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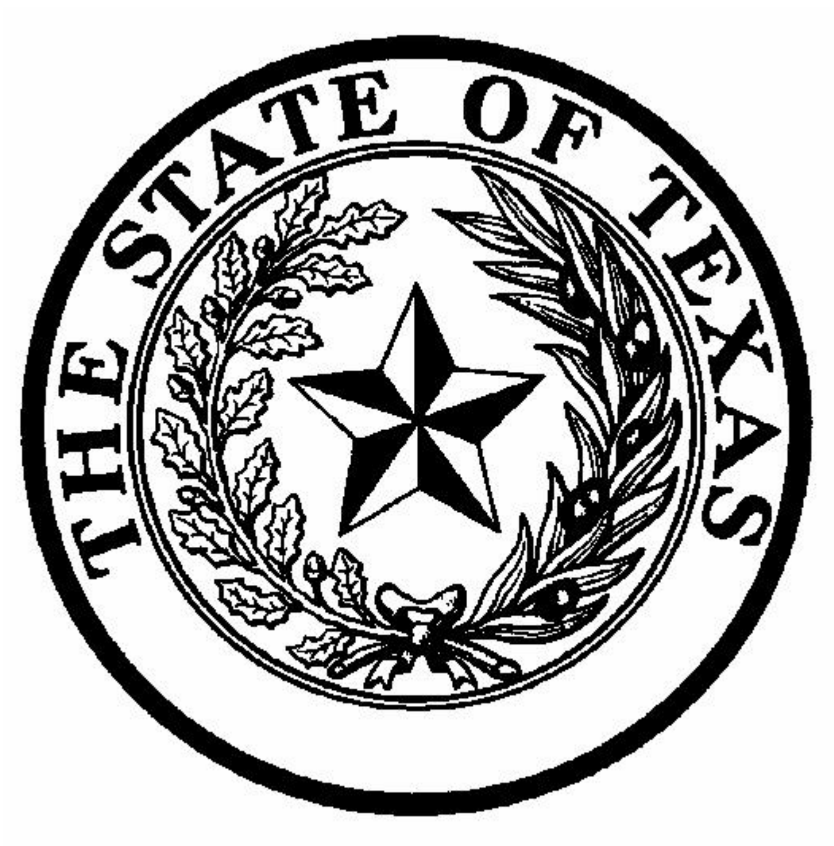

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Field Sandbur (*Cenchrus pauciflorus*) Control in Pastures Using Gramoxone, Roundup Ultra, or Touchdown

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ABSTRACT

Field studies were conducted during the 1997 and 1998 growing season to evaluate Gramoxone (paraquat), Roundup Ultra (glyphosate), or Touchdown (sulfosate) for field sandbur control, 'Coastal' bermudagrass tolerance, and effect on bermudagrass yield. All herbicides were applied within eight d of bermudagrass cut except in 1998 when herbicides were applied 17 d after cutting. Roundup Ultra at 0.5 and 1.0 pt/A controlled ≥ 90% field sandbur while Touchdown at 0.5 and 1.0 pt/A controlled ≥ 89%. Gramoxone control of field sandbur ranged from 61 to 94%. Bermudagrass injury (stunting) was greater with the 1.0 pt/A rate of RoundupUltra or Touchdown. Injury was less than 10% in most instances when herbicides were applied within 8 d of bermudagrass cut. When herbicides were applied 17 d after bermudagrass cut, bermudagrass injury varied from 11 to 93% and resulted in some bermudagrass death. Coastal bermudagrass yield was not affected by any herbicide treatments applied within 8 d of cutting when compared with the untreated check.

KEYWORDS: bermudagrass, efficacy, dry matter, grassbur, glyphosate, paraquat, sandbur, sulfosate

Forage production is an important facet of Texas agriculture as evidenced by the fact that over 40% of the land use in Texas is devoted to grazing lands and/or hay production (Census of Agriculture, 1992). Weeds are a problem on much of this production area. Field sandbur is rated the ninth most common and the second most troublesome pasture weed in Texas (Dowler, 1999).

Bermudagrass [*Cynodon dactylon* (L.) Pers.] is considered by many to be the most important grass of the livestock industry. Since the early times of fencing the ranching industry has depended on bermudagrass for grazing and hay. Weed species, such as field sandbur (*Cenchrus pauciflorus* Benth.), invade many of these bermudagrass production areas and need to be removed to prevent a reduction in yield and quality. (Ball et al., 1991). Field sandbur is adapted and grows best where mean daily temperatures are above 24°C (Burton and Hanna, 1995). *C. pauciflorus* can grow in many habitats. Often associated with low moisture and with sandy or light, well-drained soils of the tropics, the plant can spread rapidly in moderately moist regions. Under dry conditions the plant is short-lived, stays very small, and produces few burs, while under moist conditions it may be long-lived, can grow very large and produces many burs (Holm et al., 1991).

Field sandbur, commonly called grassbur, is a summer annual grassy weed that can be found in the southern part of the United States from California to North Carolina. This weed is especially adapted to dry, sandy soils but can be found growing in other types of soils as well (Holm et al., 1991).

The common name, sandbur, refers to the fact that these grasses are adapted to porous sandy soils and to the spiny lure of the seed heads which easily detach from the racemes and become attached to clothing or animal hair. The spiny burs can cause painful or annoying injuries to human skin and can contaminate feeds and hay, thus reducing its palatability and acceptability for animals. It produces from five to 70 or more spiny burs on each raceme. When mature, these burs fall to the ground and produce new plants. Undoubtedly the primary method of dispersal is its spiny bur (Holm et al., 1991). The plants flower throughout most of the year in the moist tropics (Holm et al., 1991). Competition from this grass weed delays bermudagrass establishment and reduces both the forage yield and quality (Bingham and Shaner, 1981; Walker et al., 1998).

Since atrazine [6-chloro-N-ethyl-N=-(1-methylethyl)-1,3,5-triazine-2,4-diamine] is no longer available for use in pastures, no herbicide has been cleared which will effectively control sandbur in pasture. The bipyridinium herbicide, paraquat, is widely used for total vegetation control (Fuerst and Vaughn, 1990). In cropping systems, it is applied before planting annual crops, during the dormant stage of perennial crops, or as a spray directed away from growing crops. It is active only when applied to the foliage; it is not extensively translocated in plants and has no soil activity due to strong absorption to seed colloids (Anonymous, 1994). Paraquat is a highly water-soluble divalent cation that desicates plants in a few hours in full sunlight by a series of reactions which causes cell membranes to lose integrity, resulting in water loss and rapid desication (Dodge, 1982).

Glyphosate, the active ingredient in Roundup Ultra, and Touchdown, is a nonselective, foliar-applied herbicide that is useful for perennial weed control because it translocates to the roots (Gottrup et al., 1976; Sandberg et al., 1980; Schultz and Burnside, 1980; Sprankle et al., 1975). Glyphosate accumulation in the roots of perennial weeds is required to kill root buds and other organs capable of vegetative reproduction (Claus and Behrens, 1976; Waldecker and Wyse, 1985). Factors that reduce glyphosate absorption and translocation to root tissue reduce control of vegetative reproductive parts (Chase and Appleby, 1979; Waldecker and Wyse, 1985).

Since field sandbur is such a problem in bermudagrass pastures, the objective of this research was to determine the feasibility of using a nonselective foliar-applied herbicide to control field sandbur in a bermudagrass pasture and the effects of these herbicides on bermudagrass yield.

MATERIALS AND METHODS

Field studies were conducted during the 1997 and 1998 growing season near Shiner, TX in Lavaca County. The soil at the test site was a Carbengle loam (fine-loamy, carbonatic, thermic Typic Calciustolls) with less than 1% organic matter with a pH of 7.1. The test location remained in the same vicinity of the field in each year due to the heavy population of field sandbur (2 to 3 plants/ft^2).

Herbicide treatments included Roundup Ultra and Touchdown applied at 0.5 and 1.0 pt/A and Gramoxone at 0.4 pt/A. These herbicides were applied after the first or second cutting or a combination herbicide application after both the first and second cutting. Touchdown and Gramoxone 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% (v/v). Herbicides were applied within 8 d of bermudagrass cutting except in 1998 when herbicides were applied 17 d after the second bermudagrass cutting.

Herbicide treatments were applied broadcast with a CO_2 backpack sprayer equipped with Teejet 11002 flat fan nozzles (Spraying Systems Co., Wheaton, IL 60189-7900) calibrated to deliver a spray volume of 20 gal/A at 28 psi. Field sandbur control and 'coastal' bermudagrass injury were evaluated 30 and 50 d after treatment (DAT) in 1997 and 40 and 60 DAT in 1998. Visual estimates were based on a scale of 0% (no field sandbur control or bermudagrass injury to 100% complete control of field sandbur or death of bermudagrass) relative to the untreated check. Bermudagrass injury was characterized as stunting of the regrowth except for the 60 DAT which included bermudagrass necrosis and chlorosis.

Treatments were applied in a randomized complete block design with four replications. Plot size measured 6 ft wide by 25 ft long. Grass plots were harvested 3 to 4 d prior to the commercial harvest of remaining pasture. Two randomly selected 16 in^2 quadrants were hand-cut from each plot. Field sandbur and bermudagrass were hand-separated to determine forage composition, and dried for 72h at 150°F. After samples were dried, bermudagrass yields on a dry matter basis were determined.

Plot yields were not taken at the first cutting of each year since herbicides had not yet been applied. Plots were harvested on 30 June and 27 November, 1997 and 1 September 1998. Herbicides were applied on 6 May and 8 July, 1997 and 14 May and 18 September, 1998. Lack of rainfall during the spring and summer of 1998 resulted in poor bermudagrass growth and a late season (18 September) herbicide application. Therefore a second harvest was not obtained in 1998.

All data were evaluated with analysis of variance and LSD at the 0.05 level of significance were calculated to compare treatment means. Data were evaluated individually by years because of differences in application timing and rating intervals.

RESULTS AND DISCUSSION

Sandbur control

In 1997, Roundup Ultra and Touchdown controlled ≥ 89% field sandbur when rated 30 days after first cutting herbicide treatment (DA1T) while Gramoxone provided < 85% control (Table 1). When rated 50 days after second cutting herbicide treatment (DA2T), Roundup Ultra applied after first cutting provided ≤ 76% control, while Roundup Ultra applied after second cutting provided 78 to 95% control. Roundup Ultra applied both after first and second cutting provided 100% control regardless of rate. Touchdown applied after first cutting provided < 90% sandbur control while Touchdown applied after second cutting controlled 98 to 100% field sandbur. Touchdown applied after first and second cutting controlled 100% field sandbur. Gramoxone at 50 DA2T controlled < 70% field sandbur when applied at first or second cutting but controlled 88% field sandbur when applied after first and second cutting (Table 1).

In 1998, similar trends as seen with the early rating of 1997 were evident when evaluated 40 DA1T (Table 1). Gramoxone applied once controlled less field sandbur than Roundup or Touchdown. When rated 60 DA2T all herbicide treatments except Gramoxone applied after first cutting controlled ≥ 90 field sandbur. The excellent control with all herbicide treatments was due to lack of rainfall after second cutting which resulted in less field sandbur germination.

Bermudagrass injury

In 1997, Roundup Ultra at 1.0 pt/A resulted in ≤ 11% injury when applied after first or second cutting (Table 2). Touchdown at 1.0 pt/A caused ≤ 8% injury while the 0.5 pt/A rate of Touchdown applied after second cutting resulted in 15% bermudagrass injury. Injury from Gramoxone was 5%.

Table 1. Field sandbur control with Gramoxone, Roundup Ultra, or Touchdown.

			Field sandbur control			
		Appl	1997		1998	
Herbicide	Rate	timing	30 DA1T[a/]	50 DA2T[b/]	40 DA1T[c/]	40 DA2T[d/]
	(pt/A)					
Check	-	-	0	0	0	0
Roundup Ultra	0.5	Cut 1	90	65	89	94
Roundup Ultra	1.0	Cut 1	99	76	96	93
Roundup Ultra	0.5	Cut 2	-	95	-	94
Roundup Ultra	1.0	Cut 2	-	78	-	95
Roundup Ultra	0.5	Cut 1 + 2	91	100	96	94
Roundup Ultra	1.0	Cut 1 + 2	99	100	98	93
Touchdown	0.5	Cut 1	89	73	100	93
Touchdown	1.0	Cut 1	96	89	89	93
Touchdown	0.5	Cut 2	-	98	-	95
Touchdown	1.0	Cut 2	-	100	-	95
Touchdown	0.5	Cut 1 + 2	93	100	100	93
Touchdown	1.0	Cut 1 + 2	95	100	85	95
Gramoxone	0.4	Cut 1	76	61	73	86
Gramoxone	0.4	Cut 2	-	64	-	90
Gramoxone	0.4	Cut 1 + 2	84	88	94	93
LSD (0.05)			8	33	17	5

[a/] 30 DA1T = 30 d after first cutting herbicide treatments
[b/] 50 DA2T = 50 d after second cutting herbicide treatments
[c/] 40 DA1T = 40 d after first cutting herbicide treatments
[d/] 60 DA2T = 60 d after second cutting herbicide treatments

In 1998, when rated 40 DAT, bermudagrass injury with Roundup Ultra at 1.0 pt/A ranged from 9 to 20% while injury with 0.5 pt of Roundup Ultra was ≤ 1%. Bermudagrass injury with Touchdown at 1.0 pt/A was ≤ 4%. Gramoxone resulted in ≤ 1% injury.

When rated 60 DAT all herbicides applied after the second cutting resulted in ≥ 36% injury to the bermudagrass (Table 2). Herbicides were applied 17 d after bermudagrass was cut and the bermudagrass had some leaf development (authors personal observation).

Paraquat resulted in 67 to 71% bermudgrass injury while Roundup Ultra injury ranged from 36 to 80% and Touchdown injury ranged from 75 to 80%. Although all the three herbicides are active when applied to foliage (Ambach and Ashford, 1982; Fuerst and Vaughn, 1990; McKinlay et al., 1974; Sprankle et al., 1975), Roundup Ultra and Touchdown are more useful for perennial weed control because they are translocated to the roots (Sprankle et al., 1975; Waldecker and Wyse, 1985; Wyrill and Burnside, 1976). Paraquat is not translocated in plants (Fuerst and Vaughn, 1990) and, therefore, will not effectively control perennial grasses.

Bermudagrass yield

No significant differences in bermudagrass yield were noted at any harvest date (Table 3). A second harvest was not taken in 1998 due to late herbicide application. Although some bermudagrass injury was noted after first and second cutting in 1997 and the first cutting in 1998 the bermudagrass recovered by harvest. However, yield differences would have been noted if a harvest could have been taken after the second harvest in 1998 (authors personal opinion).

Although field sandbur did not have an effect on bermudagrass yield, the presence of these spiny burs reduces feeding palatability and presents problems in handling forage or hay by hand. Roundup Ultra and Touchdown were effective for field sandbur control, however, since these herbicides do not possess any residual activity, repeat applications

Table 2. Coastal bermudagrass injury following applications of Gramoxone, Roundup Ultra, and Touchdown.

			Bermudagrass injury			
		Appl	1997		1998	
Herbicide	Rate	timing	30 DA1T[a]	50 DA2T[b]	40 DA1T[c]	40 DA2T[d]
	(pt/A)					
Check	-	-	0	0	0	0
Roundup Ultra	0.5	Cut 1	0	0	0	0
Roundup Ultra	1.0	Cut 1	11	0	9	0
Roundup Ultra	0.5	Cut 2	-	0	-	72
Roundup Ultra	1.0	Cut 2	-	10	-	80
Roundup Ultra	0.5	Cut 1 + 2	0	0	1	36
Roundup Ultra	1.0	Cut 1 + 2	1	10	20	77
Touchdown	0.5	Cut 1	0	0	0	0
Touchdown	1.0	Cut 1	0	0	3	5
Touchdown	0.5	Cut 2	-	15	-	75
Touchdown	1.0	Cut 2	-	0	-	80
Touchdown	0.5	Cut 1 + 2	0	3	0	75
Touchdown	1.0	Cut 1 + 2	0	8	4	76
Gramoxone	0.4	Cut 1	0	0	1	0
Gramoxone	0.4	Cut 2	-	0	-	71
Gramoxone	0.4	Cut 1 + 2	0	5	1	67
LSD (0.05)			7	9	4	25

[a] 30 DA1T = 30 d after first cutting herbicide treatments
[b] 50 DA2T = 50 d after second cutting herbicide treatments
[c] 40 DA1T = 40 d after first cutting herbicide treatments
[d] 60 DA2T = 60 d after second cutting herbicide treatments

Table 3. Coastal bermudagrass dry weight yield following applications of Gramoxone, Roundup Ultra, or Touchdown.

			Bermudagrass yield		
		Appl			
Herbicide	Rate	timing[a]	6/30/97	11/27/97	9/1/98
	(pt/A)		-----------------	Lbs/A	-----------------
Check	-	-	3849	1525	2326
Roundup Ultra	0.5	Cut 1	4227	1603	2178
Roundup Ultra	1.0	Cut 1	3780	1353	2468
Roundup Ultra	0.5	Cut 2	-	1494	-
Roundup Ultra	1.0	Cut 2	-	1260	-
Roundup Ultra	0.5	Cut 1 + 2	4607	1945	2662
Roundup Ultra	1.0	Cut 1 + 2	4004	2038	2807
Touchdown	0.5	Cut 1	4460	2022	3243
Touchdown	1.0	Cut 1	3970	1540	2372
Touchdown	0.5	Cut 2	-	1618	-
Touchdown	1.0	Cut 2	-	1509	-
Touchdown	0.5	Cut 1 + 2	4235	1431	2178
Touchdown	1.0	Cut 1 + 2	3803	1742	2420
Gramoxone	0.4	Cut 1	4123	1587	1936
Gramoxone	0.4	Cut 2	-	1773	-
Gramoxone	0.4	Cut 1 + 2	3964	1509	2614
LSD (0.05)			NS	NS	NS

[a]Herbicide application to bermudagrass no later than 5 day after designated cutting.

after each cutting will be necessary for effective control. Also these herbicides may cause bermudagrass injury if herbicide application is delayed more than 7 to 10 d after cutting when the bermudagrass develops new lead growth. At the present time, only Roundup Ultra is cleared for use on bermudagrass pastures.

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Effectiveness of the Southwest Dairy Center Mobile Classroom in Promoting Agricultural Literacy

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ABSTRACT

Most Americans now live in an urban setting and are two to three generations removed from life on a farm. Hence, children and many adults lack knowledge of where and how food is produced. Agricultural education programs are being initiated across the country. One program, developed at the Southwest Dairy Museum in Sulphur Springs, Texas, consists of mobile dairy classrooms (n=5), which visit elementary schools, fairs, and shopping centers in four states and present a program about the dairy industry. To assess effectiveness of these classrooms, a study was conducted that used pre-visit questionnaires (pre-test) and post-visit questionnaires (post-test). Data from each student were recorded and statistically analyzed using split-plot analysis of variance for repeated measures. Analysis indicated no differences in response between males and females. In scoring the pre-test knowledge questions, a mere 3.7% of males made a passing score of 70% or better compared to 3.4% of the females. Students showed a strong response to the dairy presentation ($P<.001$), with 50.9% and 42.4% of the males and females, respectively, passing the post-test. Ethnic background was observed and most of the students in this study were Caucasian of Non-Hispanic origin (White). A small number of African American, Hispanic, and Asian children responded, and they were collectively referred to as minority students. An interaction of ethnicity and response to teaching was observed ($P<.001$). About 2.9% of white students as compared to 4.7% of minority students passed the pre-test. Following the dairy classroom presentation 43.5% and 51.2% of the white students and minority students, respectively, passed the post-test. It appears that children are learning a significant amount about the dairy industry from programs presented by the mobile dairy classroom.

KEYWORDS: Mobile Dairy Classroom, dairy presentation, dairy specialist, agricultural literacy, questionnaire

When this country was founded, 90 percent of the population was involved in agriculture (McCracken et al., 1990). During the past 200 years, there has been a shift of the American population from the farm to the city. Most Americans now live in an urban setting and for 2 or 3 generations have had little if any contact with farm life. Therefore, the

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realization of the importance of agriculture, to not only our national but personal well being, is poorly understood (McCracken et al., 1990). Dr. J. R. Carlson was quoted as saying that "In the United States, a mere two percent of the population is able to feed 100% of the people" (Agriculture Council of America, 1994). With such a small percentage of Americans actively involved in farming, agriculture as a whole easily gets the "cows and plows" wrap (Townsend, 1990).

Richardson (1990), in his article entitled "Reinforcing the Common Bond between Urban and Agricultural Interests", says, "Americans know very little about agriculture, its social and economic significance in the United States and, in particular, its links to human health and environmental quality". Not one single person in the world is untouched by agriculture but from results of agricultural literacy studies, agriculturalists have a lot of educating to do.

Dr. Shirley Traxler, Director of the National Agriculture in the Classroom Program, United States Department of Agriculture, Washington D.C., discusses, in her article "Why Ag in the Classroom" (1990), the once intertwining relationship between agriculture and education. Planting, cultivating, and harvesting determined the school year; most of the population was involved in farming and textbooks were filled with information about agriculture. She further comments, "Students were never asked the question, 'Where does milk come from?' They all knew, many from first-hand experience."

In educating an urban population, participants should be made aware that agriculture is a viable and aggressive industry (McClintic, 1994). They should be reminded that the average American family spends a mere 10% of their disposable income on food as compared to families in Mexico and China who spend 32% and 48%, respectively, of their disposable income on food (Agriculture Council of America, 1994). In a similar context about educating the general public, Townsend (1990) writes that, "Today's world of agriculture is one of … computers, DNA manipulation, lasers, environmental expertise, ever-changing scientific knowledge, and robotic equipment." This view of the agricultural industry is one that needs to be cultivated among Americans.

Agriculturalists across the United States are actively producing programs to increase the understanding of agriculture in an urban environment. The Southwest Dairy Museum sponsors five mobile dairy classrooms that travel throughout the Southwest and present live cow-milking demonstrations and explain the preparation of milk for consumption and its value as a nutritive source.

MATERIALS AND METHODS

The Southwest Dairy Museum's mobile dairy classrooms travel to various school districts, state and local fairs and various other places such as shopping malls. The mobile dairy classroom consists of an enclosed trailer that contains a live cow and modern milking equipment. A dairy specialist travels with the mobile classroom and presents live cow-milking demonstrations and explain how milk from the cow is processed and goes to the food market and then to the home or school for consumption. The care and feeding of a dairy cow and the importance of dairy products in one's diet is discussed and followed by a question and answer period.

To determine the effectiveness of this presentation and overall acceptance of the mobile dairy classroom, a student questionnaire or data collection instrument was developed (Figure 1). The instrument was intended for use in a measurement-treatment-measurement format. First, before attending the dairy presentation at the mobile dairy classroom, the general knowledge of the student concerning the dairy industry was measured,

Figure 1. Example student questionnaire used in study.

Name: ________________________________ ID# ________________
Teacher: ______________________________

Student Questionnaire

Place an "X" beside the correct answer.

What is your sex?
A. Female ___ B. Male ___

What is your ethnicity?
A. Asian ___ B. African American ___ C. Hispanic ___
D. White ___ E. Other

Do you drink white milk?
A. Yes ___ B. No ___
If yes, do you consume: 1-4 glasses per week ___ 5-9 glasses per week ___
10-14 glasses per week ___ 15 or more glasses per week ___

Do you drink chocolate milk?
A. Yes ___ B. No ___
If yes, do you consume: 1-4 glasses per week ___ 5-9 glasses per week ___
10-14 glasses per week ___ 15 or more glasses per week ___

Do you eat cheese?
A. Yes ___ B. No ___
If yes, do you consume: 1-4 glasses per week ___ 5-9 glasses per week ___
10-14 servings per week ___ 15 or more servings per week ___

Do you eat cottage cheese?
A. Yes ___ B. No ___
If yes, do you consume: 1-4 glasses per week ___ 5-9 glasses per week ___
10-14 servings per week ___ 15 or more servings per week ___

Do you eat ice cream?
A. Yes ___ B. No ___
If yes, do you consume: 1-4 glasses per week ___ 5-9 glasses per week ___
10-14 servings per week ___ 15 or more servings per week ___

Do you eat yogurt?
A. Yes ___ B. No ___
If yes, do you consume: 1-4 glasses per week ___ 5-9 glasses per week ___
10-14 servings per week ___ 15 or more servings per week ___

Do you use butter?
A. Yes ___ B. No ___
If yes, do you consume: 1-4 glasses per week ___ 5-9 glasses per week ___
10-14 servings per week ___ 15 or more servings per week ___

Please indicate if the statement is either *A. True* or *B. False* by circling the correct answer.

1. Milk is kept cold to make it taste better.
   - A. True
   - B. False
   - C. I don't know
2. It is important to drink milk and eat dairy foods to be healthy.
   - A. True
   - B. False
   - C. I don't know
3. Each week you should drink or eat 2 servings of milk or dairy foods.
   - A. True
   - B. False
   - C. I don't know
4. Chocolate milk is made by dark colored dairy cows.
   - A. True
   - B. False
   - C. I don't know
5. Cows produce milk to feed their young.
   - A. True
   - B. False
   - C. I don't know
6. A heifer is an old cow in a herd.
   - A. True
   - B. False
   - C. I don't know
7. A dairy cow makes between 48 and 100 cups of milk each day.
   - A. True
   - B. False
   - C. I don't know
8. Cows have their first baby when they are about 2 years of age.
   - A. True
   - B. False
   - C. I don't know
9. A dairy cow weighs about 500 pounds.
   - A. True
   - B. False
   - C. I don't know
10. A dairy cow eats 90 pounds of food and drinks 25-50 gallons of water each day.
    - A. True
    - B. False
    - C. I don't know

along with their preferences for dairy products. Secondly, the instrument was used to measure the change in knowledge or preferences of the children after having experienced the presentation and reading the material distributed by the dairy specialist.

School districts were randomly chosen and the principal of each school was contacted and permission to utilize their fourth grade students in this study was requested. Once permission was granted, a packet consisting of a cover letter explaining the study and enough questionnaires for each child was mailed to the school.

The questionnaire consisted of two demographic questions, seven preference questions, and ten knowledge questions. A number encoded on the questionnaire identified the geographic location of the child.

Demographic questions were used to determine the gender and ethnicity of the child. Preference questions quizzed children about their particular choices of dairy products such as milk, butter, or ice cream. Knowledge questions dealing specifically with the dairy industry completed the student questionnaire.

The questionnaire (pre-test) was administered to children approximately one week before the mobile dairy classroom visited their school. The post-test questionnaire, identical to the pre-test questionnaire except for the color of paper on which they were printed, was administered to each child approximately one week after the dairy presentation. Test responses were scored by hand. Each correct answer of true or false received a score of one. Incorrect responses, answers of "I don't know", or unanswered questions were scored zero. The total score of each student was recorded and then statistically analyzed using split-plot analysis of variance for repeated measures (Steel et al., 1997). Main plot effects included gender, ethnicity, and geographic location of the students. Response to teaching (dairy presentation) and each main effect x response interaction was determined in each subplot. Differences observed were used to measure the effectiveness of the mobile dairy classroom.

RESULTS

Initially, 651 fourth grade students were selected to participate in a study to determine the effectiveness of the Southwest Dairy Classroom units in promoting agricultural literacy. Students were asked to answer a questionnaire about their knowledge of the dairy industry and the importance of dairy products to one's diet one week prior to attending a presentation by the Mobile Dairy Classroom dairy specialist. At the presentation, students were taught the importance of milk and other dairy products to the diet, life on a dairy farm, and the treatment and handling of dairy cattle. Students also witnessed a dairy cow being milked with modern milking equipment. Colorful posters and worksheets were left with the teacher as study materials. One week after attending the dairy specialist's presentation, the fourth grade children were quizzed using the same questionnaire as before to determine the effectiveness of the visit by the Mobile Dairy Classroom.

Gender was identified on the questionnaire to determine if male students were more receptive to the dairy presentation (teaching) than females or vice-versa. In scoring the pre-test questionnaire, only 3.7% of males made a passing score of 70% or better compared to 3.4% of females ($P>.10$). Following the dairy presentation, the questionnaire was again answered with 50.9% of males and 42.4% of females receiving a score of 70% or better. These numbers indicate that children showed a strong learning response to the dairy presentation ($P<.001$). No gender x response to dairy presentation interaction was observed ($P>.10$).

To determine if cultural differences during childhood had an effect on knowledge of the dairy industry, each student was asked to identify their ethnic background on the questionnaire. Most of the respondents were White and because of the small number of African American, Hispanic, and Asian children responding, those students were collectively referred to as minority students. An interaction of ethnicity x response to the dairy presentation (P<.001) for evaluating cultural differences as a factor affecting knowledge of the dairy industry was observed. Approximately 2.9% of white students as compared to 4.7% of minority students received a passing score on the questionnaire prior to the dairy presentation. Following the presentation, 43.5% of the white students and 51.2% of minority students received passing scores.

