eleocharis palustris* (L.) Roem. and Schult | 142 | 142 | 123 | 123 | 92 | 82 | 1,154 | 647 |
| *Eleocharis parvula* (Roem. and Schult) Link | 0 | 0 | 42 | 33 | 120 | 78 | 899 | 541 |
| *Eleocharis quadrangulata* (Michx.) Roem and Schult. | 525 | 360 | 1,481 | 503 | 1,833 | 666 | 1,776 | 659 |
| *Fimbristylis autumnalis* (L.) Roem. and Schult. | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 15 |
| *Rhynchospora corniculata* (Lam.) Gray | 0 | 0 | 10 | 10 | 0 | 0 | 0 | 0 |
| *Scirpus americanus* Pers. | 3 | 3 | 0 | 0 | 0 | 0 | 4 | 4 |
| *Scirpus californicus* (C. A. Meyer) Steud. | 176 | 165 | 379 | 308 | 1,215 | 1,172 | 1,953 | 1,297 |
| *Scirpus pungens* Vahl | 0 | 0 | 3 | 3 | 24 | 21 | 6 | 6 |
| *Scirpus robustus* Pursh | 0 | 0 | 28 | 23 | 0 | 0 | 2 | 2 |
| *Scirpus tabernaemontani* Gmelin | 295 | 277 | 363 | 288 | 680 | 591 | 905 | 410 |
| *Juncus effusus* L. | 0 | 0 | 143 | 91 | 463 | 307 | 1,940 | 1,112 |
| *Juncus roemerianus* Scheele | 0 | 0 | 55 | 48 | 197 | 117 | 277 | 198 |
| *Polygonum hydropiper* L. | 0 | 0 | 5 | 5 | 0 | 0 | 0 | 0 |
| *Polygonum hydropiperoides* Michx. | 67 | 66 | 344 | 342 | 105 | 71 | 41 | 41 |

Table 1. Continued.

| Species | September | | November | | January | | March | |
|---|---|---|---|---|---|---|---|---|
| | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE |
| *Polygonum pensylvanicum* L. | 0 | 0 | 179 | 90 | 92 | 49 | 0 | 0 |
| *Polygonum ramosissimum* Michx. | 37 | 29 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Rumex crispus* L. | 0 | 0 | 11 | 11 | 0 | 0 | 0 | 0 |
| *Rumex spiralis* Small | 0 | 0 | 0 | 0 | 0 | 0 | 174 | 174 |
| *Alternanthera philoxeroides* (Mart.) Griseb. | 666 | 480 | 671 | 483 | 536 | 375 | 391 | 316 |
| *Sesbania macrocarpa* Muhl. | 3 | 3 | 88 | 63 | 32 | 29 | 28 | 28 |
| *Ammannia coccinea* Rottb. | 0 | 0 | 104 | 94 | 126 | 126 | 119 | 119 |
| *Ludwigia peploides* Kunth. | 20 | 20 | 0 | 0 | 5 | 5 | 53 | 32 |
| *Aster tenuifolius* L. | 0 | 0 | 447 | 447 | 0 | 0 | 0 | 0 |
| *Leucosyris spinosa* (Benth.) Greene | 1,051 | 896 | 166 | 166 | 169 | 169 | 0 | 0 |
| *Mikania scandens* (L.) Willd. | 7 | 7 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Typha domingensis-Scirpus californicus* | 0 | 0 | 0 | 0 | 224 | 224 | 0 | 0 |
| *Eleocharis quadrangulata-Scirpus californicus* | 0 | 0 | 0 | 0 | 92 | 92 | 0 | 0 |
| *Distichlis spicata-Scirpus californicus* | 0 | 0 | 0 | 0 | 12 | 12 | 0 | 0 |

Table 1. Continued.

| Species | September |  | November |  | January |  | March |  |
|---|---|---|---|---|---|---|---|---|
|  | Estimate | SE | Estimate | SE | Estimate | SE | Estimate | SE |
| *Setaria magna* Griseb.-*Typha latifolia* | 0 | 0 | 11 | 11 | 11 | 11 | 0 | 0 |
| *Alternanthera philoxeroides*-*Paspalidium geminatum* | 0 | 0 | 0 | 0 | 11 | 11 | 0 | 0 |
| *Ammannia coccinea*-*Paspalum distichum* | 0 | 0 | 242 | 231 | 0 | 0 | 0 | 0 |
| *Hymenocallis caroliniana* (L.) Herb.-*Eleocharis quadrangulata* | 0 | 0 | 0 | 0 | 0 | 0 | 530 | 530 |
| *Sorghum halepense*-*Rumex spiralis* | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| *Juncus roemarianus*-*Leersia oryzoides* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |

† SE was derived from variance estimates following procedures for weighted pooled stratified random samples from Kish (1965).

ed by native species totaled 24,334 ha in September, 30,301 ha in November, 34,831 ha in January, and 55,105 ha in March.

Forty-eight species (84%) are classified as warm-season growth plants. Nine species (16%) are classified as cool-season growth plants: *Polypogon monspeliensis, Carex brittoniana, C. longii, C. muhlenbergii, Cladium jamaicense, Eleocharis austrotexana, E. obtusa, E. parvula,* and *Rumex spiralis.* Area dominated by warm-season growth species totaled 23,890 ha in September, 30,702 ha in November, 33,442 ha in January, and 53,698 ha in March. Area dominated by cool-season species totaled 2,862 ha in September, 282 ha in November, 1,945 ha in January, and 1,268 ha in March.

## DISCUSSION

The importance of wetland vegetation to waterfowl depends on several biotic and abiotic factors. Dominant plant species or community composition (White and James, 1978), seed and nutlet production (Fredrickson and Taylor, 1982; Haukos and Smith, 1993), tuber, bulb, and rhizome availability (Alisauskas et al., 1988), nutritional value of foods (Haukos and Smith, 1995; Anderson and Smith, 1998), taxa and abundance of invertebrates (Krapu, 1974), and spatial pattern of vegetation (Weller and Spatcher, 1965; Anderson, 1994) all affect use of palustrine emergent wetlands by waterfowl. Use of vegetated wetlands is also influenced by water depth, hunting pressure, juxtaposition to other wetlands, and surrounding landuse (Jorde and Owen, 1988). Our data are valuable because they address the amount of habitat available as it relates to some of these other factors affecting use by wildlife.

Our data suggests that *Typha domingensis, Phragmites australis, Spartina spartinae, Zizaniopsis milacea,* and *Scirpus californicus* are the 5 most abundant species. These species are all tall, robust, perennial plants that form dense stands and are generally invasive (Beule, 1979). Wetlands dominated by *Typha* spp., *Phragmites australis,* and other plant species that form thick stands often provide poor quality habitat for waterfowl by excluding more valuable vegetation (Beule, 1979; Smith and Kadlec, 1986). These wetland types do not provide the favored aspects of wetlands sought by waterfowl (Anderson, 1994), but no previous estimates of their extent in coastal Texas are available.

No quantitative data exist on palustrine emergent vegetation in coastal Texas, although Stutzenbaker and Weller (1989) list *Typha* spp., *Scirpus* spp., *Cyperaceae, Juncaceae, Echinodorus* spp. and *Rhynchospora* spp. as dominating palustrine and estuarine emergent wetlands. Our study suggests similar findings, but provides unbiased estimates of the amount of area covered by various plant species. Our study supports previous findings that most plant species that occur in wetlands are perennials (van der Valk, 1981).

Our data suggests that if the goal of palustrine wetland management along the Texas coast is for diversity, dominance types rather than nonpersistent emergents should be emphasized, because nonpersistent emergent vegetation is rare in comparison to persistent emergent vegetation. Nonpersistent vegetation in general provides palatable forage and abundant seeds for waterfowl (Haukos and Smith, 1993).

The amount of area dominated by vegetative types in this study should be considered minimum estimates for the area as we did not include estuarine and lacustrine wetland systems (Cowardin et al., 1979), wetlands that did not flood during the study period, and upland areas. Our estimates do, however, provide unbiased estimates of the extent of coverage of vegetation in palustrine emergent wetlands that are potentially accessible to waterfowl. Our data show that most palustrine wetlands are dominated by only one plant species, indicating that many wetlands need to be conserved in order to increase or maintain vegetative diversity.

Relatively high standard errors were associated with the estimates for vegetative dominance types. Standard errors could have been reduced if sample sizes were increased or if plots were reallocated based on palustrine emergent wetlands. One of the main purposes for this study was to estimate waterfowl populations and overall wetland abundance. Therefore, plots were reallocated among strata to reduce variance estimates for total waterfowl (Anderson et al., 1998). Lower standard errors for vegetative dominance types could have been achieved, without increasing sample size, if all plots contained palustrine emergent wetlands.

Plant dominance types are formed in response to water depth, salinity, water turbidity, frequency and duration of flooding, and other chemical and physical parameters (Mitsch and Gosselink, 1986). To decrease the area occupied by Typha spp. and other thick stands of robust emergents a proactive approach of cutting and flooding (Beule, 1979) should be pursued to create more favorable habitats for waterfowl. The goal of palustrine emergent wetland management for waterfowl in coastal Texas should aim for open water interspersed with persistent emergent vegetation and more nonpersistent emergent wetlands.

Coastal Texas has suffered substantial losses of wetlands and degradations of others. Area of wetlands in the upper coast have declined by 16% (>47,000 ha) from the mid 1960's to 1990 (Tacha et al., 1993). Estuarine subtidal unconsolidated bottom wetlands increased 69% and palustrine unconsolidated bottom wetlands increased 754%, indicating substantial losses of vegetated wetlands (Tacha et al., 1993). About 70% of palustrine wetlands in coastal Texas are natural (Tacha et al., 1993; Muehl et al., 1994). We found <10% of the wetland area to be dominated by introduced species. An additional large expanse of area is occupied by thick stands of vegetation that make the wetlands inaccessible to waterfowl. Area dominated by introduced species, wetland losses, and wetland modification combined show that little of the original wetland area is in pristine condition.

Identification of the extent of wetland vegetation types is an important step to improve the decision making process regarding palustrine wetland management for waterfowl in this region. Future research should involve identification of the important emergent vegetative types for waterfowl and other waterbirds in the central coast region of Texas.

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# Exporting Texas' Grapefruit To Southeast Asia

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## ABSTRACT

**With the various demands in grapefruit preference, market growth is very dependent on stable production of quality fruit. Most variation in quantity and quality can be attributed to freezes, production methods and variety. To be successful in exporting, keep the marketing plan simple, use an experienced importer/exporter, supply quality fresh fruits, have quality protection for grapefruit being shipped overseas, make overseas trips to monitor the market as well as meet with importers, and create an in-store promotion plan for each individual country.**

**The GE Matrix reveals that Hong Kong is the best market to enter because of higher Gross Domestic Product and Per Capita Income, better exchange rate and relaxed trade regulations. Both Singapore and Taiwan market positions are about equal in attractiveness and strength characteristics even though Hong Kong had a higher rating. Singapore and Taiwan should not be overlooked as potential markets. All of these countries were in the area of intermediate overall attractiveness and should be considered for selective enhancement and earning potential. All three of these Asian countries are densely populated while having limited domestic production. The primary objective was to develop a feasibility study for grapefruit exporters who desire to do business with this Asian market.**

**KEYWORDS:** grapefruit, market growth, market plan, GE Matrix, Gross Domestic Product, Per Capita Income

The U.S. and Brazil are by far the largest grapefruit producing countries with each supplying over 160 million cartons. U.S. citrus production (1987) represented 68 percent of the world's commercial grapefruit. Florida, the dominant U.S. citrus supply state, accounted for an average of 65 percent, Texas, 20.8 percent while California and Arizona accounted for 14.2 percent of the U.S. grapefruit supply in 1937-87 (Connolly et al., 1989). Texas has a comparative advantage for grapefruit quality due to warmer temperatures which enhance sugar formation. Texas has also been a forerunner in developing new grapefruit varieties: "Ruby" in 1934, "Star Ruby", 1970, and "Rio Red", 1984, hailed as the "state of-the-art" grapefruit, being deeper red in color, full of juice and naturally sweet.

In 1988 the net acres of all Texas grapefruit totaled 20,400. Ruby Red accounted for 65% of the hectares, Star Ruby 7%, Henderson/Ray 6%, Rio Red 19%, and other varieties accounted for 3% (Texas Department of Agriculture, 1989). Several factors make exporting difficult for U.S. firms. First, the strength of the dollar depresses the market for U.S. goods abroad. Second, U.S. exports face increasingly difficult competition. Finally, most American firms focus on our large domestic market and not on generally smaller markets overseas. Overseas marketing often requires a longer term commitment than domestic marketing. International business often takes longer, costs more, and is harder to execute.

Citrus production has varied over time mainly due to damage by freezes that occur in Texas and Florida. The 1983 and 1987 freezes were very hard on the citrus industry particularly in Texas. After the 1987 freeze, incentives for Texas citrus brokers to join in the export market are: the stability in the U.S. dollar overseas, an increase in the U.S. target export assistance program, ample supplies of citrus, fewer trade restrictions, lower tariffs, and improved technology in overseas shipping.

Stable production of high quality fruit is important domestically and for exporting. In Japan, West Germany, France and Great Britain, Texas grapefruit is promoted as a "high-value fruit" that would be marketed in specialty shops and gift shops. (Anonymous, 1989). These high-value citrus sales will establish a foothold in these competitive overseas retail citrus markets. Japan is the largest importer of fresh citrus, but other European countries also desire to import more fruit. Taiwan, Singapore, and Hong Kong were among the worlds fastest growing economies during the 1980's and U.S. high value exports there have grown 117% since 1982 (MacDonald, 1989; Kitagawa et al., 1980). Since producers have recovered from the hard freezes in the 1980's, many are looking for new markets for their grapefruit. The objective of this study is to explore the feasibility for fresh citrus shippers who desire to export grapefruit to Southeastern Asia. Sales channels, tariff barriers, and the best market to enter are explored.

## METHODS AND PROCEDURES

All the information for this study has been obtained by literature review and personal interviews, i.e., written correspondence. The primary objective is to develop a feasibility study for citrus exporters who are interested in developing markets in Southeast Asia.

Only three countries are discussed in this study. However, some or all of the material reviewed may be applied to other countries in the region. Taiwan, Singapore, and Hong Kong were selected because of the differences each has in business organization, customs, trade laws and other demographic identities. Hong Kong was studied because it is considered a stepping stone for market expansion into the People's Republic of China.

To indicate the historical time series of the price and quantity of U.S. and Texas grapefruit trade, a technique of computing index numbers is used (see Table 1). Index numbers technique is a descriptive analyses and uses both graphical and numerical methods to provide a basis for the relative change (over time) in the price or quantity of a single commodity (McClave and Benson, 1985).

The multi-factor portfolio matrix by General Electric (GE) is the computer model developed to examine market shares. Using lotus 1-2-3 software and programming designed by Gary L. Lilien, the GE matrix model will help evaluate a portfolio of five Southeast Asian countries. Countries are displayed against two composite dimensions: export attractiveness and the country's importing strengths. These dimensions, in turn, are composed of a series of weighted factors that make up the composite dimension. Each country is given a weight along with its factor. These ratings are then multiplied by weight and summed to arrive at a position in the strength/attractiveness matrix. The matrix is divided into three zones (Low, Medium, High). The three cells in the upper right are those in which the country has an attractiveness present and potential future positions should be considered for investment and growth. The three cells along the diagonal are of intermediate overall attractiveness and the country should be considered for selective enhancement and earning generation. The cells in the lower right corner are low in overall strength

Table 1: Index Numbers for Total U.S. Grapefruit Exporters 1972-87

| Year | Quantity metric tons | Value $1000 | Price per ton metric | Index Number Simple |
|---|---|---|---|---|
| 1972 | 241,840 | 14,828 | 16.30 | 100 |
| 1973 | 423,705 | 33,715 | 12.56 | 77 |
| 1974 | 546,602 | 48,273 | 11.32 | 69 |
| 1975 | 570,329 | 54,366 | 10.49 | 64 |
| 1976 | 665,018 | 61,258 | 10.85 | 67 |
| 1977 | 580,898 | 57,463 | 10.10 | 62 |
| 1978 | n/a * | | | |
| 1979 | n/a * | | | |
| 1980 | 272,625 | 90,943 | 2.99 | 20 |
| 1981 | 297,753 | 111,164 | 2.67 | 16 |
| 1982 | 260,886 | 98,420 | 2.65 | 16 |
| 1983 | 301,835 | 114,501 | 2.63 | 16 |
| 1984 | 256,949 | 95,896 | 2.67 | 16 |
| 1985 | 198,624 | 86,670 | 2.29 | 14 |
| 1986 | 269,225 | 124,446 | 2.16 | 13 |
| 1987 | 350,205 | 162,495 | 2.15 | 13 |

* No Data Available

and should be considered for harvesting and divestment. Nine exporting items and twelve importing items were used to determine each country's market position. The model is designed to change the rating for each item, view the results and see a portfolio matrix. Exporting attractiveness items are based on information gathered about the country's economic climate. Such information was gathered from "Indicators of Market Size for 109 Countries" Business International (Czinkota and Ronkamen, 1988). Japan and South Korea were included to show the trade relations and differences between the countries.

Population and market size were rated on the growth of population of each country as compared to others in Asia. Gross Domestic Product rating was based on growth rates of the total value of all goods and services by the residences of that country at current market prices. Per Capita Income rating was based on the income levels as compared to the total average income from the rest of Asia.

The Importing Strength Items are based on information published about each country, distribution network, transportation and advertising. Each has been rated according to its strengths with five being the high and one being the low. These strength items, such as a country's transportation abilities, distribution network and advertising, were rated by examining the literature and comparing each country's constraints and abilities.

## RESULTS AND DISCUSSION

Taiwan has a strict trade and distribution system. Its tariff rates vary from free to 50% *ad valorem* with higher duties on luxury and consumer items or other items which compete directly with Taiwan manufacturers. It has a 50% tariff on grapefruit from March to September. This is to protect its limited domestic fruits which are poor in quality in contrast to U.S. citrus. Taiwan consumers' preferences are for smaller size grapefruit.

Singapore has very few trade barriers, high disposable income, and is willing to try new foods. It basically functions as a free port. In Singapore an average consumer pays $1.75 for three pieces of fruit, making fruit a luxury item. Consumers desire the larger fruit size. This is why a 0.15 weight factor was given to Labeling, Marketing and Packaging Items in the GE Matrix.

Hong Kong has no general tariff, thus, is a free port, but a small declaration charge is collected on all imports and exports except transshipment cargo. Hong Kong and Singapore distribution systems are heavily dependent on the "wet shops" (Mom and Pop fresh market stands) though large retail shopping centers are growing in size and importance. Citrus importers are still the main wholesalers of fresh citrus, but Texas citrus exporters could market their fruit directly to the shopping centers. This is an excellent method of developing a distribution network with a large food retailer. Most Asian consumers are willing to pay the price for fresh fruit, however, packaging and labeling have become very important as marketing tools in Southeast Asia.

Additional care in handling and packaging should be taken when shipping to Asia. Expensive gift packages commonly used in the grapefruit trade should be shipped by container shipments only. Container shipping is more expensive, but it helps prevent spoilage and/or damaged fruit. Break-bulk shipments are less expensive, but large volumes of fruit are needed to fill the shipment. An over supply of fruit in the overseas market usually occurs with break-bulk shipments.

All of preceding information on the countries was utilized in determining the weights given to the attractiveness items. Table 2 is an example of the Factors Underlying Exporting Attractiveness worksheet in the GE Multifactor Portfolio Model.

Table 2: Exporting Attractiveness Items and Rating Worksheet

| Exporting Attractiveness Items | Weight | x | Rating | = | Value |
|---|---|---|---|---|---|
| Population/ Market Size | .20 | | 5.00 | | 1.00 |
| Gross Domestic Product | .20 | | 2.00 | | .40 |
| Per Capita Income | .15 | | 1.00 | | .15 |
| Private Consumption | .15 | | 5.00 | | .75 |
| Market Growth Rate | .15 | | 4.00 | | .60 |
| Total Imports from U.S. | .05 | | 4.00 | | .20 |
| Total Citrus Imports U.S. | .05 | | 2.00 | | .10 |
| Exchange Rate | .05 | | 1.00 | | .05 |
| Social/Political/ Legal | Must Be Acceptable | | | | |

Exporting Attractiveness Score = 3.25

Table 3 illustrates the complete tabulation of both the export attractiveness items and the rating (1-5) for each country as determined by the GE Matrix program. A rating of five is high and one is low. In this model Hong Kong was given the highest rating and Japan was given the lowest rating.

Table 3: Export Attractiveness Items and Rating

| Items | Taiwan | Singapore | H.K. | Japan | S. Korea |
|---|---|---|---|---|---|
| Population/ Mkt size | 3 | 1 | 2 | 4 | 5 |
| Gross Domestic Prod. | 3 | 4 | 5 | 1 | 2 |
| Per Capita Income | 2 | 3 | 4 | 5 | 1 |
| Private Consumption | 2 | 3 | 1 | 4 | 5 |
| Market Growth Rate | 3 | 1 | 2 | 5 | 4 |
| Total Import U.S. | 3 | 2 | 1 | 5 | 4 |
| Citrus Imports U.S. | 4 | 1 | 3 | 5 | 2 |
| Exchange Rate | 3 | 5 | 4 | 2 | 1 |
| Social/Political/ Legal | All are equal | | | | |

Table 4 is an example of the Importing Strength worksheet. The ratings and the weights were based on each country's marketing information presented previously. Citrus industry exporters, Freight Forwarder, Trade association members and other citrus industry leaders were then asked to give their opinions on what they thought about each country's importing abilities. Each was asked about the problem and/or successful areas of exporting Texas citrus products.

Table 4: Importing Strength Items and Rating Worksheet

| Importing Strength Item | Weight x | Rating = | Value |
|---|---|---|---|
| Market Share | .10 | 2.00 | .20 |
| Share Growth | .15 | 3.00 | .45 |
| Product Quality | .10 | 5.00 | .50 |
| Distribution/Sales | .10 | 3.00 | .30 |
| Transportation | .05 | 3.00 | .15 |
| Advertising | .05 | 4.00 | .20 |
| Trade Regulations | .05 | 2.00 | .10 |
| Shipping Documents | .05 | 3.00 | .15 |
| Marking, Labeling, Packing | .15 | 3.00 | .45 |
| Language Problems | .05 | 3.00 | .15 |
| Exchange Rates | .10 | 3.00 | .30 |
| Importing/Exporting Personnel | .05 | 3.00 | .15 |

Importing Strength Score = 3.1

Table 5: Shows Each Country's Final Tabulated Importing Strengths, 5 being the high and 1 being the low, along with it's assigned rating.

| Items | Taiwan | Singapore | H.K. | Japan | S. Korea |
|---|---|---|---|---|---|
| Market Share | 4 | 3 | 3 | 5 | 2 |
| Share Growth | 5 | 4 | 4 | 5 | 3 |
| Product Quality | 4 | 4 | 4 | 4 | 5 |
| Distribution/Sales | 4 | 3 | 4 | 5 | 3 |
| Transportation | 4 | 4 | 3 | 5 | 3 |
| Advertising | 4 | 4 | 4 | 5 | 4 |
| Trade Regulations | 1 | 5 | 5 | 3 | 2 |
| Shipping Documents | 3 | 4 | 4 | 4 | 3 |
| Marking, Labeling | 3 | 5 | 5 | 4 | 3 |
| Language Problems | 3 | 4 | 4 | 3 | 3 |
| Exchange Rates | 2 | 3 | 4 | 4 | 3 |
| Import Personnel | 4 | 4 | 4 | 5 | 3 |

The weights for both the attractiveness and strength items are percentages of one, with heavier or higher percent given to the areas believed to be of more importance such as market size. The results from the GE matrix reveal that all of the countries have a potential market position. Since Japan and South Korea markets were not part of this study, the next best market is Hong Kong. Table 6 shows the rating for each country according to the model.

Table 6: Exporting Portfolio Matrix Data

| Country ID | Attractiveness | Strength |
|---|---|---|
| Taiwan | 2.75 | 3.55 |
| Singapore | 2.45 | 3.90 |
| Hong Kong | 2.85 | 4.05 |
| Japan | 3.70 | 4.40 |
| South Korea | 3.25 | 3.10 |

grapefruit, provide quality protection for grapefruit being shipped overseas, make trips overseas to oversee the market and meet with importers, and create an in-store promotion activity plan for each individual country.

The GE Matrix reveals that Hong Kong is the best market to enter. Hong Kong has the competitive advantage over Singapore and Taiwan in Gross Domestic Product and Per capita Income, a better exchange rate and relaxed trade regulations. Hong Kong had the Exporting Attractiveness and Importing Strengths needed by the Texas citrus exporter. Such attributes should provide producers with an excellent market for fresh Texas Ruby Red grapefruit. Both Singapore and Taiwan market positions are equal in attractiveness and strength characteristics. Although Hong Kong had a higher rating, Singapore and Taiwan should not be overlooked as potential markets. All three of these countries were in an area of intermediate overall attractiveness and should be considered for selective enhancement and earning potential. All three Asian countries are densely populated and have limited agricultural production. The USDA has ranked Hong Kong, Taiwan, and Singapore within the top importing countries for the 1990's. All three countries have made substantial gains in their respective government/economic situations. Because of these transitional political and international situations, new Western life styles are developing in Southeast Asia.

Texas has the capability of providing a naturally sweeter and deeper red color of grapefruit that will sell and be profitable long into the next century. This potential competitive advantage along with detailed marketing strategies should provide increased income for Texas citrus producers and economic prosperity to the Rio Grande Valley.

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# Redberry Juniper Foliage Moisture Dynamics in the Texas Rolling Plains

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## ABSTRACT

**An important variable in the successful management of redberry juniper (Juniperus pinchotii Sudw.) with prescribed fire is foliage moisture content (FMC). Juniper canopies are readily ignited by fire when FMC falls below 70%. Our objectives were to determine seasonal changes in redberry juniper FMC, and to determine relationships with soil water content in the Texas Rolling Plains. Trees on sandy bottomland, clay flat, and shallow redland range sites were sampled at approximately 14-day intervals from September 1995 through March 1997 in Garza County. Soil samples were taken beyond the drip-line of each tree to a depth of 12 inches. The FMC followed similar trends on all sites, but was generally highest on the sandy bottomland site and lowest on the clay flat site. The FMC was below 70% on all range sites and sample dates after 24 January 1996. Soil water was highest on the clay flat site, which was due to the higher water holding capacity of the heavy clay soil. The FMC and soil water were poorly correlated on all sites, except for the first 12 months of sampling. Redberry juniper FMC appears to be more closely related to available soil water than to total soil water since foliage moisture was not significantly impacted by precipitation events. Subsoil moisture recharge may occur slowly with average precipitation, and FMC may remain low following severe drought.**

**KEYWORDS:** Brush management, cedar, prescribed burning, soil moisture, volatile fuels

Redberry juniper (*Juniperus pinchotii* Sudw.) is an invasive shrub that occupies over 11 million acres of Texas rangeland (Soil Conservation Service, 1985). Redberry juniper is an evergreen, multi-stemmed basal sprouter that historically occurred on northwest exposures of rocky, shallow slopes in limestone and gypsum soils (Correll and Johnston, 1970). Redberry juniper is common in southwestern Oklahoma, western Texas, southeastern New Mexico, southern Arizona, and northeastern Mexico (Ueckert et al., 1994). Redberry juniper is considered an invader on most Texas range sites and has little economic value. However, redberry juniper is desirable on some range sites because it stabilizes soil and provides food and cover for wildlife (Scifres, 1980).

Fire was an important factor in the development of grassland ecosystems. Recurrent fires suppressed woody vegetation and maintained the character of grassland ecosystems (Sauer, 1950). In its original habitat, redberry juniper was historically protected from these fires by the lack of fine fuel and the topography of the steep, rocky slopes. The sup-

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pression of fire that occurred with settlement promoted the encroachment of redberry juniper from the steep, rocky slopes onto adjacent rangeland, where it has become a major problem on many range sites in the Texas Rolling Plains (Steuter and Britton, 1983).

Prescribed burning is an important tool for managing junipers in grassland ecosystems, and has been used to manage redberry juniper. However, due to the basal sprouting characteristics of redberry juniper, results have been variable. An important characteristic determining redberry juniper response to fire is the basal bud zone position. Redberry juniper with basal bud zones elevated above the soil surface had 70% mortality following fire (Steuter and Britton, 1983). Conversely, redberry juniper with basal bud zones partially below the soil surface had only 3% mortality. To maximize redberry juniper mortality with fire, the foliage must be ignited and a crown fire generated.

An important factor for the successful, rapid ignition of redberry juniper during prescribed burning is foliage moisture content (Bunting et al., 1983). Juniper foliage ignition is highly variable during prescribed burns. Junipers are readily ignited by fire when foliage moisture content falls below 70%. However, the seasonal changes in redberry juniper foliage moisture are not well understood. The objectives of this study were to determine the seasonal changes in redberry juniper foliage moisture content, and determine the relationship between foliage moisture content and soil water content on three range sites in the Texas Rolling Plains.

## MATERIALS AND METHODS

This study was conducted at the Texas Tech Experimental Ranch in Garza County near Justiceburg, Texas in the Rolling Plains at a mean elevation of 2400 ft. Average annual precipitation is 19 inches, and approximately 50% of the annual precipitation occurs from April through July (Richardson et al., 1965). Annual temperatures are variable, ranging from an average daily minimum of 27°F in January to an average daily maximum of 95°F in July.

This study was conducted on three range sites: sandy bottomland, clay flat, and shallow redland. Soil on the sandy bottomland range site is a Lincoln loamy fine sand (Typic Ustifluvent). Soil on the clay flat range site is a Dalby clay (Typic Torrert). Soil on the shallow redland range site is a Vernon clay loam (Typic Ustochrept) (Richardson et al., 1965).

Five mature redberry junipers on each range site were sampled at approximately 14-day intervals from September 1995 through March 1997. Trees were randomly selected at sampling initiation and included both male and female trees. Redberry juniper foliage was hand-stripped from 1 to 4 ft above the soil surface from the terminal 4 inches of branches around the perimeter of each tree. Samples were collected from the same trees throughout the sampling period and included only leaf material. One foliage sample of approximately 3 oz. wet weight was collected for each tree from at least 5 random locations around the perimeter of the tree to eliminate potential aspect bias. During collection, foliage samples were placed in air-tight containers to prevent water loss. Following collection, all foliage samples were transported to the laboratory and wet weight determined to the nearest 0.01 oz. Samples were dried at 140°F for at least 72 h to a constant weight, weighed to the nearest 0.01 oz., and foliage moisture content determined on a dry weight basis using the formula: ((wet weight - dry weight)/dry weight) x 100 = % foliage moisture. Foliage moisture content for each range site on each sampling date was determined by the mean of the 5 trees sampled on the site.

Soil samples were taken beyond the drip-line around the perimeter of each tree to a depth of 12 inches with a 3/4 inch diameter push probe. One composite soil sample was collected around the perimeter of each tree from at least 3 random locations to eliminate potential aspect bias. During collection, soil samples were placed in air-tight containers to prevent water loss. Following collection, all soil samples were transported to the laboratory and wet weight determined to the nearest 0.01 oz. Soil samples were dried at 212°F for at least 72 h to a constant weight, weighed to the nearest 0.01 oz., and soil water content determined on a dry weight basis using the formula: ((wet weight - dry weight)/dry weight) x 100 = % soil water. Soil water content for each range site on each sampling date was determined by the mean of the composite soil samples collected around the 5 trees on the site. A running mean was calculated for foliage moisture and soil water content between adjacent sampling dates to smooth the data transition between sampling dates.

