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CONTENTS

An Evaluation of the GO TEXAN Marketing Program: Results of the 2002-2003 Member Survey

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ABSTRACT

Essential to the survival of any agricultural firm is its ability to market products and not simply sell them. Support for such an initiative and leadership from the state's department of agriculture is crucial in today's economy. Launched by Susan Combs, Texas Department of Agriculture Commissioner, the GO TEXAN program is an innovative marketing approach for Texas' agricultural products. The campaign uses an easily recognizable trademark – a glowing brand in the shape of Texas – to promote agricultural products produced in Texas. Evaluating such programs enables the lead organization to successful elements and those needing revision. This study assessed methods used by GO TEXAN producers to market their products. The study also focused on the level of success experienced by producers and the degree to which that success could be attributed to the program. The study found that producers experienced success directly linked to their involvement in the GO TEXAN program. These results are providing the programs' management personnel with insight into its effectiveness and opportunities for even greater results.

KEYWORDS: GO TEXAN, Agricultural marketing, Texas Department of Agriculture

With the Agricultural Marketing Act of 1946, Congress declared a sound, efficient, and privately-operated system for distributing and marketing agricultural products. The act identified that this system is essential to insure a prosperous agriculture and is indispensable to the maintenance of full employment and to the welfare, prosperity, and health of the nation (Caswell 1997).

GO TEXAN, launched by Commissioner Susan Combs, adds a new dimension to the Texas Department of Agriculture (TDA) in marketing Texas agriculture. The campaign promotes all Texas agricultural products – food, fiber, wine and horticulture – under one easily recognized trademark: a glowing brand in the shape of Texas. GO TEXAN taps into Texas loyalty, working to persuade 19 million Texas consumers to choose the state's agricultural bounty when they shop.

Support programs have been created to enhance the campaign's effectiveness. One example is the GO TEXAN Partner Program (GOTEPP), a matching grant program that doubles funds available to promote Texas agriculture. Another example is TDA's International Marketing staff recruitment of Texas companies to apply for export funding through the federal Market Access Program (MAP), a matching funds reimbursement program to develop export opportunities for branded products.

National celebrities also lend their prestige to promote Texas agriculture. Pitching great Nolan Ryan and actor Tommy Lee Jones donated time and talent to star in public service television announcements telling folks nothing beats a Texas product.

A similar agricultural marketing program is the Jersey Fresh Program established by the New Jersey Department of Agriculture. This state's sponsored program was implemented to promote locally grown fruits and vegetables with the intention of increasing the profitability of New Jersey farms and the viability of local agriculture (Govindasamy, Italia, and Thatch 1998). A study of this program reported that over 87% of people surveyed said they would prefer to purchase produce grown locally, while 75% said they would even be willing to pay a premium for the Jersey Fresh produce (Govindasamy, Italia, and Thatch 1999).

There are many potential reasons why a state marketing program may work. Researchers at Rutgers University (Adelaja, Brumfield and Lininger 1990) identified a growing interest among states to assist in marketing agricultural commodities. According to Holloran and Martin (1989), policymakers typically seek to promote (a) products that have certain state characteristics, (b) promote unique products, and (c) attempt to gain economic returns, which, according to the authors, is the most difficult to assess.

The purposes for evaluating marketing programs may include redefining program objectives and reformulating strategies to achieve those objectives. Results from these evaluations may then be used to prove how well activities meet the program objectives (Jensen and Pompelli 1998).

Little research has been conducted to analyze the factors that contribute to the awareness of state-sponsored marketing programs, thus giving the need for further investigation of the effectiveness of such programs (Govindasamy, Italia, and Thatch 1998). In this regard, the purpose of this study was to evaluate the success of the GO TEXAN program and its initiatives. The study focused on evaluating the effectiveness of GO TEXAN marketing-related activities. The objectives of this study were to determine the GO TEXAN members' demographic characteristics, participation level in various GO TEXAN programs, methods of participation in various GO TEXAN programs, and success due to participation in GO TEXAN programs.

MATERIALS AND METHODS

To evaluate the effectiveness of GO TEXAN marketing-related activities, a survey was developed and distributed to GO TEXAN members. This survey was used to capture data regarding the demographic characteristics of GO TEXAN members, selected business practices of these members, participation patterns in program events, perceptions regarding benefits associated with membership, usage of the GO TEXAN logo, media contacts made as a result of program participation, and the types of assistance obtained from TDA marketing activities. Additionally, respondents were provided an opportunity to make general statements, both pro and con, regarding the program. Results of the GO TEXAN member survey are contained herein.

To determine descriptive characteristics, these data were analyzed using frequencies, percentages, means, and cross tabulation statistics. Additional insight was gleaned through calculating correlations among the variables using the Pearson Correlation Coefficient, a measure of linear association between two variables. Values of the correlation coefficient range from -1 to 1.

The sign of the coefficient indicates the direction of the relationship, and its absolute value indicates the strength, with larger absolute values indicating stronger relationships. These correlations were used to identify relationships among the data that can assist GO TEXAN management in determining which areas of GO TEXAN assistance are best benefiting the members. All correlations used an alpha value of either .01 or .05, which identifies a confidence value of 99% or 95% respectively. These Pearson Correlations are denoted by the symbol "r" in the tables contained herein.

RESULTS

Demographic Characteristics. There were approximately 1,400 surveys mailed to the population of members. Responding members sent in 342 usable responses (25% response rate). The response rate fell below the researchers' expectations, but according to research methods, a sample size of 300 allows the research to be descriptive to a population of approximately 1500 (Krejcie and Morgan 1970). Using Krejcie and Morgan (1970), the number of responses exceeded the needed amount for statistical reliability.

Of the total respondents, 14% identified themselves as sellers of products outside Texas, while 85% sell products within the state's borders (1% non-responding). Nearly 52% of members have between one and five employees, which are considered a small business for this study. GO TEXAN members also seem to be represented largely by the wholesale (36%) and retail (32%) sales sectors. Firms reported an average sales level of $850,000 during their 2002-2003 membership.

Approximately 74% of GO TEXAN members identified that GO TEXAN marketing program impacted, at least to some degree, their marketing efforts. These members on average utilized the logo in more than one way, such as in an advertisement and in their packaging.

Respondents in the agricultural sector can be described by the way they do business. Figure 1 provides an outline of the agricultural sectors that members represent. The members are largely represented by the production sector (Food/Fiber-21% and Horticulture-21%) with nearly equal representation in the processing sector (31%). Complete results are listed in Figure 1.

How members participate in offered events may provide insight into which events bring successful business results. A look into each aspect of the program and how members are viewing the program will identify strengths and weaknesses that can be managed to continue program growth.

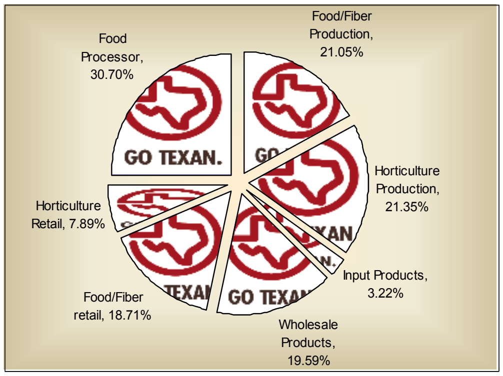

Figure 1. Member firms business involvement by agriculture sector.

Sales Increases From TDA Events. In the survey, a question was developed to discover the impact GO TEXAN membership had on a member's sales dollars, which was identified by members estimating how much their involvement in GO TEXAN events affected their sales increases. As previously stated, 74% of GO TEXAN members identified marketing benefits from membership, but more important is the level members feel GO TEXAN marketing efforts assisted them in increasing their sales. An illustration of these results is listed in Figure 2.

Figure 2 illustrates almost three-fourths (71.85%) of GO TEXAN members identified some increase in their sales directly related to their involvement in GO TEXAN marketing activities. The most widely recognized benefits were in the "5 to 10%" category and an average sale from all members was nine percent. Differences in revenue increases and perceived benefits may be that some firms are non-profit while others actually have sales. In any case, these values derived from separate questions provide a crucial consistency value that assists in developing further confidence in these results.

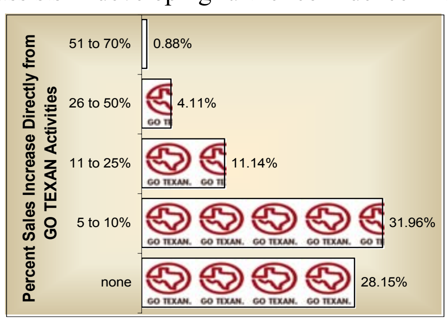

Figure 2. Percent of members that can identify direct sales increases from GO TEXAN marketing activities.

Participation in GO TEXAN Events. Approximately 15% of GO TEXAN members actually participated in a variety of GO TEXAN events. The most popular type of event, by percentage of members participating, was the domestic tradeshow (22%). This was closely followed by participation in state fairs and festivals (both 13%). Additional GO TEXAN events and the percent of members that participated in those events are illustrated in Figure 3. Involvement levels vary from using the logo on their product to using the TDA website for business contacts, but participating in events is another aspect of involvement.

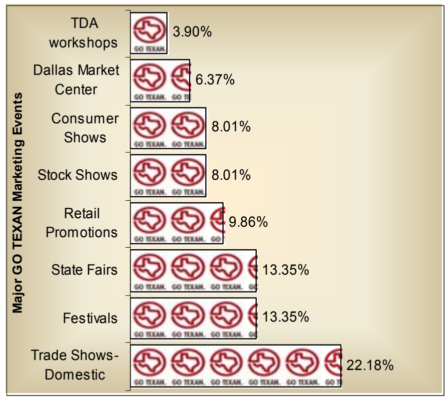

Figure 3. Percent Involvement in Major GO TEXAN Events.

A more important question other than just being involved in activities is: Did members that participated in GO TEXAN events experience sales increases? To answer this question, correlations were calculated (using a .01 significance level) to discover relationships between members' participation in GO TEXAN events and those members that reported sales increases.

The results from this analysis indicated that there were significant positive correlations (Pearson Correlation Coefficient r=.278) between the number of GO TEXAN events participated in and reported increases in sales as a result of membership (Figure 4). In short, members who participate in GO TEXAN events realized increases in sales more often than those members not participating in GO TEXAN events.

Six specific GO TEXAN events had positive significant correlations (.01 level of significance) to sales increases. Members that identified participating in these six events were more likely to experience sales increases than members who did not participate. The six events that had significant correlations to sales are illustrated in Figure 4.

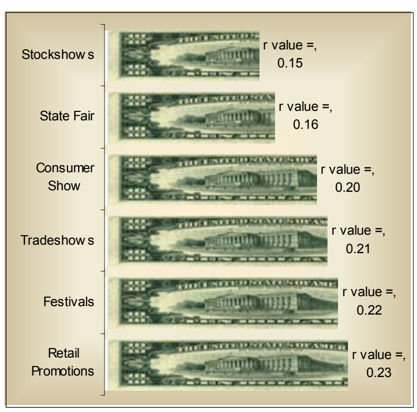

Figure 4. GO TEXAN Marketing Events that were correlated to Members that Recognized Sales Increases.

Usage of GO TEXAN Logo. Logo usage is an additional area of marketing activity that potentially increases sales for members. The logo provides a "brand recognition" value that creates additional market value and demand, which may positively impact those that use the logo in their marketing efforts.

The concept that a state-branded product may increase income was the premise used by the Jersey Fresh program. A study from that program indicated that consumers said they were more likely to purchase a product that they could associate with a logo (Govindasamy, Italia, and Thatch 1999). The most popular use (33% of members) of the GO TEXAN logo was on product packaging and labeling. Members indicated that many buyers were impressed with the logo and that they preferred the logo to appear somewhere on the product or display. Alomost one-fourth (24%) of members also used the GO TEXAN logo on various brochures and literature highlighting their products and their business. Members used the logo in other marketing areas as listed in Figure 5.

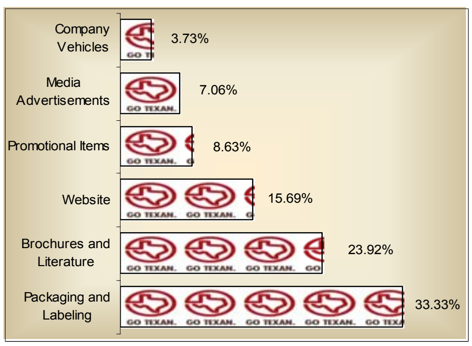

Figure 5. Percentage Uses of the GO TEXAN Logo.

Pearson correlations were calculated to discover if there were any relationships between using the GO TEXAN logo and increased sales. There was a positive correlation (at the .01 significance level) between the number of ways members used the GO TEXAN logo and their respective sales increases (r = .236). That is, those that utilized the logo more often reported higher increases in sales than firms which utilized the logo less frequently.

The correlations also illustrated that certain uses of the logo had stronger correlations to sales increases than other uses. There were three uses of the GO TEXAN logo that were found to be positively correlated to increases in sales. These were the GO TEXAN logo use in packaging, on brochure advertisements, and on promotional items (.05 level of significance). These uses of the logo and their associated Pearson correlations (r) are listed in Figure 6.

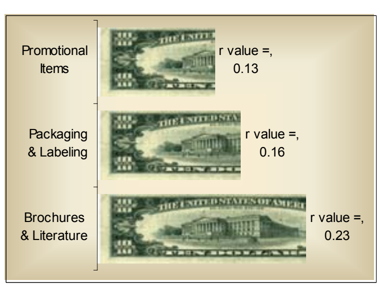

Figure 6. Uses of the GO TEXAN logo that were significantly correlated to sales increases.

CONCLUSIONS

In examining benefits of GO TEXAN membership, which included participating in GO TEXAN events or using the GO TEXAN logo, it was clear that those participating received benefits in the form of increased firm-level sales. GO TEXAN members are primarily selling their products in Texas, largely employing 1 to 5 Texans, and an overwhelming 74% of these businesses identify that the GO TEXAN marketing program is positively impacting their business. Using the average sales level from members ($850,000) and the average sales increases from membership (9%), it is estimated that an average member may associate $76,500 in sales increases from membership. Additional insight for future reporting will include a question for each member to report sales increases they directly attribute from membership.

Programmatic aspects of the GO TEXAN marketing program include events and utilizing the logo. Both areas of program participation identified a significant relationship between participation and sales increases.

This second annual reporting of GO TEXAN members resulting from participation in GO TEXAN marketing programs has yielded consistent results from the previous year's initial report. The results from this report begin to provide some management insight into the effectiveness of current GO TEXAN programs for members and which GO TEXAN activities are providing the greatest economic benefit.

RECOMMENDATIONS

Other states with marketing programs should do annual assessments to measure their program results and use the information for program management. The GO TEXAN program should utilize any of these assessments that may further permit better evaluation of its own program, as well as its improvement.

Continued reporting should be maintained to monitor results, provide greater comparisons to annual trends, and develop benchmarks that can guide future program alterations. Consideration must be given to economic factors that may affect reported results, such as those seen in the aftermath of the 9/11 attacks.

Successes of the program should be showcased to Texas legislatures as a means for securing more funding to expand and improve the program. Many untapped markets exist for Texas agricultural products, yet these markets may never be realized without continued support for the program.

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DIFFERENCES IN PERCEPTIONS AND PERCEIVED KNOWLEDGE LEVELS OF TEXAS SUPERINTENDENTS REGARDING AGRISCIENCE PROGRAMS AND ITS TEACHERS

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ABSTRACT

An agricultural science program's success depends on the superintendent, a school district's highest academic officer, recognizing the program as a vital part of the school. Recent studies by Pavelock (2001), Jackson & Herring (1998), and Hinkson and Kieth (1999) have shown administrators support agriscience, but revealed troubling insights. The primary purpose of this study was to determine differences in perceptions and perceived knowledge levels of agriscience by Texas school superintendents with various agriscience experience levels.

A large majority (88.6%) of Texas school superintendents have no agriscience teaching experience. Most (58.6%) had not been enrolled in agriscience themselves and almost two-thirds (65.7%) had not had a child enrolled.

Collectively, superintendents have a positive perception of agriscience and its teachers. Experience in agriscience was not found to have a significant effect on most perceptions and perceived knowledge levels. Differences found existed primarily in the need for more emphasis in various instructional areas, and whether all students should receive instruction in agriscience. Differences also existed in perceptions of agriscience being less vocational and more academic compared to other career and technology programs, and the inability of school districts to obtain waivers for certain agriscience courses to count for credit in related foundation courses.

KEYWORDS: Agricultural science, agriscience, agricultural education, career and technology education (CATE), professional development, superintendent, Supervised Agricultural Experience Program (SAEP), teacher, vocational agriculture.

INTRODUCTION

Expanded standardized testing and additional graduation requirements of the Texas Education Agency (2000) mandate that students complete a more advanced program of study, thereby limiting elective course options while requiring additional credits in fine arts and other languages. Schools are rewarded on the Academic Excellence Indicator System (AEIS) for having a high percentage of students on advanced graduation plans. Students considered to have higher academic skills are often discouraged from enrollment in career-oriented programs for courses perceived to be more challenging. As a result, students and parents have developed negative stereotyped attitudes regarding programs such as agricultural education (Dyer & Osborne 1997). Agricultural science and other vocational programs, almost since their inception, have been a part of the comprehensive high school system throughout the nation (Martin and Peterson 1991). The National Council for Agricultural Education (1999), the National Research Council (1988), and The National Council for Agricultural Education (1999) all recognize the importance of agricultural education. In 1988, the National Research Council stated, "Agriculture is too important a topic to be taught only to the relatively small percentage of students considering careers in agriculture and pursuing vocational agriculture studies." (p. 8).

Superintendents must help identify the portions of an ideal agriscience program necessary to help students meet the needs of a global economy and workforce because the superintendent is first and foremost the chief academic officer in a public school system (Spillane & Regnier 1998). He/she is responsible for empowering principals, who then empower her/his own staff to provide the instructional program, in addition to ensuring that established goals for the campus are met (Konnert & Augunstein 1995).

Purpose/Objectives. There have been some studies that indicated administrative support for agricultural programs: a Texas study regarding communication between agriscience teachers and school administrators found administrators have a high regard for the program (Hinkson and Kieth 1999), another Texas study revealed generally positive perceptions and perceived knowledge levels of Texas school superintendents regarding agricultural science and technology programs (Pavelock 2001). As with any high school program, its success is dependent upon the commitment of that school's educational leaders. In these regards, the primary purpose of this study was to determine differences in perceptions and perceived knowledge levels of the agriscience program by Texas public school superintendents with various agriscience experience levels.

The study focused on the demographics of Texas public school superintendents and their perceptions and perceived knowledge level regarding the agricultural science and technology program. The objectives of this study were to determine superintendents' demographic characteristics, perceptions of the agricultural science program's purpose and its role in the total school program and the school's goals, perceptions of agricultural science teachers, perceived knowledge levels regarding the agriscience program, and differences in perceptions of those with and without experience in agriscience.

MATERIALS AND METHODS

The targeted population sample was Texas public school districts superintendents of districts whose high school(s) offered instruction in agricultural science. The number to be surveyed was determined according to the formula developed by Cochran (1977). To ensure the external validity of the instrument, schools were selected within the ten geographical "areas" of the Texas FFA Association by stratified random selection.

The researcher-developed questionnaire was derived from various previous studies conducted in Georgia (Woodard & Herren 1995), Illinois (Dyer & Osborne 1997), Mississippi (Johnson & Newman 1993), Nebraska (Foster, Bell, & Erskine 1995, Viterna 1971), North Carolina (Jewell 1995, Price 1990), Oregon (Bender 1996, Thompson 1998), and Texas (Jackson & Herring 1998). The instrument was a four-part questionnaire: demographics, agriscience program perceptions, perceptions of the ideal characteristics of an agriscience teacher, the agriscience teacher's role and expectations regarding professionalism and professional development, and perceived knowledge level of the agriscience program. All parts used an eight-point Likert-type scale with an "8" indicating the highest level of agreement or perceived knowledge, and a "1" indicating the lowest level of agreement or perceived knowledge.

After pilot testing with superintendents and agricultural educators for validity and reliability, the instrument was mailed via first-class mail. Guidelines of Dillman's (1978) Total Design Method (TDM) were followed to increase response rates. One hundred superintendents were surveyed, and a 71% response rate was achieved. Data were coded, tabulated and analyzed using the Statistical Package for Social Sciences (SPSS) for the Macintosh computer and the SPSS 10.1 for Windows. Descriptive statistics and alpha levels were reported using demographic characteristics and responses of participants.

RESULTS

Demographics. Two-thirds (66.7%) indicated academics (language arts, social studies, science, or math) as their primary teaching area. Over 80% had no career and technology education teaching experience but almost 12% had some agricultural science teaching experience. Most (58.6%) superintendents had not been enrolled in agriscience while in high school or college, and almost two-thirds (65.7%) said their children had not been enrolled.

Slightly more than two-thirds (67.1%) of the participants indicated some work experience in agriculture, as the largest percentage (47.1%) were found to have been raised in a rural hometown with a population of 2,500 or less. Most (55.7%) participants' districts were located in a rural town with a population of 2,500 or fewer, with the largest percentage (45.7%) indicating their school district has less than 1,000 students.

As a total, 29 respondents (41.4%) indicated no direct or indirect involvement in agricultural science, meaning they had neither taught nor been enrolled in the program and their children had not been enrolled in the program. Over one-half (58.6% or 41) indicated either a direct or indirect involvement in the program by having taught or been enrolled in agricultural science, or having had a child enrolled in agriscience.

Perceptions Toward the Agriscience Program. Respondents were asked to indicate their level of agreement with certain statements pertaining to their perception of the agriscience program as a whole and not as they relate to the program within their individual school district. Statements scoring high, low or with significant differences in responses by the groups are reported in Table 1.

The highest levels of agreement by those with no agriscience experience indicated the need for more emphasis on technology/computer applications (7.1), leadership development (7.0), and integration of science, mathematics, etc. (6.8). They agreed at a moderately high level that agriscience should provide students with specific skills for gainful employment <u>and</u> pursuing a higher education (6.5) and that agriscience needs more emphasis placed on biotechnology (6.5). The amount of funds spent on agriscience is a wise investment (6.4) and more emphasis is needed on environmental and natural resources (6.4). Respondents did not believe that too much attention is focused on environmental and natural resources (2.9) or leadership development (2.6).

Table 1. Superintendents' agreement with statements regarding the agriscience program.

Statement focus	Mean[a]	Mean[b]	Alpha
More emphasis on technology / computer applications	7.1	6.9	.499
More emphasis on leadership development	7.0	6.6	.294
More emphasis on integrating science, mathematics, etc.	6.8	6.8	.935
Should provide students with skills needed for gainful employment and pursuing higher education	6.5	6.4	.890
More emphasis on biotechnology	6.5	6.1	.243
Amount of funds currently spent on the program is a wise investment of local, state, and federal resources	6.4	6.6	.624
More emphasis on environmental and natural resources	6.4	6.1	.452
Helps at-risk students remain interested in their education, lessening the likelihood of dropping out	6.3	6.2	.799
More emphasis on agribusiness	6.2	6.2	.891
More emphasis on horticulture	6.0	5.2	.018*
Too much attention on livestock showing	5.9	5.3	.250
More emphasis on plant production.	5.8	5.1	.045*
Too much attention on FFA activities.	4.0	3.1	.051
Less vocational and more academic than other career and technology education programs.	3.7	4.7	.016*
All students should receive instruction about agriculture throughout formal schooling years, K-12	3.3	4.7	.003**
Too much attention on environmental / natural resources.	2.9	2.2	.042*
Too much attention on leadership development.	2.6	1.8	.025*

N=29 for respondents with no experience in agricultural science
N=41 for respondents with experience in agricultural science
[a]Mean = No experience in agricultural science
[b]Mean = Experience in agricultural science
* Significant at .05 level
** Significant at .01 level

Superintendents with agriscience experience indicated the highest levels of agreement with the need for more emphasis on technology/computer applications (6.9), the integration of science, mathematics, etc. (6.8), and leadership development (6.6). Their agreement level was also found to be highest in regard to agriscience being a wise investment of local, state and federal resources (6.6). This group of respondents indicated the lowest levels of agreement for statements about the program focusing too much attention on horticulture (2.9), agribusiness management (2.4), environmental and natural resources (2.2) and leadership development (1.8).

There were significant differences in the mean levels of agreement between those that indicated some experience in agriscience and those that indicated no experience. These significant differences were in regard to statements about more emphasis being needed on plant production (α=.045) and horticulture/landscaping (α=.018), and that the program focuses too much attention on environmental and natural resources (α=.042), judging contests (α=.029), leadership development (α=.025), production agriculture (α=.016). In addition, a significant difference was found for agreement level with agriscience being less of a vocational program and more of an academic program than other career and technology education programs (α=.016). Finally, the statement that all students should receive instruction about agriculture throughout their formal schooling years (α=.003) had the most significant difference in the mean level of agreement.

Perceptions Toward Agriscience Teachers. Respondents were asked to indicate their level of agreement with certain statements pertaining to their perception of agricultural science and technology teachers as a whole and not the teacher(s) within their individual school district. High, low and significantly different responses are shown in Table 2. The same 8-point Likert-type scale was used.

Table 2. Superintendents' agreement with statements regarding agriscience teachers.

Statement focus	Mean[a]	Mean[b]	Alpha
Should possess significant knowledge about all phases of agriculture, not a specialization in one or two aspects	6.0	5.9	.816
Portray a positive professional image to, and have a positive professional relationship with, students	5.8	6.0	.504
Portray a positive professional image to, and have a positive professional relationship with, parents	5.7	6.0	.508
Portray a positive professional image to, and have a positive professional relationship with, administrators	5.6	5.9	.555
In terms of life skills and respective content areas, agriscience teachers do as good a job as "academic" teachers in educating their students.	5.5	5.6	.601
Tend to do better job of educating, encouraging, and motivating low achieving students than other teachers	5.2	5.6	.341
Well-prepared to offer instruction at challenging level for students intending to pursue higher education.	5.1	5.1	.888

N=29 for respondents with no experience in agricultural science
N=41 for respondents with experience in agricultural science
[a]Mean = No experience in agricultural science
[b]Mean = Experience in agricultural science
* Significant at .05 level
** Significant at .01 level

The highest agreement level by superintendents with no experience in agriscience was found in regard to whether teachers should possess a significant level of knowledge about all phases of the agricultural industry as compared to specialization in selected aspects (6.0). Superintendents agreed at the same level that agriscience teachers portray a positive image to, and have a positive relationship with, students (5.8), parents (5.7), and administrators (5.6). No statement received a low level of agreement from superintendents without experience in agriscience.

Similar to their counterparts with no agriscience experience, superintendents with experience in agriscience indicated highest agreement levels with statements that teachers portray a positive image to, and have a positive relationship with, students (6.0) and parents (6.0). High agreement was indicated for the statement that agriscience teachers portray a positive image to, and have a positive relationship with, administrators (5.9). They further indicated highest agreement for agriscience teachers tending to do a better job of educating, encouraging, and motivating lower achieving students compared to other teachers in the school (5.6). No statement had a low agreement level among superintendents with agriscience experience. There were no significant differences in responses of the different groups.

Perceived Knowledge Levels of the Agriscience Program. Respondents were asked to indicate their level of perceived knowledge with certain statements pertaining to the agriscience program as a whole, not their school district's program. High, low and significantly different responses are reported in Table 3 and the same 8-point Likert-type scale was used.

Table 3. Superintendents' perceived knowledge with various aspects of the agriscience program.

Statement focus	Mean[a]	Mean[b]	Alpha
Weighted funding from the state that traditional academic programs do not receive	6.7	7.3	.074
Weighted state funding can only be spent on students in CATE, except for allowable administrative costs	6.4	6.7	.550
Federal funding available through Carl Perkins Act, such funding can be used for some teacher travel	6.1	6.3	.753
Program currently comprised of 49 courses in seven systems areas, not the Ag I-IV arrangement	5.9	5.8	.723
Annual program evaluation is required	5.7	5.9	.745
Students in CATE have passing rates on TAAS equal to the percentage of all students passing all tests of TAAS	5.6	5.9	.473
Required physical education credit may be earned through work-based agriscience (and similar CATE) courses	4.8	5.7	.120
Cannot obtain a waiver to give credit in foundation courses through certain agriscience courses	4.3	5.5	.023*

N=29 for respondents with no experience in agricultural science
N=41 for respondents with experience in agricultural science
[a]Mean = No experience in agricultural science
[b]Mean = Experience in agricultural science
*Significant at .05 level

Regarding program funding, superintendents who had indicated no experience in agriscience are highly knowledgeable about the receipt of weighted state funding for students enrolled in agriscience courses (6.7). They are also quite knowledgeable in regard to the permitted use of these funds only on career and technology programs, except for allowable administrative costs (6.4), and are aware of the availability of federal funds from the Carl Perkins Federal Vocational Act and the use of these funds for teacher travel in certain instances (6.1).

Superintendents with experience in agriscience are very highly knowledgeable about the receipt of weighted state funding for students enrolled in agriscience courses (7.3). This group also indicated a high level of perceived knowledge regarding allowable uses of weighted state funds (6.7), and consider themselves highly knowledgeable that federal funds from the Carl Perkins Federal Vocational Act are available and can be used for teacher travel in certain instances (6.3).

One significant difference in the means of perceived knowledge levels was found between superintendents with and without agriscience experience. This was in regard to school districts not being able to obtain a waiver that allows students in certain agriscience courses to receive credit for related foundation courses (α=.023).

DISCUSSION

Conclusions. Important findings derived from this study indicate that a majority (58.6%) of Texas public school superintendents, whose district has an agriscience program, have at least some experience in agriscience. This experience is from having either taught, been enrolled in, or had children enrolled in, agriscience. Contrastingly, when looking at these experiences individually, barely one-tenth (11.4%) of the respondents have experience teaching vocational education/agricultural science, most (58.6%) were never enrolled in an agriscience/vocational agriculture program, and almost two-thirds (65.7%)

have not had a child enrolled in the program. Most (66.7%) of these superintendents have a teaching background in an academic field, such as language arts or mathematics, as their primary teaching area. Few (14.5%) indicated career and technology education as their primary teaching area, and only slightly more (17.1%) have any experience teaching in career and technology education. Surprisingly, most have agricultural work experience, perhaps due to another surprising fact – most were raised in a rural environment (small town with a population of 2,500 or less).

