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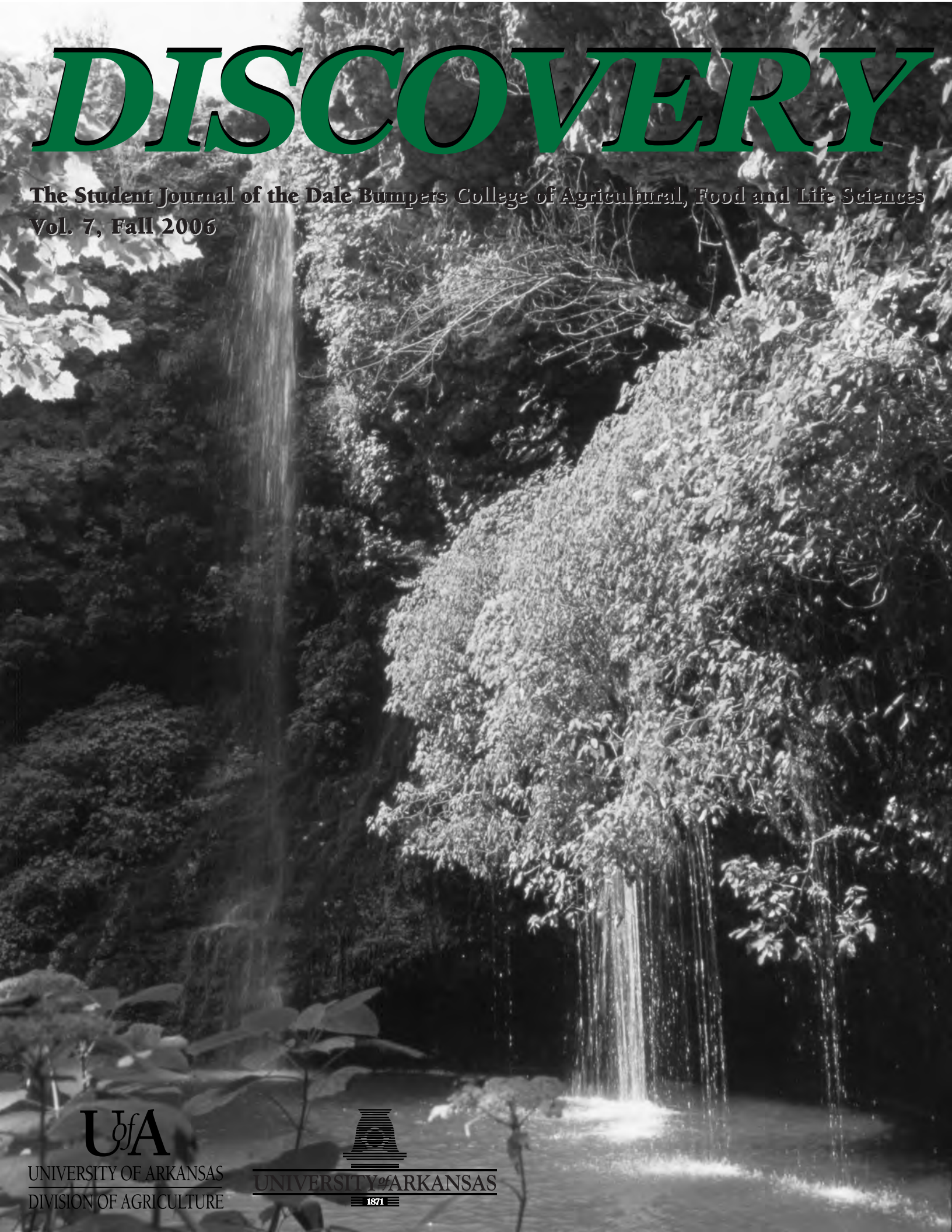
Discovery Editors



DISCOVERY

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Vol. 7, Fall 2006

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Undergraduate Research Articles

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Cover: Sparkling spring-fed waterfalls—that in under three miles feed the Illinois River—pour through karst geology at Natural Falls State Park, some eight miles west of Siloam Springs, Arkansas. (Photo by Fred Miller)

Letter from the Dean

Gregory J. Weidemann

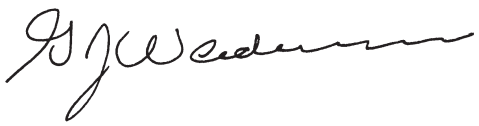
Providing opportunities for students to apply what they learn to real-world situations is a priority in the 14 diverse undergraduate majors of Bumpers College. One of the ways we do this is to encourage students to conduct a scholarly project in cooperation with a faculty mentor. This is the basic model for graduate studies, but we extend it to undergraduate studies, as well.

Many such projects are designed to meet the requirements of an honors thesis in the Bumper College Honors Program. Whether in the Honors Program or not, students who take advantage of such opportunities find that it brings into sharper focus principles they have learned. The Discovery journal provides a reporting outlet for our student scholars and scientists. It does not supersede publication elsewhere, but it does provide a forum for students and faculty to share their results and findings in a citable publication.

We encourage student research by awarding undergraduate research grants, including the Carroll Walls Undergraduate Research Fellowship with a stipend of $1,000. Our students also have been very competitive for research and travel grants awarded by the UA Honors College and the Arkansas Department of Higher Education.

The articles in this seventh annual volume of Discovery are on topics that relate to environmental issues, food safety, and agricultural production and processing technology. They include an energy-efficient rice drying method, managing plant nutrients for optimum crop production and to prevent runoff of nutrients and sediment, using grain by-products for livestock feed, propagating blackberry plant cuttings, preventing pathogen growth on food products, weed control in cotton, and a study of the effectiveness of government incentive programs to reduce nutrient and sediment runoff from agricultural land.

We are proud to present these articles as examples of the research accomplishments of our undergraduate students. I heartily congratulate the student authors on their accomplishments and extend thanks to their faculty mentors and to the editors who reviewed their manuscripts. Thanks also to the Honors Committee for providing the structure that enables our students to enhance their educational experience and provide a very tangible service to society in the process.



Gregory J. Weidemann, Dean
and Associate Vice President for Agriculture

Evaluation of water-retention ability of eastern Arkansas prairie and agricultural soil

Maria L. Barrenechea[*] *and Kristofor R. Brye*[†]

ABSTRACT

Agricultural land use affects soil physical properties, such as bulk density, water content, organic matter content, and soil structure; all of which in turn affect ecosystem productivity. The objective of this study was to evaluate the effects of: 1) time since aboveground biomass has been removed by haying (i.e., 0 vs. 23 years), and 2) land use (i.e., undisturbed tallgrass prairie vs. cultivated agriculture) on water-retention characteristics in a silt-loam soil of the Grand Prairie region of eastern Arkansas. Soil samples were collected from the 0- to 10-cm depth and were wetted with varying amounts of distillated water to create a range of soil water contents. After overnight equilibration, the water potential of the soil was measured using a dewpoint potentiameter. The relationship between water potential and water content for the prairie and the agricultural soils was modeled using the equation $Y=aX^{-b}$, where Y was the water potential and X was the gravimetric soil water content and the coefficients a and b were determined from fitting the data. The modeled a and b coefficients did not differ significantly by land use of soil series evaluated. The results of this study do not support the original hypothesis that water-retention characteristics in cultivated agricultural soils differ significantly from that of undisturbed, tallgrass prairie soil.

[*] Maria Liliana Barrenechea is a senior majoring in environmental, soil, and water sciences.

[†] Kristofor R. Brye, faculty sponsor, is an associate professor in the Department of Crop, Soil, and Environmental Sciences.

MEET THE STUDENT-AUTHOR

Maria L. Barrenechea

I am an international student from Tarija, Bolivia. I am currently a senior in the Department of Crop, Soil, and Environmental Sciences and am pursuing a B.S. degree in environmental, soil, and water sciences with an agricultural business minor. The partnership between Bolivia and Arkansas gave me the opportunity to come to this university. I have been awarded the Dale E. and Wilhemina S. Hinkle Scholarship. Throughout a year and-a-half as a student at the University of Arkansas, I have had the opportunity to be an active member and an officer in both the undergraduate Crop, Soil, and Environmental Science Club and in the International Bolivian Organization. My future plans are to possibly help Bolivia with all the environmental concerns and issues that we are facing, and to help improve environmental management and the quality of life for people in my home country. I would like to thank Dr. Brye for encouraging me to do this project and for all his help throughout research development. The project has taught me a lot about the research process. I am happy I decided to come to this department because I know I am getting a lot of benefits from this program.

INTRODUCTION

Compared to natural, undisturbed ecosystems, such as native tallgrass prairie, cultivated agricultural land use significantly affects soil physical properties, such as bulk density, water content, organic matter content, and soil structure; all of which in turn affect ecosystem productivity. Cultivated agriculture has also been shown to negatively affect the soil biological community. In contrast to cultivated agricultural soil, prairie soils that have not been affected by agricultural practices typically have higher organic- matter content than cultivated soils, thus prairie soils tend to have better soil structure and better water-retention characteristics than cultivated agricultural soils (Brye, 2003). However, few studies have been conducted in the Grand Prairie region of eastern Arkansas, which was once dominated by tallgrass prairie, to evaluate the effects of land-use transformation from native prairie to cultivated agriculture. Knowledge of the properties affected and the extent to which those properties have been altered by land-use change will provide the foundation with which better management decisions can be made towards future sustainability of the soil and water resources in the Grand Prairie.

The objective of this study was to evaluate the effects on soil water retention characteristics in a silt-loam soil of the Grand Prairie region of eastern Arkansas of: 1) time since aboveground biomass has been removed by haying (i.e., 0 vs. 23 years), and 2) land use (i.e., undisturbed tallgrass prairie vs. cultivated agriculture). It was hypothesized that water-holding capacity, due to differences in organic matter inputs, will be lower in the prairie area in which aboveground vegetation is still removed by annual haying than in the prairie area where aboveground vegetation removal by haying ceased in 1980. It was also hypothesized that, within the same soil series, the undisturbed prairie will have a better ability to hold moisture than cultivated agricultural land use.

MATERIALS AND METHODS

Site description

The Konecny Prairie Natural Area is a 20.2-ha (50 acre) tract of native tallgrass prairie in Prairie County, Ark., located within the region known as the Grand Prairie. The Konecny Prairie Natural Area was established in 1976 when the land was acquired by the Arkansas Natural Heritage Commission. The Konecny

Prairie resides on the Mississippi Alluvial Plain, which consists of soils that have developed in alluvial sediments laid down by periodic historical flooding of the Mississippi River. Vegetation within the Konecny Prairie is a mix of tall grasses, including big bluestem (*Andropogon gerardii*); little bluestem (*Schizachyrium scoparium*); indiangrass (*Sorghastrum nutans*); and switchgrass (*Panicum virgatum*), and numerous forbs, including several coneflowers (*Echinacea* spp.); black-eyed susan (*Rudbeckia hirta*); and goldenrod (*Solidago* spp.).

The Konecny Prairie Natural Area is rather unique in that it has several distinct sections based upon the number of years since vegetation has been removed annually by haying (Brye and Moreno, 2006). Approximately 4.0 ha (10 acres) of prairie vegetation was cut and vegetation removed annually until 1980. Approximately 6.1 ha (15 acres) of the prairie was cut and the vegetation removed annually until 2003. In addition, four different silt-loam soils (i.e., the Stuttgart, Loring, Calloway, and Crowley/DeWitt series) are present within the Konecny Prairie boundaries.

The Konecny Prairie is also unique in that the native (i.e., undisturbed) tallgrass prairie is adjacent to cultivated (i.e., disturbed) agricultural land that is cropped to either rice (*Oryza sativa*) or soybeans (*Glycine max*). The same four soil series that exist in the prairie also exist in the adjacent cultivated agricultural land.

Sampling scheme

Soil samples 4.8-cm in diameter were collected in April 2003—using a slide hammer—from each soil series within each of the two prairie sections and adjacent cultivated agricultural soil. Soil samples were collected from the 0- to 10-cm depth at 15-m intervals along a 60-m transect (i.e., at 0, 15, 30, 45, and 60 m) in the prairie and in a nearby portion of the adjacent agricultural land within the same soil series. The total number of transects was eight. The transects through the two land uses with the same soil series were positioned such that they were within 10 to 50 m of each other. Soil samples were oven dried at 70°C for 48 h, crushed, and sieved to pass a 2-mm mesh screen.

Laboratory analyses

Two of the five soil samples collected along each transect through the prairie areas in which vegetation removal ceased in 1980 (and in which vegetation removal by haying still continued in 2003) along with the soil samples from the adjacent cultivated agricultural land were used to determine water-retention characteristics. There was a total of 16 soil samples analyzed, 10 prairie and six cultivated agricultural soil samples.

Nine 5 ± 0.1 g-samples of soil from each replicate sample were weighed out into small cups. Varying amounts of distilled water (i.e., 2, 4, 6, 8, 10, 12, 15, 17, and 20 drops) were added to the cups and the soil mixed thoroughly. The cups were covered and allowed to equilibrate overnight. The following day the water potential of the soil in each cup was measured with a dewpoint potentiameter (Model WP4, Decagon Devices, Inc., Pullman, Wash.). The dewpoint potentiameter measures the water-vapor pressure of the air in the sample chamber after the air in the sample chamber has equilibrated with the liquid water in the soil sample. After measuring the water potential, the gravimetric water content of the soil in each cup was determined by drying at 70°C for approximately 10 to 12 h.

Statistical analyses

Water potential (y-axis) was plotted against gravimetric water content (ıg, x-axis) for each soil sample and analyzed using a spreadsheet. The power function ($Y = aX^{-b}$) was fit to the plotted data and the "a" and "b" coefficients were recorded for each soil sample. Analysis of covariance techniques were used to evaluate the treatment effects of land use, soil series, and time since vegetation removal by haying ceased on modeled water-retention curve characteristics (i.e., the a and b coefficients) using SAS (Version 9.1, SAS Institute, Inc., Cary, N.C.)

RESULTS AND DISCUSSION

As expected, the soil-water potential increased and leveled off as water content increased in both the native prairie and cultivated agricultural soils (Fig. 1). The modeled "a" coefficient for the prairie in which vegetation removal ceased in 1980 was nearly 10-fold greater than that for the adjacent cultivated agricultural soil, indicating that there may be a land-use effect. However, neither the modeled "a" and "b" coefficients, from the equation Water Potential = $a(\theta_g)^{-b}$ and as determined using soil wetting curves, differed ($P > 0.05$) by land use (Table 1). Similarly, neither the "a" or "b" coefficient differed ($P > 0.05$) among soil series (Table 1). In addition, the potential interactive effect between land use and soil series on water-retention characteristics was not significant ($P = 0.59$). Similar to the prairie area in which vegetation removal by haying ceased in 1980, neither the "a" or "b" coefficient differed ($P > 0.05$) between the prairie area in which vegetation removal by haying ceased in 2003 and the adjacent cultivated agricultural soils (Table 1). Finally, the "a" and "b" coefficients did not differ ($P > 0.05$) between the two prairie areas where vegetation removal by haying ceased in 1980 and 2003. Therefore, the results of this study do not support the hypothesis

that land use affects water-retention characteristics.

These results are similar to the findings of Colton and Brye. (2002), who evaluated the water-retention characteristics of a cultivated and undisturbed (i.e., prairie restoration) Jay silt-loam soil in northwest Arkansas and showed no significant difference in modeled water-retention characteristics among the two land uses.

Two reasons possibly explain the results of this study. One reason may have been the small number of samples, since only two of the five soil samples collected along each transect were used to determine water-retention characteristics. If all five soil samples collected had been used, the variability associated with the mean values of the "a" and "b" coefficients might have been lower. Standard error values clearly show high variability relative to the mean for both the "a" and "b" coefficients (Table 1). Hence, for improved results, more soil samples and replicates analyzed would have been better.

Another reason that may explain the results obtained in this research could be the procedure used to determine the water-retention characteristics, in which soil samples were air dried, crushed, and sieved, altering the original structure of the soil. In contrast, Scott et al. (1983) placed intact soil cores in a chamber and pressurized them at various levels in order to dry the soil core from saturation. Therefore, the original structure of the soil was left undisturbed given that soil cores were neither air-dried nor crushed and sieved. Altering the original structure of the soil affected the results of this study, leaving the authors unable to demonstrate significant differences in water-retention characteristics due to time since aboveground biomass had been removed by haying and to land-use effects.

ACKNOWLEDGMENTS

Appreciation is expressed for funding provided by the Dale Bumpers College of Agricultural, Food and Life Sciences Undergraduate Research Grant Program.

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Table 1. Summary of the effects of land use (prairie versus cultivated agriculture) and soil series on modeled water-retention characteristics at the Konecny Prairie Natural Area, Slovak, Ark., for a prairie area where aboveground vegetation removal by haying ceased in 1980.

Effect	n	a-coefficient	b-coefficient
Landuse			
Prairie	6	0.0024 (0.002)[z]	-3.08 (0.17)
Agriculture	6	0.0003 (< 0.001)	-3.51 (0.38)
P-value		0.31	0.21
Soil series			
Loring	4	0.0032 (0.003)	-2.92 (0.29)
Stuttgart	4	0.0006 (< 0.001)	-3.70 (0.49)
Calloway	4	0.0003 (< 0.001)	-3.27 (0.22)
P-value		0.42	0.20

[z] Mean values (± standard error).

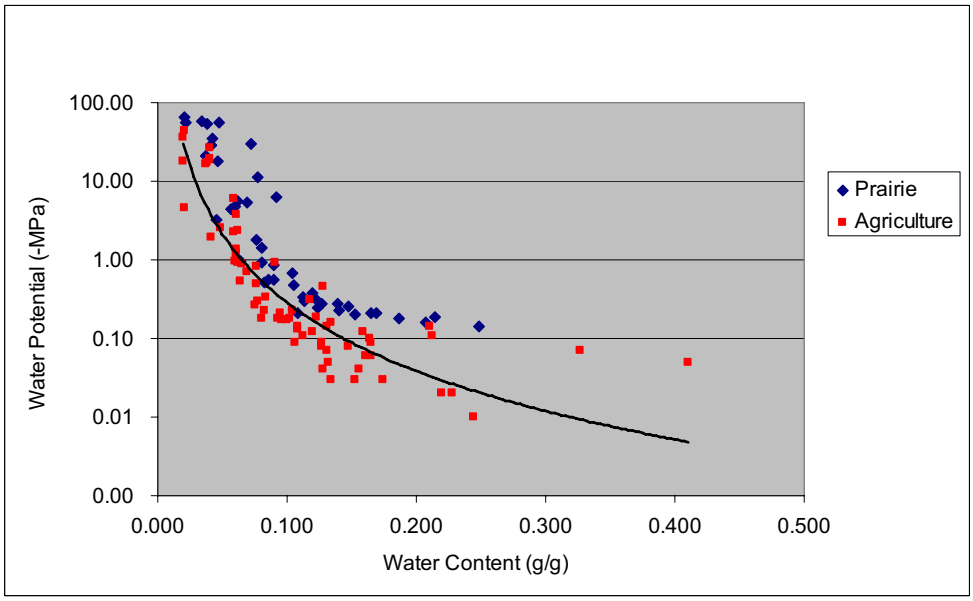

Fig. 1. Relationship between water potential, plotted on a log scale, and gravimetric water content for a prairie versus an agricultural soil in eastern Arkansas. The single line indicates no land-use effect on water-retention characteristics.

Combined inhibitory effect of nisin with EDTA against *Listeria monocytogenes* in soy-protein edible coating on turkey frankfurters stored at 4°C and 10°C

Emily Bennett[*], *T. Sivarooban*[†], *N. S. Hettiarachchy*[§] *and M. G. Johnson*[‡]

ABSTRACT

Several food contamination outbreaks are linked to *Listeria monocytogenes.* More effective methods are needed to prevent the growth and recontamination of *L. monocytogenes* on ready-to-eat (RTE) food products. Therefore, the objectives of this study were to evaluate the inhibitory activities of nisin (10,000 IU/mL), EDTA (sodium Ethylenediaminetetraacetic acid: 1.6 mg/mL), and the combination of nisin (10,000 IU/mL) with EDTA 1.6 mg/mL either in brain-heart-infusion (BHI) media at 37°C for 72 h or in soy-protein edible coating on the surface of full-fat commercial turkey frankfurters against the cell populations of approximately 106 colony forming units (CFU/mL) of *L. monocytogenes*. The surface-inoculated frankfurters were dipped into soy-protein film forming solutions with and without the addition of antimicrobial agents [(nisin (10,000 IU) or EDTA (0.16%) or the combination)] and stored at either 4°C or 10°C. The inhibitory effects of edible coatings were evaluated on a weekly basis for 45 d. The greatest inhibitory activities of 6 log cycle reductions of *L. monocytogenes* were found when nisin was combined with EDTA and eliminated 6 log cycles of *L. monocytogenes* in both systems. In the combined nisin (10,000 IU) with EDTA (0.16%) treatment, the *L. monocytogenes* population was reduced to undetectable levels after 15 h or 7 d incubation in BHI at 37°C or on turkey frankfurters stored at 4°C and 10°C, respectively. This research has demonstrated that the use of an edible film coating containing nisin with EDTA is a promising means of controlling the growth and recontamination of *L. monocytogenes* on RTE meat products.

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[†] T. Sivarooban is a Ph.D. candidate in the Department of Food Science.

[§] N. Hettiarachchy, teacher and major faculty mentor, is a professor in the Department of Food Science.

[‡] M. G. Johnson, teacher and advisor on microbiological procedures, is a professor in the Department of Food Science.

MEET THE STUDENT-AUTHOR

I grew up in Tulsa, Okla., and graduated from Union High School in 2002. I will graduate from the University of Arkansas in May 2006 with a B.S.A. in food science and a minor in Spanish. I have worked as a technical assistant in laboratories within my department for the past three years. I worked in the food safety lab last summer, which led me to this particular research project. Dr. Naval Hettiarachchy served as my research mentor and advisor. I also have served as vice president and now president of the Food Science Club. I play on the University of Arkansas' women's Ultimate Frisbee team. I have been involved with Campus Crusade for Christ while in college and am part of The Grove Church. I am a student member of the Institute of Food Technologists and Gamma Beta Phi honors fraternity. I really enjoy doing anything outside and traveling. I have loved my time at the University of Arkansas and the opportunities it has provided. After graduation I plan to work in the food industry to gain some experience in this chosen field. Someday I would like to work in foreign affairs in a food science-related field.