The experiment was a completely random design with 5 replicates (trees) at each sampling date and range site. The data between range sites were compared with analysis of variance. Sampling date means within a range site that displayed significant differences were separated using Fisher's protected least-significant-difference at $\alpha = 0.05$. Relationships between foliage moisture and soil water content were determined by evaluating the coefficients of determination for the regression of foliage moisture content against soil water content.

## RESULTS AND DISCUSSION

Drought conditions persisted during 1993 and 1994, with 11.7 and 13.3 inches of precipitation recorded, respectively. Precipitation during the sampling period from September 1995 to March 1997 was 22.2 inches, which was 7.6 inches below normal (Fig. 1). In 1995, the period from 1 January to sampling initiation received a total of 17.3 inches of precipitation, approximately 4 inches above the long-term average for this period. Only 7 days during the sampling period (September 1995 to March 1997) received >0.5 inches of precipitation.

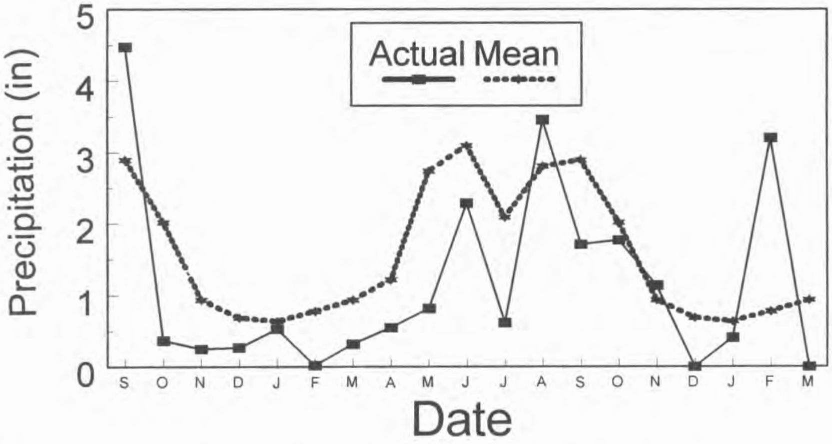

Fig. 1. Precipitation from September 1995 through March 1997 and long-term average annual precipitation at the Texas Tech Experimental Ranch near Justiceburg, Texas.

Tree height on the 3 range sites ranged from 5 to 12 ft. Canopy diameter of the trees ranged from 3 to 12 ft, which included both male and female trees. Tree height and sex had no impact on foliage moisture content.

Redberry juniper foliage moisture content was not different (P=0.625) between range sites on common sampling dates. Redberry juniper foliage moisture content on all range sites followed similar trends (Fig. 2). Foliage moisture content was generally highest on the sandy bottomland site and lowest on the clay flat site. Redberry juniper foliage moisture content was below 70% on all range sites and for all sampling dates after 24 January 1996. Foliage moisture content in June and July 1996 represent the lowest values ever observed at Texas Tech University, and are significantly lower than data reported in the literature for Juniperus species (Ortmann et al., 1995; Bunting et al., 1983).

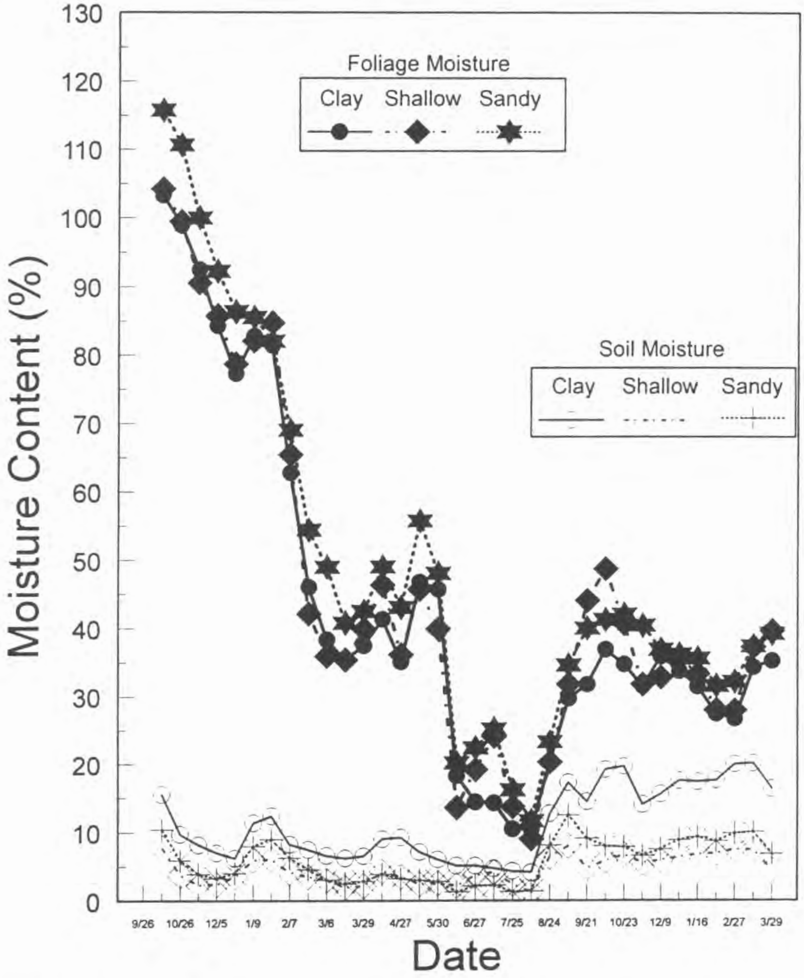

Fig. 2. Redberry juniper foliage moisture content calculated on a wet weight basis and soil water content on three range sites in the Texas Rolling Plains from September 1995 through March 1997. Data represent running averages between sampling periods.

Soil water content was always highest on the clay flat site, which was due to the higher water holding capacity of the heavy clay soil (Fig. 2). The coarse-textured nature of the soils on the sandy bottomland and shallow redland sites promoted the relatively rapid deep percolation of soil water, which resulted in lower soil water content. Precipitation in August 1996 was 3.5 inches and resulted in an elevation of soil water content on all sites (Fig. 2).

The relationship between foliage water content and soil water content was compared on the three sites for all data during the sampling period, resulting in a maximum $r^2 = 0.14$ on the sandy bottomland site (data not shown). Following initial evaluation of data from all sites, we determined precipitation events in August 1996 resulted in atypical foliage water content responses, and data were removed from analysis. Consequently, the correlation between foliage moisture content and soil water content was compared for the first 21 sampling periods during drought conditions.

Soil water content accounted for 58% of the variation in foliage moisture content on the clay flat site (Fig. 3), 32% on the shallow redland site (Fig. 4), and 59% on the sandy bottomland site (Fig. 5). Slopes were similar for all sites (F=0.34, P=0.71). The high water holding capacity of the clay soil shifted the data on the clay flat site away from the origin on the x-axis, resulting in a negative constant in the regression equation (Fig. 3). Soil water content explains a majority of the variation in redberry juniper foliage moisture content, and is a reasonable predictor of foliage moisture content on sites with high clay content and on sites with sandy soils.

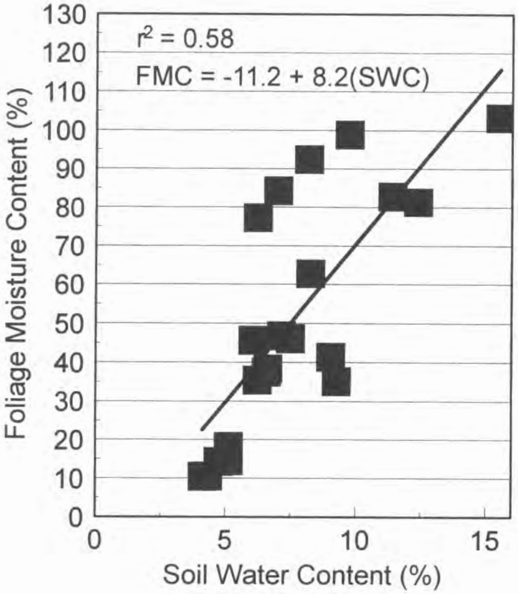

Fig. 3. Foliage moisture content and soil water content relationship on a clay flat range site in the Texas Rolling Plains. Points represent the running averages between sampling periods from September 1995 through August 1996 (n=21).

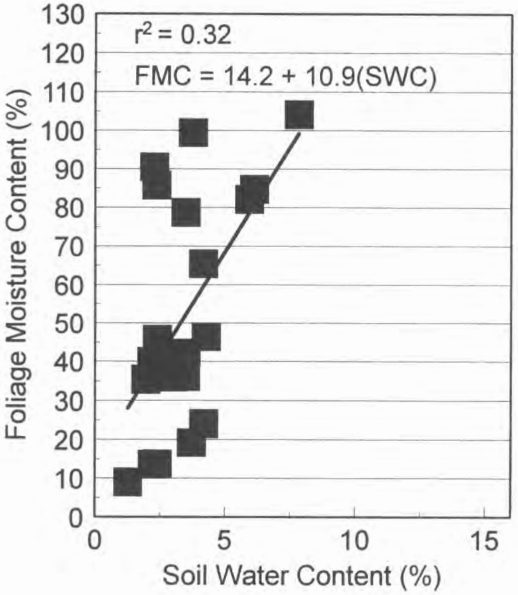

Fig. 4. Foliage moisture content and soil water content relationship on a shallow redland range site in the Texas Rolling Plains. Points represent the running averages between sampling periods from September 1995 through August 1996 (n=21).

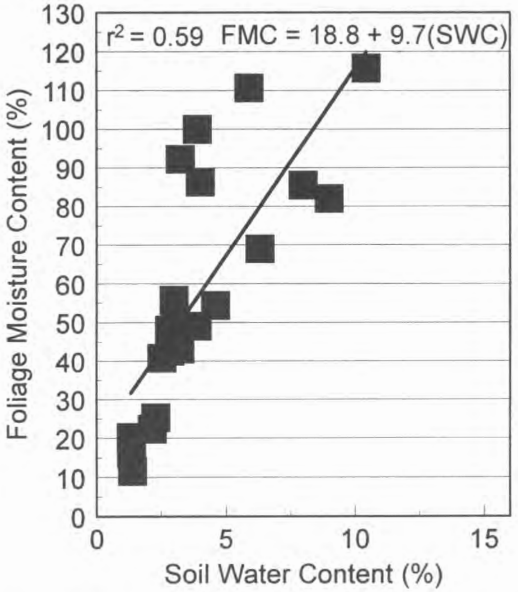

Fig. 5. Foliage moisture content and soil water content relationship on a sandy bottomland range site in the Texas Rolling Plains. Points represent the running averages between sampling periods from September 1995 through August 1996 (n=21).

Redberry juniper foliage moisture content appears to be more closely related to available soil water than to total soil water content. The lack of response in foliage moisture to rainfall events in August 1996 were likely due to inadequate subsoil moisture or lack of infiltration of precipitation (Fig. 2). The drought conditions that persisted during 1993 and 1994 in this area probably caused soil water depletion below the sampling depth. Depletion of the subsoil moisture may explain the minimal response of foliage moisture to precipitation events in mid April and mid August 1996. These precipitation events likely provided only adequate water for the soil surface and water did not sufficiently percolate to the lower portion of the redberry juniper root zone. Subsoil moisture recharge may not occur until several consecutive years of average precipitation have been received with significant fall and winter precipitation events. The occurrence of low intensity, long duration precipitation events during the fall and winter resulting in high quantity precipitation with little surface flow will provide the best opportunity for subsoil moisture recharge. Consequently, redberry juniper foliage moisture may recover slowly following drought conditions in the Texas Rolling Plains. However, redberry juniper foliage moisture content apparently responded to the above average precipitation that occurred prior to sampling in 1995 following drought conditions in 1993 and 1994.

## SUMMARY

Redberry juniper is a severe problem on Texas rangeland. Understanding the seasonal dynamics of redberry juniper foliage moisture content will indicate when prescribed fire may be most effective for managing redberry juniper. Additionally, understanding the volatile nature of junipers, especially at very low foliage moisture contents, provides information for safety considerations during juniper burning. Soil water content can be used to predict redberry juniper foliage moisture content, but the predictions appear to be site-specific. These data indicate that juniper foliage moisture content may remain dangerously low during and shortly after the conclusion of severe drought. Prescribed burning of juniper communities during or shortly after drought conditions must include the monitoring of foliage moisture content prior to burning, and necessary precautions must be taken during the planning process.

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# From Texas Vineyards to the Final Consumer: An Economic Impact Analysis

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## ABSTRACT

**This study estimates the economic impacts of the Texas wine and wine grape industry on the Texas economy through each sector of commercialization from the vineyards to the final consumer. Survey data from the state's vineyards and wineries for 1996 is used to construct an input-output model of the Texas economy and an industry impact framework using IMPLAN. Results show that the total core economic impacts of the Texas wine and wine grape industry were $85.8 million in output impacts, 1,157 jobs, $29.6 million in income impacts, and $46.6 million in total value added impacts in 1996. Much of these core economic impacts were attributable to the wine and wholesale trade sectors.**

**KEYWORDS:** economic impacts, input-output, IMPLAN, wine, wine grapes

Texas has one of the oldest wine grape growing and wine making traditions in the United States with a history stretching back over three hundred years. At the turn of the century census figures show that Texas had 1.3 million grapevines of bearing age (the equivalent of 2,900 acres today) and the state's 20 to 30 wineries produced over 100,000 gallons of wine (Mitchell, 1997). Prohibition and the decades that followed reduced the industry to a single winery located in Val Verde County, which produced 5,000 gallons of wine from approximately twenty acres of wine grapes in 1970. A renewed interest in wine and wine grape production took hold in the early 1970's and the modern Texas wine and wine grape industry emerged in the early 1980's. Today, the Texas wine and wine grape industry has over 3,200 acres of vineyards, 28 wineries, produces between 800,000 and 1,300,000 gallons of wine annually, sells 96% of its wine in-state, and holds a 5% share of the Texas table wine market (Dodd et al., 1996a). The industry's success and promise has also attracted and sustained substantial investment from California, France, and Texas.

The objective of this study was to estimate the economic impacts of the Texas wine and wine grape industry from the vineyards to the final consumer. Texas vineyards produced $4.6 million dollars worth of wine grapes in 1996. This may be compared to $4.8

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million for oranges, $15.5 million for grapefruit, and $4.8 billion for all crops produced in Texas in 1996 (Texas Agricultural Statistics Service, 1996). The processing of Texas wine grapes by the state's wineries and ultimate delivery to final consumers substantially adds value to the Texas wine grape crop. Texas wine sales in 1996, for example, totaled $34 million at suggested retail prices in 1996 (Michaud, 1997).

The industry's role, however, may be seen as that of two closely related sectors within the context of the matrix abstraction of the Texas economy as shown in (Fig. 1). The growing of wine grapes, the production of wine, and the delivery of the finished product to final demand draws goods and services from supplying sectors who themselves draw inputs from their suppliers throughout the Texas economy in a series of backward linkages. The final value of a bottle of Texas wine is the summation of the values paid to the wine sector, the transportation, wholesale, retail, and restaurant sectors, and the state and local government sectors. The allocation of the final value of a bottle of Texas wine in this way reflects the forward linkages from the winery to the final consumer. Each of the sectors along the chain of commercialization uses it's share of the final value of Texas wine in the purchase of inputs and in the payment of wages, interest, profits, and indirect business taxes.

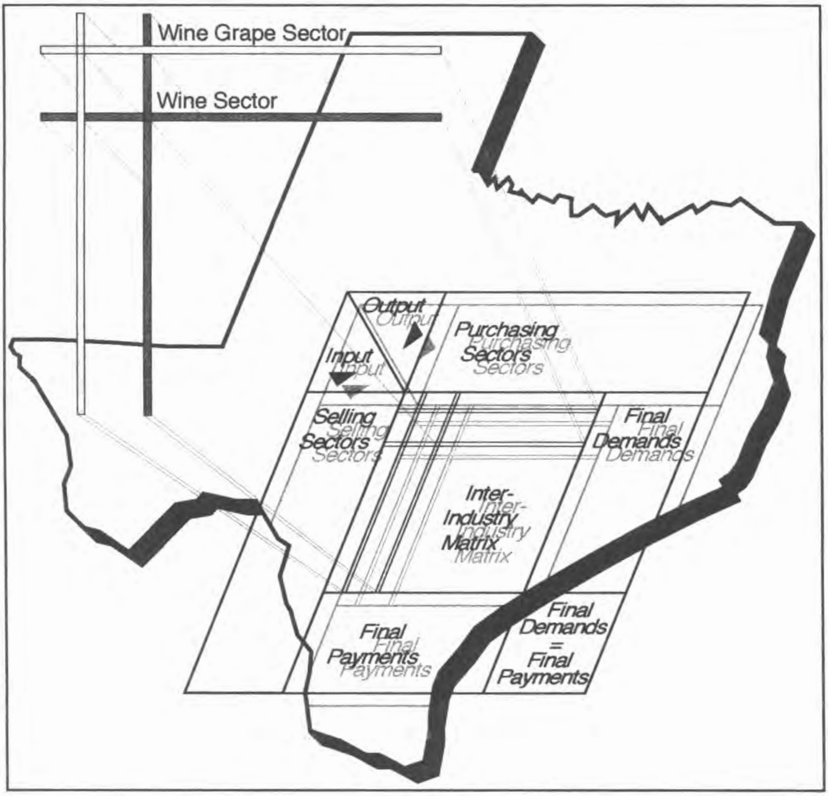

**Figure 1.** The Texas wine and wine grape industry within the matrix abstraction of the Texas economy.

The industry's economic impacts are of interest to the Texas Legislature, Texas tax payers, industry groups, and individuals as each of these has, directly and indirectly, invested substantial amounts of capital in the industry's development (Texas Department of Agriculture, 1986). Certain regions of the state are also particularly affected by the industry's role in the local economy. West Texas, for example, produces over 85% of the state's wine grape crop and wine grapes represent one of the few viable alternatives for agricultural diversification both on the Texas High Plains and the Trans-Pecos regions (Dodd and Michaud, 1995; Dodd et al., 1996a). For other regions of the state, such as the Texas Hill Country and the North-Central Region, the native wine and wine grape industry is also seen as an important component of regional tourism (Dodd, 1994).

Two approaches to assessing the economic impacts of regional wine and wine grape industries on state economies have been stressed in prior studies. The first is that of using an existing state level input-output model, and the second is that of modeling economic impacts using commercially available input-output modeling software. Brown (1985) and Folwell et al. (1987) are examples of the former. These studies estimated the economic impacts of the Washington wine and wine grape industry on the Washington economy based on the Washington input-output model. The latter approach was used by Johnson and Wade (1993), who estimated the economic impacts of Virginia's farm wineries on the Virginia economy based on the Impact Analysis for Planning (IMPLAN) modeling software managed by the Minnesota IMPLAN Group (MIG) (MIG, Inc., 1996). All of these studies measured the economic impacts of the wine and wine grape industries involved and made projections of future impacts based scenarios of industry growth.

The first approach mentioned above was also used in the case of Texas by Morse et al. (1992) and subsequent research by Dodd et al. (1996a; 1996b; 1994; 1993). Economic impacts of the industry on the state's economy in these studies were based on the Texas input-output model. These works estimated that the Texas wine and wine grape industry's total annual economic impact on the state's economy in recent years has been approximately $100 million in overall economic activity, 2,000 jobs, and $20 million in income. The Texas input-output model, however, uses broadly defined sectors that are closely related to the wine and wine grape sectors such as beverages and irrigated crops. The Texas input-output model is also static, being most recently updated in 1986, and does not permit alterations to the basic assumptions upon which each sector is constructed. Consequently, this model no longer corresponds to the state-of-the-art in micro-economic impact modeling and becomes less reliable with each passing year. There is, therefore, a need to re-examine the impacts of Texas wine and wine grape industry on the Texas economy.

## MATERIALS AND METHODS

The modeling tool chosen to estimate the economic impacts of the Texas wine and wine grape industry on the state's economy was the IMPLAN modeling software. IMPLAN is a microcomputer based non-survey hybrid input-output model, which begins with a national model that can be scaled down to a county level using regional information. Texas county data for the 1992 base year was obtained from MIG for use with the input-output software, and was complimented with primary data gathered through surveys of the Texas wine and wine grape industry.

The central variables determining the impacts of the Texas wine and wine grape industry on the state's economy were the farmgate value of Texas wine grapes sold to wineries, the value of juice and bulk wine originating within the state, and the value of Texas produced wines delivered to final demand at retail prices. These values were derived from price, quantity, and structural data collected from the state's grape growers, winemakers, and winery sales managers for 1996. The data were compiled using a survey format developed over the course of several years within the Texas Wine Marketing Research Institute at Texas Tech University.

Modifications to IMPLAN's regional data, production functions, by-products, and regional purchase coefficients were made to conform to the nature of the Texas wine grape and wine sectors. Survey data indicated that the Texas wine grape sector produces only wine grapes and is the state's sole producer of wine grapes. Likewise, the Texas wine sector produces only wine and is the state's sole producer of wine. The industry's wine grape and wine sectors were found to behave as separate but mutually dependent sectors having a defined pattern of commercialization.

Structural information from survey data was used to allocate values among the sectors directly involved from the vineyards to the final consumer. Each winery's wine grape, juice, and bulk wine purchases originating from within the state were modeled to reflect the direct link between the wine grape sector and the wine sector. Likewise, each winery's wine sales value at suggested retail prices was allocated among the wine, motor freight and warehousing, wholesale trade, food stores, miscellaneous retail, and eating and drinking sectors according to each winery's pattern of commercialization and the margins indicated by IMPLAN. Exports were assumed to pass through the same chain of commercialization until exiting the Texas economy at the wholesale stage before the application of excise taxes. Finally, the collection and re-spending of taxes by government for education and non-education purposes was applied at the wholesale level for excise taxes and at the retail level for sales taxes (Michaud, 1997a).

## RESULTS AND DISCUSSION

In general, survey response was high in terms of the proportion of the total estimated values accounted for by respondents. From 87 to 94% of the value of wine and wine grapes was confirmed with wine grape growers and winemakers. The remainder was estimated from past responses and all available information on a case by case basis. Particular follow-up attention was given to more important producers as these largely determine the final values necessary for input-output analysis. All economic impacts derived from this analysis are termed core economic impacts, as they do not include economic activity associated with periodic investment, income tax re-spending, research activities, and tourism.

The core economic impacts of the Texas wine and wine grape industry on the Texas economy in 1996 are summarized according to the sectors involved in the chain of commercialization. These are shown in terms of output, employment, income, and total value added in Tables 1 through 4, respectively. Core output impacts, for example, totaled $85.8 million as shown in Table 1. Output impacts may be considered an overall measure of economic impacts as they include the total value of all economic activity in the state attributable to the Texas wine and wine grape industry. Employment, income, and total value added impacts as shown in Tables 2 through 4 are associated with the level of overall economic activity (Table 1).

Table 1. Core output impacts of the Texas wine and wine grape industry on the Texas economy, 1996 (1996 dollars).

| Activity in the chain of commercialization | Direct ($MM) | Indirect ($MM) | Induced ($MM) | Total ($MM) |
|---|---|---|---|---|
| Wine grapes | $4.6 | $3.6 | $2.6 | $10.7 |
| Wines | $21.0 | $7.9 | $6.6 | $35.5 |
| Motor freight transport and warehousing | $0.6 | $0.4 | $0.4 | $1.3 |
| Wholesale trade | $7.1 | $2.7 | $5.4 | $15.2 |
| Excise tax re-spending | $0.2 | $0.0 | $0.3 | $0.5 |
| Food stores | $1.6 | $0.2 | $1.1 | $2.9 |
| Eating and drinking | $3.2 | $1.1 | $1.9 | $6.2 |
| Miscellaneous retail | $4.3 | $1.7 | $2.8 | $8.8 |
| Sales tax re-spending | $2.3 | $0.0 | $2.4 | $4.7 |
| Grand Total | $44.8 | $17.6 | $23.4 | $85.8 |

The Texas wine and wine grape industry's core employment impacts totaled 1,157 jobs in 1996 (Table 2). Employment impacts are understood in terms of jobs associated with all economic activity throughout the economy attributable to the industry. These include both full-time and part-time positions without the use of full-time equivalencies.

The core personal income impacts of the Texas wine and wine grape industry on the Texas economy totaled $29.6 million for 1996 (Table 3). Personal income impacts include both employee compensation and proprietor's income impacts. These are shown in Table 3 and are associated with all economic activity throughout the economy attributable to the industry.

The Texas wine and wine grape industry's core total value added impacts totaled $46.6 million in 1996 (Table 4). Total value added impacts are the sum of employee compensation, proprietor income, indirect business taxes, and other property impacts. Table 4 shows the total value added impacts associated with all economic activity throughout the economy attributable, as before, to the Texas wine and wine grape industry. Direct, indirect, and induced economic impacts are shown for each sector of activity. Direct impacts represent the final value of Texas wine grapes, juice, and bulk wine inputs originating from within the state, the value of Texas wine exports, and the final value of Texas wines consumed by households in Texas. As such, the final value of Texas wines includes the application of excise and sales taxes as well as the participation of the wine, motor freight and warehousing, wholesale trade, food stores, miscellaneous retail, and eating and drinking sectors. Direct impacts, therefore, not only involve the backward linkages associated with inputs for the production of Texas wines but also the forward linkages through the economy to the final consumer.

Table 2. Core employment impacts of the Texas wine and wine grape industry on the Texas economy, 1996.

| Activity in the chain of commercialization | Direct (Jobs) | Indirect (Jobs) | Induced (Jobs) | Total (Jobs) |
|---|---|---|---|---|
| Wine grapes | 36 | 35 | 35 | 106 |
| Wines | 153 | 85 | 90 | 329 |
| Motor freight transport and warehousing | 8 | 4 | 5 | 17 |
| Wholesale trade | 89 | 36 | 74 | 199 |
| Excise tax re-spending | 8 | - | 4 | 11 |
| Food stores | 53 | 2 | 16 | 71 |
| Eating and drinking | 100 | 11 | 26 | 136 |
| Miscellaneous retail | 123 | 18 | 39 | 180 |
| Sales tax re-spending | 74 | - | 33 | 106 |
| Grand Total | 644 | 192 | 321 | 1,157 |

Table 3. Core personal income impacts of the Texas wine and wine grape industry on the Texas economy, 1996 (1996 dollars).

| Activity in the chain of commercialization | Direct ($MM) | Indirect ($MM) | Induced ($MM) | Total ($MM) |
|---|---|---|---|---|
| Wine grapes | $1.2 | $1.1 | $1.0 | $3.2 |
| Wines | $2.7 | $3.1 | $2.5 | $8.2 |
| Motor freight transport and warehousing | $0.2 | $0.1 | $0.1 | $0.5 |
| Wholesale trade | $3.6 | $1.1 | $2.0 | $6.7 |
| Excise tax re-spending | $0.2 | $0.0 | $0.1 | $0.3 |
| Food stores | $0.9 | $0.1 | $0.4 | $1.4 |
| Eating and drinking | $1.4 | $0.3 | $0.7 | $2.4 |
| Miscellaneous retail | $1.9 | $0.7 | $1.1 | $3.6 |
| Sales tax re-spending | $2.3 | $0.0 | $0.9 | $3.2 |
| Grand Total | $14.4 | $6.4 | $8.7 | $29.6 |

Table 4. Core total value added impacts of the Texas wine and wine grape industry on the Texas economy, 1996 (1996 dollars).

| Activity in the chain of commercialization | Direct ($MM) | Indirect ($MM) | Induced ($MM) | Total ($MM) |
|---|---|---|---|---|
| Wine grapes | $1.2 | $1.9 | $1.6 | $4.7 |
| Wines | $8.0 | $4.4 | $4.0 | $16.5 |
| Motor freight transport and warehousing | $0.3 | $0.2 | $0.2 | $0.7 |
| Wholesale trade | $4.3 | $1.6 | $3.3 | $9.3 |
| Sales tax re-spending | $2.3 | $0.0 | $1.5 | $3.7 |
| Food stores | $1.4 | $0.1 | $0.7 | $2.2 |
| Eating and drinking | $1.9 | $0.5 | $1.2 | $3.6 |
| Miscellaneous retail | $2.7 | $1.1 | $1.7 | $5.5 |
| Excise tax re-spending | $0.2 | $0.0 | $0.2 | $0.4 |
| Grand Total | $22.4 | $9.8 | $14.3 | $46.6 |

Indirect impacts represent the additional economic activity generated by the chain of backward linkages throughout the economy implied in the use of inputs by all sectors involved in the production and distribution of Texas wine to the final consumer. Induced impacts are generated by the chain of backward linkages throughout the economy implied by the spending of wages paid to labor and the re-spending of taxes paid to government associated with the economic activity generated by the industry. Total impacts are the summation of the direct, indirect, and induced impacts.

The industry's economic impact on the Texas economy may be understood in terms of the value of economic activity required to deliver Texas wine to the final consumer. For example, in order to deliver $44.8 million worth of Texas wine to the final consumer in 1996 (Table 1), a total of $85.8 million of total economic activity was required. In terms of final demand multipliers, roughly $1.91 of overall economic activity was required to deliver one dollar worth of Texas wine to final demand.

The industry's core total output impacts on the Texas economy were most strongly felt through the wine sector at $35.5 million, the wholesale sector at $15.2 million, and wine grape sector at $10.7 million. The industry's total core employment impacts were also lead by the wine sector at 329 jobs and the wholesale sector at 199 jobs. Restaurants and liquor stores followed with 136 and 180 jobs, respectively. Total core personal income impacts were led by the wine sector at $8.2 million followed by the wholesale sector at $6.7 million, the liquor stores at $3.6 million, and the wine grape sector at $3.2 million. Core total value added impacts followed the same pattern being led by the wine sector with a total of $16.5 million.

These results represent an underestimation of the industry's impacts on the Texas economy, as this analysis does not include economic activity associated with periodic investment, income tax re-spending, research activities, and tourism. Estimates made in 1986 by the Texas Department of Agriculture, for example, showed that the total cumulative investment in Texas vineyards at that time stood at approximately $24.5 million while that in Texas wineries stood at nearly $35 million (Texas Department of Agriculture, 1986). In terms of input-output analysis, investment may be taken into account on a one-time-basis in the year that the actual transactions occurred. There are no reliable estimates, however, as to the value of investment in Texas vineyards and wineries for 1996.

Similarly, the re-spending of income taxes by government is not included in this analysis. In terms of input-output analysis, income taxes do not vary with output delivered to final demand and must be accounted for on a one-time-basis as a form of investment by government. Income tax information from wineries and vineyards was not available for this analysis.

The activities and benefits associated with industry related to research conducted by the state's universities and colleges were also not included in the analysis. In particular, the University of Texas, Texas A&M University, and Texas Tech University each have maintained applied wine and wine grape industry research programs, though these have been in severe decline in the past several years. Insufficient data were available for the proper assessment of the industry related economic impacts associated with these activities.

The analysis also does not include non-wine expenditures associated with Texas wine and wine grape industry tourism. Previous research in the general area of economic impact modeling and tourism activity by Douglas and Harpman (1995), Bergstrom et al. (1990), and Johnson et al. (1989) suggest that tourism can have substantial economic impacts on regional economies. Tourism expenditures, however, must be considered separately across many sectors using appropriate data gathering methods (MIG, Inc., 1996).