Superintendents of Texas public school districts with an agriscience program, as a group and regardless of their experience in agriscience, have a positive perception of the agriscience program and of those who teach it. They believe the funds spent on agriscience are a wise investment of resources, that the program provides students with specific skills needed for both gainful employment and higher education, and that the program is useful and successful in helping at-risk students remain interested in their education.

Although neither group had an exceptionally high belief, superintendents with agriscience experience did perceive the program to be less vocational and more academic than other career and technology programs, as compared to the beliefs of superintendents with no experience in agriscience as a teacher, student or parent. Experience in agriscience or a lack thereof was found to have a significant effect on superintendents' perceptions about some agriscience instructional areas that needed more emphasis. This experience factor also contributed to differences in perceptions for areas of the program that had too much attention focused upon it, and whether agriculture should be taught to all students throughout their formal schooling years.

Recommendations. Teachers should be proactive in offering courses that integrate science, mathematics, and other areas while also offering courses that fit student and industry needs, not their own personal preferences.

Superintendents should continue to provide the financial resources necessary to conduct a quality agriscience program that is current with new technology and work place practices. Teachers should be active in understanding program funding and monitor compliance.

Teachers should aggressively promote and conduct agriculture as an academic program, realizing they are an agriscience teacher first and an FFA advisor second.

Teachers that do not have support from their superintendent for a 12-month contract and smaller teaching load should seek to understand why such support is not provided. All superintendents, regardless of their experience in agriscience, should be made aware of the requirements and demands of supervising SAEPs and extracurricular activities.

Teachers should continue to ensure that the agriscience program prepares students of all academic abilities for both gainful employment and higher education. Agriscience teachers should give greater attention to academics and current practices, as well as changing the program's image, to solidify its future in the Texas public school system. This might require less emphasis on extracurricular activities such as showing livestock and judging contests.

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Survey of Hemoparasites in Scaled Quail from Elephant Mountain Wildlife Management Area, Brewster County, Texas

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ABSTRACT

There is limited information on blood parasites in scaled quail (*Callipepla squamata*) from Texas. In August 2002, 48 scaled quail, representing 10 fledged hatch-year juveniles, 12 subadults, and 26 adults, were collected at Elephant Mountain Wildlife Management Area in Brewster County, Texas. Two thin blood smears were made from each bird using heart blood. Smears were stained in DiffQuik® and examined for 15 minutes each (30 minutes per bird) with a light microscope at 1,000x magnification. No blood protozoans were observed, but 12 (25%) scaled quail were infected with microfilariae. Microfilarid prevalence was 20%, 17%, and 31% in hatch-year, subadult, and adults, respectively. Microfilarid prevalence between scaled quail <1 year old (hatch-year and subadult; $n = 22$) and adults ($n = 26$) were similar ($P = 0.32$). Based on these findings, hematozoan infections were absent or at least not actively occurring in this population of scaled quail during the period in which host collections were made, whereas infections by microfilarids were evident.

KEYWORDS: *Callipepla squamata,* Elephant Mountain Wildlife Management Area, hemoparasites, microfilariae, scaled quail, western Texas

Scaled quail (*Callipepla squamata*) are important gamebirds in western Texas. Of the three published studies that surveyed scaled quail for hemoparasites (Campbell and Lee 1953, Hungerford 1955, Stabler et al. 1974), none sampled scaled quail in Texas. Given that avian hemoparasites can cause ecological and behavioral changes in host populations (van Riper et al. 1986), alter host sexual selection (Höglund et al. 1992), and induce morbidity and mortality in susceptible host individuals (see reviews of Atkinson 1991, Forrester 1991, Greiner 1991), it is necessary to examine scaled quail populations for hemoparasites. This study was conducted to survey scaled quail for hemoparasites from Elephant Mountain Wildlife Management Area in southwestern Texas.

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MATERIALS AND METHODS

The study was conducted at Elephant Mountain Wildlife Management Area (30° 2' 1.5" N, 103° 34' 2.9" W) in Brewster County, Texas. Texas Parks and Wildlife Department acquired the property in 1985. Calamity Creek on the west side, and Chalk Valley on the east side of Elephant Mountain are the two major drainages. Calamity Creek is a dry drainage except during periods of intense or prolonged seasonal rainfall and was dry during this study. In 2001, 205 mm of precipitation was recorded and through 31 August 2002, 195 mm of precipitation was recorded, of which 109 mm fell in July 2002. At the time of scaled quail collections, precipitation on the study area had been below average for >4.5 years (TPWD, unpublished data). Livestock water troughs and spreader dams (relatively low, 1–2 m earthen berms designed to catch and retain rainfall runoff) are available on certain portions of the study area.

Major plant communities on the Chalk Valley watershed vary from grama (*Bouteloua* spp.) and tobosa (*Pleuraphis* (Hilaria) spp.)-dominated grasslands to Chihuahuan Desert scrubland (Lerich 2002). Major plant communities on the Calamity Creek watershed include dropseed (*Sporobolus* spp.) and tobosa-dominated grasslands to mesquite (*Prosopis glandulosa*)-dominated shrublands (Lerich 2002). A thorough description of the study site's climate, hydrology, and vegetation is provided in Lerich (2002).

Scaled quail were collected by shooting during August 2002 in accordance with a scientific collection permit from Texas Parks and Wildlife Department (Permit No. SPR-0498-949) along with an entry permit for Elephant Mountain Wildlife Management Area issued by M. Pittman, Texas Parks and Wildlife Department Project Leader, Trans-Pecos Ecosystems Management Project (Permit No. 02-10). August was chosen for sample collection as more hosts were available due to the reproductive effort, which would increase the chances of density-dependent parasite transmission, and sufficient numbers of fledged juveniles were present on the study area at this time. The collection method was chosen to add an element of randomness into the sampling effort and avoid biases associated with using bait stations, which can artificially concentrate hosts and reduce sampling distribution of the host population (Weatherhead and Ankney 1984). The shooting collection method, however, samples "normal" birds (those capable of maintaining covey membership, pair bond status, etc.) and does not sample individuals that have previously been eliminated from the population or those too weak to maintain social relationships. Each bird was sexed by gonadal examination and aged as hatch-year juvenile, subadult, and adult. The subadult grouping was possible as determined by presence of white tips on primary coverts indicating birds <1 year old (Dimmick and Pelton 1996) as well as presence of developed gonads.

Two thin blood smears were made from each scaled quail using heart blood extracted with a disposable glass pipette immediately upon death of the bird. Smears were fixed in methanol for 1 minute and stained in DiffQuik®. Smears were scanned for 15 minutes each (30 minutes per bird) with a light microscope under 1,000x magnification (Glass et al. 2002) covering as much of the smear as possible within the prescribed time.

Motile embryos of filariid nematodes are reported as microfilariae. No attempts were made to further identify microfilariae because identification typically requires the adult nematode (Saunders 1959, Sonin 1974). Frequency data were analyzed for goodness of fit using Chi-square (PROC FREQ; SAS Institute Inc., 1990) to determine if hemoparasite prevalence varied by host age.

RESULTS AND DISCUSSION

Blood samples were collected from 48 scaled quail, which represented 10 hatch-year juveniles, 12 subadults, and 26 adults. No blood protozoans were observed, but 12 (25%) scaled quail were infected with microfilariae, which is reported for the first time in this host. Microfilarid prevalence was 20%, 17%, and 31% in hatch-year, subadult, and adults, respectively. Microfilarid prevalence between scaled quail <1 year old (hatch-year and subadult; n = 22) and adults (n = 26) were similar (P = 0.32). Microfilariae occur in a wide range of avian species (Greiner et al. 1975) and include several genera such as *Ornithofilaria*, *Sarconema*, and *Splendidofilaria* (Cohen et al. 1991, McDonald 1969, Sonin 1974). Actual prevalence was likely higher than reported in this study, since blood smears are not the best method of detecting microfilariae (Seegar 1979).

Findings from this study were surprising since there was an expectation to find *Haemoproteus*, which was reported in scaled quail from New Mexico (Campbell and Lee 1953) and Arizona (Hungerford 1955). Haemoproteids are transmitted by hippoboscid flies (Atkinson 1991); at least one species occurs in the area, *Pseudolynchia canariensis*, being found on scaled quail in the adjoining Pecos County (Howard 1981). Additionally, no *Plasmodium* spp. were found even though mosquitoes (which can serve as vectors for malaria) were observed occurring around spreader dams that contained water. It is possible that *Plasmodium* was present and was missed. Forrester et al. (1974) found a *Plasmodium* sp. was underestimated using blood smears from wild turkeys (*Meleagris gallopavo*), compared to the subinoculation technique. However, long scan times (30 minutes per bird) used in the present study substantially increased the chances of finding *Plasmodium* even at extremely low densities on the smear.

Possibly, a larger sample size would allow for detection of hematozoans occurring at extremely low prevalences; however, collecting large numbers of scaled quail prior to the hunting season on public wildlife management areas or on private properties is not politically feasible. Stabler et al. (1974) examined 23 scaled quail from Colorado and found none were infected, whereas Campbell and Lee (1953) found 11 of 678 (1.6%) scaled quail infected with *Haemoproteus lophortyx* and (or) *Plasmodium* sp. Also, Hungerford (1955) found *H. lophortyx* in 31 of 111 (28%) scaled quail. Lowest detection limit in the present study was 1 in 48 (2%). In any case, it is uncertain what ecological significance such low prevalences would have on the host population.

SUMMARY AND CONCLUSIONS

This study represents the first published survey for hemoparasites in scaled quail from Texas and is the first study to document microfilariae in scaled quail. Findings suggest that hemoparasites are uncommon in scaled quail occurring at Elephant Mountain Wildlife Management Area or at least they were not demonstrating active infections when the birds were sampled during a period of elevated host densities resulting from the breeding effort. No statistical difference in microfilarid prevalence was found by host age. Although *Haemoproteus* and *Plasmodium* were not observed in this study, more scaled quail should be examined, particularly from other geographic regions in Texas, before conclusions are made about the occurrence of these protozoans in scaled quail from Texas.

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Northern Bobwhite Home Range and Survival in Response to Baiting Multiple Roads in Southern Texas: An Observation of Management Concern

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ABSTRACT

An increasingly common practice in southern Texas is baiting roads with grain to facilitate northern bobwhite (*Colinus virginianus*) harvest. Unfortunately, such a practice has the potential to negatively affect bobwhite survival and covey home range size, especially during relatively dry periods. However, the pattern of baiting (i.e., single road vs. multiple road baiting) could influence how baiting of roads affects bobwhites. The objective of the project was to document the effects of multiple-road baiting on bobwhite survival and movements in contrast to baiting only a single road. The project involved two study sites in Jim Hogg County, Texas (one area with a single baited road and one area with multiple baited roads) which were monitored over 3 periods, pre-baiting (Sep – Oct), baiting (Nov – Dec), and post-baiting (Jan – Feb). Bobwhite survival, home range size, and predator abundance was assessed for each area. Bobwhite survival and home range size and predator abundance did not differ between the two baiting patterns. However, during dry conditions, baiting multiple roads in a pasture may be less detrimental to the survival of bobwhite populations than just baiting one road in a pasture.

Keywords: *Colinus virginianus*, movement, northern bobwhites, road baiting, supplemental feeding, survival

Supplemental feeding is used in northern bobwhite (*Colinus virginianus*) management to potentially maintain or increase bobwhite populations (Boyer 1989). Supplemental feeding is thought to achieve this result by correcting potential nutritional deficiencies and mitigating effects of severe climatic stress such as during the harsh winters (Townsend et al. 1999). Supplemental feed is provided to bobwhites by various means such as fixed feeders or by spreading bait along roads. The impacts of supplemental feeding through fixed feeders has been researched extensively (Robel 1969, Boyer 1989, Robel and Kemp 1997, Townsend et al. 1999, Doerr and Silvy 2002, Madison et al. 2000, 2002), but the effects of baiting roads on bobwhites is less well known (Lehmann 1984, Sisson et al. 2000, Haines et al. 2004).

A potential negative effect of baiting roads is that bobwhites are thought to concentrate along baited roads thereby increasing their vulnerability to predation. Research has provided conflicting results. Lehmann (1984) found that road-baiting did not benefit bobwhite quail populations in southern Texas. However, Sisson et al. (2000)

documented that bobwhite survival in Georgia was greater on areas with baited roads than on areas without baited roads, but that such effects varied among years due to weather and condition of native vegetation. More recently, Haines et al. (2004) documented that baiting roads lowered bobwhite quail survival and localized their movements but only during relatively dry conditions when plant seed and arthropod resources were likely to be low. Thus, it appears that the effects of baiting roads on bobwhites can vary with rangeland conditions.

Another potential factor influencing the effect of baiting roads on bobwhites might be pattern of baiting (i.e., single road vs. multiple roads). For example, if bait is spread along multiple roads instead of one road, then bobwhites might not concentrate because they would have numerous feeding opportunities as opposed to only one road. Whether multiple-road baiting achieves this result is unknown. During the study of Haines et al. (2004), an opportunity arose to document the effects of multiple-road baiting on bobwhite survival and movements. Herein we report the observational results of this opportunity.

STUDY AREA

The study area was located on a private ranch 5 miles east of Hebbronville, Texas in Jim Hogg County, within the Rio Grande Plains ecoregion (Gould 1975). Topography was level to rolling with elevation ranging from sea level to 361 yards. The Rio Grande Plains was characterized by rangeland and open prairies dissected with drainages with a growth of mesquite (*Prosopis glandulosa*), huisache (*Acacia farnesiana*), granjeno (*A. berlandieri*), and pricklypear (*Opuntia engelmannii*). Annual rainfall was 14–26 inches and soils ranged from clays to sandy loams (Correll and Johnston 1979). Although large acreages of cultivated land existed within the Rio Grande Plains, predominant land use was livestock production (i.e. rangeland). Land holdings were predominately cattle ranches with abundant wildlife (Correll and Johnston 1979). Potential predators of bobwhites included bobcats (*Lynx rufus*), coyotes (*Canis latrans*), raccoons (*Procyon lotor*), striped skunks (*Mephitis mephitis*), opossums (*Didelphis virginiana*), Cooper's hawks (*Accipiter cooperi*), red-tailed hawks (*Buteo jamaicensis*), Harris' hawks (*Parabuteo unicinctus*), sharp-shinned hawks (*A. striatus*), white-tailed hawks (*B. albicaudatus*), and great horned owls (*Bubo virginianus*).

Mean monthly rainfall for July 2001 through February 2002, was 1.3 inches with a mean monthly high temperature of 78.8°F (National Climatic Data Center; http://www.ncdc.noaa.gov). Mean monthly rainfall from July 2002 through February 2003, was 2.2 inches with a mean monthly high temperature of 76.8°F (National Climatic Data Center; http://www.ncdc.noaa.gov).

MATERIALS AND METHODS

The study of Haines et al. (2004) was a two year project that involved a control site (no baiting) and a treatment site (single road baited only during November–December). During their second year of study, the opportunity arose to monitor a third site (i.e., multiple-road baiting). This multiple-road site was contained within a 2,548 acre pasture and separated by > 1.86 miles from the control and single-road site. Approximately twenty roads were baited during the fall-winter season (September – January). This study could not be replicated because nearby landowners were unwilling to halt the use of supplemental feed on roads during the bobwhite hunting season (Oct–Feb).

The impacts of baiting multiple roads on bobwhites on the multiple-road bait site during September–February 2002–2003 were documented. Roads were unpaved secondary roads that traversed through the multiple-road bait site. Beginning in September, land managers distributed a mixture of corn and milo liberally throughout the multiple-road bait site until the end of January. Haines et al. (2004) identified three distinct time periods relative to baiting on the single-road site: September–October ("pre-baiting," with no bait being spread on the single-road site), November–December ("baiting," with bait being spread on the single-road site) and January–February ("post-baiting," with no bait being spread on the single-road site). This schedule allowed for more direct comparison of the effects of road baiting between the multiple-road and single-road bait sites.

The protocol of Haines et al. (2004) was followed to estimate bobwhite survival, home range, and predator abundance on the multiple-road site in order to make this study comparable to their findings. A condensed description of this protocol is provided.

Radio-telemetry

Monitoring of bobwhite survival, home range size, and surveying for predator abundance was conducted along one road on the multiple-road bait site chosen at random. Bobwhites were captured along the selected road using standard funnel traps baited with milo (Stoddard 1931) during the month of August. Four coveys along the road and four coveys > 437 yards from the road were captured, classified by age and sex (Rosene 1969) and weighed to the nearest gram. All captured birds were banded and individual birds weighing >150 grams were radiomarked with a 6-gram, 150–MHz, neck-loop radiotransmitter (American Wildlife Enterprises, Tallahassee, Flor.). To maintain a sample size of > 20 radiomarked bobwhites for each study site, bobwhites were trapped and radiomarked throughout the study period by night-netting roosting coveys (Labisky 1968).

Each bobwhite covey was monitored five times a week (i.e., > 30 locations per time period) via radiotelemetry to document survival and estimate covey home range size (Haines 2003). Home ranges were obtained for each covey for the pre-baiting, baiting, and post-baiting periods, and home range size was determined using the 95% fixed kernel method (Worton 1989, Seaman et al. 1999). All locations were analyzed using the Animal Movement Extension (Hooge and Eichenlaub 1997) of the program ArcView 3.2 (Environmental Systems Research Institute, Inc. Redlands, Calif.).

Predator surveys

Raptor abundance. Following the protocol of Fuller and Mosher (1987), raptor surveys were conducted once per week during morning hours (0730–1100 hrs) using an all-terrain vehicle traveling at approximately 5 miles/hr along each road using the road as the transect line. The number of raptors observed and identified were recorded according to species.

Mammalian predator activity. Scent station surveys were conducted (Conner et al. 1983) for mammalian predator activity every week. Five rows of 5 scent stations were arrayed (n = 25) perpendicular to the road, each row separated by 0.5 miles. Scent stations within a row were located 109 yards apart. Two scent stations extended from each side of the road with a third scent station along the roadway so that scent stations covered approximately 219 yards along both sides of the roads.

Each station consisted of a 1.1-yard diameter circular area cleared of debris and vegetation according to the design of Linhart and Knowlton (1975). Each week, soil in the scent stations was sifted and leveled and a scent capsule with a fish oil attractant was placed in the middle. Scent stations were prepared in the late afternoon (1400–1830 hrs), and checked the next morning (0730–1200 hrs). The number of operable scent stations visited by mammalian predators were recorded. Because of the proximity between individual scent stations and rows of scent stations, scent stations were not considered independent within study sites, only between study sites.

Statistical analysis

Statistical analysis was conducted to make direct comparisons of the effects of road baiting between the multiple-road and single-road bait sites. Bobwhite survival was determined by using the staggered entry design with individual bobwhites as experimental units (Pollock et al. 1989) and assuming that individual bobwhite survival was not affected by bobwhite covey size. Kaplan-Meier (1958) survival curves using the STAGKAM program (Kuloweic 1988) were calculated for survival for each period. Bobwhites that died or were lost within seven days of capture were consored and excluded from analysis to mitigate the effects of transmitters on bobwhite survival (Pollock et al. 1989). Also censored were all bobwhites that were lost due to radio failure (Pollock et al. 1989). Censored bobwhites were used for survival probabilities up until the date signal loss occurred, but they were not considered mortalities (Burger et al. 1995). Survival curves were compared using log-rank chi-square tests (Pollock et al. 1989) run on a SAS program developed by Kuloweic (1989).

There has been some debate concerning the use of inferential statistics (i.e., ANOVA) for pseudoreplicated studies (Hurlbert 1984, Stewart-Oaten et al. 1986). Because this study was replicated (i.e., psuedoreplication through time), observations were not analyzed using a repeated measures ANOVA design because improper error terms would be used to analyze the main effects. Instead, covey home range sizes were analyzed using a univariate general linear model to test for interaction between treatment and time period. This was done using Proc Mixed in SAS (SAS Institute, Inc. 1989–1996). The statistical model was

$$Y_{ijk} = \mu + T_i + d_{ij} + B_k + (TB)_{ik} + e_{ijk}$$

Where:

Y_{ijk} = Home range size associated with the j^{th} covey in treatment i at time period k

$i = 1,2$

$k = 1,2,3$

$j = 1,\ldots,n_{ik}$

μ, T_i, B_k, and $(TB)_{ik}$ are fixed parameters such that the mean for the i^{th} treatment at time period k is $\mu_{ik} = \mu + T_i + B_k + (TB)_{ik}$

μ = Average of the treatment population means

T_i = i^{th} treatment effect

dij = Random error associated with the j^{th} covey in treatment i

B_k = k^{th} time period

$(TB)_{ik}$ = Interaction between treatment and time period

e_{ijk} = Random error associated with the j^{th} covey in treatment i at time period k

In addition, because this study was not replicated, raptor abundance and mammalian predator activity observations were analyzed using the randomized intervention analysis (RIA) following the methods of Carpenter et al. (1989). Randomized intervention analysis allows for comparison of the paired differences of time series observations for ecosystems before and after manipulation (i.e., baiting). In addition, RIA is not affected by non-normal data (Carpenter et al. 1989). In this case, the RIA method was used to compare paired differences of the weekly number of raptors counted along roads and the weekly number of scent stations visited by mammalian predators between the pre-baiting and baiting periods, and between the baiting and post-baiting periods among study sites for each year. Significance for all statistical tests was inferred at P-Value <0.05.

RESULTS

Survival and home range size

From August 2002–December 2002, 30 bobwhites (*n* = 15 males, *n* = 8 females, *n* = 7 unknown, *n* = 10 adults, *n* = 17 juveniles, *n* = 3 unknown) were trapped on the single-road bait site (Haines et al. 2004), and 21 bobwhites (*n* = 6 males, *n* = 8 females, *n* = 7 unknown, *n* = 9 adults, *n* = 12 juveniles) on the multiple-road bait site. Bobwhite survival on the single-road bait site did not differ ($P \geq 0.16$) from the multiple-road bait site during all 3 periods (Table 1).

Table 1. Kaplan-Meier survival estimates ($\hat{S}$) of northern bobwhites on the multiple-road bait and single-road bait sites by time period (pre-baiting [no baiting during Sept–Oct], baiting [baiting during Nov–Dec], and post-baiting [no baiting during Jan–Feb]) in Jim Hogg County, Texas, USA, September–February, 2002–2003.

	Single-Road Bait			Multiple-Road Bait			
Period	*n*[a]	$\hat{S}$	S.E.	*n*	$\hat{S}$	S.E.	*P*-value
Pre	27	0.89	0.069	20	0.92	0.066	0.74
Feeding	22	0.78	0.094	17	0.81	0.094	0.76
Post	17	0.88	0.072	13	0.69	0.015	0.16

[a] Number of northern bobwhites monitored.

No interaction was documented in mean home range size between treatment and time period ($P > 0.10$) for the single-road bait site (Pre-baiting: 0 = 11.50 ± 2.35, *n* = 8, Baiting: 0 = 9.19 ± 2.1, *n* = 8, Post-baiting: 0 = 10.27 ± 2.0, *n* = 8) (Haines et al. 2004) and multiple-road bait site (Pre-baiting: 0 = 16.00 ± 3.35, *n* = 6, Baiting: 0 = 9.70 ± 1.93, *n* = 6, Post-baiting: 0 = 5.64 ± 1.54, *n* = 4).

Predator Survey

Raptor abundance. Species that were counted included Cooper's hawks, sharp-shinned hawks, red-tailed hawks, white-tailed hawks, Harris' hawks, great-horned owls, northern harriers (*Circus cyaneus*), and burrowing owls (*Athene cunicularia*). A difference was found (*P* = 0.03) between the paired differences of the number of avian predators counted on the single-road bait site compared to the multiple-road bait site between the pre-baiting and baiting periods (Table 2), with more raptors being encountered on the single-road bait site (*n* = 27) during the baiting period than on the multiple-road bait site (*n* = 10). However, there was no difference (*P* = 0.27) between the paired differences of avian predators counted on the single-road bait site compared to the multiple-road bait site during the baiting and post-baiting periods.

Table 2. Comparison of mean number of raptors counted weekly on the multiple-road bait and single-road bait sites by time period (pre-baiting [no baiting during Sept–Oct], baiting [baiting during Nov–Dec], and post-baiting [no baiting during Jan–Feb]) in Jim Hogg County, Texas, USA, September–February, 2002–2003. Surveys were conducted along a 2 mile transect on each site in the morning (0730–1100 hrs).

	Multiple-road bait			Single-road bait			
Year Period	n[a]	0	SE	n	0	SE	P-value[b]
2002–2003							
Pre-	17	2.13	1.32	15	1.88	1.06	
							0.03
Baiting	10	1.25	1.02	27	3.38	1.40	
							0.27
Post-	5	0.63	0.55	12	1.50	1.03	

[a] Total number of raptors counted during each period.
[b] P-value indicates the paired differences of the number of raptors counted during the pre-baiting and baiting periods, and the baiting and post-baiting periods between sites using the Randomized Intervention Analysis.

Mammalian predator activity. Mammalian predators recorded from scent stations included (in order from most to least prevalent) coyotes, feral hogs (*Sus scrofa*), skunks (all skunks assumed to be striped skunks), bobcats, and raccoons (Table 3). No significant difference ($P > 0.24$) was found between the paired differences of the number of scent stations visited by mammalian predators on the single-road bait site compared to the multiple-road bait site during the pre-baiting and baiting periods, and the baiting and post-baiting periods (Table 3). However, during the baiting period there was a trend for a higher number of visits by mammalian predators per 100 scent station nights on the multiple-road bait site ($n = 21.1$) compared to the single-road bait site ($n = 12$) (Table 3).

Table 3. Comparison of the number of visits by species per 100 scent-station nights, surveyed weekly on the multiple-road bait and single-road bait sites by time period (pre-baiting [no baiting during Sept–Oct], baiting [baiting during Nov–Dec], and post-baiting [no baiting during Jan–Feb]) in Jim Hogg County, Texas, USA, September–February, 2002–2003.

	Multiple-road bait			Single-road bait		
Species	Pre-	Baiting	Post-	Pre-	Baiting	Post-
Coyote	2.9	12.0	9.1	7.4	6.3	9.1
Hog	2.9	4.0	1.7	2.3	5.7	1.7
Skunk	4.0	3.4	5.1	1.7	0.0	0.0
Bobcat	1.7	0.6	0.0	0.0	0.0	2.3
Raccoon	1.7	1.1	0.6	0.6	0.0	0.0
Total	13.1	21.1	16.6	12.0	12.0	13.1

DISCUSSION

Baiting multiple roads, over a five month period, had no effect on bobwhite survival, home range, or predator abundance, and observation of similar bobwhite and predator response supports previous research (Lehmann 1984, Doerr and Silvy 2002, Haines et al. 2004). Lehmann (1984) found that road-baiting did not benefit bobwhite quail populations in southern Texas. Doerr and Silvy (2002) reported no difference in relative predator abundance between sites with and without supplemental feed. All these studies were conducted in southern latitudes (southern Texas) where winters are relatively mild. Thus, it appears that supplemental feed might not affect bobwhite survival in areas with mild winter temperatures. However, drought is common in these southern latitudes and could possibly influence the effect that road baiting has on bobwhites.

Haines et al. (2004) documented that baiting a single road within a pasture concentrated bobwhite movements along the baited road and lowered bobwhite quail survival during one of two years. Haines et al. (2004) attributed this difference to a potential interaction of environmental conditions with road baiting. They observed a treatment effect during a relatively dry year but not in more mesic conditions. Haines et al. (2004) speculated that during dry conditions seed and arthropod production were reduced thereby causing bobwhites to concentrate their foraging activities around baited areas and making them more susceptible to predation.

In theory, baiting multiple roads in a pasture might be less detrimental to bobwhites than single-road baiting during dry conditions. If bobwhites and other prey species feed over an extended area consisting of multiple sites instead of within a single concentrated area, predators and hunters theoretically cannot concentrate their activities to only one area. However, it is difficult for us to determine if the lack of treatment effect resulted from a dispersing effect or mesic conditions. This study was conducted during relatively wet conditions (Haines et al. 2004) when food availability likely was greater. The fortuitous nature of this study did not allow for extension and documentation of the bobwhites' response during more xeric conditions. Thus, it cannot be determined if the lack of effect of road baiting on bobwhite response is due to multiple roads being baited or environmental conditions.

CONCLUSIONS

The study indicates that baiting multiple ranch roads in South Texas offered no discernible benefit for bobwhites during relatively mesic conditions. However, during dry conditions, baiting multiple roads in a pasture might be less detrimental to the survival of bobwhites than baiting a single road through a pasture, but no empirical data exists to support this conjecture.

Further, as suggested by Haines et al. (2004) and Doerr and Silvy (2002), the effects of supplemental feeding might be more apparent in latitudes where winters are more severe and where there are substantially lower temperatures ($< 0^0$ C) (Robel 1969, Robel and Kemp 1997, Madison et al. 2000, 2002). However, such severe winters rarely occur in southern Texas.

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Cotton Response to Imazapic and Imazethapyr Residues Following Peanut

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ABSTRACT

Field studies were conducted at Denver City, Munday, and Yoakum (Gaines, Knox, and Lavaca Counties, respectively) to simulate residual concentrations of imazapic and imazethapyr in the soil and subsequent effects on cotton (*Gossypium hirsutum* L.). Simulated imazapic or imazethapyr rates included 1/64X, 1/32X, 1/16X, 1/8X, 1/4X, and 1/2X of the full labeled rate for peanut (*Arachis hypogaea* L.) and incorporated prior to cotton planting. Cotton stunting with imazapic or imazethapyr was more severe at Denver City than other locations. All rates of imazapic and imazethapyr resulted in cotton stunting at Denver City while at Munday and Yoakum the 1/8X, 1/4X, and 1/2X rates of imazapic resulted in reduced cotton growth when compared with the untreated check. At all locations imazapic caused more cotton stunt than imazethapyr. Cotton lint yield was reduced by imazapic or imazethapyr at 1/4 X and 1/2 X rates when compared with the untreated check at all locations.