Data collected from a school in central Texas and one in Oklahoma indicated no interaction (P>.10) of geographic location x ability to learn from the dairy presentation. Also, the response to the dairy presentation was greater (P<.001) in students from central Texas who had some previous knowledge of the dairy industry as compared to those from Oklahoma with little dairy background. The percentages of students with passing scores following the dairy presentation were 50.6% and 36.0% from Texas and Oklahoma, respectively.

CONCLUSIONS

The primary objective of this study was to determine the effectiveness of the Southwest Dairy Museum Mobile Dairy Classroom units in promoting agricultural literacy. The results of this study indicate that observing a live cow milking demonstration along with a discussion on dairy cattle feeding, handling, and distribution of milk and its nutritive value greatly improved the knowledge and understanding of students about the dairy industry. Classroom study materials left with the teacher were also a valuable source of dairy information.

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Follow-Up Study of Graduates of the College of Agricultural Sciences and Natural Resources at Texas Tech University: 1995 to 1999

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ABSTRACT

This study was conducted: 1) to determine the occupational status of alumni from the College of Agricultural Sciences and Natural Resources (CASNR) at Texas Tech University who graduated between May 1995 and August 1999; and 2) to evaluate their opinions concerning recruitment, retention and placement efforts and programs offered by the University and the College. The target population was all graduates (CASNR) at Texas Tech University from May 1995 through August 1999. The results indicated that 45% of the respondents were employed as Scientists, Engineers or Related Specialists (23.9%) and as Education, Communication or Information Specialists (21.1%). A large portion (33%) of the graduates had annual incomes ranging between $25,000 and $34,999, and a significant portion (14.5%) made $50,000 and above. Recruitment efforts used by the college found to be effective were University Day and campus tours. Degrees offered and reputation of school were the most important factors in the respondent's decision to attend Texas Tech. Parents were rated as the most influential individuals in the respondent's decision to attend Texas Tech. The most challenging factor for respondents in making the adjustment to university life as a first-year student was developing proper study habits, and the most helpful factor were faculty advisors. Respondents rated concerns about what happens after graduation and concerns about grades as the most stressful factors for students in their academic program. Respondents indicated that participation in student clubs, organizations and judging teams was highly beneficial to them in preparing for future employment and in making the most of their collegiate experience. Self-initiated services were rated the most beneficial service used by graduates in their initial career job search. Almost 95% of the respondents projected employment opportunities as excellent, good, or average for their chosen field.

KEY WORDS: follow-up of graduates, occupational status, student recruitment, retention, placement, careers

In order to attract students to universities, it is imperative to find ways of improving and implementing programs which serve the needs of all students. Cheek and McGhee (1990) contend that follow-up studies are one of the most commonly used measures in evaluating programs. The follow-up study is often used in an effort to evaluate the success of a particular program or various aspects of a program. They provide the opportunity to learn from the graduates what they liked or disliked during their collegiate experience.

Recruitment, retention, and placement efforts are also areas which may be evaluated through the use of a follow-up study. Follow-up studies allow the graduates an opportunity to comment on these areas, as well as provide the college some insight as to what they may need to change to improve their methods.

The answers to the following questions were sought as means of accomplishing this objective of this study:

1. What are the demographic characteristics of the graduates from CASNR at Texas Tech University based on year degree was obtained, income and gender?
2. What is the occupational status of graduates from CASNR at Texas Tech University based upon the six occupational clusters as classified by the United States Department of Agriculture?
3. How does the occupational status of the graduates from CASNR at Texas Tech University compare to the results of the United States Department of Agriculture, Office of Higher Education, projections regarding employment opportunities for agricultural and allied graduates?
4. What are the most effective recruitment efforts used by CASNR at Texas Tech University?
5. What are the most important factors in a student's decision to attend Texas Tech University?
6. Who are the most influential individuals in a student's decision to attend Texas Tech University?
7. What are the most important items a prospective student would want delivered in a school presentation given by representatives from CASNR at Texas Tech University?
8. What are the most important factors to students in making the adjustment to university life as a first-year student?
9. What services, if any, did the students use to assist in performing well academically?
10. What are the most challenging academic areas for students, as well as the factors that caused them the most stress in their academic program?
11. What advice would alumni give to incoming freshmen in adjusting to university life and succeeding academically?
12. What role do student clubs, organizations and judging teams play in helping students better prepare for future employment, as well as in making the most of their collegiate experience?
13. What are the most beneficial services used by graduates in their initial career job search?
14. What are the most important attributes for selecting a career?
15. What are the projected future employment opportunities for graduates?
16. Would graduates enroll again in CASNR if given the opportunity?

In designing the questionnaire, the author reviewed instruments used by other researchers (Cantrell, 1996; Wrye, 1992; Major, 1988). Suggestions from the senior author's advisory committee and selected professionals in the areas of recruitment, retention, and placement were also taken into consideration for content validity. The questionnaire was pilot tested by graduate students in the Department of Agricultural Education and Communications. The instrument consisted of four parts: (1) demographics; (2) placement; (3) recruitment; and (4) retention.

METHODS

Data were collected using the researcher-designed questionnaire. An introduction letter, along with the survey and a self-addressed postage-paid envelope, was mailed on December 2, 1999. Fifty-nine respondents returned their survey after this initial mailing. A follow-up postcard was sent on December 16, 1999 as a reminder to the graduates of the importance of completing the survey and participating in the study. Eighty surveys were returned after this second mailing. A third mailing consisting of a letter, survey and postage-paid envelope, was mailed on January 24, 2000, also resulting in eighty responses. A second follow-up postcard was sent on February 15, 2000, again encouraging graduates to respond. Forty-four respondents returned their survey after this last mailing. Completion of the survey was also available to the graduates online through the website address of www.casnr.ttu.edu/survey.htm.

The data collection period ended on March 28, 2000. Two hundred-sixty-three responses were collected from the 500 mailed. Of the population sampled, 19 of the questionnaires were returned for incorrect address – therefore reducing the sample size to 481. Thus, the response rate was 54.7%.

Data were collected in four waves. A correlation matrix was established to determine if there was a relationship between date of return and the response variables included in the study. Only one variable, level of difficulty with foreign language, was found to be significantly related to date of return. People who responded later tended to have a higher level of difficulty than those who responded earlier. This general lack of significance would suggest that no differences would be found between the respondents and those who did not respond.

SUMMARY OF FINDINGS

Characteristics of Respondents

The majority of the respondents were male (74.1%) and graduated in 1998 (27.8%). Most of the respondents chose to return the survey by mail (72.6%) instead of via the website. Six occupational clusters categorized by the United States Department of Agriculture (Gilmore, Goecker and Whatley, 2000) were used to determine employment area. These are illustrated in Table 1 below.

Table 1. Characterization of graduates by current occupational category.

Employment Cluster	Number of Respondents	
Scientist, Engineer or Related Specialist	59	23.9%
Manager or Financial Specialist	36	14.6%
Marketing, Merchandising or Sales Representative	48	19.4%
Education, Communication or Information Specialist	52	21.1%
Social Service Professional	13	5.3%
Agricultural Production Specialist	39	15.7%
Total	247[a]	100.0%

[a]16 missing responses

Almost fifty percent of the respondents were employed as Scientists, Engineers or Related Specialists (23.9%) or as Education, Communication or Information Specialists (21.1%). A large portion (33%) of the graduates had annual incomes ranging between $25,000 and $34,999, and a significant portion (14.5%) made $50,000 and above.

Most Effective Recruitment Efforts Used by the College of Agricultural Sciences and Natural Resources

Respondents were asked to rate various recruitment efforts in terms of effectiveness (based on a scale of 5=Very Effective to 1=Not Effective). Various recruitment efforts and their ratings are detailed in Table 2.

Table 2. Various recruitment efforts used by college.

Recruitment Efforts	% Affected	Mean Rating
University Day	38.1	3.6
Campus Tours	46.4	3.5
Postcards and Letters	45.6	3.3
Presence at State FFA Convention	25.8	3.2
Presence at National FFA Convention	22.4	3.1
Presence at Houston Livestock Show and Rodeo	30.4	3.0
Visit by Students	23.9	3.0
Visit by Faculty	20.0	3.0
Presence at State Roundup	21.0	2.9
Phone Calls	29.2	2.8

Most Important Factors in a Student's Decision to Attend Texas Tech University

Respondents were asked to rate various factors by level of importance (based on a scale of 5=Very Important to 1=Not Important). Degrees offered (4.2) and reputation of school (4.0) were the most important factors in the respondents' decision to attend Texas Tech. Factors receiving a level of somewhat important were friendliness of people (3.8), location (3.5), reputation of faculty (3.5), size of school (3.3), other factors listed by respondents (3.2), and scholarships (3.1). Other factors listed by respondents included quality of degree, family, recommendation of professionals in chosen field, jobs available in Lubbock, visits to campus, interest advisor showed, and Lubbock as a permanent residence. Rated not as important were judging teams (1.7) and Greek life (1.6).

Most Influential Individuals in Student's Decision to Attend Texas Tech University

Respondents were asked to rate various individuals by level of influence (based on a scale of 5=Very Influential to 1=Not Influential). Parents were rated as the most influential individuals with a mean score of 3.5. Friends were rated as somewhat influential with a mean score of 3.2. Rated as only slightly influential included teachers, other relatives and siblings (2.4).

Most Important Items to Cover in a High School Presentation

Respondents were asked to rate various items a prospective student would want delivered in a school presentation given by representatives from the College of Agricultural Sciences and Natural Resources (based on a scale of 5=Very Important to 1=Not Important). The most important items to cover included careers in agricultural sciences and natural resources (4.7), departmental and degree information and scholarship opportunities (4.5), costs (4.4), and university information (4.3). Items rated as only somewhat important were information on university extracurricular activities (3.8), housing information and other items listed by respondents (3.7), and Lubbock information (3.5). Other items respondents listed as important included information on faculty, job placement, number of students in classes, loans and grants, who to contact for additional information, and student:faculty ratio.

Most Challenging Factors for Students in Making the Adjustment to University Life as a First-Year Student

The most challenging factor as determined by respondents (based on a scale of 5=Very Challenging to 1=Not Challenging) was development of appropriate study habits (3.3). Choosing a career (3.2), time management (3.1) and improving academic skills (3.0) were rated as somewhat challenging. Rated as only slightly challenging were developing close friendships and attending class regularly (2.0)

The most helpful factor for respondents in making the adjustment to university life was faculty advisors (3.6) based on a scale of 5=Very Helpful to 1=Not Helpful. Summer orientation was ranked somewhat highly with a mean score of 2.9. The least utilized factors were personnel in the Dean's Office and a freshman orientation course AGSC 1111 (2.5).

Most Used Services by Students to Assist in Performing Well Academically

The library was found to be the most used service available to students in assisting them to perform well academically with a mean score of 2.4 (based on a scale of 3=Used Often, 2=Used Occasionally, and 1=Never Used). Faculty advisors were used occasionally with a mean score of 2.3. A low percentage of students used paid tutors (1.3), the PASS Center (1.2), unpaid tutors (1.2), the Writing Center (1.2), and the Counseling Center (1.1).

Most Challenging Academic Areas for Students

Respondents were asked to rate the level of difficulty (based on a scale of 5=Very Difficult to 1=Not Difficult) various subject areas caused them in their academic career. The most challenging academic areas were science classes and other subject areas listed by respondents (3.4). Other subject areas listed by respondents included chemistry, genetics, mass communication courses, finance and accounting, and statistics. Agricultural classes within their major (2.6) and agricultural classes outside their major (2.5) were rated as only slightly difficult. Least difficult as indicated by respondents were the humanities (1.6).

Most Stressful Factors for Students in their Academic Program

Based on a scale of 5=Very Stressful to 1=Not Stressful, respondents rated concerns about what happens after graduation and concerns about grades (3.4) as the most stressful factors. Rated as only somewhat stressful were pressures from self (3.1), other factors listed by respondents (3.0), and financial pressures (3.0). Other factors listed by respondents include parking, roommates, attending school with a child, degree plan, on-campus housing and a job. Factors which turned out to be least stressful for respondents were pressures from family, adjustments to college life, and communicating with teachers (2.1).

Advice Alumni Would Give to Incoming Freshmen in Adjusting to University Life and Succeeding Academically

Through an open-ended format, respondents were asked to write advice they would give to incoming freshmen in adjusting to university life and succeeding academically. The most frequent advice was to get involved, go to class, improve study habits, time management, communicating with professors, have fun and work hard.

Role Student Clubs, Organizations and Judging Teams Play in Helping Students Better Prepare for Future Employment, as well as in Making the Most of their Collegiate Experience

Respondents indicated that participation in student clubs, organizations and judging teams was highly beneficial to them in preparing for future employment as well as in making the most of their collegiate experience. The majority of the respondents were actively involved in a wide variety of clubs, organizations and judging teams. The activities with the most participation were clubs, organizations and judging teams within the College of Agricultural Sciences and Natural Resources.

Most Beneficial Services Used by Graduates in their Initial Career Job Search

Respondents were asked to rate various services based on a scale of 5=Very Beneficial to 1=Not Beneficial. Self-initiated services were rated the most beneficial service by respondents with a rating of 4.3. These services include Internet, networking, newspapers, found jobs on their own, knew individuals beforehand, and job seeker and other employment publications. Faculty advisors were rated with a mean score of 3.6. Least beneficial to respondents was the University Career Planning and Placement Office (1.9).

Most Important Attributes to Graduates for Selecting a Career

Through an open-ended format, respondents were asked to list the most important attributes to them in selecting a career. The attributes mentioned the most were salary, enjoying what you are doing, location, advancement opportunities, and benefits.

Projected Future Employment Opportunities for Graduates

Respondents were asked to project future employment opportunities for graduates in their chosen field. Almost 95 % of the respondents projected employment opportunities as excellent, good or average for their chosen field.

Would Graduates Enroll Again in the College of Agricultural Sciences and Natural Resources if Given that Opportunity?

Over 80% of the respondents indicated they would again enroll in the College of Agricultural Sciences and Natural Resources if given that opportunity (83.3%).

CONCLUSIONS

The following conclusions are based on interpretations of data presented in the study and are restricted to the populations surveyed. The conclusions are as follows:

1. Although a large percentage of graduates were making $19,999 and below, the majority of these graduates were continuing their education in graduate school, law school and school of veterinary medicine. They generally did not hold full-time jobs. A large portion of graduates' annual gross incomes ranged from $25,000 to $34,999,

and a number made $50,000 and above. Graduates who graduated earlier tended to have higher incomes than those who graduated later.

2. Most of the respondents are employed as Scientists, Engineers or Related Specialists; Education, Communication or Information Specialists; or Marketing, Merchandising or Sales Representatives. In comparison with projections from the USDA for future employment opportunities in the next five years, CASNR produced more graduates in the previous five years in the fields of Education, Communication or Information Specialists and Agricultural Production Specialists. The larger numbers of Agricultural Production Specialists produced from the College may be because Texas Tech is located in an extensive farming region with a significant portion of the students coming from this region.
3. Recruitment efforts conducted by the college were rated as effective. Factors listed by the respondents as effective in recruiting them to the university were faculty, reputation of school and students at Tech. Of the recruitment efforts used by the college, University Day and campus tours were the most effective.
4. The degrees offered by CASNR and the reputation of the school were the most important factors in a student's decision to attend Texas Tech University.
5. Parents were the most influential individuals in a student's decision to attend Texas Tech University.
6. When making a presentation to prospective high school students, the most important items to discuss are the careers available in agricultural sciences and natural resources, departmental and degree information, as well as scholarship opportunities.
7. Study habits, choosing a career, time management and improving academic skills were most challenging for students. Developing close friendships and attending class regularly were least challenging for students. Faculty advisors were instrumental in helping students adjust to university life.
8. The library was the most used service by students in assisting them to perform well academically. Services such as tutors, the PASS Center, the Writing Center, and the Counseling Center were not used often by students.
9. Science and math classes provide a high level of difficulty for most students. In terms of difficulty, most students tended to struggle less in their agricultural classes. Least difficult for students were social sciences, foreign languages, English and humanities.
10. The most stressful factors for students were their concerns with what happens after graduation and concerns about their grades. Least stressful for students in CASNR was adjusting to college life and communicating with teachers. Though research indicates that the most critical time for first-year students is the first six weeks of the semester as they struggle to adapt to the college life, these respondents indicated this wasn't an important factor for them in comparison to other factors listed on the survey.
11. According to alumni, students need to get involved quickly, go to class, communicate with professors, improve study habits, manage time wisely, work hard and yet have fun in order to adjust to university life and succeed academically.
12. Involvement in student clubs, organizations and judging teams will benefit students in preparing for future employment and in making the most of their collegiate experience.
13. Self-initiated services, such as Internet, newspaper, networking, and job seeker and other employment publications are very beneficial to students in their initial career job search. Faculty advisors are also beneficial to students in their initial career job search.

14. The most important attributes to graduates for selecting a career are salary, enjoying what they are doing, location, advancement opportunities, and benefits.
15. The majority of the graduates from CASNR project future employment opportunities in their chosen fields as good.
16. The vast majority of graduates were pleased with their educational experience and would again enroll in the CASNR.

RECOMMENDATIONS

The following recommendations are made by the investigator as a result of having conducted this study:

1. CASNR should utilize the faculty and the reputation of the school in recruiting students to the University.
2. Recruitment efforts such as University Day and providing campus tours should be continued.
3. Based on comments received from respondents, recruiters, staff, faculty and current students should continue to emphasize the friendliness and small, family-like atmosphere found in the CASNR to prospective students as well as to current students.
4. Recruiters need to concentrate on promoting degrees offered, reputation of school, friendliness of people, location of Texas Tech, reputation of faculty, and size of Texas Tech to prospective students.
5. Recruiters need to have more contact with parents of prospective students.
6. When presenting information to high school students, material that emphasizes the opportunities and availability of careers in the agricultural industry, as well as the number of scholarships available in CASNR, should be presented to students.
7. CASNR should increase their efforts in assisting students in dealing with their concerns with what happens after graduation. Possible concerns might be: finding a job, being financially independent, the uncertainty of what will be expected of them in a full-time job, the fear of not fulfilling the employers' expectations, and the uncertainty of their abilities to deal with new situations and changes.
8. CASNR needs to make certain that students are aware of the wide variety of activities for students to get involved in within the College and throughout the University.
9. The Ag Recruitment and Career Center within CASNR should utilize and promote the Internet more in helping students with their initial career job search. The Center should teach students effective means of searching for job opportunities via the World Wide Web.
10. Further, in-depth studies should be done to evaluate individual programs and techniques used by CASNR in the areas of recruitment, retention and placement. The use of focus groups is suggested.
11. CASNR should survey students who chose not to return to Texas Tech University to determine why they left.

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Wheat Grazing and Planting Date Impacts on Livestock and Grain Production

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ABSTRACT

Wheat (*Triticum aestivum* L.) grazing systems with variable planting dates and cattle pull-off dates were grown with limited furrow irrigation at Bushland, TX. Grain yields averaged 40.4, 53.1, and 66.6 bu/ac for non-grazed check plots with mean planting dates of Aug. 24, Sept. 11, and Oct. 2, respectively. Moderate grazing increased grain yield of wheat planted in August or September. Grain yield averaged 50.9, 55.7, and 46.3 bu/ac for non-grazed, early pull-off, and late pull-off, respectively. However, early-planted, properly grazed wheat still yielded less than a later planted non-grazed control. Adjusted gross return using prevailing costs and returns was maximized with a mean planting date of Sept. 12 and pull-off of Mar. 25. These dates are slightly later than expected. Delaying planting of grazed wheat from late August to mid September increases grain yield and gross return but reduces total grazing and shifts some grazing from fall to spring.

KEYWORDS: economics, grain yield, grazing, stocker cattle

Wheat grown on the Southern High Plains is commonly used as a dual purpose crop, i.e., for grazing and grain. Using wheat in this manner reduces risk by providing two income sources. The wheat crop provides highly nutritious forage at a time of the year when most other forages are dormant. Thus, wheat forage may provide low cost gains for stocker cattle compared to other systems of wintering these animals.

Wheat grazing systems are complex with many management, environmental, and economic variables. Farmer's land and water resources vary considerably. Management styles and abilities may make some producers more inclined to grazed or non-grazed systems for non-economic reasons. This complexity requires a systems approach to study the problem of identifying the best wheat management systems. In these studies treatments are systems of production with best management practices (BMP) identified from previous research and grower experience. Using systems based on BMP as treatments requires confounding of inputs and careful interpretation of results. For example, one can not necessarily conclude anything about planting date effects, per se, from confounded systems; rather one must compare an early planted system to a late planted system. In the case of planting dates, we have included some unconfounded check treatments for clarification and comparison. A key point is that results must be interpreted carefully.

Grazed wheat systems are planted 4 to 6 wk earlier than dates identified as optimum for grain-only production (Fuehring, 1981). Thus, grazed systems require more irrigation and may encounter more disease and insect problems. Early planting can promote more fungal and viral diseases of wheat that may reduce grain yield even when fall forage production is greatly increased.

There has long been controversy over whether grazing reduces grain yield of wheat (Holliday, 1956; Redmon et al., 1995). This has been a difficult question to answer experimentally because of the complexities of the systems involved. Also, researchers have been reluctant to confound variables such as irrigation, planting date, and fertility as would be dictated by established BMP. Thus, grazed and non-grazed systems have often been studied by varying only grazing while attempting to maintain uniform planting dates and other inputs. The results of such research can be misleading or unrealistic. However, results of systems research for grain yield, cattle performance, and economic conclusions will be only as good as the researchers ability to optimize resource utilization in all aspects of each system.

The goal of this research was to provide resource managers with response functions to optimize grazing system management while comparing BMP established for grazing systems and grain-only systems. Understanding the types of responses that can occur should help producers optimize utilization of their resources.

MATERIALS AND METHODS

Wheat grazing systems research was conducted at the Bush research farm which is located 1.5 miles north of Bushland, TX. The research was conducted during five growing seasons between 1990 and 1996. The soil is a Pullman clay loam (fine, mixed, thermic Torrertic Paleustoll) with 0-1% slope and irrigated by graded furrows. This soil, when fully wet, is capable of supplying about 8 inches of plant available water for wheat. A complete description of this soil has been published (Unger and Pringle, 1981).

The climate is semi-arid with highly variable rainfall and temperature. Spring freezes and hail are serious hazards for wheat grain production. Weather during the wheat growing seasons of these studies is summarized in Table 1.

Treatments were wheat grazing systems planted with cv. 'Tam 107' with variable planting dates and cattle pull-off dates. Each system was managed using a set of best management practices in an attempt to maximize return to available resources (Winter, 1994). Since treatments were systems, some factors are purposefully confounded. For instance, earlier planted systems were commonly irrigated more in the fall than later planted systems. A non-grazed check plot was included for each planting date.

Pastures (planting dates) were 5.5 acres in size and were stocked with 3 to 12 head of 350 to 400 lb. stocker calves of mixed breeds at times appropriate for each planting date (see Tables 2-6 for grazing dates). A put and take system was used to maximize utilization of forage without severe overgrazing. This system used tester animals that remained on the pastures at all times. Tester animals were used to determine average daily gain. Other animals were added or removed to achieve uniform, desired forage removal levels. The wheat was grazed to a 2 or 3 inch stubble height at pull-off. Grazing was probably somewhat less severe than common commercial practice but adequate to utilize available forage. Head counts were taken daily. Total beef production was determined by multiplying average daily gain times total head-days for a given grazing period.

Pastures were 5.5 acres in size (200 ft by 1200 ft) and pull-off dates were achieved by moving an electric fence. Both non-grazed plots and pull-off date plots were 20 ft by 1200 ft in size and were harvested with a commercial combine. Cattle were weighed at each pull-off date after overnight shrinkage (18 hr with no feed or water). Pasture area was adjusted with each pull-off date for calculations of cattle gain and head-days/acre.

Cattle pull-off dates were by calendar dates the first two years and by first hollow

Table 1. Precipitation and temperature record at the Bush research farm during the grazing trials.

Wheat crop year	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total
	inches											
1989-90	4.24	0.00	3.57	0.00	0.56	0.10	1.17	0.34	0.59	0.78	0.30	11.65
1990-91	2.53	3.28	0.31	0.77	0.24	1.02	0.02	0.38	0.09	2.20	3.38	14.22
1993-94	2.18	0.58	0.87	0.81	0.74	0.27	0.03	0.81	1.62	2.32	3.25	13.48
1994-95	4.27	1.89	1.93	0.22	0.33	0.48	0.02	0.86	0.43	4.47	2.60	17.50
1995-96	2.47	3.94	0.70	0.06	0.79	0.10	0.19	0.12	0.00	0.60	2.98	11.95
Normal †	2.81	1.93	1.53	0.73	0.58	0.50	0.51	0.78	1.01	2.67	3.00	16.05
	Mean ^{0}F											
1989-90	73.4	63.6	57.6	46.2	29.1	35.8	39.5	44.6	54.1	61.6	79.4	
1990-91	74.0	70.1	55.0	47.1	31.0	30.5	43.6	47.9	55.9	66.6	72.7	
1993-94	74.5	66.4	53.7	40.2	37.7	34.6	35.2	47.1	53.4	63.0	77.4	
1994-95	74.6	67.9	57.1	45.0	40.2	37.5	42.5	46.4	52.0	60.5	69.3	
1995-96	76.2	66.6	56.2	47.4	37.6	34.0	40.9	42.6	55.4	70.2	75.4	
Normal †	74.6	67.1	56.0	43.8	35.3	34.9	39.1	46.0	55.4	64.0	73.1	

stem observation the last three years (Krenzer et al., 1995). Where possible, one pull-off date was before, at, and after first hollow stem. This system worked as planned in 1993-94 and 1994-95; however, in 1995-96 poor weather for establishment and growth of wheat delayed onset of grazing and limited choice of pull-off dates. The first pull-off date in 1995-96 was at first hollow stem for both planting dates. The second pull-off date was at mid-jointing and early-jointing for the early and late planting dates, respectively.

Planting dates (pastures of 5.5 acres) were replicated 3 or 4 times in a randomized block design. Non-grazed checks each 20 ft by 1200 ft of every planting date were included in each replicate. The latest planted non-grazed check, usually planted in the first week of October, was intended to provide a grain-only check treatment.

Irrigation was by graded furrow. Gross irrigation application is given in Tables 2 to 6. Usually spring applications were similar but fall applications were generally larger on earlier planted wheat. Tail water was not measured and probably averaged 10 to 20% of gross applications. Irrigation was seldom adequate to maximize forage yield or grain yield due to inadequate pumping capacity. This was particularly true in the spring when wheat water use rates can be very high. Rates applied ranged from 30 to 60% of potential crop evapotranspiration. Thus, wheat grain yields were generally limited by drought stress in these studies. The irrigation levels used are common in commercial practice because water is usually limited.

Soil tests indicated that nitrogen and phosphorus were the only deficient elements. Nitrogen was all applied preplant at levels equal to or exceeding the recommended rate. Phosphate was broadcast and incorporated with sweeps and by listing.

An economic analysis of all treatment combinations including non-grazed checks was conducted using average prices and costs observed during the study period. An adjusted gross return was calculated for each treatment. The adjustments to gross return were deductions for excess inputs such as extra tillage, chemicals, or irrigation above the lowest input treatment. Wheat grain yields, livestock gains, and adjusted gross return were statistically analyzed each year as a randomized complete block design with planting dates as main plots and grazing treatments as subplots. This treatment framework was not always valid because subplot treatments were not always the same for every planting date. Another analysis using the general linear models procedure of the Statistical Analysis System compared each planting date/grazing date combination as a separate treatment. This analysis was used to calculate Duncan's multiple range test at P =0.05. T-tests were used to compare adjusted gross returns of grazed and non-grazed systems within each year.

RESULTS AND DISCUSSION

Generally good wheat stands were achieved in these studies despite variability in precipitation and temperatures (Table 1). Dry weather necessitated irrigation for emergence with about 40% of the planting date treatments. Dry weather during the winter and spring reduced grain yield in 1989-90 and 1995-96. Severe freezes in the fall and spring plus greenbugs (*Schizaphis graminum*, Rond.) and hail reduced yields in 1993-94. Spring freezes and severe disease and insect pressure reduced grain yields in 1994-95. Untimely rains delayed planting in 1995-96 and the drought and spring freeze that followed reduced forage and grain yields. In general, the first two growing seasons were more favorable for grain production than grazing. During the last three growing seasons mild, generally dry winters, favored cattle gains over grain production.