In the case of the Texas wine and wine grape industry, Dodd (1994) showed that the purchases of ancillary items from winery tasting rooms account for 20 cents of every dollar of tasting room sales. This would roughly be $785,000 in 1996, for example, and would increase estimates of the industry's total output impact by over $1.3 million for 1996. Outside the tasting room, the purchase of goods and services made by the estimated quarter million Texas winery visitors each year are also part of the industry's impacts on the economy. Likewise, the expenditures made by another estimated quarter million visitors attending the state's several annual wine festivals also represent substantial economic activity generated by the industry.

## CONCLUSIONS

The total core economic impacts of the Texas wine and wine grape industry in 1996 were estimated at $85.8 million in output impacts, 1,157 jobs, $29.6 million in income impacts, and $46.6 million in total value added impacts. In each case, the industry's largest core economic impacts were through the wine sector and the wholesale sector. The 60% of core output impacts accounted for through these two sectors underscores the economic role of the strong distributor relationships maintained by several Texas wineries. The wine grape sector followed with about 12% of the total output impacts though it is the initiator of the industry's economic impacts on the Texas economy. In the case of total core employment, personal income, and total value added impacts, liquor stores followed the wine sector and the wholesale sector in importance. This emphasizes the significance of liquor stores for the industry in working around the patchwork wet-dry local option laws characteristic of the Texas alcohol beverage regulatory environment. Finally, the restaurant sector was shown to follow the wine, wholesale, wine grape, and liquor store sectors in leading the industry's overall economic impacts.

With regard to projections for economic growth and given the current state of the industry, the most crucial element for the foreseeable future is the wine grape sector. Texas wine grape yields have traditionally been on the order of one-half of those of other wine producing states as discussed in Michaud (1997). Empirical evidence shows, however, that about three dozen of the state's 190 wine grape growers regularly experience yields equal to or surpassing their counterparts in other wine producing states (Michaud, 1997b). As these growers operate under similar conditions and with the same varieties as their Texas peers, this implies that higher yields may be possible overall and increase the industry's economic impacts on the Texas economy. If yields were to double, for example, and if vineyard acreage were to increase by a modest 15% over ten years, then the industry would more than double its economic impacts. This scenario would imply core economic impacts of $197.3 million in output, 2,660 jobs, $68 million in income, and $107.1 million in total value added by the year 2007.

This analysis is a conservative estimate of the industry's contributions to the Texas economy as it does not include vineyard and winery investment, income tax re-spending, research activities and benefits, or tourism expenditures. Among these, tourism expenditures associated with the Texas wine and wine grape industry may be the most promising area of future economic impact research. Texas winery tasting rooms attract an estimated quarter of a million visitors annually as suggested by Dodd (1994) and perhaps as many attend the state's numerous annual wine festivals. The presence of the Texas wine and wine grape industry is largely responsible for visitor purchases of non-wine goods and services both inside and outside the tasting room and festival environment. Tourism expenditures related to the industry, therefore, may be a substantial part of the Texas wine and wine grape industry's economic impacts on the Texas economy.

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# Effects of Paraquat Application and Timing on Peanut (*Arachis hypogaea* L.) Growth, Yield and Grade

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## ABSTRACT

**Field studies were conducted to evaluate paraquat or paraquat and bentazon mixtures and timing of application on runner-type peanut yield, injury, and grade. Single applications of paraquat at 0.14 kg ha-1 reduced peanut plant growth when applied 7, 14, 21, and 28 days after peanut emergence (DAE). Multiple applications of paraquat applied at peanut emergence (Emergence) and 14 DAE, 7 and 21 DAE, 14 and 28 DAE, and 7 and 28 DAE reduced peanut plant growth more than single applications. Paraquat applied at 21 DAE, Emergence and 14 DAE, 7 and 21 DAE, and 14 and 28 DAE reduced peanut yield when compared with pendimethalin at 0.84 kg ha-1 applied preplant incorporated (PPI). Peanut grade was not affected by any paraquat treatments. Tank mixes of paraquat + bentazon resulted in less peanut stunting than paraquat alone and treatment yields did not differ from the pendimethalin treatment.**

**KEYWORDS:** groundnut, herbicide injury, peanut quality

Postemergence over-the-top applications of paraquat (1,1'-dimethyl-4-,4'-bipyridinium ion) are widely used for broadleaf weed control in peanuts (*Arachis hypogaea* L.) in the Southeastern U.S. (Wilcut et al., 1995). Paraquat has been an effective herbicide when applied within 3 weeks of crop emergence or ground cracking (Wehtje et al., 1986; Wilcut et al., 1989). Ground cracking is the term applied to the period between hypocotyl emergence and the appearance of the first true leaves (Boote, 1982).

Peanuts are tolerant to paraquat if applications are made prior to pegging and fruit development (Wilcut and Swann, 1990), which is approximately 5 weeks after emergence (Wehtje et al., 1986). Tolerance at this stage has been attributed to the size and nutrient reserves of the seed (Schroeder and Warren, 1971). Peanut tolerance to paraquat is not cultivar dependent (Knauft et al., 1990; Wehtje et al., 1991b) nor is it influenced by seed size (Wehtje et al., 1991b). Paraquat can be applied from crop emergence until 28 days after emergence (Anonymous, 1994). Paraquat applied after this 28-day period increases the chance of significant yield reductions (Wehtje et al., 1986; Brecke and Colvin, 1988).

Paraquat plus bentazon [3-(1-methylethyl)-1H)-2,1-3-benzothiadiazin-4(3H)-one 2,2-dioxide] mixtures control more broadleaf weed species than paraquat or bentazon alone, including bristly starbur (*Acanthospermum hispidum* D.C.), coffee senna (*Cassia occidentalis* L.), prickly sida (*Sida spinosa* L.), and smallflower morningglory [*Jacquemontia tamnifolia* (L.) Griseb.] (Wilcut et al., 1994). Bentazon also lessens paraquat-induced foliar injury to peanut by reducing paraquat absorption into peanut foliage (Wehtje et al., 1992). Although paraquat absorption also was reduced in several weed species,

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including Florida beggarweed [*Desmodium tortuosum* (S.W.) D.C.], sicklepod [*Senna obtusifolia* (L.)] Irwin & Barneby], and Texas panicum (*Panicum texanum* Buckl.) (Wehtje et al., 1991a; Wehtje et al., 1992) control of these species was not reduced unless the application was made to weeds larger than 5 cm tall.

Results with Virginia-type cultivars indicated that the application of paraquat to peanuts in a heavily infested weed area resulted in a significant yield decrease if the initial paraquat application was delayed past one week after peanut emergence (Wilcut and Swann, 1990). This yield decrease followed the decrease in common ragweed (*Ambrosia artemisiifolia* L.) control with the later application. They found that yields from treatments that utilized paraquat plus bentazon at 0.28 or 0.56 kg ha-1 were equivalent and did not differ from a preplant incorporated (PPI) treatment of ethalfluralin [N-ethyl-N-(2-methyl-2-propenyl)- 2,6-dinitro-4-(trifluoromethyl)benzenamine] at 0.84 kg ha-1 or ethalfluralin plus vernolate (S-propyl dipropylcarbamothioate) at 2.24 kg ha-1. However, no paraquat plus bentazon treatment provided yields equivalent to the weed-free control.

Very little paraquat is used in the Southwestern U.S. since many weeds are effectively controlled with PPI or preemergence (PRE) herbicides. Also, producers in the Southwestern U.S. are slow to accept any herbicide which injures peanut, delays flowering, and may lead to reduced yields (author's personal observation). Delayed development increases the risk from fall cold temperatures which may lead to freeze damage. However, weed escapes do occur and low cost herbicides such as paraquat are needed if research can show that their use causes no reduction in yield or quality.

All of the previously published research evaluating the use of paraquat in peanut was conducted in Alabama, Florida, Georgia, and Virginia where the predominant weed species are Florida beggarweed, sicklepod, Texas panicum, and pitted morningglory (*Ipomoea lacunosa* L.) and the peanut produced is primarily the 'Runner' or 'Virginia' type (Buchanan et al., 1982; Dowler, 1995; Sholar et al., 1995).

To date, no information has been published concerning the use of paraquat or paraquat and bentazon mixtures on runner-type peanuts grown in the Southwest. The objectives of this study were to evaluate paraquat or paraquat and bentazon mixtures and timing of application on runner-type peanut yield, injury, and grade.

## MATERIALS AND METHODS

Experiments were conducted at the Texas Agricultural Experiment Station located near Yoakum during the 1989 and 1990 growing season on a Tremona loamy fine sand (thermic Aquic Arenic Paleustalfs) with less than 1% organic matter and a pH of 7.0 to 7.2. Areas with low weed populations were selected to reduce labor for hand weeding.

No general PPI herbicide was applied prior to planting since the area selected in each year of the study had very low weed populations. 'Florunner' peanut was planted 5 cm deep at the rate of 100 kg ha-1 in a well prepared seedbed using conventional equipment each year of the study.

Paraquat at 0.14 kg ha-1 alone or paraquat plus bentazon at 0.56 kg ha-1 were applied at the following times: peanut emergence (Emergence), 7 days after emergence (7 DAE), 14 days after emergence (14 DAE), 21 days after emergence (21 DAE), 28 days after emergence (28 DAE), and various combinations of those dates. Pendimethalin at 0.84 kg ha-1 was applied PPI with a tractor-driven power tiller as a standard treatment. A nontreated control was included also.

Herbicides were applied with a compressed air bicycle sprayer using SS11002 nozzles (Spraying Systems Co., North Ave. and Schmale Road, Wheaton, IL 60188) that delivered a spray volume of 190 Lha-1 at 180 kPa. All treatments included a nonionic surfactant (X- 77, a mixture of alkylaryl polyoxyethylene glycols, free fatty acids and isopropanol; Valent USA Corp., Box 8025, Walnut Creek, CA 94596) at 1% (vv-1).

A factorial arrangement of treatments in a randomized complete block design with four replications was used. Plot size was 2 rows spaced 97 cm apart and 6.3 m long. Peanut plant height measurements were taken 40 and 60 DAE to provide an index of crop injury. Plant heights were determined randomly from each plot at eight different locations within each plot. Peanut yields were determined by digging each plot separately, air drying in the field for 4 to 8 d, and harvesting peanuts from each plot with a combine. Weights were recorded after foreign material was removed from plot samples. Peanut grades were determined for a 250 g pod sample from each plot following procedures described by the U.S. Federal-State Inspection Service.

All data were evaluated with analysis of variance, and LSD at = 0.05 level of was calculated to compare treatment means. Data were evaluated individually by years because year by treatment effects were significant. Transformation did not change the results, so non-transformed data were analyzed and presented.

## RESULTS AND DISCUSSION

Peanut plant growth. The 40 DAE measurements in 1989 indicated paraquat alone applied in a sequential application at 7 and 21 DAE, 14 and 28 DAE, or 7 and 28 DAE reduced peanut plant growth at least 18% when compared with the non-treated control (Table 1). The addition of bentazon to paraquat at these application timings resulted in no reduction in peanut plant growth compared to the non-treated control. No other herbicide applications reduced peanut plant growth.

In 1990, reductions in peanut plant growth 40 DAE were noted with paraquat alone applied at 7, 14, 21, and 28 DAE and all sequential applications of paraquat alone or paraquat and bentazon treatments (Table 1). Single applications of paraquat and bentzaon tank mixes did not reduce plant height. Wehtje et al. (1986) reported that Florunner canopy width was not reduced when paraquat was applied at the third week or sooner after peanut emergence. However, they stated that multiple paraquat applications were very injurious to late-planted peanuts.

The 60 DAE plant measurements in 1989 indicated plant height reductions compared to the non-treated control when paraquat was applied 14 DAE, paraquat and bentazon applied 21 DAE, or the sequential application of paraquat applied 7 and 28 DAE (Table 1). In 1990, sequential applications of paraquat applied at Emergence and 14 DAE, 7 and 21 DAE, 14 and 28 DAE, or 7 and 28 DAE reduced plant growth up to 18% when compared to the non-treated control (Table 1). No peanut plant size reduction occurred with the pendimethalin application in 1989 and 1990.

The interaction of paraquat with other herbicides has been variable. O'Sullivan and O'Donovan (1982) reported that the phytotoxicity of paraquat to barley (*Hordeum vulgare* L.) was not reduced when tank mixed with the ester formulations of 2,4-D [(2,4-dichlorophenoxy)acetic acid], MCPA [(4-chloro-2-methylphenoxy)acetic acid], or bromoxynil (3, 5-dibromo-4-hydroxybenzonitrile). However, dimethylamine formulations of either 2,4-D or MCPA were antagonistic. Subsequent work (O'Donovan and O'Sullivan, 1982) revealed that this antagonism was not evident if the phenoxy carboxylic acid herbicides were applied 1 day prior to application of paraquat.

Table 1. Peanut response to paraquat and paraquat plus bentazon mixtures applied up to 28 days after peanut emergence.

| | | | Plant height (cm) | | | | | | Peanut grade | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Application | 40 DAE[1] | | 60 DAE | | Yield (kg ha$^{-1}$) | | (% SMK + SS)[2] | |
| Treatment | Rate (kg ha$^{-1}$) | timing[1] | 1989 | 1990 | 1989 | 1990 | 1989 | 1990 | 1989 | 1990 |
| Check | | | 29.9 | 31.5 | 37.3 | 36.8 | 4665 | 4503 | 73.3 | 69.8 |
| Paraquat (P) | 0.14 | Emergence (E) | 28.6 | 29.7 | 37.0 | 38.9 | 4718 | 4582 | 71.8 | 70.5 |
| P+Bentazon (B) | 0.14+0.56 | Emergence (E) | 31.8 | 30.0 | 35.8 | 36.6 | 4873 | 5169 | 72.0 | 71.0 |
| P | 0.14 | 7 DAE | 27.9 | 25.4 | 33.0 | 35.1 | 4705 | 4629 | 69.8 | 69.5 |
| P+B | 0.14+0.56 | 7 DAE | 30.2 | 29.2 | 35.3 | 37.6 | 4600 | 4621 | 73.5 | 70.3 |
| P | 0.14 | 14 DAE | 28.7 | 26.9 | 30.7 | 33.0 | 4155 | 4281 | 68.8 | 69.3 |
| P+B | 0.14+0.56 | 14 DAE | 27.7 | 29.2 | 34.0 | 36.7 | 4745 | 4304 | 70.0 | 69.8 |
| P | 0.14 | 21 DAE | 27.9 | 25.9 | 33.3 | 33.0 | 3886 | 3718 | 69.8 | 69.8 |
| P+B | 0.14+0.56 | 21 DAE | 25.9 | 28.7 | 31.0 | 36.3 | 5076 | 5169 | 70.8 | 70.0 |
| P | 0.14 | 28 DAE | 26.2 | 27.9 | 33.3 | 33.5 | 4293 | 4768 | 70.5 | 70.0 |
| P+B | 0.14+0.56 | 28 DAE | 28.2 | 29.7 | 35.6 | 36.3 | 4959 | 4252 | 70.8 | 69.3 |
| P | 0.14 | E+14 DAE | 26.9 | 25.7 | 34.0 | 32.0 | 4565 | 3953 | 71.0 | 70.8 |
| P+B | 0.14+0.56 | E+14 DAE | 29.7 | 26.2 | 35.6 | 35.1 | 4846 | 4420 | 69.5 | 70.5 |

Table 1. Continued

| | | | Plant height (cm) | | | | | | Peanut grade | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Application | 40 DAE[1] | | 60 DAE | | Yield (kg ha$^{-1}$) | | (% SMK + SS)[2] | |
| Treatment | Rate (kg ha$^{-1}$) | timing$^{-1}$ | 1989 | 1990 | 1989 | 1990 | 1989 | 1990 | 1989 | 1990 |
| P | 0.14 | 7+21 DAE | 22.6 | 22.6 | 31.5 | 30.2 | 4176 | 3733 | 69.8 | 65.8 |
| P+B | 0.14+0.56 | 7+21 DAE | 28.7 | 27.4 | 34.5 | 34.3 | 4480 | 4797 | 68.5 | 70.5 |
| P | 0.14 | 14+28 DAE | 25.1 | 23.4 | 32.5 | 31.2 | 4147 | 3658 | 69.0 | 67.5 |
| P+B | 0.14+0.56 | 14+28 DAE | 27.4 | 25.7 | 33.8 | 34.8 | 4002 | 4640 | 69.3 | 68.8 |
| P | 0.14 | 7+28 DAE | 24.4 | 21.8 | 30.5 | 30.0 | 3830 | 4016 | 69.0 | 70.0 |
| P+B | 0.14+0.56 | 7+28 DAE | 30.0 | 27.9 | 34.8 | 32.5 | 4441 | 4816 | 69.5 | 69.8 |
| Pendimethalin | 0.84 | PPI | 28.2 | 31.0 | 34.8 | 36.3 | 4447 | 5395 | 71.8 | 70.3 |
| LSD (0.05) | | | 4.5 | 2.8 | 5.8 | 4.6 | 929 | 1143 | 4.8 | 4.2 |

[1] DAE=days after peanut emergence; PPI=preplant incorporated

[2] SMK=sound mature kernels; SS=sound splits

They concluded that a chemical interaction between the dichloride salt of paraquat and the dimethylamine salts of MCPA and 2,4-D leads to the production of less active compounds (O'Donovan et al., 1983).

### Peanut Yield

In 1989, paraquat and bentazon applied 21 DAE produced the highest yield, whereas paraquat alone applied 21 DAE or 7 and 28 DAE resulted in the lowest yields (Table 1). Peanut plant height 60 DAE was reduced with the paraquat and bentazon tank mix. No explanation can be given for the high yield associated with reduced peanut plant growth. In 1990, paraquat alone applied 21 DAE, Emergence and 14 DAE, 7 and 21 DAE, and 14 and 28 DAE produced significantly lower yields than the pendimethalin treatment.

Research in the Southeastern U.S. has shown that paraquat causes injury to the peanut foliage; however, the peanut plant rapidly recovers under good growing conditions and yield was unaffected (Wehtje et al., 1986; Brecke and Colvin, 1988; Wilcut et al., 1989; Wilcut and Swann, 1990). Wehtje et al. (1986) stated that paraquat application(s) can result in loss of peripheral leaves of the canopy; consequently, crop development can be temporarily delayed. Generally a peanut crop in the Southeastern U.S. will recover provided paraquat application was made to an actively growing crop prior to the main fruiting period, and sufficient time remains in the growing season for recovery (Brecke, 1983; Buchanan and Bryant, 1980).

### Peanut Grade

In 1989 and 1990, no differences in peanut grade occurred between the non-treated control and any paraquat treatment (Table 1). In 1989, paraquat and bentazon applied at 7 and 21 DAE resulted in a lower grade than paraquat and bentazon applied 7 DAE, whereas in 1990, paraquat alone at 7 and 21 DAE resulted in a lower grade than several paraquat alone or paraquat and bentazon treatments.

## CONCLUSION

The chance of paraquat causing peanut injury and subsequent yield reduction is greater in the Southwestern U.S. than the Southeastern U.S. due to the increased potential for poor growing conditions in the Southwestern U.S. Peanut growers in the Southwestern U.S. plant later in the year when air temperatures are higher than in the Southeastern U.S. The combination of higher temperature, lower humidities, and water stress may lead to more leaf damage and subsequent yield reduction. Producers in the Southwestern U.S. are slow to accept any herbicide which may cause peanut injury during poor growing conditions.

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# A Gradient Analysis of Understory Vegetation in a Sugarberry-Elm Floodplain Forest on the Brazos River

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## ABSTRACT

**Relationships between understory vegetation pattern, topography, flooding, and soil properties were studied in a bottomland hardwood forest on the lower Brazos River floodplain. Elevation varied 30 to 70 cm along 220-m transects in 3 study sites. We infer that a microtopographically-induced soil aeration gradient influenced understory vegetation pattern. Swales were flooded from autumn through spring and supported species-poor vegetation dominated by *Panicum gymnocarpon*. Unflooded areas supported more diverse vegetation varying in composition along an elevation gradient: *Carex cherokeensis* characterized lower elevations, with dominance gradually shifting to *Oplismenus hirtellus* on slightly elevated ridges. Vegetation pattern was strongly related to relative elevation and soil water content as well as to abundance of clayey horizons in the soil profile, and soil copper, iron, phosphorous, potassium, and salinity.**

**KEYWORDS:** Floodplain, understory, vegetation pattern, flooding, Brazos River

On river floodplains, duration, frequency, and timing of flooding influence plant distribution (Huenneke, 1982; Bren, 1993). Smith and Linnartz (1980; p. 154) wrote that in the flat terrain of river flood plains, "even slight variations in elevation are associated with considerable differences in soils, drainage conditions, and forest species composition." Even periodically flooded soils develop distinct morphological features that can be used to infer soil saturation (Megonigal et al., 1993). An elevation-induced flooding gradient affects many chemical, physical, and biological factors which in turn influence vegetation pattern (Gauch and Stone, 1979). Jones et al. (1994) indicated that the fine-scale effects of flooding as related to microtopographic relief have only recently been quantified; much of this work has dealt with tree species (e.g., Streng et al., 1989). There is less information on elevation-induced flooding effects on understory vegetation.

This study investigated understory vegetation patterns in a bottomland hardwood forest along the Brazos River, Texas, in relation to microtopography and its effects on flooding regime. We examined hydrologic and edaphic properties in order to correlate variation in hydrology, soils, and vegetation.

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# STUDY AREA

The study site is in the Gulf Coastal Plain Physiographic Province (Thornbury, 1965) on Sienna Plantation, a private land holding of about 3,000 ha in Fort Bend County, Texas (29°30' N, 95°30' W). The plantation, about 32 km southwest of Houston, lies on the east bank of the Brazos River. Elevation on the plantation ranges from 15 to 20 m above mean sea level. The area was settled by Anglo-Americans in about 1822, and by the end of the 1850s the site was part of the largest cotton and sugar plantation in Texas. The plantation was financially destroyed during the Civil War; it was divided and has been farmed and grazed under various landowners since that time (Wharton, 1939; Christensen, 1982).

Climate at Sienna is warm with a long growing season and a frost-free period usually exceeding 280 days. Annual precipitation averages about 110 cm and is distributed evenly throughout the year. Average annual temperature is 22° C, the hottest months being July and August (Mowery et al., 1960; National Oceanic and Atmospheric Administration, 1996).

The study was conducted on the floodplain of the Brazos River. Soils are classified as Miller Clay, although profiles deviate from the Natural Resource Conservation Service (NRCS) description for that series (Mowery et al., 1960). Flats and swales are fine, mixed, thermic Vertic Haplustolls, and ridges are fine, loamy, mixed, thermic Typic Haplustolls (Grissom, 1987). Study sites are level areas of heavy clay alluvium, with coarser horizons often present. Small channels, less than 1 m deep with gently sloping sides, are present within these flats. Still or very slowly moving water is present in these swales generally from autumn through spring. Floodplain deposits have characteristic morphological features created by the movement of a river through sediments and by periodic overbank flows. Standard nomenclature for floodplain features (Putnam et al., 1960; Hosner and Minckler, 1963; Smith and Linnartz, 1980) will be followed here, except that flooded depressions are called swales (instead of sloughs) to indicate their gentle slope, slight elevational variation, and relatively short flood duration. Ridges and flats remained above floodwaters during the period of observation and generally had similar soils and vegetation and are collectively referred to as flats unless otherwise noted.

Flats are dominated by sugarberry (*Celtis laevigata*), green ash (*Fraxinus pensylvanica*), and elm (*Ulmus crassifolia* and *U. rubra*) (scientific nomenclature generally follows Correll and Johnston, 1970). Other common species include pecan (*Carya illinoinensis*), soapberry (*Sapindus saponaria*), and woolly bucket (*Bumelia lanuginosa*). Subcanopy species include deciduous holly (*Ilex decidua*), hawthorn (*Crataegus invisa, C. Marshallii, C. texana*), and rough-leaf dogwood (*Cornus drummondii*). Average tree density is 950 trees/ha, basal area averages 26.5 $m^2$/ha, and average canopy height is 20 to 23 m. The most common vines are Virginia creeper (*Parthenocissus quinquefolia*) and poison ivy (*Toxicodendron radicans*). Shrubs are uncommon (8.2% frequency) and of small stature, usually less than 0.5 m tall. The most abundant species are small, erect greenbrier (*Smilax* spp.) plants; others include dewberry (*Rubus trivialis*) and coralberry (*Symphoricarpos orbiculatus*). Herbaceous vegetation in unflooded sites is dominated by grasses and sedges (31.7 and 43.1% frequency, respectively), with the most common species being *Carex cherokeensis, C. amphibola,* and *Oplismenus hirtellus.* Forbs have a frequency of 5%; *Ruellia pendunculata, Polygonum virginicum,* and *Sanicula canadensis* are the most common species. Grissom (1987) provides a complete vegetation description.

Seasonal soil saturation and flooding in low areas occur from fall through spring, a consequence of flat relief and impermeable, heavy clay soils. Additionally, temporary ponded water may be found following heavy rains. The incised nature of the Brazos River within its floodplain has made overbank flow uncommon (Campbell, 1925). Thus, poor internal drainage has probably been the most important factor contributing to site flooding.

## METHODS

A 40 x 220 m transect was established in each of three study sites to sample soils and vegetation in topography ranging from flats to swales. Study sites were separated by roads, ditches or natural drainages and thus drained independently. The long axis of each transect was oriented at right angles to swales. Elevation was measured with transit and rod to the nearest 0.03 cm at 2-m intervals along two parallel lines running the length of each transect. Elevation was relativized by subtracting the lowest recording from all other recordings for each transect.

Vegetation and soils were sampled in five macroplots (10 x 40 m) positioned randomly along each transect with the constraint that the plot did not include obvious disturbance caused by windthrow (Mueller-Dombois and Ellenberg, 1974). Each macroplot was oriented with its long axis perpendicular to the transect (and parallel to the swale). Relative elevation was calculated for each macroplot by averaging four elevation readings, two from each surveyed line nearest the intersection of that line and the macroplot main axis.

Vegetation data were collected along four, 40-m lines randomly placed parallel to the long axis in each macroplot. Understory species frequency was recorded along each line in 25 randomly located 10 x 10 cm quadrats. Plot size was determined after preliminary sampling (Greig-Smith, 1983). Species frequency was also recorded at 2-m intervals along each 220-m transect. Vegetation sampling was conducted in transects 1 and 2 in July and August, 1985, and in transect 3 in August, 1986. A canopy photograph was taken during vegetation sampling at each macroplot center with a 150-degree fish-eye lens, and a canopy closure was estimated following Brown (1962).

Water level was recorded at swale macroplot centers monthly from August, 1985 to August, 1986. Water levels of two creeks (Oyster Creek and Cow Bayou) and a ditch (Water's Ditch) (constructed ca. 1850) were also monitored during portions of this period to aid in understanding drainage relationships within the site. Weather data were collected from the nearest recording station approximately 4 km west of the study site.

Soil gravimetric water content (Gardner, 1965) was sampled at four locations in each macroplot of transects 1 and 2 during the driest period of the year (August, 1985), soon after initial flooding of swales (November, 1985), and just before dry-down after swales had been flooded for several months (March, 1986). Soil nutrient status [calcium, copper, iron, magnesium, maganese, nitrogen (NO3), phosphorous, potassium, sodium, zinc], pH, and salinity were determined from five samples taken from random locations in each macroplot of transect 1 in April 1987. Analyses were performed by the Texas A&M Soil Testing Laboratory, Lubbock. Soil samples for nutrient analysies were collected from the A horizon at a 12 to 18 cm depth. Comparisons between swales and flats were made with a student's t test.

Soil pits were dug near the centers of macroplots 1 and 2 (transect 1) and macroplots 25 and 26 (transect 3) for profile description. One 10-cm auger hole, about 150 cm in depth, was placed near the center of each of the 11 remaining macroplots to allow gross examination of the profile. Clay content (as indicated by relative amount of profile made up of clayey horizons) was determined for each soil pit and augur hole.

Vegetation data were collected along each of 4 transects in each macroplot; however, only one recording of relative elevation and clay content was made for each macroplot.

Reciprocal averaging (RA) (Hill, 1973; cf. detrended correspondence analysis, Wartenberg et al., 1987) of vegetation data was used for ordination analyses, with relative elevation and clay content included as supplementary variables (Gauch and Stone, 1979). Canonical correspondence analysis (e.g., ter Braak, 1986; Palmer, 1993) of vegetation data, relative elevation, and clay content was not used because there were more vegetation sampling points (4 transects per macroplot) than sampling points for relative elevation and soil clay content (1 sampling point per macroplot). Standardized principal components analysis of vegetation and soil data was used to establish correlations between soil properties and principal components. Coordinated patterns in these analyses were used to explain vegetation pattern related to soil characteristics and microtopography. Species occurring in only one sample (consisting of 25, 10 x 10 cm quadrats) were deleted (Gauch, 1982). Frequency data recorded at a 2-m intervals along the 220-m transects were ordinated and plotted in a trace diagram using axis I (Whittaker et al., 1979). Trace analysis was strongly influenced by outliers, and species occurring in 2% or less of plots in a transect line were omitted.

Similarity of macroplots was quantified in paired comparisons of presence-absence data using a coefficient of community (Whittaker, 1975). Pearson's correlation coefficient was used to examine relations between water levels and weather data.

## RESULTS

### Site Flooding Regime

Elevation varied most on transect 1, with a vertical difference of 71.9 cm over a 220-m distance; transects 2 and 3 were flatter (Table 1). Swales in transects 1 and 2 were flooded during January, March, and as late as the end of May, 1985 (pers. obs.). Swales (marcroplots 2, 4, and 8) were flooded in November, 1985 and retained standing water until March, 1986 (Table 1). Macroplot 8 had very little water in March 1986 and by April had no standing water. Macroplots 2 and 4 had relatively deep water in March, but were drying rapidly with water levels dropping 3.2 and 1.3 cm, respectively, in 3 days. In April, only scattered puddles remained in macroplots 2 and 4, and by May they had drained, although the soil was still moist.

Water levels in swales and major drainages were strongly negatively correlated with seasonal variation in temperature; correlations between water levels and mean monthly precipitation were weaker (Table 2). Poor correlation between water levels and precipitation may be partly related to differences in rain received at the weather station (4 km distant) and rain received at the site.