KEYWORDS: Carryover, cotton height, imidazolinone, lint yield, plant emergence, stunting

Pursuit (imazethapyr) and Cadre (imazapic) are imidazolinone herbicides registered for use in peanut. In most peanut growing regions, imazethapyr may be applied preplant incorporated (PPI), preemergence (PRE), ground cracking (GC), or postemergence (POST) for effective weed control (Wilcut et al. 1995). However, in west Texas, imazethapyr can be applied only after stand establishment. Imazethapyr applied PPI or PRE controls many troublesome weeds such as coffee senna (*Cassia occidentalis* L.), common lambsquarters (*Chenopodium album* L.), morningglory species (*Ipomoea* spp.), pigweed species (*Amaranthus* spp.) including Palmer amaranth (*Amaranthus palmeri* S. Wats), prickly sida (*Sida spinosa* L.), purple and yellow nutsedge (*Cyperus rotundus* L. and *C. esculentus* L., respectively), spurred anoda [*Anoda cristata* (L.) Schlecht.], and wild poinsettia (*Euphorbia heterophylla* L.) (Cole et al. 1989, Wilcut et al. 1991a, b, Grichar et al. 1992, York et al. 1995).

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Imazapic is applied POST and controls all the weeds controlled by imazethapyr (Nester and Grichar 1993, Grichar et al. 1994, Wilcut et al. 1993, 1994b, 1995). In addition, imazapic provides control and suppression of Florida beggarweed [*Desmodium tortuosum* (S.W.) D.C.] and sicklepod [*Senna* obtusifolia (L.) Irwin & Barneby), which are not adequately controlled by imazethapyr (Grey et al. 2001). Imazethapyr provides consistent control of many broadleaf and sedge species if applied within 10 d after emergence, but imazapic has a longer effectiveness period when applied POST (Wilcut et al. 1993, 1995, Richburg et al. 1993, 1996). Imazapic also is effective for control of rhizome and seedling johnsongrass [*Sorghum halepense* (L.) Pers.], Texas panicum (*Panicum texanum* Buckl.), large crabgrass [*Digitaria sanguinalis* (L.) Scop.], southern crabgrass [*Digitaria ciliaris* (Retz.)Koel.], and broadleaf signalgrass [*Brachiaria platyphylla* (Griseb.) Nash] (Wilcut et al. 1993).

In crop rotations, imidazolinone herbicides must be used cautiously. Monks and Banks (1991) observed slight corn (*Zea mays* L.) injury and severe cotton injury from imazaquin (another imidazolinone herbicide) applied to soybean [*Glycine max* (L.) Merr.] the previous year. Renner et al. (1988) observed significant corn injury from imazaquin applied the previous year in one of two years. In Arkansas, cotton yield was reduced 7 to 42% as the soil concentration of imazaquin increased from 0.16 to 0.54 oz product/A (Barnes et al. 1989). Imazethapyr has been observed to moderately injure corn (Mills and Witt 1989). Johnson et al. (1992) reported slight but significant injury to rice (*Oryza sativa* L.) from imazethapyr applied the previous year to soybean. Rotational crops such as sugarbeet (*Beta vulgaris* L.), canola (*Brassica napus* L.), cauliflower (*Brassica oleracea* L.), broccoli (*Brassica oleracea* L.), and lettuce (*Lacfuca sativa* L.) can also be damaged when planted following imazethapyr (Fellows et al. 1990, Miller and Alley 1987, Tickes and Umeda 1991).

Previous research on imazapic carryover has shown varying results. In North Carolina, imazapic applied PPI at 0.72 oz product/A reduced cotton yield 43% the following year while imazapic at the same rate applied at GC caused 20% injury but no yield reduction (York and Wilcut 1995). In Georgia, imazapic at 0.72 oz product/A reduced cotton yield an average of 34% the following year regardless of application method (York and Wilcut 1995).

A Mississippi study indicated no reduction in shoot weight when corn, grain sorghum [*Sorghum bicolor* (L.) Moench], cotton, rice, wheat (*Triticum aestivum* L.), soybean, and Italian ryegrass (*Lolium multiflorum* L.) were planted directly into soil treated and incorporated with imazapic at rates up to 0.72 oz productA (Wixson and Shaw 1992). In that study, all crops were more sensitive in the greenhouse with rates of 0.24 oz product/A reducing corn and grain sorghum shoot weights. However, cotton, rice, and wheat tolerated rates of 0.4 to 0.8 oz product/A. Grymes et al. (1995) reported that imazapic at 1.44 oz product/A or imazapic plus imazethapyr each at 0.72 oz product/A reduced rice yield the year following application. Grymes et al. (1995) felt that imazapic injury to rice grown in rotation with soybean may be reduced by implementing a later rice planting date. They hypothesized that the later date allowed time for more herbicide degradation in the soil. Herbicide metabolism by the rice plant may also be greater at the later planting date due to warmer temperatures (Grymes et al. 1995).

The persistence of the imidazolinones in soil is influenced by the degree of adsorption to soil, soil moisture content, temperature, and amount of exposure to sunlight (Allen and Casely 1987, Malik et al. 1988, Mangels 1991). The degree of soil adsorption increases as organic matter content increases and pH decreases (Che et al. 1992, Loux et al. 1989). The primary mode of decomposition is by microbial degradation. Dissipation is most rapid in soils with

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temperatures and moisture contents that favor microbial activity (Goetz et al. 1990, Loux and Reese 1993). Photodecomposition accounts for a small amount of imidazolinone degradation when the herbicide is on the soil surface but rainfall or incorporation remove the herbicide from exposure to light (Curran et al. 1992, Goetz et al. 1990).

Above pH 4.0, the carboxyl groups on imazethapyr dissociate and soil adsorption of the resulting herbicide anion is negligible (Mangels 1991). However, in the presence of clay at pH 5.0, fluorescence emission spectra indicate imazethapyr is absorbed in the neutral form (Che et al. 1992). At pH 8.0, only the ionized form was observed even in the presence of clay. Increased adsorption and persistence were observed as the pH dropped from 6.5 to 4.5 (Loux and Reese 1992). Injury to crops seeded following imidazolinone herbicide use also increased as soil pH decreased from 7.7 to 6.0 (Fellows et al. 1990). This indicated that increased adsorption did not protect crops from imidazolinone herbicide residue at pH 6.0.

Most peanut soils in south and central Texas have a pH of 6.5 to 7.5 and organic matter contents $\leq$ 1%. Therefore, in these soils, imidazolinone herbicides are readily available for microbial degradation. However, in the Texas High Plains, the pH may range from 7.0 to 8.5 resulting in reduced microbial degradation. With soils low in organic matter and near neutral pH, little of the imidazolinone herbicide should be absorbed on soil particles. Crops with low tolerance to the imidazolinone herbicides such as cotton are grown in rotation with peanut in many areas where imazethapyr or imazapic may be used. Evaluating imazethapyr or imazapic at different locations will provide a more relevant understanding of the persistence issue. Therefore, the objective of this research was to evaluate cotton tolerance to imazethapyr and imazapic concentrations when planted at several locations in the peanut growing areas of Texas.

MATERIALS AND METHODS

Field studies were conducted at Knox County (Munday), Lavaca County (Yoakum), and Gaines County (Denver City) in Texas during the 2000 and 2001 growing seasons. In 2000, only imazapic was evaluated while in 2001 imazapic and imazethapyr were evaluated. Where both herbicides were evaluated, the experimental design was a randomized complete block with a factorial arrangement of treatments with four replications. Factors included imazapic and imazethapyr applied at 0, 0.0225 oz product/A (1/64X), 0.045 oz/A (1/32X), 0.09 oz/A (1/16X), 0.18 oz/A (1/8X), 0.36 oz/A (1/4X) and 0.72 oz/A (1/2X). The standard rate in peanut for both herbicides is 1.44 oz product/A (1X). Where only imazapic was evaluated, the experimental design was a randomized complete block with four replications. Cotton stunting was visually recorded 4 to 7 wk after planting (WAP) on a scale of 0 (no stunting or injury) to 100 (complete plant death). Cotton emergence counts were taken 3 to 6 wk after cotton was planted.

At Yoakum each plot contained two rows, 36 inches apart and 25 feet long. Imazapic and imazethapyr were applied within 24 h of cotton planting and incorporated 2 inches deep with a tractor-driven power tiller. Herbicides were applied in water with a compressed air bicycle sprayer, using Teejet 11002 (Spraying Systems Co., North Avenue and Schmale Rd., Wheaton, IL 60188) flat-fan nozzles which delivered a spray volume of 20GPA at 28 PSI.

At Denver City, herbicides were applied to flat ground, incorporated twice 4 inches deep using a tandem disk and bedder. Herbicides were applied 3 wk prior to planting with a tractor-mounted compressed-air spray using Teejet 8002 flat fan nozzles calibrated to deliver 15 GPA at 28 PSI.

At Munday, herbicides were applied immediately prior to cotton planting and

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incorporated twice, 1 to 2 inches deep using a rolling cultivator. Herbicides were applied in water with a CO_2 backpack sprayer using Teejet 8002 DG or 8004 VS flat fan nozzles calibrated to deliver 20 GPA at 25 PSI. Soil characteristics and other variables are shown in Table 1. All plots were maintained weed-free using standard herbicides recommended by The Texas Cooperative Extension.

Table 1. Cotton varieties, planting dates, and soil characteristics of each site.

	Yoakum		Denver City	Munday
Variables	2000	2001	2001	
Planting date	Apr 18	Apr 27	May 18	May 11
Soil texture	Sand	Sandy loam	Sandy loam	Sandy loam
Soil Name	Hallettsville	Hallettsville	Brownfield	Miles
pH	6.7	6.8	7.6	8.1
OM (%)	1.3	1.2	<1.0	0.1
Sand (%)	64	65	80	75
Silt (%)	18	18	2.5	16
Clay (%)	18	17	17.5	8
Cotton varieties	DP436RR	ST4793RR	PM1218BG/RR	PM1218BG/RR

Cotton was mechanically harvested at all locations except Yoakum where cotton was hand-picked. Harvest dates varied by location due to cotton maturity and weather conditions.

RESULTS AND DISCUSSION

Cotton emergence. At Yoakum none of the herbicides reduced plant numbers when compared with the untreated check (data not shown). Wixson and Shaw (1992) reported that imazapic did not reduce the emergence of cotton with rates up to 0.72 oz product/A on a silty clay soil with pH of 7.2 and 3.2% organic matter. Walsh et al. (1993) reported that imazethapyr at 1 to 2 oz product/A did not cause a loss of cotton stand.

Cotton stunting. There was a herbicide by rate interaction; therefore, data are presented individually by herbicide. Stunting with imazapic and/or imazethapyr was more severe at Denver City than the other locations (Table 2). All rates of imazapic and imazethapyr resulted in cotton stunting when compared with the untreated check. At Monday and Yoakum, the 1/8, 1/4, and 1/2X rates of imazapic resulted in reduced cotton growth when compared with the untreated check.

With imazethapyr, the 1/4 and 1/2 X rates reduced cotton growth at Yoakum while at Monday only the 1/2 X rate reduced cotton growth when compared with the untreated check (Table 2). Wixson and Shaw (1992) reported that in soils with a pH 7.2 and 3.2% organic matter, corn and cotton tolerated imazapic up to 0.72 oz product/A. Crop injury was observed with imazethapyr in both crops at rates from 0.12 to 0.36 oz product/A. The authors indicated that the injury noted with low rates of imazethapyr could be related to the increase of absorption of the imidazoline herbicides with increasing organic matter content.

Table 2. Cotton stunting as influenced by imazapic or imazethapyr.

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	Denver City[a]		Munday[b]		Yoakum[c]	
Herbicide rate[d]	Imazapic	Imazethapyr	Imazapic	Imazethapyr	Imazapic	Imazethapyr
	--%--					
0	0	0	0	0	0	0
1/64 X	14	8	0	0	8	0
1/32 X	48	17	3	3	0	0
1/16 X	81	60	4	1	10	0
1/8 X	84	70	8	1	20	9
1/4 X	98	89	23	6	50	32
1/2 X	100	100	48	16	70	33
LSD(0.05)	9		7		11	

[a] Injury ratings taken 5 weeks after planting (WAP).
[b] Injury ratings taken 7 WAP.
[c] Injury ratings taken 4 WAP.
[d] Labeled 1X rate of imazapic or imazethapyr on peanut is 1.44 oz product/A.

Cotton yield. There was no herbicide (imazapic and imazethapyr) by rate interaction; therefore, herbicides were combined over rates. At Yoakum in 2000, the 1/4 and 1/2X rate of imazapic reduced cotton yield when compared with the untreated check (Table 3). None of the other imazapic rates resulted in any cotton yield reduction.

In 2001, lint yields at Denver City were reduced by 1/8X, 1/4X, and 1/2X rates of imazethapyr or imazapic while at Munday and Yoakum cotton lint yields were reduced by the 1/4X and 1/2X rates when compared with the untreated check (Table 3). Previous research on imazapic carryover has shown varying results. In North Carolina, imazapic applied PPI to peanut at 0.72 oz product/A reduced cotton yield 43% the following year while the same rate applied at GC to peanut resulted in 20% injury but no yield reduction (York and Wilcut 1995). In Georgia, imazapic at 0.72 oz product/A reduced cotton yield an average of 34% the following year regardless of application timing (York and Wilcut 1995).

Table 3. Cotton lint yield as influenced by imazapic and imazethapyr rate.

	2000[a]	2001[b]		
Herbicide rate	Yoakum	DenverCity	Munday	Yoakum
	---------------------------------------Lb/A----------------------------------			
0	460	980	1620	830
1/64 X	460	1050	1590	840
1/32 X	420	1000	1610	1050
1/16 X	440	810	1610	830
1/8 X	390	720	1590	800
1/4 X	260	300	1520	380
1/2 X	180	50	1400	210
LSD (0.05)	90	180	100	240

[a]Imazapic only.
[b]No herbicide (imazapic and imazethapyr) by rate interaction, therefore herbicides were combined over rate.

This research was supported by grants from the National Peanut Board administered by The Texas Peanut Producers Board.

CONCLUSION

Cotton stunting did not always result in reduced yield. However, when stunting was greater than 50% there was almost always a decrease in cotton yield when compared with the untreated check. This study reveals that by possibly knowing the level of imazapic or imazethapyr residual in the soil, producers could have some flexibility in crop rotations if sensitive crops such as cotton are to be planted following imidazolinone use on peanut.

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Peanut Response to 2,4-DB plus Crop Oil at Various Application Timings[1]

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ABSTRACT

2,4-DB is an effective post emergence herbicide for broadleaf weed control in peanut, but concerns over crop safety and its effect on yield and quality still exist. Field experiments were conducted to determine the effect of the dimethylamine salt of 2,4-DB with or without crop oil concentrate at various application timings on yield of runner peanut. 2,4-DB at 0.4 lb ae/A was applied 30, 45, 60, 90, and 120 days after planting (DAP). Sequential 2,4-DB timings included 30 DAP followed by (fb) 60, 90, or 120 DAP; 60 DAP fb 90 or 120 DAP; and 90 DAP fb 120 DAP. Peanut yield and quality were not affected by 2,4-DB regardless of the addition of crop oil concentrate or application timings.

KEYWORDS: Application timing, *Arachis hypogaea* L., 2,4-DB, crop oil concentrate, herbicide tolerance.

Abbreviations: AG-CARES, Agricultural Complex for Research and Extension Center; COC, crop oil concentrate; DAP, days after planting; fb, followed by; PPI, preplant incorporated; POST, post emergence; WAP, weeks after planting; WPGRF, Western Peanut Growers Research Farm.

INTRODUCTION

Peanut (*Arachis hypogaea* L.) production on the Texas Southern High Plains has increased 10-fold from approximately 18,000 acres in 1987 to 180,000 acres in 2000 (Anonymous 2000). Over this period, peanut production has increased from approximately 65 million to nearly one-half billion pounds. Yet, yield and quality are still reduced because some weeds are not controlled effectively with current weed management practices. Weeds that escape control cost producers \$20 to \$50/A due to yield reductions, \$3 to \$25/A due to quality reductions, and \$53 to \$158/A due to reduced harvest efficiency (Bridges 1992; Bryson 1989).

Control of many grass and small-seeded broadleaf weeds can be achieved with a dinitroaniline herbicide such as ethalfluralin, pendimethalin, or trifluralin applied preplant incorporated (PPI) (Wilcut et al. 1994). Bentazon, acifluorfen, pyridate, paraquat, imazethapyr, and imazapic are all used in peanut because of their post emergence (POST) activity, but weed tolerances and escapes exist with each of these herbicides (Wilcut et al. 1994). Herbicide mixtures that contain 2,4-DB provide consistent broad-spectrum weed control in the Virginia-North Carolina region, the southeastern region, and in the southwest.

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Phenoxyacetic acid herbicides are phytotoxic to both broadleaf weeds and crops. However, 2,4-DB or phenoxybutanoic acid is an inactive herbicide and must undergo beta oxidation (the removal of two carbons from butanoic acid to render acetic acid) to be activated. Leguminous crops have low beta oxidase activity, which may prevent the rapid conversion to 2,4-D (Wain and Wightman 1954). Additional tolerance is achieved in leguminous crops because of the combination of reduced spray retention and translocation and less effective absorption (Hawf and Behrens 1974). In 1997, 2,4-DB was applied to 13% of planted acres of peanuts in Texas, which totaled over 13,000 pounds of active ingredient (Smith et al. 1998). Injury to peanut with 2,4-DB is a concern to many growers in this region, especially during reproductive periods (Baughman et al. 2002). Ketchersid et al. (1978) reported that a single application of 2,4-DB at 0.8 lb ae/A (a rate that exceeds label recommendations) from maximum pegging to early pod enlargement reduced yield and affected peanut quality on Spanish-type peanut. Grichar et al. (1997) reported that runner-type peanut yield and grade was not affected by 2,4-DB during all stages of development from prebloom through early pod development. Baughman et al. (2002) reported that Virginia-type peanut yield, grade, and pod and seed weight were not influenced by 2,4-DB when applied to peanut from pre-flowering to pod maturity. There is debate as to whether differences in injury occur when 2,4-DB is used with crop oil concentrate (COC), since adjuvants enhance herbicide efficacy by increasing absorption (Wanamarta and Penner 1989). Therefore, the objective of this research was to evaluate the effects of 2,4-DB with or without crop oil concentrate at various application timing on runner-type peanut yield in West Texas.

MATERIALS AND METHODS

Field experiments were conducted at the Agricultural Complex for Research and Extension Center (AG-CARES) in 1999 near Lamesa, TX and at the Western Peanut Growers Research Farm (WPGRF) in 2000 near Denver City, TX. The soil at AG-CARES is an Amarillo fine sandy loam (fine-loamy, mixed, super active, thermic Aridic Paleustalf; 0.4% organic matter; pH 7.8). At WPGRF, the soil is a Brownfield fine sand (loamy, mixed, super active, thermic Arenic Aridic Paleustalf; 0.1% organic matter; pH 7.8). The cultivar AT 120 was planted on May 5, 1999 and Flavor Runner 458 was planted on May 16, 2000. The seeding rate was 80 lb/A. Plot size was 13 by 30 ft in both years. Center pivot irrigation was used throughout the season in both years. Traditional production practices were used to maximize peanut growth, development, and yield. All plots were cultivated and hand-weeded throughout the growing season to maintain weed-free conditions. No fungicides or insecticides were needed in either year.

Dimethylamine salt of 2,4-DB at 0.4 lb ae/A was applied once at 30, 45, 60, 90, and 120 days after planting (DAP); or twice at 30 DAP followed by (fb) 60, 90, or 120 DAP; 60 DAP fb either 90 or 120 DAP; 90 DAP fb 120 DAP. Application timings corresponded with the following approximate peanut growth stages: pre-flowering, flowering, pegging, pod development, and pod maturity. These treatments were made with COC (paraffin-based petroleum oil (83%) and surfactant blend (17%)) at 1.25% v/v and alone (without COC). A non-treated control was also included.

All herbicide treatments were applied in 10 gallons per acre at 28 psi. Peanut injury was estimated visually throughout the growing season (approximately 3, 6, 10, and 20 weeks after planting (WAP)) at each location using a scale of 0 (no injury) to 100 (peanut death) (Frans et al. 1986). Canopy height and width were recorded 10 and 20 WAP at Lamesa. Peanut yield was determined by digging the pods based on maturity of control plots, air-drying in the field for 6 to 10 d, and harvesting individual plots with a small-plot thresher. Yield samples were cleaned and adjusted to 10% moisture. Pod, shell, and peanut kernel weight were determined from each sample at WPGRF. Grades were determined for a 200-g pod sample following procedures described by the Federal-State Inspection Service (USDA, 1986).

At each location, the experimental design was a randomized complete block with three replications. Data were subjected to an analysis of variance with partitioning appropriate for the factorial arrangement of 2,4-DB application timings and COC. If no year by application timing by COC interaction or two-way interaction was observed, then only main effects were compared. Main effect means were compared using Fisher's Protected LSD test at $P = 0.05$.

Table 1. Effect of 2,4-DB applied at 0.4 lb/A on pod yield averaged over locations and crop oil.

Application Timing DAP[a]	30	45	60	90	120	30 fb 60	30 fb 90	30 fb 120	60 fb 90	60 fb 120	90 fb 120	Untreated	LSD (P#0.05)
Peanut Yield lb/A	3770	3689	3836	3984	3960	3818	3568	4038	3567	3694	4060	3668	NA

RESULTS AND DISCUSSION

Visual injury and canopy stature. No application timing by COC interaction was observed for peanut injury; therefore, main effects were compared. Visual injury was noted following all 2,4-DB applications regardless of application timing and use of COC, but no injury exceeded 5% (data not shown). This injury consisted of a chlorotic speckling of the upper leaves and petioles and a slight but easily noticeable strapping effect common of phenoxy herbicides (Prostko and Baughman, 1999). Injured petioles remained chlorotic and speckled throughout the season. Similar injury was noted by Baughman et al. (2002) and Prostko and Baughman (1999). By 20 WAP, no injury was noted for any treatment (data not shown). Regardless of application timing, 2,4-DB did not affect canopy height (data not shown). At 10 WAP, canopy width was not influenced by 2,4-DB application timing, but was affected by the use of COC (p=0.0052). Canopy width following 2,4-DB plus COC (12.8 in.) was less than the canopy width following 2,4-D applied alone (13.4 in.). No difference in canopy height or width was observed at 20 WAP.

Peanut yield and quality. No year by application timing by COC interaction or two-way interaction was observed; therefore, only main effects were compared. No differences in pod yield were noted among 2,4-DB application timings when averaged across year and COC (Table 1). Similar results were reported for runner-type (Grichar et al. 1999) and Virginia-type (Baughman et al. 2002) peanuts following 2,4-DB applications without COC. Pod yield ranged from 3789 to 3834 and was not different among COC treatments when averaged across year and application timing (data not shown). Peanut yield when averaged across application timings and COC treatments was different over years (p<0.001) (Table 2). In 1999, peanut yield was 4780 lb/A, which was greater than the yield observed in 2000 (2839 lb/A). This difference is likely the result of the differences in seasonal temperature and poor harvest conditions due to excessive fall rainfall in 2000 compared to 1999. In fact, in seven variety trials conducted in the major production regions in Texas in 1998, Flavor Runner 458 produced similar or greater yields at all locations when compared to AT 120 (Anonymous 1999). Peanut quality was not affected by application timing when averaged across COC (data not shown) nor by COC when averaged across application timings (Table 3). Ketchersid et al. (1978) reported that a single application of 2,4-DB at 0.8 lb ae/A (above the labeled rate) during the reproductive stage reduced market grade; however, Baughman et al. (2002) reported no differences in quality factors (sound mature kernels (SMK), sound splits + SMK, other kernels, damaged kernels) as a result of 2,4-DB at 0.4 lb ae/A regardless of application timing.

Table 2. Effect of 2, 4-DB applied at 0.4 lb/A on pod yield averaged over application timings and crop oil.

Year	1999	2000	LSD (P#0.05)
Peanut Yeild lb/A	4782	2839	248

Table 3. Effect of 2,4-DB applied at 0.4 b/A on peanut quality averaged across application\timings.

	Quality Factors[a]			
Crop Oil Concentrate %V/V[a]	SMK	SS	Grade	DK
0	52	24	76	1
1.25	53	24	77	2
Untreated	52	23	75	1
LSD (P#0.05)	NS	NS	NS	NS

[a]Abbreviations: SMK = Sound mature kernels, SS = Sound split kernels, Grade = sound mature kernels + sound split kernels, DK + damaged kernels, V/V = volume per volume

CONCLUSIONS

These experiments indicate that 2,4-DB with or without COC applied at various application timings from prebloom to pod maturity does not adversely affect two runner-type peanut varieties in West Texas. The addition of COC with 2,4-DB did not adversely affect peanut growth, yield, or quality (including enlarged and misshapen pods) and likely will improve weed control due to improved herbicide uptake.

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The Measurement of Carcass Characteristics of Goats Using the Ultrasound Method

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ABSTRACT

The objective of this study was to determine if ante mortem carcass characteristics measured via the ultrasound method in live goats is associated with carcass characteristic measured postmortem. Forty crossbred Spanish goats were evaluated at five different time periods for a total of 80 days. Ante mortem measurements of fat thickness (FTU), longissimus muscle area (LMAU), longissimus muscle width (LMWU), longissimus muscle depth (LMDU), rib eye area, rump fat (RFU), and rump depth (RDU) were made using an Aloka 500V. Twenty-four hours postmortem, fat thickness (FTC), longissimus muscle width (LMWC), longissimus muscle depth (LMDC), rump fat (RFC), and rump depth (RDC) was measured. Correlation analysis performed on the data revealed a high significance between LMAU and LMAC ($r = 0.75$; $P < 0.01$), and LMDU and LMDC ($r = 0.71$; $P < 0.01$). Linear regression analysis performed on the data collected over the 80 day study period revealed significance for FTU and FTC ($r^2 = 0.24$; $P < 0.01$), LMAU and LMAC ($r^2 = 0.56$; $P < 0.01$), LMWU and LMWC ($r^2 = 0.27$; $P < 0.01$), LMDU and LMDC ($r^2 = 0.51$; $P < 0.01$), and RDU and RDC ($r^2 = 0.21$; $P < 0.01$). Data indicated that when ultrasonically estimating carcass characteristics, measurements tended to overestimate characteristics in smaller goats and underestimate characteristics in older goats taken 24-hours postmortem.

KEYWORDS: goat, ultrasound, carcass

Goat meat represents about 4% of the world's production of meat from ruminants. Its major impact in production and consumption is in Asia, Africa, and Latin America (Zapata et al. 1995). While goat meat is not widely consumed in the United States, the state of Texas has a goat population of 1.0 million (USDA Livestock Statistics 1995). Over the past thirty years, goat meat consumption in the United States has increased due in part to the growth of the ethnic populations (Harrelson et al. 1995) and their demand for goat meat in their diets (Esminger and Parker 1986). Another reason for the increase in goat meat consumption is the nutritional value of goat meat. Goat meat is 10% more lean than beef carcasses and 19% more lean than lamb carcasses, which makes it a more attractive product to the health conscious American consumer (Amoah and Gelaye 2003).

The ultimate goal of the livestock and meat industry is to have an accurate and objective measurement method for assessing the economically important traits of animals, and to determine the value and merit of the carcass while the animal is still alive (Boggs and Merkel 1993). In order to accomplish this, grading systems for swine, beef cattle, and sheep consider sex, age, quality, cutability, conformation, and is used to establish the price of the meat in the market place (National Live Stock and Meat Board 1977). They are also used to predict the range of cutability or the average amount of muscling from an animal (Smith et al. 1982).

Ultrasonic evaluation is an objective method of predicting the carcass components of live animals within reasonable accuracy levels (Boggs and Merkel 1993), and is also an accurate measurement tool of fat thickness over the ribeye area in lambs (Hopkins 1990), and rump fat and longissimus muscle area in beef cattle (Robinson et al. 1992). Currently, goats are subjectively classified on age (kid or cabrito, young goat, and old goats), carcass weight, meatiness, and fat cover (Haenlein 1984), but there is no objective method for predicting carcass components. Therefore, the objective of this project was to determine if the ultrasound method could be used to predict carcass traits in live goats.

MATERIALS AND METHODS

Animal Management. Forty crossbred Spanish goats (20 males and 20 females) of different ages were subject of this study. Animals were fed alfalfa hay and a commercial feed ration (Red Tag complete feed medicated, Godbold, Inc. Lubbock TX.); containing 16% crude protein, 2% crude fat, and 17% crude fiber during a total period of 80 d. Eight goats were selected randomly every 20 d for ante mortem and postmortem evaluation.

Ante mortem Measurements. On the left side of the animal, site of isonification was determined by physical palpation between the 12th and 13th ribs for ribeye area measurements, and on the pelvic bone for rump measurements. Selected goats were clipped in the designated isonification areas to provide optimum image registration. Using corn oil (Mazola, CPC Foodservice, Englewood, Cliffs, NJ.) as a couplant and an Aloka 500V (Colorimetric Medical System, Wallingford, CT.) equipped with a 125-mm scanning width probe, a 5.0 MHz linear array transducer, and a super-flab guide (Animal Ultrasonic Services, Ithaca, NY) ultrasonic measurement were taken ante mortem.

Ultrasound measurements for fat thickness (FTU), longissimus muscle area (LMAU), longissimus muscle width (LMWU), and longissimus muscle depth (LMDU) were made by placing the ultrasound probe parallel to the 12th and 13th rib bone of the animal. A video monitor, TR-930B (Matsuchita Electronic Industrial Co., LTD. Osaka, Japan), and a software package (PLUSMORF, Woods Hole Educational Associates, Woods Hole, MA.) were used to amplify and better interpret the image. Rump fat (RFU) and rump depth (RFU) were taken directly from the ultrasonic unit screen, without the aid of a video monitor or software package.

Postmortem Measurements. After ultrasound prediction of carcass characteristics, goats were transported to the Sul Ross State University abattoir and slaughtered using standard humane procedures. Immediately after slaughter hot carcass weight (HCW) was measured and the carcasses were cooled at 32°F for 24 h. After the cooling period, chilled carcass weight (CCW) was recorded and the carcass was split along the midline. The left side of the carcass was ribbed at the 12th and 13th rib interface to determine fat thickness (FTC), longissimus muscle area (LMAC), longissimus muscle width (LMWC), and longissimus muscle depth (LMDC). Rump fat (RFC) and rump depth (RDC) were evaluated in the midline section of the pelvic bone. A USDA preliminary cutability grade ruler was used to measure fat thickness (FTC), longissimus muscle width (LMWC), longissimus muscle depth (LMDC), rump fat (RFC), and rump depth (RDC). Longissimus muscle area (LMAC) was measured using a USDA loin eye dot grid for beef.