Table 2. Cattle performance and wheat grain yield with several wheat grazing systems in 1989-90 at Bushland, TX.

Planting date	Irrigation		Grazing dates		Cumulative grazing		Grain yield
	Fall	Spring	Date on	Pull-off	Head-days	Beef gain	
	inches				d/ac	lb/ac	bu/ac
Aug. 24	7.4	8.0	Non-grazed	Non-grazed	0	0 f	56.3 c
			Oct. 27	Feb. 1	124	178 b	67.0 b
			Oct. 27	Mar. 1	163	224 a	57.3 c
			Oct. 27	Mar. 21	189	245 a	52.7 c
Sept. 5	3.8	8.0	Non-grazed	Non-grazed	0	0 f	67.4 b
			Nov. 15	Feb. 1	90	130 c	67.7 b
			Nov. 15	Mar. 1	128	177 b	67.3 b
			Nov. 15	Mar. 21	154	195 ab	65.2 b
Sept. 18	3.9	8.0	Non-grazed	Non-grazed	0	0 f	66.5 b
			Nov. 15	Feb. 1	74	94 d	79.8 a
			Nov. 15	Mar. 1	95	129 c	82.4 a
			Nov. 15	Mar. 21	121	197 ab	78.7 a
Oct. 5	4.1	8.0	Non-grazed	Non-grazed	0	0 f	82.6 a
			Jan. 11	Feb. 1	13	18 f	83.8 a
			Jan. 11	Mar. 1	30	45 e	81.5 a
			Jan. 11	Mar. 21	56	97 d	67.3 b

Table 3. Cattle performance and wheat grain yield with several wheat grazing systems in 1990-91 at Bushland, TX.

Planting date	Irrigation		Grazing dates		Cumulative grazing		
	Fall	Spring	Date on	Pull-off	Head-days	Beef gain	Grain yield
	inches				d/ac	lb/ac	bu/ac
Aug. 21	7.3	12.0	Non-grazed	Non-grazed	0	0 d	74.5 de
			Oct. 24	Feb. 1	131	154 a	77.7 cd
			Oct. 24	Mar. 1	131	154 a	69.5 e
			Oct. 24	Mar. 21	152	180 a	65.8 e
Sept. 10	6.9	12.0	Non-grazed	Non-grazed	0	0 d	92.9 a
			Nov. 15	Feb. 1	137	90 b	90.1 ab
			Nov. 15	Mar. 1	165	112 b	83.2 bc
			Nov. 15	Mar. 21	186	176 a	77.1 cd
Sept. 21	3.4	12.0	Non-grazed	Non-grazed	0	0 d	92.5 a
			Nov. 26	Feb. 1	61	74 bc	99.6 a
			Nov. 26	Mar. 1	80	104 b	94.0 a
			Nov. 26	Mar. 21	101	161 a	92.6 a
Oct. 7	0	12.0	Non-grazed	Non-grazed	0	0 d	93.5 a
			Feb. 20	Mar. 1	8	16 d	93.5 a
			Feb. 20	Mar. 21	29	70 c	91.8 a

The 1989-90 and 1990-91 Seasons

The first two growing seasons had similar treatments and similar wheat and cattle responses (Tables 2 and 3). Planting dates and grazing dates were similar across the two years. These dates were near the desired dates to test planting date effects and to properly utilize the resulting forage production. Beef gain per acre was increased by earlier planting of wheat and by later cattle pull-off. Total cattle gains were rather modest both years. A severe winter with heavy snowfall and severe wind-chills stressed the cattle. Average daily gain (beef gain/head-days) was rather low as a result.

Wheat grain yields were generally high these two years and treatment responses were similar (Tables 2 and 3). Yield was higher with later planted systems as compared to earlier planted systems. Mean yields for the earliest to latest of the four planting date systems were 65.1, 76.4, 85.8, and 85.9 bu/ac, respectively. Dry spring weather and inadequate spring irrigation limited yields in 1989-90.

Grain yield responses to pull-off date show a clear pattern. Mean yields across the two seasons of the first three planting dates for the non-grazed, Feb. 1, Mar. 1, and Mar. 21 pull-off dates were 75.0, 80.3, 75.6, and 72.0 bu/ac, respectively. The historically recommended pull-off date has been about Mar. 15 (Winter and Thompson, 1987). The mean date of first hollow stem was not recorded these years but probably averages early March in this climate. These data indicate that grain yield of grazed wheat would be maximized with a pull-off no later than March 1. This, however, is not the economically optimum date for the system as a whole because cattle gains are usually quite good during the spring after wheat begins to grow rapidly.

Last Three Growing Seasons

The last three years are discussed separately because growing conditions, cattle, and wheat performance were similar those years but different in some respects from the first two years. Available plot area was less the last three years so planting dates were reduced to three dates rather than four. The dates were as similar across these three years as planting conditions allowed.

The 1993-94 season had unfavorable fall and spring freezes, greenbugs, and hail. These factors reduced both forage and grain yields. Total cattle gain was significantly improved by early planting (Table 4). First hollow stem occurred near Feb. 25 to 28 for both the Aug. and Sept. planting dates. Forage yields of the Sept. 14 planting and early growth of the Oct. 1 planting were restricted by a severe cold spell lasting 7 days in late Oct. and early Nov. The temperature fell to near 0°F during this period. This prolonged period of excessive cold weather reduced forage yield in the fall of 1993. Wheat grain yields were limited by inadequate irrigation in the spring of 1994. These production problems limited both cattle performance and grain yield in 1993-94.

The 1994-95 growing season was another difficult year for wheat production (Table 5). A spring freeze, high insect populations (aphids), and disease pressure (barley yellow dwarf) caused severe damage especially to the system planted Aug. 23. Fall growth was good and mild weather favored good cattle performance. First hollow stem dates were about Feb. 20 and 26 for the Aug. 23 and Sept. 13 systems, respectively. Cattle gains were good with both planting date systems and for all grazing termination dates.

Severe disease and insect pressure damaged wheat in the Aug. 23 planting date system in Mar. and Apr. of 1995. Barley yellow dwarf was particularly severe. Grain yields were nearly zero with the early planted system. Because the wheat looked so poor in Mar. the final pull-off date was extended to give a graze-out treatment that terminated Apr. 1. For the Aug. 23 planting this only sacrificed 7.0 bu/ac wheat for 202 lb/ac beef gain (Table 5). The

Table 4. Cattle performance and wheat grain yield with several wheat grazing systems in 1993-94 at Bushland, TX.

Planting date	Irrigation		Grazing dates		Cumulative grazing		Grain yield
	Fall	Spring	Date on	Pull-off	Head-days	Beef gain	
	inches				d/ac	lb/ac	bu/ac
Aug. 27	8.0	4.4	Non-grazed	Non-grazed	0	0 d	29.5 d
			Nov. 2	Feb. 2	108	251 b	33.2 cd
			Nov. 2	Feb. 28	135	311 ab	36.2 b
			Nov. 2	Mar. 21	163	351 a	32.8 cd
Sept. 14	3.6	4.4	Non-grazed	Non-grazed	0	0 d	36.6 bc
			Dec. 7	Feb. 2	17	45 d	40.0 ab
			Dec. 7	Feb. 28	45	88 cd	42.8 a
			Dec. 7	Mar. 21	75	138 c	40.0 ab
Oct. 1	3.6	4.4	Non-grazed	Non-grazed	0	0 d	46.2 a

Table 5. Cattle performance and wheat grain yield with several wheat grazing systems in 1994-95 at Bushland, TX.

Planting date	Irrigation		Grazing dates		Cumulative grazing		Grain yield
	Fall	Spring	Date on	Pull-off	Head-days	Beef gain	
	Inches				d/ac	lb/ac	bu/ac
Aug. 23	3.0	8.0	Non-grazed	Non-grazed	0	0 c	1.1 d
			Nov. 15	Feb. 6	144	388 b	5.1 d
			Nov. 15	Feb. 21	158	416 b	7.0 d
			Nov. 15	Apr. 1	223	618 a	0.0 d
Sept. 13	3.0	7.0	Non-grazed	Non-grazed	0	0 c	15.5 c
			Nov. 15	Feb. 6	109	300 b	29.0 b
			Nov. 15	Feb. 28	131	335 b	32.7 b
			Nov. 15	Apr. 1	228	700 a	0.0 d
Sept. 26	3.0	7.0	Non-grazed	Non-grazed	0	0 c	44.0 a

Sept. 13 planting gave up 32.7 bu/ac of wheat for 365 lb/ac of beef gain when comparing Feb. 28 to Apr. 1 pull-off.

In 1994-95, the non-grazed treatments yielded 1.1, 15.5, and 44.0 bu/ac for the Aug. 23, Sept. 13, and Sept. 26 planting date systems, respectively. This is a rather dramatic example of the detrimental effects of early planting under severe disease and insect pressure. For the Sept. 13 planting, grazing until Feb. 28 more than doubled yield compared to the non-grazed check (Table 5). Both yields, however, were quite low.

The 1995-96 season was also poor for wheat production (Table 6). Inadequate fall irrigation followed by a record dry winter severely stressed the September planted wheat by February. A freeze March 26 on some of this dry wheat appeared to reduce the stand. This was particularly true for the Sept. 29 planting. Extremely hot, dry weather in May made it impossible to satisfy ET demand. First hollow stem dates were near Mar. 1 and 15 for the Sept. 13 and 29 planting date systems, respectively.

Both cattle performance and wheat yields were better with the earlier of the two September planting date systems in 1995-96. Dry weather and late planting caused the September 29 planting to be nearly ungrazeable. This wheat did not have grazeable forage until nearly Mar. 1, just 2 wk before first hollow stem. Grazing dates were extended somewhat with this treatment but grain yield was substantially reduced when grazing was extended to Apr. 1.

Grain Yield Responses

Production systems which were planted early, particularly in August, had lower grain yield than later planted systems (Tables 2-5). During the first four growing seasons, average grain yields for the first, second, and last planting dates of the non-grazed check were 40.4, 53.1, and 66.6 bu/ac, respectively. Average planting dates of these production systems were Aug. 24, Sept. 11, and Oct. 2 for this comparison. There was no August planting in 1995-96 and yield of the Sept. 29 planting was severely damaged by a late spring freeze. Still in 1995-96, the highest yield was with the Oct. 9 planting (Table 6). Planting date response of these systems are consistent with most prior responses where both very early and late planting dates reduced wheat grain yields (Fuehring, 1981; Winter and Musick, 1991).

Moderate grazing increased grain yield but late grazing reversed this effect. Average grain yields over 12 comparisons for non-grazed, first pull-off, and last pull-off were 50.9, 55.7 and 46.3 bu/ac, respectively. Thus, moderate grazing increased grain yield about 5 bu/ac whereas late grazing reduced it by an equal amount compared to the non-grazed check. The grain yield reduction due to late grazing is easy to understand and has been documented (Winter and Thompson, 1987; Worrell et al., 1992). The increased grain yield of early planted wheat with moderate grazing is a common occurrence at this location but to the authors knowledge has not been reported elsewhere.

There are several factors which might help explain why moderate grazing increases grain yield of early planted wheat. The excessive mass of vegetative growth typical of early planted wheat that occurs in the fall without grazing may play a role. This vegetative material can lodge during the winter due to compaction from snow or freeze damage. In the spring, this mat of dead vegetation reduces light interception, potentially inhibiting tiller emergence, photosynthesis, and growth. The mat of excess vegetation associated with early planted non-grazed wheat is an excellent incubator of foliar fungal pathogens. It is also habitat for insects which can vector viral diseases. Grazing removes this excessive vegetation and may promote improved growth of old, and possibly, new tillers in the spring. Due to irrigation and a productive environment, fall forage yields can be as high

Table 6. Cattle performance and wheat grain yield with several wheat grazing systems in 1995-96 at Bushland, TX.

Planting date	Irrigation		Grazing dates		Cumulative grazing		Grain yield
	Fall	Spring	Date on	Pull-off	Head-days	Beef gain	
	Inches				d/ac	lb/ac	bu/ac
Sept. 13	4.4	14.2	Non-grazed	Non-grazed	0	0 c	44.1 b
		14.2	Dec. 11	Feb. 28	57	165 b	44.2 b
		14.2	Dec. 11	Apr. 1	155	375 a	33.7 c
Sept. 29	4.0	11.2	Non-grazed	Non-grazed	0	0 c	34.0 c
		11.2	Feb. 28	Mar. 20	33	62 c	35.1 c
		10.1	Feb. 28	Apr. 1	95	155 b	17.3 d
Oct. 9	4.0	12.5	Non-grazed	Non-grazed	0	0 c	54.7 a

as 5,000 lb/ac of dry matter in this environment. In areas with less fall growth, later planting, or other overriding factors, the positive effect of moderate grazing may be less or nonexistant.

Severe or late grazing can reduce grain yield. Severe defoliation can increase winterkill. Severe or late grazing delays reproductive growth, kills tillers or delays tiller development, delays heading, and reduces grain yield (Winter and Thompson, 1987). This effect is especially damaging to semi-dwarf, high grain producing wheat cultivars that may not regain sufficient leaf area to maximize grain yield (Winter and Thompson, 1990; Winter, et al., 1990; Winter and Musick, 1991). Delayed heading is known to reduce grain yield in the absence of late spring freezes.

Grazing can increase grain yield in the event of a late spring freeze by delaying the onset of reproductive growth. The improvement in yield is probably no more than would occur if delayed planting were employed to delay heading an equal amount. Grazing that delays the onset of reproductive growth by a significant amount is probably reducing grain yield compared to an earlier termination of grazing. However, the loss of grain yield may be partially or fully offset by animal weight gains with the added benefit of some freeze protection. One benefit of spring grazing is that the first spring irrigation is often delayed. This delay in irrigation and resultant moderate drought stress imparts significant freeze tolerance to the wheat crop. On the other hand, severe drought stress and dry soil can increase winterkill and spring freeze damage. Damaging spring freezes usually occur in late March or early April in this environment.

Economic Analysis

An economic analysis was conducted to integrate, compare, and evaluate return from the varying production systems. The non-grazed treatment in the last planting date was used as a check treatment. This was a well managed, non-grazed check. Mean planting date for this treatment was Oct. 3 and yield averaged 62.2 bu /ac. Mean adjusted gross return was $189/ac (Table 7).

The optimum grazed system to maximize adjusted gross return each year at prevailing commodity prices is presented in Table 8. The optimum planting date ranged from Aug. 27 in 1994 to Sept. 21 in 1991 with a mean date of Sept. 12. However, in four of the five years the optimum date was Sept. 13 to 21. In commercial practice, since all wheat can not be planted on one date, a range of Sept. 10 to 20 or somewhat earlier is a recommended target date. If planting date is delayed much past Sept. 20, there will be a large loss in fall grazing as occurred in 1995-96 (Table 6). Planting will need to start earlier if all wheat acreage can not be planted in 7 to 10 days.

The optimum cattle pull-off date was Mar. 21 to Apr. 1 with an average of Mar. 25. This is later than previously recommended indicating that the cattle gains in early March more than offset the loss in grain yield. A factor in later than expected pull-off date is that later than normal planting dates were recommended. With later planting, grazing can continue somewhat longer in the spring without excessive grain yield loss. Mean grain yield for the optimum grazed system was 43.2 bu/ac, a decrease of 19 bu/ac compared to the non-grazed check. The cattle gain of 357 lb/ac associated with the optimum dates more than offset the loss of grain yield. Mean adjusted gross return was $224/ac, an increase of $35/ac compared to the non-grazed check. This, however, is not a fair comparison because it is comparing the best of several grazed systems to one standard non-grazed check. One does not know in advance what the optimum grazed system will be. A standard grazed system, with planting and pull-off dates as near as possible to optimum, gives return nearly equal to the non-grazed check (Table 9).

Table 7. Planting date, grain yield, and adjusted gross return for the late planted non-grazed check treatment at Bushland, TX.

Harvest Year	Planting date	Grain yield	Adjusted gross return at $3.00/bu
		bu/ac	$/ac
1990	Oct. 5	82.6	243
1991	Oct. 7	93.5	280
1994	Oct. 1	46.2	134
1995	Sept. 26	44.0	132
1996	Oct. 7	54.7	155
Mean	Oct. 3	62.2	189

Table 8. Optimum grazed systems to maximize adjusted gross return over 5 yr for semi-irrigated grazed wheat at Bushland, TX. Wheat $3.00/bu and cattle gain at $0.30/lb.

Harvest Year	Wheat planting date	Cattle pull-off date	Grain Yield	Beef Gain	Adjusted gross return
			bu/ac	lb/ac	$/ac
1990	Sept. 18	Mar. 21	78.7	197	296
1991	Sept. 21	Mar. 21	92.6	161	309
1994	Aug. 27	Mar. 21	32.8	351	186
1995	Sept. 13	Apr. 1	0.0	700	202
1996	Sept. 13	Apr. 1	33.7	375	192
Mean	Sept. 12	Mar. 25	43.2	357	224

Table 9. Adjusted gross returns with $3.00 wheat and $0.30 cattle for a standard grazing system compared to a standard non-grazed check over 5 yr at Bushland, TX.

Harvest year	Adjusted gross return	
	Grazed[a/]	Grain-only[b/]
	$/ac	
1990	213 B[c/]	243 A
1991	243 B	280 A
1994	155 A	134 A
1995	191 A	132 B
1996	160 A	155 A
Mean	192 A	189 A

a/ Planting dates between Sept. 5 and 13 and pull off date of Feb. 28

b/ See data in Table 7.

c/ Comparison of grazed vs. grain-only means for each year, P = 0.05.

Optimum management obviously depends on prevailing prices of wheat and cattle. If wheat grain prices increase relative to cattle prices, planting should be delayed and cattle removed earlier from wheat. If cattle prices are more favorable, earlier planting, higher stocking rates, or later pull-off might be advisable management responses. Variability in all aspects of production systems as complex as these makes economic analysis a difficult task.

In summary, these data suggest that gross return at prevailing prices for a grazed wheat production system would be maximized by planting and grazing somewhat later than common practice. Average optimum dates of planting and pull-off were Sept. 12 and Mar. 25. Later planting helps maintain grain yield with only a modest reduction in total cattle gain. Some of the grazing would, however, be moved from the fall to the spring. This may be unacceptable for some producers.

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Characterization of Diverse Cattle Breeds for a Microsatellite Genetic Marker of the Bovine Prolactin Gene

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ABSTRACT

Cattle (n = 456) were evaluated for a microsatellite genetic marker associated with the bovine prolactin gene. Breeds represented were Simbrah (n = 278), Simmental (n = 29), Santa Gertrudis (n = 71), American Breed (n = 12), Salers (n = 12), Parthenais (n = 5), and Hotlander (n = 49). Three marker alleles (designated as A, B, and C) were detected with five observed marker genotypes; no AC genotypes were observed. Chi-square analysis illustrated differences in genotype distributions between breeds (P < .01). Overall, the frequencies for the marker alleles were .054, .923, and .023 for the A, B, and C alleles, respectively. Cattle of the American and Parthenais breeds appeared to have different allele frequencies compared to other types. Animals of the Simbrah, Simmental, Santa Gertrudis and Hotlander breeds did not differ from Hardy-Weinberg Equilibrium expectations for this genetic marker. Molecular characterization of cattle such as this can provide insights into their phenotypic attributes.

KEYWORDS: cattle breeds, microsatellite marker, prolactin

The interest in identification of genes and the understanding of how genes affect specific traits in livestock have increased dramatically in recent years. Discoveries from the human genome project have provided insights into several molecular genetic mechanisms in farm animal species. A specific class of genetic marker called microsatellites (Litt and Luty, 1989; Weber and May, 1989), which refers to repetitive DNA sequences of two or three base pairs, has been used extensively in mammalian genetic research the past ten years. It has been believed that many different kinds of hormones, growth factors, cellular hormone receptors, and metabolic clearance of hormones are involved in growth of animals (Trenkle and Marple, 1983). Prolactin, placental lactogen and growth hormone are related to each other and belong to the same super gene family (Miller et al., 1981; Camper et al., 1984; Hallerman et al., 1987). These three hormones are related by amino acid sequence, immunochemistry, and partially overlapping biological functions (Miller et al., 1981). Many different factors including cAMP, glucocorticoids, dopamine, estrogens, epidermal growth factor, calcium, and thyrotropin-releasing hormone are involved in the expression of the prolactin gene (Camper et al., 1984).

Both prolactin and growth hormone should be important candidate genes for growth in cattle because of their control for mammary growth, lactogenesis and lactation (Haller-

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man et al., 1987; Cowan et al., 1989). Since both are involved in lactation, these genes can potentially be used as markers to identify genetic differences among animals for milk production. Cowan et al. (1990) reported that prolactin genetic polymorphisms are associated with milk production. The objective of this study was to characterize feedlot steers of diverse breeds for a previously published microsatellite marker of the bovine prolactin gene and to calculate allele and genotypic frequencies for the different breeds to gain insight into underlying molecular genetic diversity.

MATERIALS AND METHODS

Experimental animals

The majority of the cattle in this project were *Bos indicus-Bos taurus*. Resource beef cattle, in target progeny groups of 12 per sire, all came from producers in Texas. All calves were weaned at 6 to 8 months of age, and fed in commercial feedlots in Gruver and Lubbock, TX. Upon arrival, animals were vaccinated against common clostridia bacterial and bovine respiratory diseases. Each animal was individually weighed and ear-tagged. In addition, they were subjectively evaluated for temperament score, muscle score and breed type score on 1 to 5 scales. Specific management of the cattle was described previously by Brooks (1997).

Approximately 20 ml of blood was taken by jugular venipuncture from each animal upon arrival at the feedlot. Within 48 hours, white blood cells were isolated from whole blood samples. White blood cell samples were kept at -70° C until DNA was extracted.

Laboratory protocols

Bovine genomic DNA was extracted from leukocytes layer derived from whole blood samples on each animal by according to the procedures of Maniatis et al. (1982) or using QIAamp blood kits and tissue kits for rapid purification of genomic DNA (QIAGEN, 1996). The marker we used was based on the polymerase chain reaction (PCR) that amplifies minute quantities of DNA.

PCR primer sequences for this prolactin gene marker were obtained from published literature (Fries et al., 1993). Once the primers were synthesized by a commercial company, they were cold tested (non-radioactively labeled) to verify the ideal PCR conditions. After cold testing, radioactively labeled PCR was performed by direct labeling. The isotope ^{32}P was used for direct labeling of DNA fragments by its addition to the PCR reaction mix (in a ratio of 0.006μl of α-^{32}P-dCTP (10 mCi/ml) per 1 μl of PCR reaction) immediately prior to amplification.

Each PCR reaction contained 100 ng of genomic DNA as template, 5 pM of both forward and reverse primers, 200 μM each of dATP, dCTP, dGTP, and dTTP, 1-2 μM $MgCl_2$, 2.5 μl Taq 10X buffer (Promega), 1unit Taq polymerase (Promega), and enough double distilled water to produce a final volume of 25 ml. All reactions were overlaid with mineral oil to prevent evaporation. The PCR conditions were: (1) 95° C for 5 minutes for initial step, (2) 95° C for 30 seconds, 57° C for 30 seconds, 72° C for 1 minute for a total of 35 cycles for amplification step, and (3) 72° C for 10 minutes as final elongation step.

After PCR, 10 ml of sequencing gel-loading buffer was added to each reaction, and the samples were denatured for 5 minutes at 95° C. Three μl of each PCR reaction was electrophoresed on 8% denatured polyacrylamide gels, which were run for 2.5 hours to 3.5 hours at 85 Watts. Gels were blotted onto filter paper support, vacuum dried (25 minutes at 80° C), and exposed to autoradiography film (Fuji RX) for 36 to 48 hours at -20° C. Genotypes of animals were determined based on their location on the gel (due to their size) by their mobility on the gel relative to a known DNA sequence standard.

Statistical Analysis

Chi-square tests were used to investigate distribution of marker genotypes across breeds and to determine if the genotypic frequencies within breeds fit expectated Hardy-Weinberg equilibrium (HWE) proportions. Two-way contingency tables were constructed for breed by genotype through SAS (1992) for its Chi-square test. Derivations of expected frequencies of genotypes based on HWE proportions and an example are shown in Table 1. Because two allele frequencies were estimated from six genotypes the degrees of freedom associated with this Chi-square goodness of fit test was three (6 – 2 parameters estimated – 1 = 3). Frequencies of the three respective marker alleles were calculated from the observed marker genotypes as follows:

$$\text{Allele frequency} = \frac{2 \text{ x number of homozygotes} + \text{number of heterozygotes}}{2 \text{ x total number of individuals}}$$

Table 1. Expectations of Hardy-Weinberg Equlibrium Genotypic Proportions at a gene with three alleles.

Allele	Theoretical allele frequency	Example allele frequency
A	p	.20
B	q	.60
C	r	.20

Expected genotypic frequencies based on theoretical allele frequencies

Genotype	AA	AB	AC	BB	BC	CC
Genotype frequency	p^2	2pq	2pr	q^2	2qr	r^2

Example of calculation of expected Hardy-Weinberg proportions from estimated allele frequencies

Genotype	AA	AB	AC	BB	BC	CC
Genotype frequency	.04	.24	.08	.36	.24	.04

RESULTS AND DISCUSSION

Total number of animals with observable marker genotypes were 456 across seven different breeds. Three different alleles were detected as initially reported by Fries et al. (1993). They were designated as allele A at 156 base pairs (bp) in length, allele B at 159 bp, and allele C at 162 bp. The results showed five of the six possible genotypes (AA, AB, AC, BB, BC, and CC); no AC individuals were observed. Genotypic frequencies and allelic frequencies were calculated across all animals, and across animals within each breed (Table 2).

Table 2. Genotypic and allelic frequencies of the prolactin microsatellite marker across all animal and within each breed.

Breed	n	Genotype frequency						Allele frequency		
		AA	AB	AC	BB	BC	CC	A	B	C
Total	456	.009	.090	0.0	.862	.033	.007	0.054	0.923	0.023
Simbrah	278	.011	.061	0.0	.885	.036	.007	0.041	0.933	0.025
Simmental	29	.000	.103	0.0	.862	.034	.000	0.052	0.931	0.017
Santa Gertrudis	71	.014	.197	0.0	.789	.000	.000	0.113	0.887	0.000
American	12	.000	.083	0.0	.583	.250	.083	0.042	0.750	0.208
Salers	12	.000	.000	0.0	1.000	.000	.000	0.000	1.000	0.000
Parthenais	5	.000	.400	0.0	.400	.200	.000	0.200	0.700	0.100
Hotlander	49	.000	.082	0.0	.918	.000	.000	0.041	0.959	0.000

Table 3. Characterization of breeds involved in study.

Breed	Origin	Percent *Bos indicus*	Composition
Simbrah	USA	37.5	Composite of 5/8 Simmental, 3/8 Brahman
Simmental	Switzerland	0	Established Swiss breed with large size, high milk production, quite muscular and lean
Santa Gertrudis	USA	37.5	Composite of 5/8 Shorthorn, 3/8 Brahman
American	USA	50.0	Composite of 1/2 Brahman, 1/8 Bison, 1/4 Charolais, 1/16 Hereford, 1/16 Shorthhorn
Salers	France	0	Established French breed, moderate to large mature size, high milk production, muscular and lean
Parthenais	France	0	Established French breed, very muscular and lean
Hotlander	USA	18.8	Composite of 1/4 Angus, 1/4 Senepol, 5/16 Simmental, and 3/16 Brahman

The vast majority of our resource cattle had BB genotype (86.2%) due to the very high frequency of the B allele. Animals with AA (n = 4; 0.9%) and CC (n = 3; 0.7%) genotypes were very scarce. Animals with AB and BC genotypes were intermediate in frequencies at 9.0% and 3.3%, respectively . Allelic frequencies for the overall set of animals were .053, .923, and .023 for the A, B, and C alleles, respectively. Chi-square analysis indicated that differences in genotypic frequencies did differ between breeds (x^2, $_{24\ df}$ = 60.56; P < .001). However, one caveat with this test is that for several cells, the expected number of individuals were zero due to low frequencies of the A and C alleles. Nonetheless, these statistical differences agree with phenotypic information about these breeds, which are briefly described in Table 3. The difference in allele frequencies involving the comparison of the American breed animals (bison influenced) and the very muscular, very lean Parthenais cattle appear to have a lower frequency of the B allele than the others. Furthermore, the Parthenais animals had as many AB individuals as BB, but the American breed cattle had more BC than AB individuals. However, there are very few animals of these two breeds represented in this data set. It is therefore possible that these animals are not representative of their breeds. Of the breeds represented here, the American cattle had the higher frequency for the C allele and the Parthenais had the highest frequency of the A allele. It is possible that genes close to this marker are under selective pressure. However, of the four breeds formally tested for Hardy-Weinberg Equilibrium expectations, none significantly differed from expected values.