Table 1. Topographic, edaphic, and hydrologic data from study plots. Clay in profile is the relative amount of the top150 cm of the soil profile made up of clayey horizons.

| | | | | Vertical distance above water level (cm) | | | | | | | Gravimetric water content (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Transect | Macroplot | Relative elevation (cm) | Clay in profile (%) | Aug-Oct 1985 | Nov. 1985 | Dec. 1985 | Jan. 1986 | Feb. 1986 | Mar. 1986 | Apr-Aug. 1986 | Aug. 1985 | Nov. 1985 | Mar. 1986 |
| 1 | 1 | 65.5 | 53.3 | -[1] | 54.6 | 49.4 | | 50.6 | 57.0 | - | 23.8 | 34.5 | 29.2 |
| | 2*[2] | 3.1 | 100.0 | - | -8.2 | -13.4 | (not measured) | -12.2 | -5.8 | - | 32.9 | 55.8 | 54.5 |
| | 3 | 52.1 | 46.7 | - | 39.6 | 37.3 | | 32.6 | 35.1 | - | 25.1 | 36.7 | 37.5 |
| | 4*[3] | 21.0 | 96.7 | - | 8.5 | 6.1 | | 1.5 | 4.0 | - | 28.2 | 49.5 | 48.5 |
| | 5 | 37.5 | 76.7 | - | 25.0 | 22.6 | | 18.0 | 20.4 | - | 27.1 | 40.7 | 38.2 |
| 2 | 6 | 25.3 | 100.0 | - | 13.7 | 11.3 | 13.1 | 13.4 | - | - | 29.6 | 52.3 | 45.0 |
| | 7 | 23.5 | 100.0 | - | 11.9 | 9.5 | 10.1 | 11.6 | - | - | 29.7 | 48.2 | 46.8 |
| | 8* | 3.7 | 100.0 | - | -0.9 | -3.4 | -1.5 | -1.2 | - | - | 34.9 | 60.5 | 60.1 |
| | 9 | 18.6 | 100.0 | - | 7.0 | 4.6 | 6.4 | 6.7 | - | - | 29.4 | 49.5 | 46.2 |
| | 10 | 22.0 | 100.0 | - | 10.4 | 7.9 | 9.8 | 10.1 | - | - | 29.0 | 48.4 | 46.6 |
| 3 | 24 | 22.0 | 86.7 | (not measured) | | | | | | | | | |
| | 25 | 17.7 | 81.7 | | | | | | | | | | |
| | 26* | 4.9 | 100.0 | | | | | | | | | | |
| | 27 | 20.7 | 86.7 | | | | | | | | | | |
| | 28 | 18.9 | 86.7 | | | | | | | | | | |

[1] Dash indicates that transect was not flooded.

[2] An asterisk indicates that the macroplot was located in a swale.

[3] Macroplot was flooded even though average plot elevation exceeded elevation of standing water.

## Topo-edaphic Parameters

The soil profile on ridges of transect 1 was made up of very fine sandy loam horizons alternating with clays or silt loams (Table 1; see Grissom, 1987 for complete profile descriptions). Similar clay horizons were present in a swale 40 m away; however, coarser horizons were absent. The absence of coarse horizons, regardless of topographic position, distinguished soils on transect 2 from those of transects 1 and 3.

Soil water content was higher in swales than in adjacent flats during dry periods (August, 1985) and with "normal" flooding (November, 1985 and March, 1986) (Table 1). Soil pH was slightly alkaline. Soil Ca, Mg, Mn, N, Na, and Zn exhibited as much variability within macroplots as between macroplots of swales and flats. Soil Cu, Fe, P, K, and salinity were much higher in swales than in flats (Table 3). Flooding-induced accumulation of organic matter was noted at the soil surface in swales (see Ponnamperuma, 1984). Soil structure of clayey horizons was similar in swales and flats.

Table 2. Correlation of weather and water levels of macroplots and other drainages on study site.

| | Current Month | | Previous Month | |
|---|---|---|---|---|
| Location | Temp. | Precip. | Temp. | Precip. |
| Plot 2 | -0.80 [1/] | -0.01 | -0.52 | 0.37 |
| | 0.0032 [2/] | 0.9834 | 0.1044 | 0.2684 |
| Plot 4 | -0.71 | -0.51 | -0.81 | -0.29 |
| | 0.0144 | 0.1090 | 0.0023 | 0.3895 |
| Plot 8 | -0.74 | 0.01 | -0.36 | 0.62 |
| | 0.0061 | 0.9997 | 0.2571 | 0.0309 |
| Oyster Creek | -0.71 | 0.46 | -0.27 | 0.44 |
| | 0.0317 | 0.2114 | 0.4785 | 0.2306 |
| Cow Bayou | -0.95 | -0.69 | -0.91 | 0.37 |
| | 0.0130 | 0.1959 | 0.0305 | 0.5357 |
| Water's Ditch | -0.60 | -0.42 | -0.62 | -0.05 |
| | 0.2846 | 0.4804 | 0.2674 | 0.9323 |

[1/] Correlation coefficient.
[2/] Significance level.

Principal components analysis of data from transect 1 was used to estimate correlations between soil nutrients and principal components. Relative elevation, soil water content, clay (%), and soil Cu, Fe, P, K, and salinity were strongly related to principal component 1 (Table 4), which was interpreted as an elevation-induced soil aeration gradient (see below).

Table 3. Mean (standard deviation) of soil properties in study plots. Nutrients are expressed in parts per million. Gravimetric water content (GWC) is expressed as a percentage.

| Soil Property | Flats | | Swales | |
|---|---|---|---|---|
| pH | 7.72 | (0.19) | 7.62 | (0.11) |
| N | 4.5 | (3.7) | 5.1 | (4.3) |
| P | 39.5 | (10.6) | 60.9 | (11.1) |
| K | 580 | (119) | 766 | (78) |
| Ca | 24,320 | (7,899) | 26,248 | (6,019) |
| Mg | 1,053 | (202) | 1,070 | (59) |
| Salinity | 427 | (43) | 508 | (60) |
| Zn | 0.91 | (0.26) | 1.07 | (0.20) |
| Fe | 23.9 | (4.6) | 45.4 | (13.5) |
| Mn | 13.0 | (3.6) | 15.3 | (3.1) |
| Cu | 2.2 | (0.4) | 3.4 | (1.3) |
| Na | 96 | (25) | 112 | (17) |
| August GWC | 25.3 | (2.2) | 30.6 | (2.8) |
| November GWC | 37.3 | (3.0) | 52.6 | (6.9) |
| March GWC | 34.9 | (4.9) | 51.5 | (4.4) |

Table 4. Correlation of environmental variables with principal component 1 from an analysis of environmental and vegetation data.

| Variable | r |
|---|---|
| Salinity (ppm) | 0.9895 |
| Nov. water content (%) | 0.9739 |
| Clay (%) | 0.9716 |
| P (ppm) | 0.9651 |
| K (ppm) | 0.9608 |
| Fe (ppm) | 0.9606 |
| Relative elevation (cm) | -0.9550 |
| March water content (%) | 0.9405 |
| Cu (ppm) | 0.9395 |
| Aug. water content (%) | 0.8954 |
| Zn (ppm) | 0.6517 |
| Na (ppm) | 0.6001 |
| Ca (ppm) | 0.3746 |
| Mg (ppm) | 0.3086 |

## Vegetation

Reciprocal averaging ordination showed clear trends in plot and species ordinations related to topography. Frequency lines from swales were on the positive end of axis I, whereas those of flats were on the negative end of this axis and aligned along axis II (Fig. 1). In addition, the alignment of frequency lines from flats along axis II roughly paralleled changes in relative elevation, with frequency lines of macroplot 1 having the highest relative elevation and those of macroplot 25 the lowest. Relative elevation was ordinated among transects 1 and 2 (with the highest macroplot elevation), and clay was plotted to the right toward swales.

Little overlap between different transects was due principally to occurrence of stand-specific species. Species characteristic of swales (e.g., *Cardamine bulbosa, Panicum gymnocarpon, Leersia lenticularis*) were on the positive end of axis I (Fig. 1, right). Species common in flats (e.g., *Oplismenus hirtellus, Smilax* spp., *Carex cherokeensis*) were aligned parallel to axis II in order of their abundance along a relative elevation gradient (also see Fig. 2). Species common to both flats and swales (e.g., *Celtis laevigata* seedlings, *Carex tribuloides*) were ordinated between species of flats and swales. The transition from swale to flat was quite distinct in the ordination, and few species were shared between the two types.

Reciprocal averaging can be used as a divisive technique to examine relations within subsets of data (Gauch, 1982). When plots located in swales were removed prior to analysis, frequency lines (Fig. 3, left) and species (Fig. 3, right) were arranged along axis I in very nearly the same order as they were arranged along axis II in the ordination of the full data set (Fig. 1). The arch effect exhibited in Fig. 3 often indicates that there is only one major direction of variation in these data (e.g., Werger et al., 1978). Similarities in ordination results between Fig. 1 (complete data set) and Fig. 3 (excluding swales) shows how little effect the removal of species common to swales had on ordination of species of flats, suggesting that the two habitats each support distinct vegetation.

Ordination of frequency plots placed along the 220-m transect lines also suggested the existence of 2 distinct vegetation types (Fig. 4). Within swales, RA scores were similar and quite different from scores in higher, unflooded flats. Depth of a swale appears of little importance in determining vegetation type: both shallow and deep swales were inhabited by *Panicum gymnocarpon* with few other species present. Continuous variation of species distributions within flats, as well as the lack of overlap between swales and flats, contributed to a noticeable separation of RA scores along axis I.

Mean of similarity comparisons using coefficient of community was 0.645 among flats and 0.357 among swales. Plots in flats generally had a consistent group of core species (e.g., *Carex cherokeensis, Oplismenus hirtellus, Ruellia pedunculata, Leersia virginica*) which is reflected in relatively high coefficient of community. Swales were characterized by one ubiquitous dominant (*Panicum gymnocarpon*) and a small set of relatively uncommon species whose sporadic occurrence lowered the coefficient of community. The mean of flat/swale comparisons was 0.18, indicating little floristic overlap and supporting ordination results suggesting the existence of two relatively distinct herbaceous communities.

Species richness tended to increase with relative elevation (Fig. 5). This may be caused in part by an exchange of dominants along the gradient from flooded swales to more droughty flats and ridges (Table 1; Whittaker, 1972; Prach, 1986).

Table 5. Species abbreviations used in reciprocal averaging ordination diagrams (Figs.1, 2, and 3).

| Abbreviation | Scientific name | Common name |
|---|---|---|
| An | *Acer negunda* | Box elder |
| Ap | *Asclepias perennis* | Swamp milkweed |
| Br | *Bignonia radicans* | Trumpet-creeper |
| Ca1 | *Carex amphibola* | Sedge |
| Ca2 | *Carex* sp. | Sedge |
| Cb | *Cardamine bulbosa* | Spring-cress |
| Cc | *Carex cherokeensis* | Sedge |
| Cl | *Celtis laevigata* | Texas sugarberry |
| Ct | *Carex tribuloides* | Sedge |
| Db | *Dicliptera brachiata* | |
| Di | *Dichondra* sp. | Pony's foot |
| Dl | *Dicanthelium lindheimeri* | Lindheimer panic |
| Dt | *Desmodium tortuosum* | Tick-clover |
| Ec | *Elepantopus carolinianus* | Elephant's foot |
| El | *Eleocharis* sp. | Spikerush |
| Ev | *Elymus virginicus* | Virginia wildrye |
| Fp | *Fraxinus pensylvanica* | Green ash |
| Jl | *Justicia lanceolata* | Lance-leaved willow-water |
| Ll | *Leersia lenticularis* | Catchfly grass |
| Lv | *Leersia virginica* | White grass |
| Ma | *Malvaviscus arboreus* | Turk's cap |
| Mm | *Melica mutica* | Two-flower melic |
| Ms | *Muhlenbergia schreberi* | Nimblewill muhly |
| Oh | *Oplismenus hirtellus* | Basketgrass |
| Pg | *Panicum gymnocarpon* | Beaked panic |
| Pl1 | *Paspalum langei* | Rustyseed paspalum |
| Pl2 | *Phyla lanceolata* | Northern frog-fruit |
| Pq | *Parthenocissus quinquefolia* | Virginia creeper |
| Pv | *Polygonum virginicum* | Jump-seed |
| Rp | *Ruellia pedunculata* | |
| Rt | *Rubus trivialis* | Southern dewberry |
| Sc | *Sanicula canadensis* | Black snake-root |
| Sm | *Smilax* sp. | Green-brier |
| So1 | *Solidago* sp. | Goldenrod |
| So2 | *Symphoricarpos orbiculatus* | Coral-berry |
| Ss | Sapindus saponaria | Soapberry |
| Tr | *Toxicodendron radicans* | Poison Ivy |
| Ul | *Ulmus* sp. | |

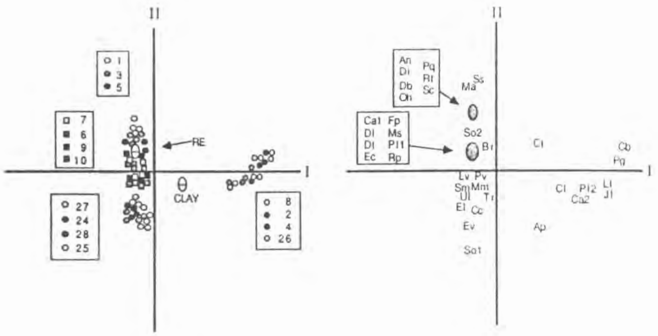

**Figure 1.** Reciprocal averaging ordination of transects 1, 2, and 3. Left: macroplot ordination; environmental variables are relative elevation (RE) and relative clay content of profile. Right: species ordination; species abbrevations are listed in Table 5.

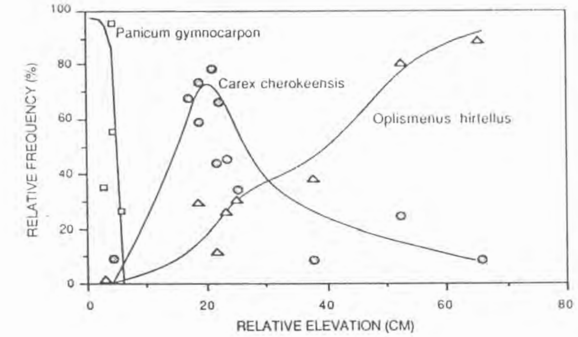

**Figure 2.** Abundance of 3 common herbaceous species in relation to relative elevation. Abundance is expressed as frequency by macroplot (1 set of 4 frequency lines). Curves are drawn free hand.

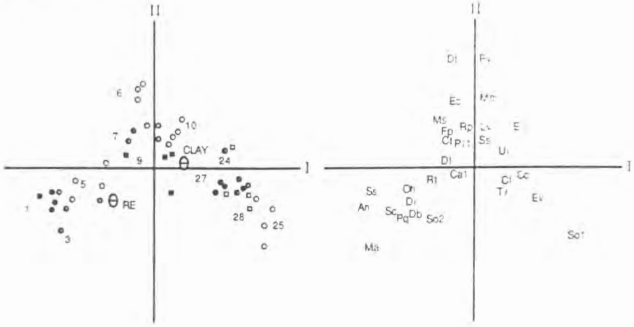

**Figure 3.** Reciprocal averaging ordination of plots from flats of transects 1, 2, and 3. Left: plot ordination; environmental parameters are relative elevation (RE) and relative clay content of profile. Right: species ordination; species abbreviations are listed in Table 5.

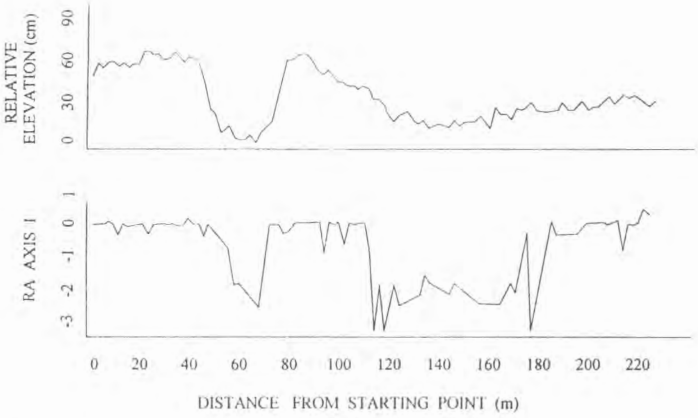

**Figure 4.** Bottom: trace diagram of frequency plots from transect line of transect 1. Reciprocal averaging (RA) score for axis I is plotted by plot location. Top: relative elevation along transect line.

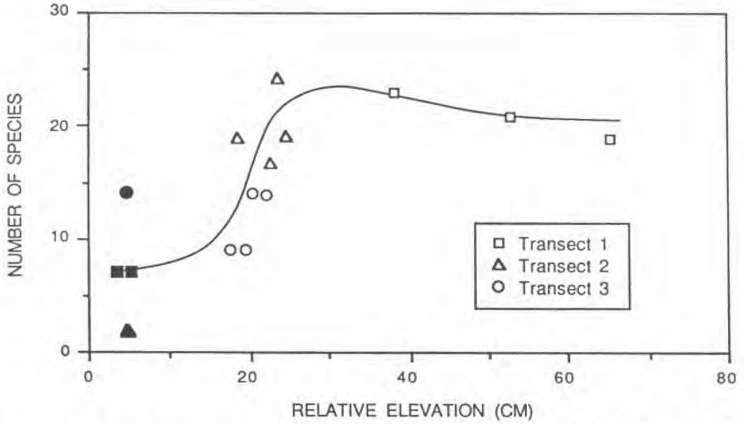

**Figure 5.** Understory vegetation richness as affected by relative elevation. Richness is express as the number of species occurring within one macroplot (1 set of 4 frequency lines).

Changes of abundance of three common species (*Panicum gymnocarpon, Carex cherokeensis,* and *Oplismenus hirtellus*) as a function of relative elevation (Fig. 2) suggests differential species response to a soil aeration gradient (Table 1). A mixture of species occupied flats with dominance gradually shifting with changing relative elevation. In contrast, swales were dominated by one species (*Panicum gymnocarpon*) whose distribution was confined to seasonally flooded areas.

Herb species diversity and canopy closure (which varied less than 9%) were uncorrelated (Grissom, 1987). Similar results were found by Collins and Pickett (1982, 1987) and Moore and Vankat (1986). The small and widely spaced gaps in our study area probably had little effect on large-scale understory vegetation pattern, and although small patches of understory vegetation may be greatly influenced by these gaps, our sampling was not designed to detect such an effect.

## DISCUSSION AND CONCLUSIONS

Floodplain microtopography and edaphic characteristics are products of flooding history. Initial alluvial landscape affects speed and distribution of subsequent floodwaters and, therefore, sediment deposition. Resulting variation in topography and soils produces a mosaic of differentially aerated sites (Wolman and Leopold, 1957; Allen, 1965) which may strongly affect patterns of plant growth (Ewing, 1996) and survival (Robertson et al., 1978; Huenneke, 1982). Thus, seasonal flooding along rivers is an important regulating influence of species richness (Nilsson et al., 1997).

Two basic types of environment, the result of landscape and flooding history, are manifested in the microtopography of our study site and are reflected in edaphic properties and vegetation patterns. Flats and ridges are elevated above standing water and often have coarse-textured horizons interspersed with clayey-textured horizons. Swales hold water during cooler months, have higher soil water content during most of the year, and have soils composed entirely of clays. Swales also had higher concentrations of soil Fe, Cu, P, and K, and were more saline than flats. Vegetation patterns are attributed to microtopographically-induced variation in flooding frequency and duration and its impacts on soil (see Robertson et al., 1978; Gauch and Stone, 1979). Topographic, edaphic, and hydrologic factors are interrelated, and it is difficult to separate and define the nature and magnitude of their individual influences (Struik and Curtis, 1962; Anderson et al., 1969; Bratton, 1976).

Floodplain vegetation has been related to elevation-induced differences in flooding regime and to changes in soil pH, Ca, Mg, and N (Parsons and Ware, 1982; Dunn and Stearns, 1987a, b). Gauch and Stone (1979) found pH, Ca, Mg, Mn, and K related to flooding. These soil parameters appeared to vary independently of elevation and flooding on Sienna and were not related to vegetation pattern. Different climate, soils, parent material, biota, and hydrologic regime, as well as temporal variation, may contribute to the difference in results between other sites and Sienna.

Flooding has been observed to reduce tree, shrub, and herbaceous richness (Bell 1974; Frye and Quinn, 1979; Robertson et al., 1978). In contrast, Nilsson et al. (1997) have recently shown that impounding rivers and decreasing flooding frequency can reduce species diversity. Herbs may be less sensitive to microhabitat differences than trees (Collins and Pickett, 1982; Huenneke, 1982), and thus plant strata within a community may sometimes exhibit different responses to the same gradient.

Understory vegetation on Sienna showed strong spatial patterns related to microtopography. *Panicum gymnocarpon* dominated species-poor swales. Leaves and stems of this species growing above normal water levels may diffuse oxygen downward from aerial to submerged plant parts (e.g., Armstrong, 1978; Hook, 1984). Additionally, the ability to root at nodes improves flooding tolerance by concentrating roots in better-aerated surface soil. These adaptations are shared by other species as well, for example *Leersia lenticularis.* Ruderal strategy was exhibited by *Solidago* sp., *Cardamine bulbosa, Justicia lanceolata,* and *Phyla lanceolata,* all of which colonized swales in summer after floodwaters disappeared. The latter species are perennials, but acted as annuals in this case, similar to floodplain perennials studied by Rogers (1982). Thus, although species richness increased during periods of drawdown, *Panicum gymnocarpon* was a predictable dominant in these habitats, and its success may be attributable to longevity and morphological features promoting flooding tolerance. In the context of vegetation dynamics, composition of swales is, therefore, generally predictable throughout the cyclic course of seasonal flooding and drawdown (van der Valk, 1981).

Flats, unaffected by seasonal flooding, supported more diverse vegetation than swales. Sedges and grasses dominated, but many forb, vine, and shrub species were also present. This vegetation reflected a soil moisture gradient. This transition, however, was spatially more gradual than that between swales and flats. Species composition shifted gradually from low flats dominated by *Carex cherokeensis* to ridges dominated by *Oplismentus hirtellus.*

Understory species richness is an important aspect of vegetation pattern and is influenced by both environment and biota (Whittaker, 1965; Robertson et al., 1978; Prach, 1986). Severe and unstable conditions usually lower diversity with few species being adapted to such harsh environments. Whittaker (1972; p. 237) wrote that extreme conditions act as a "filter, demanding adaptations for which not all genetic lines have the potentiality." In this bottomland hardwood forest, herbaceous vegetation formed two separate types in response to flooding: (1) a simple, species-poor type in swales where few species were able to tolerate the stressful and unstable conditions associated with seasonal and annual variation common in the flooding of these minor drainages; and (2) a species-rich type in unflooded areas, in which species showed relatively continuous distributions along a moisture gradient from low flats to ridges.

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# Effect of Protein Delivery Method for Steers Grazing Tobosagrass

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## ABSTRACT

**The effect of delivery method of protein supplementation on winter weight gain, and subsequent spring performance of steers was determined at the Texas Tech Experimental Ranch, in Garza County, Texas. One of the objectives of this research was to determine if the form of supplementation influences winter gain. We also evaluated protein and mineral intake. Cubes (36% crude protein) and blocks (37% and 20%) were fed during the winter season to cross-bred steers grazing tobosagrass (*Hilaria mutica*) range. Average daily gain (ADG) for the control steers was 0.40 lb/hd/day during the winter while spring gain was 1.54 lb/hd/day. Winter ADG for steers supplemented with cubes (36%) CP was 0.88 lb/hd/day while ADG in spring was similar to the control with 1.50 lb/hd/day. The winter ADG for steers supplemented with blocks were 0.40 and 0.73 lb/head/day, respectively for 37%, and 20% CP blocks, while the spring ADG was 1.42 and 1.75 lb/hd/day, for steers fed with 37%CPB and 20%CPB, respectively. We found no compensatory gain in the spring on tobosagrass rangeland. Heavier steers at the conclusion of winter supplementation remained the heaviest at the end of the spring. Protein blocks were consumed at a relatively low and variable rate during the first four weeks of feeding, increasing later to the target amount. Source of supplementation also affected the mineral intake. The source of supplementation should be determined by desired response coupled with economic and management considerations.**

**KEYWORDS:** Winter supplement, Mineral supplement, Compensatory gain, Beef, cattle, Spring grazing.

Tobosagrass (*Hilaria mutica*) is a major forage species that occurs from the Rolling Red Plains of west-central Texas through New Mexico and Arizona and into south to north-central Mexico (Stubbendieck et al. 1986). Tobosagrass is often associated with mesquite *(Prosopis* spp.) throughout its range. Tobosagrass grows primarily during the spring and summer. Culms that are not grazed or burned off remain alive and most new leaves arise as tillers from buds at elevated internodes. Such tillers are small and do not grow with the vigor of tillers arising from lateral buds at the base of culms near or beneath the soil surface.

Tobosagrass is low in palatability for livestock. Accumulation of old growth from perennial stems tends to discourage grazing. Britton and Steuter (1983) reported rapid declines in crude protein and dry matter digestibility with maturation. Crude protein in

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mature tobosagrass can drop below 5% (Nelson et al., 1970) which is an unacceptable nutritional level (NRC, 1996). During the dormant period in the Rolling Plains of Texas, tobosagrass crude protein was 4.5%, and digestibility 35% (Britton and Pitts, 1988).

Protein is the nutritional component most often deficient on rangelands during the winter. Inadequate dietary protein suppresses forage intake and digestion (McCollum and Galyean, 1985) and reduces the efficiency of metabolizable energy utilization (McCollum and Horn, 1990). Protein supplementation during the dormant season enhances weight gain and production from grazing livestock (Villalobos et al., 1997). Bohman et al. (1961) observed increases in average daily gain and intake for steers wintered on native grass hay supplemented with either cottonseed meal or alfalfa. Smith and Warren (1986) reported weight gain in steers supplemented with cottonseed meal. Supplementation programs depend on the assumption that animals consume a targeted quantity of supplement. One of the main factors that affect supplement intake is the supplement delivery method. The labor cost and frequency of supplementation is of considerable concern to producers. Feeding blocks under range conditions has the potential to reduce labor and equipment costs, but also presents a number of challenges. Some animals consume large amounts of supplements, while others consume very little. In practical herd feeding situations, it is difficult to separate the noncosumers until a potentially irreversible loss in condition or weight has occurred (McCollum and Horn, 1990). When evaluating the efficacy of supplements, an analysis that includes the performance of livestock and supplement refusals must be included (McCollum and Horn, 1990).

Despite extensive research on livestock supplementation, there is relatively little information available on the effects of the presentation or delivery method of protein supplementation on performance, supplement, and mineral intake on tobosagrass dominated rangeland. The objectives of this study were: (1) evaluate the effect of the supplementation forms on steers winter gain; and (2) determine the effect of winter feeding on spring gain, as well as the effect of source of supplementation on mineral intake and monitoring the block intake.

## EXPERIMENTAL PROCEDURES

### Study Area

Research was conducted at the Texas Tech Experimental Ranch during the dormant and growing season of 1994. The ranch lies on the edge of the Rolling Red Plains in Garza County, 16 miles southeast of Post at a mean elevation of 2400 ft. The area is dominated by clay flat range sites with gently sloping Stamford Clay soils (fine, montmorillonitic, thermic typic Chromusterts) (Richardson et al., 1965).

Perennial vegetation is dominated by tobosagrass with alkali sacaton (*Sporobolus airoides* [Torr.] Torr.) in depressions. Associated species include buffalograss (*Buchloe dactyloides* Nutt.) and plains pricklypear (*Opuntia polycantha*), with an overstory of honey mesquite (*Prosopis glandulosa* var. *glandulosa* Torr.).

The climate is warm and temperate; temperature ranges from a daily minimum of 27°F in January to a daily maximum temperature of 95°F in July. Periods of drought are frequent. Approximately 50% of the annual precipitation (19 inches) occurs from April through July (Richardson et al., 1965).

Response of steers grazing dormant tobosagrass to winter protein supplementation was evaluated using 159 crossbred *Bos taurus* x *Bos indicus* steers with a mean initial live weight of 365 lb/hd. Steers were randomly allocated to each of 4 treatments. Treatments were control (CON); 37% crude protein blocks (37 CPB), 20% crude protein blocks (20 CPB), and 36% crude protein cubes (36 CPC) (Table 1). Cubes (36 CP) were fed three times a week at a rate of 2 lb/steer/day. The target intake of the block with 37% CP was 2 lb/steer/day and 4 lb/steer/day from blocks with 20% CP.

Table 1. Nutritional composition of supplements and minerals (% dry matter basis)

| ITEM | 20% Block[1] | 37% Block[2] | 36 Cubes[3] | Mineral Block |
|---|---|---|---|---|
| Crude protein | 20.0 | 37.0 | 36.0 | |
| Total digestible nutrients | 65.0 | 59.0 | 74.8 | |
| Fiber | 9.0 | 8.0 | 12.0 | |
| Calcium | 1.0 | 1.0 | 0.9 | 11.5 |
| Phosphorous | 1.2 | 1.3 | 1.3 | 7.5 |
| Salt | 12.5 | 13.5 | 0.0 | 42.0 |
| Potassium | 1.2 | 1.2 | 1.6 | 0.0 |
| Magnesium | 0.3 | 0.3 | 0.4 | 0.5 |
| Sulfur | 0.2 | 0.3 | 0.4 | 0.0 |

1 = 20% (Natural)
2 = 37% (22.5% natural, 14.5% from urea)
3 = 36% (1% from urea)

On their arrival, steers were held in a small pasture of dormant old world bluestem. Cattle were watched closely for signs of sickness and were given the supplement. Steers were moved to the tobosagrass study site after 2 weeks.

Stocking rate for each pasture was based on standing crop at the start of grazing trial and estimated yield for the current year assuming removal of 50% of available forage. Forage yield was estimated by randomly clipping 10, 0.25 $m^2$ quadrants in each pasture at the end of the growing season. An attempt was made to maintain similar forage allowances in all pastures. Pasture areas were 235, 223, 167, and 204 acres.

Supplementation began on, 11 January, 1994, and continued until 4 April 1994. Individual steer weights were recorded at the beginning of the supplementation, on 11 January, at the end of the supplementation on 5 April, and letter on 7 July 1994. Live weights were obtained following an overnight period without water and feed. Mineral and protein blocks were weighed weekly to determine intake. We allowed 1 block of mineral and protein for every 3 to 4 steers.

Gain, mineral, and block intake were analyzed as a completely randomized (CRD) design. Least Significant Different (LSD) at 0.05 significance level was used for mean comparison. The use of animals as experimental units provided a conservative analysis because the animals were group-fed rather than individually fed. Group-feeding results in greater variation among animals within treatments as a result of uncontrolled and varied feed consumption by individuals. Hence, any significant differences observed among treatments are valid. A potential weakness of the analysis is the inability to discern smaller differences that would have been statistically significant with controlled, individual feeding (Pitts et al. 1992).

## RESULTS AND DISCUSSION

Average daily gain (ADG) during winter was different (P=0.05) between sources of supplementation (Fig. 1). Steers on the 36CPC and 20CPB treatments had a similar (P=0.05) gain; ADG of these animals was greater (P=0.05) than gain of animals in CON and 37CPB groups. During the winter, groups on 37CPB and CON gained the least with an ADG of 0.40 and 0.58 lb/hd/day, respectively.

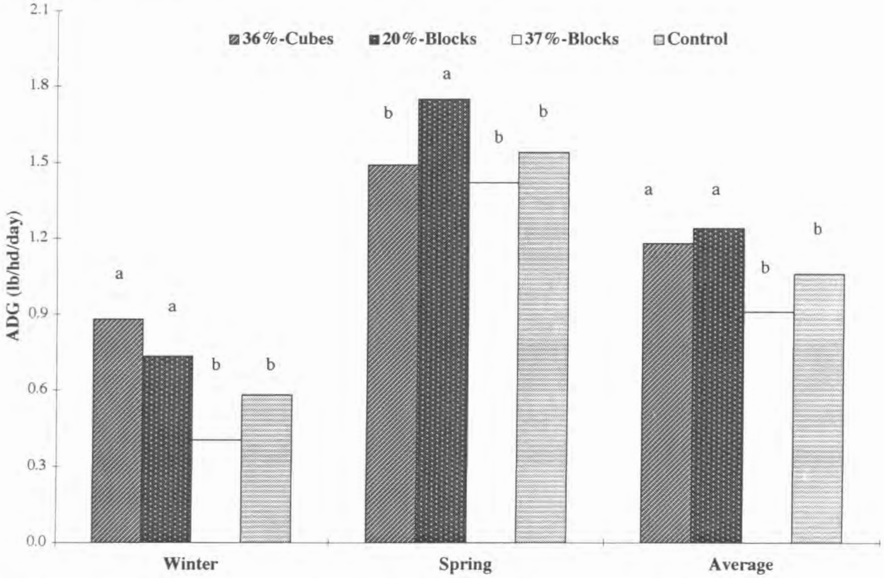

**Figure 1.** Average daily gain (ADG) of steers fed 4 sources of protein supplementation while grazing dormant tobosagrass. Means followed by the same letters are not significantly different (P=0.05).