Emily Bennett

INTRODUCTION

Listeria monocytogenes is one of the foodborne pathogens that causes the highest mortality rate (20%) in people in the U.S. (CDC, 2003). Recontamination of ready-to-eat (RTE) poultry meat with *L. monocytogenes* has posed a major health concern to the general public and was re-addressed in a recent Food Safety and Inspection Service (FSIS) directive, published in the Federal Register, requesting new standards for the processing of these meat products (Federal Register, 2003). The Food and Drug Administration (FDA) is continually coordinating, conducting, and supporting research to evaluate the effectiveness of existing commercial treatments (e.g., post-packaging pasteurization, bacteriocins, irradiation, high pressure processing, and inhibitory compounds), and developing new technologies that can eliminate or prevent the growth of *L. monocytogenes* in RTE poultry and meat products (FDA/CFSAN 2003). These demands have led to a renewed interest in the use of antimicrobial combinations for effective control on foodborne pathogens.

Nisin is a bacteriocin produced by *Lactococcus lactic* sub sp. *Lactis* fermentation and is recognized as a safe biological food preservative. Nisin acts upon the bacterial cell membrane by dissipation of proton motive force (PMF) through pore formation. The formation of pores by nisin leads to rapid removal of free amino acids, ATP, and cations from the cell (Montville et al., 2001). Nisin is effective in controlling a wide range of Gram-positive bacteria, including *L. monocytogenes* (Ko et al., 2001; Siragusa et al., 1999).

EDTA is a safe, economical metal chelator, and it facilitates the activity of nisin by destabilization of the bacterial cell membrane. EDTA has been used in combination with other bacteriosins for enhancing antimicrobial activity. It effectively binds magnesium ions in the lipo-polysaccharide layer of a gram negative organism to produce microbial cells with increased susceptibility to antimicrobials like nisin. Research has shown the significant reductions of microbial populations of Gram positive and negative organisms when nisin was combined with EDTA (Hoffman et al., 2001; Stevens et al., 1991).

To date, limited information is available on nisin with EDTA combinations in antimicrobial, edible film coating to control *L. monocytogenes* on RTE meat products. Therefore, the objectives of this study were: (1) to evaluate the inhibitory activity of nisin, EDTA, and combina-

tion of nisin with EDTA in a laboratory medium at 37°C; and (2) to evaluate the inhibitory effects of these compounds incorporated into soy-protein coatings on turkey frankfurters against *L. monocytogenes* stored at 4°C and 10°C for 45 d.

MATERIALS AND METHODS

Brain-Heart-Infusion broth (BHI) was purchased from Becton Dickinson Microbiology Systems, Sparks, Md. The Listeria Selective Agar (Oxford formulation) was purchased from EM Science, Gibbstown, N.J. *Listeria monocytogenes* strain V7, serotype 1/2 a, (FDA) was provided by Dr. Johnson's Laboratory, Center for Food Safety and Quality Research, University of Arkansas, Fayetteville. Soy protein isolate (PRO-FAM® 974, protein content >90%) (ARDEX®) was obtained from Archer Daniels Midland, Decatur, Ill. Glycerol and analytical-grade sodium EDTA were purchased from Sigma Chemical Co., St. Louis, Mo. A commercial sample of nisin, Nisaplin®, was obtained from Alpin & Barrett Ltd. Trowbridge, Wilts, England. Whirl-Pak® bags (120 mL capacity, 7.5 cm x 18.5 cm) were purchased from National Account Service Company LLC®, Fort Atkinson, Wisc.

Preparation of turkey frankfurter samples

Commercial turkey frankfurters with a fat content of 21% were purchased from a local grocery store and cut into 1-cm cubes. Each cube was individually packaged in a Whirl-Pak® bag. These cubed samples were sterilized to eliminate any natural microbial flora by a linear electron accelerator at a 30-kGy dosage at Texas A & M University, College Station. The irradiated samples were kept in frozen storage in our laboratory facility until use.

Culture preparations

A pure culture of *L. monocytogenes* was taken from a frozen stock culture stored at –70°C and grown in 10 mL fresh BHI for 24 h at 37°C in an incubator. Following incubation, 10 µL of the culture were transferred into 10 mL fresh BHI and incubated for 18-24 h. The inoculum level of this culture (approximately 10^6) was determined by decimal dilution in phosphate buffer saline (PBS at pH 7.0).

Evaluating inhibitory activity of nisin, EDTA, and the combination of nisin with EDTA against L. monocytogenes at 37°C

The antimicrobial activity of nisin, EDTA, and nisin with EDTA was tested against *L. monocytogenes* in BHI medium (approximately 10^6 CFU/mL); treated cultures were incubated for 72 h at 37°C. To prepare microbial suspensions, a 10 µL loop of *L. monocytogenes* strain V7, serotype 1/2 a, (FDA) was taken from a frozen-stock culture stored at –70°C and grown in BHI for 24 h at 37°C in an incubator. Ten microliters of this pure culture were transferred into 10 mL fresh BHI and incubated for another 24 h prior to use. To prepare microbial pellets for tests, 1 mL of culture was centrifuged at 14,000 rpm for 20 min using an eppendorf centrifuge model 5415C (Brinkman Instruments, Inc. Westbury, N.Y.) at 14,000 rpm for 20 minutes. After centrifugation, the supernatant was discarded and the bacterial pellets were used to test the antimicrobial activity of the nisin (10,000 IU/mL); EDTA (1.6 mg/mL); or nisin (10,000 IU/mL) with EDTA (1.6 mg/mL). One milliliter of BHI solution containing these components was added to the pellets. A control sample consisted of bacterial pellets dissolved in 1 mL BHI, which contained no antimicrobial compounds. Triplicate samples were incubated at 37°C for 72 h on a rotary platform shaker at 250 rpm. Following incubation, *L. monocytogenes* was enumerated by serial dilutions in PBS, plating in duplicate on LSA, and incubating the plates 48 h at 37°C. The initial inoculum levels (approximately 10^6 CFU/mL) used to inoculate test media were determined by serially diluting the control, microbial pellets dispersed in BHI, at 0 h in BHI, plating on Listeria Selective Agar (LSA), and incubating for 48 h at 37°C.

Preparation of soy-protein edible film coating containing nisin, EDTA, or the combination of nisin with EDTA

Soy-protein film-forming solution was prepared according to the procedure of Eswaranandam et al. (2004). The film-forming solution was prepared by dissolving 10 g soy protein isolate into 90 mL water followed by the addition of 3.5 g glycerol to the mixture. To ensure thorough mixing, the film-forming solution was stirred with a magnetic stir bar for 30 min. This solution was heated with continuous stirring at 85°C for 30 min in a water bath. The solution was cooled to room temperature, and the antimicrobials including nisin (N) (1 g), EDTA (0.16 g) and the combinations of nisin (1 g) + EDTA (0.16 g) were added. The resulting solutions were mixed for 30 min and used to coat the meat samples.

Inoculation and coating of meat samples

One-centimeter cut cubes of defrosted, irradiated, full-fat commercial turkey frankfurters were individually dipped for 1 min into the culture broth containing approximately 10^6 CFU/mL of *L. monocytogenes*. The pieces (each weighing approximately 1 g) were removed from the culture broth, allowed to drip free of excess inoculum, and allowed to dry for 30 min under a laminar hood with blowing air. A total of 192 [triplicates (3) of each type of coating (4) per temperature (2) per day (8)] pieces were coated with the different coating treatments by dipping them into film-forming solutions for 1

min. Coating treatments were performed in triplicates and included four treatments: SPI (soy protein coat without antimicrobials); SPI+N; SPI+EDTA; and SPI+N+EDTA. Each of the four treatments was subjected to two temperatures (4°C and 10°C), and *L. monocytogenes* was enumerated at d 0, 7, 14, 21, 28, and d 45. Following the film coating, the frankfurters were allowed to drip dry. Two types of positive controls were used. One consisted of inoculated frankfurter pieces without the SPI coating (Lm control) and the other consisted of pieces with the SPI coating but without the addition of antimicrobials. The treated pieces were placed individually into sterile Whirl-Pak® bags and refrigerated at 4°C and 10°C for 45 d.

Bacterial count during storage at d 0, 7, 14, 21, 28, and d 45

Bacterial counts at different storage periods were determined to test the ability of nisin, EDTA, and their combination incorporated in soy-protein film coatings in killing or inhibiting the growth of *L. monocytogenes*. Triplicates of the 1-cm cubes of meat in Whirl-Pak® bags stored at 4°C and 10°C were used. Phosphate buffer saline (PBS) diluents were added to make a 10-fold dilution. The samples were stomached for 2 min, decimally serially diluted with 0.1% PBS, and surface-plated in duplicate onto plates of LSA for the enumeration of *L. monocytogenes*. Plates were incubated at 37°C. After 48 h, colonies were counted and CFU/mL was calculated.

Statistical analysis

All values are reported as means of three experimental replications, performed in duplicate. Analysis of variance was conducted using general linear model, a procedure of the Statistical Analysis System (SAS 8.2, SAS Institute, Cary, N.C. 2000). The least significant difference procedure (student t-test) was used to compare means, significant mean differences among treatments, and treatment combinations. Significant differences were determined at $P<0.05$.

RESULTS AND DISCUSSION

Antimicrobial activities of nisin, EDTA, or the combination of nisin with EDTA in BHI broth medium at 37°C

As shown in Fig. 1, it was observed that the initial population of *L. monocytogenes* as the control was about 6.7 logs of CFU/mL and it grew to 9.1 logs of CFU/mL after 72 h at 37°C in BHI medium. Neither nisin nor EDTA alone was ineffective against the growth of *L. monocytogenes*. The cell populations were 8.6 and 8.2 logs of CFU/mL, respectively, after 72 h incubation.

The nisin treatment initially controlled the population of *L. monocytogenes* by a log of 3.4 CFU/mL. After 6 h of incubation, the populations were similar to the control. The initial reduction of *L. monocytogenes* by nisin (10,000 IU) might be due to its inhibitory activity. With prolonged incubation, nisin might have lost its activity against *L. monocytogenes* or the *L. monocytogenes* cells might have become resistant to nisin activity (Fig. 1). The nisin resistance in *L. monocytogenes* has been demonstrated in previous studies and it is a complex phenomenon (Crandall et al., 1998).

The combination of nisin with EDTA had effective inhibitory activity against *L. monocytogenes* in BHI medium at 37°C. In combination, the initial count of 6.7 logs CFU/mL was reduced to an undetectable level after 15 h of incubation. In combination, EDTA might have enhanced the activity of nisin against *L. monocytogenes*. Similarly, Brannen et al. (1990) also demonstrated that the combined activity of nisin with EDTA was more potent compared to nisin alone against *L. monocytogenes*. There were no survivors detected after 15 h of incubation in BHI medium at 37°C (Fig. 1).

Inhibitory effects of nisin, EDTA, and the combined effect of nisin with EDTA against L. monocytogenes on full-fat commercial turkey frankfurters stored at 4°C and 10°C

Tables 1 and 2 show the effect of nisin (10,000 IU); EDTA (0.16%); and the combination of nisin (10,000 IU) with EDTA (0.16%) against *L. monocytogenes* on full- fat turkey commercial frankfurters at 4°C and 10°C for 45 d respectively. The control without the addition of EDTA or nisin in the SPI coating showed the initial population of *L. monocytogenes* at 6.3 log CFU/g grew to 7.5 and 7.9 log CFU/g after 45 d at 4°C and 10°C respectively. EDTA (0.16%) alone did not have any significant inhibitory activity against *L. monocytogenes* on frankfurters at both 4°C and 10°C for 45 d ($P<0.05$). The cell populations were similar to the controls and were 7.9 and 8.2 log CFU/g at 4°C and 10°C respectively on d 45 when coated with EDTA-incorporated SPI on turkey frankfurters.

Nisin (10,000 IU) treatment had significant influence on the populations of *L. monocytogenes* for the first 7 d on frankfurters at 4°C and 10°C. The population of *L. monocytogenes* declined by 1.4 and 1.7 log cycles of CFU/g at 4°C and 10°C, respectively, in comparison with the *L. monocytogenes* control. After a 7 d, the population increased and was similar to the control containing no antimicrobials: up to 7.3 and 7.2 log CFU/g at 4°C and 10°C respectively on d 45. The sensitivity of *L. monocytogenes* towards nisin activity might have reduced during extended, refrigerated storage conditions. Janes et al. (2002) also found nisin incorporated into corn-zein coatings did not have significant ($P<0.05$) inhibitory effects after 24 d of storage at 4 and 8°C.

In combination, nisin (10,000 IU) with EDTA (0.16%) dramatically reduced the *L. monocytogenes* pop-

ulation at both 4°C and 10°C. The initial population of approximately 6 log CFU/mL was reduced to undetectable levels at d 7 at both 4°C and 10°C. Furthermore, no survivors were detected after a 7 d until 45 d at both temperature-storage conditions.

Results indicate that the usage of combined nisin (10,000) with EDTA (0.16%) was more highly effective than nisin (10,000 IU) or EDTA (0.16%) alone against *L. monocytogenes*. This combination can improve the efficacy and eliminate practical problems associated with the use of nisin against *L. monocytogenes* in meat preservation systems. Further studies are required to enhance the combined effects of nisin with EDTA against *L. monocytogenes* on other food products that are more susceptible to *L. monocytogenes* contamination.

ACKNOWLEDGMENTS

The financial support for this research study by the Food Safety Consortium is greatly appreciated.

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Table 1. Combined effect of nisin with EDTA on inhibition of *L. monocytogenes* on full-fat commercial turkey frankfurters stored at 4° C.

	L. monocytogenes population (Mean ± SE) Log CFU/g					
Treatment [z]	Day 0	Day 7	Day 14	Day 21	Day 28	Day 45
Lm control	6.4± 0.1[a] [y]	6.1± 0.2[a]	6.5±0.1[b]	7.0 ± 0.2[b]	7.1± 0.1[b]	7.5± 0.1[b]
SPI	5.9± 0.1[b]	6.3± 0.1[a]	7.4±0.3[a]	7.9± 0.0[a]	8.4± 0.1[a]	8.3 ± 0.0[a]
SPI+ N	6.4± 0.1[a]	4.7± 0.1[b]	5.2±0.1[c]	5.5± 0.0[c]	6.2± 0.0[c]	7.2± 0.1[c]
SPI+ EDTA	6.3± 0.0[a]	6.3± 0.0[a]	6.7± 0.1[b]	7.1 ± 0.1[b]	8.2± 0.1[a]	8.2± 0.1[a]
SPI+ N+EDTA	6.3± 0.0[a]	0.0± 0.0[c]	0.0± 0.0[d]	0.0± 0.0[d]	0.0± 0.0[d]	0.0± 0.0[c]

[z] Lm control: Inoculation of *L. monocytogenes* without coating. SPI: Soy protein coating without Nisin/EDTA, SPI+ N = Nisin (10,000 IU/g) incorporated soy protein coating, SPI+N+EDTA: Nisin (10,000 IU/g) + EDTA 0.16% incorporated soy protein coating.

[y] All means were measurements of three experiments in duplicates. Means within a column followed by same superscript are not significantly different ($p<0.05$).
Minimum detection limit was 100 CFU/mL.

Table 2. Combined effect of nisin with EDTA on inhibition of *L. monocytogenes* on full-fat commercial turkey frankfurters stored at 10° C

	L. monocytogenes population (Mean ± SE) Log CFU/g					
Treatment [z]	Day 0	Day 7	Day 14	Day 21	Day 28	Day 45
Lm control	6.5± 0.0[a] [y]	6.1±0.1[b]	5.7±0.0[b]	7.1± 0.3[b]	7.5± 0.4[b]	7.9± 0.1[a]
SPI	5.9± 0.5[a]	7.8 ± 0.0[a]	7.5 ± 0.1[a]	7.3± 0.2[b]	7.9± 0.0[b]	8.1± 0.1[a]
SPI+ N	6.3± 0.1[a]	4.4± 0.1[c]	5.4± 0.1[b]	5.8± 0.1[c]	7.7± 0.1[c]	7.3± 0.3[b]
SPI+ EDTA	6.2± 0.1[a]	7.7± 0.1[a]	7.5± 0.2[a]	8.1± 0.2[a]	7.8± 0.1[a]	7.9± 0.1[a]
SPI+ N+EDTA	6.2± 0.1[a]	0.0± 0.0[d]	0.0± 0.0[c]	0.0± 0.0[d]	0.0± 0.0[d]	0.0±0.0[c]

[z] Lm control: Inoculation of *L. monocytogenes* without coating. SPI: Soy protein coating without Nisin/EDTA, SPI+ N = Nisin (10,000IU/g) incorporated soy protein coating, SPI+N+EDTA: Nisin (10,000IU/g) + EDTA 0.16% incorporated soy protein coating.

[y] All means were measurements of three experiments in duplicates. Means within a column followed by same superscript are not significantly different ($p<0.05$).
Minimum detection limit was 100 CFU/mL.

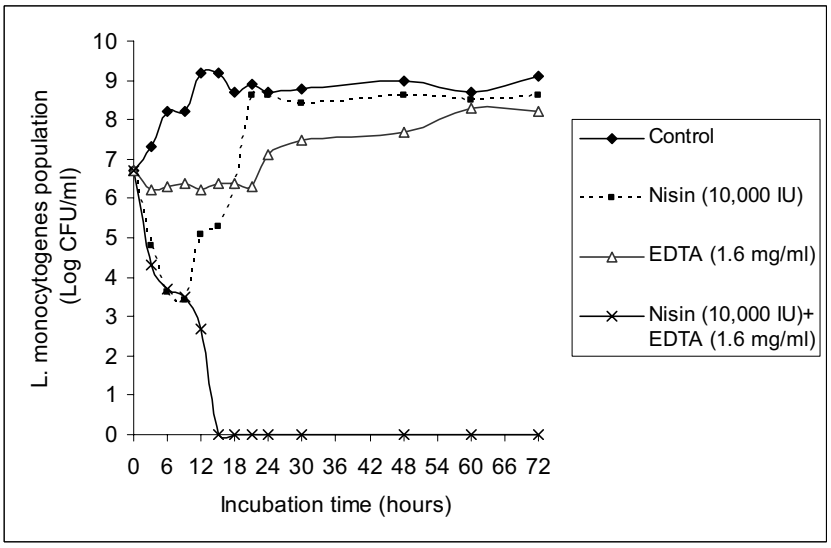

Fig. 1. Inhibitory effects of nisin, EDTA, and the combination of nisin with EDTA against *L. monocytogenes* in BHI broth medium at 37°C. (Values are means of three determinations.)

Infiltration and short-term movement of nitrogen in a silt-loam soil typical of rice cultivation in Arkansas

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ABSTRACT

Rice production in Arkansas is one of the top three crop commodities in terms of cash receipts. Researchers and farmers report that nitrogen (N) needs to be managed according to a variety of factors with two important ones being soil and fertilizer type. The objectives of this experiment were to determine: 1) the degree to which floodwater-incorporated N applied as urea or as ammonium sulfate infiltrates intact cores (7.2-cm dia., 10-cm depth) containing DeWitt silt-loam soil, and 2) the distribution of N during 12 h of ponding. Inorganic-N concentrations were analyzed at 2-cm depth intervals in cores following removal of the flood. Nitrogen from applied fertilizer was recovered as ammonium. Ammonium sulfate-N remained in the top 4 cm of soil with concentrations of 375 μg N g^{-1} in the surface 2 cm and 300 μg N g^{-1} at the 2 - 4 cm depth after 12 hr of ponding. At all depth intervals below 4 cm, ammonium sulfate-N remained below 30 μg N g^{-1}. In contrast, after 12 h of ponding, N in soil receiving urea was 105 μg N g^{-1} in the top 2 cm and 173 μg N g^{-1} at 2-4 cm. At 4-6, 6-8, and 8-10 cm, N was 109, 108, and 35 μg N g^{-1}, respectively, after 12 h of ponding. These results demonstrate immediate and deeper movement of ammonium into silt loam soil receiving urea as compared to ammonium sulfate, demonstrating how the form of N in fertilizer affects its movement into the soil profile.

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MEET THE STUDENT-AUTHOR

Lindsay M. Copenhaver

I graduated from Conway High School in 2004 and enrolled in the University of Arkansas in fall 2004 as an environmental, soil, and water sciences major with minors in chemistry and global agriculture, food, and life sciences. I was awarded the Honors college Academy Scholarship as well as the Agriculture Beginning Scholarship, Charles A. Stutte Memorial Scholarship, R.P. and Mildred Bartholomew Scholarship, Johnnie N. Jenkins Scholarship, and Delta Classic Scholarship from the Dale Bumpers College of Agricultural, Food and Life Sciences and from the Department of Crop, Soil and Environmental Sciences. I am a member of the Environmental, Soil and Water Sciences Club.

I began working in the Soil Biology and Microbial Ecology lab with Dr. Savin during the fall of my freshman year, where I was introduced to and began working on y honors research thesis concerning nitrogen movement in Arkansas rice soils. I applied and received the Student Undergraduate Research Fellowship (SURF) and the Carroll Walls Research Stipend for the 2006 academic year. I attended the American Society of Agronomy meeting in Salt Lake City in fall of 2005 where I placed second in the Undergraduate Oral Research Symposium. I competed in the 2006 Gamma Sigma Delta undergraduate research competition and placed second. I plan on continuing my graduate studies after I receive my environmental, soil, and water sciences degree.

INTRODUCTION

Arkansas has been the nation's leading rice-producing state since 1973, ranking first in acres planted and producing about 40 to 45% of the U.S. rice crop annually (Slaton, 2001). Approximately 55, 35, and 9% of the rice grown in Arkansas is produced on silt-loam, clay, and sandy-loam soils, respectively. Field preparation has the primary objective of removing winter vegetation and reducing the chance of seedling drift, so most Arkansas rice production is a delayed-flood, direct dry-seeded culture, with flooding of fields beginning at the end of May and early June.