Statistical Analyses. Simple correlation analysis was used to determine the relationship between the different traits measured ante mortem and the carcass characteristics measured postmortem (SPSS 1993). Regression analysis was used to test the ability of the ultrasound measurement method to estimate the carcass traits (SPSS 1993). Differences between predicting methods among carcass characteristics were assessed using one-way analysis of variance (Zar 1984).

RESULTS AND DISCUSSION

The overall descriptive statistics taken from the 40 crossbred Spanish goats used in the study are displayed in Table 1.

Table 1. Overall descriptive statistics of the carcass traits from 40 crossbred Spanish goats during eighty days.

	Ultrasound			Carcass		
Trait	Mean	SD	Range	Mean	SD	Range
FT	0.09	0.04	0.07-0.29	0.05	0.07	0.00-0.25
LMA	6.65	1.60	3.46-10.29	9.98	2.17	5.81-14.84
LMW	4.50	0.52	3.26-5.35	4.44	0.68	2.67-5.33
LMD	2.44	0.48	1.41-2.69	1.96	0.31	1.52-3.30
RF	0.14	0.05	0.10-0.20	0.02	0.05	0.00-0.13
RD	2.01	0.39	1.00-2.50	2.75	0.63	1.78-4.95

$P < 0.05$

The differences of means using ultrasound and carcass methods of measurement reveal an overestimation of the fat thickness in goats. This trend was also found in beef (Perkins et al. 1992; Waldner et al. 1992) and pork (Moeller and Christian 1998). In contrast, Realini et al. (2001) found that ultrasound measurement means were lower than adjusted beef carcass fat thickness; indicating a tendency to underestimate carcass measurements in beef. Ozutsumi et al. (1996) also indicated that fat thickness in steers also tended to be slightly smaller than the actual thickness measured.

A possible reason for difficulty in measuring fat thickness in goats is due to the lower content of fat over the loin area in goats and has been identified as a problem in sheep. Houghton and Turlington (1992) concluded that ultrasound has limited utility for predicting carcass characteristics in sheep due to the lack of variation and small size in fat thickness and longissimus muscle area. Fernandez et al. (1998) suggested that it is difficult to obtain accurate identification of muscle fat boundaries with ultrasound in lambs due to the presence of muscle layers interspersed with fat. Finally, Ensminger and Parker (1986) stated that when compared to sheep, goat fat thickness is difficult to measure due to the lack of subcutaneous fat over the loins.

A possible advantage to measuring longissimus muscle area of goats when compared to beef cattle, is the fact that the area is so small on goats that the researcher does not have to split the image to capture the entire area, which must be done in cattle. With respect to the longissimus muscle area, the results indicate an overestimation for smaller ribeye areas associated with kids or small sized goats. As animals become larger and older in age, the opposite effect of underestimation of ribeye area occurs. The underestimation of longissimus muscle area is due to the relationship of the brightness of the image captured by the ultrasound, and the reflection of the sound waves, especially in the narrowness or end areas of the rib eye. Several studies have noticed that longissimus muscle area in beef was underestimated by ultrasound (Realini et al. 2001, Perkins et al. 1992). This was also noticed in swine when researchers concluded ultrasound tended to overestimate smaller carcasses and underestimate larger carcasses (Moeller and Christian 1998). In contrast, Waldner et al. (1992) noticed cattle with longissimus areas of less than 70 cm^2 were underestimated, and cattle with longissimus areas of more than 85 cm^2 were overestimated. The reason for the overestimation of smaller ribeye areas is due to the close space between ribs in relationship to the probe width. Stanford et al. (1995) also reported difficulty obtaining distortion-free ultrasound images due to the closeness of the 12^{th} and 13^{th} ribs in Alpine goats. Fernandez et al. (1998) also stated that small dimensions are difficult to measure with accuracy. Measurements that were taken at the first lumbar vertebrae in the study were distortion free, which could be a possible alternative site of measurement to remedy the overestimation problem in the current study.

Simple correlation coefficients for carcass traits measured at five different time periods during eighty days via ultrasound were calculated (Table 2) and were statistically significant for several carcass traits.

Table 2. Simple correlation between goat carcass traits with respect to the ultrasound method measured during eighty days at five different time periods.

	Correlation coefficients (r)				
Trait	0-Day	20-Day	40-Day	60-Day	80-Day
FTU vs FTC	0.00	-0.35	0.79*	0.49	0.26
LMAU vs LMAC	0.43	0.84**	0.62	0.42	0.57
LMWU vs LMWC	0.33	0.01	0.63	0.60	0.41
LMDU vs LMDC	0.87**	0.43	0.30	0.36	0.51
RFU vs RFC	0.38	0.71*	0.58	0.44	-0.22
RDU vs RDC	0.83**	-0.39	-0.30	0.25	0.76*

**P < 0.01
*P < 0.05
n = 8

Day 20 measurements revealed that RFU was significantly correlated with RFC (r = 0.71, P < 0.05). Measurements of RDU and RDC were significantly correlated on day 0 (r = 0.83, P < 0.01) and on day 80 (r = 0.76, P < 0.05). Pooled data of all goats collected over an 80-day period (n = 40) indicated a highly significant relationship between certain carcass traits, including LMWU and LMWC (r = 0.52, P < 0.01), and RDU and RDC (r = 0.45, P < 0.01) (Table 3).

Table 3. Pooled simple correlations between goat carcass traits with respect to the ultrasound method during the eighty-day trial period.

Trait	Correlation coefficient (r)
FTU vs FTC	0.49**
LMAU vs LMAC	0.75**
LMWU vs LMWC	0.52**
LMDU vs LMDC	0.71**
RFU vs RFC	0.26
RDU vs RDC	0.45*

** P < 0.01
*P < 0.05
n = 40

FTU was significantly correlated with FTC on day 40 only (r = 0.79, P < 0.05). The pooled correlation coefficient of all 40 animals measured for FTU and FTC (r = 0.49, P < 0.01) is much lower than the coefficient reported by Fernandez et al. (1997) in lambs (r = 0.74, P < 0.001), but 40-day measurements were similar indicating a high relationship between FTU and FTC. In another study by Fernandez et al. (1998), higher correlations were found for 25 kg (r = 0.90, P < 0.05) and 35 kg (r = 0.92, P < 0.05) Manchego lambs measured between the 12th and 13th rib. Ultrasound measurements of FTU and FTC in other species also yielded higher correlation coefficients. In swine, Moeller et al. (1998) reported a correlation of 0.87 for 10th rib backfat. In cattle, Perkins et al. (1992) reported a higher pooled correlation of 0.86 when comparing the accuracy of two technicians. Waldner et al. (1992) also had a higher reported correlation of 0.86, while May et al. (2000) reported a slightly higher correlation of 0.81 for 12th rib fat thickness. Finally, Crews et al. (2002) reported correlations ranging from 0.64 to 1 when measuring fat thickness. Therefore, fat measurements taken over an 80-day period may not be a good indicator of the relationship between ultrasound and carcass fat thickness.

Day 20 measurements revealed that LMAU was highly significantly correlated with LMAC (r = 0.84, P < 0.01), and the pooled data from all 40 goats also revealed that LMAU and LMAC were highly significantly correlated (r = 0.75, P < 0.01). Both these values are greater than the coefficient of 0.64 found for Alpine goats measured between the 12th and 13th ribs (Stanford et al. 1995), indicating an improvement in the study for measuring longissimus muscle area with ultrasound. These values were similar to the coefficients found in lambs (r = 0.88, P < 0.001) (Fernandez et al. 1997) and swine (r = 0.74) (Moeller et al. 1998). More recent studies involving beef, May et al. (2000) reported a smaller correlation of 0.61, while Crews et al. (2002) reported a similar correlation of 0.86. When measuring longissimus muscle area it is possible to measure the animals for an entire 80 days, but day 20 is the best indicator of the relationship between longissimus muscle area measured with ultrasound and actual carcass measurements.

Day 0 measurements of LMDU were highly positively correlated with LMDC postmortem measurements ($r = 0.87$, $P < 0.01$), and pooled LMDU and LMDC data ($r = 0.71$, $P < 0.01$) were also highly significantly correlated. Both values indicate a strong relationship between LMDU and LMDC, but measurements taken on day-0 are stronger than the pooled data. Both the day-0 correlation value and the pooled data value were higher than the value of 0.62 reported by Stanford et al. (1995) in Alpine goats, and the value of 0.56 reported by Fernandez et al. (1997) in lambs.

Simple linear regression equations and their determination coefficients for predicting carcass traits from crossbred goats pooled for the entire eighty-day trial period are shown in Table 4.

Table 4. Pooled simple linear regression equations predicting goat carcass traits from 40 crossbred goats using the ultrasound method during the eighty-day trial period.

Equation	Determination coefficient (r^2)
FTC = -0.25 + 0.85(FTU)	0.24*
LMAC = 3.21 + 1.02(LMAU)	0.56*
LMWC = 1.39 + 0.68(LMWU)	0.27*
LMDC = 0.27 + 1.10(LMDU)	0.51*
RFC = -0.01 + 0.23(RFU)	0.07
RDC = 1.27 + 0.73(RDU)	0.21*

*P < 0.01
n = 40

During day 0 measurements, the LMDC equation ($r^2 = 0.76$, $P < 0.05$) and the RDC equation ($r^2 = 0.69$, $P < 0.05$) were highly significant. On day 20 of the study, the LMAC equation was highly significant ($r^2 = 0.70$, $P < 0.01$). For the 40-day measurements, the FTC equation was significant ($r^2 = 0.63$, $P < 0.05$) with respect to FTU. For the 60-day measurement data there was not any significance for the regression equations calculated from the carcass measurements taken postmortem and the ultrasonic carcass measurements taken ante mortem. Finally, during day 80 of measurements, the RDC was the only equation that was significant ($r^2 = 0.58$, $P < 0.05$).

The equations for LMAC and FTC using ultrasound explained a moderate amount of the total variation. The LMAC equation was not as accurate as the single-trait prediction model for longissimus muscle area reported by Crews et al. (2002) in beef. The longissimus muscle area equation was found to have a much higher r^2 of 0.88. In the same study the r^2 value for FT of weaned cattle was 0.73, while the yearling r^2 value equaled 0.80. Both these values were improved when both weaning and yearling fat thickness were included in the equation ($r^2 = 0.83$).

The fact that measured fat thickness r^2 was increased by combining both weaning and yearling measurements indicates that possibly using other factors, such as body weight or body measurements, can improve the accuracy of equations using ultrasound in goats. This can been seen in a study conducted by Fernandez et al. (1998) that used ultrasound to predict fat thickness and longissimus area in Manchego lambs. When using live weight as a predictor of both carcass characteristics, r^2 values ranged from 0.54 to 0.64. When using ultrasound measurements combined with the live weight measurements, r^2 values ranged from 0.60 to 0.95. Therefore using other measurements in conjunction with ultrasound measurements can improve the accuracy of carcass characteristic prediction equations, which warrants further research.

One-way analysis of variance showed a low ability for ultrasonic measurements to predict postmortem carcass measurements (data not shown). This is especially true of fat thickness, longissimus muscle area, longissimus muscle depth, rump fat, and rump depth. The lone exception was for longissimus muscle width. Here the analysis indicated no difference between the ultrasound measurements and the measurements taken directly from the carcass ($P < 0.05$).

CONCLUSION

The use of ultrasound on crossbred Spanish goats tended to overestimate both fat thickness and longissimus muscle area. Correlations revealed strong relationships between ultrasound and carcass characteristics measured, in agreement with other studies conducted with beef, pork, and lamb. Regression equations indicated that not many carcass characteristics measured by ultrasound could be used to accurately make models for prediction. This research reveals the need for further studies with an increase in sample size at the different times of prediction, as well as, reducing the variability of the animals to be evaluated (the age and size of the animals).

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ABSORPTION OF NON-PROTEIN NITROGEN IN GUAJILLO BY WHITE-TAILED DEER

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ABSTRACT

Guajillo (*Acacia berlandieri*) is an important forage for white-tailed deer (*Odocoileus virginianus*), but has high concentrations of non-protein nitrogen (N). To determine if non-protein N is absorbed by deer, 4 diets with different proportions of guajillo were assigned randomly to 4 male deer in a Latin square design and total balance trials were conducted. Urea and ammonium N were assayed and subtracted from total urinary N, resulting in a pool of N we called uncharacterized N. Our hypothesis was if non-protein N was absorbed but not used by the deer, the amount of uncharacterized N in urine would increase with increasing amounts of guajillo in the diet. Uncharacterized N did not differ among diets ($F_{3,6}$= 2.37, P = 0.169). Our data suggest non-protein N must have either not been absorbed in the digestive tract, or was converted to amino acids by rumen microbes prior to absorption.

KEYWORDS: ammonium, digestibility, guajillo, *Acacia berlandieri*, nitrogen, *Odocoileus virginianus*, urea, white-tailed deer

Guajillo is a leguminous, multi-stemmed shrub common in many habitats and soil types of southern Texas and northern Mexico, often associated with black brush (*Acacia rigidula*), cenizo (*Leucophyllum frutescens*), and prickly pear (*Opunita* sp.) (Taylor 1997). It is an important forage for livestock and deer during drought (Varner

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and Blankenship 1987, Barnes et al. 1991). Conventional nutritional analyses suggest guajillo is high in crude protein (Barnes et al. 1991). This, however, may be misleading because a considerable amount of N in guajillo is in non-protein forms (e.g. amines and alkaloids), not protein (Clement et al. 1997). Additionally, N in guajillo is poorly digested because of binding that occurs between protein and tannins and between and cell wall components during digestion (Barnes et al. 1991).

Ruminants may benefit from some forms of non-protein N because rumen microbes can use this N to produce amino acids, which can be absorbed by the animal (Van Soest 1982; Minson 1990). Alternatively, non-protein N may be absorbed, metabolized, and excreted without any benefit to the animal. For example, nitrogen-containing chemicals in guajillo cause toxicosis in livestock (Price and Hardy 1953). Furthermore, goats and deer fed increasing concentrations of guajillo excreted more detoxification conjugates, suggesting guajillo contains chemicals that are absorbed then metabolized through secondary pathways (Campbell 1999, Nantoumè et al. 2001). Most of the N in amino acids that are absorbed will be metabolized and excreted in the urine as urea or ammonium. However, a small portion of the N within amino acids will be excreted in the urine as other metabolic by-products (Van Soest 1992), which we define as uncharacterized N. Non-protein N that is not used by rumen microbes to produce amino acids and that is absorbed will be detoxified and excreted in the urine (Klaassen et al 1986) as uncharacterized N. Therefore, if significant amounts of non-protein N in guajillo are absorbed from the digestive tract, changes in the amount of dietary guajillo should result in changes in the amounts of uncharacterized N in the urine.

Our objective was to examine urinary N of deer consuming diets differing in guajillo concentration to determine if N is absorbed from the digestive tract in forms other than amino acids. We used uncharacterized N in urine as the response variable. If uncharacterized N increases with increased consumption of guajillo, then not all N digested by deer consuming guajillo will be available for protein metabolism. This information will help range managers more fully understand the role of guajillo in animal nutrition.

MATERIALS AND METHODS

Urine samples from Campbell and Hewitt (*In press*), in which we fed guajillo to white-tailed deer in feeding trials, were analyzed at the Texas A&M University-Kingsville Animal Nutrition Laboratory. Our feeding trials involved collecting herbaceous guajillo stems and leaves from plants in Webb and Duval counties of southern Texas. Dried guajillo and alfalfa were run through a 1 cm hammer mill screen and mixed into 4 diets containing guajillo: alfalfa ratios (dry mass: dry mass) of 0:100, 25:75, 50:50, and 75:25. We used alfalfa (*Medicago sativa*) as the control forage because its nutritive value is similar to native forbs. We completed *in vivo* metabolism trials with 4 adult male white-tailed deer in a 4x4 Latin square design. We randomly assigned diets and each successive trial randomization was limited to insure each deer received a diet it had not received previously. Urine was collected, quantified, and sampled daily during a 7-day collection phase. We analyzed urine for urea N with a 535-A Blood Urea Nitrogen Kit (Sigma-Aldrich Diagnostics, St. Louis, MO), without deproteinization. Urine samples were diluted 1:50 with deionized water. We assayed urinary ammonium N using the Kjeldahl procedure without the sulfuric acid digestion step. We analyzed nitrogen excretion for diet effects with a 3-way ANOVA without interaction effects using SAS (SAS Institute 1999). Diet, individual deer, and feeding trial period were main effects. We used Tukey's test for means separation. Results were considered significant at $P< 0.05$.

RESULTS

Total urinary N decreased as dietary guajillo increased ($F_{3,6}= 98.38$, $P< 0.001$; Table 1). Urea and ammonium urinary N also decreased as dietary guajillo increased ($F_{3,6} = 33.78$, $P< 0.001$), with diets containing 50 and 75% guajillo differing from the other two diets (Table 1). Uncharacterized N did not differ by diet ($F_{3,6}= 2.37$, $P = 0.169$), and the trend was opposite of that predicted if large amounts of non-protein N were being excreted in the urine.

Table 1. Urea, ammonium, uncharacterized and total nitrogen (N; $g \cdot day^{-1}$) for male white-tailed deer fed 4 diets containing guajillo in Kingsville, Texas.

Percent	Urea and ammonium		Uncharacterized N		Total N	
Guajillo[a]	Mean	SE	Mean	SE	Mean	SE
0	18.5 A[b]	1.2	8.5 A	1.7	27.0 A	0.8
25	17.3 A	0.7	5.6 A	1.0	22.9 B	0.4
50	11.7 B	1.1	5.9 A	0.6	17.5 C	1.5
75	8.0 B	1.1	4.6 A	0.3	12.7 D	1.2

[a] Percent guajillo in diets based on alfalfa hay to guajillo ration (dry mass: dry mass)
[b] Means in a column with different letters differ at the $P = 0.05$ level.

DISCUSSION

Declines in total urinary N and the sum of urea and ammonia N with increased dietary guajillo were expected because of the decline in dietary N from 4.1 to 3.1% in the 0% and 75% guajillo diets, respectively, and a decline in N digestibility from 75.9 to 40.5% in the 0% and 75% guajillo diets, respectively (Campbell 1999). Uncharacterized N, representing excretion of N containing secondary plant compounds as well as some products of normal metabolism, did not differ. This suggests that non-protein N in guajillo was not absorbed and excreted as uncharacterized N, at least not in large amounts. Instead, the non-protein N must have either not been absorbed, or was converted to amino acids by rumen microbes prior to absorption. Because digestible N was so low in guajillo containing diets (Campbell 1999), it seems most likely that most of the non-protein N was not absorbed.

Our results indicate that N absorbed from guajillo diets is predominantly in forms that can be converted to protein for use by deer. It does not appear that deer absorb large amounts of non-protein N that must be detoxified and excreted. Thus, even though the N in guajillo is not highly digestible, the N that is absorbed appears to be useful in protein synthesis. For this reason, and because guajillo is abundant in southern Texas and remains available during drought, it is beneficial in livestock and deer management.

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Technological Efficiency Gains in Irrigated Cotton Production

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ABSTRACT

Precision farming technology in irrigated cotton production has the potential to precisely manage inputs and outputs. This success of this technology depends on the economic efficiencies gained over traditional whole-field farming. The overall objective of this study was to evaluate the profitability of precision farming and optimal decision rules for production of cotton in the Southern High Plains of Texas. A dynamic optimization model with a nitrate-nitrogen carryover function allowed for the derivation of optimal input application levels, yield, and net present value of returns (NPVR). On the average, precision farming increased yield and NPVR by 4.01% and 4.50%, respectively, as compared to whole-field farming. However, precision farming also used 0.1564% more nitrogen application on the average. Yield and net present value of returns also had less variability under precision farming management practices. This study suggests that nitrogen fertilizer can be used more efficiently to maximize NPVR under precision farming.

KEYWORDS: Cotton Economics, Mathematical Optimization, Precision Farming, Technology Adoption

The adoption of technological advances in agricultural production has the potential to increase yields and profitability, while positively impacting the environment (Moreenthaler 2003). Adoption of technological advances in agriculture is necessary because with a highly competitive market structure, where the producer is a price-taker, consumers demand high quality products at low prices. These demands can be met through the adoption of precision farming practices. Therefore, the objective of this study was to evaluate the economic impacts of using precision farming technology.

Traditional whole-field farming assumes spatial and temporal field homogeneity, and optimal levels of input use do not account for inherent differences within fields (Weiss 1996, Shanahan 2004). However, fields are not homogeneous, indicating that many field characteristics, such as nitrogen, sand, clay, and silt content levels, vary within the field. In general, optimal input use under traditional whole-field farming optimizes for average characteristics, for example, average nitrogen residual levels, within the field. In other words, traditional whole-field farming optimizes input use on what is best for the field as a whole, or "on average". Optimal application rates are uniform across the field, regardless of the specific characteristics and requirements of any particular location within the field. This may not be efficient if there is significant spatial variability of characteristics. Given that all locations do not necessarily have the same yield potential, a uniform application may not necessarily result in optimal yields or profitability (Onken 1972, English et al. 2001).

Inherent differences within fields have been addressed with precision farming. Precision farming involves the sampling, mapping, analysis, and management of specific areas within fields in recognition of spatial and temporal variability with respect to soil fertility, pest populations, and crop characteristics (Weiss 1996). Precision farming optimizes input use under these conditions.

Precision farming involves the use of many site-specific technologies that can aid producers in management decisions. Global Positioning System (GPS) is a technology that allows site-specific information to be collected through interface with satellites. Many of these site-specific technologies are commercially available as separate components. This allows individual producers to assemble a package of technologies specifically tailored to their operation. Basic technologies include aerial photography and soil survey maps. Other advanced technology includes optical sensors that collect, process, and dispense inputs according to a decision rule as a tractor moves through the field, and Variable Rate Application, which is the ability to apply various amounts of inputs while moving across the field (Khanna et al. 1997).

There are several commodities, including cotton, that lead the state's agricultural industry in importance in terms of production and generation of revenue. Therefore, cotton is addressed in this study due to its importance in Texas. The Southern High Plains of Texas (SHPT) is the region in this study; largely due to the emphasis and importance it commands in agricultural production in Texas. The SHPT is a semi-arid region, which encompasses 22 million acres, located in the northwestern portion of the state.

Cotton is the most important crop in this area in terms of value and acreage. Of the approximately 6 million acres of cotton planted annually in Texas, 2.6 to 3.3 million acres are planted in the SHPT region, with approximately half of these acres irrigated (Segarra et al. 1989). Cotton earns more dollars per gallon of irrigation water applied than any other crop grown in the region. Cotton lint yields in Texas have averaged approximately 450 pounds per acre since 1992 (National Agricultural Statistics Service). Cotton is also unique in that it adapts to poor soils and uses fertilizers efficiently (National Cotton Council).

Potential advantages of precision farming may include higher average yields, lower farm input costs, and environmental benefits from applying fewer inputs (English et al. 2000, Batte and Arnholt 2003). Thus, there is potential for increased profits if inputs can be allocated with greater economic efficiency across the field. This idea of "farming by the inch" provides a better understanding of the many factors that affect yields and profitability. Precision farming minimizes the likelihood of over-application or under-application of inputs because optimal input levels are not based on average conditions within a field. Inefficient use of inputs can cause producers to lose money and the environment to suffer.

The acceptance of precision farming practices in cotton production will ultimately depend on its economic performance as compared to conventional whole-field farming (Bullock et al. 2002). Research efforts have been directed toward the new technologies involved with precision farming. There has been an expressed need for more information on the economic performance of precision farming.

The overall objective of this study is to evaluate the profitability of precision farming and evaluate optimal decision rules for production of cotton in the Southern High Plains of Texas. The following are the specific objectives of this study:

(1) To assess the spatial relationship between input utilization and cotton yields;

(2) To derive optimal levels of spatial input use and develop decision rules for input application.

MATERIALS AND METHODS

Optimal decision rules for specific inputs are desired to maximize the net present value of returns to risk, management, overhead, and all other inputs in the production of cotton. The deterministic specification of the empirical dynamic optimization model formulated in this study, which will be used to derive optimal decision rules of input use for the cotton experiment, is shown in equations (1) through (4):

$$MaxNPV = \sum_{t=0}^{n} (PC_t \times Y_t(NT_t) - (PN_t \times NA_t))/(1+r)^t \qquad (1)$$

subject to:

$$NT_t = NA_t + NR_t \qquad (2)$$

$$NR_{t+1} = f_t(NA_t, NR_t) \qquad (3)$$

$$NR_0 = NR(0) \qquad (4)$$

and NA_t, NR_t, $NT_t \geq 0$ for all t

Where, *NPV* is the net present value of returns to land, irrigation water, overhead, risk, and management from production; the length of the decision-maker's planning horizon is n years; PC_t is the price of cotton in year t; Y_t is the cotton yield function in year t; PN_t is the price of the input in year *t*; NA_t is the amount of input applied in year *t*; *r* is the discount rate; NT_t is the total amount of input available for crop growth in year *t*; NR_t is the residual amount of input already available in the soil in year *t*; and NR_0 is the initial residual amount of input available in the soil at the beginning of the planning horizon.

Equation 1 was the objective function, or performance measure of the optimization model. Equation 2 was the equality constraint that summed the amount of input applied and residual input to obtain the total amount of input available for cotton growth in any given year. This equation was used in the objective function to calculate cotton yield. Equation 3 was the equation that updated residual input annually, which was necessary for equation 2. This equation was the equation of motion because it updated the input residual at time *t*+1 depending on residual input at time *t* and input application at time *t*. Equation (4) was the initial input residual condition, which represented the residual level at the beginning of the planning horizon. Non-negativity constraints were also specified for input application, residual, and total amount of input.

Data for cotton were collected in Lamesa, Texas over two years. Twenty-six locations in the field were identified for data points. Four replications for each of the twenty-six locations were taken. Two water levels were used, one at 50% evapotranspiration (ET), and the other at 75% ET. Altitude was measured for each location as well as for residual nitrate-nitrogen. The residual nitrate-nitrogen was measured in increments of 12 inches, up to 48 inches of the soil profile. Nitrogen was applied at three different rates including 0, 80, and 120 lbs per acre. Sand, clay, and silt content in the soil were also measured. A cotton stripper equipped with sensors and GPS was used to harvest the cotton.

The data were used to estimate the production function, $Y = f(X)$, and the input carry-over function, $NR_{t+1} = f(NA, NR_t)$. Using GLM (General Linear Model) procedures in SAS, alternative functional forms were evaluated to find the best statistical fit between yield (dependent variable) and crop characteristics, input levels, location characteristics, and other variables in the experiment (independent variables) (SAS, 2002). The carry-over function was also estimated in SAS to represent the relationship between time *t*+1 input residual and the independent variables input residual in time t and input application in time *t*.

The economic feasibility of the two management practices were analyzed and compared with respect to input use, net present value of revenue above nitrogen and water costs, and yield. Optimal decision rules for a dynamic ten-year planning horizon were then derived.

The optimization models in equations (1) through (4) were used in the cotton analysis. Combinations of two water, nitrogen, and commodity prices were solved for both precision farming and whole-field farming practices. A 5.0% discount rate (average discount rate for the time period studied) under a 10-year planning horizon was used. Under the precision farming scenario, the initial residual nitrogen conditions varied across locations in the field. Under the whole-field farming scenario, the initial residual nitrogen conditions were held at the average initial condition across the whole field for all locations.

The optimal decision rules derived in this study for nitrogen use varied across time periods in the planning horizon for a given input and output price combination. However, given that a stable decision rule was desirable to simplify management implementation, an additional constraint of equating nitrogen input applications across time periods within the planning horizon was introduced. Without this constraint, application recommendations would vary both spatially and temporally for the entire management horizon. Therefore, to condense the sheer volume of data into a useable amount for management implementation, the constraint allowed for the optimal application for the 10-year planning horizon for each location in the field. Cotton yield, net per-acre present value of returns above nitrogen and water costs (NPVR), and ending residual nitrogen levels for the 10-year planning horizon were obtained. GAMS (General Algebraic Modeling System), a mathematical optimization software system developed by the World Bank in Washington D.C., was used to solve the optimization models for both farm management practices.

Due to the changing prices of technology and region specific application costs, no costs for implementing precision farming above whole-field farming were included in the analysis. Thus, the cost of collecting the site-specific information, analysis of the data, and variable rate application costs have not been accounted for in this study. The decision to exclude these costs allows the change in profitability per acre when employing precision farming technology to be compared to the current cost of implementation in the SHPT to determine the feasibility of implementing the new technology into farm management practices. For example, if precision farming technology gains 7% efficiency, which translates to $14 per acre, then the producer has $14 per acre to spend implementing this technology. With the cost of technology changing so rapidly, it would be inefficient to include this price in the model and re-calculate every time technology fees change. Instead, efficiency gains tell the producer the amount gained from the new technology. The producer would adopt precision farming if the technology could be implemented in their area for something less than the efficiency gain.

The cotton models were solved under a high irrigation water scenario with all possible combinations of two cotton prices, $0.40 and $0.60 per pound, two nitrogen prices, $0.25 and $0.30 per pound, and two water prices, $2.68 and $3.50 per acre-inch. However, the results obtained did not vary much as input and output prices changes, therefore, one representative scenario with water price of $2.68 per acre-inch, cotton price of $0.40 lb. and nitrogen price of $0.25 are reported. Percentage changes in net revenues above nitrogen and water costs, cotton yields, and nitrogen application levels were also analyzed to obtain an overall picture of the impacts of one management practice over the other.

RESULTS

Three overall scenarios were analyzed: 1) precision farming, 2) naïve whole-field farming, and 3) actual whole-field farming. Under the precision farming scenario each individual location's characteristics within the field were used in the optimization modeling to determine the optimal nitrogen application level for each location. Under the naïve scenario, the initial nitrogen condition and location characteristics were set at the mean level of the field to determine a single optimal nitrogen application level for the entire field. The actual whole-field farming scenario used the optimal nitrogen application level determined under the naïve scenario and each individual location's characteristics. This scenario was evaluated because it provides the most realistic comparison of whole-field farming to precision farming**.**

In the experiment, cotton yield was found to be a quadratic function of total nitrogen, which was defined as the addition of residual nitrogen from 0 to 12 inches of soil depth and nitrogen applied during the season, altitude, sand, silt, irrigation water, and year. The residual nitrogen function, which estimated the residual nitrogen from 0 to 12 inches of soil depth at the end of the season, was found to be a linear function of nitrogen applied, irrigation water, residual nitrate-nitrogen from 0 to 12 inches of soil depth, and year.