The vast majority of our cattle were *Bos taurus-Bos indicus* hybrids. Bishop et al. (1994) calculated average heterozygosity for 369 genetic markers (various types) and indicated that *Bos taurus* x *Bos indicus* F_1 crosses were most heterozygous (74.7 % ± 1.5 %, P < 0.001) across all genes. Unfortunately, this marker is not useful for mapping performance traits in this group even though they are primarily *Bos taurus-Bos indicus*. Further molecular genetic research with *Bos taurus-Bos indicus* animals will be very interesting.

The comparisons of allele and genotypic frequencies in these cattle are potentially useful, however. MacHugh et al. (1998) reported that microsatellite markers can be a very effective tool to identify breed in cattle. They assigned and identified 4 British Isles breeds and the Swiss Simmental breed cattle by using only eight microsatellites, with an accuracy of breed identification over 99%. MacHugh et al. (1997) also performed research with microsatellite markers to verify the genetic relationships among different groups of cattle (twenty distinct populations from Africa, Europe and Asia) and to characterize the extent and pattern of zebu genetic introgression in African populations. Ten of the microsatellite markers displayed large allelic differences when comparing Bos taurus and zebu cattle populations. These 10 marker loci showed a single allele or group of alleles that were present at high frequencies in Asian zebu breeds, intermediate frequencies in crossbred African zebu populations, low frequencies in African Bos taurus populations, and either absent or present at very low frequencies in European Bos taurus populations.

One aspect not covered by our study was the determination of relationship between this prolactin marker and performance data because of the very high frequency of the B allele. Genetic markers useful for gene mapping of performance traits should have high heterozygsity levels, which this prolactin marker did not. Quite a bit of research has been done to reveal associations between DNA markers for prolactin and growth hormone with growth and carcass traits in cattle. Herring (1995) reported that growth hormone microsatellite marker genotype had a significant effect on kidney, pelvic and heart fat percentage and slaughter hip height. Tank et al. (1994) reported that the genotypes of growth hormone PCR-RFLP marker had significant effects on hot carcass weight, rib section, and longissimus dorsi muscle. Rocha et al. (1992) reported growth hormone polymorphisms were related to birth weight and shoulder width at birth. This type of information is valuable for additional genetic characterization of domestic livestock and future development of marker assisted selection programs for livestock breeders. However, none of these researchers found a single genetic marker that is powerful enough to become a good selection tool for growth, development or carcass traits in cattle.

There is another point that should be considered; combinations of small effects from several different genes probably regulate most economically important traits. Breeds that drastically differ from one another, and family lines that drastically differ from one another should be targets for molecular genetic research because those with the most variation in performance have the best chance for genetic differences. Researchers and breeders with both performance and pedigree data should attempt to maintain DNA libraries of those animals so that future potentially useful genetic markers can be verified across other populations.

SUMMARY

The interest in identification of genes affecting economically important traits and study of the underlying molecular genetic differences in livestock have increased dramatically in recent years. We investigated a previously published microsatellite genetic marker associated with the bovine prolactin gene. Among 456 cattle representing seven breeds, three marker alleles (designated as A, B, and C) were detected with five observed marker genotypes; no AC genotypes were observed. Apparent differences in genotype distributions between breeds were observed. Overall, the frequencies for the marker alleles were .054, .923, and .023 for the A, B, and C alleles, respectively. Cattle of the American and Parthenais breeds appeared to have different allele frequencies compared to other types. Animals of the Simbrah, Simmental, Santa Gertrudis and Hotlander breeds did not differ from Hardy-Weinberg Equilibrium expectations for this genetic marker. Molecular characterization of cattle such as this can provide insights into understanding of their phenotypic differences.

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Linear Evaluation of Actual Points Program (LEAPP)

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ABSTRACT

How one intuits a series of points that form one or more lines is a physiological and mathematical problem. To quantify the mathematical portion of this phenomenon, a Linear Evaluation of Actual Points Program (LEAPP) algorithm was written in C++. This program uses the Hough transform to convert Cartesian (x, y) coordinates into Hough space (r, q). Line intersections in Cartesian space are represented by points of intersection or accumulations in Hough space. These intersections are stored in a temporary vote space matrix of size (n = 100, m = 180). The n values span the data set in incremental length units to the maximum Euclidean distance. The m values in the vote space matrix are the compass angles in degrees from 0° (North) to 180° (South). Based on the accumulation of this n by m matrix, physiographic lineations can be represented.

KEYWORDS: Linear Evaluation, Hough Transform.

How one intuits a series of points that form a line or a series of lines is a physiological and mathematical problem. The physiological problem of perception of objects and what constitutes "discernible" and "indiscernible patterns" has been discussed by Dennett (1991). The Hough transform (HT) is a mathematical solution of the problem of detecting straight lines (Hough, 1962). HT has been used for military applications (Casasent and Krishnapuram, 1987; Kiryati and Bruckstein, 1991; Yankowich and Farooq, 1998) and machine vision (Leavers, 1992; Chung and Park, 1994; Ham et al., 1995). No record of its use in evaluating or approximating linear physiographic phenomena has been identified.

Our objective was to develop a computer program to discern alignment of points from physiographic features in two-dimensional space. The Linear Evaluation of Actual Points Program (LEAPP) algorithm was written to determine physiographic lineations using the HT.

THEORY

The basic concept behind HT is that a straight line can be represented by a slope-intercept equation:

$$Y = m * X + b \qquad [1]$$

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where "m" is the slope and "b" is the intercept. Every point on a straight edge falls on a given line in space. Duda and Hart (1972) replaced the slope-intercept formula with the "normal" (perpendicular) representation of a line:

$$\rho = x \cos \theta + y \sin \theta \qquad [2]$$

where "ρ" is the distance from the origin and "θ" is the angle of the line perpendicular to the line of concern. This transforms Cartesian coordinate points (x, y) in real, two-dimensioned space into Hough space coordinates (ρ, θ) that are 90° out of phase with a typical polar coordinate representation. Cartesian coordinates (0, 0) in R^2, are represented by $\rho = 0, 0 < \theta \leq 2\pi$ which is a point in H^2. A line in R^2 from the points (x_1, y_1) and (x_2, y_2) gives rise to the accumulation point (ρ_{12}, θ_{12}) in H^2. Since θ is periodic in 2π radians, for a unique value only π radians (180°) need be evaluated. Therefore, the accumulation point (ρ_{12}, θ_{12}) in H^2 for all ρ values where ρ_{12} and $0 < \theta_{12} \leq 2\pi$ represents the one accumulation point for $0 < \theta \leq \pi$ for the line from (x_1, y_1) to (x_2, y_2) in R^2. To find the alignment of points x_i, y_i in R^2, an n by m matrix called a "vote space matrix" is created. There are n rows (n = 100) representing the distance (r) parameter. There are 180 columns (m = 180) representing θ in one-degree intervals between 0 and π radians. The intersection of lines in R^2 are accumulation points in H^2 and are collected as the cell values of this n by m matrix. The cell values or votes relate to the accumulation points in H^2 or the collinear points in R^2. The discritization constant, m, may be $m < 1$ or any multiple of 1°. The discritization constant, n, may be $n > 0$ to a value greater than the geometric distance which spans the data set in R^2. Our program uses n = 100 and associates each individual point with every other point.

VERIFICATION AND DISCUSSION

The ability of LEAPP to discern linear features from physiographic points will be demonstrated from three diverse data sets. A first data set will be the one analyzed by Zartman and Fish (1992). The set of data points, representing the centers of playa lakes in the southwestern portion of Castro County, Texas, are presented in Fig. 1. The LEAPP lines are nearly identical to those presented in Zartman and Fish (1992) for the first four rows of playas below the Running Water Draw. LEAPP lines were quantified from the data points alone, while the regression lines were manually selected. This excellent agreement between the two-presented formats clearly demonstrates the utility of the LEAPP algorithm. The other lines selected by the LEAPP algorithm (Table 2a) also qualitatively demonstrate the utility of this program.

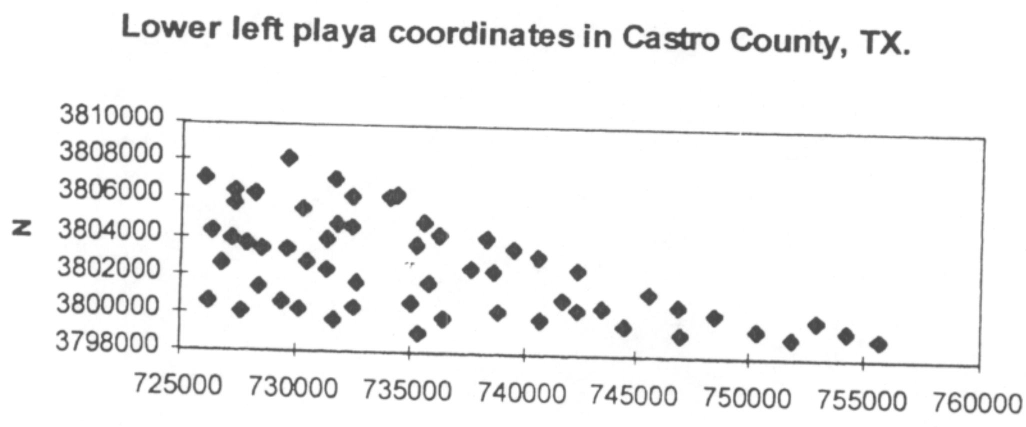

Fig. 1. Coordinates of playas in the lower left corner of Castro County, Texas.

Table 1. Comparison of the LEAPP lines with the Zartman and Fish (1992) line representations. N is Northing and E is Easting in UTM coordinates.

LEAPP line	Zartman and Fish (1992)	Regression value	Row
Y = -0.364 * X + 4.074e + 06	N = 4073140 – 0.364 * E	$R^2 = 0.981$	1
Y = -0.4877 * X + 4.171e + 06	N = 4171546 – 0.500 * E	$R^2 = 0.837$	2
Y = -0.4663 * X + 4.155e + 06	N = 4169465 – 0.499 * E	$R^2 = 0.984$	3
Y = -0.404 * X + 4.103e + 06	N = 4122858 – 0.439 * E	$R^2 = 0.987$	4

Table 2b presents the 13 best angles for the whole data set as determined by LEAPP. These angles are clustered around 112°. These 13 angles account for 29.3% of the angles while arithmetically they should account only for 7.2% (13/180). The non-LEAPP lines were physiologically discriminated against by the presence of the Running Water Draw. Linear regression of the data presented in Fig. 1 was as follows:

North = -0.18446 * East + 3938258 with a nonsignificant $R^2 = 0.33$. This further demonstrates the utility of the LEAPP algorithm for evaluating multiple lines.

Table 2a. The 10 best lines (angle, distance, number of points on the line, and equation) for the lower left corner of Castro County, Texas data set.

Angle	Distance	Number of points	Equation
110	-480.5	7	Y = -0.364 * X + 4.073e + 06
86	-2573	5	Y = 0.06993 * X + 3.749e + 06
93	-3839	5	Y = -0.05241 * X + 3.839e + 06
94	-3710	5	Y = -0.06993 * X + 3.852e + 06
110	-2022	5	Y = -0.364 * X + 4.071e + 06
111	-2003	5	Y = -0.3839 * X + 4.086e + 06
112	-462	5	Y = -0.404 * X + 4.102e + 06
112	-2188	5	Y = -0.404 * X + 4.101e + 06
115	-5134	5	Y = -0.466 * X + 4.143e + 06
116	-5239	5	Y = -0.488 * X + 4.159e + 06

†Negative distances represent values below the center of the data.

Table 2b. The 13 best angles, number of lines (any two points) and percent of total possible lines the Lower left corner of Castro County, Texas data set.

Angle	Number of lines	Percentage of possible
110	51	3.2
112	50	3.1
111	43	2.7
113	39	2.4
86	34	2.1
104	34	2.1
115	34	2.1
109	32	2.0
114	32	2.0
91	30	1.9
96	30	1.9
102	30	1.9
116	30	1.9

A second example of the use of this program is determining the flight pattern of geese (Branta spp.). A photograph of a "vee" of geese (supplied by D. Haukos; U.S. Fish and Wildlife Service) was digitized using the left eyeball of each goose for coordinates (Fig. 2). LEAPP results identify two lines having angles of 77 and 123 degrees, respectively. Linear regression analysis gives one line $Y = 0.2188 * X + 5.27$ with an R^2 value of 0.105. While the specific angle values of the lines may not be of interest due to distortion during photography, clearly the LEAPP representation of two lines is superior to the single linear regression line.

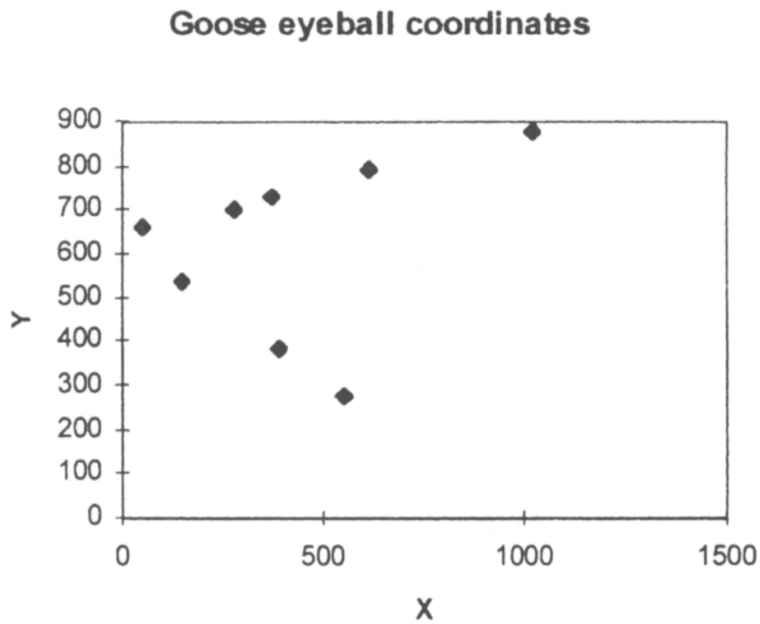

Fig. 2. Relative coordinates for the left eyeball of a flock of geese.

The third data set to be presented are the corners of place squares on a checker board (Fig. 3). LEAPP results presented in Table 3a provide the proper orientation for the 11 best lines. Table 3b presents the best 4 angles selected by LEAPP. These 4 angles account for 30% of the possible angles, but account for the principal axes and diagonal directions. Linear regression analysis of the checkerboard data is $Y = 0 * X + 4$ with a nonsignificant R^2 value of 0. This data set, again, clearly demonstrated the value of this program compared to a regression analysis of the data. While the human eye perceives the horizontal, vertical, and 45 degree lines, linear regression does not.

CONCLUSIONS

We believe that the utilization of the Hough transform allows us to quantitatively describe linear physiographic features. Random data sets give random values in the vote matrix. Data sets with only one set of points in a line, generate only that line in the vote matrix. With just one line, this algorithm is no better than a least squares procedure. This program is beneficial in detecting multiple lines (Fig. 1). Least squares programs are unable to identify multiple lines and can only give an equation for one line representing the whole data set. By knowing the coordinates of points in real, Cartesian space, transformed data can display the orientation or orientations of these features.

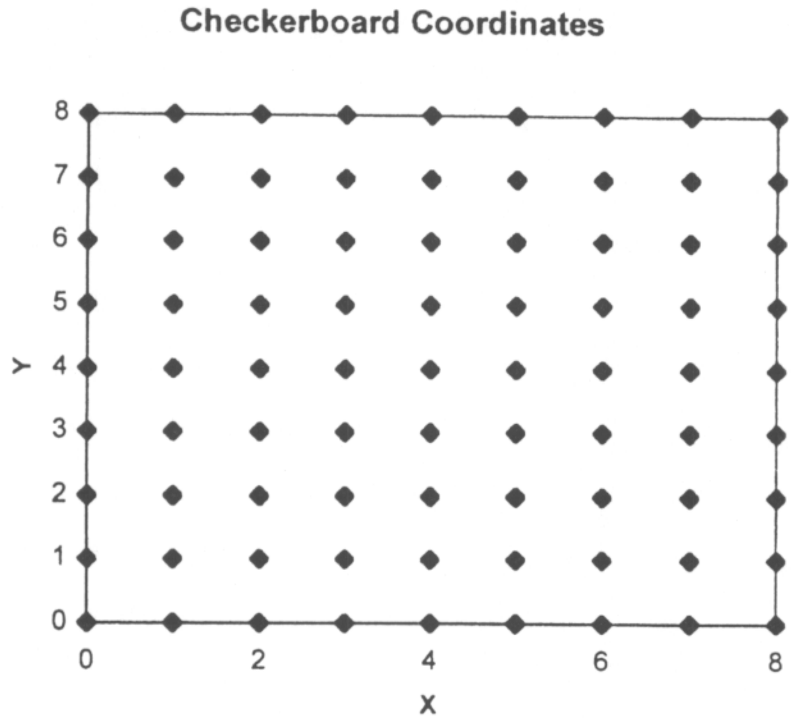

Fig. 3. Coordinates of the corners of place squares on a checkerboard.

Table 3a. The 15 best lines (angle, distance, number of points on the line, and equation) for the corners of place squares on a checkerboard data set.

Angle	Distance	Number of Points	Equation
45	0	9	Y = 1 * X + 5.007e -06
90	4	9	Y = 0 * X + 8
90	3	9	Y = 0 * X + 7
90	2	9	Y = 0 * X + 6
90	1	9	Y = 0 * X + 5
90	0	9	Y = 0 * X + 4
90	-1	9	Y = 0 * X + 3
90	-2	9	Y = 0 * X + 2
90	-3	9	Y = 0 * X + 1
90	-4	9	Y = 0 * X + 2.384e - 07
135	0	9	Y = -0 * X + 8

Table 3b. The 4 best angles, number of lines (any two points) and percent of total possible lines the corners of place squares on a checkerboard data set.

Angle	Number of lines	Percentage of Possible
90	324	10
180	324	10
45	192	5
135	192	5

PROGRAM DESCRIPTION

Program use

The LEAPP algorithm was written in C++ using Windows 97. LEAPP may be run from a 3.5-inch floppy or loaded onto a hard drive and run from that location. For both the floppy and hard disk program, go to the "File" option and chose the "Run" option. Data are entered as columns of numbers in Cartesian coordinates (x, y) or can be read from most commonly utilized spreadsheets. To terminate the data entry, input the coordinates x = 9999 and y = 9999. If the data are read from existing data sets, the terminating coordinates (9999, 9999) need not be entered. The data should be saved as a "Text [Tab delimited]" file with the appropriate ".txt" extension. Once the data are entered or read, a screen menu will display options. Chose the "C" option to compute the actual lines. After the computation is complete, the display option menu will allow the user to display the data or consider other options. Choosing the "F" option will allow the user to input the number of lines to be displayed. Users have the option of selecting the number of lines to be presented with the caveat that the number of lines selected should not exceed the points in the line. The "Q" option will allow the results to be displayed and printed in the directory from which the program was run. The extension ".out" allows the information to be printed from a word processing program.

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Response of Herbaceous Vegetation to Aeration of a Blackbrush-Guajillo Community

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ABSTRACT

Herbaceous vegetation productivity was compared on blackbrush (*Acacia rigidula*)-guajillo (*Acacia berlandieri*) dominated rangeland sites following mechanical aeration and on adjacent untreated areas. Herbaceous plant biomass was estimated by clipping vegetation in 10.8 ft^2 plots. Grass and forb diversity was greater on aerated sites. Grass biomass was more than 4-fold greater on aerated sites than untreated sites. There were no differences in biomass of individual grass and forb species between treatments, with the exception of sida (*Sida spp.*) which produced greater yields on aerated plots. When grasses were combined into preferential rating classes, grasses of fair forage value produced greater biomass on aerated sites. Beneficial native grasses produced greater biomass and were more commonly encountered on aerated sites. Bristlegrasses (*Setaria spp.*) were more common on aerated sites. Invasive, introduced species such as Lehmann lovegrass (*Eragrostis lehmanniana*) showed no treatment effects. When pooled, forbs preferred by white-tailed deer (*Odocoileus virginianus*) and cattle such as erect dayflower (*Commelina erecta*) and Dillens oxalis (*Oxalis dillenii*) were more common on treated than untreated sites. Grass productivity appears to be adequate to allow the use of prescribed burning as a maintenance tool. To determine the long-term implications of brush management activities, further investigation into the effects of maintenance treatments combined with livestock grazing on herbaceous and woody vegetation is warranted.

KEYWORDS: aeration, herbaceous vegetation, productivity, maintenance treatment

The overgrazing of domestic livestock has caused the Rio Grande Plains of south Texas to change from a grassland savanna to a dense thorn woodland (Archer et al., 1988; Archer, 1994). With the development of heavy equipment such as the root plow and roller chopper, ranchers have a tool that could be utilized to effectively manage woody vegetation (Allison and Rechenthin, 1956) and enhance herbaceous vegetation productivity

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(Scifres et al., 1976; Drawe, 1977; Bozzo et al., 1992). A major problem with mechanical treatments is that woody vegetation can reinvade treated rangelands in a relatively short time period (Welch et al., 1985). In addition, the diversity of reestablished woody plants can be dramatically reduced, especially on root plowed rangelands (Fulbright and Beasom, 1987; Ruthven et al., 1993). Other mechanical treatments have less of an impact on woody plant diversity (Scifres et al., 1976; Fulbright, 1987; Fulbright and Beasom 1987).

The rapid response of woody vegetation to mechanical treatments indicates the necessity for maintenance treatments to sustain the benefits of increased herbaceous yields. Prescribed burning is a follow-up treatment tool that is effective in reducing brush cover, maintaining woody plant diversity, and enhancing herbaceous productivity (Box and White, 1969).

In recent history, land ownership and land use practices in south Texas have changed. The size of individual land holdings has decreased and many new landowners are from urban rather than rural backgrounds. For many new landowners, recreational hunting is the primary use of the land. In fact, many traditional ranchers are realizing that income derived from wildlife related enterprises can exceed that of livestock production. Hunting opportunities for species such as white-tailed deer can command prices > $3,500.00 (Payne et al., 1987).

With the increased interest in wildlife management, land managers are utilizing brush management to enhance wildlife habitat. Mechanical top removal methods have been shown to increase crude protein, phosphorous, and potassium content of browse species preferred by white-tailed deer (Everitt, 1983; Fulbright et al., 1991). Mechanical aeration is a top-removal method that has gained popularity in south Texas within the last 10 years (J. Burnside pers. comm.). Aerators differ from roller choppers in that the blades along the chopper drum are toothed and set at an angle across the face of the drum. The effects of aeration on vegetation and soil properties are not well documented, especially in xeric environments such as the western Rio Grande Plains.

Vegetation communities in the western Rio Grande Plains are mostly dominated by two woody species, honey mesquite (*Prosopis glandulosa*) and blackbrush. Blackbrush dominated communities can form dense stands of woody vegetation with little or no herbaceous vegetation (McLendon, 1991). Under pristine conditions, these communities were dominated by grasses including multiflowered false rhodesgrass (*Trichloris pluriflora*), plains bristlegrass (*Setaria macrostachya*), and tanglehead (*Heteropogon contortus*) and forbs such as awnless bush sunflower (*Simsia calva*), bundleflower (*Desmanthus spp.*), and orange zexmenia (*Wedelia texana*) (Gabriel et al., 1994). Under optimum conditions, herbaceous yields can exceed 3,600 lb/ac.

Because of potential productivity, dense stands of blackbrush dominated rangeland may be ideal locations to conduct mechanical brush treatments. The objectives of this study were to determine the response of herbaceous vegetation to aeration and determine if any increases in herbaceous yields are substantial enough to permit the use of prescribed burning as a follow-up maintenance treatment.

METHODS

The study area was the 15,200 acre Chaparral Wildlife Management Area (WMA) in the western South Texas Plains (Gould, 1975; Scifres, 1980; Hatch et al., 1990). The Chaparral WMA has been managed by the Wildlife Division of the Texas Parks and Wildlife Department since 1969 and serves as a research and demonstration area for the

South Texas Plains ecoregion. Climate is characterized by hot summers and mild winters with an average daily minimum winter (January) temperature of 45° F and an average daily maximum summer (July) temperature of 100° F (Texas Parks and Wildlife Department, unpubl. data). Average annual precipitation is 22 inches with peaks occurring in late spring (May to June) and early fall (September to October).

Three sites, ranging in size from 3.0 to 5.7 ac., were aerated utilizing a Lawson, double/tandum 12 ft. x 30 in. drum aerator pulled by a D7 bulldozer during early-August 1998. Control plots, which were similar in size to treated plots, were established on untreated areas adjacent to aerated sites.

Soils were similar between treatments and consisted of Duval fine sandy loam, Dilley fine sandy loam, Brystal very fine sandy loam, Caid very fine sandy loam, Webb very fine sandy loam, and Goldfinch very gravelly sandy loam (Gabriel et al., 1994). The Duval series are fine-loamy, mixed, hyperthermic Aridic Haplustalfs; Dilley series are loamy, mixed, hyperthermic shallow Ustalfic Haplargids; Brystal series are fine-loamy, mixed, hyperthermic Ustollic Paleustalfs; Caid series are fine-loamy, mixed, hyperthermic Ustollic Paleustolls; Webb series are fine, montmorillonitic, hyperthermic Aridic Paleustalfs; and Goldfinch series are loamy-skeletal, mixed hyperthermic, shallow Ustalfic Haplargids. Topography is nearly level to gently sloping and elevation ranges between 580 and 610 ft.

The study area had been grazed by domestic livestock since the 18th century (Lehmann, 1969). Cattle have been the major species of livestock since about 1870, whereas sheep were grazed from about 1750 to 1870. Grazing strategies have varied from continuous grazing to various rotational grazing systems (Ruthven et al., 2000). Under the current high-intensity, low-frequency grazing system, aerated and control sites were grazed at a density of one animal unit (two steers $\leq$ 500 lb = one animal unit) per 3.26 ac. during the period 22 February 1999 through 15 March 1999.

Plant communities on all sites were characteristic of the blackbrush/guajillo-prickly pear (*Opuntia engelmannii*) community within the blackbrush-twisted acacia (*Acacia schaffneri*) association (McLendon, 1991). Woody vegetation canopy cover was > 50% (Texas Parks and Wildlife Department, unpubl. data). Prominent herbaceous species included sixweeks grama (*Bouteloua barbata*), hooded windmillgrass (*Chloris cucullata*), Texas bristlegrass (*Setaria texana*), pink pappusgrass (*Pappophorum bicolor*), Halls panicum (*Panicum hallii*), slender evolvulus (*Evolvulus alsinoides*), Dillens oxalis, and sida. Scientific names follow Jones et al. (1997). Common names follow Hatch et al. (1990).

Transects were established through the center of each site in late-June and early-July 1999. Ten 10.8 ft^2 frames were placed at random locations along each transect. Current year's growth of grasses and forbs was clipped down to ground level within frames. Vegetation was sorted into paper bags by species. Samples were air-dried. Dry samples were weighed to the nearest 0.02 oz. Grass and forb diversity was quantified with Shannon's Index (Pielou, 1975) utilizing frequency data. Data were analyzed by a 1-way analysis of variance with treatment as the main effect.

RESULTS AND DISCUSSION

Grass species richness and diversity were greater on aerated sites (17 ± 1 species/treatment [$\bar{x}$ ± SE], P = 0.0056; 2.63 ± 0.04, P = 0.0012, respectively) than on untreated sites (10 ± 1 species/treatment, 2.18 ± 0.04). Overall grass yields were greater on aerated sites (2,173 lb/ac ± 463, P = 0.0257) than on untreated sites (445 lb/ac ± 169).

Species productivity was similar between treatments (Table 1). When pooled into preference ratings of good, fair, and poor grazing value (Gould, 1978), grasses of fair grazing value produced greater yields on aerated sites (Table 2). When preferred native grasses, based on Gould (1978) and Everitt et al. (1981), were pooled, natives produced greater biomass on aerated sites (Table 2). Favored natives were also more frequently encountered on aerated than untreated sites (80 ± 6% and 40 ± 12%, P = 0.0363, respectively). Dominant grasses that were more frequent (P < 0.05) on aerated areas include Texas bristlegrass and hooded windmillgrass (Table 3). When pooled, bristlegrasses (Texas bristlegrass, plains bristlegrass [*Setaria macrostachya*], knotgrass [*Setaria firmula*], and [*Setaria ramiseta*]) were more commonly encountered on aerated plots (70 ± 6% compared to 27 ± 3%, P = 0.0028).