Nitrogen (N) fertilizer is one of the most important investments, monetarily and environmentally, in a successful rice crop (Wilson et al., 2005). Nitrogen accounts for approximately 67% of the fertilizer (N + P + K) applied to rice (Vlek and Byrnes, 1986). While the amount of N required depends on rice culture, soil conditions, cultural practices, crop rotations, and other factors (Wilson et al., 2005), the goal of any fertilization program is to apply the optimal rate that will result in maximal yields.

Due to the complicated transformations N can undergo and the potential for inefficient N use, N is difficult to manage in flooded soil systems (Reddy and Patrick, 1984). Recovery by rice can be as low as 20 to 40%, if managed poorly, leading to extensive N losses (DeDatta et al., 1988). Because nitrate serves as an electron acceptor during denitrification, the use of nitrates for fertilization is avoided. Urea ((NH2)2CO) is an ammonium-forming N source that is widely available, relatively inexpensive, and has a large percentage (46%) of N. More than 90% of the total fertilizer-N is applied as urea instead of other forms (Vlek and Byrnes, 1986). Ammonium sulfate is another reduced-N source but is generally more expensive and has lower N content (21%), which also increases application costs (Wilson et al., 2005).

The movement of N from urea and ammonium sulfate on a silt-loam soil was analyzed in a laboratory study with a simulated field "flood." The objective was to

measure the immediate movement of N into the surface soil and compare how the different fertilizer N forms affected the depth to which N moved within 12 h of application and water ponding. It was hypothesized that N from urea would move farther down into the soil than N from ammonium sulfate.

MATERIALS AND METHODS

Soil cores.

Fifty-four intact soil cores (7.2 cm-dia., 10 cm-length) were collected from a 1.1 x 2.3 m plot at the University of Arkansas Rice Research and Extension Center, Stuttgart. Cores were kept intact inside plastic sleeves, placed on ice for transportation, and stored at 4°C. At the same time, five samples were taken for bulk density and 10 samples were taken for chemical composition (Mehlich III, total C & N, pH, N, OM, EC, P & K). Soil chemical composition was determined at the Soil Test Laboratory at the University of Arkansas, Fayetteville.

Infiltration and movement of N in top 10 cm of soil.

Nitrogen (90 mg N for each fertilizer) was applied to the center of cores (202.3 mg urea or 444.5 mg ammonium sulfate). Just enough water was added to dissolve the fertilizer, and then a flood was applied and maintained using Mariotte bottles (Fig. 1). The principle of the Mariotte bottle is that the pressure inside the bottle at the bottom of the bubble tube is at atmospheric pressure, which then maintains the water surface in the soil core at the same height as the end of the bubble tube (Bouwer, 1986) (Fig. 1).

Cores (four replications for a total of 48 cores) were leached at time intervals of 0.5, 1, 2, 4, 8, or 12 h for each fertilizer. When the allotted time elapsed, the floodwater and leachate were collected; volumes were measured, and frozen. Each core itself was capped and immediately placed in a -80°C freezer. Background N concentrations before (three replications) and after 12 h of flooding (three replications) were determined in cores not receiving N fertilizer.

Analysis.

The frozen cores were cut at 2-cm depth intervals with a band saw. Each thawed section was homogenized with a glass stirring rod. Moisture content was determined gravimetrically after drying 5 g of wet soil at 105°C for 24 h using the following equation:

$$\theta g = (W - D)/D \quad x \quad 100 \qquad (1)$$

where θg = gravimetric moisture, W = wet soil (g), and D = dry soil (g). Inorganic N was measured in 2M KCl solutions (1:10 soil:extract) after shaking for 1 h and filtering through a Whatman #42 filter. Filtrate was stored at 4°C, or frozen if analysis could not be conducted within a month of extraction, before colorimetric analysis of nitrate and ammonium (Mulvaney, 1996) on a nutrient autoanalyzer (Skalar Instruments, Norcross, Ga.). In the analysis procedure, NO_{3^-} extracted from soil with 2M KCl is reduced to NO_{2^-} by passage through a column of copperized cadmium, and the NO_{2^-} formed is determined by a modified Griess-Ilosvay method (Mulvaney, 1996). NH_4^+ extracted from soil with 2M KCl is determined by measuring the intensity of the emerald green color that forms upon treatment of an aliquot of the extract with salicylate and hypochlorite at high pH. A catalyst (sodium nitroprusside) increases the rate and intensity of color development, and a chelating agent (EDTA) prevents the precipitation of divalent and trivalent cations as hydroxides (Mulvaney, 1996).

Mean N concentrations and standard deviations were calculated for each depth and time interval. Concentrations were analyzed and compared across fertilizer type and over time using analysis of variance. Background soil-N concentrations were subtracted from the measured 12-h concentrations to obtain fertilizer-N concentrations.

RESULTS AND DISCUSSION

The soil chemical properties of the DeWitt silt loam (fine, smectitic, thermic, Typic Albaqualf) are summarized in Table 1. According to Brady and Weil (2002), the range for an average silt-loam soil bulk density is 0.9 – 1.5 g/cm^3, with a typical medium-textured soil having a bulk density of 1.25 g/cm^3. The DeWitt silt-loam bulk density is well within the reported range with an average bulk density of 1.38 g/cm^3. Carbon and pH values also fell within normal ranges of 0.9-3.3% for carbon and 5-7 for pH (Brady and Weil, 2002).

Neither fertilizer contained N in nitrate form and because of the short time intervals used in this study, nitrification was not expected to occur. Fertilizer was expected to be recovered as NH_4^+-N. In fact, after subtracting out background nitrate levels after 12 h of ponding, almost all inorganic N recovered was ammonium (data not shown).

Floodwater incorporated NH_4^+-N into soil to varying degrees within the 12-h ponding time utilized in this study. The concentrations of NH_4^+-N at the 0-2 cm depth ranged from 523 μg N g^{-1} soil measured after 0.5 h to 375 μg N g^{-1} soil after 12 hours. Nitrogen at the 2-4 cm depth after 0.5 h was 154 μg N g^{-1} soil and after 12 h was 300 μg N g^{-1} soil. These results represent an accumulation in the upper 4 cm. There was a sharp, visible downward trend over time in 0-2 cm depth, accompanied by a similarly apparent increase in the 2-4 cm depth (Fig.

2). Below 2-4 cm, accumulation was slow, and inconsistent with concentrations ranging from a background 9 μg N g^{-1} to 29 μg N g^{-1} soil after 12 h. There was no significant downward movement below 4 cm when compared to the upper 4 cm (Fig. 2). These results were expected because the positive charge of ammonium (NH4+) associates with negative charges on soil-particle surfaces.

In contrast to ammonium sulfate applied-N, there was deeper movement of NH_4^+-N from surface-applied urea (Fig. 3). In order to measure increases in NH_4^+ with urea applications, NH_4^+ must be released during breakdown of composition of urea, leading to the expectation that urea will be able to move farther down into the soil. Concentrations of NH_4^+-N were 130 μg N g^{-1} soil after 0.5 h and 105 μg N g^{-1} soil after 12 hours at 0-2 cm (Fig. 4). Nitrogen was approximately 175 μg N g^{-1} soil at the 2-4 cm depth after a 0.5 h and remained at 175 μg N g^{-1} after12 h of ponding. In contrast, NH_4^+ concentrations at the 4-8 cm depths were higher than those measured in soil receiving ammonium sulfate (Figs. 2 and 3). Ammonium concentrations at the 4-8 cm depth also increased during 12 h of flooding. At the 4-6 and 6-8 cm depths, 75 and 39 μg N g^{-1} soil, respectively, were measured after 0.5 h of ponding and concentrations reached approximately 109 μg N g^{-1} soil at both depths after 12 h (Fig. 3). Although concentrations of urea were not as high in the top 4 cm as ammonium sulfate, concentrations below 4 cm increased over time (Fig 3).

While N from ammonium sulfate stayed in the surface 4 cm of soil, N from urea infiltrated farther and was accumulating at depths below 4 cm during 12 h of ponding. These results have significance because if urea breaks down to release ammonium before a flood is established, fertilizer N will behave more like ammonium sulfate and N will not infiltrate as far. Any ammonium that remains at the surface and under aerobic conditions can undergo nitrification. Nitrate can leach with downward water movement and move into the anaerobic zone. In the anaerobic zone, nitrate can undergo denitrification. Some cultural practices take 5 d to establish a flood. These results suggest that management practices that prevent the breakdown of urea and the subsequent accumulation of NH_4^+-N near the soil surface need further investigation.

ACKNOWLEDGMENTS

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Table 1. Mean soil properties (± standard deviation) of a DeWitt silt-loam soil (fine, smectitic, thermic, Typic Albaqualf) collected from the University of Arkansas Rice Research and Extension Center, Stuttgart (n=5 for bulk density, n=10 for all other properties).

pH	EC[z]	P	K	C	N	OM	Bulk Density
	(umhos/cm)	(mg/kg)	(mg/kg)	(%)	(%)	(%)	(g/cm^3)
6.37	164.80	10.43	108.34	0.95	0.09	2.37	1.38
(0.03)	(7.16)	(0.39)	(3.25)	(0.02)	(0.00)	(0.14)	(0.02)

[z]EC is electrical conductivity and OM is organic matter.

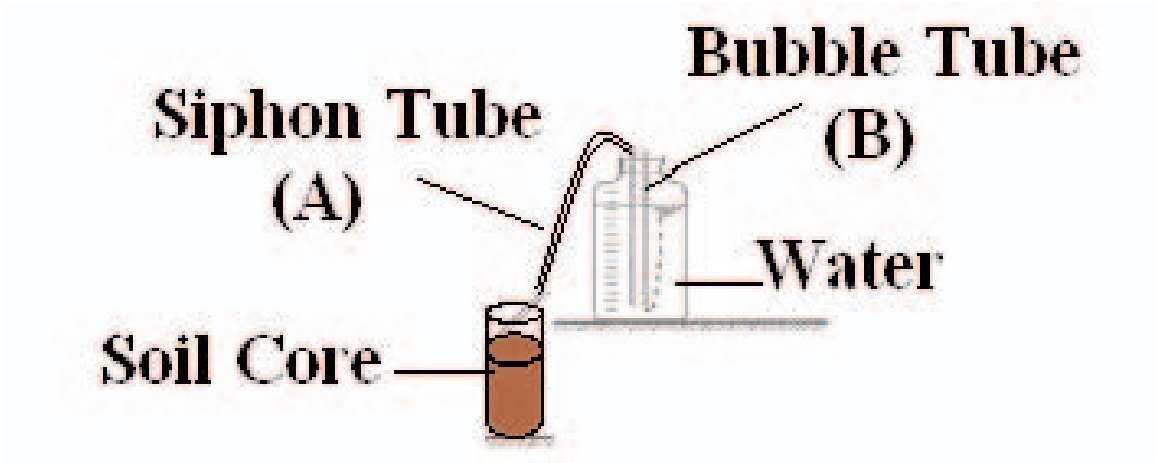

Fig. 1. Mariotte Bottle. Two tubes are inserted through the stopper. One tube (A) is for siphoning the water to the soil core and the other tube (B) allows air into the bottle. The bottom of this "bubble" tube is set at the level at which the water surface in the soil core is to be maintained (Bouwer, 1986).

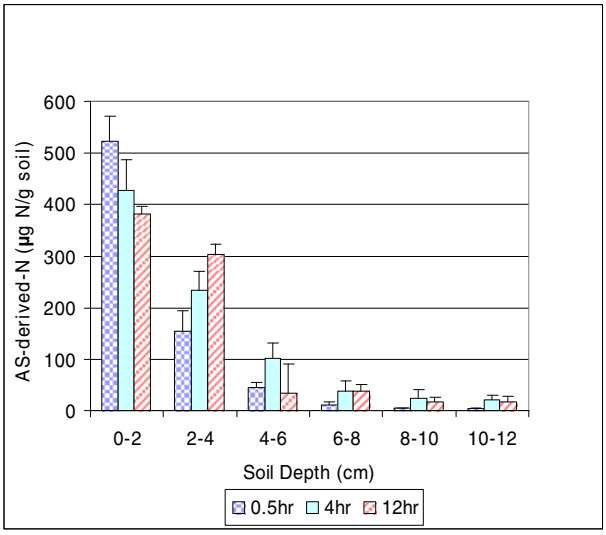

Fig. 2. Mean NH4+-N concentrations (± standard deviation) from ammonium sulfate (AS) recovered after time intervals of 0.5, 4 or 12 h at 2-cm depth intervals in soil cores containing DeWitt silt loam.

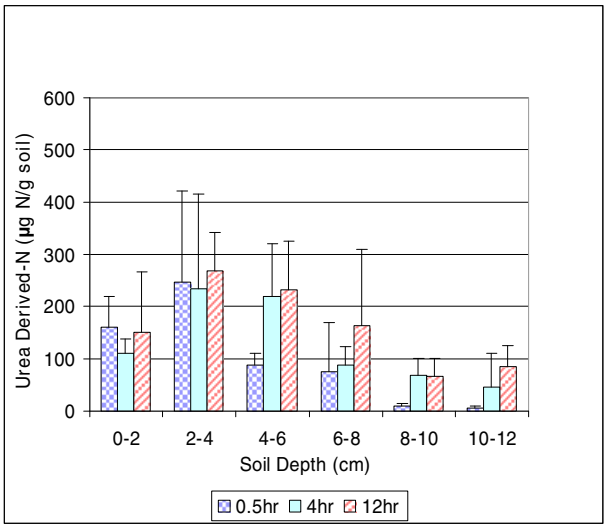

Fig. 3. Mean NH4+-N concentrations (± standard deviation) from urea recovered after time intervals of 0.5, 4 or 12 h at 2-cm depth intervals in soil cores containing DeWitt silt loam.

Effects of grain by-products as supplements for stocker cattle grazing bermudagrass

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ABSTRACT

Two experiments were conducted to compare corn, dried distillers' grains (DDG), and pelleted soybean hulls (SH) as supplements for cattle grazing bermudagrass. In Exp. 1, 66 crossbred steers (306 ± 3.2 kg) were stratified by weight and allotted randomly to six 2.4-ha bermudagrass pastures for a 107-d study. One of three supplement treatments (corn, DDG, or SH) was assigned randomly to each pasture group and was offered at 0.5% (as fed) of body weight. Calves were weighed at 28-d intervals and supplement was adjusted after each weigh period. In Exp. 2, five ruminally cannulated steers grazed bermudagrass pasture and were individually fed supplements (corn, DDG, or SH) at 0.5% of body weight in a 3 x 3 replicated, incomplete Latin-square design with a 14-d adaptation and a 5-d sampling period. In Exp. 1, supplementation with DDG and corn increased ($P < 0.04$) the average daily gain compared to supplementation with SH (0.89, 0.87, and 0.74 kg for DDG, corn, and SH, respectively). In Exp. 2, in situ dry-matter-disappearance kinetic measures of bermudagrass were not affected by type of supplementation. The potential extent of digestion for DDG (93%) was lower than for corn (97%, $P = 0.01$) and SH (96%, $P = 0.06$). Supplementation with corn or DDG at 0.5% of body weight improved the gain of stocker cattle grazing bermudagrass compared to supplementation with SH, but these differences were not explained by differences in bermudagrass degradation kinetics.

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INTRODUCTION

Arkansas ranks 16th in the United States in cattle and calf numbers with approximately 1.8 to 1.9 million head. These cattle have a cash value of more than $430 million and a total impact of $1.4 billion on the Arkansas economy (UACES, 2005). Additionally, Arkansas has approximately 420,000 stocker cattle and compared to data over past years, the number of stocker cattle continues to rise (USDA, 2005). Stocker calves are weaned beef calves (typically 136 to 272 kg) that graze forage generally and are provided supplements of grain to provide additional energy, protein, and minerals to achieve desirable gains.

The type of feed and its cost play a role in the profitability of the enterprise; therefore, new sources of low-cost highly nutritious supplemental feeds are constantly being sought. With the increasing number of ethanol plants (Tjardes and Wright, 2002) in the United States due to a demand for less dependency on foreign oil and more environmentally friendly energy, there is also an increasing amount of by-products. These by-products, known as distillers' grains, remain following the production of ethanol mostly from corn and contain high concentrations of protein and energy (Tjardes and Wright, 2002). However, phosphorus (P) concentrations in this by-product are well above cattle requirements and could potentially cause cattle-health (possible formation of urinary calculi) and environmental (P in run-off) problems (Tjardes and Wright, 2002). Distillers' grains have been used as an economical feed source for feedlot and dairy cattle for years; however, with this increasing supply, they may now be a more economical supplement for use in grazing animals.

There has been limited research investigating using distillers' grains as a supplement for calves grazing bermudagrass [*Cynodon dactylon*]. Bermudagrass can be

MEET THE STUDENT-AUTHOR

Upon graduation from Ashdown High School in May 2002, I enrolled at the University of Arkansas. My dream of being a "Razorback" was finally fulfilled. I was awarded the Honors College Academy Scholarship and the Alumni Society "Roads" Scholarship. In addition to these scholarships, I was fortunate to receive the Brandon Burlsworth Memorial Scholarship in 2005.

While on campus I have been actively involved with the Student Alumni Board, Pre-Dental Society, Associated Student Government, and served as President of the Block and Bridle Club. As a sophomore, I began working part-time on the Division of Agriculture Stocker-Receiver Beef Unit under the direction of Pete Hornsby and my mentor, Dr. Beth Kegley.

Tyler E. Davis

Being from a strong agricultural background, I have always possessed a passion for agriculture. My family owns and operates a commercial cow-calf and stocker cattle operation in rural Little River County, and I also own a herd of registered Angus cattle. This research project presented me with an opportunity to expand my knowledge and explore other aspects of the cattle and agricultural industries.

I am a senior majoring in animal science and will graduate with honors in May 2006. I have been accepted at the University of Tennessee-Memphis College of Dentistry and plan to specialize in pediatric dentistry.

I would like to thank especially Dr. Beth Kegley for her support and guidance as well as Dr. Ken Coffey for his research expertise. Additionally, I would like to thank Doug Galloway, Pete Hornsby, and Robin Ogden for their assistance during my research trial. All of those involved are greatly appreciated.

found on many farms in Arkansas; it is estimated that over 2 million acres of bermudagrass exist in the state (UACES, 2006). Although soil fertility, rainfall, and maturity affect bermudagrass nutritive value, the high fiber content of bermudagrass limits optimal calf growth. Calves grazing bermudagrass generally respond positively to supplementation of energy provided from grains. Yet, high levels of starch-containing grains, such as corn, decrease forage intake and fiber digestion of forage-based diets if supplemented at higher levels (Garces-Yepez et al., 1997). Soybean-hull pellets are a locally available by-product of milling soybeans; these pellets are low in starch and thus provide energy without possible negative impacts on fiber digestion (Galloway et al., 1993). A comparison of these feedstuffs (distillers' grains, soybean-hull pellets, and corn) in growing cattle would provide important information for Arkansas producers and allow them to make more informed and economical supplementation choices. Therefore, objectives in this study were to determine the impact of providing cattle with supplements of corn, dried distillers' grains (DDG), or soybean-hull pellets (SH) on growth performance, blood metabolites and ruminal-forage degradation kinetics in cattle grazing bermudagrass pastures.

MATERIALS AND METHODS

There were two phases of this project. Experiment 1 was conducted to evaluate corn, DDG, and SH as protein and energy sources for stocker cattle grazing bermudagrass as well as to determine if supplementation influenced blood metabolites. Experiment 2 was conducted to evaluate the impact of these same supplements on ruminal digestibility of these supplements as well as bermudagrass pasture samples, using an in situ procedure. All procedures involving steers were approved by the University of Arkansas Animal Care and Use Committee.

Experiment 1: Sixty-six crossbred steers (initial body weight averaged 306 ± 3.2 kg) were stratified by weight and allotted randomly to six 2.4-ha pastures at the University of Arkansas Stocker-Receiving Unit near Savoy, Ark. on 11 May 2005. Calves had ad libitum access to fresh water and were monitored daily for morbidity. One of three supplement treatments (corn, DDG, or SH) was assigned randomly to each pasture group and steers were offered these supplements at 0800 h daily at a rate of 0.5% (as fed) of body weight. Pastures were predominately bermudagrass (14.7% crude protein, 68% neutral digestible fiber, 32% acid detergent fiber, 0.39% P) and averaged 6,377 kg/ha of available forage over the 107-d study. Calves were weighed at 28-d intervals and the amount of supplement offered was adjusted after each weigh period such that calves were offered 0.5% of body weight; any supplement refusals were recorded daily. Supplement samples were collected every 28 d and were analyzed for crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), and P on a dry-matter (DM) basis.

Cattle were weighed at the beginning and end of the trial on two consecutive days, and interim weights were taken every 28 d. Blood samples were collected on d 0, 28, 56, 84, and 107 via jugular venipuncture with vacuum tubes. These samples were stored on ice after collection until centrifuged at 1,200 x g for 20 min for separation of serum or plasma; then serum or plasma samples were stored frozen (-20°C) until analyzed. Samples for serum urea nitrogen concentrations were collected into glass tubes containing a clot activator (BD Vacutainer®, Franklin Lakes, N.J.) and analyzed with a colorimetric assay (L-Type UN kit, Wako Chemicals USA, Inc., Richmond, Va.). Samples for serum P concentrations were also taken in tubes with the clot activator; serum was deproteinated with 10% trichloroacetic acid and then P was determined with a colorimetric procedure (Bodine and Purvis, 2003). Samples for plasma non-esterified fatty acid (NEFA) concentrations were taken in tubes with EDTA (BD Vacutainer®). Plasma was analyzed with a commercial colorimetric assay (NEFA-C kit, Wako Chemicals USA, Inc., Richmond, Va.).

Fecal grab samples were taken from four calves per pen on d 84 and 107 and stored frozen to examine fecal P concentrations. Fecal material was later thawed, dried, ground to pass through a 1-mm screen of a Wiley Mill, sub-sampled, wet-ashed with nitric acid, and P determined with a colorimetric assay (Bodine and Purvis, 2003). Additionally, forage availability was measured every 28 d with a calibrated, rising disk meter, and grab samples were taken and combined in a composite sample to determine CP, NDF, ADF, and P.

Steer weights, average daily gain, blood metabolites, and fecal P were statistically analyzed using PROC MIXED of SAS (SAS Inst., Cary, N.C.). The experimental unit was a pen. A repeated statement was used for blood data.