During the spring season, ADG was higher for steers that were fed 20CPB during the winter (P=0.05) (Fig. 1). ADG was similar for steers on 37CPB, 36CPC and control, respectively. In this case, the winter weight differences were minimized but maintained at the end of the grazing season. The total gain (winter+spring) was different (P=0.05) among treatments (Fig. 1). The steers that were heaviest after winter, remained heaviest at the end of the spring; however, the weight margins varied. At the end of the grazing season, the steers that were in the 20CPB group gained 86.0 and 26.0 lb/hd more (P=0.05) than those that were in the 37CPB and CON treatments, respectively. In contrast, at the end of spring, steers in the 36CPC gained 81.0 and 21.0 lb/hd more (P=0.05) than those that were in the 37CPB and CON groups. This indicates that no compensatory gain was shown for this kind of vegetation. Usually spring gains are more closely related to rainfall quantity and distribution (Villalobos et al., 1997). In this year spring rainfall was below the long term average, and was well distributed during the winter months (Fig. 4).

The primary objective of this research was to determine if supplementation source influences spring gain. We found no compensatory gain in the spring on tobosagrass rangeland. Heavier steers at the conclusion of winter supplementation remained the heaviest at the end of the spring. Our results agree with (Villalobos et al., 1997), here no differences in compensatory gain was observed using different levels of cottonseed cubes.

## Supplement Intake

Cubes were hand-fed, allowing close control of supplement allowance. Steers required about 30 minutes to consume their portion of supplement per day. No refusals on the cube consumption were observed. In contrast, both types of protein blocks were consumed at relatively low and variable rates during the first four weeks of feeding (Fig. 2). As a result, crude protein intake from the 20CPB averaged only 0.42 lb/hd, less than 48% of the target amount, and 46% less protein than from 36CPB. Steers on 37CPB treatment had an average of 0.55 lb/hd/day of protein, 26% less intake than the amount targeted, and 24% less than steers fed with cubes. Livestock exposed to new feeds often exhibit neophobia, or a cautious sampling or rejection of the feed that is not related to palatability (Launchbaugh, 1995). Neophobia is characterized by a period of low feed intake, followed by increased consumption leading to a relatively stable level of intake. The neophobic eating pattern exhibited by feedlot cattle lasts less than 2 weeks (Hicks et al., 1990). In our study, even if blocks were fed two weeks before the initial weight was taken, livestock showed this neophobic effect and the level of supplement consumption was below target levels. Acceptance of supplements increased substantially after 5 weeks of study (Fig. 2), and intake increased to supplement target. Similar variability in supplement intake has been demonstrated in cows fed traditional supplements (Huston et al., 1987). Langlands and Bowles (1976) found that animals refused to consume liquid supplement offered in roller lick tanks. Langlands and Donald (1978) reported a refusal of molasses-urea supplement in a study using yearling heifers. The variation in supplement consumption for these studies was 40% (Langlands and Bowles, 1976), and 37% (Langlands and Donald 1978) for the supplement target. Coombe and Mulholland (1983) found that mean supplement intake as a percentage of the target supplement intake was 41% for blocks, 76% for molasses-urealiquid, and 80% for molasses. Over the 10-week experimental period, target supplement intake was never achieved with block supplement, whereas target consumption was reached by weeks 4 and 5 for molasses-urea liquid supplements. Our results agree with these findings. Steers on the 20% blocks consumed 52% below the target consumption during the first 4-week, and with the 37% block consumed 74% of the target amount.

Blocks can be classified as self-fed supplement which theoretically should increase an animal's opportunity to consume the supplement. Conversely, cubes are hand-fed, which allows close control of supplement allowance. Therefore, cubes and blocks may differ in two characteristics that can affect the efficiency of the supplementation program. First, steers can eat cubes faster than blocks. Therefore, animals supplemented with cubes may require less time to consume their portion of supplement per day and may have more time available to graze. Second, cubes are usually fed on the ground, 2 to 3 times a week. The distribution of the cubes over a large area allows both dominant and subordinate animals to have simultaneous access to the feed and to obtain their allowance of supplement. Dominant animals may prevent subordinate animals from gaining access to the blocks, reducing the efficiency of the supplement. If the consumption of supplement occupies a significant part of the time available for grazing, it may conflict with utilization of the forage available. If competition between animals for access to the blocks is intense, steers may waste grazing time trying to obtain the supplement that is monopolized by dominant animals. We observed this phenomenon with the block treatments. Because cubes allow a high intake rate, most of the feed given at each feeding event is consumed. In this case, supplementation does not interfere with grazing activities. The final result, in terms of weight gain per head and profit will depend on the supplement cost and labor to deliver the supplement.

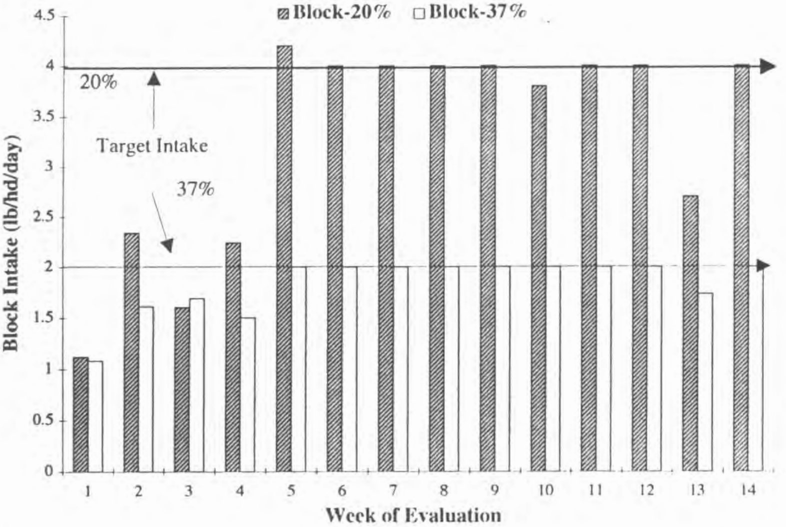

**Figure 2.** Total protein block intake (lb/hd/day) of steers fed 2 sources of protein while grazing tobosagrass range.

## Mineral Intake

Mineral intake for all treatments decreased from the beginning of supplementation, and increased as soon as supplementation was stopped during April (Fig. 3). At each month of evaluation, steers in the CON group had a higher ($P<0.05$) mineral intake than other treatments (Fig 3). Control steers had the highest ($P<0.05$) mineral intake with an average of 0.21 lb/hd/day, followed by steers on the 36% cubes (Fig. 3). The lowest ($P<0.05$) intake was detected for the steers fed 37% blocks. During March, similar to February, intake was higher ($P<0.05$) for the control and steers fed with 36% cubes. Mineral intake was lowest for the three feeding treatment in April. During May, the control group and steers fed with cubes had a higher ($P<0.05$) mineral intake than the other groups. The last month of evaluation intake was similar for the three groups that were under feeding conditions and control steers had the highest intake with an average of 0.07 lb/hd/day.

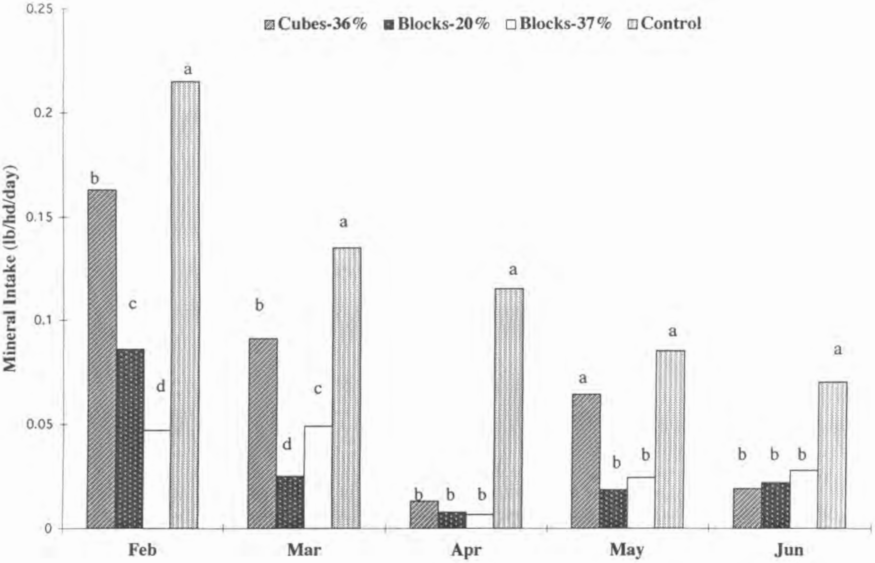

**Figure 3.** Total mineral intake (lb/head/day) of steers fed 4 sources of protein supplementation while grazing dormant and spring season on a tobosagrass range. Means followed by the same letters are not significantly different (P=0.05).

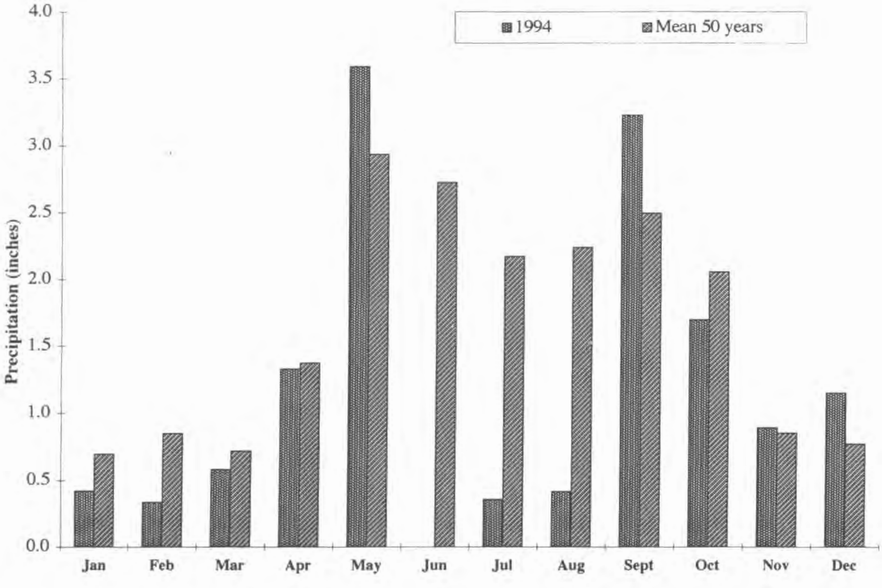

**Figure 4.** Precipitation at the Texas Tech Experimental Ranch during 1994 and long term average. Average precipitation is taken from the Garza County Soil Survey.

A great deal of variation exists in the consumption of blocks for protein and mineral supplementation. High levels of competition for blocks generally increases the proportion of non-feeders, whereas low levels of competition occur with cubes. Supplement delivery method has the potential to alter competition, reduce the time of consumption of supplement and possibly to improve the effectiveness of a supplement program.

Results indicate that protein supplementation is beneficial to steers grazing tobosagrass rangelands during the winter. Consequently, steers with greater weights during winter remained heavier in spring. The source of supplementation should be determined by expected response coupled with economic and management considerations.

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# Habitat Use of Texas Horned Lizards in Southern Texas

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## ABSTRACT

**Microhabitat characteristics for the Texas horned lizard (*Phrynosoma cornutum*) were quantified from information gained from radio-tracking in Duval County, Texas. Microhabitat characteristics were assessed from known locations of lizards and random locations and included soil pH, soil particle size distribution, soil organic content, percent herbaceous vegetation, vegetation height, percent bare ground, vegetative basal area for bunch grasses, plant stem density, soil temperature, percent canopy cover, percent grasses, and percent forbs. Lizards (n = 16) disproportionately used the range of values for 11 of the 14 (soil pH, soil particle size distribution, soil organic content, percent bare ground, plant stem density, soil temperature, percent canopy cover, percent grasses, and percent forbs) microhabitat characteristics from their availability. Microhabitat characteristics recorded at bedding sites were used pro rata to availability. Soil moisture at bedding sites averaged 2.2% during the months July through October. Lizards would not bury themselves in soil for several days after precipitation; instead, the bases of trees and bunch grasses were used as bedding sites.**

**KEYWORDS:** bedding site characteristics, habitat characteristics, *Phrynosoma cornutum*

Habitats of Texas horned lizards (*Phrynosoma cornutum*) have been described, but to our knowledge no one has quantified the characteristics of selected microhabitats. Price (1990) reported Texas horned lizards have been found in a variety of habitats ranging from open deserts to grasslands, located from sea level to 1,830 m elevation. Soil types included deep, pure sands, sandy loams, coarse gravels, conglomerates, and desert pavements of alluvial plains and mesa tops. Jameson and Flury (1949), Milstead et al. (1950), Minton (1959), Whitford and Creusere (1977), and Price (1990) reported that Texas horned lizards inhabited different ecological associations including shortgrass prairie, mesquite (*Prosopis glandulosa*)-grasslands, shrublands, desert scrub, and desert grasslands. Milstead and Tinkle (1969) reported finding Texas horned lizards in terrain consisting of low, gently rolling sand dunes with about 20% cover from desert vegetation. Whiting et al. (1993) suggested spatial distribution of Texas horned lizards was dependent on the presence of harvester ants (*Pogonomyrmex barbatus*) and open, partially vegetated habitat. They also reported that Texas horned lizards selected mechanically disturbed areas

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(asphalt airstrip, dirt roads, and mowed areas), which they believed allowed for greater ease of movement. Fair and Henke (1997a) also believed Texas horned lizards selected areas that were easily traversed, reporting that lizards favored the use of recently burned areas over areas with built-up ground litter.

Because Texas horned lizards are a federal Species of Concern and a threatened species within Texas, a better understanding of habitat use is needed to develop recommendations for managing the species. Microhabitat data can provide insight as to the quality of habitat necessary to maintain a population. Therefore, our objective was to determine microhabitat preferences for Texas horned lizards in south-central Texas.

## MATERIALS AND METHODS

### Study Area

The study was conducted from March through October 1994 on the Marvin and Marie Bomer Wildlife Management Area (BWMA), an experimental wildlife management area operated by the Department of Animal and Wildlife Sciences of Texas A&M University-Kingsville, and on the adjoining Pena Ranch. The BWMA is a 48.2-ha area located 19.3 km south of Benavides in Duval County, Texas. The climate is subtropical and semiarid. The mean annual rainfall is 65.7 cm (Natl. Oceanic and Atmos. Adm., 1994), although rainfall can vary greatly from year to year (Norwine and Bingham, 1986). The mean annual temperature is 22.1° C (Natl. Oceanic and Atmos. Adm., 1994).

The BWMA soils are well to moderately well-drained, loamy fine sands and fine sandy loams with moderate-slowly draining lower soil layers and moderate shrink-swell potential (Nat. Resour. Conserv. Serv., unpublished data). The topography is nearly level to gently sloping uplands ranging in elevation from 106 to 109 m above sea level. Although the habitat of the BWMA is not widely diverse, it is representative of southern Texas where populations of Texas horned lizards are considered stable (Donaldson et al., 1994).

Past agricultural practices on the BWMA included planting kleingrass (*Panicum coloratum*) and buffelgrass (*Cenchrus ciliaris*) in what is now the Conservation Reserve Program (CRP) land. Other sections of the BWMA were root plowed, each root plowed area being 2 to 3 ha in size. Sides of the root plowed areas were left in brush lines up to 10 m wide. Approximately half of the management area is under CRP control and the current land management emphasizes the production of northern bobwhites (*Colinus virginianus*). Quail management techniques conducted on the BWMA include burning portions of the CRP on a rotational basis, burning and discing non-CRP land on a rotational basis, and shredding roads. These activities keep most of the BWMA in early to mid-seral stages.

### Habitat Assessment

Twenty-six horned lizards were captured by pitfall and funnel trapping, systematic searches, and random sightings (Fair and Henke, 1997b). Lizards were equipped with backpacks containing radio-transmitters (Model SM1, AVM Instrument Co., Livermore, CA) and located every 1 to 2.5 hours from sunrise to sunset for 5 days each month from initial capture (beginning in May) through October. Due to differential capture dates and survival rates of lizards, we were unable to obtain observation data on each captured lizard throughout the entire study period; however, a total of 1,434 lizard observations was obtained .

Microhabitat characteristics for Texas horned lizards were assessed from a random sample of horned lizard observations; however, to reduce dependency among observations only one observation per lizard per day was used for analyses (Swihart and Slade, 1985). One hundred plots from points where Texas horned lizards were observed were sampled each month. A 0.25-$m^2$ Daubenmire quadrat was placed at each lizard observation point with the location of the lizard being the center of the quadrat and microhabitat characteristics within the quadrat were recorded. In addition, 100 random plot locations were sampled each month. Microhabitat characteristics for random plots were assessed within 0.25-$m^2$ Daubenmire quadrat along two transects. Each transect was 500 m long, spaced 100 m apart, and traversed the study area. Plot locations were determined by walking a random number of meters (0 to 50 m) along the transect and then walking a random number of meters (0 to 50 m) perpendicular to the transect, either to the left or right of the transect line. A random number table was used to assign distances and direction (Steel and Torrie, 1980); if the number was even then the perpendicular distance was measured to the right of the transect line, and if the number was odd then the perpendicular distance was measured to the left of the transect line. Microhabitat characteristics at horned lizard bedding sites (i.e., sites where the lizards were buried in the soil) were recorded using a 0.25-$m^2$ Daubenmire quadrat as previously described.

Microhabitat characteristics recorded within each horned lizard plot and each random plot included soil pH, soil particle size distribution, soil organic content, percent herbaceous vegetation, vegetation height, percent bare ground, vegetative basal area for bunch grasses, plant stem density, soil temperature, percent canopy cover, percent grasses, and percent forbs. Soil pH was analyzed as described by Hendershot et al. (1993). Soil particle size distribution was analyzed using the hydrometer method (Gee and Bauder, 1986). Soil organic content was analyzed by the rapid colorimetric procedure as described by Texas Agricultural Extension Service (1980). Percent herbaceous vegetation was calculated as described by Bonham (1989). Percent forbs and percent grasses represented the percentage of each vegetation type from the total count of herbaceous plants within the 0.25-$m^2$ Daubenmire quadrat. Cacti were included with the forbs. Vegetation height was measured using a meter stick to the nearest 0.5 cm. Percent bare ground was estimated using the ocular estimation method (Gysel and Lyon, 1980). The percent bare ground values measured the amount of the 0.25-$m^2$ Daubenmire quadrat not covered by ground litter or herbaceous plants at ground level. Vegetative basal area was measured as outlined by the National Academy of Sciences (1962) and was calculated from basal circumference. Plant stem density was measured as described by Gysel and Lyon (1980). Stem density was measured as the number of individual plants within each 0.25-$m^2$ Daubenmire quadrat. Bunch grasses were considered 1 stem for each clump. Soil temperature was measured by inserting a thermometer 2.5 to 3.5 cm into the soil and taking the reading at 1 minute. The percent cover was measured with a photometer as described by Gysel and Lyon (1980), with readings taken at ground level and at 1 m above the ground (full light). An additional measurement of soil water content was calculated for bedding sites of Texas horned lizards. Soil water content was calculated by the gravimetric method using a drying oven (Topp, 1993).

Measurements for each microhabitat characteristic were initially partitioned into 5 intervals, each interval comprising 20% of the recorded values for random locations for each microhabitat characteristic. Organic matter, percent sand, soil temperature, stem density, and pH intervals were created *a posteriori* by combining intervals to ensure there was at least 1 expected value in each interval, a requirement of the Chi-square analysis (Neu et al., 1974).

Differential use of habitat was determined as described by Neu et al. (1974) using Chi-square analyses and Bonferronni Z-statistics to control the experiment-wise error probability at 0.10 because statistical analyses were considered to have potential biological significance at $P < 0.10$ (Tacha et al., 1982). Microhabitat characteristics were considered preferred or avoided, respectively, if the proportion of available study plots was below or above the corresponding 90% confidence interval. Expected values for each microhabitat characteristic were calculated from the percent occurrence on the BWMA as determined by the random plots.

Three assumptions must be met to use the Neu et al. (1974) analysis of habitat utilization. The first is that animals must have free access and mobility to select any of the available habitats. This assumption was tested and satisfied by monitoring movements of Texas horned lizards in a concurrent study (Fair, 1995). It was determined a horned lizard could traverse the research area in <1 week. The second assumption is that observations are collected in a random, unbiased manner. This assumption was met by randomly choosing lizard locations and random plots. The third assumption is that observations are independent. To reduce dependency among lizard plots, plots used in analyses were from individual lizards that had at least a 24-hour interval between successive relocations (Swihart and Slade, 1985).

Bedding site characteristics were tested for differential use as described for lizard observation plots. Expected values were calculated using all lizard observation plots.

## RESULTS AND DISCUSSION

Texas horned lizards disproportionately used the range of values for 11 of 14 microhabitat characteristics, which included percent bare ground, percent forbs, percent canopy cover, percent organic matter, soil pH, soil temperature, percent sand, plant stem density, percent clay, percent grass, and percent silt, from their availability (Tables 1 and 2). Texas horned lizards in southern Texas preferred areas with >80% canopy cover that consisted of <20% forbs and a plant stem density of <25 stems/0.25 $m^2$. Sandy loam soils with a pH >8.0, an organic matter content of 0.9 - 1.8%, and soil temperatures between 23 - 31 C also were preferred. Horned lizards in our study avoided areas with 40-60% canopy cover that consisted of <20% grass and bare ground and >80% forbs, and a plant stem density of >26 stems/0.25 $m^2$. Soils with a neutral pH, temperature >31 C, percent organic matter content <0.9% and >2.7%, and soil particle size distribution <66% sand and >16% clay also were avoided by Texas horned lizards. Three microhabitat characteristics (basal area of bunch grasses, percent total herbaceous vegetation, and vegetation height) were used *pro rata* to availability (Table 3).

Table 1. Habitat characteristics used disproportionately to availability by Texas horned lizards at the 0.10 significance level, as determined from 0.25-$m^2$ random and lizard observation plots on the Bomer Wildlife Management Area, Duval County, Texas during 1994.

| | Random locations | | | Lizard locations | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Habitat characteristic | $\bar{x}$ | SE | Range | $\bar{x}$ | SE | Range | $\chi^2$ | df | *P*-value |
| Percent bare ground | 31.06 | 0.23 | 0.0 - 99.0 | 36.73 | 0.39 | 0.0 - 92.0 | 11.65 | 4 | 0.0202 |
| Percent canopy cover | 43.12 | 0.34 | 1.5 - 99.3 | 29.90 | 0.47 | 2.3 - 99.1 | 44.64 | 4 | 0.0001 |
| Percent forbs | 55.54 | 0.26 | 0.0 - 100 | 47.01 | 0.47 | 0.0 - 100 | 10.18 | 4 | 0.0375 |
| Percent grass | 41.66 | 0.26 | 0.0 - 100 | 49.35 | 0.47 | 0.0 - 100 | 8.94 | 4 | 0.0628 |
| Plant stem density | 17.72 | 0.20 | 0 - 149 | 8.18 | 0.21 | 0 - 47 | 35.32 | 1 | 0.0001 |
| Percent organic matter | 1.17 | 0.04 | 0.3 - 4.1 | 1.20 | 0.06 | 0.1 - 2.7 | 39.77 | 3 | 0.0001 |
| Soil pH | 7.44 | 0.03 | 5.9 - 8.8 | 7.57 | 0.06 | 6.0 - 8.7 | 20.77 | 3 | 0.0001 |
| Soil temperature (C) | 32.07 | 0.15 | 20.0 - 53.3 | 27.25 | 0.16 | 17.8 - 43.3 | 182.3 | 3 | 0.0001 |
| Percent sand | 73.16 | 0.13 | 30.0 - 87.5 | 75.93 | 0.17 | 62.5 - 90.0 | 14.69 | 2 | 0.0006 |
| Percent silt | 12.14 | 0.10 | 2.5 - 27.5 | 11.55 | 0.15 | 2.5 - 25.0 | 8.38 | 3 | 0.0388 |
| Percent clay | 14.70 | 0.11 | 5.0 - 50.0 | 12.52 | 0.15 | 5.0 - 22.5 | 5.25 | 1 | 0.0220 |

Table 2. Occurrence of Texas horned lizards in selected intervals of selected habitat characteristics on Bomer Wildlife Management Area, Duval County, Texas.

| Habitat characteristic | Interval | Proportion of random locations | Lizard locations | Expected number of lizard locations | Proportion observed in each interval ($p_i$) | Bonferronni's 90% confidence interval for $p_i$ | Preference outcome |
|---|---|---|---|---|---|---|---|
| Percent bare ground[a] | | | | | | | |
| | 0.0 - 20.0 | 0.451 | 55 | 74.4 | 0.333 | $0.248 \leq p_1 \leq 0.419$ | Avoided |
| | 20.1 - 40.0 | 0.247 | 54 | 40.7 | 0.327 | $0.242 \leq p_2 \leq 0.412$ | Neutral |
| | 40.1 - 60.0 | 0.147 | 23 | 24.2 | 0.139 | $0.077 \leq p_3 \leq 0.202$ | Neutral |
| | 60.1 - 80.0 | 0.110 | 24 | 18.2 | 0.145 | $0.082 \leq p_4 \leq 0.209$ | Neutral |
| | 80.1 - 100.0 | 0.045 | 9 | 7.4 | 0.055 | $0.013 \leq p_5 \leq 0.055$ | Neutral |
| Percent grass[a] | | | | | | | |
| | 0.0 - 20.0 | 0.362 | 45 | 59.7 | 0.273 | $0.192 \leq p_1 \leq 0.354$ | Avoided |
| | 20.1 - 40.0 | 0.172 | 31 | 28.4 | 0.188 | $0.117 \leq p_2 \leq 0.259$ | Neutral |
| | 40.1 - 60.0 | 0.168 | 26 | 27.7 | 0.158 | $0.091 \leq p_3 \leq 0.224$ | Neutral |
| | 60.1 - 80.0 | 0.116 | 21 | 19.1 | 0.127 | $0.067 \leq p_4 \leq 0.188$ | Neutral |
| | 80.1 - 100.0 | 0.182 | 42 | 30.3 | 0.255 | $0.176 \leq p_5 \leq 0.334$ | Neutral |

Table 2. Continued.

| | | | | | | |
|---|---|---|---|---|---|---|
| **Percent forbs**[a] | | | | | | |
| 0.0 - 20.0 | 0.222 | 52 | 36.6 | 0.315 | $0.231 \le p_1 \le 0.399$ | Preferred |
| 20.1 - 40.0 | 0.120 | 19 | 19.8 | 0.115 | $0.057 \le p_2 \le 0.173$ | Neutral |
| 40.1 - 60.0 | 0.174 | 28 | 28.7 | 0.170 | $0.102 \le p_3 \le 0.238$ | Neutral |
| 60.1 - 80.0 | 0.170 | 28 | 28.1 | 0.170 | $0.102 \le p_4 \le 0.238$ | Neutral |
| 80.1 - 100.0 | 0.314 | 38 | 51.8 | 0.230 | $0.154 \le p_5 \le 0.307$ | Avoided |
| **Percent canopy cover**[a] | | | | | | |
| 0.0 - 20.0 | 0.086 | 5 | 8.8 | 0.049 | $0.000 \le p_1 \le 0.099$ | Neutral |
| 20.1 - 40.0 | 0.121 | 8 | 12.4 | 0.078 | $0.016 \le p_2 \le 0.140$ | Neutral |
| 40.1 - 60.0 | 0.333 | 14 | 34.0 | 0.137 | $0.058 \le p_3 \le 0.217$ | Avoided |
| 60.1 - 80.0 | 0.293 | 36 | 29.9 | 0.353 | $0.243 \le p_4 \le 0.463$ | Neutral |
| 80.1 - 100.0 | 0.167 | 39 | 17.0 | 0.382 | $0.270 \le p_5 \le 0.494$ | Preferred |
| **Stem density**[a] | | | | | | |
| 0 - 25 | 0.786 | 161 | 129.7 | 0.976 | $0.952 < p_1 < 0.999$ | Preferred |
| 26 - 150 | 0.214 | 4 | 35.3 | 0.024 | $0.001 < p_2 < 0.048$ | Avoided |

Table 2. Continued.

| | | | | | | |
|---|---|---|---|---|---|---|
| Soil temperature (C)[a] | | | | | | |
| 15.0 - 23.0 | 0.194 | 30 | 31.2 | 0.186 | $0.118 \leq p_1 \leq 0.255$ | Neutral |
| 23.1 - 31.0 | 0.269 | 116 | 43.3 | 0.720 | $0.641 \leq p_2 \leq 0.800$ | Preferred |
| 31.1 - 39.0 | 0.367 | 14 | 59.1 | 0.087 | $0.037 \leq p_3 \leq 0.137$ | Avoided |
| 39.1 - 55.0 | 0.170 | 1 | 27.4 | 0.006 | $0.000 \leq p_4 \leq 0.020$ | Avoided |
| Soil pH[a] | | | | | | |
| < 6.7 | 0.042 | 8 | 6.9 | 0.049 | $0.011 \leq p_1 \leq 0.086$ | Neutral |
| 6.7 - 7.3 | 0.432 | 48 | 70.8 | 0.293 | $0.213 \leq p_2 \leq 0.372$ | Avoided |
| 7.4 - 8.0 | 0.413 | 74 | 67.7 | 0.451 | $0.364 \leq p_3 \leq 0.538$ | Neutral |
| > 8.0 | 0.114 | 34 | 18.6 | 0.207 | $0.136 \leq p_4 \leq 0.278$ | Preferred |
| Percent soil organic matter[a] | | | | | | |
| 0.00 - 0.90 | 0.486 | 52 | 79.7 | 0.317 | $0.236 \leq p_1 \leq 0.398$ | Avoided |
| 0.91 - 1.80 | 0.317 | 88 | 51.9 | 0.537 | $0.449 \leq p_2 \leq 0.624$ | Preferred |
| 1.81 - 2.70 | 0.157 | 23 | 25.8 | 0.140 | $0.080 \leq p_3 \leq 0.201$ | Neutral |
| 2.71 - 4.50 | 0.032 | 1 | 5.3 | 0.006 | $0.000 \leq p_4 \leq 0.020$ | Avoided |

Table 2. Continued.

| | | | | | | |
|---|---|---|---|---|---|---|
| Percent sand[a] | | | | | | |
| 30.0 - 66.0 | 0.130 | 6 | 21.2 | 0.037 | $0.005 \leq p_1 \leq 0.068$ | Avoided |
| 66.5 - 78.0 | 0.653 | 111 | 107.1 | 0.677 | $0.599 \leq p_2 \leq 0.755$ | Neutral |
| 78.5 - 90.0 | 0.218 | 47 | 35.7 | 0.287 | $0.211 \leq p_3 \leq 0.362$ | Neutral |
| Percent clay[a] | | | | | | |
| 5.0 - 16.0 | 0.738 | 134 | 121.1 | 0.817 | $0.758 \leq p_1 \leq 0.876$ | Preferred |
| 16.5 - 60.0 | 0.262 | 30 | 42.9 | 0.183 | $0.124 \leq p_2 \leq 0.242$ | Avoided |
| Percent silt[a] | | | | | | |
| 0.0 - 6.0 | 0.075 | 13 | 12.3 | 0.079 | $0.032 \leq p_1 \leq 0.127$ | Preferred |
| 6.5 - 12.0 | 0.356 | 63 | 58.4 | 0.384 | $0.299 \leq p_2 \leq 0.469$ | Neutral |
| 12.5 - 18.0 | 0.510 | 87 | 83.6 | 0.530 | $0.443 \leq p_3 \leq 0.618$ | Neutral |
| 18.5 - 30.0 | 0.059 | 1 | 9.7 | 0.006 | $0.000 \leq p_4 \leq 0.020$ | Neutral |

[a] See Table 1 for Chi-square values, degrees of freedom, and *P*-values for each habitat characteristic.