Table 1. Productivity (lb/ac) of dominant (frequency ≥ 30%) grasses and sedges and dominant (frequency ≥ 15%) forbs on aerated (n=3) and untreated (n=3) areas at the Chaparral Wildlife Management Area, LaSalle County, Texas, June-July 1999.

	Aerated		Untreated		
Class/Species	$\bar{x}$	SE	$\bar{x}$	SE	P-value
Grasses and Sedges					
Aristida purpurea	401	205	151	89	0.3164
Boutloua barbata	71	36	53	27	0.6398
Chloris cucullata	169	71	36	18	0.1442
Cyperus retroflexus	45	18	9	9	0.1313
Digitaria californica	401	205	143	89	0.3164
Erogrostis lehmanniana	276	107	116	116	0.3799
Panicum hallii	426	285	36	18	0.2373
Pappophorum bicolor	730	419	249	125	0.3308
Setaria texana	534	187	125	27	0.0902
Forbs					
Abutilon fruticosum	18	9	2	2	0.1983
Amphiachyris dracunculoides	53	53	1	1	0.3328
Commelina erecta	62	36	6	6	0.2361
Evolvulus alsinoides	27	9	45	45	0.6139
Oxalis dillenii	5	2	2	0	0.1367
Sida spp.	18	4	3	<1	0.0253

Forb species richness and diversity were greater on aerated sites (17 ± 2 species/treatment, P = 0.0224; 2.62 ± 0.12, P = 0.0433, respectively) than on untreated sites (10 ± 1 and 2.17 ± 0.09). Total forb productivity was similar between treatments, with 98 lb/ac ± 46 produced on aerated sites compared to 27 lb/ac ± 9 on control areas. Sida had greater yields on aerated sites (Table 1). Pelotazo (*Abutilon fruticosum*) was more frequently encountered on aerated sites (Table 3). Forbs were pooled into forage groups utilized by white-tailed deer, quail, and cattle (Everitt et al., 1999). Forbs preferred by white-tailed deer and cattle were more commonly encountered on aerated sites (Table 4).

Table 2. Productivity (lb/ac) of grasses of good, fair, and poor grazing value (Gould, 1978) and preferred native grasses (Gould, 1978; Everitt et al., 1981) on aerated (n=3) and untreated (n=3) sites on the Chaparral Wildlife Management Area, LaSalle County, Texas, June-July 1999.

	Aerated		Untreated		
Class/Species	$\bar{x}$	SE	$\bar{x}$	SE	P-value
Good	392	294	169	169	0.5418
Leptochloa dubia					
Pennisetum ciliare					
Setaria macrostachya					
Fair	1,006	303	143	53	0.0505
Chloris cucullata					
Digitaria californica					
Panicum hallii					
Pappophorum bicolor					
Paspalum setaceum					
Sporobolus cryptandrus					
Urochloa ciliatissima					
Poor	107	9	80	36	0.5123
Aristida purpurea					
Bouteloua barbata					
Cenchrus spinifex					
Eragrostis secundiflora					
Preferred Native (includes sedges)	579	178	71	53	0.0498
Cyperus retroflexus					
Leptochloa dubia					
Panicum hallii					
Setaria firmula					
Setaria macrostachya					

Our results indicate that mechanical aeration is an effective tool to increase herbaceous diversity and productivity of blackbrush-guajillo communities, especially species preferred by wildlife and livestock, without increasing undesirable and invasive species such as Lehmann lovegrass. Increases in overall grass yield were similar to aerated sites of mixed brush in the eastern Rio Grande Plains (Texas Agricultural Experiment Station, unpubl. data). In the eastern Rio Grande Plains, Texas bristlegrass on clay loam soils increased following aeration; however, Texas bristlegrass was not a common component of the herbaceous plant community on sandy loam soils. Texas bristlegrass appears to be an important element of the herbaceous community on sandy loam soils in the western Rio Grande Plains, and increases reported in this study were similar to responses on clay loam soils in the eastern Rio Grande Plains. Few data are available on the value of Texas bristlegrass as forage. Bristlegrasses are generally considered to be fair to good forage species for both livestock and wildlife (Gould, 1978). As Texas bristlegrass is a dominant species throughout much of southern Texas, research into the utilization of Texas bristlegrass by wildlife and livestock is needed. Increases of hooded windmillgrass in this study were also similar to those on aerated sites in the eastern Rio Grande Plains. Herbaceous plant responses were similar to other mechanical treatments reported from the Rio Grande Plains (Scifres et al., 1976; Drawe, 1977; Bozzo et al., 1992).

Table 3. Frequency (%) of dominant (frequency ≥ 30%) grasses and sedges and dominant (frequency ≥ 15%) forbs on aerated (n=3) and untreated (n=3) areas at the Chaparral Wildlife Management Area, LaSalle County, Texas, June-July 1999.

	Aerated		Untreated		
Class/Species	$\bar{x}$	SE	$\bar{x}$	SE	P-value
Grasses and Sedges					
Aristida purpurea	47	20	17	3	0.2181
Boutloua barbata	40	21	33	9	0.7827
Chloris cucullata	50	6	23	7	0.0390
Cyperus retroflexus	60	6	20	15	0.0705
Digitaria californica	33	18	7	3	0.2116
Erogrostis lehmanniana	33	12	3	3	0.0739
Panicum hallii	37	9	23	12	0.4216
Pappophorum bicolor	40	15	27	15	0.5614
Setaria texana	53	3	23	3	0.0031
Forbs					
Abutilon fruticosum	27	3	3	3	0.0078
Amphiachyris dracunculoides	20	6	7	7	0.2051
Commelina erecta	17	7	3	3	0.1481
Evolvulus alsinoides	20	12	13	9	0.6702
Oxalis dillenii	40	10	17	7	0.1242
Sida spp.	50	12	23	3	0.0907

Timing of aeration treatments may have affected herbaceous responses. Previous studies of mechanical top-removal methods in south Texas (Scifres et al., 1976; Bozzo et al., 1992) and central Texas (Rollins and Bryant, 1986) showed increases in herbaceous vegetation following treatments conducted in early- to mid-summer. In north central Texas, Mathis et al. (1971) reported decreases of grasses following root plowing in early spring. Mid-summer is typically hot and dry in south Texas. During the period of May through July 1998, 0.8 inches of precipitation were recorded at the study site.

Prescribed fire is a cost-effective method for controlling woody vegetation and enhancing herbaceous vegetation productivity (White and Hanselka, 1989). In south Texas, fuel loads are the most limiting factor for the use of prescribed fire as a management tool. Optimum herbaceous fuel loads for conducting prescribed burns in the western Rio Grande Plains are greater than 1,800 lb/ac (D. Ruthven, unpubl. data). Increases in grass productivity following aeration appear to be adequate to provide fuel loads to conduct prescribed burns. However, based on individual plots, available grass fuel loads were highly variable, ranging from 0-5,740 lb/ac. This uneven fuel load is typical of most south Texas rangelands and may result in a mosaic of burned and nonburned areas. Additional mechanical treatments may be necessary before fire can be utilized as a successful maintenance tool.

Table 4. Frequency (%) of forbs utilized by white-tailed deer, quail, and cattle (Everitt et al., 1999) on aerated (n=3) and untreated (n=3) sites on the Chaparral Wildlife Management Area, LaSalle County, Texas, June-July 1999.

	Aerated		Untreated		
Class/Species	$\bar{x}$	SE	$\bar{x}$	SE	P-value
Deer	93	3	53	7	0.0058
Abutilon fruticosum					
Acleisanthes obtusa					
Ambrosia psilostachya					
Aphanostephus ssp.					
Argythamnia humilis					
Commelina erecta					
Cooperia drummondii					
Dyssodia tenuiloba					
Evolvulus alsinoides					
Hybanthus verticillatus					
Lepidium virginicum					
Melampodium cinereum					
Oxalis dillenii					
Palafoxia texana					
Parthenium confertum					
Sida spp.					
Sphaeralcea pedatifida					
Quail	53	3	33	7	0.0550
Abutilon psilostachya					
Ambrosia cumanensis					
Argythamnia humilis					
Commelina erecta					
Evolvulus alsinoides					
Hybanthus verticillatus					
Lepidium virginicum					
Cattle	83	7	47	3	0.0079
Argythamnia humilis					
Commelina erecta					
Hybanthus verticillatus					
Lepidium virginicum					
Oxalis dillenii					
Palafoxia texana					
Sida spp.					

Livestock grazing may have affected herbaceous response on aerated plots. Although high-intensity low-frequency grazing systems may enhance herbaceous productivity under optimum environmental conditions (Heitschmidt et al. 1982), they have been shown to reduce the abundance of forbs that are important components of white-tailed deer diets (Cohen et al. 1989). Although forbs and grasses preferred by livestock and wildlife increased on aerated sites, grazing may have resulted in smaller increases than aeration alone. Increased availability of grasses on aerated areas concentrates livestock (D. Ruthven, unpubl. data). In turn, hoof action and deposition of nitrogen rich waste products may stimulate germination and growth of herbaceous plants. How various high-intensity low-frequency grazing strategies affect herbaceous vegetation in this ecosystem is not clear and warrant further investigation.

Aeration did not appear to significantly affect Lehmann lovegrass (Table 1, Table 3). Lehmann lovegrass is an introduced perennial that has been planted throughout the southwestern United States to control erosion and increase forage production (Cable 1971). However, it is generally considered unpalatable for livestock. On southern Arizona rangelands, this aggressive invader has been shown to out compete native grasses and quickly become the predominant grass species (Anable et al., 1992). Areas dominated by Lehmann lovegrass have been shown to have lower wildlife diversity than areas dominated by a mixture of native grasses (Brock et al. 1986). Lehmann lovegrass now dominates herbaceous communities on many sandy range sites in south Texas. Lack of an increase in Lehmann lovegrass may be attributed to the soil disturbance of the aeration treatment. Lehmann lovegrass germinates from very shallow depths (Cox and Martin, 1984), and aeration treatments may cover seeds at a depth that will not permit successful germination. The fact that prescribed burning may increase Lehmann lovegrass germination (Ruyle et al. 1988) may preclude its use as a maintenance treatment if controlling Lehmann lovegrass is a concern. Grazing ruminants may also disseminate Lehmann lovegrass seed (Fredrickson et al. 1997). Diets of cattle on the study area, a site of high Lehmann lovegrass infestation, are dominated by lovegrasses (R. Kazmaier, unpubl. data). However, utilization of prescribed burning, which may increase palatability of Lehmann lovegrass, followed by livestock grazing may provide a measure of control.

It is clear, as shown by this and other studies, that most mechanical brush management methods are effective means to stimulate production of herbaceous vegetation in the short-term. A perennial problem is that most treated rangelands continue to be overgrazed and lack follow-up maintenance treatments, which may result in the establishment of depauperate woody plant communities with low herbaceous productivity. It is likely that a complex interaction between mechanical treatments, maintenance treatments, and herbivory exists. Further investigation is needed to assess the long-term response of herbaceous vegetation to mechanical treatments, as well as the impacts of maintenance treatments, such as prescribed burning and various grazing regimes, on herbaceous and woody vegetation.

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College Senior Interns Satisfaction Concerning Intern Station Supervisor Performance

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ABSTRACT

Faculty in the Department of Agricultural Services and Development at Tarleton State University supervise 45-55 agri-industry interns each year. This study covered a five and one half year period and interns who were placed in a broad range of agricultural occupations. This study had as one objective to determine the satisfaction level of interns toward the performance of selected tasks by their supervisors. The responses were studied according to the various types of occupations. The training stations were divided into the following six groups: agricultural sales, extension service, other governmental agencies, agricultural communications, production oriented companies, and companies supplying technological services.

The order of rankings according to satisfaction of interns was: (1) sales, (2) extension, (3) other governmental agencies, (4) agri-communication, (5) production, (6) technological services. Sales were significantly higher than all categories except extension. Technology scored significantly lower than all categories except production.

The study also divided interns according to type of compensation. Two categories were established - paid and non-paid. It was found that interns who were not paid were significantly more satisfied with the performance of their supervisors than those who were paid.

KEYWORDS: Satisfaction, agri-industry interns

INTRODUCTION

Internships have been used by both education and private industry for a relatively long period of time. However, in the field of agricultural education most of the activity began in the 1960's with the advent of the cooperative part-time training program. These programs placed secondary students in agricultural employment areas for a part of each school day.

In recent years, internships have become very popular and important in most academic disciplines and in all types of private enterprise. Internships seem to come in a variety of formats. The internships vary in length, amount of structure and supervision, type of compensation, and evaluation.

The Agricultural Services and Development Department at Tarleton State University provides internship opportunities to approximately 45 to 55 students per year. These interns are in addition to approximately the same number who are placed into teaching internships in the public schools. The interns are distinguished from each other by the names of "teaching interns" and "agri-industry interns". This study covered a period of five and a half years or eleven semesters and dealt with only the agri-industry interns.

Considerable work has been dedicated to evaluating student teaching interns and structuring high school teachers as supervisors. However, little has been done in the agri-industry intern area. At Tarleton State, both type of interns are structured in essentially the same manner. The grade point requirements are the same. The class preparations are the same up until the final semester, and the length of internships are the same. Each intern spends one third of the semester at the university in specialized training and the other two-thirds of the semester at the training station. Both are supervised by a university coordinator during their internship, and both are brought back to the university at the end of the internship. This study evolved from a concern of the university faculty that quality of training among the industry interns might vary more than among teaching interns. Agri-industry supervisors usually change from one semester to the next. No formal training program is held to train the supervisors as in the student teaching area. Therefore, there was a need to know more about how interns felt toward their supervisors and the type of training and assistance they had received.

THEORETICAL / LITERATURE BASE

The importance of evaluating performance of supervisors responsible for the education and training of students has been a widely accepted concept for educators throughout the years. However, research dealing with the perceptions of university interns concerning training in the various facets of the agricultural industry appear to be very limited.

One concern of interns is the length of time the job search requires. Donald (1998) encourages intern supervisors to spend time with the intern on helping with job search strategies which was one of the task areas assessed. He also alludes to the importance of professional contact during the internship.

In a study conducted by Hite and Bellizzi (1986), an examination was made concerning student expectations regarding internship programs. Their findings revealed that students overall viewed internships as valuable learning experiences for which participants should receive academic credit and be financially compensated. He also pointed out that formal training should be provided at the beginning and the supervisor should direct training throughout the internship.

In another study conducted by Garrett and Bauer (1995) where students talked about internship preference, students preferred paid internships.

In a study of students' expectations by Cannon and Arnold (1998), students listed expectations for internships and outcomes from those internships. One expectation observed was that students expected the internship site training to be at least comparable to a new employee's training for the same job.

Many universities and colleges of agriculture have patterned their internship programs after cooperative education programs. One is the high school vocational agricultural cooperative program. Johnson (1978) discussed the importance of planning for cooperative students and planning on spending time with the student. If this did not happen then he suggested that "...any other approach is haphazard and the chance that proper skill will be developed is purely accidental". Williamson (1978) in reference to cooperative employers stresses that the important link in the success of on-the-job-training programs is the willingness of the supervisor to accept many responsibilities for that student's training and success.

PURPOSE AND OBJECTIVE

The purpose of this study was to determine levels of satisfaction held by interns at the end of their eleven-week internship concerning selected tasks performed by their industry supervisor. The responses were studied according to the type of occupation and as to the type of pay received by the intern.

The specific objectives for the study included:

1. Determine if significant differences existed in the satisfaction levels expressed by interns among the six types of agri-industry employment.
2. Determine if a significant level of difference existed between the satisfaction levels expressed by interns using the variable of pay or no pay.
3. Determine which tasks performed by agri-industry supervisors received higher satisfaction levels as judged by interns at program completion.

The overall purpose was to obtain data that could be used to develop training materials and educational sessions for agri-industry supervisors. The desired result was to locate areas of strengths and weaknesses so that internships could be a more rewarding and educational fulfilling experience.

METHODS AND PROCEDURES

The first step was to establish a list of tasks for industry supervisors which were acceptable to all groups including university staff, agri-industry supervisors, and interns. This was accomplished by individual interviews and panel discussions, involving fifteen individuals from the groups mentioned above. Also once a seemingly acceptable list had been established an advisory group of university staff and agri-industry supervisors was formed for final review. It was recognized that the final list did not contain every possible task and was not intended to be all-inclusive. However, the final review panel considered the list to contain all important components, and that it could be used in total to measure the overall effectiveness of supervisors. It was recognized that possibly some types of occupations were better suited for satisfactory performance in some of the skills areas than were others. However, the advisory group felt it was important that interns receive assistance in each of the items on the list regardless of where the assistance was initiated.

The items or task on the final list were then developed into a questionnaire employing a five point Likert Scale of Satisfaction. 1 = very satisfied, 2 = satisfied, 3 = neutral, 4 = dissatisfied, 5 = very dissatisfied. University interns were asked to respond as to their satisfaction on fifteen different tasks. The responses were solicited on the completion of their internship. Respondents were assured confidentiality of their individual responses.

The responses were then divided into six occupational categories according to the nature of work performed at each training station. The groups were agricultural extension, other governmental agencies, agricultural communications, production of agricultural products, agricultural sales, and technological services. An analysis of variance was applied to the groups using the total of all responses. Appropriate t-values were obtained to find significant differences between groups. Then a comparison of Likert scales of intern satisfaction was made by area using analysis of variance with least squares adjusted means. The least squares adjusted means were produced by SAS statistical programs. The significance level set for the study was .05. Also, responses were divided into two groups depending upon whether the intern was paid or non-paid. Approximately 40% of interns received compensation during their internship and the remaining 60% did not.

In order to identify overall supervision strengths and weaknesses, the final step was to determine average overall responses on each of the fifteen tasks.

RESULTS AND CONCLUSIONS

Two hundred and nine interns were included in the study. The study spanned a period beginning with the fall semester of 1993 and ended with the fall semester of 1998. Table 1 depicts the overall average response of each of the six occupational areas. The 2.35 rating experienced by technological services was the poorest rating of the six occupational categories. However, all responses still fell within the "satisfied" category. It is still apparent that improvements can be made in all occupational categories, especially in agri-communications, agri-production, and technological services.

Table 1. Likert Scales of intern satisfaction by occupational area.

Area	N	Mean
Agricultural Sales	33	1.24
Extension Service	30	1.36
Other Governmental Agencies	64	1.59
Agri-Communications	35	1.88
Agri-Production	18	2.05
Technological Services	29	2.35

Table 2 is a comparison of Likert scales of internship satisfaction by occupational area using analysis of variance with least squares adjusted means. Agri-sales supervisors scored significantly higher than all areas except the Extension Service. Technological services scored significantly lower than all areas except production. Perhaps these observations that production and technological occupation score lower is the result of the more exacting nature of their work where student tasks are performed in the absence of supervisors. Also, the agri-sales could have scored higher because of the constant personal contact of supervisor and student. However, this study is not of the scope to make these conclusions.

Table 2. Comparison of Likert Scales of internship satisfaction by occupational area using ANOVA with least squares adjusted means.

		Area				
Area	LSMean	Extension	Government	Production	Sales	Technological
Agricommunication	1.9	0.006	NS	NS	0.0007	0.02
Extension Services	1.4	-	NS	0.003	NS	0.0001
Other Govt. Agencies	1.6	-	0.02	0.04	0.0001	
Production	2.1			-	0.004	NS
Ag Sales	1.3				-	0.0001
Technological Services	2.4					

The researchers were also interested to see if intern compensation influenced the satisfaction levels. Table 3 shows that non-paid interns were significantly more satisfied than their peers who were paid during their internship. It is possible that supervisors who do not pay interns feel more obligated to assist the student during their internship. This is a topic for further study and cannot be concluded at this point.

Table 3. Least squares mean of paid verses non-paid interns and level of significance.

Type of Compensation	N	LSMean	Significance of Difference
Non-Paid	126	1.39	0.0001
Paid	83	2.17	

The last objective of the study was to gain general information on how well the interns were satisfied with supervisors' performance regardless of occupational area. Table 4 shows the fifteen supervisory tasks and how they ranked in satisfaction levels as perceived by interns upon completion of their internship. Tasks which ranked toward the top of the list are those that university educators emphasized more in communications with intern supervisors.

Table 4. Means of overall satisfaction levels on all supervisors task.

Task of Supervisor	Overall Mean
1. Explaining what was expected of you	1.44
2. Giving you periodic progress reports	1.53
3. Introducing you to other professionals in the field	1.57
4. Showing a sincere interest in helping you better understand Profession.	1.74
5. Involved you in a social and community activity such as service organizations, etc.	1.63
6. Assisting you in learning technical details	1.66
7. Treating you as a professional instead of a student	1.69
8. Allowing you to be involved in the profession by asking your opinions, etc.	1.71
4. Showing a sincere interest in helping you better understand the profession	1.74
9. Providing you with literature that helped you better understand the profession	1.74
10. Exhibiting a positive attitude toward the profession	1.76
11. Explaining career opportunities in the profession	1.77
12. Allowing you to attend in-service meetings and other important meetings	1.77
13. Explaining the overall operation of the business	1.82
14. Assigning you tasks which were professionally challenging	1.87
15. Assisting you in your job search	1.93

IMPORTANCE AND IMPLICATIONS OF STUDY

The data of this study seemed to indicate that interns in general were satisfied with the performance of assigned tasks of their supervisors. All scores were above the 2.49 average which was required to be in the "satisfied" level. However, there were significant difference in levels of satisfaction among the occupational categories with sales and all types of government employment at the top and more exacting occupations such as agri-communication, production, and technological services at the bottom. It seems obvious that future studies need to be conducted as to the reason for the noted differences.

Also, non-paid interns expressed significantly higher satisfaction rates than paid interns. Speculations can be made as to the reason for this observation, but variables such as attitudes and other factors need to be analyzed before conclusions can be made as to the reason differences existed. The important point is that differences were identified which shows a need for further study on the effect of compensation.

This study was the first initiated by Tarleton State University to analyze the quality of the internship program. Although the study was somewhat limited in scope and depth, areas were identified that lead to future studies in directions which could quite possibly result in an improved internship program.

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Economic Evaluation of Texas High Plains Cotton Irrigated by LEPA and Subsurface Drip

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ABSTRACT

As water supplies and availability continue to decline in Texas, it is imperative to adopt the most efficient irrigation systems and management techniques. The focus of this study was to optimize irrigation management techniques for low energy precision application (LEPA) irrigation and subsurface drip irrigation (SDI), and compare resulting cotton lint yields and profitability of these irrigation approaches. Four-year average LEPA and SDI cotton lint yields were 1046 lb/ac and 1171 lb/ac, respectively, using only 7.3-in or less of seasonal irrigation water per year. Differences in LEPA and SDI yields are attributed to higher water losses by the LEPA system due to soil surface evaporation. Economic analysis of Texas High Plains cotton production showed that LEPA resulted in higher net returns to management and risk than SDI as irrigation capacity increased above the 0.1 in/d level. However, SDI treatments resulted in net returns of over $80/ac and may be an acceptable alternative where LEPA installation costs are greater than $333/ac, physical constraints prevent the use of LEPA, or SDI installation costs are lower than $800/ac.

KEYWORDS: Drip irrigation, LEPA, Irrigation, Economics, Cotton.

The low energy precision application (LEPA) irrigation concept was developed by the Texas Agricultural Experiment Station at Halfway, TX between 1976 and 1978. The concept was designed to maximize the use of declining ground water supplies and sporadic seasonal rainfall. Subsequent LEPA experiments determined the best combination of irrigation quantities and frequencies for optimum cotton lint yield and water use efficiency (Bordovsky, et al., 1992). Results indicated irrigation water use efficiencies from 72-h irrigation interval treatments were almost twice the levels of those for 216 and 360-h treatments and suggested that the optimal interval for alternate furrow LEPA may be lower than 72-h.

In recent years, interest in the use of subsurface drip irrigation (SDI) for cotton production has increased in West Texas. Systems installed in the Trans-Pecos, TX area in the early 1980's continue to be used today (Henggeler, 1997). The High Plains Underground Water Conservation District No. 1 installed multiple 10-ac demonstration sites to obtain general production information from SDI systems. It is estimated that 30,000 acres of cotton were irrigated with SDI on the Southern High Plains of Texas in 1999 with an addi-

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tional 10,000 acres projected to be irrigated in 2000 (Funck, 1999). However, a major issue concerning SDI is its ability to pay for the system by improving water use efficiency and cotton lint yield over existing, well managed systems.

An experiment was conducted in Halfway, TX from 1995 through 1998 to determine cotton response to high frequency, deficit irrigation using LEPA and SDI. The objective of this experiment was to find the optimum irrigation interval using LEPA at low irrigation capacities and compare its associated cotton lint yields to those resulting from daily SDI irrigation treatments. This paper summarizes the findings of the experiment and compares the net returns to management and risk of cotton irrigated by these systems.

METHODS AND MATERIALS

Crop Response to Irrigation

From 1995 through 1998, an experiment was conducted at the Texas Agricultural Experiment Station at Halfway, TX on moderately permeable Olton loam (fine, mixed, thermic Aridic Paleustolls) soil with a slope of less than 0.2 percent. Five replications of the 9 LEPA treatments (3 irrigation capacities x 3 irrigation intervals) and 3 replicates of 3 SDI treatments (3 irrigation capacities x 1 irrigation interval) plus "preplant only" irrigated checks were randomly placed in a 6-ac area under a five-span lateral LEPA irrigation system. Each span was subdivided into two sections with each section delivering water to 16-40-in wide rows through a manifold system. The manifold system consisted of solenoid valves, pressure regulators, and three manifolds, each nozzled at different flow rates and controlled by a programmable controller (Bordovsky et. al., 1992). This irrigator could apply a wide range of irrigation amounts based on the daily needs of respective treatments as well as provide a method to reset valve/manifold combinations as the system moved between treatment plots. Water was delivered by the LEPA method to alternate diked furrows from the manifold system through a drop tube into a wide, flat sock. SDI treatments were randomly placed among the LEPA irrigation plots. Drip tubing was buried in alternate furrows, 12-in deep in the SDI treatment areas. Emitter spacing along the drip lateral was 24-in with emitter flow rate at 0.33 gal/h at 8 lb/in^2 pressure. The automated LEPA system was programmed to terminate flow over the SDI and check plots. Furrow dikes were maintained in all furrows, both LEPA and SDI, to capture rainfall and retain applied irrigation water. Dikes were removed in non-irrigated furrows in early August to facilitate crop termination and harvest. Nutrients were banded on sides of the crop bed based on soil nutrient analysis. Preplant irrigations with LEPA and SDI elevated profile water content to approximately 85 percent of field capacity prior to planting based on neutron moisture measurements with respective plots. Paymaster HS26 cotton variety was planted in early May of each year. Normal cultural practices were used to control weed and insect pests.

Decisions related to irrigation initiation, termination, quantities, and the integration of rainfall during the growing season were based on the comparison of calculated and target soil water contents as well as irrigation delivery rates (Bordovsky and Lyle, 1996 and 1997). Calculated soil water content (estimated field water content) was determined daily using irrigation and effective rainfall amounts, regional ET and heat degree unit data (degree days, base 60°F) obtained from the South Plains PET network (Lyle, et al., 1996), and a locally derived crop curve. Target soil water content was 85 percent field capacity from emergence to peak bloom, declined linearly to 40 percent field capacity at 2080 cumulative heat units, and was held at 40 percent field capacity for the remainder of the irrigation season. Irrigations were initiated if calculated soil water (field conditions) were lower than the target water content. Irrigation amounts equaled the difference between the target and calculated soil water content subject to three delivery rates. Irrigation delivery rates of 0.1, 0.2, and 0.3 in/d limited application amounts in respective quantity treatments. These quantities corresponded to ? -mile pivot flow rates of 233, 470, and 770 gpm and represent pumping rates of 1.9, 3.8, and 5.7 gpm/ac. Due to these irrigation rate limits, the target soil water content (85% of field capacity) could not be maintained during portions of the growing season, particularly in the 0.1 in/d and 0.2 in/d treatments, unless rainfall occurred. A detailed description of this irrigation protocol is presented by Bordovsky and Lyle (1996, 1997). LEPA irrigation interval treatments were 24, 48, and 72-h. SDI treatments were irrigated daily (i.e., 24-h). Irrigations were terminated at maturity of upper bolls or at the beginning of a significant late season cooling trend. Areas (87 ft^2) were hand harvested within all replicates in October of each year. Yield samples were ginned using a small gin stand.