Experiment 2: In a replicated incomplete 3 x 3 Latin square design, five ruminally cannulated crossbred (Gelbvieh x Angus x Brangus) steers (initial weight averaged 794 kg) grazed a bermudagrass pasture (1.46 ha) and had ad libitum access to fresh water. Steers were weighed at the beginning and end of each period. Each period consisted of 19 d, with 14 d of supplement adaptation followed by 5 d of in situ procedure. Period 1 began on 28 June 2005. Steers were caught daily at 0800 h and fed each of the supplements used in Exp. 1 (Table 1) at 0.5% (as fed) of body weight.

Bermudagrass was collected immediately prior to Period 1 of in situ collection from the same pasture the steers were grazing. In situ procedures were used as

described by Vanzant et al. (1998). Dacron bags (10 x 20 cm; 53 ± 10-µm pore size; Ankom Co., Fairport, N.Y.) were filled with 5 g (as-fed) of dried (50°C), ground (to pass through a 2-mm screen of a Wiley mill) bermudagrass, or the appropriate supplement then heat sealed to determine in situ DM digestibility. All Dacron bags for each time period were placed in mesh laundry bags (35- x 50-cm), pre-incubated in tepid (39°C) water for 20 min to decrease the lag time associated with microbial attachment, and then inserted (except for 0 h) into the ventral rumen prior to the morning feeding. Bags containing the appropriate supplement were removed at 0, 3, 6, 9, 12, 18, 24, 36, 48, and 72 h after insertion. Bags containing dried bermudagrass were removed at 0, 6, 9, 12, 18, 24, 48, 72, 96, and 120 h after insertion. All bags were rinsed five times with tap water, then five times with deionized water, in a top-loading washing machine with a 1 min agitation and a 2 min spin per rinse to remove particles adhering to the outside of bags as outlined by Coblentz et al. (1997) and Ogden et al. (2005). Bags were dried under forced air for at least 48 h at 50°C and then weighed after equilibration with atmospheric moisture. Dry-matter disappearance was calculated as the dry weight remaining minus the initial dry weight in each bag. Ruminal disappearance data were fitted to the non-linear regression model of Mertens and Loften (1980). Fraction A represented the immediately soluble portion, Fraction B was defined as the portion of DM that disappeared at a measurable rate, and Fraction U represented the portion that was undegradable in the rumen. Potential extent of digestion was calculated as 100 minus U. Kinetic parameters (B, U, digestion lag time [L], and rate of disappearance [k_d]) were estimated using PROC NLIN of SAS (SAS Inst., Cary, N.C.). After parameters were estimated, treatment comparisons were made using PROC MIXED of SAS where the model included animal, period, and treatment.

RESULTS AND DISCUSSION

Experiment 1: Steer weights were not different until d 107, when steers supplemented with corn and DDG weighed more than steers supplemented with SH ($P < 0.04$) (Fig. 1). Average daily gains of steers supplemented with corn (0.87 kg) and DDG (0.89 kg) were greater than average daily gains of steers supplemented with SH (0.74 kg; $P < 0.04$) for the 107-d trial. These lower average daily gains in steers supplemented with SH differ from the results of Anderson et al. (1988) and Garces-Yepez et al. (1997). They reported similar average daily gains for cattle supplemented with corn versus SH. In the current study, supplement type did not affect forage availability in the pastures, and forage availability was never limiting (minimum observed was 3,080 kg DM/ha).

There was a main effect of supplement type on serum urea-N (Fig. 2). Steers supplemented with DDG had the greatest serum urea-N concentrations, steers supplemented with SH had intermediate concentrations, and steers supplemented with corn had the lowest concentrations of serum urea-N ($P < 0.01$). This was due to the greater amount of CP that the DDG and SH contained as compared to corn (Table 1). This excess protein was degraded in the rumen and the ammonia was absorbed across the rumen wall. The liver detoxified the ammonia by forming urea that circulates in the bloodstream until being excreted in the urine (Church, 1988). Because of the high level of CP in the bermudagrass, none of these steers, even those supplemented with corn, should have been deficient in protein. All of these serum urea-N concentrations are considered high for cattle, and the concentrations for the steers supplemented with DDG were approaching levels that may cause decreased fertility for heifers of breeding age (Elrod and Butler, 1993).

Concentrations of plasma NEFA (Fig. 3) were not different among treatment sources. Plasma NEFA concentrations are increased when fat stores are being metabolized. Concentrations of NEFA were greatest on d 0, before supplementation started, and were low for the remainder of the experiment, indicating that energy was not limiting for these growing steers (Clarenburg, 1992).

There was a treatment x day interaction ($P < 0.05$) for serum-P concentrations (Fig.4). Serum-P concentrations were consistent until d 107, when steers supplemented with corn had lower concentrations of serum P than steers supplemented with DDG or SH.

There was a main effect of supplement source and day on fecal-P concentrations ($P < 0.003$). Steers supplemented with DDG had the greatest fecal-P concentrations (0.84%), corn supplemented steers were intermediate (0.70%) and did not differ from that of steers supplemented with SH who had the lowest concentrations of fecal-P (0.66%) (data not shown). These results were expected due to DDG having a greater concentration of P, corn being intermediate, and SH containing the lowest P concentration. Fecal-P concentrations also varied by day, with concentrations on d 84 (0.70%) being lower than concentrations on d 107 (0.84%). This probably reflected the increased supplement intake during this last month of the study and also was due to an increased concentration of P in the bermudagrass during this last period due to regrowth after a rain event.

Experiment 2: There were no effects of supplement type on ruminal disappearance of bermudagrass (Table 2). These results agree with the results of Garces-Yepez et al. (1997) where sheep were fed a corn-based supplement or SH at a similar rate as in this study and no suppression of ruminal organic-matter digestibility was observed.

However, Galloway et al. (1993) showed a decrease in bermudagrass hay intake and NDF digestion when cattle were supplemented with corn at 0.5% of body weight.

Ruminal disappearances of supplements were different among sources, with DDG having the greatest A fraction, corn intermediate, and SH having the smallest ($P < 0.01$) (Table 2). Soybean hulls had the greatest B fraction ($P < 0.01$), corn was intermediate, and DDG the smallest. Rate of disappearance (k_d) did not differ between DDG and SH, yet both rates were lower than that of corn ($P < 0.01$). Lag times were greatest ($P < 0.01$) from SH, intermediate from DDG, and smallest from corn. The potential extent of ruminal disappearance was greater for corn ($P < 0.03$) than for DDG with SH being intermediate and not different from either corn or DDG. However, all potential extents of ruminal disappearance were greater than 92%.

In conclusion, supplementation with corn or DDG at 0.5% of body weight improved average daily gains of stocker cattle grazing bermudagrass compared to supplementation with SH. However, in situ disappearance of bermudagrass was not different when these supplements were fed at the rate of 0.5% of body weight daily. All these supplement types produced desirable rates of gain for stocker cattle grazing bermudagrass in Arkansas.

ACKNOWLEDGMENTS

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Table 1. Nutrient composition of supplements fed to steers grazing bermudagrass pasture.

	CP	NDF	ADF	P
	----------% of DM----------			
Corn	9.0	13.3	3.0	0.14
Distillers grains	29.0	45.3	17.6	0.72
Soybean hulls	12.1	65.3	47.4	0.11

Table 2. In situ disappearance kinetics of bermudagrass forage and supplements for steers grazing bermudagrass pasture in Exp. 2.

	Fraction A[1]	Fraction B[1]	Fraction U[1]	Lag time	K_d[2]	Potential Extent[3]
	----------% of DM----------			h	/h	%
Bermudagrass						
Corn	18.6	52.3	29.1	0.75	0.032	70.9
Distillers grains	17.2	52.2	30.6	1.15	0.038	69.4
Soybean hulls	17.3	52.2	30.5	1.33	0.038	69.5
P-value	0.32	0.99	0.29	0.67	0.38	0.29
SEM[4]	0.64	1.08	0.65	0.46	0.0033	0.65
Supplement						
Corn	32.7[b]	64.3[b]	3.0	0.4[f]	0.108[a]	97.0[d]
Distillers grains	37.2[a]	55.6[c]	7.2	1.4[e]	0.043[b]	92.9[e]
Soybean hulls	14.4[c]	81.1[a]	4.5	4.5[d]	0.055[b]	95.6[de]
P-value	<0.0001	<0.0001	0.034	0.0111	0.0011	0.034
SEM[4]	0.77	0.97	0.84	0.65	0.007	0.84

[1]Fraction A = immediately soluble fraction, B = fraction disappearing at a measurable rate, and U = undegrade
[2]K_d = ruminal disappearance rate
[3]Calculated as (100-U)
[4]Standard error of the mean
[abc]$P < 0.01$
[def]$P < 0.05$

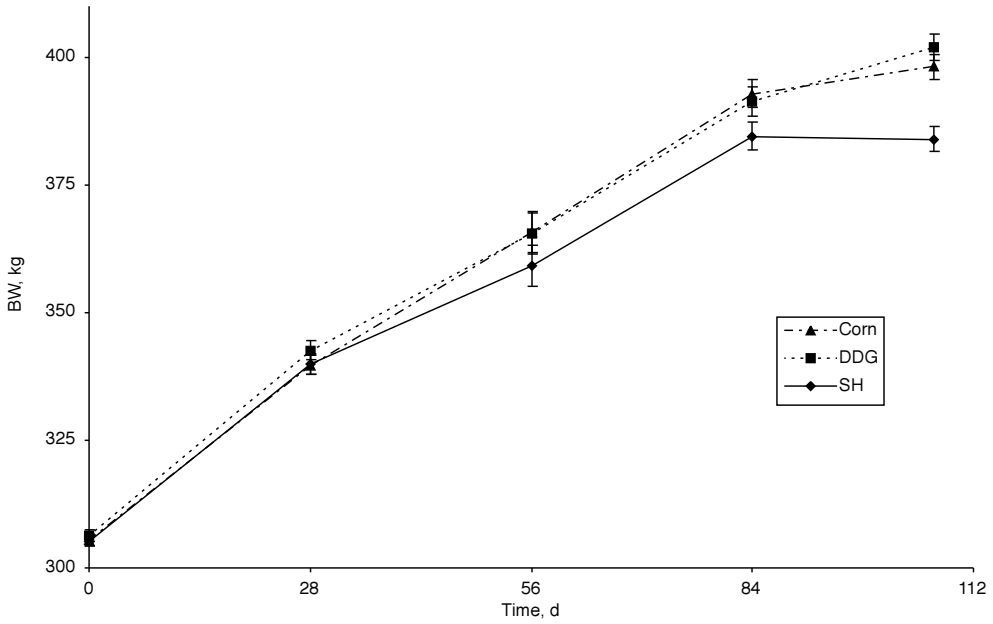

Fig. 1. Effect of supplement source on performance of steers grazing bermudagrass pastures in Exp. 1 throughout a 107-d trial. DDG = dried distillers' grains; SH = soybean hulls.

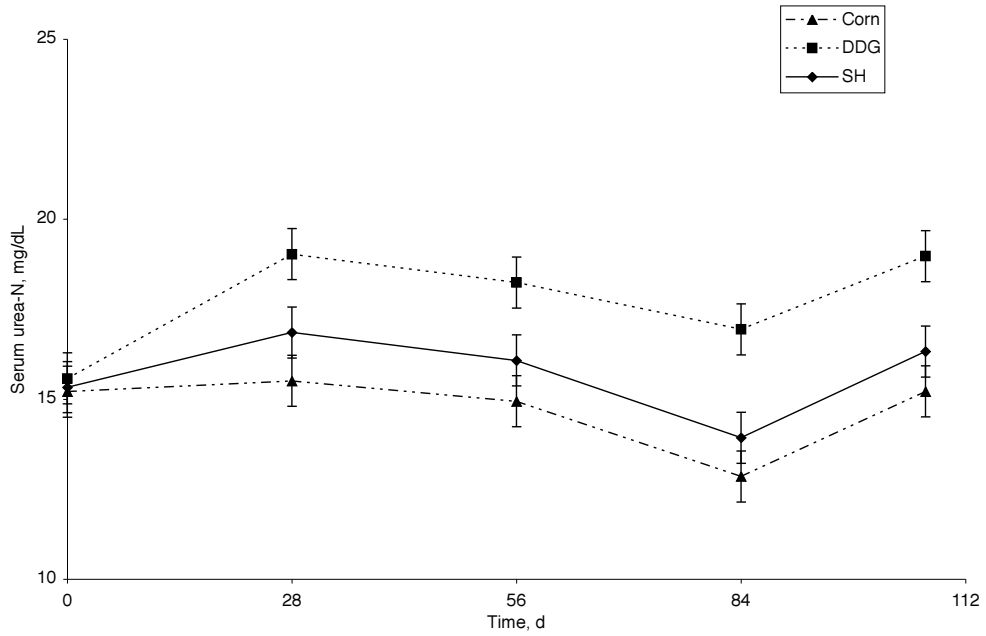

Fig. 2. Effect of supplement source on serum urea-N concentrations from steers grazing bermudagrass pastures in Exp. 1. DDG = dried distillers' grains; SH = soybean hulls.

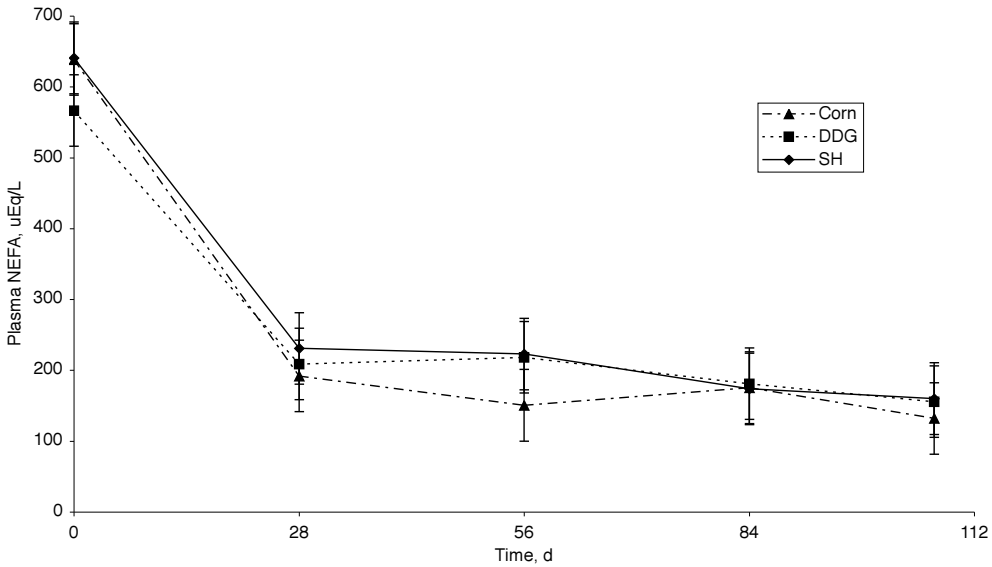

Fig. 3. Effect of supplement source on plasma NEFA concentrations from steers grazing bermudagrass pastures in Exp. 1. DDG = dried distillers' grains; SH = soybean hulls.

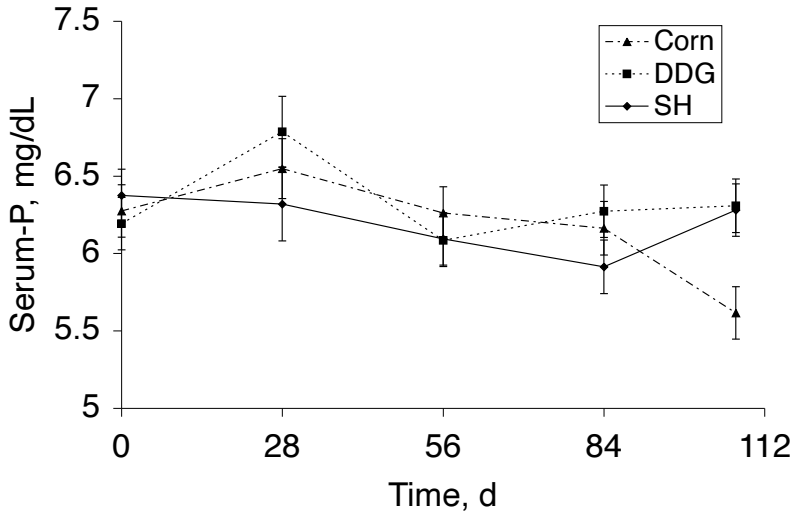

Fig. 4. Effect of supplement source on serum-P concentrations from steers grazing bermudagrass pastures in Exp. 1. DDG = dried distillers' grains; SH = soybean hulls.

Adventitious shoot propagation and cultural inputs in nursery production of a primocane-fruiting blackberry selection

Kimberley Dennis[*]*, John R. Clark*[†]*, and James A. Robbins*[§]

ABSTRACT

Studies were conducted from January to October 2005 to determine the effect of root-cutting length on adventitious shoot yield and the management practices necessary to produce nursery-quality primocane-fruiting blackberry plants. The first portion of the study measured the average number of shoots produced from 7.6 cm- and 15.2 cm-long root cuttings of APF-44 blackberry—a primocane-fruiting genotype from the University of Arkansas breeding program. Cuttings were forced in a shallow bin containing a soilless potting medium. The average number of shoots per root cutting from 7.6 cm- and 15.2 cm- long root cuttings averaged 1.6 and 2.7 shoots per root cutting, respectively. Rooting percentage for collected shoots was nearly 100% regardless of root-cutting length source. A qualitative comparison of shoots from the two roots lengths was similar. The latter part of the study included various treatments on the rooted shoots that might affect the productivity and quality of the final product intended for nursery sales in early fall. With the aim of producing a flowering/fruiting shrub by late September, three treatments were applied: pot dimension, fertilizer rate, and shoot tipping. Fertilizer rate had the greatest impact of all treatments with the higher rate producing larger and more attractive plants. Above-normal summer/fall temperatures may explain lack of fruiting on APF-44 blackberries, but the dimension and size of some plants provided a portion of the intended aesthetic.

[*] Kimberley Dennis graduated in December, 2004 with a B.S. in horticulture.

[†] John R. Clark, faculty co-sponsor, is a professor in the Department of Horticulture.

[§] James A. Robbins, faculty co-sponsor, is extension ornamental-horticulture specialist, Arkansas Cooperative Extension Service.

INTRODUCTION

Blackberries are a fruiting shrub in the genus *Rubus*, the same genus as raspberries; thus, cultivation of the two plants is very similar (Pritts and Handley, 1991). Traditional propagation methods of blackberries include tip layering, suckering, leaf-stem cuttings, tissue culture, and root cuttings (Caldwell, 1984). These techniques are often used but all have some limitations for propagators. Root cuttings, of all options, can be the most economical and timely way to propagate blackberries and the University of Arkansas uses root cuttings for nearly all blackberry propagation (John R. Clark, personal communication). Based on a study by University of Arkansas undergraduate, Ellen Thompson (Thompson et al., 2004), a "simple modification" to the traditional root-cutting propagation method led to increased propagule yield and rooting success. However, cultivar effects were sometimes significant. This modification of propagation technique allows for space-limited and/or greenhouse production and greatly decreases the time and monetary investment associated with traditional methods. Thompson's study was based on precedents of a Swiss *Rubus* propagation system, and the findings were supported by the idea that forcing multiple adventitious shoots from a single root cutting increases the success and number of blackberry daughter plants. Moreover, the closely related raspberry is propagated in this way with similar results (Pritts and Handley, 1991).

The advent of primocane-fruiting blackberries, first introduced by the University of Arkansas breeding program in 2004, provides for potential increases in fruit yield and extends the growing season well into early fall (Clark et al., 2005). With this in mind, it might be possible to produce a nursery-quality plant that could produce fruit for home-gardeners into the autumn months. Moreover, the ornamental qualities of APF-44 blackberry specifically are conducive to a nursery's aesthetic requirements; the plant is observed to have relatively short internodal length and a "bushy" mounded shape, and produces flowers and fruit in early September through October (John R. Clark, personal communication). Management practices to enhance these qualities—mid-summer tipping, fertilizer rates, and pot dimension—are investigated in this study.

MATERIALS AND METHODS

Experiment I: Adventitious shoot propagation

Root cuttings of two sizes, 7.6 cm and 15.2 cm, were evaluated in greenhouse conditions for propagule yield from January to April 2005. The APF-44 blackberry root cuttings used in propagation were collected from the University of Arkansas Fruit Substation, Clarksville, in late fall, 2004 (APF-44 is a breeding selection and is not released to the public nor is it an item of commerce). The diameter of the roots averaged approximately 5.3 mm. After one month of cold storage, the root cuttings were positioned in drainable plastic bins filled with LC1® soil-less potting mix (SunGro Horticulture; Alberta, Canada) to the fill line. Root cuttings were posi-

Kimberley Dennis

MEET THE STUDENT-AUTHOR

After graduating from Lee's Summit North High School in Kansas City, Mo., I enrolled at the University of Arkansas and graduated in the fall of 2005 with a B.S. in horticulture and a minor in global agriculture, food, and life sciences. While in college, I was involved in choir, a summer research internship in the Department of Plant Pathology, a community design project in Clarendon, Ark., and independent student research such as this project.

My undergraduate research has inspired me to attend graduate school, and I plan to apply for the spring semester of 2007. All of my undergraduate experiences have contributed to my goals for the future, and I cannot wait to apply all I have learned in a graduate program and a career. It has been an honor to be involved in the University of Arkansas' thriving scientific community.

tioned horizontally at a depth of 2.5-3.5 cm below the medium surface. Greenhouse temperatures were maintained at a minimum temperature of 20°C and a maximum temperature of 25°C. Cutting bins were watered as needed. The experimental design was a randomized block of 10 replications of three root cuttings per replication. After the initial planting of root cuttings on 27 Jan. 2005, shoots began to appear on 1 March, and shoots continued to be harvested every 3-4 days as they grew to a length of approximately 5 cm with two partially expanded leaves. This harvest continued until 4 Apr. One hundred-three total shoots from the two root-cutting treatments were transplanted into individual Jiffy® peat pellets (Jiffy Co., Batavia, Ill.), and were subsequently placed under an intermittent mist system that misted the cuttings for 8 s every 10 min until shoots had rooted. Each shoot rooted in approximately 2.5 weeks. Shoot harvest continued until 4 Apr. when shoot production had significantly diminished. Data collection included percent shoot production per week, total number of shoots produced, shoot rooting success, and average number of shoots per root cutting.