Yield was measured in lbs per acre and was defined as Y. Total nitrogen was measured in lbs per acre and was defined as NT. Altitude was measured in feet above a reference point and was defined as ALT. Sand and silt were measured as a percentage of the soil content. They were defined as SAND and SILT, respectively. Irrigation water was introduced as a dummy variable that represented two irrigation water levels, 50% ET and 75% ET. Irrigation water was defined as W, with 0 representing 50% ET and 1 representing 75% ET. Year was also introduced as a dummy variable, with 0 representing Year #1 and 1 representing Year #2, defined as YEAR. Residual nitrate-nitrogen from 0 to 12 inches of soil depth at the end of the season was measured in lbs per acre and was defined as NR_{t+1}. Nitrogen applied was the amount of nitrogen applied during the season in lbs per acre and was defined as NA. Residual nitrate-nitrogen from 0 to 12 inches of soil depth was measured in lbs per acre at the beginning of the season and was defined as NR_t. The functions for yield and residual nitrate-nitrogen at the end of the season with their parameter estimates are shown in equations (5) and (6), respectively.

$$Y = 516.7297 - 0.0097 \times NT^2 + 0.0050 \times NT \times ALT \times SAND - 14.0392 \times NT \times SILT + 0.1488 \times ALT \times W + 20.4874 \times YEAR \quad (5)$$
$$R^2 = 0.494$$

$$NR_{t+1} = 53.3405 + 0.0805 \times NA \times W + 0.2083 \times NR_t - 37.3192 \times YEAR \quad (6)$$
$$R^2 = 0.530$$

The R-squared was .494 for the yield model and .530 for the residual model. This indicates that 49.4% of the variation in irrigated cotton yield was explained by NT*NT, NT*ALT*SAND, NT*SILT, ALT*W, and YEAR. NA*W, NR_t, and YEAR account for 53.0% of the variation in NR_{t+1}. The models were estimated using the Generalized Linear Modeling procedures (GLM) in SAS. The results were then used to formulate the optimization models in GAMS to determine optimal input application decision rules (equations 1 through 4). The constraint to equate nitrogen application across all time periods was included as well for simpler management decision rules.

Solutions to the 97-optimization models (48 for precision farming, 48 for actual whole-field farming, and 1 for the naïve whole-field farming approach) are presented in Table 1. This table corresponds with a water price of $2.68 per acre-inch, a cotton price of $0.40 per lb, and a nitrogen price of $0.25 per lb under a high level of irrigation water.

Several water, nitrogen, and cotton prices were used in the study and the results were very robust, therefore, a representative scenario was chosen for detailed discussion in the paper.

The scenario discussed in Table 1 corresponds to Figures 1 through 6 generated with MapInfo (Vertical Mapper, Version 1.50, Capital Region, NY). Table 1 shows the nitrogen residual (NRES), net present value of returns above nitrogen and water costs for precision farming (NREVpf), yield for precision farming (YIELDpf), optimal nitrogen application under precision farming (NApf), net present value of returns above nitrogen and water costs for whole-field farming (NREVwf), yield for whole-field farming

Table 1. Comparison of Precision Farming and Whole-Field Farming Scenarios with Water Price=$2.68/acre-inch, Cotton Price=$0.40/lb., and Nitrogen Price=$0.25/lb.

Location	NRES lbs/ac.	NREVpf $/acre	YIELDpf lbs/ac./yr.	NApf lbs/acre	NREVwf $/acre	YIELDwf lbs./ac./yr.	NAwf lbs/acre	NREV CH	YIELD CH	NA CH
1a	48.44	2378.07	848.16	78.12	2330.98	835.99	81.51	2.02%	1.46%	-4.16%
2a	65.76	2379.67	847.10	75.83	2331.26	836.08	81.51	2.08%	1.32%	-6.97%
3a	203.89	2319.51	819.64	57.53	1657.70	628.39	81.51	39.92%	30.43%	-29.42%
4a	60.78	2379.42	847.46	76.49	2333.11	836.65	81.51	1.98%	1.29%	-6.16%
5a	41.34	2576.79	925.08	102.98	2526.22	896.20	81.51	2.00%	3.22%	26.34%
6a	92.80	2578.90	921.25	96.17	2578.99	912.47	81.51	0.00%	0.96%	17.98%
7a	74.12	2580.22	923.18	98.64	2579.11	912.50	81.51	0.04%	1.17%	21.02%
8a	66.42	2580.07	923.80	99.66	2572.76	910.55	81.51	0.28%	1.46%	22.27%
9a	36.96	2617.98	941.01	108.03	2550.34	903.63	81.51	2.65%	4.14%	32.54%
10a	67.73	2622.42	939.54	103.96	2619.83	925.06	81.51	0.10%	1.57%	27.54%
11a	32.28	2616.75	941.08	108.65	2534.54	898.76	81.51	3.24%	4.71%	33.30%
12a	26.08	2614.88	941.12	109.47	2511.52	891.66	81.51	4.12%	5.55%	34.30%
13a	26.18	2595.53	933.86	107.41	2496.91	887.16	81.51	3.95%	5.26%	31.78%
14a	74.22	2603.08	931.74	101.05	2605.15	920.53	81.51	-0.08%	1.22%	23.97%
15a	44.67	2600.29	933.53	104.96	2555.74	905.30	81.51	1.74%	3.12%	28.77%
16a	57.71	2602.26	932.93	103.23	2584.32	914.11	81.51	0.69%	2.06%	26.65%
17a	41.59	2547.34	913.98	99.76	2499.67	888.01	81.51	1.91%	2.92%	22.39%
18a	51.51	2549.11	913.98	98.44	2520.49	894.43	81.51	1.14%	2.19%	20.78%
19a	48.89	2548.71	913.59	98.79	2515.59	892.92	81.51	1.32%	2.32%	21.20%
20a	65.66	2550.47	913.71	96.57	2539.46	900.28	81.51	0.43%	1.49%	18.48%
21a	44.51	2517.31	912.74	96.00	2476.75	880.94	81.51	1.64%	3.61%	17.77%
22a	60.22	2519.45	902.33	93.92	2500.34	888.22	81.51	0.76%	1.59%	15.22%
23a	82.58	2519.61	901.55	90.95	2507.13	890.31	81.51	0.50%	1.26%	11.59%
24a	45.97	2517.58	899.68	95.80	2479.60	881.82	81.51	1.53%	2.03%	17.54%
25a	80.12	2579.21	902.27	97.80	2580.54	912.94	81.51	-0.05%	-1.17%	19.99%
26a	80.12	2579.21	922.34	97.80	2580.54	912.94	81.51	-0.05%	1.03%	19.99%
27a	42.10	2576.11	922.34	102.83	2527.39	896.56	81.51	1.93%	2.88%	26.16%
28a	113.80	2573.75	924.77	93.34	2551.61	904.02	81.51	0.87%	2.30%	14.51%
29a	36.71	2197.66	918.05	52.12	2096.87	763.81	81.51	4.81%	20.19%	-36.06%
30a	59.92	2200.75	776.38	49.05	2066.32	754.39	81.51	6.51%	2.92%	-39.83%
31a	35.20	2197.33	775.21	52.32	2097.68	764.06	81.51	4.75%	1.46%	-35.81%
32a	34.29	2197.13	776.43	52.44	2098.10	764.19	81.51	4.72%	1.60%	-35.66%
33a	79.91	2257.71	776.45	56.23	2121.35	771.35	81.51	6.43%	0.66%	-31.02%
34a	73.22	2258.06	797.23	57.11	2137.57	776.36	81.51	5.64%	2.69%	-29.93%
35a	90.64	2256.52	797.89	54.81	2089.49	761.53	81.51	7.99%	4.77%	-32.76%
36a	62.79	2257.99	796.00	58.49	2157.19	782.41	81.51	4.67%	1.74%	-28.24%
37a	88.22	2404.54	798.76	76.18	2342.58	839.57	81.51	2.65%	-4.86%	-6.54%
38a	134.85	2391.71	854.98	70.00	2194.18	793.81	81.51	9.00%	7.71%	-14.12%
39a	132.43	2392.74	847.66	70.32	2205.23	797.22	81.51	8.50%	6.33%	-13.72%
40a	130.47	2393.55	848.14	70.58	2213.95	799.91	81.51	8.11%	6.03%	-13.40%
41a	69.94	2250.58	848.52	56.26	2131.50	774.49	81.51	5.59%	9.56%	-30.97%
42a	67.68	2250.58	795.05	56.56	2136.08	775.90	81.51	5.36%	2.47%	-30.60%
43a	142.15	2232.31	795.25	46.70	1816.26	677.28	81.51	22.91%	17.42%	-42.71%
44a	116.87	2242.73	784.01	50.05	1963.95	722.82	81.51	14.19%	8.46%	-38.60%
45a	63.50	2376.55	846.05	75.67	2328.15	835.12	81.51	2.08%	1.31%	-7.17%
46a	70.09	2376.72	845.54	74.80	2324.03	833.85	81.51	2.27%	1.40%	-8.24%
47a	98.49	2374.09	842.43	71.03	2274.98	818.73	81.51	4.36%	2.89%	-12.85%
48a	126.79	2366.02	837.91	67.28	2175.61	788.09	81.51	8.75%	6.32%	-17.45%
Whole-Field	**72.72**	**2430.66**	**866.36**	**81.51**						
AVERAGE		**2439.56**	**871.91**	**81.50**	**2346.22**	**840.69**	**81.51**	**4.50%**	**4.01%**	**-0.01%**
VARIANCE		**21838.47**	**3296.12**	**425.98**	**53150.53**	**5053.35**	**0.00**			

(YIELDwf), optimal nitrogen application for whole-field farming (NAwf), net present value of returns above nitrogen and water costs percentage increases when using precision farming over whole-field farming (NREV CH), yield percentage increases when using precision farming over whole-field farming (YIELD CH), and nitrogen application percentage increases when using precision farming over whole-field farming (NA CH). The initial residual nitrogen in Table 1 corresponds to those shown spatially in the cotton field map in Figure 1.

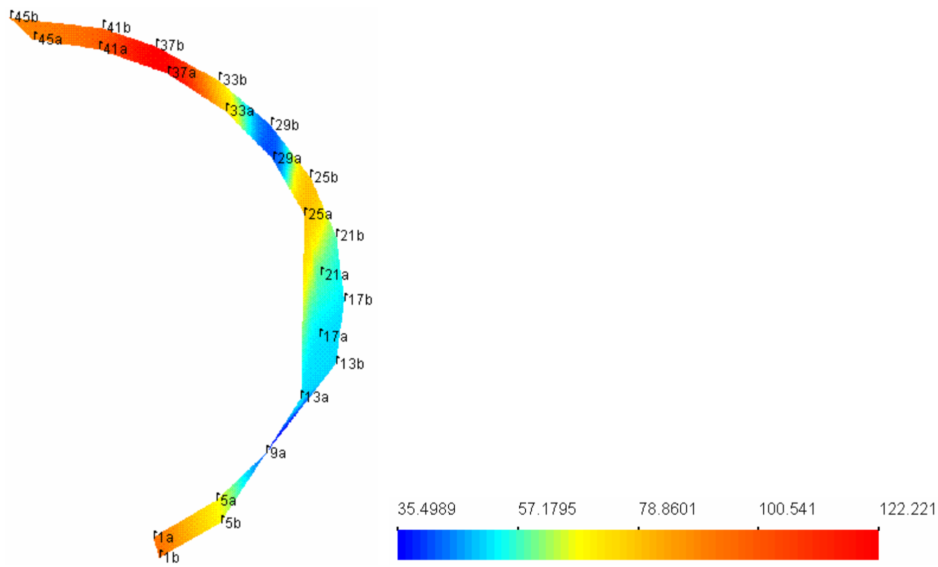

Figure 1. NO3-N Pre-Season Residual Map in lbs/acre from 0 to 12 Inches of Soil Depth, Lamesa, Texas.

In this figure, the red area in the northern portion of the field indicates locations with the highest residual nitrogen in the soil from 0 to 12 inches. This field was a research plot irrigated under a center pivot; therefore, the shape of the field is a portion of a plot (50 acres). As shown in Table 1, location 17a has an associated residual nitrogen level of 41.59 lbs per acre, which can be found in Figure 1 in the center portion of the field, whereas location 37a is shown to have 88.22 lbs per acre of residual nitrogen, which is in the northern portion of the field. The red areas indicate locations with the most residual nitrogen before the experiment, while the blue areas represent locations within the cotton field with the least residual nitrogen.

The optimal levels of nitrogen applied to maximize NPVR for precision farming are illustrated in Figure 2. It is clearly more likely to be profitable to fertilize the center and southern portions of the field (red zones) heavier than the northern locations (blue zones). The optimal nitrogen application map in Figure 2 mirrors the spatial yield map in Figure 3. The optimal levels of spatial nitrogen to apply are shown in Table 1. For example, at location 5a, NPVR will be maximized if 26.34% more nitrogen is applied than the optimal application recommendation under whole-field farming practices. Also, location 35a is shown to use 32.76% less nitrogen application than under optimal whole-field farming practices to maximize NPVR. A blanket nitrogen application of 81.51 lbs per acre is shown to be optimal for whole-field farming practices. Overall, for the whole-field, precision farming is shown to use 0.01% less nitrogen on the average than under whole-field farming, thus it becomes critical to observe individual location needs.

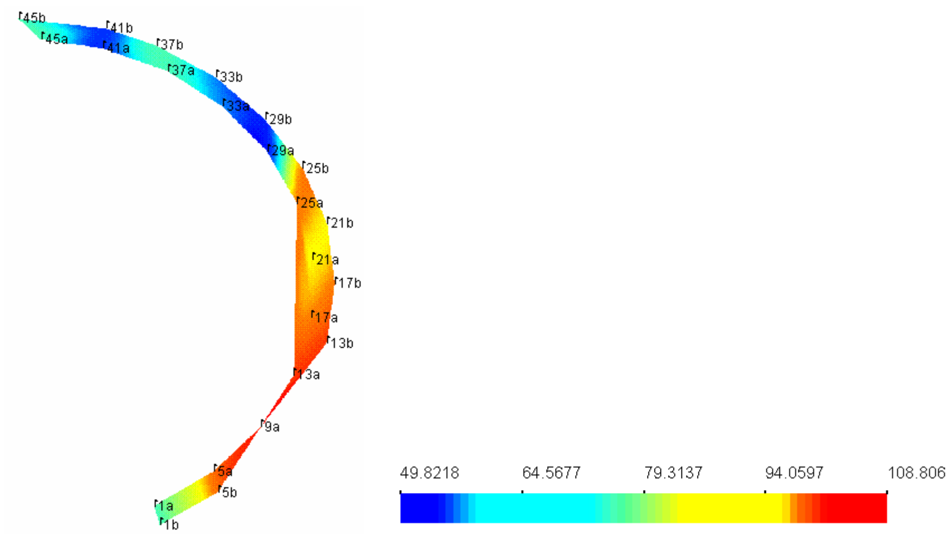

Figure 2. Optimal Levels of Spatial Nitrogen Application (lbs/acre) Map for Precision Farming Practices on a Per-Year Basis for a Ten-Year Planning Horizon, Lamesa, Texas.

The spatial yield map for precision farming is illustrated in Figure 3. The red areas in the northern portion of the field, where residual nitrogen concentrations are highest, yield the lowest. This same phenomenon holds true for whole-field farming yields in Figure 4.

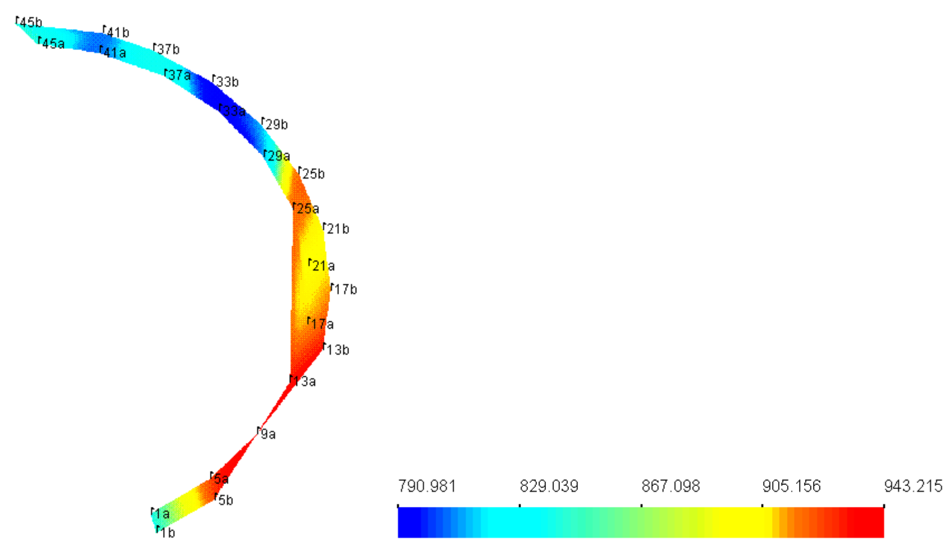

Figure 3. Spatial Cotton Yield Map (lbs/acre) for Precision Farming Practices, Lamesa, TX.

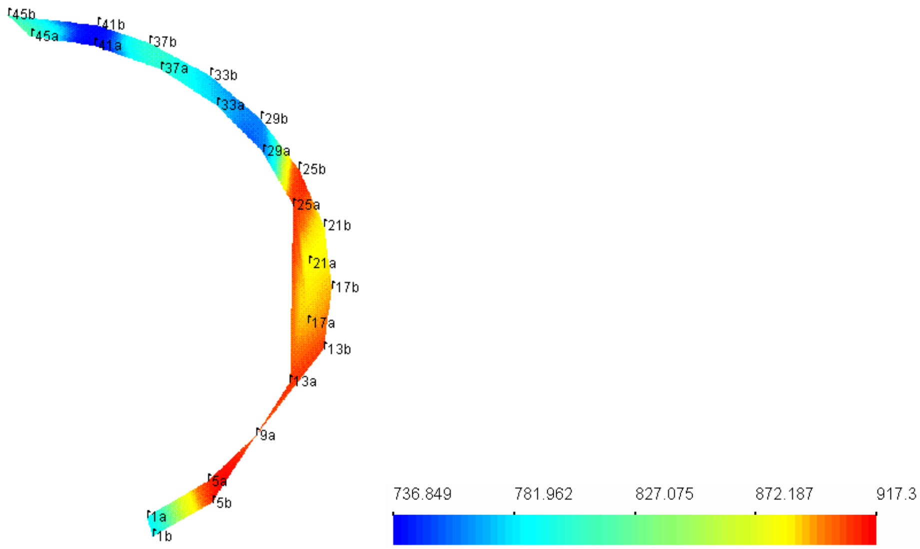

Figure 4. Spatial Cotton Yield Map in lbs/acre for Whole-Field Farming Practices, Lamesa, Texas.

For example, location 25a is shown to yield 1.17% less under precision farming practices, in contrast to location 29a, which is shown to yield 20.19% more under precision farming practices as compared to whole-field farming practices. Overall, the naïve whole-field farming scenario estimated lower yields than precision farming, but higher than actual whole-field farming on the average. The actual whole-field farming yield was shown to be 4.01% lower when compared with precision farming management practices.

The optimal levels of spatial NPVR for precision farming are illustrated in Figure 5. Notice that this figure closely resembles the corresponding spatial cotton yield map in Figure 3. This same trend holds for Figure 6 under whole-field farming management practices. Individual locations, such as location 3a, have the potential to increase NPVR by 39.92% if the optimal nitrogen application is observed under precision farming practices. Thus, it is crucial to observe individual location potential as well as the average potential of the field as a whole. The NPVR estimates for the ten-year planning horizon are more optimistic under the naïve whole-field farming scenario than under the actual whole-field farming scenario. However, under the precision farming scenario, NPVR is shown to increase by 4.50% on the average across the field as compared to the actual whole-field farming scenario.

The spatial pdf's for cotton NPVR and cotton yields, respectively are illustrated in Figures 7 and 8. Figure 7 indicates that there is less spatial variability in precision farming NPVR than with whole-field farming NPVR. Precision farming is also shown to have a greater probability of higher and mid-level NPVR. There is a greater probability of lower NPVR under the whole-field farming scenario, indicating more downside variability when whole-field farming practices are employed. The dashed line in Figure 7 indicates a higher NPVR on the average for precision farming than with whole-field farming (solid line). Figure 8 indicates less spatial yield variability under precision farming practices with less downside variability and more upside potential. On the average, cotton yields are shown to be higher under precision farming practices as compared to whole-field farming practices. Figure 9 shows the cumulative density function for both precision and whole-field farming NPVR. The spatial cdf for precision farming (dashed line) clearly dominates the spatial cdf for whole-field farming (solid line), indicating that more NPVR would be expected from precision farming practices than from whole-field farming practices.

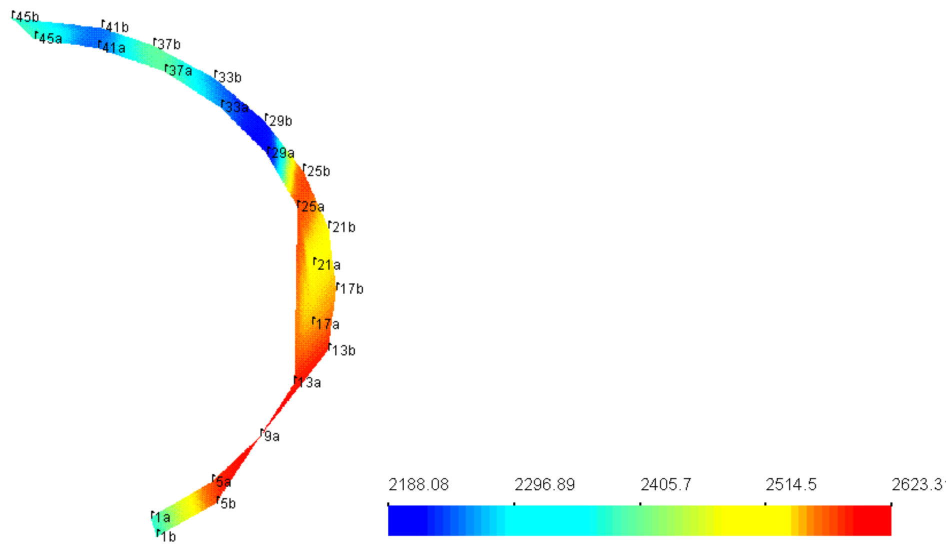

Figure 5. Spatial Net Revenue Above Nitrogen and Water Costs for a Ten-Year Optimization Model for Precision Farming Practices, Lamesa, Texas.

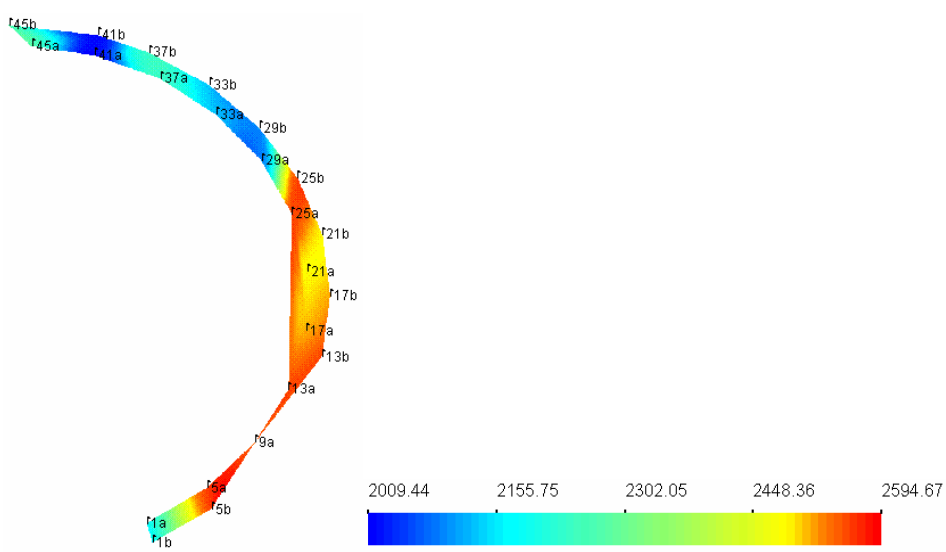

Figure 6. Spatial Net Revenue Above Nitrogen and Water Costs for a Ten-Year Optimization Model for Whole-Field Farming Practices, Lamesa, Texas.

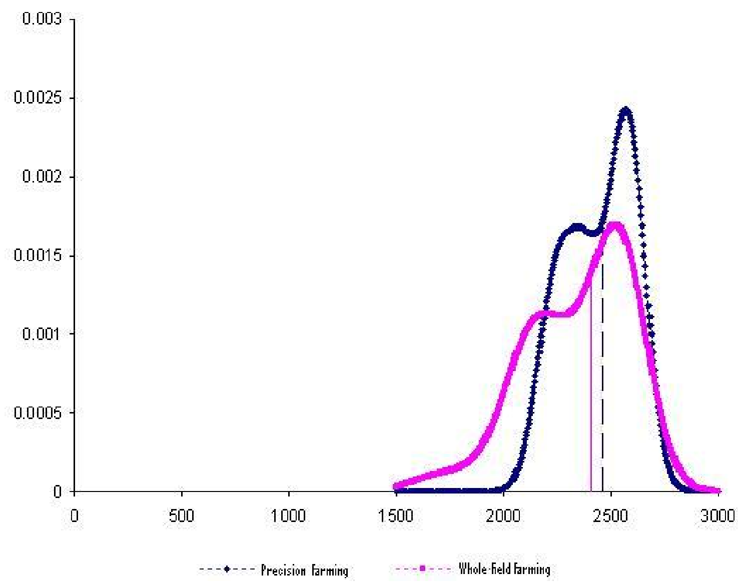

Figure 7. Probability Density Function for Cotton Net Revenues Above Nitrogen and Water Costs.

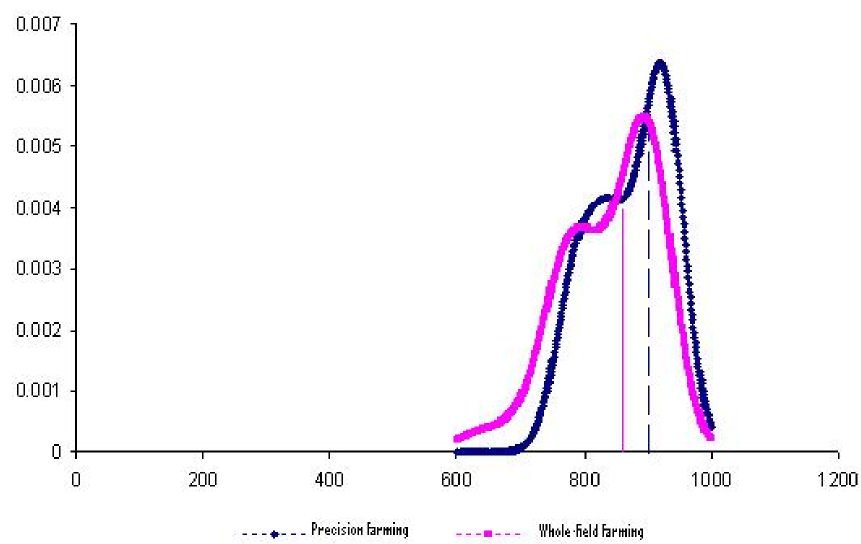

Figure 8. Probability Density Function for Cotton Yields.

In this experiment, yield and NPVR on average increased by 4.01% and 4.50%, respectively, when using precision farming practices. Nitrogen application was virtually the same with 0.01% less nitrogen application on the average under precision farming practices. Variability associated with yield and NPVR is clearly smaller under precision farming practices. There is more downside variability with whole-field farming for both yields and NPVR. Therefore, precision farming clearly dominates whole-field farming in terms of average yield and NPVR as well as decreases variability.

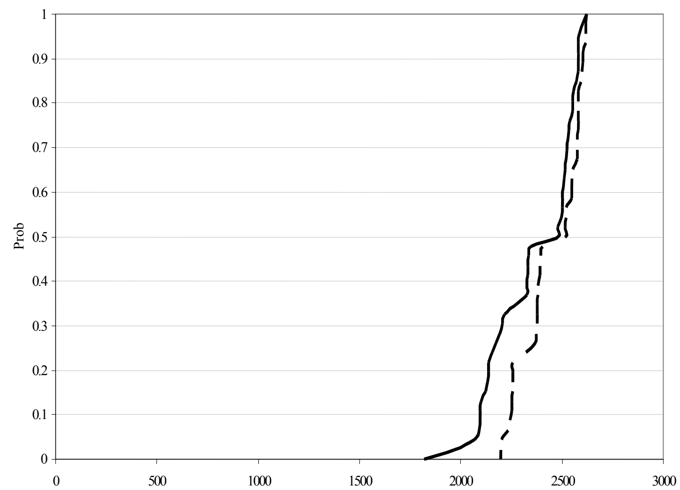

Figure 9. Cumulative Density Function for Cotton Net Revenues Above Nitrogen and Water Costs. (- - - Precision Farming ▬ Whole-Field Farming)

SUMMARY AND DISCUSSION

Both yields and NPVR increased on the average when precision farming practices were employed. On the average, yield was shown to increase by 4.01%, while NPVR were shown to increase by 4.05% as compared to whole-field farming. The optimal level of spatial nitrogen application was slightly lower in the precision farming scenario, by 0.01%. The naïve whole-field farming scenario overestimated both yield and NPVR. Finally, precision farming had less yield and NPVR variability as compared to whole-field farming.

This study suggests that nitrogen fertilizer can be used more efficiently to maximize NPVR under precision farming. Precision farming increased yield and NPVR on the average. The naïve whole-field farming scenario consistently overestimated yield and NPVR in cotton.

Optimal nitrogen application was not significantly different in cotton when using precision farming technology as compared to whole-field farming. The spatial NPVR cdf for precision farming clearly dominated the whole-field farming cdf. Therefore, precision farming is shown to be more profitable than whole-field farming based on net revenues above nitrogen and water costs. As mentioned earlier, the purpose of determining the difference in NPVR when using precision farming practices was to determine the maximum amount a producer could spend to implement precision farming practices. Knowing that precision farming will cost more than whole-field farming to implement, this study determines the magnitude a producer could afford to pay for the implementation of this new technology.