Economics Analysis

The relative profitability of cotton production under LEPA and SDI was evaluated based on the production data generated by this experiment. The approach was to assume the dryland-to-irrigated development of a 120-ac Texas High Plains field and to make economic comparisons using irrigated cotton budgets. These budgets were composed of expected revenues, variable costs, and fixed costs (Segarra, et al., 1999). These components were then used to derive expected levels of net revenues to management and risk above variable and fixed costs. Expected revenue calculations used the corresponding yields for the 12 irrigation treatments (3 SDI and 9 LEPA) over the four-year test period. Constant prices of $0.64/lb cotton lint and $110/ton for cottonseed were used throughout the calculations to derive the levels of expected net revenues. The variable cost estimate took into account all of the variable inputs needed to produce irrigated cotton including herbicide, fertilizer, crop insurance, seed, seed treatment, insecticides, fuel and lube, repairs, labor, harvest-aid chemicals, stripping, module charges, and ginning. These expenses differed across irrigation treatments due to varying pumping costs associated with irrigation capacity treatments and varying harvest and ginning costs associated with cotton lint yield.

Annual fixed costs were separated into three categories: machinery, land and irrigation system. The machinery and land charges were assumed to be $48/ac and $40/ac, respectively. The irrigation system cost was composed of irrigation well cost and irrigation system cost. The irrigation well cost was assumed to be $33,000 for the 120-ac area (Segarra, et al., 1999). The irrigation system and installation costs were assumed to be $40,000 for LEPA, with SDI costs analyzed at both $600/ac and $800/ac levels (Funck, 1999). Three planning horizons were assumed in the calculations of the annual irrigation system cost, these were 10, 15 and 20 years.

RESULTS

Yield Response

Average cotton lint yields resulting from treatment combinations of irrigation interval, delivery system, and irrigation delivery rates from 1995 through 1998 are presented in Table 1. Within the LEPA treatments, there were no statistically significant ($P<0.05$, Duncan) cotton lint yield differences due to irrigation interval when irrigation capacity equaled 0.2 in/d. However, when capacity is severely limited (0.1 in/d), the 48-h interval resulted in a significantly higher cotton lint yield than either the 24 or 72-h treatments. With very limited pump delivery rates, decreasing the time between irrigations from 72 to

48 hours increases lint yield. However, at the 24-h interval, soil surface evaporation apparently depleted a high portion of the daily irrigation amount significantly reducing yields compared to the 48-h interval.

Cotton lint yields during the 4-year period were higher for treatments watered by SDI than LEPA at all irrigation capacities. At the 0.1, 0.2, and 0.3 in/d capacities, SDI resulted in 4-year average cotton lint yields of 1109, 1190, and 1215 lb/ac, significantly higher by 14, 9, and 5 percent, than yields of the best LEPA treatments at 978, 1091, and 1156 lb/ac, respectively (P<0.05, Duncan). The increase in yield from SDI use was attributed to less soil surface evaporation and more available crop water under SDI than under LEPA.

Table 1. Average annual water use and cotton lint yield resulting from irrigation with LEPA and SDI at three irrigation capacities and up to three irrigation intervals.

Irrigation Capacity (in/d)	Average Annual Irrigation (in/y)	Total Water[1/] (in/y)	Cotton Lint Yield (lb/ac)				
			Preplant Irr. Only	SDI 24 h	LEPA 24 h	LEPA 48 h	LEPA 72 h
0.0	0.0	12.4	539				
0.1	5.2	17.2		1109 a[2/]	897 c	978 b	911 c
0.2	7.1	18.8		1190 a	1091 b	1077 b	1088 b
0.3	7.3	19.0		1215 a	1113 bc	1101 c	1156 b
Avg.				1171 A	1034 B	1052 B	1052 B

[1/] Average change in seasonal soil water content (mid June to frost, neutron attenuation to 5 ft depth) + effective seasonal rainfall (planting to frost) + seasonal irrigation.

[2/] Values in a row followed by the same letter are not statistically different (0.05 Duncan)

Economic Analysis

Comparisons of the net return to management and risk of LEPA and SDI systems using various economic assumptions and based on average lint yields are depicted in Figures 1 through 3. Figure 1 contrasts the two delivery systems as a function of irrigation capacity with the assumed initial cost of $333/ac for LEPA, and both $600/ac and $800/ac for SDI. Other assumptions include a pumping depth of 300-ft, life expectancy of both LEPA and SDI systems of 20 years, and yield response at 100 percent of the corresponding treatment yields during the 1995-1998 experiment. Figure 1 shows that both LEPA and SDI resulted in positive net returns of at least $80/ac, regardless of initial cost of system or irrigation capacity. Notice, that the net returns of the $800/ac SDI scenario were very close to those of LEPA at the irrigation capacity of 0.1 in/d. However, as irrigation capacity exceeded 0.1 in/d, net return increased much faster for LEPA than SDI. This is due to increased water use efficiency of LEPA with increased irrigation capacity compared to consistently high water use efficiencies of SDI. When the initial cost of SDI was reduced to $600/ac, net returns from the SDI treatments at $120/ac were much higher than LEPA and increased with irrigation capacity. This implies that SDI is a viable irrigation delivery system for cotton production and may be a better alternative than LEPA in situations where LEPA installation costs are higher that $333/ac or irrigation capacity is at or near 0.1 in/d.

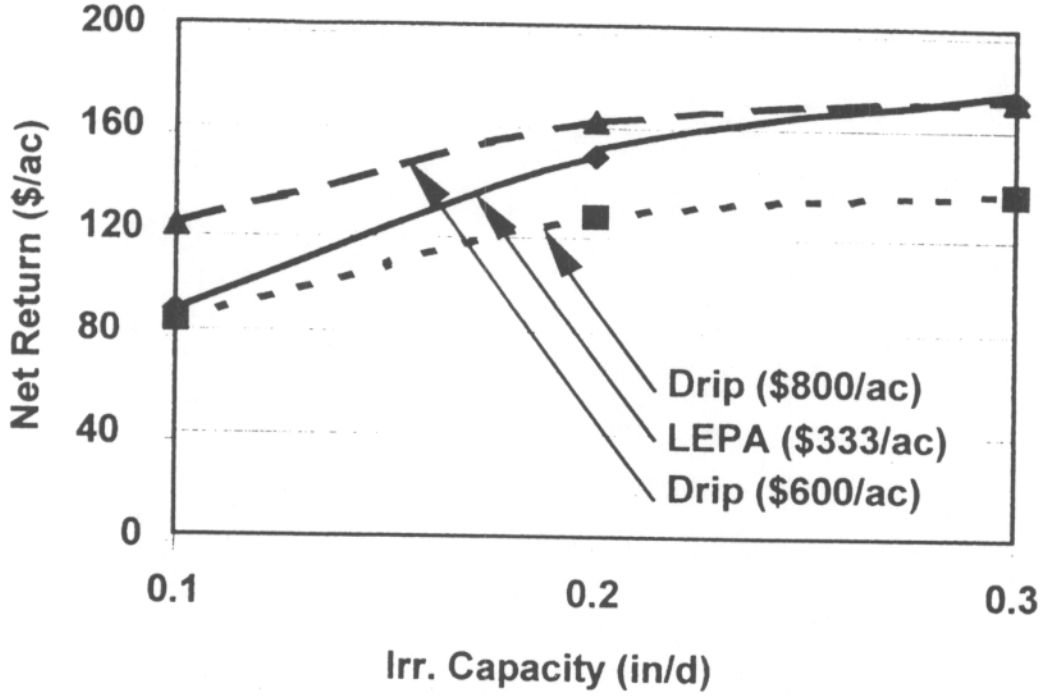

Figure 1. Net return of LEPA and SDI at irrigation capacities of 0.1, 0.2, and 0.3 in/d, with pumping depth of 300 ft and system life expectancy of 20 years.

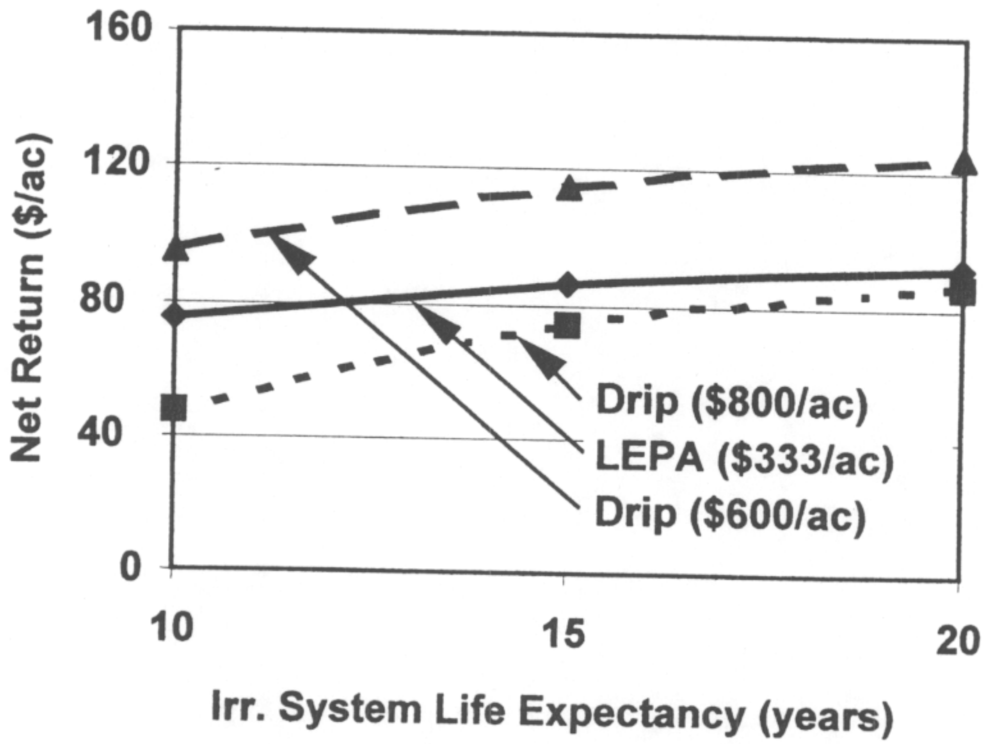

Figure 2. Net returns of LEPA and SDI irrigation systems with life expectancies of 10, 15, and 20 years, with pumping depth of 300-ft and irrigation capacity of 0.1 in/d.

Figure 2 shows the effect on net returns of irrigation system life. Assumptions included pumping depth of 300-ft, irrigation capacity of 0.1 in/d, and yield response at 100 percent of treatment yield. SDI at $800/ac resulted in a net return ranging from $46/ac to $87/ac, almost a 90 percent increase, as system life increased from 10 to 20 years. Net returns of the LEPA system were much less sensitive ranging from $75 to $95/ac over the 10-year period. As one would expect, as initial SDI costs were reduced to $600/ac, net returns became less sensitive to the life expectancy of the system.

The level of yield required to cover fixed and variable expenses is an important benchmark for cotton producers considering installation of a sophisticated irrigation system. Figure 3 displays net returns for LEPA and SDI systems at 80 and 100 percent of the average annual treatment yields assuming 300-ft pumping depth, 0.1 in/d irrigation capacity, system life expectancy of 20 years, and initial SDI installation cost of $800/ac. By assuming a linear relation between yield and net return, the quantity of cotton lint yield required to meet expenses was found to be approximately 812 lb/ac for LEPA and 955 lb/ac for SDI. Additional analysis showed that increases in irrigation capacity would not significantly alter the break even cotton lint yield requirements found.

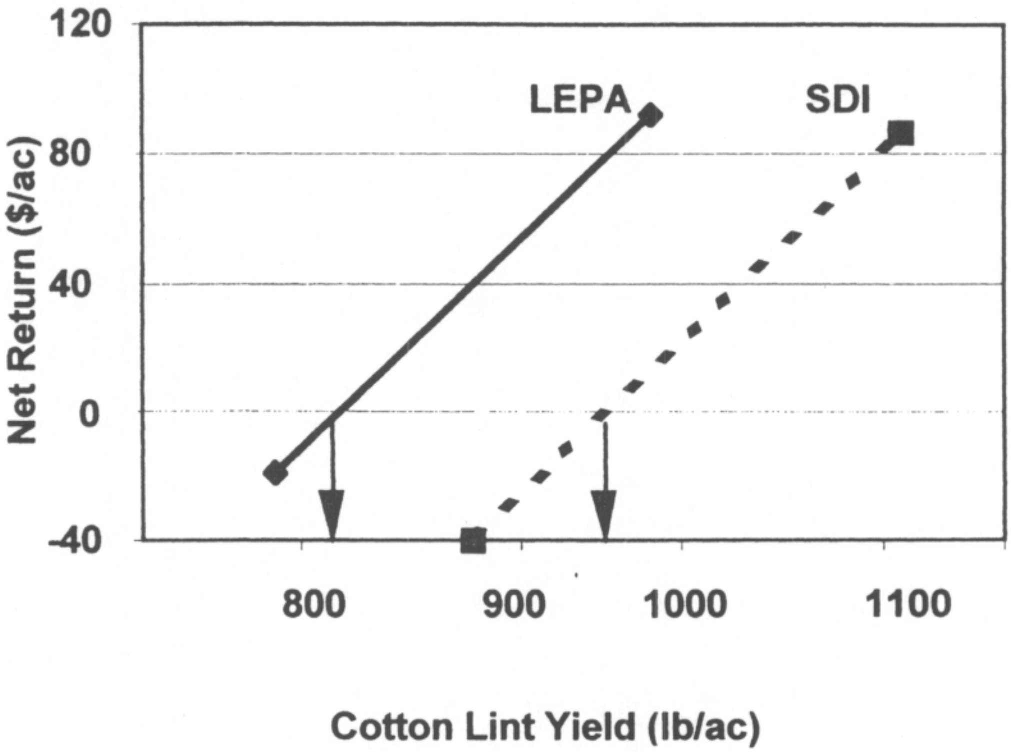

Figure 3. Comparison of net return and break even cost for installation of LEPA and SDI irrigation systems, with pumping depth of 300 ft, irrigation capacity of 0.1 in/d, system life expectancy of 20 years, and SDI cost of $800/ac.

SUMMARY AND CONCLUSIONS

In this study it is shown that both, LEPA and SDI systems can be managed to utilize available water resources while maintaining high cotton lint yields. Four-year average LEPA and SDI cotton lint yields of 1046 and 1171 lb/ac, respectively, resulted from using an average of 7.3-in or less of seasonal irrigation per year. As irrigation capacity increased, cotton lint yields also increased, however, the increase was small relative to the higher level of water applied. Average cotton lint yields ranged from a low of 897 lb/ac at 0.1 in/d (24-h, LEPA) to 1215 lb/ac at 0.3 in/d (24-h, SDI). Forty-eight hour LEPA irrigations increased lint yields compared to 24 and 72-h intervals at the 0.1 in/d capacity, with differences among interval treatments reduced as irrigation capacity increased. Cotton lint yields were higher for SDI than LEPA within all irrigation capacity treatments analyzed. SDI treatments resulted in significantly higher cotton lint yields than 48-h LEPA at the 0.1 in/d capacity (1109 versus 978 lb/ac, respectively) over the four-year period. Differences in cotton lint yields between LEPA and SDI treatments are attributed to higher water losses by the LEPA system due to soil surface evaporation.

The primary advantages of SDI over LEPA in cotton production are increased cotton lint yield and improved water use efficiencies, particularly at very low irrigation capacities. The advantages of LEPA over SDI include lower initial cost, lower management and maintenance requirements, less uncertainty about LEPA life expectancy, and the ability to apply foliar materials. An economic analysis of this data, demonstrated that LEPA would result in higher net returns to management and risk than a $800/ac SDI system, but that it would not be the case for a $600/ac SDI system. Also, LEPA resulted in much higher net returns as irrigation capacity increased above the 0.1 in/d level. However, the SDI system resulted in net returns of over $80/ac and may be an acceptable alternative to LEPA if installation costs are greater than $333/ac, physical constraints prevent the use of LEPA, or SDI installation costs are lower than $800/ac.

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Use of Weather-based Advisory Programs to Manage Peanut Foliar Diseases in South Texas

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ABSTRACT

Studies were conducted over a 2-year period at Yoakum, TX, using the Neogen EnviroCaster® equipped with models to time fungicide sprays for control of early leaf spot (*Cercospora arachidicola* S. Hori), late leaf spot [(*Cercosporidium personatum*) (Berk. & M. A. Curtis) Deighton] and rust (Puccinia arachidis Speg.) of peanut. Models used were version 4.5 of the early leaf spot advisory and version 2.5 of the late leaf spot advisory. The EnviroCaster® is a computerized weather station which collects weather data that drives the algorithms (models) and produces interpretive output. Advisory programs were compared to a 14-d calendar program in field plots of Florunner peanut. In both years, the incidence of early leaf spot and rust was heavy, while late leaf spot incidence was moderate in unsprayed plots. The fungicides chlorothalonil and tebuconazole were applied according to each spray program to control disease. Plots managed by 14-d calendar program with chlorothalonil or tebuconazole had significantly lower incidence of leaf spot ($P \leq 0.05$) than advisory programs each year. Plots managed by 14-d calendar program with chlorothalonil or tebuconazole had significantly lower incidence of leaf spot ($P \leq 0.05$) than advisory programs each year. Plots receiving four sprays in 1991 and three sprays in 1992 with chlorothalonil according to the late leaf spot (LLS) advisory showed levels of rust that were not significantly higher than plots receiving eight sprays on the calendar schedule. Plots treated with four tebuconazole sprays according to the LLS advisory model had significantly higher levels of rust ($P \leq 0.05$) than plots sprayed on a 14-d schedule or either of the early leaf spot (ELS) or combination early leaf spot/late leaf spot (ELS/LLS) advisories in 1991. Plots sprayed according to the ELS/LLS combination model in 1992 with tebuconazole had significantly less rust ($P \leq 0.05$) than the calendar or the ELS or LLS advisories. Although results from both years show a higher disease incidence in advisory programs compared to the 14-d program, there were no significant differences in yield ($P \leq 0.05$) among any of the programs. These results imply that the number of sprays can be reduced without sacrificing yield and the timing of sprays is important in managing foliar diseases in Texas.

KEYWORDS: advisory program, peanut diseases, fungicides, groundnut

Early and late leaf spot of peanut (Arachis hypogaea L.) are caused by Cercospora arachidicola S. Hori and Cercosporidium personatum (Berk. & Curt.) Deighton, respectively. Either disease can cause severe defoliation and reduced pod yield over 50% (Smith and Littrell, 1980). Peanut rust, caused by Puccinia arachidis Speg., can also be a destruc-

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tive disease of peanut when it becomes established early in wet seasons (Wells, 1962). This disease has been reported in all production areas of the United States (Jackson and Bell, 1969). Epidemics each year are thought to originate from subtropical areas since the fungus apparently does not overwinter in this country (Wells, 1962). While factors such as moldboard plowing, crop rotation and resistant cultivars may lessen leaf spot severity, the single most effective method of control has been the use of fungicides (Smith and Littrell, 1980). In the absence of agronomically-accepted cultivars with resistance to leaf spot diseases, multiple applications of fungicide have been justified in numerous field studies of disease management (Smith and Littrell, 1980; Johnson et al., 1986a; Knudson, et al., 1988). Fungicides have traditionally been applied on a 10-14 d schedule beginning at 30-40 d after planting (DAP) to control foliar disease. However, this relatively expensive spray program has spurred research on weather-based advisory programs improving the efficiency of fungicide use in disease management. (Jensen and Boyle, 1966; Parvin, et al., 1974; Phipps and Powell, 1984; Matyac and Bailey, 1988; Cu and Phipps, 1993; Davis et al., 1993; Damicone et al., 1994; Jacobi and Backman, 1995).

Early and late leaf spot and rust can be very prevalent on peanut in south Texas where producers usually initiate fungicide sprays at 30-45 DAP and apply an average of 5.6 sprays per season (Clyde Crumley, personal communication). Extension recommendations for Texas include starting fungicide sprays at 35-55 DAP and continuing sprays at 10-14 d intervals. However, the use of fungicide sprays can have consequences in addition to capital expense. In the early 1970s, *C. arachidicola* and *C. personatum* developed resistance to benomyl, a benzimidazole carbamate fungicide (Clark et al., 1974; Littrell, 1974). With the registration of sterol demethylation inhibiting fungicides (DMI's) in the United States, concerns are warranted about fungicide resistance resulting from the intensive use of these products (Koller and Scheinpflug, 1987). The DMI's have been tested extensively and proven to be highly effective against both foliar and soilborne diseases of peanut (Brenneman and Murphy, 1991, Brenneman et al., 1991). Cu and Phipps (1993) proposed that the effects of fungicide programs on nontarget organisms, soil compaction and vine injury by tractor tires, and the cost of fungicides can be minimized by reducing the frequency of fungicide applications.

The weather-based advisory spray program was proposed by Parvin et al. (1974) to provide an alternative to calendar-based applications of fungicides. This program was designed to recommend fungicide application only during periods when environmental conditions were favorable for disease development. Their system used the duration of periods with relative humidity (RH) above 95% and minimum air temperature during periods of high RH to detect conditions favoring inoculum production and infection by C. arachidicola . Relative humidity was used in this system as an indirect measurement of leaf wetness (Jensen and Boyle, 1966). Temperature and the duration of period of RH > 95% have an effect on infection by early and late leaf spot (Jensen and Boyle, 1965, 1966; Alderman and Beute, 1986; Shew et al., 1988). Since then, the use of temperature, relative humidity and leaf wetness have been used to develop improved models for precise timing of fungicide sprays for disease management (Nutter and Culbreath, 1991; Cu and Phipps, 1993).

Weather based, advisory programs are being used successfully in several peanut production areas (Bailey et al., 1994; Phipps et al., 1997). Field studies in the southeast and the Virginia-Carolina area have compared advisory programs and 14-d program effects on various diseases, yield and economic return (Phipps and Powell, 1984; Johnson et al., 1985, 1986b; Matyac and Bailey, 1988). Overall, the results of these studies indicate that a) leaf spot advisories can reduce the number of fungicide applications for leaf spot control without risk of loss in crop yield and value (Powell et al., 1980; Phipps and Powell, 1984; Matyac and Bailey, 1988; Cu and Phipps, 1993; b) leaf spot incidence may be greater where an advisory program is used, but yields do not differ significantly from plots sprayed on a 14-d program; (Phipps and Powell, 1984; Matyac and Bailey, 1988; Cu and Phipps, 1993; Damicone et al., 1994); and c) advisory programs improve the efficiency of production by reducing input costs, crop injury that may increase the severity of some soil borne diseases and soil compaction by spray equipment (Monzingo, 1981). Furthermore, reductions in the number of fungicide applications can reduce input costs, the environmental impact of fungicides, and the potential risk for fungal populations to become highly resistant to certain fungicides (Bent, 1978). The use of advisory sprays may result in lengthening the life of the new DMI fungicides by using them in timed, precise applications.

This paper reports the results of field evaluations of leaf spot advisory programs used in South Texas and compares performance to a 14-d spray program. The paper also reports on field evaluations of rust control by using leaf spot advisory programs.

MATERIALS AND METHODS

Field trials were conducted during 1991 and 1992 at the Yoakum Experiment Station in Lavaca County, Texas. The soil type was a Tremona loamy fine sand with a pH of 7.7, and the site was planted to peanut the previous two years. Field preparation each year included moldboard plowing followed by disking and bedding of rows. Fertilizer was applied prior to planting according to soil test recommendations. Herbicide was preplant incorporated with a power tiller at recommended rates. Florunner peanut seed was planted at approximately 100 lb/A following herbicide treatment on 25 Jun and 8 Jun in 1991 and 1992, respectively. The experimental design was a randomized complete block with four replicates per treatment. Plots were two rows 20 ft long spaced 3 ft apart. Two unsprayed border rows were between treatment rows to serve as a source of disease inoculum and provide a buffer zone for protection against spray drift.

Foliar sprays of fungicides were applied according to advisories issued by the Neogen EnviroCaster®, (Neogen Corp., Lansing, MI) or a 14-d calendar schedule. The EnviroCaster microprocessor was equipped to issue advisories for early and late leaf spot. Also an early/late leaf spot model combination in which either advisory could call for fungicide spray was used. In addition to a microprocessor and printer, components included a rain gauge, temperature/relative humidity sensor and leaf wetness sensor. The temperature /relative humidity sensor was placed over a test field peanut row at a height of 18 in while the leaf wetness sensor was placed in a peanut row in the lower canopy. The computerized weather station recorded data every 15 minutes and stored records for up to 20-d. This data was accessed by Liquid Crystal Display and printer at the test site.

The EnviroCaster Version 4.5 early leaf spot model was used to issue advisory sprays. The model uses a temperature range of 60.8°F to 89.6°F during periods of > 95% relative humidity to issue index units leading to a spray advisory. The late leaf spot model used Version 2.5. All that is known about this model is that a temperature range above 60.8°F during 10 hours of leaf wetness would issue indices leading to a spray advisory.

Chlorothalonil (Bravo 720®) was applied at 1.5 pt/A while tebuconazole (Folicur 3.6®) was applied at 6.66 fl oz/A. Tebuconazole was tank mixed with a non-ionic wetter/spreader adjuvant (Induce®) at 0.06% v:v. Sprays were applied with a CO_2 pressurized backpack sprayer equipped with a two-row boom having three nozzles (D2 tips, #13 cores and slotted strainers) per row. Foliar sprays delivered 15 gal/A at 64 psi with a ground speed of 3.0 mph. All advisory treatment plots were sprayed with fungicide within 24-72 hr of the respective advisory.

In 1991, sprays on the 14-d schedule were initiated at 30 DAP, with a total of eight sprays being applied. Accumulation of weather data for each advisory program leading to spray advisories was initiated at average emergence of the peanut crop which was 10 DAP each year. The early leaf spot advisory called for the initial spray at 23 DAP with a total of six sprays being applied. The late leaf spot advisory called for the initial spray at 30 DAP and a total of four sprays were applied. In the early/late leaf spot advisory combination program, a total of six sprays were applied starting at 23 DAP. All sprays on the early/late leaf spot advisory were determined by the early leaf spot model except the application on 16 Sep which was according to both the early and late leaf spot advisory models. When an advisory spray was applied, the date was entered into the EnviroCaster along with a 14-d protection period against disease; the advisory model then started accumulating data for the next advisory spray after the protection period expired.

Two mainstem assessments were performed during the 1991 growing season on 9 Sep and 30 Oct. Data presented in Table 1 are from the final disease assessments of each year's test. Mainstems from four randomly selected locations in each plot were removed. The number of nodes, expanded leaflets, defoliated leaflets and leaflets with lesions of early or late leaf spot were counted on each stem. Percentages of infected and defoliated leaflets were calculated (Davis et al., 1993; Jacobi and Backman, 1995). In addition to percent leaf spot infection, rust infection percentages were determined on 30 Oct when the disease was prevalent using the same method employed in determining leaf spot infection. Rainfall from 25 Jun to 11 Nov 1991 totaled as 15.6 in. Plots were sprinkler irrigated with 7.5 in of supplemental water during the growing season. Plots were dug and inverted on 11 Nov. Due to adverse weather that delayed combining, plants were placed in burlap bags and dried on a forced air dryer. Pods were then removed from the vines with a stationary thresher. Pods were dried to approximately 10% moisture and then cleaned to remove foreign material before weighing to determine plot yield. A 1.1 lb sample of peanuts from each plot were graded according to Federal State Inspection Methods (U.S. Dept. Of Ag. 1986; Jacobi and Backman, 1994). Economic values ($/A) were calculated based on U.S. loan support schedule.

In 1992, sprays on the 14-d schedule were initiated at 30 DAP. Eight 14-d sprays were applied. Five sprays were applied according to the early leaf spot advisory beginning at 24 DAP. The late leaf spot advisory called for three fungicide sprays initiated at 28 DAP. The combined advisory late/early model received five fungicide applications starting at 24 DAP. The 22 Jul spray advisory was issued simultaneously by the early and late leaf spot models. The 2 Sep advisory was issued by the late leaf spot model.

Disease evaluations for the 1992 study included mainstem assessments which were done on 14 Sep and 21 Oct. The 21 Oct count included an evaluation of rust. Rainfall recorded at the 1992 test site totaled 8.5 in from 8 Jun to 29 Oct. Supplemental water provided by sprinkler irrigation provided an additional 18.8 in. Test plots were dug and inverted on 29 Oct. Plots were air dried in the field and threshed on 3 Nov. Yield and grade determination after harvest were the same as defined for the 1991 test.

All data were subjected to an analysis of variance and significant differences were determined by Duncan's Multiple Range Test ($P < 0.05$). Arcsine transformed data were used for analysis of variance determination for percent leaf spot, rust and defoliation (Steel and Torrie, 1980). Untransformed numerical means and transformed groupings are reported in the results. Data were not combined over years due to significant treatment-by-year interactions for all parameters.

RESULTS

The incidence and severity of early leaf spot and rust were excessive in both years of this study, while late leaf spot pressure was moderate. Epidemics of rust were helpful in evaluating the utility of peanut leaf spot advisory programs.