Experiment II: Cultural inputs in nursery production of APF-44

Shoot cuttings rooted in peat pellets were transplanted into black plastic pots with the same media volume (9,000 cm^3) but different pot dimensions: a "tall" Classic 1000-C® (25 cm top diam. x 23 cm tall) and a "squat" Classic 1200S-C® (28 cm top diam. x 19 cm tall) (Nursery Supplies Inc. (Chambersburg, Penn.). Transplanting began on 21 March and was completed on 4 April. On 30 April, potted plants were randomly arranged on an outdoor gravel pad. Plants were watered as needed using overhead impact sprinklers. Fertilizer rate and tipping treatments began on 13 May. The design was a randomized block of eight replications of eight of the following combination of treatments: 1) two pot dimensions (described above); 2) PolyOn 18-6-12, 8-9 month fertilizer topdress applied at a rate of 0.65 kg N/m^3 or 1.31 kg N/m^3; and 3) and the tipping treatment applied to half of the plants in mid-summer. On 13 May, all plants were tipped to 30 cm in preparation for the growing season, and the fertilizer treatments were applied. On 15 July, all flowers and developing berries were removed and the tipping treatment was applied to the appropriate plants; these plants were again reduced to 30 cm in length by this tipping. By 12 Oct., the study was concluded and the following data were collected: 1) shoot growth index (GI); 2) shoot fresh weight; and 3) qualitative measurements—flowering and fruiting, plant shape, internodal length, leaf color, etc.

RESULTS AND DISCUSSION

Experiment I:

Root length had a significant effect on the number of adventitious shoots produced. The average number of shoots per root cutting for short (7.6 cm) and long (15.2 cm) root cuttings was 1.6 and 2.7, respectively. This finding supports results from an earlier study (Thompson et al., 2004). Shoot collection began approximately 4 weeks after roots were placed in the medium. Shoot collection was greatest in the first 4 weeks of shoot emergence; after this point, shoot production was significantly decreased (Fig. 1). A total of 72.3% of shoots from the 7.6 cm roots was harvested in the first 4 weeks. Similarly, 84.8% of shoots from the 15.2 cm roots had been harvested in the same time period. All shoots were of similar quality, and shoots were collected at the same point in development. The percent survival was nearly 100% (data not shown). Similar rooting percentages were reported previously (Thompson et al., 2004). These results suggest that this method also is successful for propagation of this blackberry genotype. The shoots grew vigorously in the peat pellets and rooted in approximately 1-2 weeks.

Experiment II:

Fertilizer rates of 0.65 kg $N/m^3$and 1.31 kg N/m^3 had a significant effect on all plant growth parameters. Shoot fresh weights for plants grown at the low and high fertilizer rates were 155 and 400 gm, respectively (Table 1). Fertilizer rate also had an effect on the height of the plants; on average the plants with the lower fertilizer rate were 0.43 m tall versus 0.59 m for the higher rate (Table 1). In a similar way, average plant widths of the high-fertilizer-rate plants were greater than for those receiving the low fertilizer rate (Table 1). The plants that were not tipped averaged 0.47 m tall, whereas the plants that underwent the July tipping treatment were 0.55 m tall (non-signficant difference) (data not shown). All of the plants that were not tipped had a one-dimensional growth habit, with shoots tending to fall over and grow horizontally, while the tipped plants were more spreading and attractive (data not shown). No treatment resulted in plants with consistently different numbers of flowers or fruits (data not shown). Qualitatively, the plants with the best shape, leaf color, and size were the two tipped treatments and the higher fertilizer rate; pot dimension did not cause any aesthetic disparity (data not shown).

The main objective of these studies was to determine the propagation and production methods necessary to produce nursery-quality plants of APF-44 in a timely manner. As previous studies have concluded, root length plays a significant role in forcing adventitious shoots.

Longer roots produce more shoots – this is expected as they are simply longer. On the other hand, analysis of these values indicates that per 15.2 cm of root length, the shorter root produces more shoots on average for a similar length of space (i.e. 2 – 7.6 cm roots can produce 3.2 shoots per 15.2 cm, whereas the 15.2 cm roots produced 2.7 shoots in this study). This finding is of potential value to propagators, who need thousands of shoot cuttings. For instance, 2000 7.6 cm roots cuttings with a total root cutting length of 15,200 cm should yield 3200 shoots. Likewise, 1000 15.2 cm of root cuttings with the same 15,2000 cm total should yield 2700 shoots. On the other hand, shoot quality was the same for the two root lengths. In fact, shoot quality was maintained at an excellent level throughout the first portion of the experiment: all shoots rooted and indicated no nutrient deficiency. Thompson et al. (2004) noted the same observation with 'Apache', 'Arapaho', and 'Ouachita' blackberry cultivars.

Building upon an efficient propagation method, this study is the first to investigate plant management techniques that might create a nursery-quality, primocane-fruiting blackberry marketable to homeowners during autumn. After shoots had been rooted and potted and treatments were applied, disparities began to appear among the plants. Plants that were tipped in mid-summer and fertilized with the higher fertilizer rate displayed the intended mounded shape and short internodal lengths. On the other hand, the main objective of this portion of the experiment was not met; at the conclusion of the study, no plants had plentiful berry or flower displays. The negative effects of heat on flowering have been observed for APF-44, and this may explain the problem (John R. Clark, personal communication). Also, plants remaining in a juvenile state due to pruning may be less likely to flower (John R. Clark, personal communication). In this particular study, flowers were plentiful before the May flower/bud removal; after this time, plants rarely produced buds. Blackberry plants without berries in September are not marketable as a nursery-quality ornamental intended for autumn sale. Fortunately, it is possible that additional breeding might achieve more abundant blooming and increased heat tolerance for flowers and fruits.

Further studies might include use of an adult second-year plant, a different genotype identified with more abundant flowering in heat, or simply moving the study to a more temperate climate. The root cutting method was successful, and no improvements are suggested.

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Table 1. Effect of fertilizer rate on nursery plant shoot and plant growth parameters of APF-44 blackberry (APF-44 is a breeding selection and is not released to the public nor is it an item of commerce).

Fertilizer rate (kg N/m3)	Shoot fresh weight (g)	Shoot height (m)	Plant width 1 (m)	Plant width 2 (m)	GI[z] (m3)
0.65	155.3 b[y]	0.431 b	0.658 b	0.292 b	0.076 b
1.31	400.3 a	0.586 a	1.200 a	0.729 a	0.428 a

[z] GI = growth index. Calculated by the formula hr^2, where h is shoot height, r=0.5d, and d is the mean of two diameter measurements taken at 90° angle from each other.
[y]Mean separation by LSD, P<0.05.

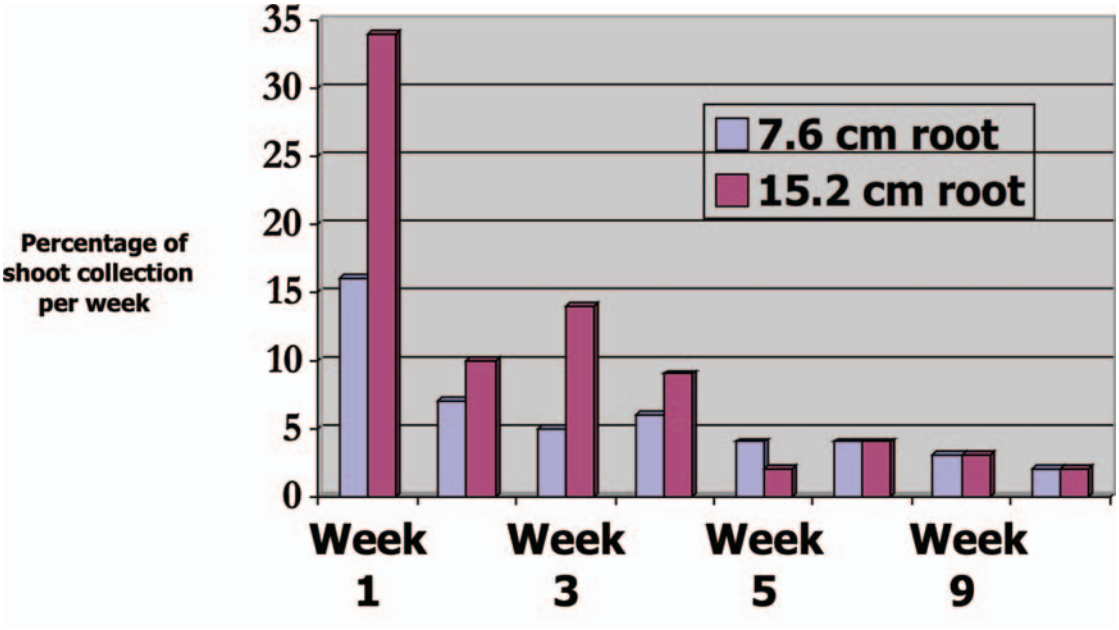

Fig. 1. Dates of adventitious shoot collection from APF-44 blackberry.

Initial evaluation of novel preparations of *Bordetella avium* by determination of antibody-response titers

Joel L. Gallagher[*], *Stacy E. Higgins*[†], *Luc Berghman*[§], *Billy M. Hargis*[‡]

ABSTRACT

The efficacy of killed vaccines generally is not equal to live vaccines. However, due to safety and ease of production, they remain a vital part of controlling and preventing diseases. In this study, the immune response to four different vaccination preparation techniques for the agent of bordetellosis of turkeys, *Bordetella avium* (BA), was compared. Preparation/inactivation techniques included (1) formalin inactivation, (2) opsonization of formalin-inactivated BA, (3) buffered acetic-acid BA inactivation, or (4) opsonization of buffered acetic-acid-inactivated BA. Non-adjuvated suspensions containing equal antigen mass were administered subcutaneously (0.2 mL) at day-of-hatch in all cases. For each treatment (N=40/treatment), plasma samples were obtained on d 6, 10, and 21. Specific antibody titer was determined by enzyme-linked immunosorbent assay (ELISA). Results were analyzed by percentage of responders, calculated by determination of sample-to-positive (S/P) ratio. At d 6, the formalin-killed vaccination caused the most rapid response with significantly higher S/P ratios than other treatments. At d 10 there were no significant differences between the treatments. By d 21, formalin-inactivated antigen produced the highest percentage of responders. In this preliminary experiment, neither buffered acetic-acid BA inactivation nor opsonization of inactivated BA antigen improved turkey poult responsiveness to this pathogen.

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INTRODUCTION

Bordetellosis is an extremely contagious poultry disease caused by the organism *Bordetella avium* (BA), a small, Gram-negative bacterium that colonizes in the ciliated epithelium of the trachea of young turkeys (poults). The disease is characterized by interference with the respiratory mucosa and symptoms include sneezing and oculonasal emissions (Skeeles and Arp, 1997). Although it is difficult to determine the precise economic loss to the poultry industry because the disease is often coupled with mortality and morbidity due to secondary infections, estimates of economic losses due to reduced body weight, reduced feed efficiency, and animal mortality are in the millions of dollars each year (USDA ARS, 2002).

Once infection has become apparent, treatments for bordetellosis have focused chiefly on antibiotic treatment rather than preventative care. This approach is slowly being phased out as the industry is moving away from using antibiotics in animals intended for human consumption (USDA ARS, 2002). Additionally, the emergence of antibiotic resistance has become a major concern worldwide. Indeed, several years ago in a document outlining strategies against microbial antibiotic resistance, the European Union labeled the situation as a "public health priority" and addressed the problem by taking steps to restrict antibiotic use to serious humans and animal health problems only (Commission of the European Communities, 2001).

Various studies have focused on treating the problem only after it arises with such treatments as the use of niacin (Yersin, 1991) and a novel oxy-halogen formula (Pardue and Luiginbuhl, 1998), both of which are administered through drinking water. Prevention in the form of vaccination is certainly the most effective as well as economic treatment, but current vaccines are not consistently protective. One research team explored the idea of passive immunity by isolating serum and tracheal remnants from convalescent poults, which resulted in a small reduction of adherence of *B. avium* to tracheal mucosa (Arp and Hellwig, 1988). A temperature-sensitive *B. avium* mutant known as ART-VAX, given via eyedrop/oral and spray cabinet protocols, showed a reduced severity of lesions although it failed to prevent infection upon challenge (Houghten and Skeeles, 1987). A formalin-inactivated bacterin also failed to produce consistent and long-lasting results under a challenge model (Hofstad and Jeska, 1985).

One promising method of vaccine production takes advantage of immune complexes, which are formed during an immune response to a foreign antigen through the binding of highly specific antibodies to a specific antigen. Introducing immune complexes to lymphoid follicles is thought to promote the creation of germinal centers, which in turn leads to the proliferation of memory B cells. This can result in increased antibody pro-

MEET THE STUDENT-AUTHOR

Joel L. Gallagher

After graduating from Ruston High School (La.) in 2002, I decided to attend the University of Arkansas and major in biology on the premedical track. Upon acceptance to the university, I was awarded the Chancellor's Scholarship, and during my junior year I was awarded the Gilbert Premedical Scholarship. I am member of the American Chemical Society, Alpha Epsilon Delta, and Golden Key International. I am also active with Catholic Campus Ministries, where I lead a student group that provides aid and advocacy for the poor.

During the spring semester of my freshman year, I began working for Dr. Hargis with his research on probiotic treatments for *Salmonella* enteriditis. I started my research project examining the immunological responses to novel *Bordetella avium* vaccines two years later, and then applied for and was awarded a State Undergraduate Research Fellowship (SURF) for two consecutive years. After graduation, I plan to pursue a career in medicine, specializing in pediatrics.

duction (Nayak et al., 1999; Nie et al., 1997; Kunkl and Klaus, 1981).

Although the precise mechanism remains uncertain, studies that examined the effects of immune complexes made with immunoglobulin-E (IgE) hypothesized that the increased antigen-specific response is due to efficient absorption of the complexes into B-cells via a low-affinity IgE receptor located on the B-cell surface. They also observed that the complexes specifically led to an increase in the number of immunoglobulin-G (IgG)-secreting cells, leading to the possibility of the existence of a secondary mode of antibody response that occurs without the need for priming (Westman et al., 1997). Complexes composed of equal amounts of antigen and antibody or a slight surplus of antigen had greater success at generating memory B-cells than antigen alone. The constant portion of the antibody appeared to be the key; the variable portion of the antibody protein proved to be less effective (Klaus and Humphrey, 1978). Immune complexes may also play a role in controlling the release of antigens by increasing the amount of time that immune cells are exposed to the antigen (Sah and Chien, 1996). Additional studies have shown that immune complexes resulted in a stronger localized response compared to the uncomplexed controls (Levy et al., 2001).

This concept of immune complexes has been incorporated into the development of a vaccine for infectious bursal disease virus (IBDV). Field trials have proven somewhat successful. Jeurissen et al. (1998) found that virus detection in the IBDV/complex group was delayed for 5 d compared to the IBDV group, and that germinal centers were much more prevalent in the spleens of the IBDV/complex chickens, demonstrating higher activity of B-lymphocytes in the IBDV/complex group. Although both treatments lead to depletion of B-cells in the bursal follicles, the reduction was less severe at all time points in the IBDV/complex group (Jeurissen et al., 1998). Using reverse-transcriptase PCR to detect the presence of IBDV in trials with the vaccine, it was found that the viral load peaked at d 17 for the SPF chickens and d 21 for the maternally immune broilers, eventually disappearing altogether as seroconversion occurred (Ivan et al., 2005). Another research team concluded that the IBDV/complex vaccine can be administered quite successfully as early as d 1 despite the presence of variable levels of maternal antibodies (Haddad et al., 1997).

Another area of vaccine production that can be improved upon is the inactivation method of killed vaccines. They are usually created by growing the organism of interest, and then adding formalin to ensure the organism is killed prior to administration via injection. Numerous vaccines have been created in this fashion, ranging from the Salk polio vaccine to diphtheria and tetanus vaccines. However, formalin will often cross-link proteins on the surface of cells through hydroxymethylene bridges and thus modify the three-dimensional protein structure within 24-48 hours of exposure (Metz et al., 2004; Werner et al., 2000; Rappuoli, 1997). Therefore, the animals might produce antibodies to artificial epitopes formed by the crosslinks rather than antibodies that are protective against live organisms during an actual infection. It is necessary to preserve antigenic structure in order to allow an adequate amount of antigen to be present for an extended period of time on the surface of dendritic follicular cells. This leads to the synthesizing of a higher number of B-memory cells specific to that antigen and hence a stronger immune response (Regenmortel, 1992).

The tendency of formalin to alter antigenic epitopes has been shown in several studies (Metz et al., 2003; Nencioni et al., 1991), especially with pertussis vaccines for humans. Clearly, formalin has the potential to alter the epitopes in a detrimental fashion. A more natural deactivation method is needed in order to avoid the potential outcomes associated with the use of formalin. An ideal deactivating agent would retain intact bacterial epitopes while inactivating the pathogen. Therefore, the objective of this study was to manufacture a killed vaccine that could be administered with a single injection and produce a strong, long-lasting immune response.

MATERIALS AND METHODS

Production of antibodies for immune complexes

Turkey-origin antibodies (Ab) were generated for use in these studies. Briefly, turkeys were injected twice with inactivated BA at 6 (10^{10} cfu) and 9 (10^{5} cfu) weeks of age. Serum obtained 10 d after the final injection was used for this experiment. Agar gel immunodiffusion (AGID) assays were used to estimate the relative titers for standardization during the opsonization process.

Vaccine production and administration

Four groups of vaccines were created – two batches killed with 3% formalin and two additional batches killed with 10% acetic-acid. One formalin and one acetic-acid group were complexed with the harvested turkey antibodies (Ab), while the two remaining formalin and acetic-acid groups were left uncomplexed (Table 1). The acetic-acid was buffered with the addition of NaOH to a pH of 4.75, which is near the pKa of acetic-acid. To create the complexed vaccines, *B. avium* was killed using methods described above, and dilutions of Ab were combined with 100 µl of *B. avium* at a concen-

tration of 10^9 cfu/ml on slides, stained with Trypan blue, and examined in a microscope. The least Ab dilution that displayed evidence of immune complexes with some loose bacteria present was selected for opsonization. Once the dilution was determined, the formalin-complexed and acetic-acid-complexed vaccines were prepared. A fifth group consisted of negative controls, which were injected with either a formalin or acetic-acid vehicle (0.2 ml/poult).

The vaccines were administered to poults on the day of hatch by subcutaneous injection (0.2 ml/poult at 5.68 x 10^9 cfu inactivated). Each group, consisting of 40 tagged poults each, was kept in separate pens furnished with heat lamps, feed, and water arranged in similar locations in each pen. Blood samples were obtained at d 6, 10, and 21 using 22-gauge needles and 5-ml syringes. In order to minimize clotting, heparin was used at a concentration of 20 units/ml. Each sample was centrifuged at 1500 RPM for 10 min and the plasma was isolated and stored in 1.5-ml microcentrifuge tubes at –20°C.

Titer determination

The antibody titer of each group at each time point was determined using an ELISA. The 96-well plates for the test were prepared and stored according to Hopkins et al. (1988), using 0.1M carbonate/bicarbonate buffer rather than 0.05M. Each plate contained triplicates of seven identical positive dilutions of serum from the hyperimmunized birds and triplicates of a negative dilution composed of pooled sera from the control group samples. These positives and negatives served as internal standards in each plate (Table 2).

A preliminary assay was conducted with selected dilutions of unknown samples to determine the appropriate dilution factor. From this preliminary assay, it was determined that a dilution of 1:25 provided the most reliable results while maintaining a feasible development time. Therefore, each unknown sample was diluted 25-fold and placed as duplicates into the remaining wells on each plate. The results from each plate were normalized using the internal standards and the absorption values of each of the unknowns were averaged. These values represented the relative titers between the samples. These relative titers provided a numerical measure of the amount of antibody present. In order to put the results into a more easily understood value, the sample-to-positive (S/P) ratio of each sample was calculated according to the below equation:

$$\frac{(Sample\ mean - NC\bar{x})}{(PC\bar{x} - NC\bar{x})}$$

where $NC\bar{x}$ represents the negative control mean and $PC\bar{x}$ represents the positive control mean. It was decided to use the 1:16,000 positive dilutions because it gave absorption readings around 2 absorption units. Readings around 2 absorption units indicated that those samples were on a part of the standard curve graph that was less sigmoidal and more linear. Using a more linear portion of the graph is more useful for titer predication purposes. This technique is widely used in various immunological contexts (Hendrick et al., 2005; Nagy et al., 2002). S/P ratios can even act as a rough estimate of the level of antibody in the serum (Snelson, 2003).

The mean, standard deviation, standard error, and probability were calculated using SAS (SAS, Inc., Cary, N.C.) statistics software to determine significant differences among groups. Differences are reported at $P<0.05$.

RESULTS AND DISCUSSION

S/P Ratios

Those samples that displayed a positive S/P ratio were said to have had an immune reaction to the vaccines. Alternatively, those with a negative S/P ratio were said to have little or no reaction. The graphs for each day depicted both the average positive and total average S/P ratio for each group in order to compare both the averages of those that responded and the total averages of responders and non-responders alike.

Percent of Positive S/P Ratios

All groups reacted to the vaccines to some extent (Fig. 1). More birds initially reacted to the formalin-inactivated group (F) compared to the acetic-acid-inactivated group (AA). However, by d 21, 50% of the acetic-acid group had responded. No obvious differences were evident until d 21. At d 21, percentages generated by both formalin groups (F/F+Ab) were higher than those induced by both acetic-acid groups (AA/AA+Ab), reaching levels commonly believed to be necessary for flock immunity. The formalin-complexed (F) group on d 21 had statistically higher coverage than either of the acetic-acid groups (AA/AA+Ab), although results were not statistically different than formalin inactivation (F) alone.