Several agricultural consulting groups in the Southern High Plains of Texas were contacted to determine the additional costs of implementing precision farming practices above whole-field farming. A wide range of responses left no real confidence in the values obtained. Yield monitors could cost $4000-$7000; with soil sampling estimated at $3-$7 per acre. GIS software is estimated at $3000. Service costs including yield monitoring, crop scouting, GPS receiver and, possibly a satellite signal subscription, and variable rate fertilizer application in the range of $2.50-$ 14.50 above whole-field farming costs on a per acre basis. (Cowan 2000). The cotton study increased NPVR by $9.33 per acre when precision farming was employed, covering all variable costs and contributing towards the fixed investment costs of implementing this new technology. This is the amount that producers can justify spending on precision agriculture in dollar terms. This is the figure to compare with costs of implementation in an area considering precision agriculture.

Overall, this study suggests that precision farming overall would be more profitable than whole-field farming. With the current cost of implementation of this technology, precision farming is expected to be more profitable today than whole-field farming is in the SHPT. This is very optimistic for precision farming as only one input was optimized. The results could reasonably be expected to improve even more if other inputs, such as phosphorus or water were to be considered. Future studies should address the specific costs of implementing this technology, as well as including more variable inputs. Also, a thorough risk analysis would be beneficial in future explorations.

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Economic Analysis of Roundup Ready Versus Conventional Cotton Varieties in the Southern High Plains of Texas

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ABSTRACT

The adoption of Roundup Ready cotton varieties has provided cotton producers alternative weed management options with the potential of lowering overall production costs and increasing lint yields. The objective of this study was to evaluate the cost of production and profitability of Roundup Ready cotton compared to conventional cotton varieties in the Southern High Plains (SHP) of Texas from 1998 to 2000. Individual enterprise and whole farm financial analyses were conducted on irrigated cotton operations and combined into a database to generate aggregate enterprise profitability and production cost data for Roundup Ready and conventional cotton varieties in the SHP. Stochastic simulations were utilized to evaluate the profitability of Roundup Ready and conventional cotton varieties accounting for the variability of prices, yields, and production costs. Stochastic dominance (STODOM) with respect to a function was used to rank the varieties accounting for the inherent stochasticity and different levels of producer risk aversion. Weighted average results indicate that producers in the SHP received, on an aggregated basis, higher net incomes for Roundup Ready varieties compared to conventional varieties. STODOM results were consistent with the "average" results and indicated Roundup Ready varieties dominated conventional cotton varieties when accounting for risk preferences and stochasticity of yields, prices, and production costs.

KEY WORDS: Roundup Ready cotton, Stochastic Dominance, conventional cotton

ABBREVIATIONS: ARAC, Absolute Risk Aversion Coefficient; SHP, Southern High Plains; SPA, Standardized Performance Analysis; SPA-ME, Standardized Performance Analysis for Multiple Enterprises; STODOM, Stochastic Dominance with respect to a function.

INTRODUCTION

The development of transgenic cotton varieties has provided opportunities for cotton producers to increase productivity and efficiency in their farming operations. The introduction of Roundup Ready cotton varieties along with Roundup Ultra (*glyphosate*) has provided cotton producers in the Southern High Plains (SHP) of Texas with an effective tool to help control troublesome weed infestations throughout the growing season (White, Beaty, and Johnson, 2000). Roundup Ready cotton varieties have been widely adopted by Texas cotton producers since being introduced in 1997. The planting of Roundup Ready cotton varieties has increased from 2.5% of Texas cotton acres in 1997 to 62.0% in 2001 (USDA, Cotton Varieties Planted).

The use of Roundup Ready cotton varieties may allow producers to reduce the number of chemical applications and mechanical operations resulting in alternative weed management options and the incorporation of reduced tillage practices into their operations. Alternative weed management options and the opportunity to replace traditional tillage operations has the potential to lower overall production costs, while providing potential environmental advantages compared to conventional weed control systems utilizing pre-plant herbicides and traditional tillage practices (Monsanto, 2001). In addition, the ability to control weed infestations which are resistant to pre-plant herbicides may increase cotton lint yields.

Substantial research has been conducted evaluating the agronomic and environmental aspects of Roundup Ready cotton varieties. However, there has been limited research evaluating cost of production, profitability, and potential economic advantages of planting Roundup Ready cotton varieties. White, Beaty, and Johnson (2000) evaluated the profitability and production costs of Roundup Ready versus conventional cotton varieties in the SHP of Texas for 1998. Results indicated Roundup Ready cotton varieties produced higher net returns to operator labor, management, and risk of $72.55 per acre compared to $58.93 per acre for conventional cotton varieties. However, the authors acknowledged the limitation of only one year of data and emphasized the need for further research with a multi-year database. Slinsky et al. (1998) evaluated cost and returns for Roundup Ready cotton varieties in Tennessee for the 1996 crop year. Results indicated that conventional weed-control practices produced higher lint yields, lint prices, and total revenues compared to Roundup Ready treatments. In addition, their study indicated that Roundup Ready treatments had lower production costs compared to conventional weed-control practices. The results of these two studies were limited by data constraints associated with one year of data.

Cotton producers need reliable information evaluating the profitability and production costs of Roundup Ready versus conventional cotton varieties over a longer time horizon. Therefore, the objective of this study was to evaluate the costs of production and profitability of Roundup Ready cotton compared to conventional cotton varieties in the SHP of Texas from 1998 to 2000.

METHODS AND PROCEDURES

The methods utilized in this study included a combination of the Standardized Performance Analysis-Multiple Enterprises (SPA-ME) computer program, Standardized Performance Analysis (SPA) database, and stochastic simulations. The SPA-ME computer program was utilized to complete all individual analyses used in this study. SPA-ME is an analytical program that allows for individual enterprise and whole farm financial analysis (McGrann, Michalke, and Stone, 1996). The SPA-ME program starts by identifying all enterprises and farming units within a specific farming operation. Additionally, whole farm financial statements (Balance Sheets, Accrual Adjusted Income Statement, Statement of Cash Flows, and Statement of Owner Equity) are developed for the operation according to recommendations from the Farm Financial Standards Council. Upon completion of the financial statements, the SPA-ME program allows for specific enterprise assets, liabilities, revenues, and expenses to be allocated from the whole farm financial statements to the individual enterprises and farming units. The end result for the producer is an assessment of actual production costs and profitability of each enterprise and farming unit. Individual SPA analyses were entered into a database, which compiled aggregated enterprise profitability and production cost data for Roundup Ready and conventional cotton enterprises within the SHP.

The stochastic simulations were generated with SIMETAR, a risk analysis software add-in for Microsoft Excel (Richardson, 2002). A total of 1000 simulations per year were generated to evaluate the profitability of Roundup Ready and conventional cotton varieties accounting for the stochastic nature of prices, yields, and variable costs. The means and standard deviations of lint prices, cash operating expenses, and yields were obtained from SPA database average results from 1998 to 2000. All stochastic variables were truncated by their absolute minimums and maximums within the dataset for simulation purposes. To account for potential differences in lint quality between Roundup Ready and conventional varieties, lint price distributions were estimated separately. It is important to note that the loan deficiency payments are embedded in lint prices. Government payments, miscellaneous revenues, and overhead expenses were not included in the stochastic simulations. Furthermore, seed revenues were not included in this study as they were netted out against ginning expenses.

Upon completion of the simulations, stochastic dominance (STODOM) with respect to a function was utilized to rank Roundup Ready and conventional cotton varieties. STODOM is a mathematically precise evaluative criterion to rank actions or choices for classes of decision makers defined by specified lower and upper bounds of their absolute risk aversion coefficient (ARAC) (King and Robison, 1981). The ARAC is defined as the –U”(x) divided by U’(x), where U represents a von Neumann-Morgenstern utility function (Segarra, Keeling, and Abernathy, 1991; Giesler, Paxton, and Millhollan, 1993; Richardson, 2002). Hence, a positive ARAC implies a concave utility function resulting in a risk averse decision maker. Conversely, a negative ARAC implies a convex utility function resulting in a risk loving decision maker. Furthermore, the specification of lower and upper bounds places constraints on the range of risk attitudes entering the STODOM analysis (Giesler, Paxton, and Millhollan, 1993). The advantages of STODOM is that it utilizes all simulated observations and provides an indication of the confidence a decision maker has regarding the ranking of alternative variety selections (Richardson, 2002). Furthermore, the results from STODOM are preferred to the simple “average” results, which do not internalize any considerations for risk preferences.

The data utilized in this study were collected for irrigated cotton production under crop share rental agreements in the SHP from 1998 to 2000. The data included detailed production, financial, and marketing information from each individual producer. It is important to note that all results are reported on an aggregate basis to protect the confidentiality of individual producers.

RESULTS

Standardized Performance Analyses of individual farming operations provided 27, 12, and 21 observations for Roundup Ready[1] cotton varieties, and 38, 22, and 15 observations for conventional cotton varieties from 1998 to 2000, respectively. The per acre results are reported on a 75% crop share bases and are given in Tables 1 and 2 for Roundup Ready and conventional cotton varieties, respectively.

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[1] None of the Roundup Ready observations included a stacked gene variety.

Table 1. Irrigated Roundup Ready Cotton Results from the Texas Southern High Plains.

	1998	1999	2000	Weighted Average
		(lbs/acre)		
Total Yield	532	405	665	553
Crop Share Yield[1]	399	304	499	415
		($/acre)		
Gross Cash Income				
Cotton Lint[2]	231.29	145.39	242.31	217.97
Program Payments	50.20	81.78	61.02	60.30
Crop Insurance Proceeds	4.11	0.00	1.02	2.21
Other Income[3]	34.32	20.73	48.99	36.74
Gross Accrual Revenue	319.92	247.90	353.34	317.21
Cash Operating Expenses				
Chemicals				
Herbicide	23.21	28.66	24.80	24.86
Insecticide	4.14	3.84	16.35	8.35
Harvest Aide	6.49	3.24	6.90	5.98
Growth Regulator	2.33	2.26	4.46	3.06
Fertilizer & Lime	14.43	14.94	18.82	16.07
Gasoline, Fuel, & Oil	12.10	10.34	14.16	12.47
Seeds & Plants	14.87	12.61	17.72	15.42
Repairs & Maintenance	15.73	14.92	22.83	18.05
Hired Labor & Management	27.82	22.26	30.69	27.71
Irrigation	46.61	33.19	43.79	42.94
Other Operating Expenses[4]	49.20	12.26	38.70	38.14
Total Cash Operating Expenses	216.93	158.52	239.22	213.05
Total Interest Expense	13.66	15.43	20.09	16.26
Depreciation Expense	31.68	14.87	35.05	29.50
Total Overhead Expenses	45.34	30.30	55.14	45.76
Total Enterprise Cost	262.27	188.82	294.36	258.81
Net Income[5]	57.65	59.08	58.98	58.40
Enterprise Cost of Production[6]	173.64	86.31	183.33	159.57

[1]Crop share yield is based on 75% of total yield. [2]Accrual adjusted to account for the entire 1998, 1999 and 2000 crop share yield. [3]Other income includes farm coop distributions, custom hire earnings and miscellaneous income. [4]Other expenses include custom hire, insurance, rent, supplies and miscellaneous expenses. [5]Net income is before family living withdrawals. [6]Enterprise cost of production is total enterprise cost less non-primary enterprise revenues, and represents the cost of production that must be covered with primary enterprise revenues.

Table 2. Irrigated Conventional Cotton Results from the Texas Southern High Plains.

	1998	1999	2000	Weighted Average
		(lbs/acre)		
Total Yield	504	397	409	454
Crop Share Yield[1]	378	298	307	340
Gross Cash Income		($/acre)		
Cotton Lint[2]	222.14	153.93	160.38	189.78
Program Payments	48.03	58.05	46.70	50.70
Crop Insurance Proceeds	0.49	7.96	16.51	5.89
Other Income[3]	32.42	13.57	46.69	29.74
Gross Accrual Revenue	303.08	233.51	270.28	276.11
Cash Operating Expenses				
Chemicals				
Herbicide	15.45	12.63	13.18	14.17
Insecticide	6.64	3.40	17.88	7.43
Harvest Aide	6.59	4.18	6.24	5.81
Growth Regulator	1.73	2.63	2.35	2.12
Fertilizer & Lime	16.93	13.53	14.65	15.48
Gasoline, Fuel, & Oil	9.70	7.58	11.95	9.53
Seeds & Plants	8.99	7.58	9.92	8.76
Repairs & Maintenance	17.43	16.10	11.94	15.94
Hired Labor & Management	28.89	28.05	32.61	29.39
Irrigation	42.66	29.62	38.71	38.04
Other Operating Expenses[4]	48.14	35.31	41.51	43.05
Total Cash Operating Expenses	202.15	160.61	200.94	189.72
Total Interest Expense	10.70	9.31	10.01	10.15
Depreciation Expense	30.96	22.10	34.72	29.11
Total Overhead Expenses	41.66	31.41	44.73	39.27
Total Enterprise Cost	243.81	192.02	245.67	228.99
Net Income[5]	59.27	41.49	24.61	47.12
Enterprise Cost of Production[6]	162.87	112.44	135.77	142.66

[1]Crop share yield is based on 75% of total yield. [2]Accrual adjusted to account for the entire 1998, 1999 and 2000 crop share yield. [3]Other income includes farm coop distributions, custom hire earnings and miscellaneous income. [4]Other expenses include custom hire, insurance, rent, supplies and miscellaneous expenses. [5]Net income is before family living withdrawals. [6]Enterprise cost of production is total enterprise cost less non-primary enterprise revenues, and represents the cost of production that must be covered with primary enterprise revenues.

Gross enterprise accrual revenues for Roundup Ready cotton averaged $317.21 per acre compared to $276.11 per acre for conventional cotton varieties. This was primarily the result of higher primary product income and government payments for Roundup Ready cotton varieties. Crop share yields for Roundup Ready cotton were 75 pounds per acre higher on average compared to conventional cotton varieties, which contributed to the higher primary product income. Crop share yields were 399, 304, and 499 pounds per acre for Roundup Ready varieties, and 378, 298, and 307 pounds per acre for conventional varieties from 1998 to 2000, respectively.

Producers received cotton lint prices of $0.59, $0.52, and $0.52 per pound for conventional varieties compared to $0.58, $0.48, and $0.49 per pound for Roundup Ready varieties from 1998 to 2000, respectively. Government payments for Roundup Ready cotton were $23.73 per acre higher than for conventional cotton varieties in 1999 and $14.32 per acre higher in 2000. However, there is no apparent explanation for the higher government payments other than the possible variability resulting from the random selection of producers across the SHP.

Total cash operating expenses were higher for Roundup Ready cotton varieties at $216.93 and $239.22 per acre compared to $202.15 and $200.94 per acre for conventional cotton varieties in 1998 and 2000, respectively. However, the results indicated that total cash operating expenses were lower for Roundup Ready varieties in 1999 at $158.52 per acre compared to $160.61 per acre for conventional cotton varieties. Herbicide expenses were $10.69 per acre higher on average for Roundup Ready varieties compared to conventional varieties. The higher herbicide expense is primarily the result of increased Roundup herbicide applications. Insecticide expenses were relatively constant across both varieties averaging $8.35 and $7.43 per acre for Roundup Ready and conventional varieties, respectively. In 2000, there was a significant increase in insecticide expenses for both varieties. This increase was the result of several producers in the study who incurred higher insecticide expenses to control boll weevils without the assistance of a Boll Weevil Eradication program.

Producers also incurred higher average seed costs per acre for Roundup Ready varieties of $15.42 per acre compared to $8.76 for conventional varieties. This is consistent with expectations given the technology fees associated with Roundup Ready varieties. Furthermore, producers incurred hired labor and management expenses that were $1.68 per acre lower on average for Roundup Ready varieties. Producers also incurred other cash operating expenses (custom hire, insurance, rent, supplies, and other miscellaneous expenses) that were $4.91 per acre higher on average for conventional varieties. However, there is no apparent explanation for the increased expenditures other than the variability associated with the random selection of producers.

Total overhead expenses were consistent for both varieties averaging $45.76 and $39.27 per acre for Roundup Ready and conventional cotton varieties, respectively. It is important to note that overhead expenses only included interest and depreciation expenses. Family living withdrawals were not included in the overhead expenses due to the significant variation in this expense across producers. Total enterprise costs were $18.46 and $48.69 per acre higher for Roundup Ready varieties compared to conventional varieties in 1998 and 2000, respectively. However, total enterprise costs were lower for Roundup Ready varieties at $188.82 per acre compared to $192.02 per acre for conventional cotton varieties in 1999.

Further analysis suggests that producers faced a total average breakeven cost of $0.62 and $0.67 per pound on average from 1998 to 2000 for Roundup Ready and conventional varieties, respectively. Total breakeven costs represent the total primary product income, government payments, crop insurance, and other income necessary to cover total costs of production. In other words, the total breakeven cost indicates how much total revenue from all sources is needed to breakeven. The unit cost of production (breakeven price) averaged $0.38 and $0.42 per pound from 1998 to 2000 for Roundup Ready and conventional varieties, respectively. The unit cost of production represents the cotton lint price necessary to cover all costs after accounting for all non-primary product income. In other words, the unit cost of production represents the cotton lint price necessary to breakeven.

Producers in the SHP received, on an aggregate basis, higher net incomes for Roundup Ready varieties compared to conventional varieties in 1999 and 2000. Producers received net incomes of $57.65, $59.08, and $58.98 per acre for Roundup Ready varieties compared to $59.27, $41.49, and $24.61 per acre for conventional varieties from 1998 to 2000, respectively.

The above "average" results evaluate the profitability of Roundup Ready and conventional cotton varieties without any consideration of risk preferences or variability associated with prices, yields, and production costs. Therefore, stochastic simulations were developed to evaluate the variety decision when accounting for variability and different levels of producer risk aversion.

The data used to generate the stochastic simulations for Roundup Ready and conventional varieties are provided in Tables 3 and 4, respectively. The per acre yields, prices, and cash operating expenses were assumed to be stochastic. Again, government payments, miscellaneous revenues, and overhead expenses were not included in the simulations. The input data components of Tables 3 and 4 provide the means, standard deviations, absolute minimums, and absolute maximums associated with the stochastic variables utilized in the simulations. This input data was then utilized to generate the stochastic variables with a truncated normal function. A total of 1,000 net income observations were simulated for each year from 1998 to 2000, while accounting for the stochastic nature of yields, prices, and production costs. The simulated net income observations for Roundup Ready and conventional cotton varieties were then truncated by their respective absolute minimums and maximums observed in each year of the study. All truncated simulated observations from 1998 to 2000 were combined to provide one simulated dataset for Roundup Ready and conventional varieties.

STODOM was used to evaluate and rank Roundup Ready and conventional cotton varieties and compare various levels of risk aversion and risk neutrality. The STODOM analyses were conducted for twenty different alternative levels of risk aversion coefficients (ARAC) ranging from 0 to 0.05. Under all levels of ARAC's evaluated in this study, Roundup Ready varieties dominated conventional cotton varieties when accounting for risk preferences and stochasticity of yields, prices, and production costs. This is supported graphically in Figure 1, which depicts the cumulative probability density functions of the simulated net incomes for Roundup Ready and conventional cotton varieties. Figure 1 indicates that Roundup Ready varieties resulted in higher net incomes for any level of probability. Furthermore, this figure indicates that conventional cotton varieties had roughly a 15% greater probability of generating a negative net income.

Table 3. Dynamic Simulation Data for Roundup Ready Cotton.

	Mean	Standard Deviation	Absolute Minimum	Absolute Maximum
		1998		
Price ($/lb)	0.573459	0.068426	0.456	0.651
Yield (lb/ac)	399	197	165.31	751.61
TCOE[1] ($)	216.93	71.16	137.61	425.37
		1999		
Price ($/lb)	0.478257	0.048045	0.454	0.506
Yield (lb/ac)	304	11	113.4	456.08
TCOE[1] ($)	158.52	49.96	122.32	259.61
		2000		
Price ($/lb)	0.483607	0.055637	0.378	0.518
Yield (lb/ac)	499	298	102.38	1069
TCOE[1] ($)	239.22	98.16	158	297

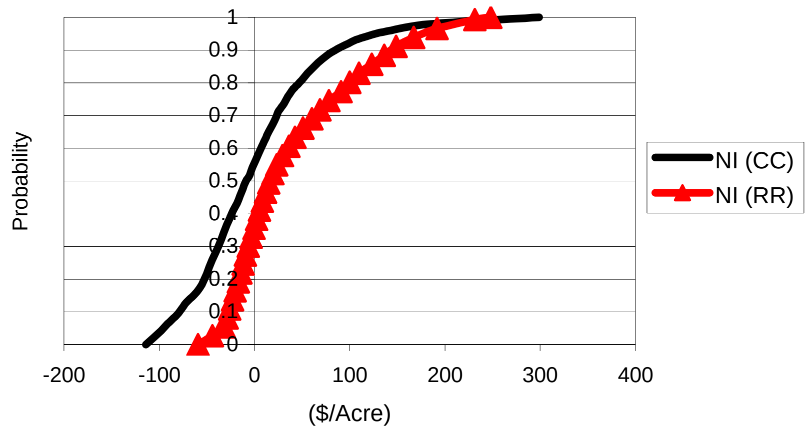
[1]TCOE - Total Cash Operating Expenses

Table 4. Dynamic Simulation Data for Conventional Cotton

	Mean	Standard Deviation	Absolute Minimum	Absolute Maximum
		1998		
Price ($/lb)	0.578677	0.077439	0.481	0.649
Yield (lb/ac)	378	171	161.11	913.84
TCOE[1] ($)	202.15	66.52	144.43	396.78
		1999		
Price ($/lb)	0.516544	0.061953	0.429	0.592
Yield (lb/ac)	298	91	114.95	890.74
TCOE[1] ($)	160.61	56.15	130.65	249.03
		2000		
Price ($/lb)	0.494235	0.078278	0.377	0.584
Yield (lb/ac)	307	129	173.3	747.25
TCOE[1] ($)	200.94	70.67	133.98	256.97

[1]TCOE - Total Cash Operating Expenses

Figure 1. Cumulative Density Functions of Net Incomes for Roundup Ready and Conventional Cotton Varieties.



CONCLUSIONS

The results of this study indicated that Roundup Ready and conventional cotton varieties produced similar net returns in 1998 of $57.65 and $59.27, respectively. However, results indicated that Roundup Ready varieties produced net incomes that were $17.59 and $34.57 per acre higher compared to conventional cotton varieties in 1999 and 2000, respectively. This was primarily the result of higher yields and government payments for Roundup Ready varieties in 1999 and 2000. This result was consistent with the results from White, Jones, and Johnson (2000) and Monsanto (2001). Further, Roundup Ready varieties incurred higher total costs of production with the exception of 1999. This higher production cost was inconsistent with results from Slinsky et al. (1996) and Monsanto (2001). However, results suggest that producers should be willing to accept higher costs of production for Roundup Ready varieties to realize higher lint yields and net incomes. The weighted average results indicated that Roundup Ready varieties produced higher net incomes of $11.28 per acre compared to conventional cotton varieties. While this result may not seem significant on a per acre basis, this would represent $11,280 on a 1000-acre farm.

However, one could make the case that government payments should be excluded from the average results. The exclusion of government payments in the average results would have produced similar net incomes under both varieties. The STODOM results, which did not include government payments, indicated higher net incomes for Roundup Ready varieties for any level of probability. Furthermore, the STODOM results should be preferred to the "average" results, since the STODOM results internalize the year-to-year variability. Finally, for risk averse and risk neutral producers in the SHP of Texas, the optimal strategy appears to be the selection of a Roundup Ready variety.

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THE COST AND EFFECTIVENESS OF PRE-HARVEST INTERVENTIONS IN BEEF CATTLE

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ABSTRACT

Because cattle have been identified as a reservoir for foodborne pathogens, interest has grown in developing interventions to reduce levels of pathogens at the producer level (pre-harvest). Several pre-harvest interventions have been identified as potentially effective for reducing pathogen levels in animals, yet no comparative research has been done comparing the cost and effectiveness of different interventions. This article provides a current assessment of existing interventions for their effectiveness and economic costs and suggests where additional evaluation is needed to continue to improve pre-harvest food safety in the beef industry.

KEYWORDS: pre-harvest food safety, *Escherichia coli* O157, cattle, economics.

INTRODUCTION

Deaths and illnesses from foodborne illness have a major impact on the economic and public health of the United States. More than 200 illnesses are transmitted through food and the Centers for Disease Control (CDC) estimates that “76 million illnesses, 325,000 hospitalizations, and 5,000 deaths” are caused by foodborne disease in the each year (Mead et al, 1999). What is more, new information suggests that these estimates may be low due to previously unknown long-term mortality rates associated with foodborne illness (Helms et al, 2003). While food safety is an obvious public health threat, it also has economic consequences. The United States Department of Agriculture (USDA) estimates that losses from foodborne illness cost society approximately $6.9 billion per year due to medical costs and lower productivity alone (Crutchfield and Roberts, 2000). In addition, executives of the top beef processing companies in the United States have identified food safety as the number one challenge facing the beef industry today (Ledbetter, 2002). John Simons, President and CEO of Swift & Co., summarized the industry’s concern at the Texas Cattle Feeders Association annual meeting in 2002, when he said, “None of us wants, or can afford, more frequent and larger recalls.” (Ledbetter, 2002) Recalls and outbreaks have a devastating impact on the beef production and processing industry as well as on the consumers who become ill due to contaminated product.

In attempting to reduce the prevalence of foodborne illness in the United States, scientists, government officials, food producers and processors have sought to implement a comprehensive "farm to table" approach to food safety. Such an approach operates under the theory that each component part of the food production chain has responsibilities in ensuring safe, wholesome food. Yet efforts to reduce contamination in the beef products have primarily focused on the post-harvest stage of production and cattle producers have had little involvement. Nevertheless, live animals play a significant role in the contamination of beef products. Live cattle have been identified as a reservoir for several foodborne pathogens including *Escherichia coli (E. coli)* 0157:H7, *Salmonella spp.*, and *Campylobacter spp.* (USDA 1994). These pathogens can enter the food supply during slaughter from transmission from the hide, workers or machinery in the processing environment, or by direct contact with feces or digesta from the intestinal tract (Elder et al, 2002). Moreover, a positive correlation has been found between positive fecal and hide samples for *E. coli* O157:H7 taken from cattle and subsequent contamination of the carcasses. (Elder et al 2000) Because the potential for direct contamination of the carcass from the animal exists, scientists are looking at ways to reduce, control, or eliminate foodborne pathogens prior to harvest. Decreasing the level of pathogens in the live animal should decrease the occurrence of the pathogen in the food supply and reduce the risk of food-borne illness to consumer (Jordan et al, 1999). Although research in the area of pre-harvest food safety is in its early stages, studies have suggested several interventions have potential to consistently reduce pathogens in the live animal. Nevertheless, while previous studies have addressed the potential effectiveness of individual interventions, little or no comparative research on interventions or the cost associated with the interventions is available.

While microbiological effectiveness in reducing pathogens is the primary goal when developing pre-harvest interventions, the economic and practical concerns of producers must also be considered. In order to achieve the most effective and efficient use of pre-harvest interventions, questions about the cost, effectiveness, and external effects of different interventions will need to be addressed. The objective of this paper is to provide a review of the effectiveness and economic costs of several potential pre-harvest interventions to be used in cattle production. Table 1 provides a summary of these interventions, including the name, description, effectiveness, and associated economic costs associated, while more detailed information follows below.

PRE-HARVEST INTERVENTIONS

Dietary Changes/Feed Supplements

Fiber

Using increased amounts of fiber or roughage in cattle diets as a means of reducing foodborne pathogens has been subject to controversy due to conflicting reports about its effectiveness. Scientists have speculated that levels of *E. coli* O157:H7 are related to the ruminal pH and the volatile fatty acid (VFA) content in the gastrointestinal tract. Diets with increased hay or roughage result in an increased ruminal pH and a decrease in VFA concentration, whereas high-concentrate (grain) diets result in the

TABLE 1. PRE-HARVEST INTERVENTIONS.

NAME	DESCRIPTION	INHIBITORY EFFECT ON E. COLI O157:H7	ECONOMIC COSTS	CURRENTLY AVAILABLE
I. DIETARY CHANGES/FEED SUPPLEMENTS				
Fiber	Using increased amounts of fiber in cattle diets.	Unknown. Inconsistent reports on its effectiveness make it difficult to state whether there is any inhibitory effect at this time.	Too impractical to implement on a wide-scale basis. Requires extra time on feed and may see decreased animal performance.	Yes.
Whole Cottonseed	Whole cottonseed is substituted in concentrate to feed at a rate 10 to 15% dry matter.	Unknown. Young dairy calves fed whole cottonseed have been found to be less likely to carry E. coli O157:H7. Preliminary data have shown similar results in feedlot cattle.	Unknown. Prices may vary significantly due to volatility of price due to seasonal and geographic variation, and potential external costs are still being studied.	Yes.
Probiotics / Direct Fed Microbials	Bacterial organisms which maintain proper balance and health in the digestive system and help fight illness and disease.	Supplementing cattle diet with a Lactobacillus-based direct fed microbial has been shown to reduce the prevalence of E.coli O157:H7 by approximately 50%.	Estimated at approximately 1.5 – 2.0¢ head/day on feed, depending on the size of the operation. At 160-170 days, approximate $2.40 to $3.40 per head.	Yes. Currently FDA-approved as a feed supplement in cattle to improve performance.
Tasco	A commercially available feed supplement derived from brown seaweed.	Supplementing Tasco-14 at 2% during the final two weeks of the feeding period has reduced pathogenic E. coli in the feces and on the hides of cattle at harvest.	14-day feeding before slaughter was estimated at $3.75 to $4.25 per head.	Yes. Currently FDA-approved as a feed supplement in cattle.
Bacteriophage	Viruses which can infect and kill harmful bacterial cells.	Studies have shown that contamination of E. coli O157:H7 has been reduced by feeding O157-specific bacteriophages after inoculation with the pathogen.	Unknown. Direct cost of treatment are estimated to be low (< $1.00 per head) as it is likely be used only as a one-time treatment before slaughter.	No. Currently not FDA-approved for use in human food.
Sodium Chlorate	When ingested, sodium chlorate has a bactericidal effect on E. coli O157:H7	Orally administering sodium chlorate to cattle inoculated with E. coli O157:H7 significantly reduced the amount of the pathogen in the feces.	Unknown. Direct cost of treatment estimated at 30¢ per animal.	No. Currently not FDA-approved for use on animals which will be slaughtered for food.

opposite (Magnuson et al, 2000; Owens and Goetsh, 1988). Yet the results from studies increasing the amount of fiber in cattle diets have not been consistent.