In both years, there was an equal amount or more leaf spot and rust disease in the advisory treatments than the calendar treatments (Table 1). There was one exception in the 1992 test in which the ELS/LLS program using tebuconazole resulted in less rust than the calendar treatment. It is important to note that in the 1991 test the level of infection from leaf spot, as measured by leaf spot incidence, from the 14-d chlorothalonil and tebuconazole treated plots was not different from the untreated control. The level of rust infection between the ELS and ELS/LLS combination advisory plots sprayed with tebuconazole and the 14-day schedule plots sprayed with tebuconazole was also not different from the untreated control. This was due in both of the above respective cases, to the high level of defoliation (90%) from leaf spot in the untreated plots, resulting in fewer leaflets to count as infected by leaf spot and rust in the untreated plots thereby causing a false low infection percentage (10%) for leaf spot and rust (Table 1). Defoliation in each years test was equal to or greater in the advisory treatment than the calendar treatments.

In each year's test, although the advisory treated plots received fewer chlorothalonil and tebuconazole sprays and had numerically higher levels of leaf spot and rust than the 14-d treatments, there was no difference in yield. In the 1992 test, tebuconazole sprayed plots according to the ELS/LLS combination advisory had an increase in yield over chlorothalonil plots sprayed by the same advisory. Leaf spot and rust reduced yield of the untreated control compared to advisory and 14-d treatments in each year's test. Plots sprayed by advisory did not differ in value ($/A) from plots sprayed on the 14-d schedule from either fungicide in 1991 but values were higher than the untreated control. The same statement is true for the 1992 test with the exception of the tebuconazole ELS/LLS combination treatment which resulted in a statistically higher ($/A) figure than the chlorothalonil sprayed plot by the same advisory.

DISCUSSION

In both years of testing, even though the level of leaf spot disease was higher in advisory plots receiving fewer sprays, yields did not differ significantly from 14-d treatment yields. This data agrees with that of the studies cited earlier in this paper. Since differences in yield were not evident in each year under additional rust pressure, the data from these tests implies control of rust was achieved by ELS and LLS advisory sprays for leaf spot. There was no yield advantage with chlorothalonil or tebuconazole over each other in relation to the number or frequency of sprays applied in this study. It is the authors opinion that the peanut plant may have the ability to compensate for yield under slightly higher disease pressure, as was the case with advisory programs. The peanut plant may react in periods of stress, such as degree of leaf spot incidence, to compensate for damage done by slight infection. The results indicate that the peanut plant can tolerate a certain level of disease without loss in yield. Growers should not be overly concerned about seeing moderate levels of foliar disease in fields which are sprayed according to advisory programs.

While both early and late leaf spot are present in south Texas, rust is also a major disease which can result in yield and economic losses. The data presented here showed leaf spot and rust were controlled by fewer applications of fungicide when the timing of sprays

Table 1. The effect of fungicides and spray programs on disease incidence, yield and value of Florunner peanuts in 1991 and 1992[a].

Fungicide[b]	Spray program[c]	No. of sprays	Incidence: Leaf spot[d]	Incidence: Rust[e]	Incidence: Defoliation[f]	Yield	Value
			%	%	%	lb/A	$/A
1991							
Chlorothalonil	ELS	6	34 a	42 ab	47 b	3307 a	1200 a
Chlorothalonil	LLS	4	29 ab	40 ab	48 b	3409 a	1203 a
Chlorothalonil	ELS; LLS	6	35 a	52 a	38 b-d	3085 a	1089 a
Chlorothalonil	14 DAY	8	14 d	35 b	25 d	3281 a	1132 a
Tebuconazole	ELS	6	25 bc	15 c	40 bc	3669 a	1322 a
Tebuconazole	LLS	4	21 c	33 b	49 b	3312 a	1194 a
Tebuconazole	ELS; LLS	6	24 bc	13 c	45 b	3295 a	1177 a
Tebuconazole	14 DAY	8	10 d	7 c	31 cd	3405 a	1204 a
Untreated check			10 d	10 c	90 a	1932 b	703 b
1992							
Chlorothalonil	ELS	5	15 bc	68 a	32 c	3888 ab	1415 ab
Chlorothalonil	LLS	3	24 a	59 ab	41 b	3541 ab	1295 ab
Chlorothalonil	ELS; LLS	5	15 bc	67 a	32 c	3410 b	1214 b
Chlorothalonil	14 DAY	8	4 d	56 b	29 c	4268 ab	1536 ab

Table 1. (Cont'd.)

Fungicide[b]	Spray program[c]	No. of sprays	Incidence: Leaf spot[d]	Incidence: Rust[e]	Incidence: Defoliation[f]	Yield	Value
			%	%	%	lb/A	$/A
Tebuconazole	ELS	5	24 a	53 b	42 b	3939 ab	1395 ab
Tebuconazole	LLS	3	25 a	56 b	44 b	3622 ab	1292 ab
Tebuconazole	ELS; LLS	5	19 ab	37 c	30 c	4606 a	1663 a
Tebuconazole	14 DAY	8	9 c	51 b	29 c	4254 ab	1558 ab
Untreated check			26 a	32 c	68 a	2144 c	789 c

[a]Means within a given year and column followed by the same letter indicate Duncan's multiple range groupings of treatments which do not differ significantly (P=0.05).

[b]Chlorothalonil (Bravo 720) used at 1.5 pt/A and tebuconazole (Folicur 3.6F) used at 6.66 fl oz/A plus Induce at 0.06% (v:v).

[c]ELS (early leaf spot advisory) sprays were applied six times in 1991 and five times in 1992. ELS advisory sprays were initially applied at 23 days after planting (DAP) in 1991 and 24 DAP in 1992. LLS (Late leaf spot advisory) sprays were applied 4 times in 1991 and three times in 1992. LLS advisory sprays were applied at 30 DAP in 1991 and 28 DAP in 1992. The 14 d sprays were applied 8 times each year starting at 30 DAP. ELS/LLS combination advisory sprays were applied six times in 1991 and five times in 1992. ELS/LLS sprays were initiated at 23 DAP in 1991 and 24 DAP in 1992.

[d] Final leaf spot incidence (percent leaflets with lesions) assessed on 30 Oct. 1991 and 21 Oct. 1992.

[e]Final rust incidence (percent leaflets with lesions) assessed on 30 Oct. 1991 and 21 Oct. 1992.

[f]Final defoliation percentage assessed on 30 Oct. 1991 and 21 Oct. 1992.

was according to the ELS and LLS advisory program. Calendar spray schedules are based on the assumption of continuous infection by the pathogen. This may not be true during weather periods which are unfavorable for infection. Growers in south Texas have been and will likely continue to control leaf spot and rust with fungicides on other than a 14-d schedule as long as there is not a sustained yield loss to disease. Advisory sprays are valuable to time fungicide applications in that their predictions are based on accumulated weather data favorable for infection by the pathogen. It is important to point out that while advisory programs can save sprays, additional sprays can be advised if weather conditions are more favorable for disease progress. The use of disease forecasting models allow the use of fungicides on an as needed basis rather than a routine schedule.

In each year of the study, the ELS program called for the first spray at 23 and 24 DAP respectively. The early season sprays were advised first by the ELS model in each year due to temperature and relative humidity requirements being met by the model. The LLS model advised sprays at 30 and 28 DAP in 1991 and 1992, respectively. These early sprays may also be partly responsible for no yield differences between advisory and 14-d sprayed plots. The LLS advisory resulted in the least number of treatments each year but resulted in yields comparable to other fungicide treatments.

At present there is no advisory program being used in Texas commercial peanut production. South Texas growers could save from one and three sprays by using an advisory program. The use of the recently registered tebuconazole in a block or tank mix application with chlorothalonil for disease resistance management may suit an advisory program due to the systemic activity of this product. Since chlorothalonil must be present prior to spore germination to inhibit infection, timing of each application is critical to effective disease control (Nokes and Young, 1992; Elliott and Spurr, 1993). The systemic or curative action of tebuconazole may allow delays in fungicide application and result in fewer sprays than the protectant chlorothalonil (Cu and Phipps, 1993). Tebuconazole, in addition to having activity against leaf spot and rust is effective in controlling southern blight (Sclerotium rolfsii Sacc.) (Brenneman and Culbreath, 1994; Besler et al., 1996). Southern blight often occurs in fields affected by leaf spot and rust in south Texas. Sprays applied using this product need to be timed to achieve effective control not only of foliar disease but soilborne disease as well. An EnviroCaster® late leaf spot model (Version 3.0) has been enhanced for soilborne disease management (Anonymous, 1995). This model forecast indicates whether a leaf spot or leaf spot/southern blight spray should be applied. Tebuconazole can be applied for leaf spot/southern blight advisories issued from 50-100 DAP by this model. The company label rate restricts the number and quantity of tebuconazole treatments (Noegel, 1992). This product should work well in an advisory program due to its multi-target and systemic nature. The evaluation of tebuconazole in this study was below the label rate, but exceeded the seasonal cumulative dose in some of the treatments.

Weather-based advisory programs can provide producers with a tool needed to effectively and efficiently manage peanut disease. Since few south Texas producers spray according to a calendar schedule, weather-based advisories should fit into a management program. Weather-based advisory programs are being compared at this time to possibly be used in producer management programs.

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Comparison of Agricultural Gypsum with Power Plant By-Product Gypsum for South Texas Potato Production

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ABSTRACT

Field studies were conducted in 1998 and 1999 in Frio County to evaluate the effects of power plant by-product gypsum in comparison with agricultural gypsum applied at planting on potato (Solanum tubersum) production. 'Atlantic' and '1625' potato varieties were grown using rates of 1000 to 4000 lb/A of commercial agricultural grade gypsum and power plant by-product gypsum. Potato yield and quality were not affected by gypsum rate regardless of product source. In addition, no heavy metal accumulation in plant tissue was noted with by-product gypsum.

KEYWORDS: Atlantic, tuber, quality, yield, 1625.

Gypsum (calcium sulfate) is a common source of calcium and sulfur for many crops. It has a relativity high solubility and therefore is quickly available to plants. Because gypsum is a neutral salt, it will does not increase soil pH.

Gypsum is especially recommended as a source of calcium for peanuts (*Arachis hypogaea* L.) and potatoes (*Solanum tuberosum* L.) (Grichar et al. 1986; 1990; Harris, 1982; Vitosh, 1990). High yielding and good quality peanuts require adequate Ca in the top 3 in of soil during pegging and pod filling (Cox et al. 1982; Gascho et al. 1993). Gypsum has been reported as being effective in reducing the incidence and severity of bacteria potato soft rot (*Erwinia carotovora*) (Hooker, 1981; Wright 1995). Corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), and tobacco (*Nicotiana tabacum* L.) have responded to gypsum under acid soil conditions.

Calcium in potato tubers is primarily concentrated in the peel, and the lowest concentration is in the medullary tissue in the center of the tuber (Harris, 1982). The means by which calcium affects soft rot pathogenicity is not fully understood, but it seems likely that calcium improves the structural integrity of cell walls and membranes. It also may interfere with the activity of the pectic enzymes produced by the soft-rotting bacteria (Wright, 1995).

Fertilizer placement can significantly affect uptake of calcium by the potato tuber. Calcium can move directly into potato tubers via the stolon and tuber roots, so it is important that gypsum be placed near the zone in which the young tubers will grow (Wright, 1995).

The potato ranks fourth after wheat (*Triticum aestivum* L.), rice (*Oryza sativa* L.), and corn as an important source of food worldwide (Ulrich, 1993). In the United States, the potato has essentially moved to second place, replacing rice and even corn as a direct food source because of its culinary adaptability and the popularity of french fries at fast food establishments (Wright, 1995).

Potato production in south Texas has continued to increase in the past five years. Production in Frio County in 1999 was over 9000 acres. Due to demand and greater economic potential, more growers are interested in potato production (Scott Russell, personal communication). Gypsum is applied over many of the potato fields in south Texas without regard to gypsum calcium concentration. No information is available on use of gypsum on potatoes in the south Texas growing region. Therefore, the objective of this study was to evaluate the effects (if any) of power plant by-product gypsum on potato yield and quality in fields with high calcium levels.

MATERIALS AND METHODS

Field studies were conducted during the 1998 and 1999 growing seasons at three locations in Frio County to determine the effects of two sources of gypsum upon potato yield and quality. Agricultural gypsum obtained from a local distributor[1] was compared with gypsum obtained as a by-product of a coal-generated power plant[2] located near LaGrange, TX. Representative samples of agricultural gypsum and by-product gypsum were collected prior to study initiation and submitted to the Texas Agricultural Extension Service Soil Test Laboratory for chemical analysis.

Soils at all locations were a Duval loamy fine sand (fine-loamy, mixed, hyperthermic Aridic Haplustalfs) with < 1% organic matter and a pH of 7.1 to 7.3. The '1625' potato variety was planted 28 January 1998 while the 'Atlantic' variety was planted 16 January 1998 and 11 January 1999. Potatoes were mechanically planted approximately 12 in apart using a commercial planter furnished by a local potato grower-distributor.[3]

Gypsum at rates of 1000, 2000, 3000, and 4000 lbs/A were hand applied to plots within three wk of potato planting. The gypsum for each plot was pre-weighed, spread over the potato row and lightly raked into the soil surface. Within 1 to 2 wks of application, the test area was furrow-diked and potatoes 'hilled' with 2 to 4 in of soil pulled from middles over each row. Fungicide, herbicide, and insecticide programs closely followed standard industry practices.

Plot size was 4 rows 12 ft wide by 30 ft. The treatment design was a factorial (two types gypsum by four rates) randomized complete block with four replications. An untreated check was included for comparison. Rainfall for the 1998 growing season was 6.0 inch while in 1999 rainfall was 10.7 inches. Supplemental irrigation was applied in each year to bring up the water applied to test plots of approximately 21 inches.

Treatment response data were obtained from the middle two rows of each plot to prevent edge effects from adjacent plots on soil chemical properties and potato yield. Soil core samples were taken prior to the initiation of each trial and at the conclusion of each growing season for soil chemical analysis. Soil cores were divided into increments of 0 to 6, 6 to 12, 12 to 28, 18 to 24, and 24 to 36 in. Samples were analyzed by the Texas Agricultural Extension Service (TAES) Soil, Water, and Forage Testing Laboratory in College Station, Texas. Since no differences were noted at any depths, only those at the 0 to 6 inch depth are reported.

At harvest, plots were hand dug in 1998 and mechanically dug in 1999. All potatoes greater than 1.0 inch in circumference were collected and total weight was determined for each plot. In 1998, three potatoes were collected at random from each plot of the untreat-

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[1]Hoe-Down, Standard gypsum Crop, 1650 Gypsum Mine Rd., Fredricksburg, TX 78624.

[2]Boral Material Technologies Inc., San Antonio, TX 78216.

[3]Black Gold, Pearsall, TX.

ed check and the 4000 lb/A rate of agricultural and by-product gypsum for laboratory analysis. Samples were thin cut into 1/4 in sections, allowed to dry for 7 d at 65°C and ground to a pass a 1/16 in screen. Tissue samples were analyzed by the TAES Soil, Water, and Forage Testing Laboratory for N, P, K, Ca, Na, S, salinity and selected heavy metals.

Yield data were evaluated using analysis of variance. Since there was not a variety by location interaction, potato yield data were combined for analysis. Means were separated using Duncan's multiple range test ($P = 0.05$), where appropriate.

Potato tissue data were statistically analyzed by variety to evaluate differential absorption of elements. The numeric values for each element were subjected to ANOVA and means separated using Duncan's multiple range test ($P = 0.05$).

RESULTS AND DISCUSSION

Gypsum composition. Chemical analysis of the two gypsum sources indicated that by-product gypsum contained greater concentrations of boron, chloride, fluoride, magnesium, potassium, and sodium (Table 1). Concentrations of Ca and S were similar for the two products, thus any differences in plant uptake likely would be attributed to variations in solubility (author's personal opinion). Moisture levels were higher in by-product gypsum compared to agricultural gypsum.

Table 1. Chemical composition of by-product gypsum and agricultural gypsum.

Component	By-product gypsum	Agricultural gypsum
	------------------------mg/kg----------------------	
Aluminum	< 0.05	< 0.05
Arsenic	< 0.01	< 0.01
Barium	0.09	0.06
Boron	0.25	0.12
Calcium	590	570
Cadmium	< 0.005	< 0.005
Chromium	< 0.01	< 0.01
Copper	< 0.02	< 0.02
Iron	< 0.02	< 0.02
Lead	< 0.005	< 0.005
Magnesium	12.0	< 0.5
Manganese	< 0.01	0.01
Mercury	< 0.0002	< 0.0002
Molybdenum	< 0.02	< 0.02
Nickel	< 0.02	< 0.02
Phosphorus	< 1.0	< 1.0
Potassium	3.7	< 1.0
Selenium	< 0.01	< 0.01
Silver	< 0.01	< 0.01
Sodium	41.0	0.92
Vanadium	< 0.02	< 0.02
Zinc	0.06	0.1
Chloride	40.0	< 1.0
Sulfate	1580.0	1500.0
Sulfur (%)	14.3	16.3
pH	7.3	8.0
Moisture (%)	20.0	1.0

Potato yield. Application of either type of gypsum did not increase potato yield compared to the untreated check (Table 2). Yields tended to be greatest in the check plots, averaging over 20,000 lb/A. Yields in the by-product gypsum plots tended to decrease slightly with increasing gypsum rates, although differences among treatments were not significant. Although calcium has been found to aid in reducing potato diseases, calcium in the form of gypsum has not been reported to improve potato yields. In contrast, research in the southeast has shown that calcium deficiency in peanuts limits yields more often than any other plant nutrient (Cox et al., 1982). A portion of the low yield attributed to calcium deficiency is due to pod rot (Walker and Csinos, 1980). Grichar and Boswell (1986; 1990) reported that peanut plots treated with gypsum consistently had higher yields and lower incidence of pythium pod rot (*Pythium myriotylum* Drechs.). Csinos et al. (1984) suggested that fungi are secondary in the peanut pod disease complex with nutritional deficiency or imbalance being the primary cause.

Table 2. Effect of gypsum on potato yield combined over years.

Treatment	Gypsum rate	Yield
	---lb/A---	
Untreated	-	20,166 a[1/]
By-product gypsum	1000	19,109 a
By-product gypsum	2000	19,476 a
By-product gypsum	3000	17,444 a
By-product gypsum	4000	16,676 a
Ag gypsum	1000	19,299 a
Ag gypsum	2000	18,773 a
Ag gypsum	3000	19,967 a
Ag gypsum	4000	19,400 a

[1/] Means within a column followed by the same letter are not significantly different at the 5% probability level by Duncan's New Multiple Range test.

Calcium deficient potato plants are spindly, with small, upward rolling, crinkled leaflets having chlorotic margins that later become necrotic. Tubers on calcium deficient plants develop diffuse brown necrosis in the vascular ring near stolon attachments, and later similar flecks form in the pith. Tubers may be extremely small (DeKock et al. 1975; Hooker, 1981; Wallace and Hewitt, 1948). No calcium deficiency symptoms were observed on potatoes in this study.

Heavy metals in tissue. Analysis of potato tissue taken from tubers at harvest indicated differences among treatments relative to nutrient concentrations but no differences in heavy metal uptake (Table 3). Copper concentrations in tuber tissue from commercial agricultural gypsum plots were significantly greater than those in tissue from the untreated check, and a similar trend was observed for by-product gypsum plots.

Table 3. Levels of nutrients extracted from tissue of 'Atlantic' and '1625' potato varieties at harvest using gypsum at 4000 lbs/A.

	Atlantic			1625		
	Untreated	Ag gypsum	By-product gypsum	Untreated	Ag gypsum	By-product gypsum
	mg/kg					
Boron (B)	7.6 ab [1/]	8.2 a	6.1 b	17.1 a	11.8 b	9.3 b
Chromium (Cr)	1.6 a	2.4 a	1.7 a	2.0 a	1.7 a	1.8 a
Manganese (Mn)	13.4 a	15.6 a	15.2 a	12.7 a	1.7 a	1.8 a
Iron (Fe)	616.9 a	779.3 a	760.5 a	134.8 a	238.3 a	232.0 a
Nickel (Ni)	0.5 a	1.5 a	0.6 a	0.5 a	0.6 a	0.5 a
Copper (Cu)	11.6 a	9.1 a	15.5 a	7.9 b	14.5 a	10.0 ab
Zinc (Zn)	16.7 a	21.1 a	20.8 a	23.2 a	24.9 a	25.6 a
Arsenate (As)	3.3 a	4.0 a	3.9 a	2.1 a	2.1 a	2.1 a
Selenium (Se)	1.2 a	1.3 a	0.9 a	1.6 a	1.4 a	0.7 a
Molybdenum (Mo)	1.2 a	0.8 a	0.6 a	2.2 a	1.1 a	1.0 a
Cadmium (Cd)	0	0	0	0	0	0
Lead (Pb)	0.12 a	1.7 a	1.1 a	4.8 a	3.3 a	4.9 a
Aluminum (Al)	522.5 a	645.9 a	669.3 a	134.5 a	239.8 a	199.8 a
Vanadium (V)	1.9 a	2.8 a	2.3 a	1.4 a	1.4 a	1.1 a
Mercury (Hg)	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Barium (Ba)	10.4 a	10.5 a	10.8 a	11.1 a	10.0 a	10.0 a

[1/] Means within a row and potato variety followed by the same letter are not significantly different at the 5% probability level by Duncan's New Multiple Range test.

In addition, boron concentrations were significantly lower in plots treated with 4000 lb/A of by-product gypsum compared to untreated plots. No other differences in tissue concentrations of elements were observed among gypsum treatments.

Soil pH. No differences in soil pH due to either gypsum treatment were noted (data not shown). This was expected since gypsum has no effect on soil pH (Buckman and Brady, 1969).

Soil elements. Average extractable soil Ca and S concentrations tended to increase with increasing rates of gypsum application, regardless of product source (Table 4). Extractable soil Ca and S increases were similar for both sources suggesting similar levels of nutrient solubility. Extractable N,P,K, Na and soil salinity were not affected by gypsum treatment.

CONCLUSION

Application of by-product gypsum did not significantly affect potato yield in 1998 or 1999. In addition, although concentrations of several elements were greater in by-product gypsum compared to commercial agricultural gypsum, few differences in tissue concentrations were observed. Increases in extractable soil Ca and S indicated that solubility and potential plant availability are similar for by-product gypsum and commercial agricultural gypsum. One advantage of gypsum may be to aid in the digging process by

Table 4. Concentration of various elements and salinity at the 0 to 6 inch soil depth taken after potato harvest at the three locations.

Treatment	Gypsum rate (lb/ac)	N[a]		P[b]		K[c]		Ca[d]		Na[f]		S[g]		Salinity[e]	
		ppm													
		X[h]	Range	X	Range	X	Range	X	Range	X	Range	X	Range	X	Range
Untreated	-	13	7-23	78	65-99	284	244-323	1463	1411-1515	71	42-113	70	48-135	178	130-398
By-product gypsum	1000	14	5-23	70	64-79	291	269-323	1507	1401-1613	75	35-127	80	52-103	318	208-438
By-product gypsum	2000	13	5-23	54	51-58	277	246-329	1659	1522-1795	83	30-136	84	74-102	284	183-374
By-product gypsum	3000	13	1-28	89	69-101	302	248-379	1664	1559-1768	69	40-112	106	69-171	334	234-419
By-product gypsum	4000	13	4-26	85	52-139	312	288-356	1687	1572-1802	72	30-141	115	78-143	359	208-439
Agricultural gypsum	1000	11	3-19	82	63-118	298	263-362	1610	1374-1846	74	45-110	69	33-93	257	182-310
Agricultural gypsum	2000	11	2-21	85	61-119	320	244-442	1709	1676-1741	72	40-127	82	75-87	325	221-390
Agricultural gypsum	3000	13	2-23	83	59-125	319	239-430	1737	1708-1766	65	35-115	104	75-130	307	201-423
Agricutural gypsum	4000	16	2-33	82	59-113	271	260-277	1712	1687-1737	73	46-114	118	74-162	365	169-553

[a]Values for nitrogen (N) are very low to low
[b]Values for phosphorus (P) are very high
[c]Values for potassium (K) are high to very high
[d]Values for calcium (Ca) are high to very high
[e]No salinity was noted
[f]Values for sodium (Na) are very low to low
[g]Values for nitrogen (N) are very low to low
[h]Mean value

reducing clod size and improving shedding of soil from potatoes (authors personal observation). Since by-product gypsum is about one-half the cost of agricultural gypsum, the reduced cost of by-product gypsum should be an advantage for producers on soils low in Ca and/or S. However the use of gypsum in fields with moderate to high calcium levels will not increase potato yield or quality and would not be economically feasible.

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Efficacy of Rhodamine B as a Fecal Marker for White-tailed Deer

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ABSTRACT

Rhodamine B has been used as a wildlife marker for microherbivores and mesopredators, but has yet to be evaluated for ruminants. Our objective was to determine the efficacy of rhodamine B as a wildlife marker for white-tailed deer (Odocoileus virginianus). We tested the effect of rhodamine B on the production of mold growth, the palatability, lag time, variable concentration effectiveness, and persistence of rhodamine B as a fecal marker in penned white-tailed deer. Liquid rhodamine B was added to corn and alfalfa-based, pelleted deer feed in concentrations of 0.06-oz. and 0.13-oz. of rhodamine B/lb. of grain and either placed in metal containers immediately or allowed a 1-hr drying period before being placed in metal containers. Grain samples that were sprayed with rhodamine and not allowed to dry produced mold quicker than non-marked grain; however, if the dye was allowed a 1-hr drying period immediately after application, then rhodamine B did not enhance mold production. Five deer (2 M, 3 F) were fed for two days a pelleted diet sprayed with a surface coating of 0.00045 oz. of rhodamine B/lb. body weight, and five deer (3 M, 2 F) were fed the same diet but sprayed with a surface coating of 0.0009 oz. of rhodamine B/lb. body weight, then fed a pelleted diet ad libitum thereafter without rhodamine B. Seven deer (n = 10) had feces marked during the first 12 hours and all deer produced marked feces after 36 hours. Rhodamine B persisted as a fecal marker up to 60 hours post-ingestion. White-tailed deer selected against feed that was marked by rhodamine B, but would consume feed that contained the dye. Rhodamine B can be a useful marker of white-tailed deer, especially if one wishes a non-lethal and noncapture method to determine animal movements.

KEY WORDS: Feces, fluorescent dye, marker, Odocoileus virginianus, palatability, rhodamine B, white-tailed deer

Rhodamine B is an industrial and analytical dye that has been used as an external marker to trace animal movements (Clover, 1954; Taber et al., 1956), aid animal identification (Wadkins, 1948), and determine animal use of baits (Farry et al., 1998). Its use as a biological marker has been evaluated in rodents (New, 1958; Gast, 1963), black-tailed jackrabbits (*Lepus californicus;* Evans and Griffith, 1973), mountain beavers (*Aplodontia rufa;* Lindsey, 1983), coyotes (*Canis latrans;* Johns and Pan, 1981; Farry et al., 1998), and birds (Wadkins, 1948; Paton and Pank, 1986). However, to our knowledge, rho-

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damine B has yet to be evaluated as a biological marker for white-tailed deer (*Odocoileus virginianus*).

When mixed with water the dye appears maroon, but fluoresces orange in color under UV light (approximate wavelength 366 nanometers) (Evans and Griffith, 1973; Fisher, 1999). Rhodamine B can be detected visually in concentrations as low as 0.1 part per billion (Gast, 1963; Fisher, 1999).

Lindsey (1983) reported that when ingested, rhodamine B can be used as a short-term marker of the gastrointestinal tract, urine, feces, and blood. Wadkins (1948) used rhodamine B as a short-term external marker of birds by spraying the dye directly onto feathers. Rhodamine B also was used as a long-term marker of claws and growing hair in coyotes (Johns and Pan, 1981).

Potential problems with the use of rhodamine B include reduced palatability of feeds (Webb and Hansen, 1961) and human health concerns (Kawachi et al., 1980). However, Fisher (1999) reported that no epidemiological evidence exists that suggests rhodamine B has carcinogenic, mutagenic, or teratogenic effects.

Our objectives were to determine 1) if mold growth was expedited due to the spraying of rhodamine B on two feedstuffs, 2) the concentration of rhodamine B required to mark feces of white-tailed deer, 3) the lag time required from ingestion of rhodamine B to produce marked feces, 4) the persistence of rhodamine B as a fecal marker in white-tailed deer, and 5) palatability of feed that was surface-coated with rhodamine B to white-tailed deer.