Day 6 S/P Ratios

It is possible that the negative values displayed in the S/P ratio averages could be a result of the presence of non-specific binding sites on the *B. avium* bacteria for the constant (Fc) portion of antibodies (Fig 2). However, this possibility was not evaluated in our study. Although all groups had some negative S/P ratio averages, the formalin group (F) was significantly higher than the acetic-acid-complexed group (AA+Ab) and not significantly different from the other two groups. The acetic-acid group (AA) and formalin-complexed group (F+Ab) were not significantly different than the other

groups. Of the birds that had a positive S/P ratio and hence did respond to the vaccine, no significance was observed in any of the groups.

Day 10 S/P Ratios

The averages on d 10, where intermediate responses were anticipated, were not elucidating. No significant differences existed in either the total averages or positive averages in any of the groups (Fig. 3). Due to the similarity of the formalin/formalin-complexed and acetic-acid/acetic-acid-complexed averages, especially the positive averages, it appears that the addition of immune complexes did nothing to aid in the immunological reaction to the vaccine.

Day 21 S/P Ratios

With regard to the positive S/P ratio averages, the formalin and formalin-complexed groups exhibited significantly higher averages than the acetic-acid-inactivated group. The acetic-acid-complexed group was not significantly different from any group. Including all birds increased the interpretability of these results. The formalin-complexed and formalin groups both featured significantly higher averages than the acetic-acid-complexed and acetic-acid groups (Figure 4).

The formalin-inactivated vaccines, which approached 80% positive antibody response, were superior to the acetic-acid-inactivated vaccines by d 21. Addition of immune complexes was not of any benefit. From this experiment, it does not appear that either opsonization or the acetic-acid method for inactivation of BA for vaccine generation offer improved methods for inactivated BA vaccination of turkeys.

Development of an improved vaccine for *Bordetella avium* would have implications on all species that are susceptible to infection by Bordetella species, including canines and humans. Improvement of killed vaccines in general would have repercussions for many of our current vaccines for various animal immunizations.

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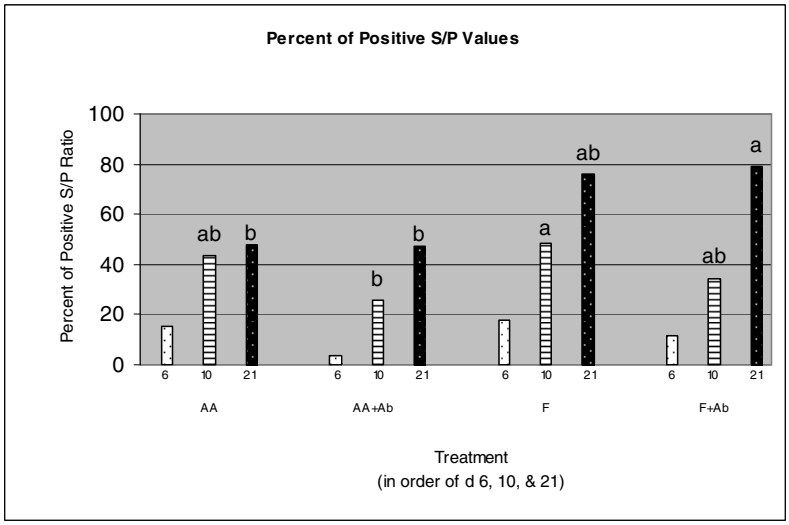

Fig 1. Percentages of each group with positive S/P ratios at day 6, 10 or 21. Histograms with different letters are significantly ($p<0.05$) different. Abbreviation of treatments are as follows: AA = acetic-acid, AA+Ab = acetic-acid-complexed, F = formalin, F+Ab = formalin-complexed.

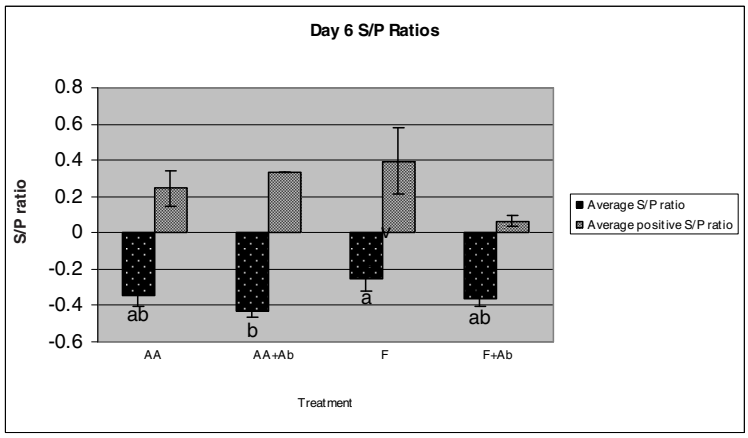

Fig 2. Averages of all S/P ratios and positive S/P ratios in each group as measured on day 6. Histograms with different letters are significantly ($p<0.05$) different. Abbreviation of treatments are as follows: AA = acetic-acid, AA+Ab = acetic-acid-complexed, F = formalin, F+Ab = formalin-complexed.

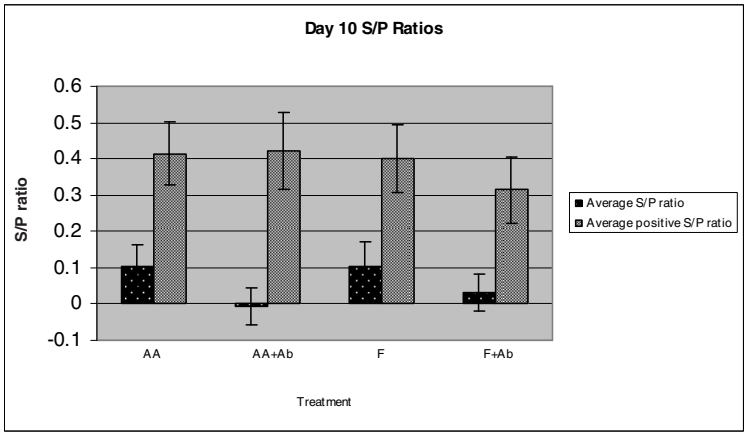

Fig 3. Averages of all S/P ratios and positive S/P ratios in each group as measured on day 10. Differences between groups were not significant ($p>0.05$). Abbreviation of treatments are as follows: AA = acetic-acid, AA+Ab = acetic-acid-complexed, F = formalin, F+Ab = formalin-complexed.

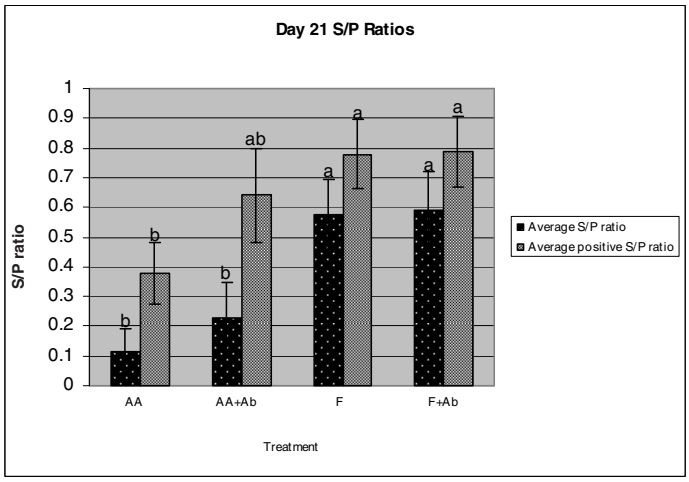

Fig 4. Averages of all S/P ratios and positive S/P ratios in each group as measured on day 21. Histograms with different letters are significantly ($p<0.05$) different. Abbreviation of treatments are as follows: AA = acetic-acid, AA+Ab = acetic-acid-complexed, F = formalin, F+Ab = formalin-complexed.

Table 1. Production process of the four vaccines and controls.

Grow *B. avium* (10^{10} CFU/ml)				0.9% Saline	
Kill using 10% AA @ pH 4.2-4.5 (AA)		Kill using 3% formalin (F)		Add 10% acetic acid @ pH 4.2-4.5 (AA)	Add 3% formalin (F)
Group 1 Complexed Acetic acid **AA+Ab** (*Ba* + Ab)	**Group 2** Uncomplexed acetic acid **AA** (*Ba* only)	**Group 3** Complexed formalin **F+Ab** (*Ba* + Ab)	**Group 4** Uncomplexed formalin **F** (*Ba* only)	**Group 5** Acetic acid negative controls (saline + AA)	**Group 6** Formalin negative controls (saline + F)

Effects of tank mixes of MON 3539 and selected compounds in RoundupReady Flex® cotton – 2005

Jarrod T. Hardke[*]*, Gus M. Lorenz*[†]*, Kyle Colwell*[§]*, and Craig Shelton*[‡]

ABSTRACT

Field experiments were conducted in 2005 to evaluate potential weed control interactions when MON 3539 (glyphosate) was applied with several insecticides and a plant growth regulator to RoundupReady Flex® cotton. Applications were made at the 1-3 leaf stage, the 6-8 node stage, and at the 12-14 node stage. Different combinations of tank mixes were used in each of the three applications. In the first application, all plots received the same treatment: MON 3539 at a rate of 0.75 lb ae/a. A second application was made to evaluate crop injury. Only the MON 3539 + Dimate (dimethoate) mixture significantly increased crop injury 7 days after treatment two (DAT2) when compared with MON 3539 alone (20 vs. 13% injury). Bidrin (dicrotophos), Trimax (imidacloprid), Mustang Max (zeta-cypermethrin), Karate Z (lambda-cyhalothrin), Baythroid (cyfluthrin), Intrepid (methoxyfenozide), Steward (indoxacarb), Denim (emamectin benzoate), insecticides or Mepichlor (mepiquat chloride) plant growth regulator in combination with MON 3539 showed less than 8% crop injury at 7 DAT2, which was significantly less than MON 3539 applied alone (13% injury). Crop injury ratings were taken following a third application and only the MON 3539 + Mepichlor mixture significantly increased crop injury at 7 days after treatment three (DAT3) when compared with MON 3539 alone (13 vs. 5% injury). None of the remaining treatments in the third application significantly differed from that of MON 3539 alone. Weed control rating indicated that MON 3539 + Centric (thiamethoxam) significantly reduced weed control at 15 DAT2 when compared with MON 3539 alone (72 vs. 84% control). MON 3539 tank mixed with each of the following significantly differed from the 95% rating of MON 3539 alone at 14 DAT3: Bidrin at 75%, Centric at 72%, and Denim at 79%.

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INTRODUCTION

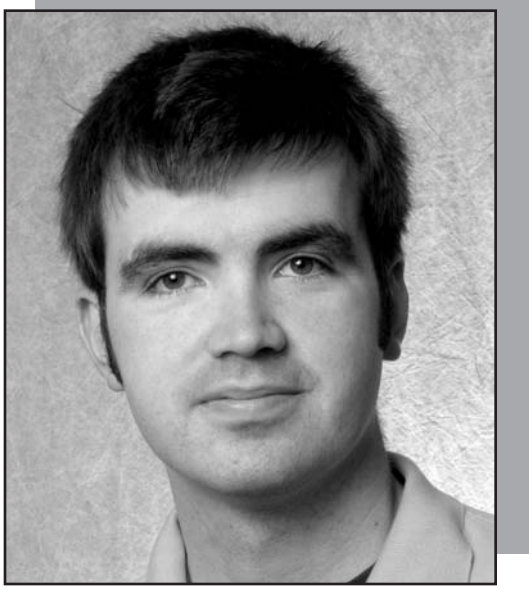
RoundupReady® cotton, which is tolerant to glyphosate herbicides, requires over-the-top herbicide applications before the cotton plant reaches the 5-leaf growth stage. During this period, environmental conditions such as rain and wind can make these applications difficult. RoundupReady Flex® cotton cultivars provide the ability to make over-the-top applications after the 5-leaf growth stage with higher rates of glyphosate. RoundupReady Flex® cotton has been found to show "excellent tolerance to POST glyphosate applications up to the 14-leaf cotton growth stage at rates two to three times higher than the current use rate in RoundupReady cotton" (Keeling et al., 2004). The ability to apply glyphosate later in the season allows mixing with insecticides as well as combining with the plant growth regulator (PGR), mepiquat chloride to control plant height.

During the 2002 growing season, an estimated 10% of the total cotton crop was lost due to weed infestation of grasses and broadleaves. This equates to 130,000 bales lost out of a total of 1,300,000 bale yield potential. From 1,615,035 bales classed, the revenue lost in Arkansas was $130,000 with the assumed price reduced by $0.03 per pound of lint (Byrd, 2003). Currently in Arkansas cotton, glyphosate is used in preplant-burndown situations for annual grasses and broadleaf weeds. It is also used in postemergence applications for the control of emerged annual grasses, johnsongrass, and numerous other weeds, including cocklebur, sicklepod, pigweed, morningglory, prickly sida, velvetleaf, hemp sesbania, northern jointvetch, and smartweed (Scott, 2004).

Antagonism/synergism resulting from the tank-mixture of glyphosate products with various insecticides have become important considerations in recent years. It has become a serious question as to whether it is feasible for a grower to mix glyphosate with insecticides to save application time and money. The ability to apply herbicides over-the-top of cotton past the 5-leaf growth stage will create an opportunity for growers to reduce production costs by the combination of glyphosate and

MEET THE STUDENT-AUTHOR

I am a 2002 graduate of Carlisle High School in Carlisle, Ark. I am currently a senior majoring in crop management and pest management with minors in agricultural business and environmental, soil & water science. Through the University I have received the Chancellor's Scholarship, and I have also received the Governor's Scholarship from the Arkansas Department of Higher Education. My future plans include attending graduate school to obtain my master's degree in entomology, and eventually, my doctorate. During the summer following my sophomore year of high school, I began working with the University of Arkansas Cooperative Extension Service in the Department of Entomology.



Jarrod T. Hardke

For the past six summers I have continued to work there as an agricultural technician. While working with Dr. Gus Lorenz over the years, I have had the opportunity to learn a great deal about agricultural research in the field of entomology. I have had the privilege of presenting my research at the Arkansas Crop Protection Association Conference in Fayetteville, Ark., and at the Beltwide Cotton Conference in San Antonio. I have participated in many activities at the University of Arkansas including serving as Vice President and House Manager of Kappa Sigma; serving as Event Coordinator for Greeks Advocating Mature Management of Alcohol; serving as a member of Student Alumni Board where I have been in charge of the homecoming parade the past two years; and being inducted into the Greek honor society, Order of Omega.

insecticides in a single operation (Mascarenhas and Griffin, 1997). This study investigate the mixing of various insecticides and a PGR, mepiquat chloride tank-mixed with glyphosate to determine any positive and/or negative effects.

MATERIALS AND METHODS

The experiment was conducted on Hooker Farms, Pine Bluff Ark., (Jefferson County) in 2005. MON B2RF, a non-commercial Monsanto cultivar, was planted on 6 May. The planted field was subdivided into plots of four rows (38-inch spacing), 30-feet in length. Plots were set up in a randomized complete block with four replications. Treatments were made according to statewide threshold recommendation. Treatments were applied with a CO_2 backpack applicator using a 4-row boom with Tee-Jet TXVS 6 nozzles on 19-inch spacing. Operating pressure was 40 pounds per square inch and volume applied was 10 gallons per acre. Three separate applications were made in this test. The first application was made 26 May at the 1-3 leaf stage. All plots were treated with MON 3539 (glyphosate) at a rate of 0.841 kg/ha (0.75 lb ae/a). The second application was made 14 June at the 6-8 node stage and consisted of MON 3539 alone as a control, or MON 3539 tank-mixed with selected insecticides or mepiquat chloride to determine the potential for crop injury (phytonecrosis) and/or loss of weed control. Treatments included MON 3539 at 0.841 kg/ha (0.75 lb ae/a) alone or mixed with one of the following: Orthene (acephate) at 1.12 kg/ha (1 lb a/a), Bidrin (dicrotophos) at 0.56 kg/ha (0.5 lb ai/a), Vydate C-LV (oxamyl) at 0.529 kg/ha (0.47125 lb ai/a), Dimethoate at 0.56 kg/ha (0.5 lb a/a), Trimax (imidacloprid) at 0.053 kg/ha (0.0469 lb ai/a), Centric (thiamethoxam) at 0.056 kg/ha (0.05 lb ai/a), Mustang Max (zeta-cypermethrin) at 0.028 kg/ha (0.025 lb ai/a), Karate Z (lamba-cyhalothrin) at 0.045 kg/ha (0.04 lb ai/a), Baythroid (cyfluthrin) at 0.056 kg/ha (0.05 lb ai/a), Intrepid (methoxyfenozide) at 0.18 kg/ha (0.16 lb ai/a), Steward (indoxacarb) at 0.123 kg/ha (0.11 lb ai/a), Tracer (spinosad) at 0.095 kg/ha (0.085 lb ai/a), Denim (emamectin benzoate) at 0.017 kg/ha (0.015 lb ai/a), and a Mepichlor (mepiquat chloride) at 1.76 l/ha (24 oz/a). The third application was made 30 June at the 12-14 node stage. All treatments remained the same as in the second application, except that Bidrin at a rate of 0.35 kg/ha (0.312 lb ai/a) was added to the tank mix with Mustang Max, Karate Z, and Baythroid. Weed control was visually rated on a scale of 0 to 100% where 0 = no control and 100 = all weeds dead. Crop injury was visually rated on a scale of 0 to 100% where 0 = no crop injury and 100 = total crop injury/all plants dead. Observations were conducted for crop injury on 21 June at 7 days after treatment two (DAT2), and for weed control on 29 June at 15 DAT2. For the third application, crop injury ratings were taken on 7 July at 7 DAT3 and ratings for weed control were taken on 14 July at 14 DAT3. Data were analyzed using Agricultural Research Manager Version 7 using Analysis of Variance and LSD (P=0.10).

RESULTS AND DISCUSSION

Results from the ratings after the second application for crop injury indicated that the 0.841 kg/ha (0.75 lb ae/a) rate of MON 3539 showed 13% phytonecrosis at 7 days after treatment two (DAT2)(Table 1). All other treatments ranged from 4 to 20% phytonecrosis. MON 3539 tank mixed with Dimate had the highest rating of 20% phytonecrosis, which significantly differed from that of MON 3539 alone. Several treatments (tank-mixed with MON 3539) showed significantly lower phytonecrosis than MON 3539 alone at 7 DAT2 (Table 1): Bidrin, Trimax, Mustang Max, Karate, Baythroid, Intrepid, Steward, Denim, and Mepichlor. All other treatments did not differ significantly. Weed control in all treatment combinations ranged from 71% to 98% when evaluated 15 DAT2, with MON 3539 having a rating of 84% weed control (Table 1). The only treatment that significantly differed from MON 3539 in weed control at 15 DAT2 was Centric mixed with MON 3539. All other treatments did not significantly differ from that of MON 3539 alone. However, three treatments – Mustang Max, Trimax, and Steward – differed significantly from MON 3539 + Bidrin and MON 3539 + Centric.

Results from evaluations after the third application are indicated MON 3539 had a rating of 5% phytonecrosis at 7 DAT3 (Table 2). All other treatments ranged from 5 to 13% phytonecrosis. Only the treatment of MON 3539 tank-mixed with Mepichlor had significantly higher phytonecrosis than MON 3539 alone and than MON 3539 tank mixed with Vydate, Baythroid + Bidrin, and Intrepid (Table 2). Weed control in all treatment combinations ranged from 72% to 98% at 14 DAT3, with MON 3539 alone having a rating of 95% control (Table 2). MON 3539 tank mixed with Bidrin, Centric, and Denim showed ratings of 75, 72, and 79% percent control, respectively, which significantly differed from MON 3539 alone and from all other treatments (Table 2).

It should be noted that problems occurred in the tank when mixing certain compounds with MON 3539. Severe flocculation was observed when tank-mixing Trimax with MON 3539. This tank mix was repeated in

the lab with the same general results. A new container of Trimax was used to attempt the tank mix again, causing only minimal flocculation, which was difficult to detect. Finally, the latest experimental formulation of Trimax was used and no flocculation was observed. Settling was observed when Orthene was tank-mixed with MON 3539. When the tank was allowed to remain at rest for more than a few minutes, material in the tank settled to the bottom. This phenomenon was easily corrected by simple agitation. It should be noted that proper, steady agitation may be needed to prevent settling of materials when tank-mixing Orthene with MON 3539.

Certain compounds tank-mixed with MON 3539 in this study showed a significant difference in weed-control effectiveness of MON 3539. MON 3539 tank-mixed with Centric showed a loss of weed control 15 DAT2 and at 14 DAT3. MON 3539 tank-mixed with Bidrin and with Denim showed losses of weed control at 14 DAT3. In regard to crop phytonecrosis, Dimate significantly differed from that of MON 3539 alone at 7 DAT2, as did Mepichlor at 7 DAT3.

ACKNOWLEDGMENTS

The authors would like to thank Chuck Hooker for providing a test location and Monsanto for their support of this study.

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Table 1. Weed control and phytonecrosis ratings of MON 3539 alone and tank-mixed with selected compounds

Ratings based on a scale of 0-100% phytonecrosis and 0-100% weed control			
		Phytonecrosis[z]	Weed Control[z]
Treatment and Rate	Rate	7 DAT2	15 DAT2
MON 3539 (Glyphosate)	0.841 kg/ha (0.75 lb ae/a)	13 b[y]	84 ab
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Orthene (Acephate)	1.12 kg/ha (1.0 lb ai/a)	9 bcd	94 ab
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Bidrin (Dicrotophos)	0.56 kg/ha (0.5 lb ai/a)	6 cd	80 b
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Vydate C-LV (Oxamyl)	0.529 kg/ha (0.47125 lb ai/a)	11 bc	92 ab
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Dimate (Dimethoate)	0.56 kg/ha (0.5 lb ai/a)	20 a	94 ab
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Trimax (Imidacloprid)	0.053 kg/ha (0.0469 lb ai/a)	6 cd	97 a
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Centric (Thiamethoxam)	0.056 kg/ha (0.05 lb ai/a)	13 b	71 c
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
cypermethrin)	0.028 kg/ha (0.025 lb ai/a)	4 d	98 a
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Karate Z (Lamba-cyhalothrin)	0.045 kg/ha (0.04 lb ai/a)	4 d	90 ab
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Baythroid (Cyfluthrin)	0.056 kg/ha (0.05 lb ai/a)	4 d	95 ab
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Intrepid (Methoxyfenozide)	0.18 kg/ha (0.16 lb ai/a)	8 cd	90 ab
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Steward (Indoxacarb)	0.123 kg/ha (0.11 lb ai/a)	7 cd	97 a
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Tracer (Spinosad)	0.095 kg/ha (0.085 lb ai/a)	9 bcd	94 ab
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Denim (Emamectin benzoate)	0.017 kg/ha (0.015 lb ai/a)	6 cd	83 ab
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Mepichlor (Mepiquat chloride)	1.76 l/ha (24 oz/a)	5 d	89 ab

[z] Application date: 14 June (second application)

Evaluation date: 21 June (7 DAT), 29 July (15 DAT)

[y] Means followed by same letter do not significantly differ (P=0.10, Student-Newman-Keuls).