Early studies reported that feeding sheep diets high in fiber resulted in large amounts of shedding of *E. coli* O157:H7 in experimentally inoculated animals, while shedding was decreased in animals fed a high-nutrient diet consisting of corn and pelleted alfalfa (Kudva, Hatfield and Hovde, 1995; Kudva et al, 1997). One study that examined the shedding of *E. coli* O157:H7 found that hay-fed cattle shed the pathogen for longer periods (39 to 42 days) than those fed a concentrate diet (4 days) (Hovde, 1999). Other studies, however, reported no relationship between diet and the ruminal presence of *E. coli* O157:H7 (Magnuson et al, 2000; Tkalcic et al, 2000). For example, Magnuson et. al reported that there were no differences in the shedding of *E. coli* O157:H7 in heifers fed growing diets (typically lower concentrate) or finishing diets.

Finally, still other studies have reported that the amount of acid-tolerant *E. coli* shed by cattle fed hay was less than those fed a concentrate diet (Diez-Gonzalez, 1998). In fact, a recent study found that although low levels of fiber in sheep diets increased shedding, while higher levels decreased shedding. Normal concentrate diets consisting of approximately 5% acid detergent fiber increased fecal shedding in lambs, while increasing the percentages to rates between 10% and 20% decreased fecal shedding without adversely affecting performance (Lema et al, 2002).

Nevertheless, even if increased hay or roughage in the diet was found to be significant in reducing levels of pathogens, questions regarding cost, practicality, and marketing currently limit its use. While grass-fed beef may be a positive niche market for some producers, it is not considered economically feasible for the industry as a whole (Callaway et al, 2003). Finishing cattle on a non-concentrate diet requires additional time and has been reported to decrease performance and marketability. Grass-fed, or forage finished cattle have also been reported to have a lower dressing percentage, higher shrinkage, and lower quality grade (Schroeder et al, 1980). Additionally, grass-fed beef has been reported to be more variable in flavor and color and less appealing to consumers due to the different flavor and deterioration during retail display (Schroeder et al, 1980).

Whole Cottonseed

Similar to increased fiber in cattle diets, the inhibitory effects of whole cottonseed on shedding of *E. coli* O157:H7, has not been clearly established. Some studies have reported a negative association (Garber et al, 1995, Hancock et al, 1994), while others have reported finding no association (Buchko et al, 2000; Dargatz et al, 1997). A recent preliminary data from Texas Tech University, however, indicated that whole cottonseed may be effective in decreasing the shedding of *E. coli* O157:H7 in feedlot cattle; and a large-scale study is currently underway (Younts-Dahl et al, 2003).

If whole cottonseed is proven as effective intervention, it may some unique advantages for producers. Whole cottonseed has long been an important feed ingredient in the dairy industry, particularly in the Western U.S. Often fed at a concentration of 10 to 15% of the dietary dry matter, whole cottonseed is an excellent source of protein, fat, and digestible fiber. Whole cottonseed (with lint) typically contains 23.5% crude protein, 19.3% ether extract (fat), and approximately 50% neutral detergent fiber (Council, 2001). Although less frequently used in the feedlot beef cattle industry, whole cottonseed can be used effectively in high-concentrate finishing diets of beef cattle (Zinn and Plascencia, 1993), potentially replacing all supplemental fat.

Finally, with regard to cost, depending on two important variables, whole cottonseed may be an economical intervention for producers. First, while whole cottonseed has advantage over other feeds in that it does not require any processing before being fed to cattle, seasonal and geographic differences can cause its price to vary widely. Second, depending on the availability of other nutrients, whole cottonseed may not always be the most economical option for producers' nutritional needs (Rodgers, Poore and Paschal, 2002).

Probiotics/Direct-Fed Microbials

The inhibitory effect of probiotics or direct-fed microbials (DFMs) such as lactic acid bacteria on pathogens has been known for many years. The inhibition occurs in vitro during both growth and refrigerated storage and has been documented in various food products. Direct-fed microbials are already used in the poultry industry to inhibit *Salmonella* and several studies have confirmed the potential for DFM to decrease the shedding of *E. coli* O157:H7 and other pathogens in cattle.

Zhao et al. reported that probiotic organisms (*Proteus mirabilis* and non-pathogenic *E. coli)* reduced the duration of shedding of *E. coli* O157:H7 in calves (Zhao et al, 1998). Those fed the probiotics shed the pathogen for 9 to 17 days, whereas the controls shed the pathogen for up to 32 d.

Researchers at Texas Tech University evaluated the effect that dietary supplementation with a *Lactobacillus*-based DFM had on fecal shedding of *E. coli* O157:H7, prevalence of *E. coli* O157:H7 in pens, on carcasses, and on hides, and cattle performance (Brashears, Jaroni and Trimbleb, 2003). The study consisted of a feeding trial using 180 beef steers that were evaluated for shedding of *E. coli* O157:H7 at feedlot arrival, just before supplementation with the DFM, and every fourteen days thereafter until slaughter. *Lactobacillus acidophilus* strain NPC 747 decreased shedding of *E. coli* O157 in the feces of individual cattle during the feeding period. *E. coli* O157 was approximately twice more likely to be detected in control samples than in samples from cattle receiving supplementation with the DFM, and the number of positive hide samples at harvest and the number of pens testing positive for the pathogen, were decreased.

Even so, these results were not achieved at the expense of performance. Body weight gain (live or carcass basis) and feed intake during the DFM supplementation period did not differ among treatments. Gain efficiency on a live-weight basis did not differ among treatments, but carcass-based gain efficiency was improved for the two DFM treatments compared with the control. These results suggest that feeding DFM to cattle will decrease fecal shedding of *E. coli* O157, as well as contamination on hides, without detrimental effects on performance.

The cost of this intervention ranges from approximately 1.5 to 2.0 cents per head per day, depending on the size of the feeding operation (Ware, 2003). Thus, for a feeding period of 160-170 days, the cost would range between $2.40 and $3.40 per head, indicating that this may be an economical and effective pre-harvest intervention.

Tasco

Tasco is a commercially produced feed supplement derived from the brown seaweed *Ascophyllum nodosum*. Although currently FDA-approved and marketed for other purposes, researchers at Texas Tech University have found that supplementing Tasco during the final 2 weeks on the feedyard has reduced pathogenic *E. coli* in the feces and on the hides of cattle at harvest (Behrends et al, 2000). The cost of feeding Tasco for a 14-day period, however, has been reported to be approximately $3.75 to $4.25/head (Seamann, 2003). Nevertheless, trials are currently underway to examine the effectiveness of feeding for only 7 days prior to slaughter, which would reduce the cost to $1.75 to $2.00/head (Seamann, 2003).

Bacteriophages

Bacteriophages are viruses that can infect and kill certain bacterial cells, and their use as an intervention to reduce pathogen levels in cattle may have some unique advantages. Bacteriophages are natural, nontoxic, have historically been used to treat human infections, and present a possible alternative to using antibiotics. Also, bacteriophages can target specific pathogens, thus reducing the risk of upsetting the normal flora of the rumen. Also, because bacteriophages are viruses, infecting a few animals with the virus could be sufficient to treat an entire herd (Randerson, 2003).

In clinical trials, enteropathogenic *E. coli* infections in mice, calves, piglets, and lambs (Smith and Huggins, 1982) have been decreased by using bacteriophage therapy. More specifically, Kudva et al. (Kudva, 1999), and Waddell et al. (Waddell, 2000), reported that bacteriophages been effective in inhibiting *E. coli* O157:H7. More recently, researchers at Evergreen College in Washington state have discovered a phage that in a small clinical trial reduced numbers of *E. coli* O157:H7 by 99 percent in just two days (Randerson, 2003).

Like antibiotics, bacteriophages would likely be used as a one time treatment before slaughter and are likely to be comparable in cost (Brabban, 2003). However, bacteriophages are currently not approved for use in human food, and before gaining FDA-approval, more research is likely needed to prove that the viruses are not only effective, but also safe should they be passed on to humans through the food chain (USDA, 2002; Randerson, 2003).

Sodium Chlorate

Small amounts of sodium chlorate have been proven to kill harmful intestinal bacteria such as *Salmonella typhimurium* and *E. coli* 0157:H7. A recent study conducted by found that administering small amounts of sodium chlorate to cattle via drinking water 24 hours before slaughter was effective in reducing the amount *E. coli* O157:H7 in the feces, but did not reduce levels of hide contamination (Callaway et al, 2002).

In large amounts, sodium chlorate is toxic to cattle and is not yet approved for use in cattle for human consumption. According to a recent USDA report, however, "the [FDA] is currently considering whether sodium chlorate is generally recognized as safe (GRAS), or whether it should be regulated as a food additive, feed additive or a drug," (USDA, 2002). Moreover, additional studies on performance, meat quality, and residue may be needed. Due to these uncertainties, it is currently unknown what the economic costs of this intervention will ultimately be, although one report estimates the direct cost of the treatment at 30 cents per animal (Duckworth, 2001) thus indicating this could be a cost effective intervention.

Medicines

Vaccination

Although still in commercial development, vaccination may be an effective intervention strategy for decreasing *E. coli* O157:H7 in cattle. While not expected to be 100% effective in reducing or eliminating levels of *E. coli* 0157:H7, a vaccine may significantly reduce the amount of infection in cattle or reduce the number of days that the animals shed the pathogen. Potter and Finlay reported that two separate vaccinations decreased fecal shedding of the pathogen by cattle, possibly by preventing adherence of the organism to the gastro-intestinal tract (Potter and Finlay, 2000). Because a vaccine is not expected to be commercially available until at least February 2004 (Bradford, 2003), the price of such a vaccine is not known for certain. However, if it falls within the current price range for other bovine vaccines, it would only cost about $1 to $2 per head (Potter, 2003).

TABLE 1. PRE-HARVEST INTERVENTIONS (Continued).

NAME	DESCRIPTION	INHIBITORY EFFECT ON *E. COLI* O157:H7	ECONOMIC COSTS	CURRENTLY AVAILABLE
II. Medicines				
Vaccination	Vaccines produce antibodies that prevent adherence and colonization of pathogens in the digestive tracts of cattle.	While not a 100% barrier to the pathogen, it may reduce the amount of infection in cattle or reduce the number of days that the animals carry the pathogen. Field trials are currently underway in Canada.	Anticipated to cost between $1.00 to $2.00 per head. .	No. Not likely to be approved and available for commercial use for until at least February 2004
Neomycin Sulfate	Broad spectrum antibiotic.	Oral administration of therapeutic amounts reduced *E. coli* O157:H7 to non-detectable levels in naturally infected cattle.	Direct cost of the treatment has been estimated at approximately $1.34 per head, not including handling costs	No. Current regulations only allow for use on cattle which are suffering from bacterial enteritis, and should not be universally administered.

Neomycin Sulfate

Neomycin sulfate is a broad spectrum antibiotic used to treat cattle. Elder et. al. (Elder et al, 2000) recently reported that orally administering therapeutic levels of the antibiotic significantly reduced levels of *E. coli* O157:H7 in naturally-infected cattle and lowered total numbers of generic *E. coli*. Nevertheless, even if proven effective, the potential for widespread use of neomycin sulfate in the industry may be limited due to concerns about antibiotic resistance and cost. Concerns about antibiotic resistance recently led McDonald's to announce a new policy to encourage its suppliers to reduce antibiotic use (McDonald's, 2003). Additionally, current FDA regulations only permit the use of neomycin sulfate "[f]or the treatment and control of colibacillosis (bacterial enteritis) caused by *Escherichia coli* susceptible to neomycin sulfate in cattle (excluding veal calves), swine and goats[,]" and does not specifically allow for the use of neomycin to reduce levels of *E. coli* O157:H7.

Moreover, even if neomycin is ultimately approved for reducing levels of *E. coli* O157:H7, one report speculated that neomycin may be too expensive to administer universally, but may be cost-effective for "high risk cattle two days before slaughter." (Maday, 2002). Nevertheless, for a 1200-pound steer the cost of the treatment (minus any handling costs) has been estimated at only $1.34 per head. (Keen, 2003)

Management Practices

To date no specific sanitation or management practices have been proven that are effective at reducing the levels of foodborne pathogens prior to harvest. Certain

TABLE 1. PRE-HARVEST INTERVENTIONS (Continued).

NAME	**DESCRIPTION**	**INHIBITORY EFFECT ON *E. COLI* O157:H7**	**ECONOMIC COSTS**	**CURRENTLY AVAILABLE**
III. Management Practices				
Best Management Practices	The USDA is currently working on a list of specific management practices for producers to follow to help reduce pathogen loads on animals.	Unknown. While individual impacts of management practices may be too small to notice, their aggregate effect may be significant.	Unknown. May be very inexpensive for simple sanitation practices, but major changes to management practices or facilities could be expensive.	No. A list of best management practices is still under development.
Cattle Cleanliness	Practices relating to keeping mud, tag, and feces off the animals before slaughter.	While the actual amount of reduction is not known, scientists have found a positive correlation between hide contamination and carcass contamination.	Unknown. Costs may vary significantly due to variations in geography, facilities and season.	Yes, as long as the methods used to keep the cattle clean do not violate state or federal laws and regulations.

factors, however, such as the conditions of pens and presence of pathogens in the water troughs may lead to an increase in higher prevalence of infected animals (Lejeune, Besser and Hancock, 2001; Smith et al, 2001). Because of this potential for an increase in pathogens, the USDA's Food Safety Inspection Service is developing a list of best management practices that may help reduce foodborne pathogens before slaughter (USDA, 2003). One management practice that has already gained attention as a way to increase safety before slaughter is cattle cleanliness. Manure on the hides of animals has been identified as a source of contamination of beef products during slaughter (Hancock et al, 1999), and levels of carcass contamination have been found to be associated with levels of physical contaminants such as mud or feces on the hide (Elder et al, 2000). Therefore, if these contaminants can be removed before slaughter, it should in turn reduce the probability of contamination of the final product. One processing company in Alberta, Canada, has already taken this to heart. It recently devised a system that scores the levels of tag, mud and manure on the animals, and awards those producers that consistently provide the cleanest animals (Cargill, 2003).

TABLE 1. PRE-HARVEST INTERVENTIONS (Continued)

NAME	**DESCRIPTION**	**INHIBITORY EFFECT ON *E. COLI* O157:H7**	**ECONOMIC COSTS**	**CURRENTLY AVAILABLE**
IV. Other				
Multiple Interventions	Using two or more interventions at a time.	Using direct fed microbials, nemoycin sulfate, and a bacterial vaccine together was shown to be more effective in reducing the number of animals shedding *E. coli* O157:H7 in their feces or carrying it on their hides than most single interventions.	Using all three of the interventions in concert is estimated to likely exceed $7.00/head.	No. See above comments on Neomycin and vaccines.

FUTURE IMPLICATIONS FOR PRE-HARVEST FOOD SAFETY RESEARCH

This paper examined the current state of knowledge regarding the potential for pre-harvest interventions to effectively and efficiently reduce foodborne pathogens. Because many pre-harvest interventions are still in development (or not FDA-approved for use in food production) specific data about economic costs of interventions were not always available. Also, because of the differences in study design and measures of effectiveness, direct comparison of the effectiveness of the interventions was not possible. For example, some studies inoculated only a few animals and measured the levels of *E. coli* O157:H7 following treatment. In contrast, other studies used naturally-infected animals and measured the number of animals that tested positive for shedding the pathogen in the feces or carrying it on their hides. Thus, as these interventions are developed, additional studies to directly compare their cost and effectiveness will be needed.

In addition to evaluating individual interventions, more research is needed on using two or more interventions in concert. Most studies to date have only considered the effectiveness of utilizing single interventions. Yet using two or more interventions in concert or as separate treatments is likely to be more effective. Utilizing a stochastic model of the effects of pre-harvest interventions, Jordan and McEwen initially found that using a vaccine and a feed supplement to reduce the amount of pathogens in the feces would be more effective than using them individually (Jordan et al, 1999). More recently, researchers at Colorado State University found that utilizing a direct-fed microbial (*Lactobacillus acidophilus)*, neomycin sulfate, and a bacterial vaccine in combinations generally resulted in lower numbers of animals shedding *E. coli* O157:H7 or carrying it on their hides than were found using a single intervention (Roybal, 2003). This "multiple-hurdle" approach to pathogen reduction works under the presumption that although no individual intervention will be 100% effective, implementing multiple interventions at various steps throughout the chain will have an additive effect of reducing the probability of contamination of the final product. Such an approach has already been successfully utilized in processing plants as an integral part of their hazard analysis critical control point (HACCP) plans (Bacon et al, 2000).

More research is also needed into how of pre-harvest food safety is to be incorporated into a system-wide, multiple hurdle approach to controlling foodborne pathogens in the food chain. The prevalence of foodborne pathogens in live animals, their feces, and on their hides suggests that they are major source of contamination, and scientists expect that increases in safety at the pre-harvest stage will ultimately result in fewer foodborne illnesses. Nevertheless, while pre-harvest food safety interventions are likely to reduce the probability of contamination of the final product, the amount of any such reduction of is yet unknown. Although significant progress has been made, we do not yet fully understand the epidemiology of how foodborne pathogens move throughout the food chain. Gaining an understanding of the ultimate impact of pre-harvest food safety interventions on the number of foodborne illnesses is critical for determining where to focus our food safety efforts in the future.

In conclusion, although pre-harvest food safety interventions in beef cattle are still in the early stages of development, several possibilities for safe, effective, and practical interventions clearly exist. Still, more information is needed on the cost and effectiveness of these interventions as well as the overall impact on the rest of the production chain in order to most effectively and efficiently protect the safety of our food supply.

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Effects of Shade and Rhizobium Inoculation on Herbage of Black and Button Medics

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ABSTRACT

Shade tolerance and *Rhizobium* inoculation in annual, cool-season legumes may affect yield of both herbage and seed under arboreal canopies. Naturalized black (*Medicago lupulina* L.) and button (*M. orbicularis* [L.] Bartal.) medics were grown under 0, 30, 55, and 80% shade with and without specific *Rhizobium* inoculation in a two-year field trial. Soil moisture was greatest under 55 and 80% shade and in Yr 1 prior to herbage harvest. Under more stable growing conditions (Yr 1) herbage yields decreased under 80% shade. Herbage yields were undifferentiated between species in Yr 1 but were greater for button medic in Yr 2. Black medic stems were longer in Yr 1 while button medic stems were longer in Yr 2. Seed number peaked for black medic in Yr 1 under 30 and 55% shade but was undifferentiated between species or shade levels in Yr 2. Herbage crude protein concentration was greatest in Yr 2 and at 55% shade for button medic. Acid detergent fiber and lignin concentrations of both species tended to increase as shade levels increased. *Rhizobium* inoculation had no consistent effects on parameters measured. Regression analyses provided no significant model statements. These medics appear tolerant of up to 30% shade and may not require commercial *Rhizobium* inoculation in field conditions where native Rhizobia are already present.

Key words: cool season legumes, forage, quality
Abbreviations: CP, crude protein; ADF, acid detergent fiber; NS, no significant differences at $P = 0.05$.

INTRODUCTION

The planting of introduced and widely naturalized (Diggs et al. 1999) herbaceous cool-season forage legumes into pastures and native range can increase crude protein (CP), energy, and minerals in animal diets, improve animal performance, and increase total herbage production and grazing capacity during critical winter months (Muir et al. 2001). In addition, introduction of supplemental forage legumes as a wildlife management tool may be an efficient and effective technique for improving wildlife habitat, increasing wildlife populations, and enhancing reproductive efficiency.

Forage legumes have also been studied for uses in agroforestry and silvicultural systems. The inclusion of legumes in alley cropping production systems has been shown to contribute to nutrient recycling, reduction in soil nutrient leaching losses, stimulation of higher soil faunal activities, reduction in soil erosion, improved soil fertility, and sustained levels of crop production (Kang 1997). Silvopastoral systems have many benefits over open pastures including greater nutrient cycling, increased soil organic matter (OM) content, reduced erosion, shade for livestock, and greater herbage availability during the dry season (Bazill 1987).

When infected with the effective *Rhizobium* bacteria species, legumes and bacteria form a symbiotic association that enables them to fix atmospheric nitrogen (N_2) (Recourt et al. 1991; van Kessel and Hartley 2000) and transform it into plant-available nitrogen (NH_4^+) (Salisbury and Ross 1992; Graham and Vance 2000). Inoculating legumes with species-specific *Rhizobium* increases the success of legume establishment (Java et al. 1995), root nodulation, herbage yields, and herbage N yield (Zhu et al. 1998). However, the *Rhizobium* inoculation requirements of many cool-season forage legumes are unknown. Research has shown that species exhibiting the C_3 photosynthetic pathway, such as forage legumes, are usually more adaptable to shade than species with the C_4 photosynthetic pathway (Kephart et al. 1992). There is, however, limited research on the shade tolerance of many annual cool-season forage legumes, especially members of the genus *Medicago*. The objectives of this study were to evaluate the shade tolerance and the efficacy of specific *Rhizobium* inoculation of black medic (*Medicago lupulina* L.) and button medic (*M. orbicularis* [L.] Bartal.) in field conditions.

MATERIALS AND METHODS

This research was conducted from 2000-2001 (Yr 1) and repeated in 2001-2002 (Yr 2) at the Texas Agricultural Experiment Station (TAES) in Stephenville, Texas USA (32° 13' N / 98° 10' W at 401 m elevation). Soil at the site was a Windthorst fine sandy loam (fine, mixed, thermic Udic Paleustalf) and no amendments or sterilization were applied. November to April (effective growing period for the trial) rainfall was 493 mm in Yr 1 and 366 mm in Yr 2 (Fig. 1).

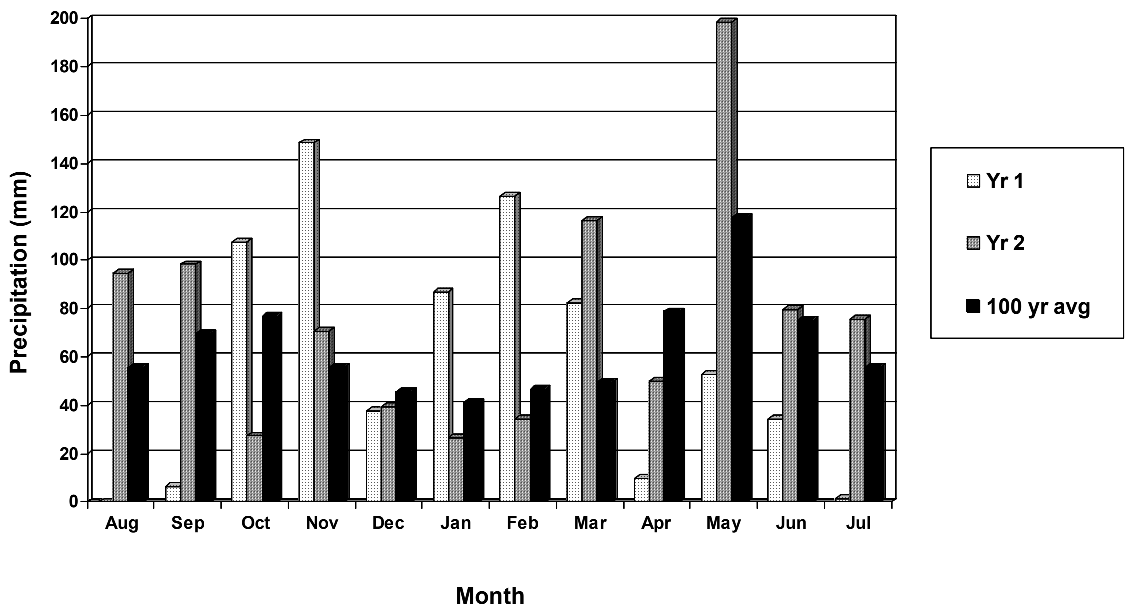

Figure 1. Total monthly precipitation for 2001, 2002, and the 100 yr average for Stephenville, TX.

The study area was treated with clethodim [(E)-2[1-[[(3-chloro-2-propenyl)oxy] imino]propyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one] at 1122 ml ha^{-1} in September of each trial year to remove vegetation prior to seedling transplantation. The plots were disked in October 2000 but were only manually weeded in preparation for transplanting in Yr 2. Established plots were manually weeded throughout both study periods to reduce competition from other vegetation. Carbaryl [1-naphthyl N-methylcarbamate] was applied in February 2002 at 3553 ml ha^{-1} to control the damage by alfalfa weevil larvae (*Hypera postica* Gyllenhal). In June 2002, fluazifop-P-butyl [butyl (*R*)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]oxy]phenoxy]propanoate] was applied at 1122 ml ha^{-1} to control invasive grasses, especially grassbur (*Cenchrus incertus* Curtis).

Seeds of locally collected black and button medics were scarified and planted in peat pellets (Jiffy pot #7, Jiffy Products, Batavia, IL) in early to mid-September of each study year. Seedlings were established in the greenhouse and manually thinned to contain one seedling per peat pellet. Seedlings were transplanted into the field plots each year in November. Seedlings that were transplanted into the inoculated treatments were inoculated with Urbana Powdered Peat inoculant for medics (Urbana Laboratories, St. Joseph, MO) by dipping the peat pellet in an aqueous solution of the inoculant just prior to transplanting.

The study area was divided into four blocks; each contained four shade treatments (0, 30, 55, and 80% shade) organized randomly within the block. The artificial shade environment was created by covering the top and sides of steel frames (1.68 m L x 1.20 m W x 1.03 m H) with 30, 55, and 80% UV resistant black polypropylene PAK woven shade cloth (PAK Unlimited, Inc., Cornelia, GA). Each block contained three frames; the 0% shade plots did not contain frames.

The experimental research design for this study was a randomized split-split block comprised of degree of shade, species, and *Rhizobium* inoculation treatment. Each plot was randomly divided into species subplots consisting of two rows of four black medic plants and two rows of four button medic plants. Each species sub-plot was further randomly divided in half into inoculation sub-sub-plots (one row of four inoculated plants and one row of four uninoculated plants per species). Plants were spaced 20 cm apart within each row and 35 cm apart between rows in order to allow for plant spread, reduce plant overlap and mutual shading, and insure desired number (sixteen plants total) and spacing arrangement within plots.

Photosynthetic photon flux density (PPFD) measurements (μmol s^{-1} m^{-2}) were recorded as descriptors of shade treatments. Measurements were taken with a LI-COR® LI-190SA quantum sensor mounted to a LI-COR® LAI-2000 plant canopy analyzer (LI-COR, Inc., Lincoln, NE). Soil samples, taken to a depth of 15 cm, were collected at approximately the same time each month from each plot to measure gravimetric soil moisture (%) concentration (Gardner 1965). At approximately the mid-point of each growing season, soil from each plot was analyzed for pH (Thomas 1996), %OM (Walkley-Black Method as described by Nelson and Sommers, 1996), and NO_3^- concentration (mg NO_3^- kg^{-1} soil) (copperized cadmium reduction method as described by Mulvaney 1996).

Plant harvest was initiated each year when plants achieved approximate early bloom stage of maturity. A maximum of 2 plants from each sub-sub-plot were harvested each year for laboratory analysis of CP (utilizing a modification of the aluminum block digestion procedure of Gallaher et al. 1975), acid detergent fiber (ADF), and acid detergent lignin (ADL) concentrations (utilizing the methods described by Van Soest and Robertson 1980). The longest stem of each harvested plant was measured to estimate maximum stem length (cm) per treatment. Plants were clipped to approximately 3 cm from the crown and dried in a forced-air oven at 55°C for 48 h. Dried plants were weighed to estimate herbage dry matter (DM) yield (g $plant^{-1}$), and ground through a sheer mill fitted with a 1 mm screen. Seeds from plants not harvested for herbage quality and yield analyses were collected and counted to estimate average seed number (seed $plant^{-1}$) and average seed yield (g $plant^{-1}$) for each treatment.

Measured variables were submitted to analysis of variance (ANOVA) by general linear model to identify differences across and within treatments and years. For the soil variables, ANOVA was used to detect differences between shade treatments and years, as well as interactions. For herbage quality and production variables, ANOVA was used to detect differences for shade, species, inoculation, years, and interactions. A least significant difference (LSD) test was utilized to separate means among entries whenever appropriate (P<0.05). Linear and quadratic regression analyses were performed by species for DM yield, stem length, seed number, CP, ADF, and ADL against shade level.

RESULTS AND DISCUSSION

Soil

Shade affected soil moisture (P=0.002; $LSD_{0.05}$=0.57) although there was a year x month interaction (P<0.0001; $LSD_{0.05}$=0.90) (Table 1). Soil under the 55 and 80% shade cloth contained greater soil moisture (14.10 and 14.37%, respectively) than the 0 and 30% treatments (12.57 and 13.11%, respectively). Soil moisture was greater in the cooler months of January and March than in the warmer months of June and July for Yr 1. There were also differences in monthly soil moisture across years, with January, March, and April of Yr 1 having greater soil moisture levels than Yr 2, and June and July of Yr 2 having greater soil moisture levels than Yr 1.

Table 1. Soil moisture as affected by shade level (P=0.002) and year x month interaction (P<0.0001) at Stephenville, TX.

Shade (%)	**Soil Moisture (%)**
0	12.57 b†
30	13.11 b
55	14.10 a
80	14.37 a

Month	**Yr 1**	**Yr 2**	***P***
	-------Soil Moisture (%)-------		
Jan	18.77 b	14.43 a	* ‡
Mar	19.98 a	13.64 ab	*
Apr	16.28 c	13.32 b	*
Jun	9.43 d	13.45 b	*
Jul	6.95 e	9.16 c	*

† Means in the same column followed by same letter are undifferentiated at 0.05 probability level.
‡ "*" Difference between years at 0.05 probability level.

There were no differences (P>0.05) in soil NO_3^- or OM concentrations related to shade treatments or years. There was a difference (P=0.03; $LSD_{0.05}$=0.193) in pH between years, with the mean pH for Yr 1 (6.073) being slightly lower than Yr 2 (6.308), likely due to spatial variability of pH in the plots (data not shown).