Thirty different bedding sites were located for 16 Texas horned lizards. Soil moisture at bedding sites averaged 2.2% during the months July through October (Table 4). Bedding sites were not located in May or June. Minimum and maximum soil moisture levels were 0.88% and 5.49%, respectively. Microhabitat characteristics for bedding sites were used in accordance with availability (Table 5).

Abiotic and biotic factors must be within tolerable limits for a species to survive in a given area (Nebel, 1990). Values of microhabitat characteristics for our lizard observation plots must have been consistent with the range of tolerance for Texas horned lizards; otherwise their population should decline on the BWMA. However, the population of Texas horned lizards on the BWMA has been stable (S.E. Henke, unpubl. data).

Table 3. Habitat characteristics used in accordance to availability by Texas horned lizards at the 0.10 significance level, as determined from 0.25-$m^2$ random and lizard observation plots on the Bomer Wildlife Management Area, Duval County, Texas during 1994.

| | Random locations | | | Lizard locations | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Habitat characteristic | $\bar{x}$ | SE | Range | $\bar{x}$ | SE | Range | $\chi^2$ | df | $P$-value |
| Basal area of bunch grasses ($cm^2$) | 44.65 | 0.43 | 5.0 - 2027 | 60.92 | 1.16 | 14.1-2919 | 6.43 | 4 | 0.1693 |
| Percent total herbaceous vegetation | 34.65 | 0.23 | 0.0 - 100 | 31.32 | 0.40 | 0.0 - 100 | 6.38 | 4 | 0.1728 |
| Vegetation height (cm) | 33.73 | 0.21 | 0.0 - 132.1 | 32.40 | 0.37 | 0.0 - 122 | 7.28 | 4 | 0.1217 |

Table 4. Soil moisture content (%) for bedding sites of Texas horned lizards on the Bomer Wildlife Management Area and Pena Ranch, Duval County, Texas during 1994.

| Month | $n$ | $\bar{x}$ | SE | Range |
|---|---|---|---|---|
| July | 4 | 1.59 | 0.15 | 1.18 - 2.00 |
| August | 14 | 2.43 | 0.33 | 0.88 - 5.49 |
| September | 4 | 1.84 | 0.14 | 1.57 - 2.30 |
| October | 6 | 2.32 | 0.29 | 1.29 - 3.52 |
| Total | 28 | 2.20 | 0.19 | 0.88 - 5.49 |

Table 5. Descriptive statistics for measured habitat characteristics at bedding sites (n=30) of Texas horned lizards on the Bomer Wildlife Management Area and adjoining Pena Ranch, Duval County, Texas during 1994.

| Habitat characteristic | Bedding sites | | |
|---|---|---|---|
| | $\bar{x}$ | SE | Range |
| Percent bare ground | 46.88 | 1.05 | 5.0 - 90.0 |
| Percent herbaceous vegetation | 13.25 | 0.88 | 0.0 - 80.0 |
| Vegetation height (cm) | 22.43 | 0.95 | 0.0 - 94.6 |
| Percent forbs | 46.67 | 1.33 | 0.0 - 100 |
| Percent grass | 45.00 | 1.33 | 0.0 - 100 |
| Plant stem density (stems per 0.25 $m^2$) | 6.17 | 0.63 | 0 - 47 |
| Basal area of bunch grasses ($cm^2$)[a] | 40.60 | --- | --- - --- |
| Percent organic matter | 1.16 | 0.14 | 0.1 - 2.7 |
| Soil pH | 7.42 | 0.10 | 6.4 - 7.8 |
| Percent sand | 78.83 | 0.40 | 67.5 - 90.0 |
| Percent silt | 10.50 | 0.32 | 5.0 - 17.5 |
| Percent clay | 10.67 | 0.35 | 5.0 - 17.5 |

[a] Only 1 plot contained a bunch grass for both bedding and hibernation site plots.

The morphology of Texas horned lizards, with their wide, flat torso and short legs, makes navigation difficult in sites containing a lot of ground clutter. Therefore, it is not unreasonable for Texas horned lizards to avoid sites with a large quantity of leaf litter. We agree with Whiting et al. (1993) that a high number of plant stems potentially create a difficult terrain for the lizards to negotiate.

The lizards were located in open areas during the morning hours, either thermoregulating, feeding, or moving. By afternoon the lizards typically were found resting under cover, out of direct sunlight and hidden from predators. Sites with intermediate canopy cover were not often used by Texas horned lizards, potentially because these sites did not allow the lizards to adequately thermoregulate nor did they provide sufficient cover from predators.

It is worth noting that some of the microhabitat characteristics were autocorrelated. For example, sites with high production of grasses contain more organic materials in the soils than sites composed primarily of woody species or sites of scant vegetation (Plaster, 1992). Also, fine-textured or clay soils tend to contain higher amounts of organic matter than coarse soils (Plaster, 1992). Because the quantity and type of vegetation and soil composition affects organic content and that Texas horned lizards most often used sites with moderate amounts of vegetation, by default sites that contained intermediate levels of organic content appeared "preferred." Also, the soil pH within the A horizon located on the BWMA did not vary greatly. About 43% of the random plots contained pH levels between 6.7 and 7.3; however, lizards were found in sites within this pH range less often than was expected. Potentially this could be an artifact of another habitat characteristic, and that lizards were not utilizing habitat based on soil pH.

Prieto and Whitford (1971) reported the mean critical thermal minimum and maximum internal temperatures for Texas horned lizards to be 9.46 C and 47.91 C, with a preferred mean temperature of 38.5 C. Because of their wide body close to the ground, horned lizards will gain surface heat via radiation and conduction. To maintain a viable body temperature, horned lizards must be able to dissipate additional heat either physiologically or behaviorally. A preference for substrates of cooler temperatures in south Texas may be a behavioral adaptation to meet this thermoregulatory need. However, the soil temperature results potentially could be biased by when the random samples were collected. Although random plots were assessed throughout the day, more samples were collected during the late afternoon than during early morning and midday.

The disposition towards sandy soils and away from clay and silty soils by Texas horned lizards can likely be attributed to the lizard's behavior of burying itself. The friability of sandy soils eases this action to a swimming motion more so than digging. Texas horned lizards prefer soil textures classified as sandy loam, sandy clay loam, and loamy sand.

Before July, horned lizards were not observed burying themselves during the day or night. Beginning in July the lizards often buried themselves prior to becoming inactive. However, lizards did not bury themselves after rain showers until after the upper soil layer had dried, which typically required 1 to 2 days after a rain. Potential reasons for lizards not burying themselves after rainfall include excessive energy expenditure to dig into moist soil and decreased soil temperature causing the lizard's temperature to fall below critical levels required for activity. Also, the lizards usually selected sites with small to moderate amounts of herbaceous vegetation for bedding sites. This could potentially be attributed to plant root systems in the upper layers of the soil affecting the ability of Texas horned lizards to dig into the soil.

Although our sample size was small and only from one locale, the described microhabitat characteristics are useful for their descriptive nature into the requirements of Texas horned lizards. The information herein can be useful in the management of this Texas threatened species.

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# Cost/Trade-Offs of Stripper Mounted Bur Extractors from the Cotton Industry Perspective

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## ABSTRACT

**This study provides estimates of cost/trade-offs of stripper mounted bur-extractors from the producer, ginner, and the overall cotton industry perspective. Results indicated that cotton producers incur net savings of about $6.00 per bale as a result of using a bur-extractor in the harvesting process. It was also determined that gins incur a net loss of about $3.00 per bale of cotton by processing bur-extracted cotton. The overall cotton industry was thus found to experience savings of about $3.00 per bale when a bur-extractor is used in the harvesting process.**

## INTRODUCTION

Harvested cotton contains a mixture of lint, seed, and foreign matter such as burs, sticks, leaves, hulls, and non-plant materials such as sand and rocks. The cotton cleaning process to remove this foreign matter has been conventionally limited to the gin plant and textile mill. This cleaning process has subsequently been broadened to include cleaning in the harvesting stage. Research to develop a bur-extractor to remove foreign matter in cotton during stripper harvesting was initiated as early as 1927 (Kirk et al., 1970).

Eighty-five percent of the cotton produced in Texas is currently stripper harvested and is, therefore, available to be harvested using a portable, stripper mounted bur-extractor (Glade et al., 1996). About twenty-five percent of cotton in Texas is currently bur-extracted (McPeek, 1997).

Producers are currently being charged a uniform price per hundred weight of harvested cotton to have cotton ginned. In other words, producers can have bur-extracted cotton, which contains more lint cotton per hundred weight of harvested cotton, ginned for the same price as non-bur-extracted cotton, which contains less lint cotton per hundred weight of harvested cotton. This implies that producers who use bur-extractors could incur savings in ginning charges at the cost of ginners.

However, gins may also experience savings when a bur-extractor is used by producers. Since bur-extracted cotton contains less foreign matter, gins providing transportation

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of modules from the field to the gin plant are likely to save in transportation cost. Further, bur-extractors may be altering operating costs of gins by affecting the ginning rate, drying efficiency, and/or cleaning efficiency. The gin plant may incur savings in trash disposal costs, since with bur-extracted cotton there is less trash to collect and dispose of. The wear and tear on gin machinery and its components may be reduced as a result of the gin plant processing bur-extracted cotton. The potential for different equipment configurations in the gin plant due to the use of bur-extracted cotton may also result in further savings.

Currently, there is a lack of information regarding the costs and savings of bur-extractors to the producer, the gin plant, and for the cotton industry. The objectives of this study are to provide estimates for the cost effectiveness of bur-extractors to producers, the costs and benefits of bur-extractors to gins, and the net cost/savings for the overall industry. This knowledge should benefit producers and gins that use bur-extractors and process bur-extracted cotton, as well as the cotton industry as a whole.

# METHODS AND PROCEDURES

## Producer and Ginner Surveys

The ownership and maintenance costs of a bur-extractor were calculated by surveying several local producers and an area implement company. A survey was also administered to twenty-three gin plants in the Southern High Plains of Texas to obtain information about the costs and savings incurred by gins due to processing bur-extracted cotton. In response to the survey questions, the participating gins provided estimates of costs in terms of ginning charges and savings in transportation costs, labor and energy, maintenance and repair, and trash disposal costs. The costs and savings reported by participating gins were averaged and presented in the form of dollars per bale.

## Producer Cost of Owning and Operating a Bur-Extractor

Survey results as well as secondary data were used to calculate producer costs of owning and operating a bur-extractor. The average size of a cotton farm in Texas, the number of planted acres of non-irrigated and irrigated upland cotton, and the number of bales harvested in the Southern High Plains of Texas during the 1996 year were obtained from the Texas Agricultural Statistics (1996). Average cotton yield per planted acre in the Southern High Plains was calculated by dividing the number of harvested bales of upland cotton by the number of planted acres of upland cotton. The average yield was then multiplied by the average cotton farm size to find the total number of bales produced on a typical farm.

To determine the cost of owning and operating a bur-extractor over a ten-year life, a present value of the maintenance cost ($PV_M$) associated with a bur-extractor was determined by using the following equation:

$$PV_M = \sum_{t=0}^{9} \frac{CM_t}{(1+i)^t} \qquad (1)$$

where $CM_t$ is the cost of maintenance and repairs on the bur-extractor in time t, and $i$ is the interest rate, assumed to be 10.5 percent (Norwest Bank Texas), for a farm loan. This present value was then divided by 10 to obtain an average maintenance cost per year of operating a bur-extractor. This average maintenance cost was then added to the average per-year cost of a bur-extractor (total cost of a bur-extractor divided by 10) to obtain the per-year average cost of owning and operating a bur-extractor. The total cost of the initial investment of the bur-extractor and maintenance and repair costs was divided by the total number of bales produced on the typical cotton farm to determine the cost per bale that is incurred by the producer.

### Savings (Loss) in Ginning Charges for Producers (Gins)

The savings incurred by producers as a result of the use of bur-extractors is primarily due to the current pricing structure of gins in the Southern High Plains of Texas. Because producers are currently charged a uniform price per hundred weight of harvested cotton, the effective ginning charge for a bale of bur-extracted cotton amounts to be less than non-bur-extracted cotton. Thus, the producer's savings in ginning charges are equal to the ginner's loss in ginning charges.

To estimate the magnitude of loss to gins (savings for producers) in ginning charges for bur-extracted cotton, gin survey participants were asked to provide information such as turnout percentage for non-bur-extracted and bur-extracted cotton and ginning charges, in dollars per hundred weight of harvested cotton. Several steps were undertaken to determine the effective ginning charges, in a uniform unit of dollars per bale, for non-bur-extracted and bur-extracted cotton. First, the number of pounds of non-bur-extracted and bur-extracted seed cotton required to make one bale of lint cotton was determined. This was accomplished by dividing the average weight of a bale of lint cotton (480 pounds) by the non-bur-extracted and bur-extracted turnout percentage, respectively. Effective ginning charges were then calculated by multiplying the number of pounds of non-bur-extracted and bur-extracted seed cotton required to make one bale of lint cotton by the uniform ginning charge reported by ginners. The difference in effective ginning charges was used as an estimate of both the net loss to gins and the savings to producers in ginning charges per bale of lint cotton.

### Possible Gin Savings Due to Processing Bur-Extracted Cotton

It was determined from the survey that gin plants may be incurring savings in the areas of transportation of modules, equipment and equipment components, labor and energy, bypassed machinery, and trash disposal due to processing bur-extracted cotton.

### Savings in Transportation Cost of Modules

Modules containing bur-extracted cotton contain a lower percentage of trash to lint cotton than non-bur-extracted modules. Given that the transportation cost is generally borne by gins in the Southern High Plains of Texas, savings in the transportation cost of harvested cotton may be incurred by gins as a result of processing bur-extracted cotton. The module transportation cost per bale, for non-bur-extracted and bur-extracted cotton was calculated by dividing the transportation cost per module by the average number of non-bur-extracted and bur-extracted bales of cotton transported per module, respectively. The saving to gins was calculated by taking the difference in the transportation cost of non-bur-extracted and bur-extracted modules.

### Labor and Energy Savings

Assuming there is a steady flow of harvested cotton delivered to the gin plant, which enables continuous operation of the gin, it is possible that gins may be able to shorten the ginning season by processing bur-extracted cotton faster than non-bur-extracted cotton.

This was estimated by taking the difference in the number of days required to process the same number of bales of bur-extracted and non-bur-extracted cotton. If gins experience a reduction in ginning season days due to processing bur-extracted cotton, then it is possible that gins may incur a reduction in labor and energy costs. Labor cost savings were calculated by multiplying the labor cost per day by the number of reduced ginning season days. Savings in energy cost were calculated by taking into account the cost of energy per bale and the additional number of days and volume of cotton that the gin would have processed if the cotton was not bur-extracted.

### Gin Equipment and Equipment Components Savings

Gin plants may potentially incur savings in maintenance and repair costs of gin equipment due to processing bur-extracted cotton. Total savings in maintenance and repair of gin equipment were calculated by adding all individual savings for each piece of equipment, as reported by each survey respondent. Total savings, for each gin plant, in maintenance and repair were standardized to a per bale basis by dividing the total savings by the number of bur-extracted bales processed.

### Savings in Energy due to Bypassed Machinery

Less foreign matter in bur-extracted cotton may possibly decrease the amount of cleaning required. Energy savings due to reduced gin machinery use were estimated using the following equations:

$$K = (A * V) / 100 \tag{2}$$

$$MC = K * KR \tag{3}$$

$$CS = MC / GR \tag{4}$$

where K is the number of kilowatts, A is the amps of the motor that runs that piece of machinery, V is the voltage of the specific machine, MC is the dollar per hour required to operate the motor of that specific piece of machinery, KR is the rate per kilowatt charged by the gin plant's electric company, CS is the per bale cost savings incurred by the gin due to ginning bur-extracted cotton, and GR is the number of bales per hour that can be ginned.

### Trash Disposal Cost Savings

Gins may also incur savings in trash disposal costs when processing bur-extracted cotton. The difference in trash disposal costs per bale for non-bur-extracted and bur-extracted cotton was used as an estimate for potential savings in trash disposal cost. To determine the trash disposal cost per bale for non-bur-extracted and bur-extracted cotton, the weight of an average bale of lint cotton was first divided by the non-bur-extracted and bur-extracted turnout percentages, respectively. This was then multiplied by the percentage of total matter consisting of trash and the trash disposal cost per pound of harvested cotton required to make one bale of cotton lint.

### Determination of Cost/Savings to the Industry

A net loss or savings was determined for the cotton industry as a whole by calculating the difference in the net loss or savings that was incurred by cotton producers and gin plants as a result of the use of bur-extractors in the cotton harvesting process.

# RESULTS AND IMPLICATIONS

### Sample Characteristics

A non-stratified sample of local producers were contacted to identify costs associated with owning and operating a bur-extractor. An area implement company was then consulted to assure the accuracy of the information provided by the local producers. A sample of twenty-three gins were surveyed to collect information pertaining to the costs and benefits incurred due to processing bur-extracted cotton. The sample included both cooperatives and individually owned gins. All of the responding gins processed bur-extracted and non-bur-extracted cotton and irrigated and dryland cotton. The proportion of bur-extracted cotton processed by the responding gins ranged from 4 to 89 percent. The average number of total bales processed by the responding gins was about 34,615 bales per season. The average number of bales of bur-extracted and non-bur-extracted cotton processed by the responding gin plants was about 14,281 and 20,334, respectively (Table 1). The average ginning rates for bur-extracted and non-bur-extracted cotton were about 28.5 and 25 bales per hour, respectively. The average turnout percentages for bur-extracted and non-bur-extracted cotton were about 28 and 22 percent, respectively.

Table 1. Sample Characteristics of Responding Gin Plants.

| Characteristics | Average | Standard Deviation | Maximum | Minimum |
|---|---|---|---|---|
| Total Bales | 34615.39 | 19425.08 | 71329 | 5800 |
| BE Bales* | 14281.26 | 11409.29 | 41000 | 543 |
| NBE Bales** | 20334.17 | 14021.66 | 51329 | 2320 |
| BE Ginning Rate (bales/hr.) | 28.50 | 7.30 | 40 | 15 |
| NBE Ginning Rate (bales/hr.) | 24.95 | 6.09 | 36 | 13.5 |
| BE Turnout Percentage | 28.12 | 1.33 | 30 | 25 |
| NBE Turnout Percentage | 22.13 | 1.64 | 25 | 18 |

* BE indicates Bur-Extracted

** NBE indicates Non-Bur-Extracted

### Producer Costs of Owning and Operating a Bur-Extractor

The producer-incurred ownership cost is comprised of an initial investment of $11,000 for a new bur-extractor with a ten-year expected life. Assuming that the bur-extractor will have no salvage value at the end of the ten-year period, the straight-line depreciation cost per year of the bur-extractor is $1,100. The repairs to the bur-extractor include: replacing all top saws at a cost of $500 every two years, replacing all bottom saws at a cost of $500 every four years, replacing one and one-half of all brushes each year at a cost of $180, replacing two belts per year at a cost of $100, replacing four bearings per year at a cost of $160, and replacing one and one-half reclaimer brushes every year at a cost of $75. The summation of the initial investment expense and the present value for maintenance on a bur-extractor yields a total cost of $15,712.62 for using and maintaining a bur-extractor during harvest. The straight-line depreciation cost per year of owning and operating a bur-extractor is $1,571.26.

The average size of a Texas cotton farm in 1996 was about 630 acres (Texas Agricultural Statistics, 1996). The number of acres of non-irrigated and irrigated upland cotton that were planted and the number of bales of non-irrigated and irrigated upland cotton that were harvested in the Southern High Plains was 2,800,000 acres and 2,235,000, respectively (Texas Agricultural Statistics, 1996). An average of about 0.80 bales of upland cotton was produced per planted acre of cotton in the Southern High Plains of Texas. The total number of bales produced on a typical Texas cotton farm was found to be about 504 bales. Therefore, the cost per bale incurred by the typical producer as a result of using a bur-extractor in the harvesting process of cotton was determined to be about $3.12 per bale.

### Savings (Loss) in Ginning Charges for Producers (Gins)

The average ginning charge of the responding gins was $1.95 per hundred weight of harvested cotton. Survey results indicated that the average ginning rate for bur-extracted cotton was about 28.5 bales per hour and 25 bales per hour for non-bur-extracted cotton. The average turnout percentage for bur-extracted and non-bur-extracted cotton was about 28.12 and 22.13 percent, respectively. Thus, the "effective" ginning charge was calculated to be about $40.28 per bale for bur-extracted cotton and $49.21 per bale for non-bur-extracted cotton, which translates to a loss to gins (savings to producers) of about $8.93 per bale as a result of using a bur-extractor in the harvesting process.

### Gin Savings Due to Processing Bur-Extracted Cotton Transportation of Modules

Survey results indicated that the average transportation cost per module from the producer's field to the gin plant in 1996 was about $41.44 per module (Table 2). The average distance that these modules were hauled in 1996 was approximately 22 miles and there was an average of 11.13 bales and 8.37 bales of bur-extracted cotton and non-bur-extracted cotton per module, respectively. Thus, while it is costing ginners about $4.95 to transport a bale of non-bur-extracted cotton, the module transportation cost for bur-extracted cotton is about $3.72 per bale. This results in possible transportation cost savings to gins of about $1.23 per bale when a bur-extractor is used during the stripper harvesting of cotton (Table 2).

Table 2. Module Transportation Characteristics and Costs of Responding Gin Plants.

| Characteristics | Average | Standard Deviation | Maximum | Minimum |
|---|---|---|---|---|
| Transportation Cost ($/module) | 41.44 | 15.38 | 66 | 7 |
| Distance (miles) | 22.12 | 15.13 | 80 | 6 |
| No. BE Bales/Module | 11.13 | 1.27 | 14.2 | 9 |
| No. NBE Bales/Module | 8.37 | 0.69 | 9.3 | 7 |
| Transportation Cost for BE Cotton ($/bale) | 3.72 | | | |
| Transportation Cost for NBE Cotton ($/bale) | 4.95 | | | |
| Transportation Cost Savings ($/bale) | 1.23 | | | |

Note: BE indicates Bur-Extracted and NBE indicates Non-Bur-Extracted Cotton.

### Gin Equipment and Equipment Components

About 83 percent of the participating gin managers reported savings in the maintenance and repair of gin equipment, which included the green boll trap, automatic feed control, dryers, incline machine, stick and bur machine, conveyor/distributor, extractor/feeder, gin stand, lint cleaners, and bale press due to ginning bur-extracted cotton. Results indicated that gins save about \$0.50 per bale in maintenance and repair of gin equipment due to processing bur-extracted cotton (Table 3).

About 91 percent of the participating gin managers reported savings in the repair and replacement of gin equipment components as a result of ginning bur-extracted cotton. Results of the survey indicated that gins save about \$0.71 per bale in repair and replacement of gin equipment components due to processing bur-extracted cotton (Table 3). These gin equipment components included tinwork on pipes, elbows, and ductwork, fans, cyclones, and saws.

### Bypassed Machinery

About 57 percent of responding gin managers indicated that while a majority of them are not currently bypassing any equipment, it is possible to bypass some cleaning equipment when ginning bur-extracted cotton. If some cleaning equipments are bypassed, gins may incur savings in energy expenses due to the motor of those equipments not being in operation. From this study, it was found that gins may incur energy savings of about \$0.09 per bale when bypassing some machinery (Table 3). The specified bypassed equipment, by surveyed gin managers, included the second stick and bur machine, incline cleaner, and the third lint cleaner. All gin plants are unique in that they have different configurations of gin equipment. Therefore, each gin must decide the specific equipment(s) in its unique gin setup, if any, that should be bypassed.

Table 3. Savings in Gin Equipment, Equipment Components, and Bypassed Machinery Due to Processing Bur-Extracted Cotton.

| Characteristics | Average | Standard Deviation | Maximum | Minimum |
|---|---|---|---|---|
| **Equipment:** | | | | |
| Total Equipment Savings (\$) | 6737.27 | 12010.62 | 53600 | 0 |
| Equipment Savings/Bale (\$/bale) | 0.50 | 0.65 | 2 | 0 |
| **Components:** | | | | |
| Savings in Tinwork (\$) | 7820 | 4485.05 | 15000 | 1750 |
| Savings in Fans (\$) | 4954.56 | 3559.88 | 10000 | 1000 |
| Savings in Cyclones (\$) | 7908.33 | 12684.23 | 33500 | 450 |
| Savings in Saws (\$) | 3649.90 | 3283.30 | 10000 | -1500 |
| Total Equipment Components Savings (\$) | 18006.65 | 18928.87 | 70125 | 0 |
| Equipment Components Savings/Bale (\$/bale) | 0.71 | 0.68 | 3 | 0 |
| **Bypassed Machinery:** | | | | |
| Energy Savings in Bypassed Machinery (\$) | 455.46 | 310.23 | 1096.48 | 201.89 |
| Energy Saving in Bypassed Machinery (\$/bale) | 0.09 | 0.08 | 0.28 | 0.02 |

### Labor and Energy

Sixty-five percent of the participating gins indicated that they were able to process bur-extracted cotton at a faster rate than non-bur-extracted cotton. Results indicated that gins can process about 3.5 bales per hour more of bur-extracted cotton than non-bur-extracted cotton. This is mainly due to more lint cotton and less foreign matter being processed per hundred weight of bur-extracted seed cotton. Thus, if it is assumed that a gin plant is processing 100 percent of bur-extracted cotton, then the ginning season could potentially be shortened and savings in labor and energy could be experienced. Survey results indicated that the average reduction in ginning season days was about 6.75 days. As a result of this reduction in ginning season days, gins may save an average of about $1.89 per bale in labor costs and $1.09 per bale in energy costs. These savings are incurred only when the gin plant processes 100 percent bur-extracted cotton.

### Trash Disposal

Survey results indicated that 100 percent of the responding gin managers noticed a decrease in gin trash of about 459 pounds (from 783 to 324 pounds) per bale as a result of ginning bur-extracted cotton (Table 4). Gins do not use a standard practice to dispose of gin trash. While some gins sell a portion or all of their gin trash, others pay to dispose it. Thus, a net trash disposal cost was first calculated for each responding gin and then an average was calculated over all gins. Results indicated that the responding gins incurred a net cost of about $2.15 per ton to dispose of a ton of gin trash. Given that gins generate about 459 pounds less of gin trash by processing bur-extracted cotton, it was estimated that gins could decrease gin trash disposal costs by $0.45 per bale (Table 4).

Table 4. Gin Trash Disposal Characteristics.

| Characteristics | Average | Standard Deviation | Maximum | Minimum |
|---|---|---|---|---|
| Trash per gin (tons) | 11505.91 | 8845.33 | 32098 | 300 |
| Trash from BE cotton (lbs/bale) | 323.96 | 16.15 | 363.62 | 303.01 |
| Trash from NBE cotton (lbs/bale) | 782.55 | 58.87 | 959.49 | 690.84 |
| Gin trash disposal cost ($/ton) | -2.15 | 2.16 | 0 | -9.89 |
| Gin trash disposal cost savings ($/bale) | 0.45 | 0.44 | 1.95 | 0 |

### Net Cost/Saving to the Industry

While producers are incurring a cost of about $3.12 per bale as a result of owning and operating a bur-extractor, they are saving about $8.93 per bale due to being charged a uniform price per hundred weight of bur-extracted and non-bur-extracted seed cotton. Thus, producers are incurring net savings of about $5.81 per bale as a result of using a bur-extractor in the harvesting process of cotton.

Results further indicated that gins incur a net loss due to ginning bur-extracted cotton. Gins incur a revenue reduction of about $8.93 per bale in ginning charges. They are incurring savings in the areas of transportation of modules ($1.23 per bale), trash disposal ($0.45 per bale), gin equipment ($0.50 per bale), gin equipment components ($0.71 per bale), energy ($1.09 per bale), labor ($1.89 per bale), and bypassed machinery ($0.09 per bale). Therefore, gins are incurring a net loss of about $2.97 per bale as a result of processing bur-extracted cotton (Table 5).

Table 5. The Savings and Costs for Gin Charges and Gin Equipment Due to Bur-Extracted Cotton.

| Areas of Gin Plant | Savings ($/bale) | | Costs ($/bale) | |
|---|---|---|---|---|
| | Average | Standard Deviation | Average | Standard Deviation |
| Ginning Charge | | | 8.93 | 3.37 |
| Module Transportation | 1.23 | 0.79 | | |
| Trash Disposal | 0.45 | 0.44 | | |
| Equipment | 0.50 | 0.65 | | |
| Equipment Components | 0.71 | 0.68 | | |
| Current Cost/Savings | 2.89 | | 8.93 | |
| Current Net Cost/Savings | | | -6.04 | |
| Energy | 1.09 | | | |
| Labor | 1.89 | | | |
| Possible Cost/Savings | 5.87 | | | |
| Possible Net Cost/Savings | | | -3.06 | |
| Bypassed Machinery | 0.09 | 0.20 | | |
| Total | 5.96 | | 8.93 | |
| Net Total | | | -2.97 | |

The net savings for the industry as a whole can be determined by calculating the difference in the net savings that is incurred by the producers ($5.81) and the net loss incurred by the gin plants ($2.97). Therefore, the industry is experiencing net savings of about $2.84 per bale due to the use of a bur-extractor in the harvesting process (Table 6).

Table 6. Costs, Savings, and Net Results for the Producer, Gin, and Industry.

| | Costs ($/bale) | Savings ($/bale) | Net Savings ($/bale) |
|---|---|---|---|
| Harvesting Stage | 3.12 | 8.93 | 5.81 |
| Ginning Stage | 8.93 | 5.96 | -2.97 |
| Industry | 12.05 | 14.89 | 2.84 |

## SUMMARY AND CONCLUSION

It was found in this study that producers who use bur-extractors in the harvesting process incur net savings of about $6 per bale. Further, it was determined that gins incur a net loss of about $3 per bale due to processing bur-extracted cotton. Therefore, the industry is incurring net savings of about $3 per bale due to producers using a bur-extractor in the harvesting process and gins processing bur-extracted cotton.