Table 2. Weed control and phytonecrosis ratings of MON 3539 alone and tank-mixed with selected compounds

Ratings based on a scale of 0-100% phytonecrosis and 0-100% weed control			
		Phytonecrosis[z]	Weed Control[z]
Treatment and Rate	Rate	7 DAT3	14 DAT3
MON 3539 (Glyphosate)	0.841 kg/ha (0.75 lb ae/a)	5 b[y]	95 a
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Orthene (Acephate)	1.12 kg/ha (1.0 lb ai/a)	6 b	96 a
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Bidrin (Dicrotophos)	0.56 kg/ha (0.5 lb ai/a)	9 ab	75 c
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Vydate C-LV (Oxamyl)	0.529 kg/ha (0.47125 lb ai/a)	5 b	91 a
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Dimate (Dimethoate)	0.56 kg/ha (0.5 lb ai/a)	10 ab	96 a
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Trimax (Imidacloprid)	0.053 kg/ha (0.0469 lb ai/a)	6 b	90 ab
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Centric (Thiamethoxam)	0.056 kg/ha (0.05 lb ai/a)	6 b	72 c
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
cypermethrin) +	0.028 kg/ha (0.025 lb ai/a)		
Bidrin (Dicrotophos)	0.35 kg/ha (0.312 lb ai/a)	6 b	98 a
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
cyhalothrin) +	0.045 kg/ha (0.04 lb ai/a)		
Bidrin (Dicrotophos)	0.35 kg/ha (0.312 lb ai/a)	6 b	85 ab
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Baythroid (Cyfluthrin) +	0.056 kg/ha (0.05 lb ai/a)		
Bidrin (Dicrotophos)	0.35 kg/ha (0.312 lb ai/a)	5 b	89 ab
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Intrepid (Methoxyfenozide)	0.18 kg/ha (0.16 lb ai/a)	5 b	95 a
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Steward (Indoxacarb)	0.123 kg/ha (0.11 lb ai/a)	8 b	97 a
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Tracer (Spinosad)	0.095 kg/ha (0.085 lb ai/a)	8 b	97 a
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Denim (Emamectin benzoate)	0.017 kg/ha (0.015 lb ai/a)	9 ab	79 bc
MON 3539 +	0.841 kg/ha (0.75 lb ae/a)		
Mepichlor (Mepiquat chloride)	1.76 l/ha (24 oz/a)	13 a	86 ab

[z]Application Date: 30 June (Third Application)

Evaluation Date: 7 July (7 DAT), 14 July (14 DAT)

[y]Means followed by same letter do not significantly differ (P=0.10, Student-Newman-Keuls).

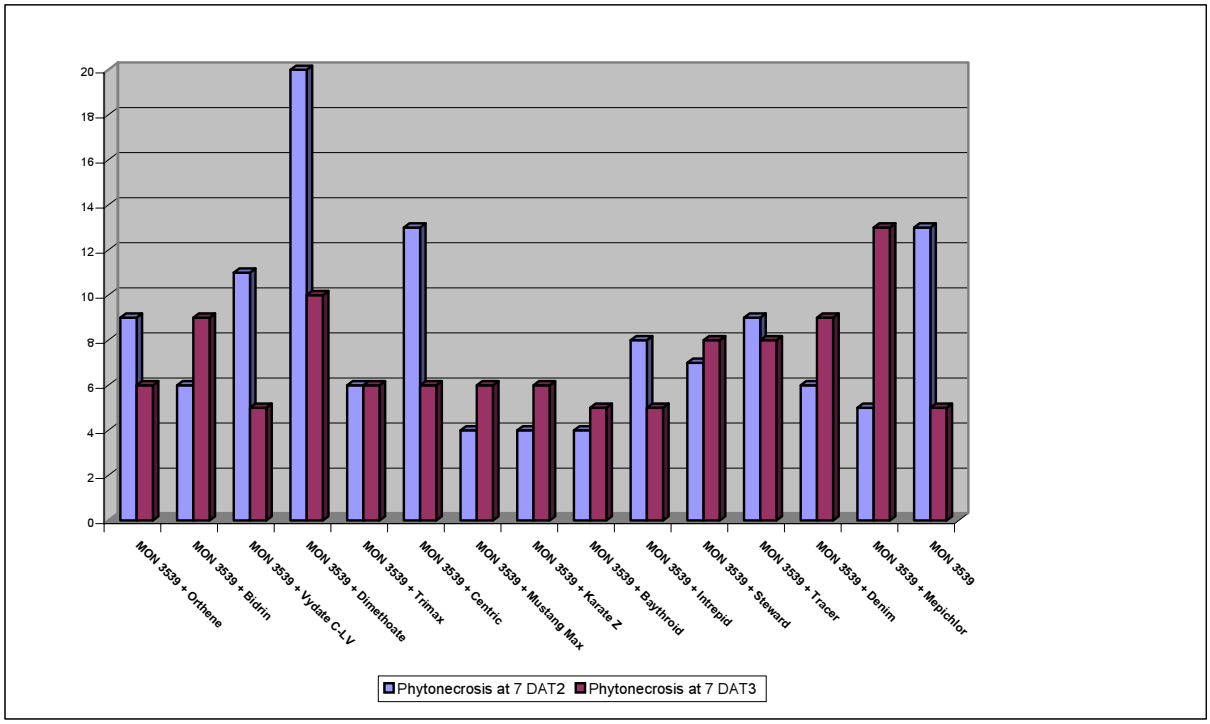

Fig. 1. Comparison of phytonecrosis ratings after treatments 2 & 3

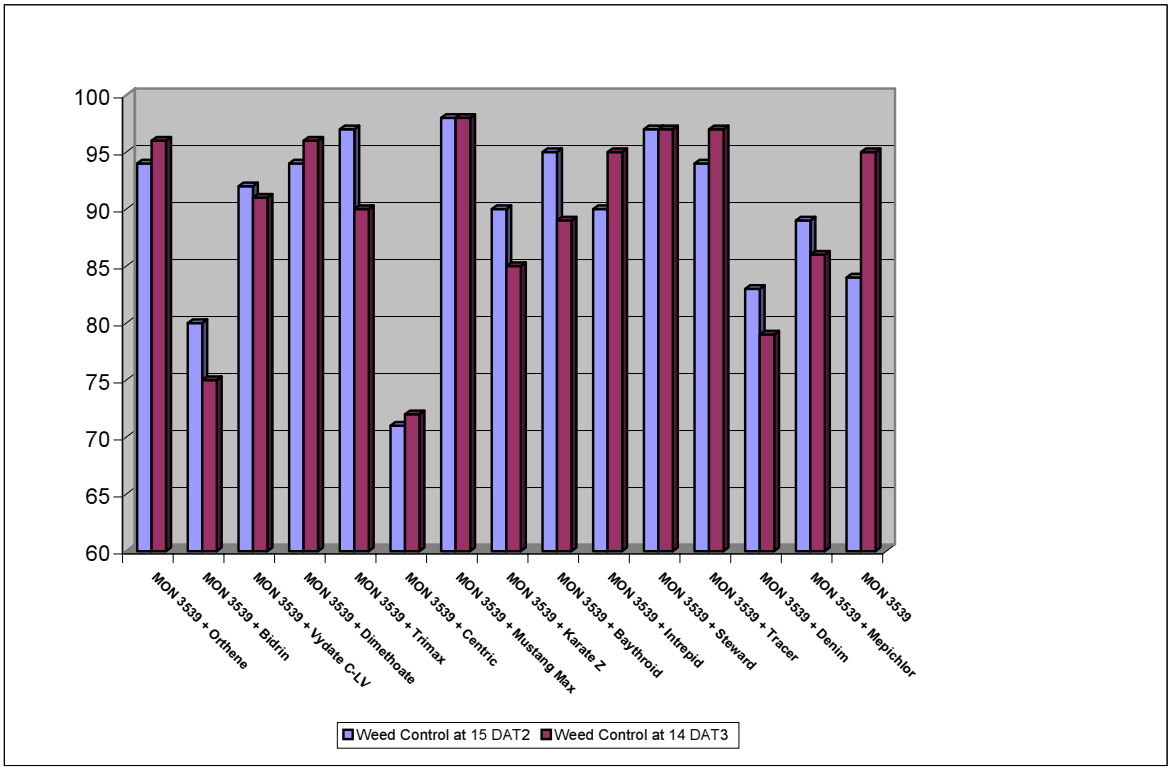

Fig. 2. Comparison of weed control ratings after treatments 2 & 3

Water quality issues in the Illinois River watershed: A proposal for new voluntary incentives

Tory B. Hodges[*] *and Jennie S. Popp*[†]

ABSTRACT

Concerns about water quality degradation exist in Northwest Arkansas. The purpose of this study was to analyze the potential usefulness of U.S. conservation programs in addressing water quality concerns on farms in the Illinois River watershed as well as greater Washington County, Arkansas. It was hypothesized that neither the Environmental Quality Incentives Program (EQIP) nor the Conservation Security Program (CSP) in their current forms effectively assists farmers in meeting water-quality management goals. That hypothesis was tested by 1) examining agricultural characteristics of the watershed, 2) actual adoption of EQIP and CSP in Washington County and Arkansas, and, 3) identifying factors that influence program adoption. Results show that based on watershed and farmer characteristics, neither program can meet water quality goals for the region. EQIP adoption is hindered by high rejection rates of applications and farmer dissatisfaction with the program. CSP adoption is unlikely because it does not consider watersheds with degraded water quality and allowable best management practices (BMPs) do not include those related to waste management – precisely the practices most often used by these watershed farmers. Suggestions are offered to modify both EQIP and CSP and use them as a two-part plan to better serve the needs of farmers and improve both adoption rates of BMPs by farmers and water quality in the region.

[*] Tory B. Hodges is a 2006 graduate with a degree in agribusiness

[†] Jennie S. Popp, faculty sponsor, is an associate professor in the Department of Agricultural Economics and Agribusiness

MEET THE STUDENT-AUTHOR

Tory B. Hodges

I graduated from Alpena High School, Alpena, Ark., in 2002 and enrolled at the University of Arkansas in the fall as an agribusiness major. While studying abroad as a UA junior at Oxford University, I researched the Common Agriculture Policy and farm conservation programs specific to England. As a senior I worked with Dr. Jennie Popp in the Department of Agricultural Economics and Agribusiness (AEAB) to explore similar conservation programs in the United States. I was awarded a Student Undergraduate Research Award in 2006 and presented my research at the National Conference for Undergraduate Research at the University of North Carolina in Asheville, N.C.

For four years, I have been actively involved in the AEAB Department; in 2005-2006 I served as president of the Agribusiness Club and was honored with the Outstanding Senior Award from the department and with the college's John W. White Undergraduate Award. I am graduating summa cum laude in May 2006 and will be attending Vanderbilt Law School in the fall as a Harold Sterling Vanderbilt Scholar.

I would like to thank Dr. Jennie Popp for her guidance in my research project. Also, I would like to acknowledge Dr. Martin Redfern and Dr. Duane Wolf for their active participation on my research committee.

INTRODUCTION

The Illinois River begins in Washington County, Arkansas, and flows east into Oklahoma. Oklahoma received approval from the Environmental Protection Agency (EPA) to set a 0.037 mg/L limit on the amount of phosphorus (P) in the river as it crosses the Oklahoma border. This effort has farmers, legislators, and community leaders at odds. Phosphorus is found in high concentrations in animal waste, such as poultry litter. Litter is used as fertilizer on pastureland and if applied in excess amounts, litter can run off the land and into Illinois River and its tributaries. This could reduce water quality and negatively impact the water recreation industry in Oklahoma. The poultry and cattle industries also play a crucial role in the area's economy. Therefore, means are needed to sustain water quality without reducing the economic vitality of the region.

Washington County has 2,800 farms (USDA, NASS, 2004). Beef cattle production dominates the agricultural activities within the county and the watershed. Half of the county's farms include roughly 20 ha of hay production. Broiler production makes up roughly 10% of farms in Washington County (USDA NASS, 2004) but roughly 20% of farms in the Illinois River watershed (J. Gunsaulis, personal communication). A typical broiler producer has four houses and raises five flocks of birds (or 110,000 birds) that generate 218 metric tons of litter per year (S. Watkins, personal communication). Many of the poultry and cattle producers apply litter to their land. Some have also adopted Best Management Practices (BMPs) to address water quality issues including building stacking sheds, applying alum, constructing ponds and water facilities, composting, using buffer strips, and pasture and hayland improvements. However, BMPs can be costly and often require technical expertise to use effectively.

Traditionally, U.S. conservation efforts have targeted the reduction of existing resource quality problems. The Environmental Quality Incentives Program, or EQIP, provides farmers with cost share and technical assistance to adopt BMPs. An EQIP contract, which can last up to 20 years, can provide a BMP cost share of 50 to100%; however, that payment comes as a reimbursement after BMPs are in place (USDA NRCS, 2006a, 2006b).

A newer approach to water quality preservation in the

U.S. is environmental incentives programs that offer payments to landowners who take specific steps to improve resource quality. The Conservation Security Program (CSP) financially rewards land managers for high stewardship levels. Producers qualify for one of three tiers, determined by how well they address resource concerns on their land (USDA, NRCS, 2005). They receive a base payment (or rental rate) and cost share for select BMPs. While CSP is available nationwide, sign-up is only offered in watersheds that meet specific criteria. Qualifying farmers in seven Arkansas watersheds are eligible for CSP payments in 2006 (D. Mobley, personal communication).

Previous research by Hodges (forthcoming) has examined rationale for such environmental programs. Others have examined program efficiencies and policy development. While EQIP and CSP offer incentives to farmers, they also have components that can limit farmer access to or interest in the programs (Hodges, 2006; Giannakas and Kaplan, 2005; Smith and Weinberg, 2004; Wu and Babcock, 1996). The purpose of this paper is to examine actual and potential adoption of EQIP and CSP in the Illinois River watershed and greater Washington County and to propose alternatives to better facilitate the meeting of water quality goals in the region.

MATERIALS AND METHODS

The analysis took place in three parts. First, information on BMPs and farmer participation in EQIP was gathered from Moore and Edwards (2005), United States Department of Agriculture Natural Resource Conservation Service (USDA NRCS) (2006a, 20006b, and 2006c) and USDA NRCS and University of Arkansas personnel. Second, CSP criteria (USDA NRCS, 2002, 2004, 2005) were applied to Washington County to determine if the Illinois River Watershed is likely to be recommended for the CSP program. Finally, those results were used to develop recommendations for better conservation and incentive program implementation and adoption.

RESULTS AND DISCUSSION

Cost considerations of BMPs

The mentioned common BMPs are eligible for cost share through EQIP. Most practices are eligible for 50% cost share; waste storage facilities and amendment alum receive 75 and 100%, respectively. However, the total cost to establish these practices can be expensive. For example, it costs approximately $392.20 per typical 1,486 m^2 broiler house to purchase and spread 725.8 kg of alum; total costs exceed $1,500 annually if a farmer has four houses. Watering facilities may cost $800 for a freeze proof tank but up to $3,000 for a typical pond. An appropriate litter stacking shed may cost $11,400 but a farmer with four houses may need two, for a total cost of $22,800. EQIP could substantially reduce the net cost—cost after cost share—to the farmer for these practices.

Evaluation of EQIP

Surprisingly, very few EQIP contracts exist in the watershed and across the state. In 2003 only 4,606 (10%) farmers in the state made applications to EQIP. Of those only 570 farmers (just 1% of state farmers) secured contracts. Only 4% of (108) Washington County farmers applied for and only seven farmers secured a contract. By 2005, the number of approved contracts doubled in Washington County to 14 and average total contract value had increased to $43,380. Similar gains were found statewide. However, this still represents a small percentage of farmers in Arkansas EQIP.

In Arkansas, EQIP has stalled for two reasons. First, application rejection rates are very high; second, very few farmers have applied. The official reason cited for high rejection rates is that applicants generally failed to meet high-or medium- priority criteria, criteria that are set at the state level. Additionally, these criteria generally require adoption of a larger mix of BMPs than farmers have proposed.

Farmers have offered the following reasons for their lack of participation in the program. First, EQIP requires the adoption of too many costly practices. Second, in Arkansas, the reimbursement process has been slow for many. Third, some farmers find it difficult or costly to meet BMP guidelines provided in the NRCS technical guide. Fourth, EQIP contracts require maintenance of the practice for its "life" that could span 10 to 20 years. Farmers who wish to terminate their contract earlier could risk financial penalties. Farmers have also expressed confusion over the ever-changing focus of the program (new priority areas can be set each year). Finally, farmers rarely reapply if ever denied a contract. These reasons suggest that participation in EQIP in the watershed and the county will remain low and therefore, EQIP is not an effective means to seriously address water quality concerns in the region.

Evaluation of CSP

CSP is not likely to be implemented in the Illinois River watershed. Two sets of criteria are used to determine watershed eligibility for CSP. The first relates to technical resources and abilities of local NRCS staff to manage a program. The other is related to high-priority resource issues and good land stewardship in the region. While the Washington County NRCS office likely meets the technical requirements, the watershed itself fails the test of consistent and good land stewardship. Because

this watershed includes impaired waterways, it would receive very low scores in the CSP prioritization process.

Even if the program was implemented, it would still be very difficult for many farmers in the Illinois River watershed to benefit from participation. While there is a long list of approved conservation practices under CSP (USDA NRCS, 2002), none of them include the common waste disposal/control practices (alum, stacking sheds, or composting) adopted in the region.

Suggested alternatives for improving water quality

The following suggestions are proposed for improving BMP adoption in the watershed. First, the current EQIP program could be enhanced to increase farmer participation. By cutting the length of most EQIP contracts to five years, producers may be more motivated to enter into an agreement. Increases in cost-share rates to 75% for most practices and improved efficiency in payments may render BMPs economically viable for more producers.

Second, modifying CSP to be compatible with EQIP could be beneficial to long-term success in the Illinois River watershed. Currently, CSP only targets pristine watersheds. If adopted in conjunction with EQIP, annual funding could be directed toward regions with high participation in the five-year EQIP agreements and with the greatest resource improvements made in that five-year period. Furthermore, funding would be available for all BMPs including those pertaining to waste management.

This two-part program could offer producers significant benefits. By implementing CSP in watersheds that have effectively utilized EQIP to make environmental improvements, farmers could be eligible for one-time cost-share payments during the EQIP contract period as well as annual rental payments after the five years, once the EQIP contract period is over and their CSP contracts have been secured. Ideally, farmers would continually improve land stewardship by participating in EQIP then moving through the three tiers of CSP until watershed degradation has been effectively eliminated. Combined with a well-funded EQIP program, incentives similar to CSP could have a tremendous impact on the water quality and environmental practices of producers in Northwest Arkansas.

ACKNOWLEDGMENTS

Financial support for this project was provided by a State Undergraduate Research Fellowship (SURF) and a Dale Bumpers College of Agricultural, Food and Life Sciences Undergraduate Research grant. The authors wish to thank Mr. Kenneth Lee, Mr. Dennis Mobley, and Ms. Rhonda Foster of USDA NRCS and Dr. H.L. Goodwin and Dr. Susan Watkins of the University of Arkansas for their help and support with the overall undergraduate research project, of which this paper represents one part.

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Estimating surface runoff in the Illinois River Basin for the management of nonpoint-source phosphorus loads

Adam T. McClymont[*], *Mary C. Savin*[†], *and Brian E. Haggard*[§]

ABSTRACT

With the growing concern about elevated phosphorus (P) concentrations in regional lakes, rivers, and streams, it is essential to investigate factors contributing to P transport from the landscape. Phosphorus fluxes from nonpoint sources, particularly land applications of poultry litter and other animal manures, are closely related to the amount and production of surface runoff. Daily stream discharge and the software program, Base Flow Index (BFI), were used to estimate the amount and temporal patterns of surface runoff at different locations within the Illinois River Basin, including selected tributaries in northwest Arkansas and northeast Oklahoma. Daily streamflow data from nine U.S. Geological Survey discharge stations were imported into the BFI program to estimate base flow, where surface runoff was the difference between total streamflow and base flow. Surface runoff was found to be greatest during spring and winter (November-June), and least during the summer and early fall (July-October). Land on which poultry litter and other animal manures are applied during the summer and early fall when runoff is less could pose less risk of P transport, likely helping to minimize nonpoint source P loads introduced into the Illinois River.

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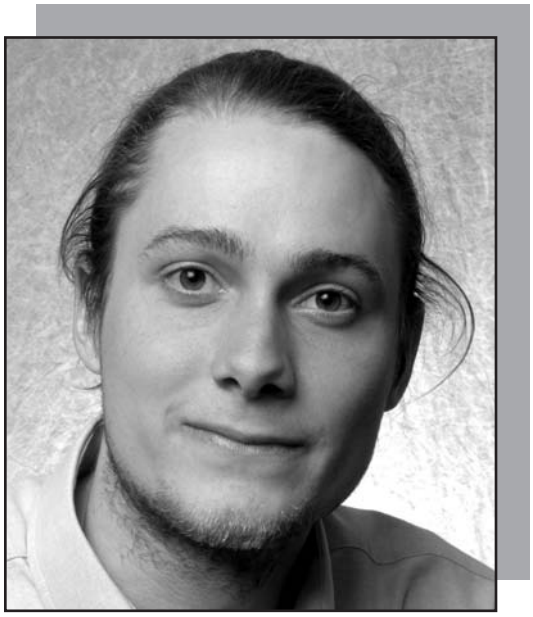
MEET THE STUDENT-AUTHOR



Adam T. McClymont

I am from Ferndale, Ark., and graduated from the Arkansas School for Mathematics, Sciences, and the Arts in 2002. I am majoring in environmental, soil, and water sciences, and will graduate in 2006. During my career at the University of Arkansas I worked for two years in cotton physiology under Dr. Derrick Oosterhuis, and in fall 2004 studied at the Scottish Agricultural College, Edinburgh. After returning in spring 2005 I began working under Dr. Mary Savin in soil microbiology and ecology. My interest in the outdoors led not only to a passion for northwest Arkansas, but also to an internship with the Rocky Mountain Field Institute during summer 2005.