MATERIAL AND METHODS

Mold Growth Trials

Mold growth trials were conducted in the Lehmann Research Laboratory on the campus of Texas A&M University-Kingsville. Rhodamine B powder (Sigma Chemical, St. Louis, Mo.) was dissolved in water. A total of 15 lbs. of whole kernel corn (Wal-Mart, Kingsville, Tex.) and alfalfa-based deer pellets (Purina Mills, Inc., Gonzales, Tex.) was divided into 15 1.0-lb. samples, respectively. Grain samples were initially free from the appearance of mold. Five samples of corn and five samples of pellets were sprayed with a surface coating of liquid rhodamine B to yield minimum dosages of 0.06-oz. and 0.13-oz. of rhodamine B/lb. of grain. Minimum dose of 0.00045 oz. rhodamine B/lb. of animal body mass was needed to produce visible marks in coyote hair (Johns and Pan, 1981). Thus a minimum dosage of 0.06 oz. rhodamine B/lb. of grain was needed to achieve the recommended 0.00045 oz. rhodamine B/lb. of body mass, based on the mean mass of deer from southern Texas (132 lbs.; Cook, 1984) and assuming deer eat 1.0 lb. of rhodamine-dyed feed daily. The remaining five samples of each food type was used as a control. Samples were immediately placed in 1.0 lb. metal containers and sealed with a plastic lid. Metal containers were used to simulate feed being placed in 55 gallon drum feeders. Metal containers were stored at 76°F and 66% RH. Grain samples were checked every 24 hours and inspected for the presence of mold. Trials were arbitrarily discontinued after 20 days if mold was not present. Distributions of residual errors were tested for normality using the Shapiro-Wilk test (SAS Institute, Inc., 1989). Homogeneity of variances among treatments was evaluated with the Bartlett's test (Steel and Torrie, 1980). Because assumptions of parametric tests were satisfied, analysis of variance (SAS Institute, Inc., 1989) was used to test the effect of concentration of rhodamine B on the time required for mold to first appear. Multiple comparisons were made using Tukey's procedure when a significant F-test occurred (Ott, 1993). Tests were considered significant at $P < 0.05$.

A second trial was conducted similar to the one described above, except a 1 hr drying period was allowed before the grain was stored in the metal containers. Trials were arbitrarily discontinued after 45 days if mold was not present.

Fecal Marking Trials

Ten white-tailed deer (5 M, 5 F) were individually housed at the Texas A&M University-Kingsville Captive Deer Facility (Kingsville, Tex.). Individual pens measured 12 H 12 H 8 ft. and consisted of chain link walls, tin roof, and rubber-padded floors. Deer were acclimated to the pens for 1 week prior to the initiation of the experiment. Alfalfa-based, pelleted deer feed (Purina Mills, Inc., Gonzales, Tex.), alfalfa hay, and water were given *ad libitum* during the acclimation period.

Pelleted deer feed was sprayed with a surface coating of liquid rhodamine B as described in the mold growth trials to yield minimum dosages of 0.06-oz. and 0.13-oz. of rhodamine B/lb. of grain (0.00045 oz. and 0.0009 oz. rhodamine B/lb. of body mass, respectively). Five deer (2 M, 3 F) received 1.0 lb. of pelleted feed that contained 0.06-oz. of rhodamine B/lb. of grain and another 5 deer (3 M, 2 F) received 1.0 lb. of pelleted feed that contained 0.13-oz. of rhodamine B/lb. of grain daily for two days. Rhodamine-dyed pellets that were not consumed after 2 days were removed and replaced with non-dyed pellets and alfalfa hay.

We collected feces from each deer at 12 hr intervals during the 48-hr period of feeding white-tailed deer rhodamine-marked feed and the 96-hr period immediately thereafter. Gloves were used to collect feces and were changed between deer pens to avoid cross-contamination. Feces were placed in ziplock bags and labeled with deer number, time of collection, and concentration of rhodamine B feed. Feces were examined for the presence of rhodamine B staining using an ultraviolet light. We recorded the amount of rhodamine B detected in the feces on a subjective scale of 0 to 4. Ratings given were 0 if rhodamine was not detected under the ultraviolet light, 1 if rhodamine was not visible to the naked eye but was slightly detectable under ultraviolet light, 2 if rhodamine was not visible to naked eye but was very noticeable under ultraviolet light, 3 if rhodamine staining was slightly visible to the naked eye, and 4 if rhodamine staining was easily observed by the naked eye.

Assumptions of parametric tests were evaluated as described in the mold growth trials. Analysis of variance (SAS Institute, Inc., 1989) was used to test the effect of rhodamine B concentration on the average ratings of dye detectability. Multiple comparisons were made using Tukey's procedure when a significant F-test occurred (Ott, 1993).

Palatability Trials

Ten white-tailed deer (5 M, 5 F), which were used in the fecal marking trials, were maintained in their individual pens. Palatability trials were conducted using cafeteria style trays containing three compartments. Trays were built to minimize spillage and 20 inch tall dividers were placed between trays to reduce the possibility of deer spilling feed between compartments. Each deer was given 3, 4-lb. rations of pelleted deer feed. Two rations were sprayed with a surface coating of liquid rhodamine B to yield final concentrations of 0.00045 and 0.0009 oz. rhodamine B/lb. body weight (as previously described), respectively, and the remaining ration was used as a control. Rations were placed into randomly selected compartments at the beginning of the trial. Amount of feed remaining in each compartment was weighed at 24-hr intervals after the initiation of the trial and continued for 5 days. At each weighing interval, compartment placement of the rations was re-randomized to avoid the bias of deer that selected food from the same compartment.

Program RODGERS (Krebs, 1989:600-602) was used to calculate the area under the plotted feed consumption versus time curve and the diet preference index for each diet by each deer. Assumptions of parametric tests were evaluated as described in the mold growth trials. Analysis of variance (SAS Institute, Inc., 1989) was used to test the effect of rhodamine B concentration on the preference indices. Multiple comparisons were made using Tukey=s procedure when a significant F-test occurred (Ott, 1993).

RESULTS

Mold Growth Trials

Feedstuffs sprayed with rhodamine B that were not allowed to dry before being placed in metal containers produced mold quicker ($F_{5, 24} = 6.3$, $P < 0.0001$) than feedstuffs not sprayed with the dye (Table 1). Corn tended to mold faster (range = 2 - 9 days) than pelleted feed (range = 4 - 12 days). Feedstuffs not marked by rhodamine B dye did not mold within the 20-day trial.

However, corn sprayed with rhodamine B dye that was allowed a 1-hr drying period did not mold during the 45-day trial (Table 1). Samples of pelleted feed not marked with rhodamine B and samples sprayed with rhodamine B concentrations of 0.06 oz./lb. produced mold within 4 and 5 days, respectively, which produced mold quicker ($F_{5, 24} = 8.8$, $P < 0.0001$) than samples that received rhodamine B concentrations of 0.13 oz./lb. grain or samples of corn at any concentration of rhodamine B (Table 1).

Table 1. Time required for the production of mold on two feedstuffs sprayed with 0.06 and 0.13 oz. rhodamine B/lb. grain and not allowed (A) and allowed (B) a 1-hr drying period before being placed in metal containers.

Feedstuff	Rhodamine concentration (oz./lb.)	N	Time to mold ($\bar{x}$ ± SE, days)		Range (days)
(A) - *No drying period*[1]					
Corn	0	5	20.0 ± 0.0	A[2]	Never
Pelleted feed	0	5	20.0 ± 0.0	A	Never
Pelleted feed	4	5	10.2 ± 0.7	B	9 - 12
Pelleted feed	8	5	6.6 ± 0.9	C	4 - 9
Corn	4	5	4.4 ± 1.2	CD	3 - 9
Corn	8	5	2.0 ± 0.0	D	2
(B) - *1-Hour drying period*[1]					
Corn	0	5	45.0 ± 0.0	A[2]	Never
Corn	4	5	45.0 ± 0.0	A	Never
Corn	8	5	45.0 ± 0.0	A	Never
Pelleted feed	8	5	29.4 ± 9.6	A	6 - 45
Pelleted feed	0	5	5.0 ± 0.0	B	5
Pelleted feed	4	5	4.0 ± 0.0	B	4

[1] First trial was conducted for 20 days; second trial was conducted for 45 days.

[2] Means within a trial with the same letter are not different (P > 0.05).

Fecal Marking Trials

Feces from 3 (60%) and 4 (80%) of the deer fed 0.00045 oz./lb. body weight and 0.0009 oz./lb. body weight, respectively, of rhodamine B were marked within the first 12 hours of exposure to the dye. After 36 and 24 hours of being fed rhodamine-marked feed 100% of deer fed 0.00045 oz./lb. body weight and 0.0009 oz./lb. body weight, respectively, of rhodamine B produced marked feces. Average ratings of dye detectability were greater ($F_{1, 8} = 9.52$, $P = 0.015$) in the 0.0009 oz./lb. body weight concentration of rhodamine B than the 0.00045 oz./lb. body weight concentration only during the 13 - 24 hour period (Table 2). Deer fed rhodamine B for >36 hours produced rhodamine-marked feces that was visible to the naked eye.

Table 2. Average ratings of dye detectability in feces of white-tailed deer fed 0.00045 and 0.0009 oz. of rhodamine B/lb. body weight and the persistence of rhodamine in feces.

	Average ratings[1]		
Period (hrs)	0.00045 oz./lb. body weight	0.0009 oz./lb. body weight	P-values
	Rhodamine in feed[2]		
0 - 12	1.2 ± 0.5	1.8 ± 0.7	0.488
13 - 24	1.6 ± 0.5	3.6 ± 0.4	0.015
25 - 36	3.0 ± 0.4	4.0 ± 0.1	0.056
37 - 48	3.0 ± 0.4	3.4 ± 0.2	0.126
	Rhodamine persistence[3]		
0 - 12	2.6 ± 0.2	3.0 ± 0.3	0.347
13 - 24	2.0 ± 0.4	3.0 ± 0.6	0.233
25 - 36	0.8 ± 0.4	2.0 ± 0.4	0.074
37 - 48	0.2 ± 0.2	0.8 ± 0.4	0.195
49 - 60	0.0 ± 0.0	0.2 ± 0.2	0.347
61 - 72	0.0 ± 0.0	0.0 ± 0.0	1.000

[1]Average ratings were based on 5 white-tailed deer per rhodamine concentration. Ratings given were 0 if rhodamine was not detected under the ultraviolet light, 1 if rhodamine was not visible to the naked eye but was slightly detectable under ultraviolet light, 2 if rhodamine was not visible to naked eye but was very noticeable under ultraviolet light, 3 if rhodamine staining was slightly visible to the naked eye, and 4 if rhodamine staining was easily observed by the naked eye.

[2]Pelleted deer feed sprayed with liquid rhodamine B and fed to white-tailed deer during first 48-hr period.

[3]Time period immediately after feeding white-tailed deer feed containing rhodamine B.

During the rhodamine B persistence phase of the trial (i.e., length of time in which deer continued to produce rhodamine B-marked feces after consumption of rhodamine-marked feed was discontinued), 100% of the deer that were fed 0.00045 oz./lb. body weight and 0.0009 oz./lb. body weight rhodamine produced marked feces up to 24 and 36 hours, respectively, after being taken off of rhodamine-marked feed. Rhodamine staining of feces was no longer detectable in deer that were fed 0.00045 oz./lb. body weight and 0.0009 oz./lb. body weight rhodamine after 60 and 72 hours, respectively. Differences in rhodamine persistence in feces was not noted ($F_{1, 8} = 4.24$, $P > 0.074$) between the two concentrations of rhodamine B during any 12-hr time period (Table 2).

Palatability Trials

White-tailed deer avoided ($F_{2, 27} = 105.4$, $P < 0.0001$) feed marked with rhodamine B. Deer preferred feed without rhodamine B, then feed with rhodamine B concentrations of 0.00045 oz./lb., followed by feed with rhodamine B concentrations of 0.0009 oz./lb. Average Rodger's indices for white-tailed deer were 1.000 ± 0.00, 0.416 ± 0.08, and 0.025 ± 0.01 for feed containing rhodamine B concentrations of 0 oz./lb., 0.00045 oz./lb., and 0.0009 oz./lb., respectively.

DISCUSSION

Rhodamine B is potentially a very useful, simple to use, and inexpensive bait marker for white-tailed deer. Rhodamine B does not require the capture of animals to produce a mark and it offers a non-invasive and non-lethal means to assess the mark.

Selection criteria for bait markers have included 1) ease of application to the bait material, 2) mark is easily detectable, 3) persistence of mark, 4) no effect on bait acceptance by the target animal, and 5) no adverse health effects (Cowan et al., 1984). When evaluated against these criteria as a bait marker for white-tailed deer, rhodamine B scored favorably in most categories. Rhodamine B is highly soluble in water and is easily mixed with most bait materials. However, if rhodamine B is dissolved in water and then used to surface coat baits, it is advisable to allow the baits to air dry before placing the baits in containers or in storage. Corn and pelleted feed that were sprayed with rhodamine B and not allowed to dry became moldy within one week during our study. Aflatoxins, secondary metabolites of Aspergillus flavus and Aspergillus parasiticus that are produced in moldy grains, could result. Quist et al. (1997) found that white-tailed deer fawns exposed to aflatoxins had reduced body weights and degenerative hepatopathy compared to unexposed fawns. In the present study white-tailed deer that were exposed to rhodamine B for 48-hr produced marked feces that was visible to the naked eye within 36 hours of their initial exposure and the mark persisted for up to three days. Our findings are consistent with other researchers who found that the persistence of rhodamine marking in excreta lasted 1-3 days in mountain beavers (Lindsey, 1983) and 6 - 8 days in black-tailed jackrabbits (Evans and Griffith, 1973). However, white-tailed deer in our study did find rhodamine-marked feed unpalatable. Palatability problems caused by rhodamine B also have been noted in brush-tailed possums (Trichosurus vulpecula; Morgan, 1981), black-tailed jackrabbits (Evans and Griffith, 1973), and laboratory rats (Rattus norvegicus; Webb and Hansen, 1961). Morgan (1981) noted that concentrations <1% rhodamine did not reduce bait palatability. However, Johns and Pan (1981) found that rhodamine concentrations of 0.00045 oz./lb. were required to produce visible marks into keratinous tissue. Therefore, we selected for our study the dosage recommended by Johns and Pan (1981) as the minimum dose of rhodamine to give white-tailed deer, especially if the marking of pelage hairs was desirable. Although white-tailed deer did not prefer feed coated with rhodamine B, they would consume it. Lastly, even though rhodamine B has been described as the most toxic of the xanthene dyes (Smart and Laidlaw, 1977), the lethal concentration values calculated for various species of vertebrates is very high (i.e., >0.008 oz./lb.; Smart, 1984). Fisher (1999) noted that there is no epidemiological evidence of adverse effects of ingestion of rhodamine B by wildlife.

Typically, white-tailed deer movements are studied through the use of radio telemetry (Labisky et al., 1999). However, the use of rhodamine B to mark deer offers an inexpensive technique to approximate deer movements (eg., distances deer will travel to and from feeders). Dyes have been used in the past to trace animal movements (Clover, 1954; Taber et al., 1956). In addition, movements could be determined without having to capture the animal, as would be the case with radio telemetry. Also, rhodamine B does not require destroying animals, like does tetracycline to assess marks in bones and teeth (Crier, 1970), but can be assessed within an animal by non-invasive techniques, such as hair clipping. Rhodamine B will persist in hair until the hair is shed during the molt (Fisher, 1999).

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Potential Fire Effects on Seed Germination of Four Herbaceous Species

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ABSTRACT

Fire is a natural component of grasslands throughout the world, but information on the impact of fire on seed germination is lacking. Our objective was to determine the influence of different levels of heat on Johnsongrass (*Sorghum halepense*), Lamb's quarters (*Chenopodium album*), partridge pea (*Cassia chamaecrista*), and rough pigweed (*Amaranthus retroflexus*) seed germination under laboratory conditions. Seeds were heat-treated in 4 replicates for 120 seconds at 200, 400, 600, 800, and 1000°F, plus a control. Germination was determined on 100 randomly selected seeds of each species from each heat treatment and control replicates. None of the species had increased germination after being subjected to heat treatments when compared to controls. In all species, germination was reduced when treatment temperature reached 600°F, and germination was eliminated at 800 and 1000°F. Laboratory evaluations indicate the heat generated by prescribed fires is adequate to sterilize seed not buried below the soil surface. These responses support the general recommendation to burn during the winter dormant season to promote forbs for wildlife species by burning under cooler conditions to reduce heat damage to seeds of desirable plant species.

KEYWORDS: fire, Johnsongrass, Lamb's quarters, Northern bobwhite, partridge pea, prescribed burning, rough pigweed

Fire is a naturally occurring, historic component of grasslands throughout the world. However, due to fire suppression, the natural ecological impacts of fire can generally only be realized using prescribed fires. Much like prescribed fires today (Masters et al., 1993), historic fires likely increased seed production in grassland systems, providing additional germplasm for dispersal and winter food sources for granivorous birds such as the Northern bobwhite (*Colinus virginiana*). In Texas, prescribed fire has effectively reduced broadleaf herbaceous plants in some situations, and increased broadleaf herbaceous plants in other situations (Wright and Bailey, 1982). This has been generally attributed to timing of the fire in relation to seedling establishment. However, this reduction in broadleaf herbaceous plants may be a result of seed sterilization from the passing fire front. Although post-fire plant response has been thoroughly studied, information on direct heat impacts to seeds during burning is lacking, because field data are difficult to conduct and replicate.

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The temperature of grassland headfires at the mineral soil surface is a linear function of the amount of non-compacted fine fuel available for combustion (Wright and Bailey, 1982). Average soil surface temperatures of grass fires have been reported to vary from 215 to 730°F when fine fuel ranged from 1500 to 7000 lb/acre (Stinson and Wright, 1969). However, in monoculture grasslands, soil surface temperatures have been recorded as high as 1167 °F with weeping lovegrass (*Eragrostis curvula*) fine fuel loads of 4100 lb/acre (Rummel et al., 1999). Additionally, peak temperature in these fires occurred for 15 to 146 seconds with a maximum duration of 450 seconds.

Seeds are typically considered to be very tolerant to heat generated by burning because cellular material in the seeds is dormant and often dehydrated (Whelan, 1995). Seeds are often protected from direct heat during burning by burial in the soil, so seed banks accumulate in the soil, or in the canopy as serotinous cones or fruits (Keeley and Fotheringham, 1998). Some species, such as members of the families Cupressaceae and Fabaceae, exhibit increased seed germination following fire due to bradyspory or destruction of an impermeable seed coat (Whelan, 1995). Germination in some species may be fire-triggered by either heat shock or by combustion products such as smoke and charred wood (Keeley and Fotheringham, 1998). Grass species have been reported to tolerate temperatures of 180 to 240°F for up to 5 minutes (Sampson, 1944). However, little information is available on the impact of specific levels of heat on seed germination for plant species managed primarily for wildlife food sources. We hypothesized that lower levels of heat (i.e. 200°F), which simulate temperatures associated with fires occurring in low and medium (<2,000 lb/acre) fine fuel loads will promote seed germination, whereas higher levels of heat (i.e. 800 and 1000°F), simulating fires occurring in heavy (>4,000 lb/acre) fine fuel loads will inhibit seed germination of herbaceous species. Our objective was to determine the influence of different levels of heat on the germination of Johnsongrass (*Sorghum halepense*), Lamb's quarters (*Chenopodium album*), partridge pea (*Cassia chamaecrista*), and rough pigweed (*Amaranthus retroflexus*) seeds under laboratory conditions. These species were selected because they represent common sources of food for Northern bobwhite throughout much of the central U.S. (Dimmick, 1992).

MATERIALS AND METHODS

This laboratory study was conducted in 1998 at Texas Tech University. Single seed lots of each species were acquired from a commercial vendor. Four replicates of 0.18 oz of each species were placed in porcelain crucibles. The 0.18 oz sample of each species was heat-treated for 120 seconds at 200, 400, 600, 800, and 1000°F. These temperatures were chosen to represent the spectrum of temperatures likely to occur at the soil surface in grassland fires. Heat treatments were applied independently to the four replicates in an electric muffle furnace (Thermolyne Type 30400 Furnace). Temperatures were recorded at 15 second intervals to determine average temperatures for each treatment. Upon removal from the muffle furnace, seeds were emptied into individual trays to prevent potential seed damage from the residual heat of the crucibles. Four replicates of each species received no heat treatment and were maintained at room temperature (68 - 72°F) as controls.

Following heat treatment, seed germinability was determined by placing 100 seeds of each species from each heat treatment and control replicate into separate germination dishes lined with blotter paper. Approximately 1 oz of a solution of 2% KNO_3 and 1% captan ([N-[(trichloromethyl)-thio]-4-cyclohexene-1,2-dicarboximide}, a fungicide, were added to each dish. Dishes were stored at 40°F for 14 days to break seed dormancy

(Crosier, 1970), then placed in a germination chamber where temperature and light alternated from 68 and 86°F for 16 (dark) and 8 (light) h, respectively. A seed was considered to have germinated when the radicle emerged through the seed coat. The number of germinated seeds in each germination dish were counted, recorded, and discarded at 2 to 3-day intervals for 28 days.

The experiment was conducted as a completely random design with 4 replicates per treatment. A one-way analysis of variance was used to determine the influence of heat on seed germination. Treatment means were considered different at $\alpha=0.05$ (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Temperature was well controlled during all heat treatments. Average temperatures ($\bar{x}$ ± SE) for the 120 second treatment period were 199.85 ± 1.42, 398.08 ± 0.39, 596.75 ± 2.26, 792.28 ± 2.18, and 993.20 ± 5.71°F for the 200, 400, 600, 800, and 1000 °F temperature treatments, respectively. At the 800 °F treatment, the seeds on the surface of the crucible began to smolder, and at 1000 °F, the seeds on the surface of the crucible combusted. However, we had no problem randomly selecting 100 non-combusted seeds for germination.

None of the four species had increased germination after being subjected to heat treatments when compared to seeds stored at room temperature (Fig. 1). The lack of seed germination increase at 200°F failed to support our hypothesis that this low temperature treatment would increase germination, particularly in the hard-seeded partridgepea. In all species, seed germination was significantly reduced when treatment temperature reached 600°F, and germination was eliminated at 800 and 1000°F (Fig. 1). This elimination of germination at 800 and 1000°F supported our hypothesis that germination would be reduced at the highest temperatures.

In Johnsongrass, no differences in germination occurred among the control and treatment at 200 and 400°F. Average germination of seeds stored at room temperature and treated at 200°F was 52%, and seeds treated at 400°F was 52.75%, which is within the range of germination reported by Egley (1990). However, when the treatment temperature was elevated to 600°F, Johnsongrass seed germination was reduced to 16.75%, a value only 32% of the germination in the control seeds.

In Lamb's quarters, germination decreased with each increase in temperature from the control, to 200, 400, and 600°F (Fig. 1). However, germination at 600, 800, and 1000°F were similar, and were not different from 0% germination. Germination of seeds stored at room temperature was 19.25% and declined linearly ($r^2 = 0.98$) as temperature increased to 600°F. Lamb=s quarters seed germination was 13.25, 9.75, and 1.5% at 200, 400, and 600°F, respectively. Germination declined by an average of 57% for each 200 °F increase in temperature.

Partridgepea seed germination was lower than all other species in the seeds stored at room temperature, and averaged only 14% (Fig. 1), which is consistent with previous germination research on Cassia species (Martin et al., 1975). Partridgepea seed germination declined in a manner similar to Lamb's quarters, but germination was not different among the control, 200, and 400°F (Fig. 1). However, germination at 600°F was lower than the control. Only 6.5, 6.25, and 1.5% of partridgepea seeds germinated at 200, 400, and 600°F, respectively.

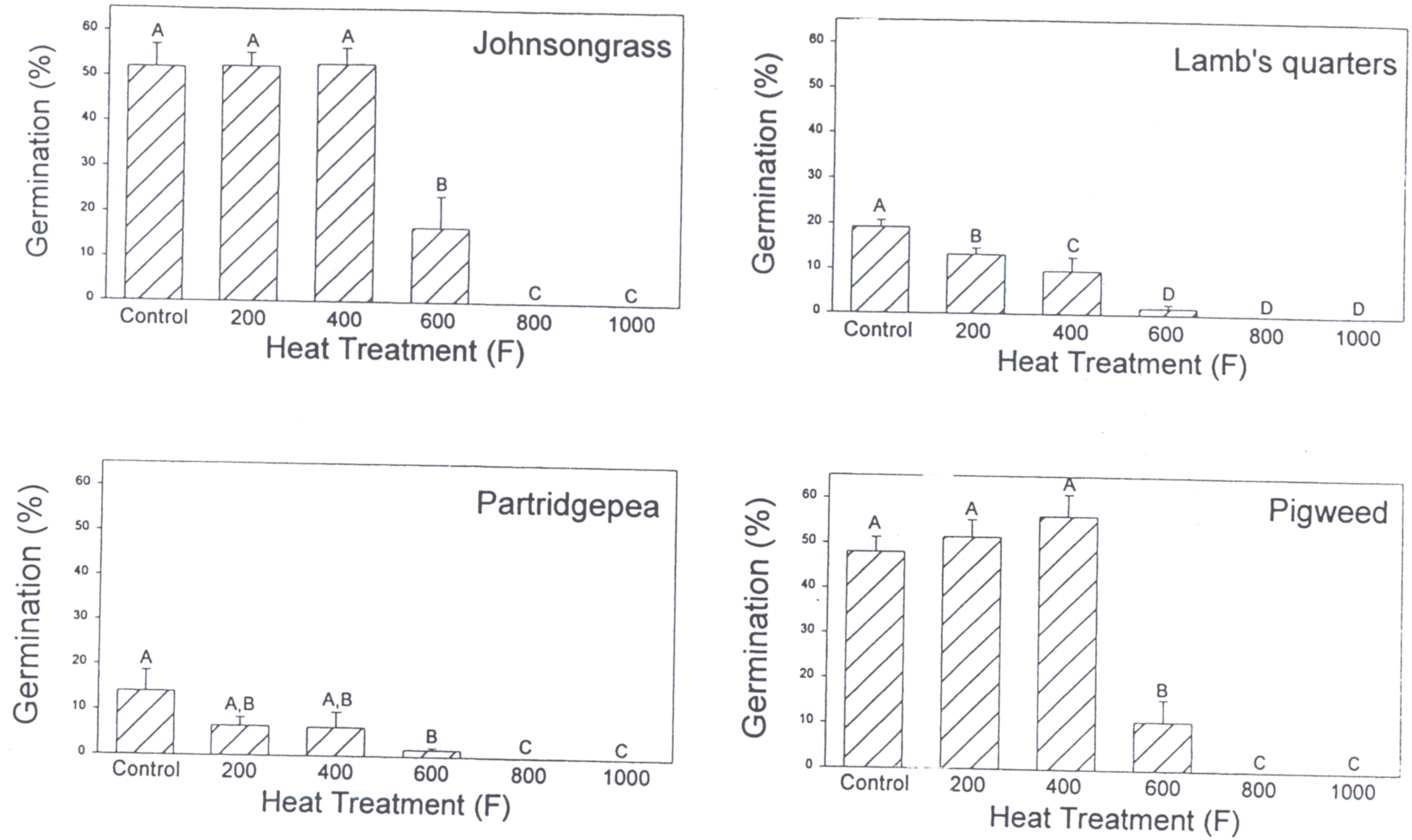

Figure 1. Mean germination ($\bar{x} \pm$ SE) response of Johnsongrass, lamb's quarters, partridge pea, and pigweed treated for 120 seconds at 200, 400, 600, 800, and 1000°F, and controls. Different letters over bars indicate differences among treatments within a seed species ($P < 0.05$).

Pigweed seed germination responded to temperature increases similar to Johnsongrass (Fig. 1). In pigweed, no differences in germination occurred between the control and treatment at 200 and 400°F. Average germination of pigweed seeds stored at room temperature was 48%, which is higher than the 13% reported by Zahnley and Fitch (1941). Average germination of seeds treated at 200°F was 51.5%, and seeds treated at 400°F was 56.25%. However, as in Johnsongrass, when the treatment temperature was elevated to 600°F, pigweed seed germination was reduced to 10.75%, 22% of the germination in the control seeds.

Four species of herbaceous plants, 1 grass and 3 forbs, were subjected to heat treatments. Heat treatments did not increase seed germination in any of the species. Laboratory evaluations indicate the heat generated by prescribed fires is adequate to sterilize seed not buried below the soil surface. Although we did not directly simulate the conditions of fires in the field, the temperatures and duration we evaluated approximate those present in grassland fires at the soil surface. These responses support the general recommendation to burn during the winter dormant season to promote forbs for wildlife species such as Northern bobwhite by burning under cooler conditions to reduce heat damage to seeds of desirable plant species. Additionally, by burning in early winter, seeds have not yet germinated so seedlings will not be exposed to heat.

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