Herbage Dry Matter Yield and Stem Length

Dry Matter Yield: Year x Shade Interaction

Dry matter yield was affected by a year x shade interaction (P=0.02; $LSD_{0.05}$=0.84). In Yr 1, DM yield was lower at the 80% shade level (0.46 g DM $plant^{-1}$) than at the 0, 30, and 55% shade levels (2.27, 2.17, and 1.84 g DM $plant^{-1}$, respectively) (Table 2). The greater soil moisture level at 80% shade (Table 1) did not appear to compensate for lower sunlight in terms of DM production. However, in Yr 2, DM yield was lower at the 55% shade level (0.43 g DM $plant^{-1}$) than at the 0 and 30% shade levels (1.58 and 1.43, respectively). When comparing DM yields across years, there was a difference (P=0.002) only at the 55% shade level, with Yr 1 DM yields greater than Yr 2 (1.84 g DM $plant^{-1}$ and 0.43 g DM $plant^{-1}$, respectively). Plants under 0, 30, and 80% shade were undifferentiated across years. Reductions in DM yields of cool-season legumes under high levels of shade and no differences in yield under moderate levels of shade were also reported by Lin et al. (1999).

Table 2. Herbage dry matter (DM) yield as affected by year x shade interaction (P=0.02) at Stephenville, TX pooled for two legume species.

Shade (%)	**Yr 1**	**Yr 2**	***P***
	-------g DM $plant^{-1}$------		
0	2.27 a†	1.58 a	NS ‡
30	2.17 a	1.43 a	NS
55	1.84 a	0.43 b	*
80	0.46 b	1.26 ab	NS

† Means in the same column followed by the same letter are undifferentiated at the 0.05 probability level.
‡ "NS" No difference between years at 0.05 probability level;
"*" Difference between years at 0.05 probability level.

Dry Matter Yield: Year x Species Interaction

Species DM yields responded to shade differently each year (year x species interaction P=0.004) (Fig. 2) and there were no differences in DM yield between black and button medics for Yr 1 (P>0.05). However, the DM yields were different (P<0.0001) between the two species for Yr 2 (0.50 g DM $plant^{-1}$ black medic and 1.85 g DM $plant^{-1}$ button medic). There was no difference in DM yields for button medic between years (P>0.05). However, DM yield of black medic was greater (P<0.0001) in Yr 1 than Yr 2

(1.80 and 0.50 g DM $plant^{-1}$, respectively). The average DM yield for Yr 1 was greater (*P*=0.03) than Yr 2 (1.60 and 1.17 g DM $plant^{-1}$, respectively).

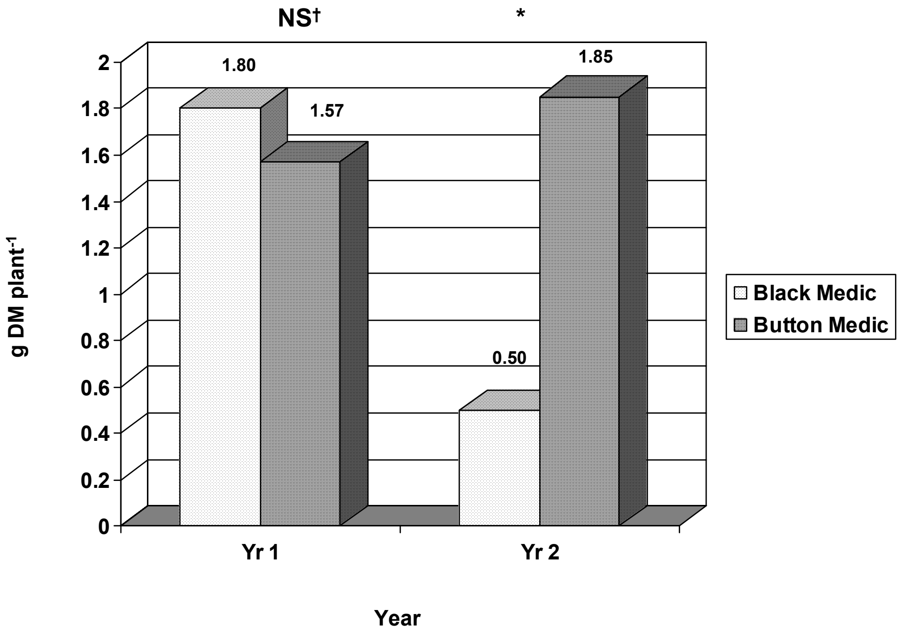

Figure 2. Herbage dry matter (DM) yields as affected by a medic species x year interaction (*P*=0.004) pooled over four levels of shade († No difference between species at 0.05 probability level; * Difference between species at 0.05 probability level).

There was considerable plant damage in Yr 2 from alfalfa weevil larvae, and carbaryl was sprayed in mid-February as a control measure. Average temperatures in November, December, and January of the Yr 2 trial were warmer than both Yr 1 and the 20 yr average (data not shown), which, along with possible population buildup from Yr 1, may have contributed to more favorable growing conditions for alfalfa weevil larvae that resulted in reduced black medic DM yields in Yr 2. Average temperatures in November, December, and January of Yr 1 were cooler than the 20 yr average, which possibly inhibited weevil egg-hatching, thus minimizing plant damage and DM yield loss in Yr 1. Black medic appears to be either less tolerant than button medic to alfalfa weevil larvae damage or preferred over button medic as a host plant to the larvae. There were also greater soil moisture levels in Yr 1 than in Yr 2 for the months prior to harvest. This reduction in soil moisture in Yr 2, alone or compounded with insect damage, could also have contributed to the greater DM yields in Yr 1 as compared to Yr 2. Foulds (1978) determined that black medic DM production was reduced under low soil moisture levels (5% moisture) although levels this low were not recorded in the present study. Button medic may be more tolerant to reduced soil moisture than black medic.

Inoculation was not a factor in DM yield (*P*>0.05). Zhu et al. (1998) reported similar results regarding annual medic inoculation in a field study. They concluded that the native soil rhizobia were as effective as the commercial inoculum in root nodulation and symbiotic N_2-fixation. In this field plot, naturalized medics were locally abundant and indigenous *Rhizobium* population in the soil appeared to have been as effective as local populations in combination with commercial inoculum in root nodulation and symbiotic N_2-fixation. In soils without local *Rhizobium* populations, these results may be different.

Stem Length: Year x Species Interaction

Species stem length changed with year (year x species interaction, P=0.001) (Fig. 3) since there was no difference in button medic stem length across years (P>0.05). Stems of black medic were longer (P<0.0001) in Yr 1 (26.89 cm) than Yr 2 (14.30 cm). Stem lengths also differed for species within years as shown in Fig. 3. In Yr 1, black medic stems (26.89 cm) were longer (P=0.01) than button medic stems (19.63 cm) while in Yr 2 stems of button medic (20.65 cm) were longer (P=0.01) than black medic (14.30 cm).

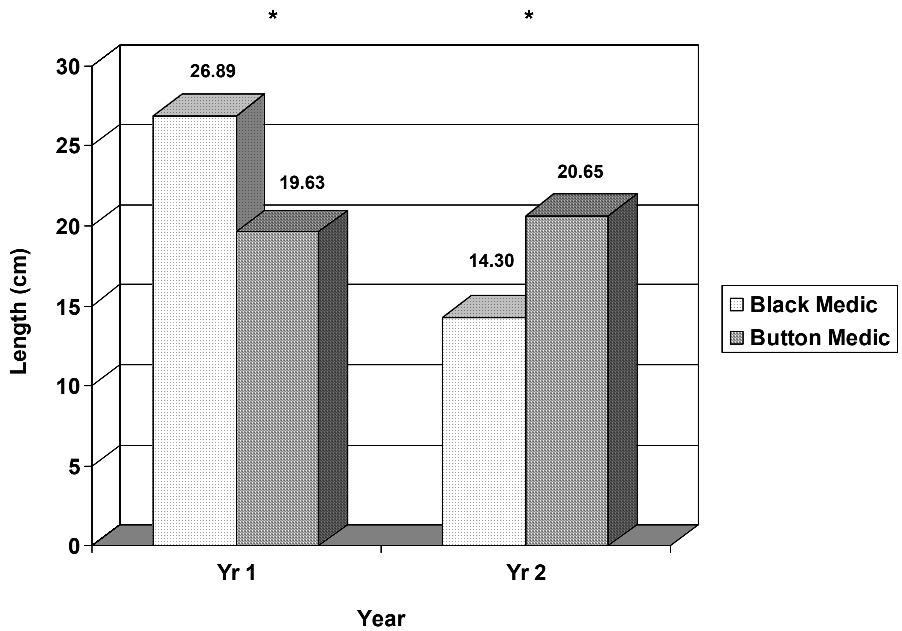

Figure 3. Stem length as affected by a medic species x year interaction (P=0.001) pooled over four shade levels (*Difference between species at 0.05 probability level).

The damage inflicted by alfalfa weevil larvae on plants in Yr 2 could account for the decrease in black medic stem length from Yr 1 to Yr 2 because black medic appeared to be more susceptible to insect damage than button medic. There were also greater soil moisture levels in Yr 1 than in Yr 2 for the months prior to harvest (Table 1) and this reduction in soil moisture in Yr 2, alone or compounded by insect damage, could also have contributed to the longer stems in Yr 1 as compared to Yr 2. Foulds (1978) determined that black medic herbage yield was reduced under low soil moisture conditions, which could explain the reduction of stem length in Yr 2. Button medic may be more tolerant to reduced soil moisture than black medic.

Seeds

Seed Number: Year x Shade x Species Interaction

There was a year x shade x species interaction (P=0.001; $LSD_{0.05}$=457) for total number of seeds produced plant^{-1} (Table 3). In Yr 1, there were no surviving seed-producing button medic plants in the 0 or 80% shade treatments. The lower temperatures in Yr 1, possibly compounded with the reduced irradiation in the 80% shade treatment, may have contributed to the greater mortality of button medics.

Table 3. Seed number of black and button medic as affected by year x shade x species interaction (*P*=0.001).

Year	Shade (%)	Black medic	Button medic	*P*
		---------number plant^{-1}-------		
1	0	1672 b†	-- ‡	--
	30	2365 a	478 a	* §
	55	2027 ab	131 a	*
	80	280 c	--	--
2	0	198 a	218 a	NS
	30	266 a	127 a	NS
	55	77 a	25 a	NS
	80	0 a	11 a	NS

† Within year, means in the same column followed by the same letter are undifferentiated at 0.05 probability level.
‡ No surviving seed-producing plants for treatment data collection.
§ "*" Difference between species at 0.05 probability level;
"NS" No difference between species at 0.05 probability level.

Button medic seed number was unaffected by shade levels for either year, and was not different between years (*P*>0.05). It was also undifferentiated at the 30 and 55% shade levels evaluated. In both years, button medic produced mature seeds later than black medic, possibly accounting for the lower seed number of button medic as compared to black medic as a result of greater soil moisture in March and April of Yr 1.

Black medic produced more seeds at 30 and 55% shade than button medic in Yr 1 but seed was unaffected by shade levels in Yr 2. In Yr 1, the greatest seed production occurred under 30 and 55% shade, with black medic producing more seeds (*P*<0.0001) at these levels than button medic. Black medic seed number at 55% shade (2027 seeds plant^{-1}) was not different from 0 and 30% shade. There were no differences in the number of seeds produced in Yr 2 between species or shade levels.

In the absence of severe insect pest damage, black medic has the potential to produce more seeds than button medic at moderate shade levels than in full sun environments. From their study on flowering of crimson clover, Butler et al. (2002) determined that high temperature inhibited flowering. The effect of shade cloth in moderating temperatures under the frames may have created a more favorable environment for black medic flowering and seed production in Yr 1. Moomaw (1995) found that black medic planted under soybean canopies produced viable seeds, a characteristic desired in potential cover crops. Rumbaugh and Johnson (1986) also found that black medic was a prolific seed producer capable of quickly developing a soil seed bank.

The difference in soil moisture between years could have contributed to differences in black medic seed number. Soil moisture concentrations were greater in January, March, and April of Yr 1 compared to Yr 2, while soils in June and July of Yr 2 exhibited greater soil moisture levels than in Yr 1. Foulds (1978) reported that the number of flowers per inflorescence and total seed production of black medic were reduced under low soil moisture conditions. The lower soil moisture concentration in January, March, and April of Yr 2 could have accounted for reduced black medic seed number. Likewise, the lower soil moisture concentration in June and July of Yr 1 could also have accounted for the reduced seed yield of button medic because it flowers later than black medic. The greater soil moisture concentration at 80% shade (Table 1) did not appear to compensate for lack of sunlight in terms of black medic seed number for Yr 1.

Seed Yield: Year x Shade x Species Interaction

Shade affected seed yield, reported as total weight (g) of seeds produced $plant^{-1}$, differently for each species (year x shade x species interaction P=0.0004; $LSD_{0.05}$=0.787) (Table 4). In Yr 1, there were no surviving seed-producing button medic plants in the 0 or 80% shade treatments. The lower temperatures in Yr 1, possibly compounded by extreme light interception in the 80% shade treatment, may have contributed to the greater mortality of button medics. Seed yield of button medic did not differ between years (P>0.05) and were also undifferentiated at the 30 and 55% shade levels. Seed yields for button medic in Yr 1 at 30 and 55% shade were lower than for black medic.

Table 4. Total seed yield of black and button medic at Stephenville, TX as affected by year x shade x species interaction (P=0.0004).

Year	**Shade (%)**	**Black medic**	**Button medic**	***P***
		------------g $plant^{-1}$	-----------	
1	0	3.00 b†	-- ‡	--
	30	3.85 a	1.14 a	* §
	55	3.23 ab	0.61 a	*
	80	0.40 c	--	--
2	0	0.28 a	0.54 a	NS
	30	0.42 a	0.29 a	NS
	55	0.15 a	0.06 a	NS
	80	0.00 a	0.02 a	NS

† Within year, means in the same column followed by the same letter are undifferentiated at 0.05 probability level.
‡ No surviving seed-producing plants for treatment data collection.
§ "*" Difference between species at 0.05 probability level;
"NS" No difference between species at 0.05 probability level.

Black medic can potentially produce greater seed yields per plant than button medic at moderate shade levels when insect damage is not severe. As in seed number, the differences in soil moisture between Yr 1 and Yr 2 could also explain the differences in seed yields. Foulds (1978) reported that the number of flowers per inflorescence and total seed production of black medic were reduced under low soil moisture conditions. The lower soil moisture concentration in January, March, and April of Yr 2 could have accounted for the reduced seed yield of black medic and possibly button medic. Likewise, the lower soil moisture concentration in June and July of Yr 1 could also have accounted for the reduced seed yield of button medic. The greater soil moisture levels under 80% shade (Table 1) did not appear to compensate for lack of sunlight in terms of black medic seed weight for Yr 1 whereas moderate shade levels appeared to enhance the seed yield of black medic. Moderate, but not extreme, shade appears to favor seed production in black medic when moisture becomes limiting.

Seed Yield: Year x Species x Inoculation Interaction

Total seed yield was also affected by a year x species x inoculation interaction (P=0.04) (Table 5). There were no differences in total seed weights in Yr 2 between species or across inoculation treatments (P>0.05). In Yr 1, uninoculated button medic plants produced more seeds by weight than inoculated button medics (1.35 and 0.24 g $plant^{-1}$, respectively). Black medic seed yields were unaffected by inoculation in Yr 1 (P>0.05) but were greater than button medic for both inoculated and uninoculated treatments in that year. Although uninoculated button medics in Yr 1 (Table 5) produced more seeds by weight than inoculated button medics, inoculation was not a factor in total numbers of seeds produced.

Table 5. Total seed yield of black and button medics as affected by year x species x inoculation interaction (*P*=0.04).

Year	Inoculation	Black medic	Button medic	
		----------- g plant^{-1}---------		*P*
1	+ †	2.46	0.24	* ‡
	-	2.78	1.35	*
		NS §	*	
2	+	0.33	0.23	NS
	-	0.11	0.22	NS
		NS	NS	

† "+" Plants inoculated with *Rhizobium*; "-" Plants not inoculated with *Rhizobium*.
‡ Within year, means in the same row are compared.
"*" Difference at 0.05 probability level; "NS" No difference at 0.05 probability level.
§ Within year, means in the same column are compared.

Bhalu et al. (1995), Rani and Kodandaramaiah (1997), and Singh et al. (1998) observed increases in seed yields with inoculation treatments in field studies on blackgram, soybean, and pigeonpea, respectively. Materon and Zibilske (2001) determined that nodule initiation was determined by the *Rhizobium* strain that was initially exposed to the host plant. In the present study site, naturalized medics were locally abundant and appeared to be well established. The commercial inoculum might have been redundant or less effective for legume nodulation and symbiotic N_2-fixation compared to indigenous soil *Rhizobium*. Commercial inoculation did not appear to be a requirement for black or button medic seed production in this study area.

Herbage Crude Protein

<u>Year</u>

Herbage CP concentrations changed with year (*P*=0.03), with Yr 2 (21.4%) having 10% greater CP than Yr 1 (19.5%). Extremes in temperature, moisture, and pH negatively affect soil rhizobial populations. The numbers of rhizobia that are symbiotic with medics, *Sinorhizobium meliloti*, were found to be numerous in alkaline soils (pH 7-8) but rare or absent in soils more acidic than pH 6 (Hirsch 1996). The pH of the soil in Yr 1 could have been too acidic for high survival of rhizobia, and may have resulted in reduced nodule formation, N_2-fixation, and herbage CP concentration (Ibekwe et al. 1997). Lower soil moisture levels in January, March, and April of Yr 2 may also have contributed to the increase in CP concentration that year, although there are inconsistent reports in the literature on the effects of soil moisture on CP concentration of forage legumes. Carter and Sheaffer (1983) and Halim et al. (1989) reported that soil water deficits had no effects on CP concentration in alfalfa while, in contrast, Walgenbach et al. (1981) and Petit et al. (1992) reported that, under reduced soil moisture conditions, alfalfa exhibited increased concentrations of N fractions. Peterson et al. (1992) reported that the effects of drought conditions on CP concentrations of perennial forage legumes were not consistent. Whatever the reason in the CP differences among years, these were minute and would not likely change herbage nutritive value to herbivores.

<u>Shade x Species Interaction</u>

Shade affected the CP concentration differently in each species (shade x species interaction *P*=0.03; $LSD_{0.05}$=1.52) (Table 6). Black medic CP concentration was unaffected by shade level while button medic CP concentration was greatest at 55% shade (21.96% CP), was undifferentiated at 0 and 30% shade (19.07 and 19.79% CP, respectively), and was lowest at 80% shade (16.48% CP). When comparing CP across species, black medic produced greater concentrations of CP than button medic at 0 and 80% shade (*P*=0.01 and *P*=0.001, respectively). The CP concentrations of black and button medics were not different at 30 and 55% shade.

Table 6. Black and button medics herbage acid detergent fiber (ADF) concentration as affected by year x shade x species x inoculation interaction (*P*=0.0004) and crude protein (CP) concentration as affected by shade x species interaction (*P*=0.03) and pooled over two study years at Stephenville, TX.

Year	**Inoculation**	**Shade (%)**	**Black medic**	**Button medic**	***P***
			--------- % ADF ----------		
1	+[†]	0	21.6 c [‡]	21.3 b	NS[§]
		30	23.7 ab	21.7 b	NS
		55	23.1 bc	23.7 a	NS
		80	25.2 a	-- ∂ --	
	-	0	21.9 c	22.3 a	NS
		30	23.9 b	23.0 a	NS
		55	24.4 b	23.5 a	NS
		80	28.4 a	-- ∂ --	
2	+	0	22.9 b	20.5 b	NS
		30	24.4 ab	20.7 b	*
		55	-- ∂	21.5 b	--
		80	25.6 a	27.7 a	NS
	-	0	25.4 a	18.5 b	*
		30	19.2 c	21.0 a	NS
		55	-- ∂	21.2 a	--
		80	23.6 b	22.3 a	NS
	Pooled		----------- % CP -----------		
		0	22.1 a	19.1 b	*
1 & 2	+ & -	30	21.4 a	19.8 b	NS
		55	21.4 a	22.0 a	NS
		80	20.8 a	16.5 c	*

†= "+" Plants inoculated with *Rhizobium*; "-" Plants not inoculated with *Rhizobium*.
‡= Within year, inoculation treatment, and species, means in the same column followed by the same letter are undifferentiated at 0.05 probability level.
§= "NS" No difference between species at 0.05 probability level; "*" Difference between species at 0.05 probability level.
∂= Insufficient plant material for analysis.

Inoculation had no effect on CP concentration of either black or button medics (*P*>0.05). Based on results obtained from a field study in Minnesota, Zhu et al. (1998) reported that the herbage N production of black medic and two other medic species were not affected by inoculation. They concluded that the indigenous soil rhizobia were effective in root nodulation of these medics. In the present study, the indigenous *Rhizobium* in the soil appeared to have been either as effective as the commercial inoculum in root nodulation and symbiotic N_2-fixation or similarly negatively affected by low soil pH.

Many studies have reported that shade does not affect CP concentration in cool-season legumes. Watson et al. (1984) reported that shade did not affect the total N or CP concentrations of hairy vetch or several *Trifolium* species studied in Mississippi. Lin et al. (2001) found that CP concentrations of 'Cody' alfalfa and white clover were not affected by shade treatments in Missouri. In contrast, several authors studying tropical legumes have reported increased herbage CP concentrations with increasing shade levels (Wong et al. 1985; Muir and Pitman 1989; Lin et al. 2001). In this study, the CP concentration of black medic was not affected by shade while button medic CP was affected by shade. It appears that the CP concentration of button medic can be increased with shade levels up to 55% but, at 0 and 80% shade, black medic produced greater CP concentrations than button medic.

Baltensperger and Smith (1984) reported that black medic had similar CP concentrations (12.44%) to the other forages studied in New Mexico. Zhu et al. (1996) reported that black medic consistently produced high CP concentrations (239 g kg^{-1} DM) when compared to other medic species. Reported CP requirements for growing and finishing beef cattle range from 6.5 to 18.4% (NRC, 1996) while the American Farm Bureau Federation recommended general CP concentrations of 8% for maintenance of older ruminants, 12% for young animals at 50% of their mature weight, 12-14% for nursing cows and sheep, and 16-18% for lactating dairy cows, ewes, and goats (Ball et al. 2001). The Texas Agricultural Extension Service defined poor quality forage for beef cattle production as less than 6% CP concentration, medium quality forage as 7-11% CP concentration, and high quality forage as 12-14% CP concentration (Hammack and Gill 2000.) At moderate shade levels, both black and button medics appear to produce sufficient amounts of CP for livestock maintenance and production.

Acid Detergent Fiber

Year x Shade x Species x Inoculation Interaction

Herbage ADF concentrations were affected (P=0.0004; $LSD_{0.05}$=1.70) by a year x shade x species x inoculation interaction. Between species, there were no differences in ADF concentrations except at inoculated 30% shade and at uninoculated 0% shade in Yr 2 (Table 6). In both cases, button medic had lower ADF concentrations than black medic. When LS mean separation for inoculation was calculated, there was a 4% increase in ADF with inoculation (0.93% ADF) (P=0.03). When LSD mean separation for years was calculated, there was a 7% increase in ADF in Yr 1 (0.72% ADF) (P=0.001). In general, ADF concentration for both species, regardless of inoculation or year, increased as shade levels increased. The low DM yields at 80% (Yr 1) and 55% shade (Yr 2) (Table 2) resulted in insufficient plant material for ADF analysis because the majority of the plant material harvested at these shade levels was used for CP analysis.

Lin et al. (2001) reported that ADF concentration of cool-season legumes in Missouri was either unaffected or increased with 50 and 80% shade treatments. They attributed the reduced digestibility to decreased non-structural carbohydrate contents and increased cell-wall contents at greater shade levels. Blair et al. (1983) also attributed a decrease in digestibility with shade level to a decrease in the content of readily digestible cell solubles and an increase in fibrous cell-wall fractions. The explanation for the increase in ADF with inoculation was not known. Elsheikh and Elzidany (1997) reported that *Rhizobium* inoculation had no significant effects on the crude fiber or ash contents of faba bean seeds.

The higher soil moisture levels in January, March, and April of Yr 1 may have also affected the increase in ADF concentration in Yr 1, although the literature on the effects of soil moisture level on ADF was inconsistent. Seguin et al. (2002) reported that, as soil moisture decreased, ADF concentrations increased. Conversely, Peterson et al. (1992) and Petit et al. (1992) reported that ADF decreased as soil moisture levels decreased. The decrease in ADF in Yr 2 may have resulted from a decrease in soil moisture in that year.

Lignin

Year x Shade x Species x Inoculation Interaction

Herbage lignin concentration was affected (P=0.02; $LSD_{0.05}$=0.39) by year x shade x species x inoculation interaction (Table 7). There were no differences in lignin concentration between species except at uninoculated 0% shade in Yr 2, in which the lignin concentration of black medic was higher (P=0.0001) than button medic (5.12 and 3.70% lignin, respectively). When LSD mean separation for inoculation was calculated, there were no differences between inoculation treatments (P>0.05). When a LS means separation for years was calculated, there were no differences between years for lignin (P>0.05).

Table 7. Black and button medic herbage lignin concentration as affected by year x shade x species x inoculation interaction (*P*=0.02) at Stephenville, TX.

Year	Inoculation	Shade (%)	Black medic	Button medic	*P*
			------------ %Lignin -----------		
1	+ †	0	4.29 b ‡	4.18 b	NS§
		30	4.52 b	4.79 a	NS
		55	4.33 b	4.95 a	NS
		80	4.93 a	-- ∂	--
	-	0	4.30 c	4.11 b	NS
		30	4.71 b	4.81 a	NS
		55	4.83 b	4.92 a	NS
		80	5.68 a	-- ∂	--
2	+	0	4.63 b	4.11 c	NS
		30	4.69 b	4.64 b	NS
		55	-- ∂	4.89 b	--
		80	5.84 a	5.72 a	NS
	-	0	5.12 a	3.70 c	*
		30	4.28 b	4.38 b	NS
		55	-- ∂	4.95 a	--
		80	4.64 b	5.23 a	NS

†= "+" Plants inoculated with *Rhizobium*; "-" Plants not inoculated with *Rhizobium*.
‡= Within year, inoculation treatment, and species, means in the same column followed by the same letter are undifferentiated at 0.05 probability level.

§= "NS" No difference between species at 0.05 probability level; "*" Difference between species at 0.05 probability level.
∂= Insufficient plant material for analysis.

In general, lignin concentration for both species, regardless of inoculation or year, increased as shade levels increased. This trend was similar to the trend for ADF concentration and shade level. Forage quality, as estimated by ADF and lignin, tended to decrease as shade levels increased, regardless of inoculation or year. The low DM yields at 80% (Yr 1) and 55% shade (Yr 2) (Table 2) resulted in insufficient plant material for lignin analysis. The majority of the plant material harvested at these shade levels was used for CP analysis and there was not sufficient plant material remaining to analyze lignin.

The effects of shade on plant morphology and digestibility have been reported in many studies. Buxton (1989) suggested that shading induced stem elongation, achieved through lignification, so that leaves were oriented higher in order to be exposed to and to capture more sunlight for photosynthesis. Babu and Nagarajan (1993) also described higher shoot height, internodal elongation, and lower leaf area index as competitive responses of plants grown under shade. Lin et al. (2001) also reported decreased leaf: stem ratios at 50% shade for 'Cody' and 'Vernal' alfalfa.

Visual observation of plants growing in the field in this study indicated that plants growing under 80% shade exhibited a more upright growth habit, while plants in full sun were more decumbent. As shade levels increased, upright growth habit of plants became more prominent. However, medic stem length was not affected by shade. The increase in lignin of both black and button medics at greater shade levels was possibly a result of lower leaf area indices, and reduced leaf: stem ratios, although these characteristics were not measured directly.

Linear and Quadratic Regression Analyses

Regression analyses were not significant for any of the models tested. This indicated that levels of shade did not have correlating effects on any of the variables measured during the trial.

CONCLUSIONS

Irregular soil moisture levels and insect predation in Yr 2 may have contributed to the reduction in black medic DM yield, stem length, and seed numbers. These results are consistent with the findings of Foulds (1978) on the effects of water deficit on black medic. Dry matter yield, stem length, and seed numbers of button medic were not different between years, indicating that button medic may be more tolerant to differences in soil moisture level and to insect damage than black medic. Additional research on the soil moisture requirements and tolerance to insect damage of local medics appears to be warranted. In the absence of severe insect damage and with greater soil moisture (Yr 1), black medic produced equivalent DM yields, longer stems, and more seeds than button medic.

The increase in available soil moisture at 55 and 80% shade may have partially compensated for the reduced solar irradiation at these shade levels in terms of overall DM yield and black medic seed numbers (Yr 1). In Yr 1, black medic produced more seeds under moderate shade levels than button medic, indicating that the overall seed production of black medic may be increased with up to 55% shade. The seed production of button medic was not affected by shade.

Shade, however, did affect the CP concentration of button medic, with CP concentrations greatest at 55% shade (not different from black medic). By contrast, black medic CP concentration was not affected by shade and produced greater CP concentrations than button medic at the shade extremes (0 and 80% shade). While black medic can maintain high herbage CP concentrations at all shade levels, button medic appears to benefit from moderate shade and can produce similar CP concentrations to black medic at moderate shade levels.

In general, digestibility, as estimated by ADF and lignin, decreased as shade levels increased. There were few differences in ADF and lignin concentrations between black and button medics.

Rhizobium inoculation generally had no effect on yield or quality of black or button medics. In areas such as this study area, where annual medics are naturalized, occur frequently, and soil rhizobia populations are well established, the need for commercial inoculation does not appear to be essential in obtaining comparable DM and seed yields and herbage CP concentrations in black and button medics. Nevertheless, application of commercial *Rhizobium* inoculum should be recommended as a precautionary measure. Additional research on local medics and their commercial *Rhizobium* requirements appears to be warranted.

Moderate shade levels (up to 30% shade) did not appear to negatively affect either black or button medics. When growing conditions were favorable (Yr 1), overall DM yield was not negatively affected for either species until shade levels reached 80%. Seed numbers of black medic and CP concentration of button medic may be increased with up to 55% shade.

When soil moisture is adequate and the damage from insects is not severe, both black and button medics have the potential to produce high quality forage and abundant quantities of seeds under moderate shade environments such as those present in agroforestry, silvicultural, and silvopastoral systems. The apparent shade tolerance of both black and button medics indicates their potential value for use as understory forage crops in agroforestry, silvicultural, and silvopastoral systems, where multiple commodity yields are desired. In grazing situations where the goal is improved forage nutritive value and animal performance, addition of forage legumes such as black and button medics into pastures could help livestock producers achieve these goals.

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