If gins decide to increase ginning charges for bur-extracted cotton to avoid this net loss of about $3 per bale, ginning charges may increase by about $0.14 per hundred weight of seed cotton. With this scenario, producers would incur net savings of about $3 per bale and gins would break even (zero net loss or savings). However, the industry would continue to incur net savings of about $3 per bale due to producers using a bur-extractor in the harvesting process. This analysis is based on information pertaining to a typical cotton farm and an average size gin in the Southern High Plains of Texas. Therefore, attempts to apply the results of this study to individual scenarios should be exercised with caution.

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# Mineral Composition of Bermudagrass and Native Forages in Texas

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## ABSTRACT

**This project was conducted to compile mineral composition of Bermudagrass and native forage samples analyzed by the Texas A&M University Extension Soil, Water and Forage Testing Laboratory.**

**Approximately 12,000 forage samples originating from either Bermudagrass or native pastures over a five year period were analyzed for potassium (K), calcium (Ca), phosphorus (P), magnesium (Mg), sulfur (S), copper (Cu), zinc (Zn), manganese (Mn) and iron (Fe) content. Fertilization and other forage management practices pertaining to the samples are not known. The data suggest a widespread occurrence of deficient levels of plant phosphorus, copper and zinc for beef cattle grazing Texas forages. Forage K, Ca, P, Mg, S, Cu, Zn, Mn and Fe averaged 1.5 and 0.91%; 0.43 and 0.48%; 0.21 and 0.10%; 0.17 and 0.12%; 0.34 and 0.13%; 6.4 and 5.0 ppm; 23.4 and 21.4 ppm; 86 and 49.7 ppm; and 114 and 205 ppm for Bermudagrass and native forages, respectively. Mineral concentration distribution of the native and Bermudagrass forages indicate important differences for grazing cattle. A numerically greater percentage of native forage K, P, Cu and Zn concentrations were categorized as deficient for all classes of beef cattle compared to Bermudagrass forage (38, 88, 45 and 52 vs. 1.5, 21, 19 and 38%, respectively). These data indicate major differences in forage mineral concentration between Bermudagrass and native forages.**

**KEYWORDS:** Bermudagrass, Native Forage, Mineral Composition, Beef Cattle, Texas

Forage production is an important component of agriculture in Texas and is evidenced by the fact that 43.6% of land use in Texas is devoted to grazing lands and/or hay production (Census of Agriculture, 1992). Forages used for grazing are harvested by animals throughout their growth cycle which results in a tremendous variation of forage nutrient supply. These variations are due to time of growing season, live or dead vegetation, plant phenology, fertility and many environmental factors (Greene, 1997). These variations result in significant fluctuations in nutrient supply. As a consequence, nutrient

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supplementation of grazing livestock is a challenge to maintain optimum production efficiency. The objective of this project was to determine the mineral composition of Bermudagrass and native forages produced in Texas and discuss the variations observed with respect to grazing beef cattle requirements.

## MATERIALS AND METHODS

The forage mineral concentrations utilized in this study were assembled from forage reports issued by the Texas Agricultural Extension Service Soil, Water and Forage Testing Laboratory on the campus of Texas A&M University to its clientele over a five year period. Knowledge of the forage sample is limited to that issued in the original report, and the fertilization practices and maturity management is not known. Bermudagrass cultures or species composition of the native range samples are unknown. Approximately 88% of potassium (K), calcium (Ca), phosphorus (P) and magnesium (Mg) and 43% of sulfur (S) Bermudagrass concentrations were analyzed by near infrared reflectance spectroscopy (NIRS) (ISI, 1991). Copper (Cu), zinc (Zn), manganese (Mn) and iron (Fe) in Bermudagrass and all the mineral concentrations of native forage were analyzed by the wet chemistry (WC) procedure as outlined by Parkinson et al. (1975) followed by determination by inductively coupled argon plasma emission spectrophotometry. Initial comparison between NIRS and WC techniques for estimating mean concentrations of Bermudagrass K, Ca, P, Mg and S concentrations indicated the NIRS analysis overestimated mean K, Ca, P and Mg concentrations by 7 to 15% ($P<.001$) and underestimated mean S concentrations 7% lower ($P<.001$) than that estimated by WC. Therefore, NIRS values for these minerals in Bermudagrass were adjusted to WC values based upon the following assumptions: (1) that Bermudagrass samples analyzed by NIRS and WC estimate the same population and (2) that the adjustment factor is consistent over the range of mineral concentrations in the data. Frequency histograms of the number of observations within a prescribed range of forage mineral concentrations are presented in Fig. 1 through 18 to provide data on the sample population. Mineral requirements for a mature, non-lactating beef cow (NRC, 1996) were used to determine breakpoints between categories where necessary to relate forage mineral concentration to animal mineral requirements. The original database contained extremely high and extremely low mineral concentrations for both forages and for each mineral analyzed. Therefore, observations separated from the sample population mean by ± 3 standard deviations have been excluded from Fig. 1 through 18. In all cases, these observations represented less than 1.5% of the total samples. Bermudagrass pasture and Bermudagrass hay have been pooled and native pasture and native hay have been pooled. Forage mineral concentrations are presented on a dry matter basis. The TTEST procedure was used to determine differences in mean mineral concentration between forage types (SAS, 1985).

## RESULTS AND DISCUSSION

For comparison between forage mineral concentration and cattle mineral requirements, Table 1 presents mineral requirements estimated for various classes of beef cattle (NRC, 1996). Bermudagrass forage had greater ($P < .0001$) mean concentrations of K, P, Mg, S, Cu, Zn and Mn than native forage (Fig. 1, 2 and 5 through 16). Native forage had greater ($P<.0001$) mean concentrations of Ca and Fe than Bermudagrass (Fig. 3, 4, 17 and

18). The greater average K, P and S concentrations of Bermudagrass compared to native forage are presumably due to forage type, soil conditions and to fertilization with these minerals in the production of Bermudagrass. The controlling factor that can potentially alter forage mineral composition more than any other practice is fertilization. Application of fertilizer to optimize plant growth and productivity also changes plant mineral composition. Most improved forages in the South have been maintained through extensive fertilization programs. The demand for minerals such as P is often higher than supplied by the soil and application of this mineral in fertilizers has increased the amount of P available for livestock consumption. This is proven due to the fact that most native, non-fertilized forages are often deficient in P.

The greater average concentration of Cu, Zn and Mn for Bermudagrass compared to native forage may also reflect forage type, soil conditions and agronomic practices associated with Bermudagrass production that result in changes in soil pH and mineral availability for plant uptake. Soils are very different with respect to the minerals found in the soil matrix. Sandy soils often allow specific minerals to leach more easily from the growing surface than heavier clay soils. Soil acidity will also impact the availability of soil minerals for uptake by roots and subsequent translocation to plant tissues.

Table 1. Mineral requirements for various classes of grazing cattle.[a]

| | Cows | | | | |
|---|---|---|---|---|---|
| | | Lactating [b] | | Stocker calf [c], 200 kg | |
| Mineral | Non-lactating [d] | Early lactation | Late lactation | .5 kg gain | 1.0 kg gain |
| Calcium, % | 0.30 | 0.36 | 0.27 | 0.40 | 0.60 |
| Phosphorus, % | 0.18 | 0.24 | 0.19 | 0.22 | 0.32 |
| Magnesium, % | 0.12 | 0.20 | 0.12 | 0.10 | 0.10 |
| Potassium, % | 0.60 | 0.70 | 0.60 | 0.60 | 0.60 |
| Sulfur, % | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| Copper, ppm | 10 | 10 | 10 | 10 | 10 |
| Zinc, ppm | 30 | 30 | 30 | 30 | 30 |
| Manganese, ppm | 40 | 40 | 40 | 20 | 20 |
| Iron, ppm | 50 | 50 | 50 | 50 | 50 |

[a] NRC, 1996

[b] Assumes average milk production

[c] Calcium and phosphorus requirement decreases (% of DM intake) as stocker calf increases in weight and increases (% of DM intake) as rate of gain increases.

[d] Late gestation

## Potassium

Approximately 90% of the Bermudagrass K concentrations ranged from .65 to 2.09%, with 1.5% deficient and 8.6% potentially excessive for mature, non-lactating beef cows (Fig. 1). In comparison, 57% of the native forage K concentrations ranged from .65 to 2.09% K, with 38% deficient and only 5.2% being excessive (Fig. 2). These data are similar to other data that shows forage K is higher in warm-season perennial forages compared to the native grasses (Mills, unpublished; Brown et al., 1988; Kappel et al., 1985). Previous data from our laboratory (Greene et al., 1987) show that stage of growth is important when predicting forage K concentrations. Actively growing (green) plant tissue is much higher in K content than dormant tissue. In general, cattle grazing actively growing, fertilized pastures will acquire adequate quantities of K in the forage diet. However, if forages are not fertilized and/or dormant, additional K in free choice supplements may prove advantageous. Unlike most minerals, K is excreted in the urine and adequate amounts must be supplied daily either from the forage base or from supplements. Excessive intake of K (>2. 1 %) may reduce the absorption and utilization of Mg (Greene et al., 1983). This is a much greater problem when cows graze cool-season perennial or annual forages compared to the forage types presented in this manuscript. An excessive intake of K is generally not a practical problem when cattle consume either Bermudagrass or native forages.

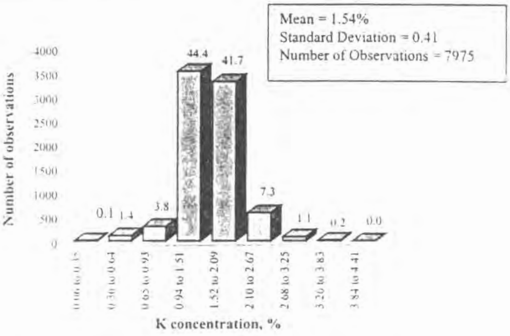

Figure 1. Number of observations within each range of potassium concentrations (% dry matter) for Bermudagrass forage.

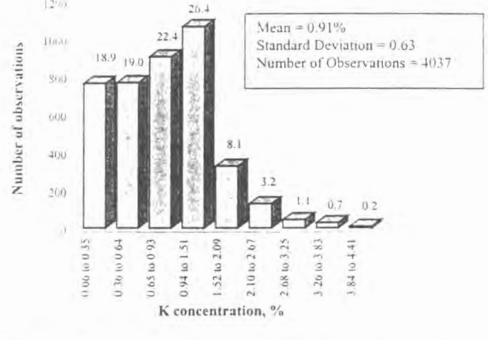

Figure 2. Number of observations within each range of potassium concentrations (% dry matter) for Native forage.

## Calcium

Calcium requirement changes with level of milk production and stage of growth. Data presented in Fig. 3 and 4 show that 8.6 and 2.1 % of the Bermudagrass and native forage, respectively, was deficient in Ca for most classes of cattle. The majority of the forage Ca concentrations ranged from .31 to .66% which will be adequate for beef cattle production in most cases. The percentage of the forage population within this range was 71 and 71.8% for Bermudagrass and native forage, respectively. The growth rate of steers while grazing Bermudagrass or native forage will probably not be great enough to warrant more than .6% dietary Ca. The amount of Ca required in forage to meet grazing animal requirements depends on the relationship of Ca with other dietary minerals. Usually, metabolic disorders are more prominent when P levels are high with respect to Ca, especially on highly fertilized productive forages. Without adequate liming of acid soils that have been fertilized with P, Ca is often too low relative to P. On the other hand, Ca is relatively high and P very low in unfertilized forages produced on alkaline soils in certain regions of Texas.

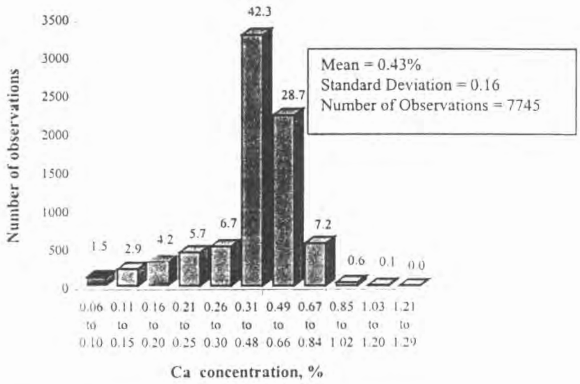

Figure 3. Number of observations within each range of calcium concentration (% of dry matter) for Bermudagrass forage.

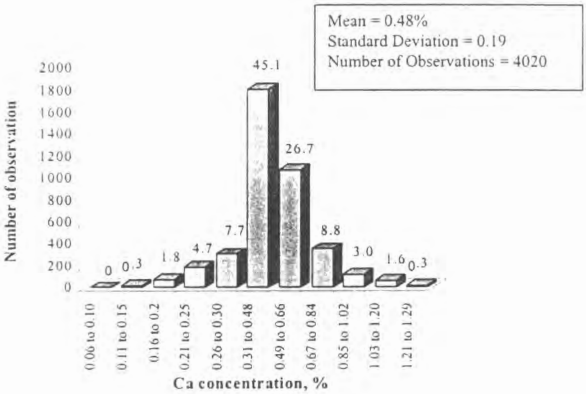

Figure 4. Number of observations within each range of calcium concentrations (% dry matter) for native forage.

## Phosphorus

There was a large numerical difference between Bermudagrass and native forage in the percentage of the population deficient in P. Twenty-one percent of the Bermudagrass samples were deficient in P for grazing livestock compared to 88% of the Native samples (Fig. 5 and 6). For a lactating cow, that proportion of the population deficient in P would be approximately 65 and 96% of Bermudagrass and native forages, respectively. Common mineral supplements used throughout the south supply equal portions of Ca (12%) and P (12%), and a 1:1 percentage of Ca and P is still required in mineral supplements for many production environments. However, when cattle graze forages fertilized with P and low in available Ca (such as those reported in this manuscript), mineral supplementation programs will be more effective if the Ca P ratio is 2:1 to supply 12% Ca and 6% P. This ratio supplies a more balanced Ca and P supplement to cattle grazing P fertilized forages when Ca may be low. In the present data, approximately 74 and 8.9% of the Bermudagrass and native forage P concentrations, respectively, ranged from .17 to .30% P. Native forages are predominately deficient in P, and P must be supplied as a supplement to optimize production.

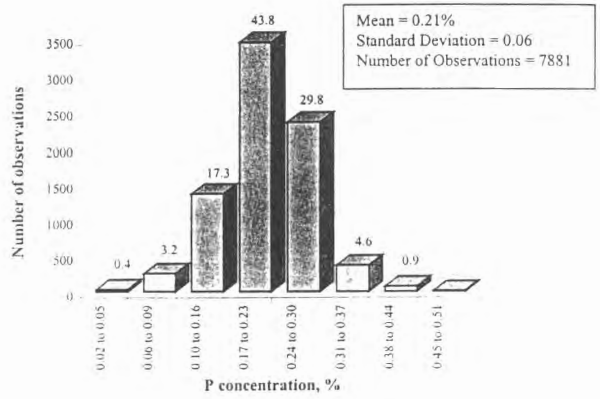

Figure 5. Number of observations within each range of phosphorus concentrations (% dry matter) for Bermudagrass forage.

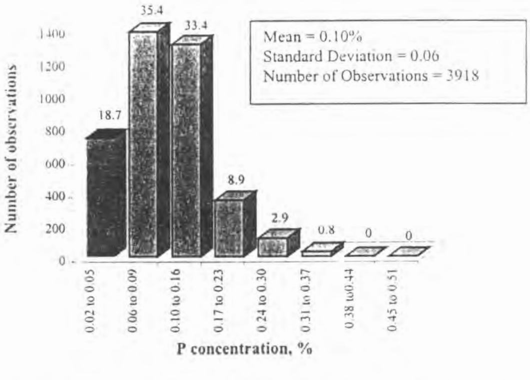

Figure 6. Number of observations within each range of phosphorus concentrations (% dry matter) for Native forage.

## Magnesium

Based upon NRC (1996) recommendations, 8.2 and 49.7% of Bermudagrass (.1%) and native (2.9%) forage samples, respectively, were deficient in Mg for a mature, non-lactating cow (Fig. 7 and 8). Seventy three percent of the Bermudagrass forage Mg concentrations ranged from .14 to .22% Mg compared to 24% of the native population. The majority of native forage Mg concentrations (53%) fell within a range of .08 to .13%, lower than required by a lactating cow. However, Mg deficiency (grass tetany) is not reported to be a problem when cattle graze native pastures. Usually cattle grazing Bermudagrass pastures have an adequate Mg supply to meet the physiological needs of the cattle. It is well known that high (>2.4%) dietary K (as seen in rapidly growing winter pastures) will interfere with Mg utilization (Greene et al., 1983). Usually, dietary K in Bermudagrass and native forage is not high enough to negatively impact Mg availability in these forages. Pastures heavily fertilized with nitrogen have been identified to create a higher incidence of the grass tetany syndrome in cows during late gestation and early lactation, which is probably due to mineral imbalances in the forage. (Robinson etal., 1989).

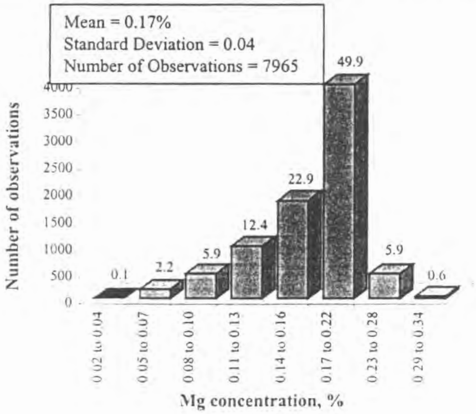

Figure 7. Number of observations within each range of magnesium concentrations (% dry matter) for Bermudagrass forage.

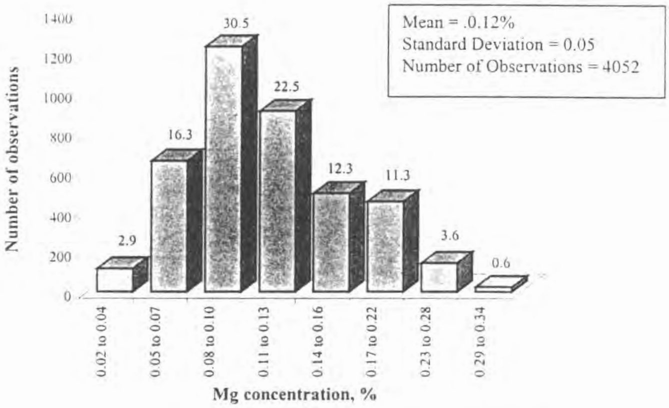

Figure 8. Number of observations within each range of magnesium concentrations (% dry matter) for Native forage.

## Sulfur

No Bermudagrass forage was deficient in S compared to 58.6% of the native forage (Fig. 9 and 10). Of more importance in Bermudagrass is the proportion of samples with excessive levels of S. Fifty percent of the Bermudagrass S concentrations were at levels (.32 - .67%) that have been implicated in reducing Cu utilization and/or dry matter intake. Less than 2.3% of the native S concentrations are considered to be excessive, and S supplementation is advised when native forage is below .10% S. Sixty five percent of Bermudagrass S concentrations ranged from .20 to .43% S. The majority of the S concentrations for native forage (73%) ranged from .08 to .16% S. In Bermudagrass, elevated levels of S that result in a reduction in Cu availability is more of a practical problem for cattle than is S deficiency. In addition, many sources of water have been found to provide excess levels of S. These should be considered when evaluating total S intake.

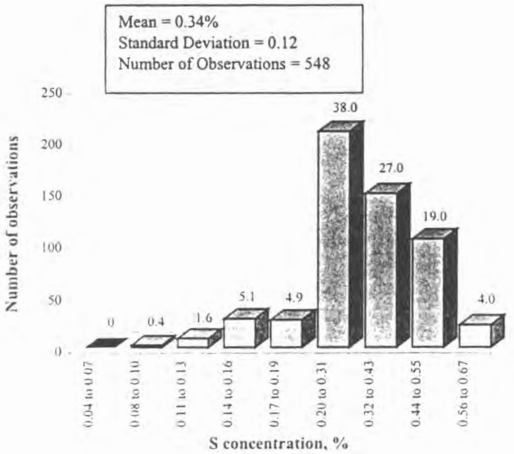

Figure 9. Number of observations within each range of sulfur concentrations (% dry matter) for Bermudagrass forage.

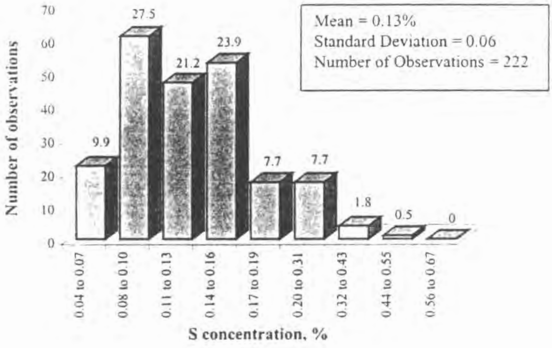

Figure 10. Number of observations within each range of sulfur concentrations (% dry matter) for native forage.

## Copper

The average Cu concentration in Bermudagrass and native forages was 6.4 and 5.0 ppm, respectively. This level of Cu is less than the requirement for all classes of beef cattle. The percentage of the forage samples deficient in Cu was numerically greater for native compared to Bermudagrass forage (Fig. 11 and 12). Over 95 and 84% of the Bermudagrass and native forage Cu concentrations, respectively, were categorized as deficient for all classes of cattle. Elevated dietary Fe or S plus molybdenum (Mo) have been shown to have a dramatic reduction on Cu bioavailability (Suttle etal.,1984). Interactions of these dietary components can increase Cu requirements 1.5 to 4 fold. In the present data S is high in 50% of Bermudagrass samples, and Fe is high in 35% of native samples. Limited information is available on forage Mo concentration, but it is not uncommon to find Mo in excess in these forages. The distribution of Cu concentrations shown in Fig. 11 and 12 indicate that forage Cu levels are not adequate to maintain animal productivity in many situations. Therefore, most mineral supplementation programs should supply Cu to forage-fed animals.

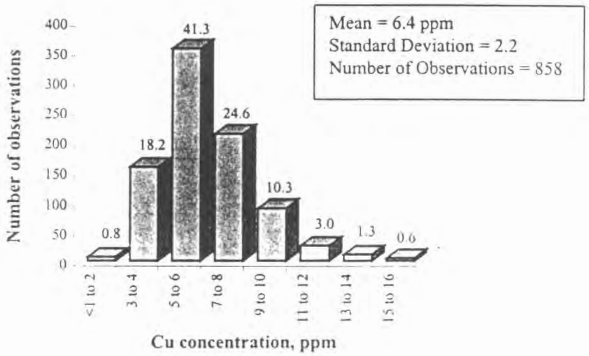

Figure 11. Number of observations within each range of copper concentrations (ppm dry matter) for Bermudagrass forage.

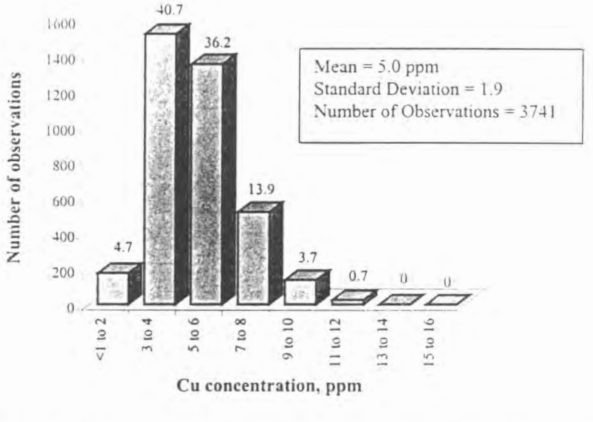

Figure 12. Number of observations within each range of copper concentrations (ppm dry matter) for native forage.

## Zinc

The mean forage Zn concentrations were 23.4 and 21.4 ppm for Bermudagrass and native forage, respectively. Based on NRC (1996) requirements and data collected in this study, there is a widespread occurrence of deficient levels of Zn for cattle fed Bermudagrass and native forages (Fig.13 and 14) in Texas. Approximately 79.4 and 84.1% of Bermudagrass and native forage Zn concentrations, respectively, are below levels recommended for grazing cattle. This data is similar to that found by Corah and Dargatz (1996), Kappel et al. (1985) and Brown et al. (1988). Zinc should be a component of mineral supplements for cattle in Texas to optimize production efficiency.

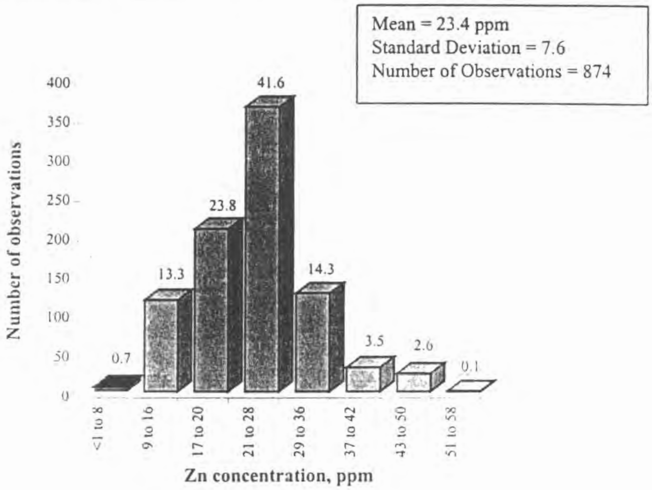

Figure 13. Number of observations within each range of zinc concentrations (ppm dry matter) for Bermudagrass forage.

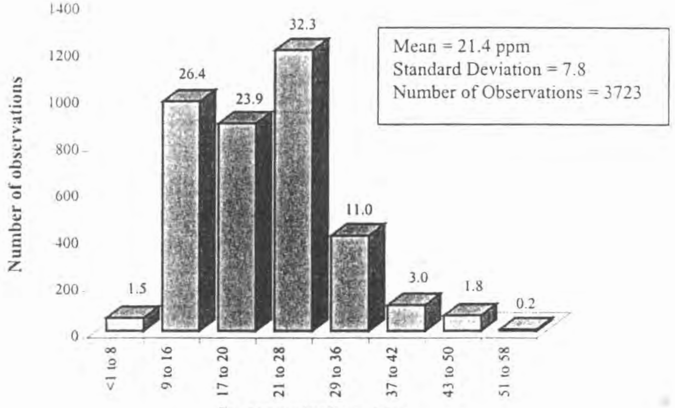

**Figure 14. Number of observations within each range of zinc concentrations (ppm dry matter) for native forage.**

## Manganese

Both Bermudagrass and native forages exhibited a large range in Mn concentrations (3 to 285 and 3 to 149 ppm, respectively; Fig. 15 and 16). The average Mn concentrations were 86.0 and 49.7% for Bermudagrass and native forage, respectively. The majority of the Bermudagrass Mn concentrations (57.3%) ranged from 48 to 116 ppm. Approximately 45% of the native forage Mn concentrations fell within this range. Kappel et al. (1985) reported that Mn concentrations averaged 111 ppm and Corah and Dargatz (1996) reported average Mn concentrations of 125 ppm in Bermudagrass. However, Brown et al. (1988) reported Mn concentrations to be only 52 ppm in Bermudagrass forage. Generally, levels of 100 ppm Mn are not considered to be detrimental to animal production. Little is known about the interaction of Mn with other trace minerals but levels of up to 1000 ppm have not had any known adverse effects on cattle.

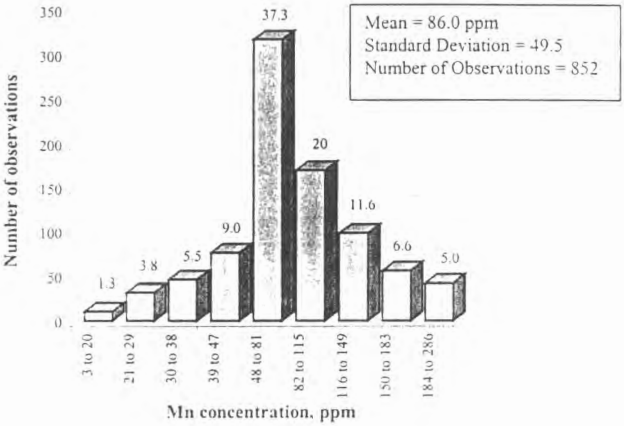

Figure 15. Number of observations within each range of Mn concentrations (ppm dry matter) for Bermudagrass forage.

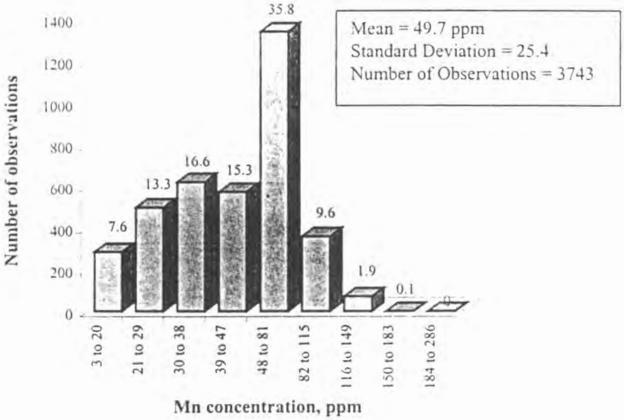

Figure 16. Number of observations within each range of Mn concentrations (ppm dry matter) for native forage.

## Iron

Iron concentrations were generally adequate for beef cattle with 9.1 and 3.3% of Bermudagrass and native forage Fe concentrations categorized as deficient (Fig. 17 and 18). Approximately 80 and 62% of the Fe concentrations ranged from 50 to 208 ppm for Bermudagrass and native forage, respectively. With the majority of Bermudagrass and native forages containing adequate to high levels of Fe, additional Fe supplementation is not recommended, and is advised against due to its negative interaction with other minerals which are likely to be marginal to deficient in the forage.

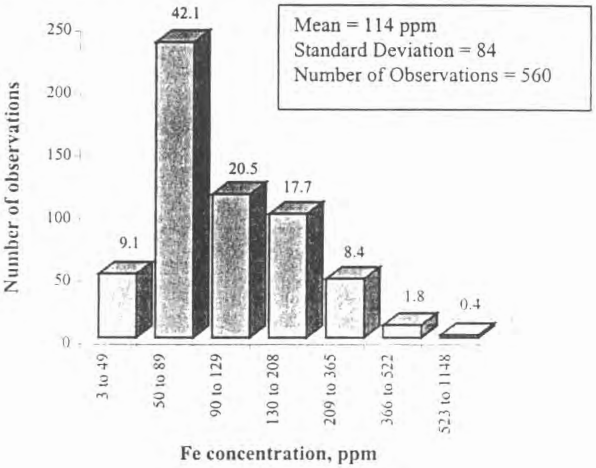

**Figure 17. Number of observations within each range of Fe concentrations (ppm dry matter) for Bermudagrass forage.**

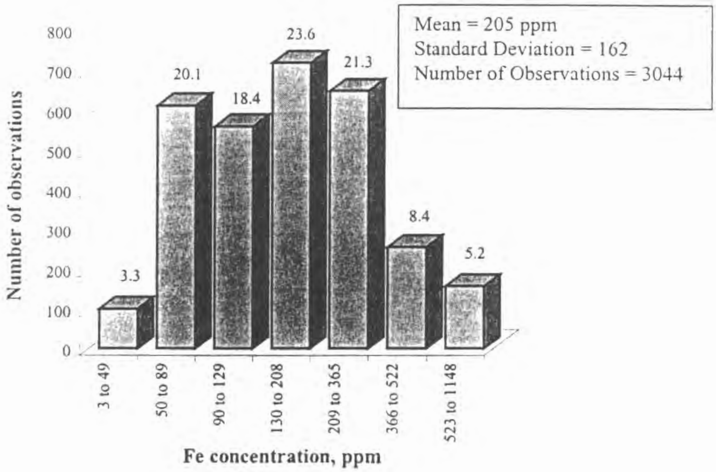

**Figure 18. Number of observations within each range of Fe concentrations (ppm dry matter) for native forage.**

## SUMMARY AND CONCLUSIONS

The ability of forage minerals to meet grazing livestock mineral requirements depends upon the concentration of minerals in the plant and the bioavailability of these minerals. Mineral bioavailability depends upon various digestive tract interactions, mineral solubility and digestive tract pH. The digestive tract interactions are extremely important when defining animal requirements and formulating mineral supplements for grazing livestock. Many forages contain antagonists that reduce the availability of minerals. There are many mineral-mineral interactions that increase requirements such as high Mo-S diets increasing the requirement for Cu, and Mg requirement increasing as dietary K increases as previously discussed. In addition to mineral-mineral interactions, there are significant interactions between minerals and organic constituents found in plants. Organic compounds may be present that reduce the bioavailabilty of forage minerals. Many of these interactions are not clearly understood and, therefore, often makes the evaluation of forage mineral supply confusing.

Although the fertilization, management, Bermudagrass varieties, or native grass species are not known, the data presented in this report suggest a widespread occurrence of deficient levels of forage P, Cu and Zn for grazing cattle. In contrast S, Fe and Mn concentrations were at levels considered to be adequate to excessive in these forages. Mineral concentration distribution reported in this paper is confounded by many factors. It is advisable to develop a forage sampling and analysis scheme on individual farms and ranches. This will ensure a closer approximation of nutrient intake to assist in developing mineral supplementation practices specific for a particular production environment or vegetation type.

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# Influence of Planting Scheme and Planting Dates on Yield and Grade of Four Peanut Cultivars

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## ABSTRACT

**Studies were conducted to determine the influence of planting scheme (solid vs skip-row) and planting date on three runner and one Spanish-type cultivar in a non-irrigated field near Stockdale, Texas, during the 1994 and 1995 seasons. Florunner, GK-7, Andru-93 (runner type), and Tamspan-90 (Spanish type) cultivars were planted at 25 to 30 day intervals beginning about 15 April. Although not statistically significant, the skip-row planting scheme yielded more than the solid planting scheme by 10 to 35% depending on the year. Peanut yield and total sound mature kernels (TSMK) were significantly affected by planting date. In 1994, highest yields were obtained from the June planting, while the April planting produced the highest yield in 1995. Year effects on yield are the result of rainfall distribution and temperature differences during the critical flowering and pegging period.**

**KEYWORDS:** Solid plant, skip-row, groundnut, Florunner, GK-7, Andru-93, Tamspan-90, dryland

Many dryland peanut (*Arachis hypogaea* L.) producers in Texas question the optimum planting date and cultivars to achieve maximum yield and grade. Yearly variations in weather patterns affect the length of growing season as well as flowering date and pod development.

Court et al. (1984), using one planting date and five harvest dates, found that delaying harvest date increased yield, sound mature kernels, and value of the Spanish-type cultivar Comet and the valencia-type cultivar McRan. Knauft et al. (1986) also using one planting date and five genotypes harvested at three dates (105, 118, and 132 days after planting), found that earlier digging dates tended to reduce market grade characters. In their study, major differences were the result of genotype x digging date interactions.

Mixon and Branch (1985) conducted a 3-year study, with the full season runner-type cultivar Florunner and the short season Spanish-type cultivar Pronto, using six digging dates at 10-day intervals beginning 90 days after planting. Florunner dug at 110 days and with each succeeding 10-day growth period up to 140 days, produced greater yields, more sound mature kernels, large and jumbo seed, and greater market value than Pronto. Pod yields of both cultivars, when averaged over the 3-year period, increased with each harvest date.

Mozingo et al. (1991) in Virginia planted four large-seeded Virginia-type cultivars

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(Florigiant, NC7, NC9, and VA 81B) under dryland conditions. These cultivars were planted at four 10-day intervals. They found that cultivar selection and digging dates are more important than planting dates in normal years. They noted, however, since environmental stress conditions cannot be anticipated, early planting dates would seem to be an advantage when soil temperatures and moisture levels are conducive to good germination and seedling growth.

Pattee et al. (1980) illustrated the complexities of peanut maturity in establishing the relationship of the seed/hull ratio to yield and dollar value. With some cultivars they found that yield and value increased with later digging dates whereas other cultivars reached a peak and declined within the same year. Yearly variations were noted also for cultivars. In another study, Pattee et al. (1982) showed that the seed/hull maturity index is correlated to yield and value but this optimum index value must be determined for each cultivar.

While previous studies have evaluated peanut planting patterns and digging dates under rainfed conditions in other peanut growing regions, no work has been done evaluating digging dates in the southwestern U.S. Therefore, the objectives of this research were to determine the optimum planting and digging dates for three runner and one Spanish-type cultivar grown in Texas and the influence of planting scheme (solid vs skip-row) on peanut yield and grade.

## MATERIALS AND METHODS

Two normal season runner-type peanut cultivars (Florunner and GK-7), one early maturing runner cultivar (Andru 93), and a Spanish-type cultivar (Tamspan 90) were grown in a randomized complete block split-split plot design in separate fields near Stockdale, Texas during the 1994 and 1995 growing seasons. The whole plots were two planting schemes (solid vs skip row), the split plots were four planting dates, and four cultivars were the split-split plot. Of the four cultivars used, Florunner and GK-7 have a maturity period of 140 to 150 days, Andru-93 has a maturity period of 120 to 130 days, and Tamspan 90 has a maturity period of 115 to 125 days.

This non-irrigated field study was conducted on a Wilco loamy fine sand (fine, mixed, hyperthermic Udic Paleustalfs) in Wilson County, Texas near Stockdale. In each year the study was conducted in a field which had been fallow the previous year. Whole plots were 48 rows wide, split plots were 24 rows wide, and split-split plots were 6 rows wide with 36" row spacing. Data was taken from the middle two rows of each plot. For the skip row plantings, two rows were planted and a row on each side left blank. Data was collected from the middle two planted rows. Plots were 25 ft long, with four replications. Seeding rate was 60 lb acre-1 for each cultivar.

Pendimethalin [N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine] at 1.0 lb acre-1 and imazethapyr {2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid} at 0.063 lb acre-1 were tank mixed and preplant incorporated prior to planting of peanut to control annual grasses and broadleaf weeds. Yellow nutsedge (*Cyperus esculentus* L.) escapes were controlled with postemergence applications of bentazon [3-(1-methylethyl)-(1H)-2,1,3-benzothiadiazin-4(3H)-one,2,2-dioxide] at 0.5 lb acre-1. Other agronomic and production practices, including insect and disease control followed Texas Agricultural Extension Service recommendations.

In 1994, runner peanut were dug when at least 150 days old except for the last planting date. At that planting date, peanut was dug when 138 days old because of sustained cold weather. The Spanish variety, Tamspan 90, was dug when 121 to 127 days old. In

1995, runner peanut were dug when 146 to154 days old while Tamspan 90 was dug when 120 to126 days old (Table 1).

Air temperature and rainfall were recorded at a weather station located near the test site. Weather data was from a weather observation site supervised by the National Oceanic and Atmospheric Administration/National Weather Service.

The peanut plants in each plot were dug, sacked, placed in a forced-air dryer and allowed to dry 48 to 72 hours. After drying, the pods were removed from the vines using a small plot thresher. Pods were cleaned, weighed and graded according to USDA procedures for peanut. Grade data is reported as percent total sound mature kernels (TSMK) which includes a combination of sound mature kernels plus sound splits.

Analysis of variance were conducted for each year. Each year was analyzed separately because test sites were at slightly different locations and rainfall and soil temperature varied for each year.

Table 1. Planting and digging dates used in 1994 and 1995.

| | | 1994 | 1995 |
|---|---|---|---|
| **Planting Date** | | | |
| 1 | | 14 April | 18 April |
| 2 | | 9 May | 10 May |
| 3 | | 7 June | 7 June |
| 4 | | 6 July | 6 July |
| **Digging Date** | | | |
| 1 | Tamspan | 17 Aug (125)[a] | 17 Aug (121) |
| | Runner | 13 Sept (152) | 14 Sept (148) |
| 2 | Tamspan | 13 Sept (127) | 7 Sept (120) |
| | Runner | 10 Oct (154) | 11 Oct (154) |
| 3 | Tamspan | 10 Oct (125) | 11 Oct (126) |
| | Runner | 4 Nov (150) | 8 Nov (154) |
| 4 | Tamspan | 4 Nov (121) | 8 Nov (125) |
| | Runner | 21 Nov (138) | 29 Nov (146) |

[a] Number in parenthesis represents number of days after planting.

Table 2. Mean squares from analysis of variance for yield (lb/A) and grade (TSMK) for 1994 and 1995.

| | | Yield | | TSMK | |
|---|---|---|---|---|---|
| Source | df | 1994 | 1995 | 1994 | 1995 |
| | | $(X10^{-5})$ | | $(X10^{-1})$ | |
| Reps | 3 | 1.32 | 6.12 | 0.50 | 17.79 |
| Skip/Solid (SS) | 1 | 1.95 | 16.80 | 11.12 | 217.80$^{*}$ |
| Error A | | 2.05 | 4.23 | 10.81 | 3.79 |
| Plant Date (PD) | 3 | 20.20$^{**}$ | 18.89$^{**}$ | 397.82$^{**}$ | 135.40$^{*}$ |
| SSXPD | 3 | 1.64 | 0.38 | 32.51$^{*}$ | 41.78 |
| Error B | 18 | 1.13 | 0.65 | 4.48 | 13.54 |
| Cultivar © | 3 | 0.38 | 0.69 | 36.30$^{*}$ | 75.18$^{*}$ |
| SSXC | 3 | 0.27 | 0.77 | 52.04$^{*}$ | 60.13$^{*}$ |
| PDXC | 9 | 0.94 | 1.20 | 94.04$^{*}$ | 30.20$^{*}$ |
| SSXPDXC | 9 | 0.39 | 0.47 | 31.59$^{*}$ | 33.48$^{*}$ |
| Error C | 72 | 0.57 | 0.65 | 4.01 | 6.31 |

$^{*}$,$^{**}$Indicate 0.05 and 0.01 significance level, respectively.

# RESULTS AND DISCUSSION

Planting and digging dates for the study are presented in Table 1. Mean squares from the analyses of variance for yield and total sound mature kernels (TSMK) are presented for 1994 and 1995 (Table 2).

Yield (lb/A). The skip row-solid planting scheme was based on planted area not total area required. There were no significant differences in peanut yield either year between skip row and solid planting (Fig. 1). However, each year the skip-row treatments were numerically higher than solid planting. Similar results have been reported by Schubert et al. (1983). Yields based on the total area (planted-row plus skip-row area) have generally been lower for skip-row planting, owing to inclusion in the yield determination of the fallow, skip-row area. Cotton (*Gossypium hirsutum* L.) yields of skip-row compared to equidistant-row plantings were higher based on the planted area, but similar based on total area (Hons and McMichael, 1986).

Planting date had a significant effect on yield in both years (Fig. 2). In 1994, peanut yields were highest with the June planting while the lowest yield was with the April planting. In 1995, highest peanut yields were from the April planting while the lowest yield occurred with the June planting.

Soil temperature during reproductive development, may have a significant impact on final yield. In a study of soil temperatures in the pegging zone, Ono et al. (1974) found an optimum temperature of 88° to 92°F for pod development. High soil temperature (99° to 102°F) and low soil moisture (6 to 8%) indicated that a critical stage in pod development occurred 20 to 30 days after the peg entered the soil (Ono et al., 1974). This would be approximately 90 to 100 days after peanuts were planted since pegging period usually begins when peanuts are approximately 60 days old. In 1994, high temperature along with low soil moisture was observed 90 to 103 days after the first (April) planting (Fig. 3). The first planting had the lowest yield in 1994. This difference in yield pattern may have been the result of rainfall distribution (Fig. 3) and temperature differences throughout the growing seasons during the critical flowering and pegging period.

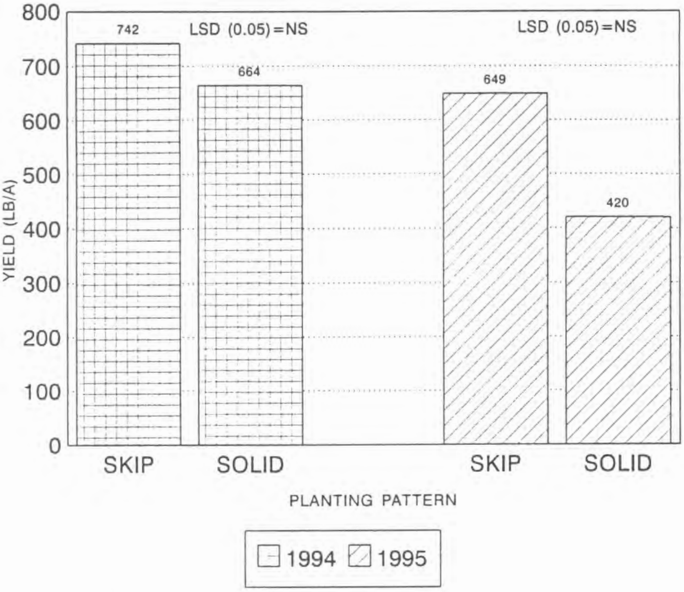

**Figure 1.** Peanut yield comparing skip-row versus solid planting patterns. NS=not signifiant.

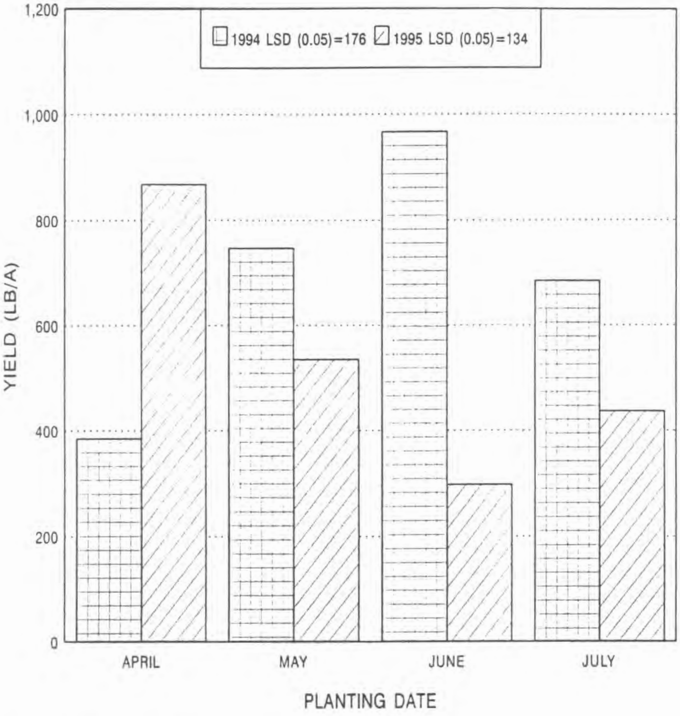

**Figure 2.** Influence of planting date on peanut yield.

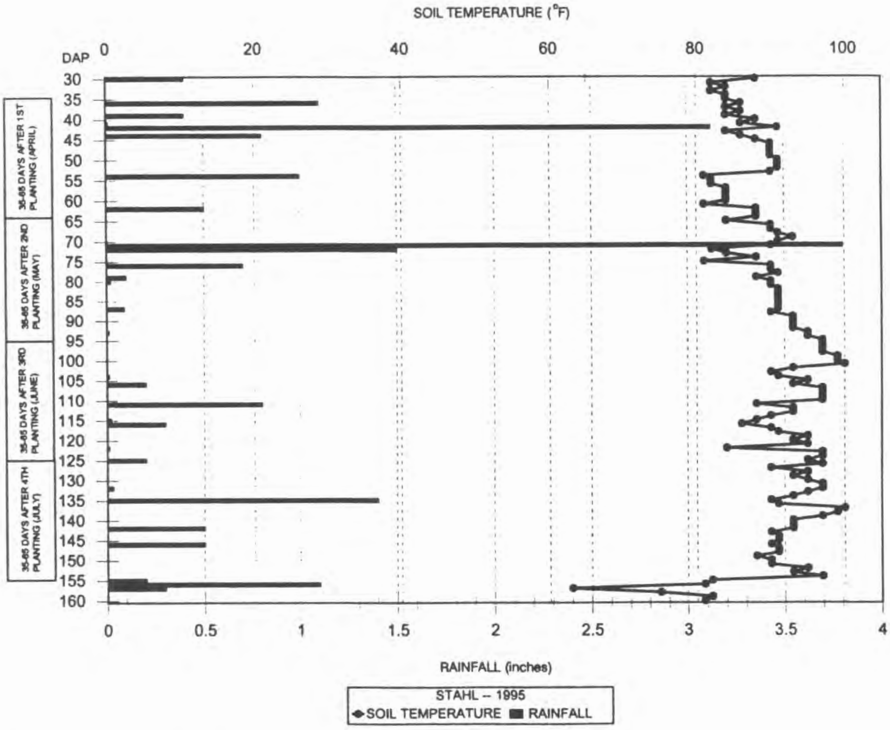

**Figure 3.** Soil temperature and rainfuall during the 1994 growing season.

The lower yield observed in 1995 for the June planting may be due in part to the high temperatures observed (Fig. 4) during the initial flowering (35 to 50 days after planting) and pegging (60 to 70 days after planting). However, moderate rainfall was received during this time period. The optimum temperature is different for each phase of peanut development and may not always occur in relation to the sequence of events from planting to harvest, i.e., vegetative growth occurs during the cool spring and early summer planting season while reproductive growth takes place during the hot summer relative to the latitude at which the crop is grown (Ketring et al., 1982).

Mozingo et al. (1991) found that in years which lacked moisture, vegetative growth of the later plantings was slowed and once rain was received, the peanuts did not mature as rapidly as the earlier planting. April and May rainfall was above average in 1994 with only a trace received in July, while in 1995, extremely heavy rains were received in May and June (Table 3) which resulted in waterlogged conditions thereby delaying peanut emergence.

Cultivars selected for the study possess differing yield potential; however, no yield differences within years were noted (Fig. 5). Florunner produced the highest yields in 1994 (745 lbs acre-1) while Tamspan 90 was the top producer in 1995 (597 lb acre-1). Florunner has been the most common runner cultivar grown in the Southwestern U.S. for the past ten years. Approximately 45% of Texas peanut runner acreage is planted to Florunner (authors personal observation). Tamspan 90 is a typical Spanish-type peanut cultivar with an erect growth habit. Tamspan 90 has sustained less yield loss than other Spanish and runner cultivars under natural infection of Sclerotina blight (*Sclerotina minor*) and pythium pod rot (*Pythium myriotylum*) (Smith et al. 1991).

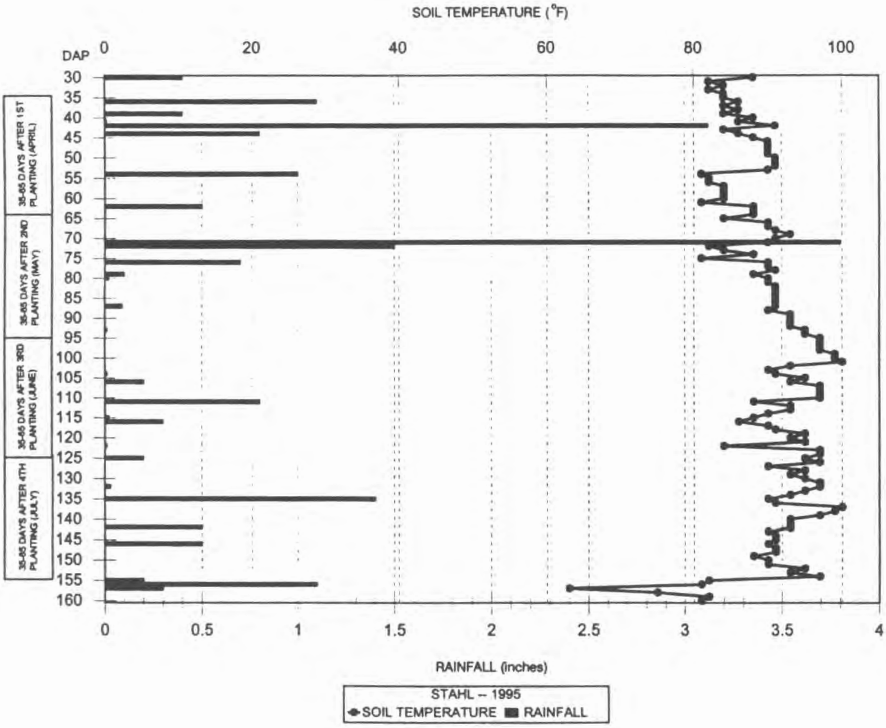

**Figure 4.** Soil temperature and rainfall during the 1995 growing season.

Total sound mature kernels (% TSMK). In both years cultivar effects were significant for TSMK (Fig. 6). However, TSMK were extremely low in each year. The low percentage TSMK can be attributed to lack of maturity with each cultivar. Andru 93 had the highest percentage in both years, GK-7 and Tamspan 90 were intermediate, and Florunner was inconsistent. In 1994, Florunner had one of the highest percentage TSMK whereas in 1995 Florunner was among the lowest (Fig. 6.).

Later planting dates resulted in a larger percentage of TSMK in 1994 (Fig. 7). In 1994, the early planting resulted in an extremely low percentage of TSMK whereas in 1995 the early planting date produced a much higher TSMK. This can be related to the lower soil temperatures at the earlier planting in 1994 which resulted in delayed maturity. In 1995, the May and June planting resulted in lower percentage TSMK (Fig. 7). However, the July planting resulted in a significant increase in TSMK.

Table 3. Monthly precipitation for 1994 and 1995 (planting to harvest).

| | Precipitation (inches) | | |
|---|---|---|---|
| Month | Normal* | 1994 | 1995 |
| April | 2.36 | 3.23 | 1.95 |
| May | 3.41 | 5.39 | 6.12 |
| June | 2.91 | 2.57 | 7.53 |
| July | 1.93 | 0.00 | 0.89 |
| Aug | 2.35 | 2.69 | 2.92 |
| Sept | 3.64 | 1.43 | 2.59 |
| Oct | 2.65 | 6.28 | 0.45 |
| Nov | 5.03 | 0.55 | 1.32 |
| Total | 24.28 | 22.14 | 23.77 |

*Eighty year long term average rainfall for Floresville, Texas.

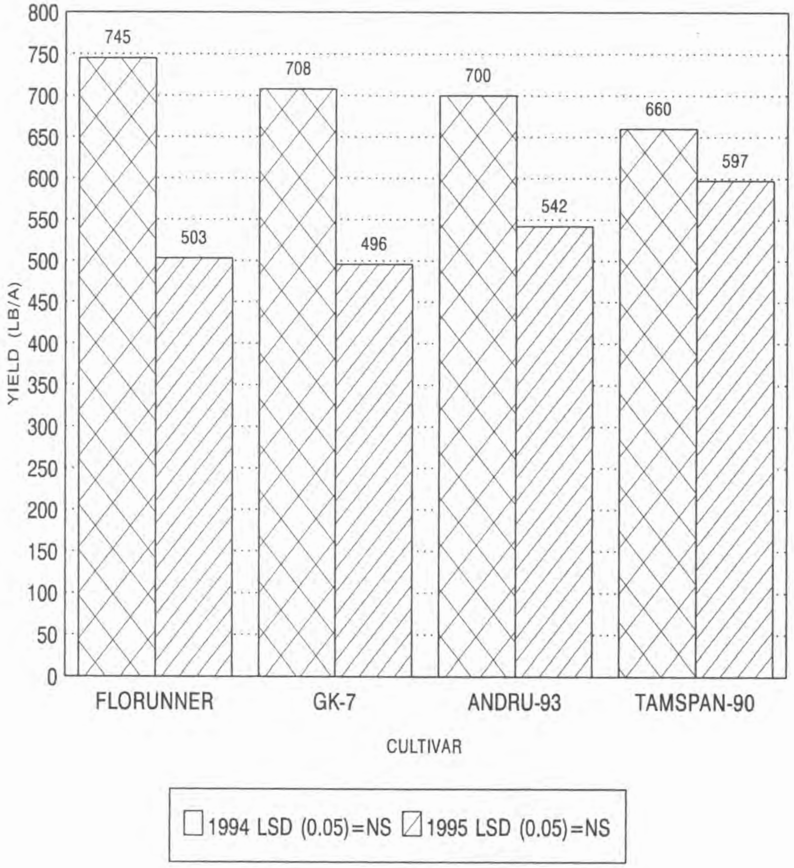

**Figure 5.** Peanut cultivar yield response by years. NS=-not signficant.

Planting date x cultivar interactions for TSMK occurred each year (Fig. 8). In 1994, TSMK for Florunner were high for the three later planting dates whereas in 1995 the April and July plantings resulted in the highest percentages TSMK. For GK-7, the later planting resulted in a higher percentage TSMK in both years. With Andru 93, the May planting in 1994 and the July planting in 1995 resulted in the highest total kernels. With Tamspan 90, the later plantings generally resulted in the highest percentage TSMK. This disagrees with the work of Mozingo et al. (1991) in Virginia. They found that a lower percentage of TSMK was obtained with delayed planting dates. They attributed this to environmental conditions which delayed maturity.

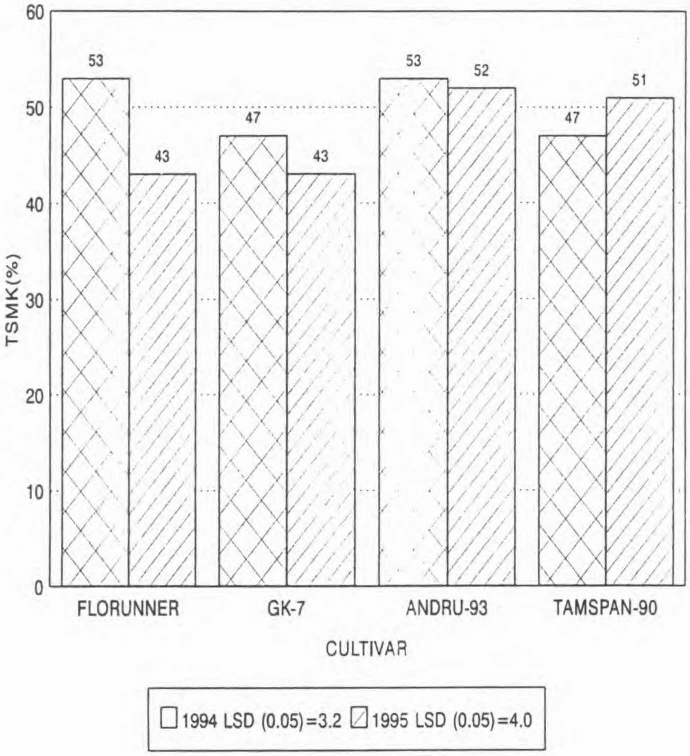

**Figure 6.** Influence of cultivars upon percentage total sound mature kernals (TSMK).

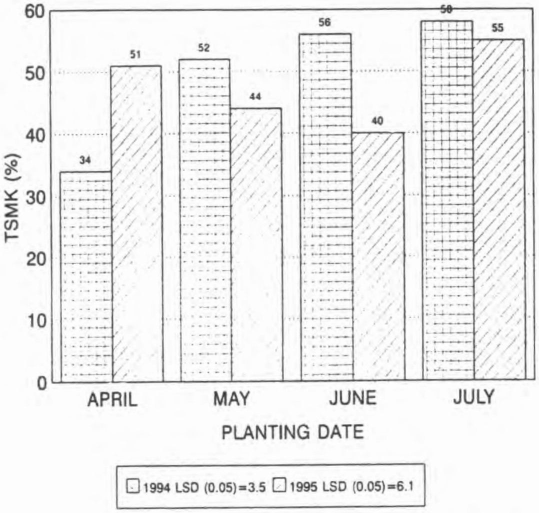

**Figure 7.** Effect of planting date on percentage total sound mature kernals (TSMK).

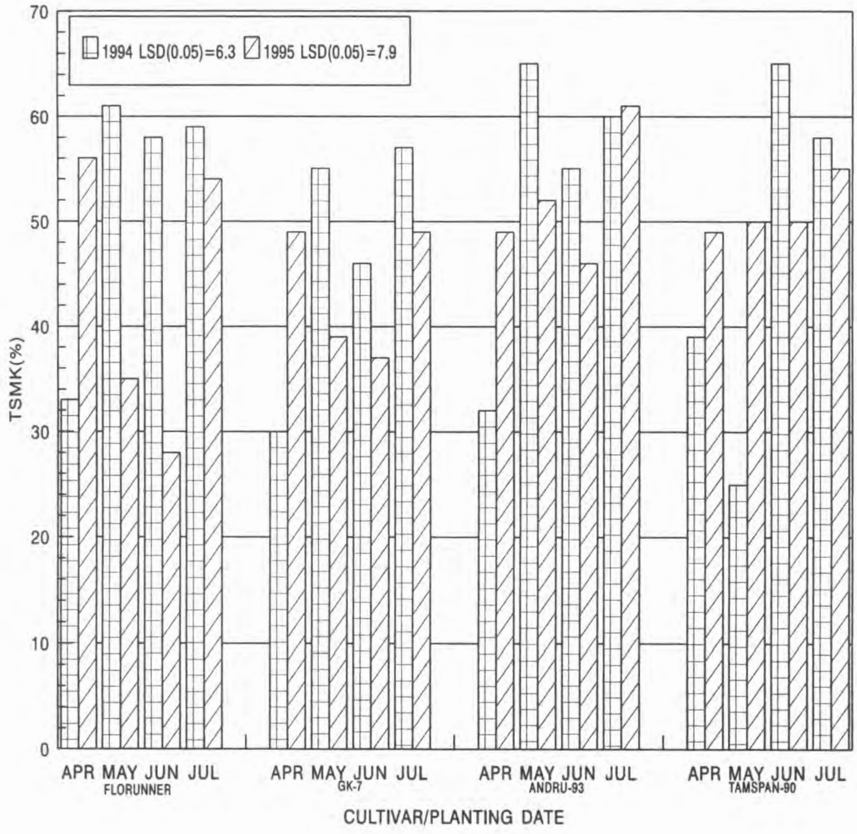

**Figure 8.** Influence of planting date x cultivar on percentage TSMK.

## CONCLUSIONS

The results of this study indicated that under dryland conditions, skip-row patterns have the potential to increase yield. However, producers must realize that this planting scheme will require more total acreage to obtain acceptable production. Also, weed control in the fallow rows will be necessary in wet years to prevent weed/crop competition, especially for valuable soil moisture.

Planting date interacts directly with available soil moisture in a given year. In most years, South Texas normally receives rainfall in April and May which provides adequate soil moisture for planting of dryland peanut. However, in 1996, very little rainfall was received from January through June severely hampering optimum dryland peanut production. Rainfall in August and September were above normal but it was too late in the growing season to produce a peanut crop before the onset of cold temperatures.

Varietal differences were not noted in this study. Soil moisture is such an important factor under dryland conditions that Spanish-type cultivars often produce higher yields than runner-type. Spanish-types can take advantage of late-season rainfall, setting a crop near the crown of the plant that matures 20 to 30 days sooner than runner-types. Longer-season runner types often do not accumulate enough heat units to mature.

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