About that time I became interested in the project presented in this paper through conversations with Drs. Tommy Daniel and Brian Haggard. Since then I have also begun work on antibiotic resistance in local streams under Dr. Savin and am excited about continuing this research as a graduate student at the University of Arkansas. I would like to thank those mentioned above for their support and encouragement of my academic career and interests.

INTRODUCTION

Nonpoint source (NPS) pollution has been identified as a major source of phosphorus (P) loading in waterways. NPS pollution contributes more than 80% of P loads to surface waters in the United States (Carpenter et al., 1998). Agriculture and confined animal feeding operations are an important component of NPS pollution because of the practice of land applying fertilizers, poultry litter, and other animal manures. Long-term applications of fertilizers and manures can lead to the build-up of P near the soil surface and can increase the potential for P to be transported from the land surface into waterways (Kingery et al., 1994).

Algal blooms are often a consequence of excessive P loading to waterways and can have several negative effects. The excessive growth and subsequent decomposition of dead algae results in anoxic conditions, which damage the health of freshwater ecosystems (Carpenter et al., 1998). Drinking-water supplies are degraded from the release of secondary compounds (e.g. geosmin, 2-methylisoborneol) from excessive algal production that are difficult and expensive to remove in drinking-water treatment facilities and result in an unpleasant odor and taste in finished drinking water (Smith, 1998; Wnorowski, 1992). The aesthetic problem of taste and odor in drinking water has resulted in lawsuits over elevated P loading from the landscape into drinking water-supply reservoirs.

The amount of NPS-P loading is strongly related to the amount of surface runoff that occurs from a given area. In order to minimize NPS-P loading it is necessary to plan land applications of fertilizers and manures during times when the risk of runoff is lowest. Surface runoff occurs when the amount of precipitation exceeds the amount of water infiltrating the soil, such as during rainfall events of high intensity. Rainfall events that are long or frequent increase the potential for runoff due to soils becoming saturated with water. Land surfaces with higher slope, higher amounts of disturbance, less vegetation, and less permeable surface area have an increased potential for surface runoff (Brady and Weil, 2002).

The objective of this study was to determine the amount of surface runoff that occurs within a month using actual streamflow data from the Illinois River Basin and hydrograph separation techniques. These estimated surface-runoff data were used to determine months of high and low surface-runoff production in the Illinois River Basin. The Illinois River Basin is a trans-boundary watershed situated in northwest Arkansas and northeast Oklahoma that has been the focus of environmental, scientific, and political debates since the early 1990s. This basin contains a large num-

ber of poultry and cattle operations where poultry litters are land-applied to fertilize pastures and haylands. This study provides surface-runoff data that will be used to guide poultry litter application in the Illinois River Basin and to define application-timing factors for use in a P index that manages land applications of P. It was hypothesized that monthly runoff estimates will display a unique temporal pattern in the Illinois River Basin, similar to that observed in the Eucha-Spavinaw Basin (DeLaune et al., 2006).

MATERIALS AND METHODS

Sub-basins of the Illinois River (Table 1) were chosen based on the availability of at least 10 years of daily streamflow data available from the National Water Information Systems (NWIS) database of the U.S. Geological Survey (USGS) Arkansas Water Resources (USGS, 2005). Sufficient data were available from nine sites located in the Illinois River basin in northwest Arkansas, including the Illinois River at Savoy, Osage Creek near Cave Springs, Osage Creek near Elm Springs, the Illinois River at Hwy. 16, the Illinois River south of Siloam Springs, Flint Creek at Springtown, Baron Fork at Dutch Mills; and in northeast Oklahoma, including Flint Creek near west Siloam Springs, and Lee Creek near Short. Daily streamflow was downloaded from the on-line NWIS database for these sites and used to determine the daily estimates of base-flow discharge and surface-runoff discharge. Daily streamflow was separated into base-flow and surface-runoff discharge using the Base Flow Index (BFI) program (Wahl and Wahl, 1995), instead of manual hydrograph separation. The BFI is a computer program developed by Wahl and Wahl (1995) for separating base flow from total streamflow using hydrographs, which chart streamflow over time.

The BFI operates on a partition length (N) and turning point test factor (F). The program divides the hydrograph into N-day periods (based on partition lengths), and within each N-day period, minimum flows (Q, $m^3 s^{-1}$) are determined. A partition length (N) of 5 and a turning point test factor (F) of 0.5 were used in this study. These values were based on program defaults and the turning point test factor (F) previously used in streamflow analysis and hydrograph separation in the Eucha/Spavinaw Basin (DeLaune et al., 2006). A minimum flow (Q_1) is defined as a turning point if, when multiplied by the turning point test factor (F), it is less than both the preceding (Q_0) and subsequent (Q_2) minimum flows (Q_1 is a turning point if $Q_1 * F \leq Q_0$ and $Q_1 * F \leq Q_2$). Straight lines are drawn between turning points on the hydrograph and the area below those lines is estimated as base flow; surface runoff is the difference between total flow and base flow.

Daily surface-runoff discharge was calculated for each day using the difference between total streamflow and estimated base flow from BFI. Daily estimates of surface-runoff discharge were averaged within a month, and then these monthly averages were averaged for all available years. Average monthly surface-runoff values were multiplied by the days within a month (i.e., time) to calculate the surface-runoff volume (ft^3) and then divided by catchment area to calculate runoff depth (ft). Runoff depth (ft) was converted to runoff depth (cm) using unit conversion. Average annual rainfall measured for Benton County, Ark. was obtained online (NOAA, 2005) and used to calculate the percentage of rainfall estimated as surface runoff.

RESULTS AND DISCUSSION

Average surface-runoff depth ranged between 9.5 and 28.2 cm annually for the nine sites evaluated in this study (Table 2). The average amount of surface runoff for all nine sub-basins within the Illinois River Basin was approximately 14% of average annual rainfall measured for Benton County, Ark. (NOAA, 2005; Table 3). There was variability in annual average surface runoff among different sub-basins (Table 2). Basin area was taken into consideration since data were presented as runoff depths. However, basin area was investigated as a factor in inter-basin variability, but no relationship was found. Simple linear regression of runoff depth as a function of basin area did not have a slope value significantly different from zero and basin area did not explain a significant amount of the variation in runoff depth, i.e. R-squared was approximately zero (data not shown). The variability among sub-basins may be attributed to factors not considered in this study, such as vegetative characteristics and catchment slope, which have been shown to influence surface-runoff depths (Dodds, 1997).

Average monthly surface-runoff values ranged between 0.1 and 4.3 cm at the selected sites within the Illinois River Basin (Table 2). On average, the highest amounts of surface runoff occurred from winter through spring (November-June), and the lowest amounts of surface runoff occurred from summer through early fall (July-October; Table 2; Fig. 1). For example, average monthly surface-runoff depth ranged from 1.1 to 4.3 cm across all nine sub-basins in May, whereas surface-runoff depth ranged from 0.2 to 0.5 cm across all nine sub-basins in August (Table 2). These data show the contrasting amounts of surface runoff that occur during these time periods. Estimated monthly surface-runoff depth as a fraction of average monthly rainfall near Fayetteville, Ark. ranged from 3.6 - 23.4%

(Table 3), where the lower percentages occurred from summer through early fall (July-October).

Some sub-basins of the Illinois River Basin had lower depths of surface runoff than those observed in the Eucha-Spavinaw Basin, while other sub-basins of the Illinois River Basin had higher amounts of surface runoff than observed in the Eucha-Spavinaw Basin. The annual average surface-runoff depth at the Eucha-Spavinaw Basin was 11.9 cm (DeLaune et al., 2006), while the sub-basins of the Illinois River Basin ranged from 9.5 to 28.2 cm (Table 2). DeLaune et al. (2006) used historical streamflow data from one site in the Eucha-Spavinaw Basin and if surface-runoff depth was estimated at more sites, then spatial variations in surface-runoff depth similar to that observed in the Illinois River Basin would most likely be found. Although surface-runoff depths varied spatially throughout the Illinois River Basin, the temporal pattern of surface-runoff depth was very similar across all nine sub-basins and even the Eucha-Spavinaw Basin.

The variations in monthly surface-runoff depth found in this study of the Illinois River Basin are important for determining when to land-apply poultry litter in order to reduce the risk of NPS-P loading into waterways. Because lower depths of surface runoff occur from July through October, this time frame would represent the time frame with the least risk of P transport in surface runoff and thus is preferable for land applications of poultry litter. The typical practice of land-applying poultry litter occurs in the spring for forage management, but this practice involves applying poultry litter during times of increased surface runoff and thus greater risk of phosphorus transport from the landscape. The use of actual streamflow data over an extended period of time with consistent hydrograph-separation techniques was essential to estimate surface-runoff depth and to determine the temporal patterns of surface runoff in the Illinois River Basin.

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Table 1. U.S. Geological Survey (USGS) descriptive information about selected sites in the Illinois River Basin, Arkansas and Oklahoma, including USGS station number, sub-basin name, county, state, latitude, longitude, drainage area of sub-basin (km2), and period of record.

USGS #	Name	County	State	Latitude	Longitude	Area (km^2)	Period of record
07194800	Illinois River at Savoy	Washington	AR	36°06'11"	94°20'39"	433	1979-2004
07194880	Osage Creek near Cave Springs	Benton	AR	36°16'53"	94°13'40"	90	1990-2004
07195000	Osage Creek near Elm Springs	Benton	AR	36°13'19.45"	94°17'11.69"	337	1950-2004
07195400	Illinois River Hwy 16	Benton	AR	36°08'40.97"	36°08'40.97"	1319	1979-2004
07195430	Illinois River South of Siloam Springs	Benton	AR	36°06'33.32"	94°32'04.3"	1490	1995-2004
07195800	Flint Creek at Springtown	Benton	AR	36°15'19.73"	94°26'02.19"	37	1961-2004
07195855	Flint Creek near west Siloam Springs	Delaware	OK	36°12'58"	94°36'15"	155	1979-2004
07196900	Baron Fork at Dutch Mills	Washington	AR	35°52'48"	94°29'11"	105	1958-2004
07249985	Lee Creek near Short	Sequoyah	OK	35°31'09"	94°27'58"	1088	1930-2004

Table 2. Average monthly surface-runoff depth (cm) and annual total surface-runoff depth (cm) as calculated using USGS daily streamflow data and hydrograph separation using the Base Flow Index software program at selected sites in the Illinois River Basin, Arkansas and Oklahoma.

USGS #	Name	County	State	Latitude	Longitude	(km^2)	
07194800	Illinois River at Savoy	Washington	AR	36°06'11"	94°20'39"	433	1979-2004
07194880	Osage Creek near Cave Springs	Benton	AR	36°16'53"	94°13'40"	90	1990-2004
07195000	Osage Creek near Elm Springs	Benton	AR	36°13'19.45"	94°17'11.69"	337	1950-2004
07195400	Illinois River Hwy 16	Benton	AR	36°08'40.97"	36°08'40.97"	1319	1979-2004
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07196900	Baron Fork at Dutch Mills	Washington	AR	35°52'48"	94°29'11"	105	1958-2004
07249985	Lee Creek near Short	Sequoyah	OK	35°31'09"	94°27'58"	1088	1930-2004

Table 3. Average monthly and annual rainfall (cm) as measured in Benton County, Ark., and the percentage of rainfall estimated as average monthly and annual surface runoff.

Month	Average rainfall (cm)	% of rainfall estimated as surface runoff
January	5.7	19.8
February	6.4	23.4
March	11.2	17.1
April	10.6	22.8
May	13.3	16.1
June	13.2	13.6
July	8.1	11.5
August	8.5	3.6
September	12.0	5.7
October	9.1	8.5
November	12.2	14.6
December	8.9	18.1
Annual	119.2	14.2

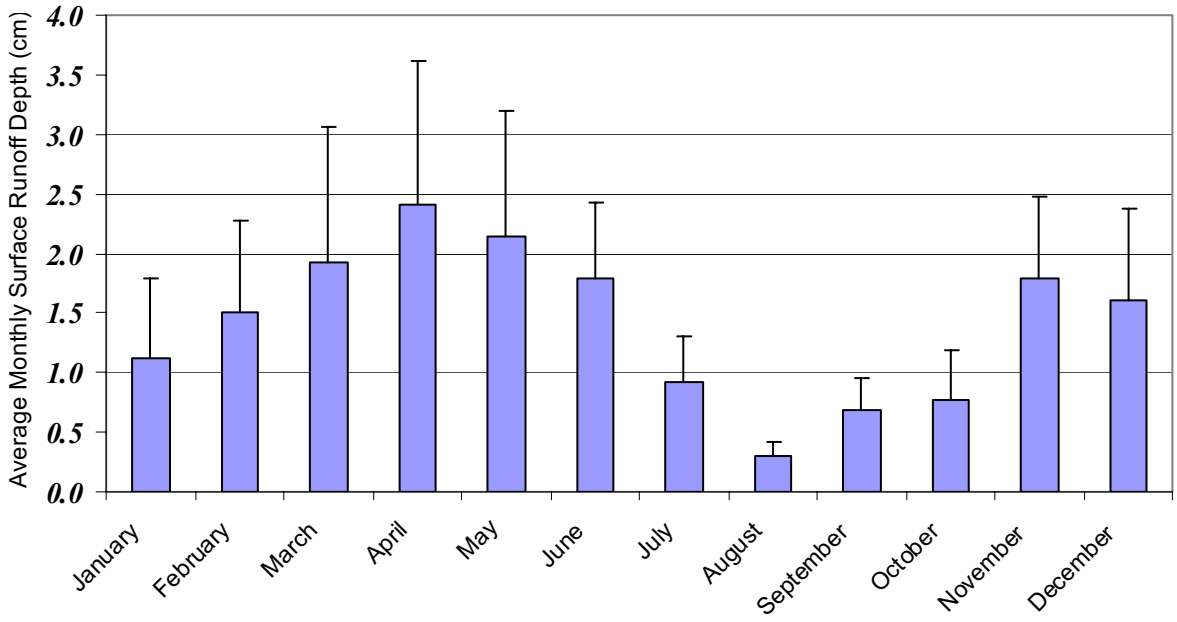

Fig. 1. Average monthly surface-runoff depth (cm) and standard error as calculated using daily streamflow data and hydrograph separation using the Base Flow Index software program for nine sub-basins within the Illinois River Basin, Arkansas and Oklahoma.

A tool for estimating Best Management Practice effectiveness in Arkansas

Katherine R. Merriman[*]*, Margaret Gitau*[†]*, and Indrajeet Chaubey*[§]

ABSTRACT

Increased nutrient and sediment losses from expanding agricultural practices and urban development in Arkansas are important environmental concerns. Best Management Practices (BMPs) are being implemented to lessen the effects of these developments on existing water bodies. There is, however, insufficient scientific base as to the effectiveness of these practices. A number of studies have been conducted in recent years to determine BMP effectiveness. Data from these studies can only be reliably used for the individual site from which they were obtained. When considered collectively, these data comprise quantitative effectiveness over a wide range of conditions and can thus be used to provide reliable estimates of BMP effectiveness. This study develops a tool for estimating BMP effectiveness, based on accumulation and analyses of data reported in previous studies, with a focus on site conditions and management interventions in Arkansas. This study incorporates data from a variety of regions in the southeastern U.S., which have site conditions and management similar to those in Arkansas. Developed within Microsoft® Access© from a pre-existing BMP characterization tool, this tool will be made accessible to local and state agencies and will aid rural and urban planners in developing management solutions for nutrients and sediment control. The tool describes individual BMPs in detail and gives site-specific estimates of their long-term effectiveness in sediment and nutrient control.

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INTRODUCTION

Agriculture is the number one source of impairment to surfacewater (USEPA, 2000). As of 2002, over 14.5 million acres (43.5%) of Arkansas land were in agricultural production (FedStats, 2006; USDA National Agricultural Statistics Service, 2006). Agriculture is listed as the source of impairment for 764.4 miles (9.7%) of Arkansas streams (Arkansas Department of Environmental Quality, 2002), with sediment and nutrients being the major pollutants of concern.

Healthy aquatic environments require the nutrients nitrogen (N) and phosphorous (P); however, those nutrients in excess can deteriorate the health of aquatic bodies by encouraging rapid algal growth (USEPA, 2001). Algal bloom from excessive nutrients starts the process of eutrophication, where excessive growth removes dissolved oxygen from the water, asphyxiating aquatic organisms including fish. Eutrophication can cause serious health problems and restricts industrial use (Martin and Cooke, 1994; Sharpley et al., 2003; Sharpley et al., 2000). Eutrophic waters make swimming, fishing, and navigation difficult and are cloudy or green (Khan and Ansari, 2005).

Most sediment pollution occurs when topsoil is carried away with runoff during a storm event (USEPA, 2005). Sediments can carry nutrients, metals, pesticides, and toxic organics (Novotny and Olem, 1994). Sediments degrade water quality, inhibit aquatic life, fill in culverts, lakes, and streambeds, and increase the difficulty of navigation (Cooper and Lipe, 1992).

Best management practices (BMPs) are intended to reduce the negative environmental consequences of land use and maintain the productivity of the land (Heatwole et al., 1991). The USDA has over 160 BMPs approved for use on agricultural areas and about 90 urban BMPs (USDA-NRCS, 2006a; USDA-NRCS, 2006b). The Natural Resources Conservation Service (NRCS) often advises farmers on BMP selection to attain water-quality improvements. There is, however, some question as to how effective these BMPs are in preventing pollutant movement into surfacewaters, with effectiveness being defined as the percentage by which nutrients or sediment are reduced by the BMP. BMPs are costly and some may require significant alteration in routine management operations, thus the need to determine the potential effectiveness of the BMPs before BMPs are implemented. BMP effectiveness can be influenced by several factors, including site conditions, agricultural activity, and extent of implementation. Various studies have been performed to determine effectiveness based on these factors; however, there is no conclusive definition of the effectiveness of any one BMP. Individual

MEET THE STUDENT-AUTHOR

Katherine R. Merriman

I graduated from Jonesboro High School in 2001. I was awarded a Humphries' Chancellor's Scholarship after my first semester studying chemical engineering at the University. In spring 2003, I took an internship with a major oil company. Although it was a great learning experience, I decided that oil would most likely take me away from Arkansas and I was determined to stay in state. I then changed my major to Biological & Agricultural Engineering with a focus on ecological engineering. In the summer of 2004, I worked for the USDA-National Resources Conservation service in my hometown of Jonesboro. During the following academic year, I worked part-time for Dr. Indrajeet Chaubey on several water quality-related projects. I am a member of Gamma Sigma Delta, (the honor society of agriculture), and Tau Beta Pi, (an engineering honor society). After receiving my B.S. in biological engineering, I plan to enroll in graduate school at the University of Arkansas under Dr. Chaubey and study natural resources management using remote sensing technology.

studies may only be applicable for the site where the BMP was applied. A compilation of these individual studies gives a wide range of data of BMP effectiveness for the varying influencing factors.

BMP effectiveness, as reported in the literature, varies widely. For example, two different studies reported on the effectiveness of an alternative watering facility for cattle, but gave dissimilar sediment reduction values. Line et al. (2000) reported a 38% reduction in sediment while Sheffield et al. (1997) reported 89% sediment reduction effectiveness.

The objective of this study was to quantify BMP reduction effectiveness under various site characteristics, land use, and study methods based on the literature and to provide a tool with which site-specific effectiveness estimates can be made. The Gitau et al. (2005) BMP tool provided a foundation for development of a new tool, where the data are focused on BMPs implemented in Arkansas.

MATERIALS AND METHODS

This study expounds upon the BMP database and tool developed by Gitau et al. (2005). The original database focused on P pollution problems and management interventions in New York City watersheds. Data collected included particulate, dissolved, and total P (PP, DP, and TP). Many features were left intact, but some changes were necessary to expand its reach to include data for nitrate (NO_3-N), ammonium (NH_4-N), total N (TN), and total sediment reduction effectiveness. The Gitau et al. (2005) BMP database tool was re-designed to fit the expanded data set while making the data more accessible.

Tool structure

The Gitau et al. (2005) BMP tool is designed to run from four main tables. Its primary table, "Effectiveness Table," holds all of the data relating to the effectiveness of the BMP reference, including the effectiveness reduction and the site and study characteristics. The secondary tables, "BMP Attributes Table" and "References Table", support the "Effectiveness Table." These two tables maintain relevant information about the BMPs and citations useful for further queries about the individual records in the database. The final table is the main look-up table, "Choices Table." This table provides information that is read into several drop-down lists. Some of its fields are: BMP class, hydrologic soil-group (HSG), slope, a list of commonly cited journals, and other commonly used records. Fig. 1 provides a schematic to the original tool. Since the original BMP database was developed specifically for P reductions, expansion was necessary to integrate N and sediment data. Additional alterations were required to enable improved data flow and ensure data integrity. Fig. 2 illustrates the flow of data stored within the database. The major difference between the structures of the two databases is in the look-up tables.

The Effectiveness Table received additional fields for quantitative and qualitative values of NO_3-N, NH_4-N, TN, and total sediment. The location field was changed to reflect the state of study, instead of the region of study, since now only sites in the Southeast or states adjacent to Arkansas were considered. A "Detailed Location" field was included for a more specific location of the study such as the Arkansas Delta, Tennessee River Valley, or Georgia Coastal Plain.

The structure of the BMP Attributes Table was untouched. However, the number of BMPs listed increased from 32 to 201. This increase reflects the addition of the entire list of National Conservation Practice Standards used by the NRCS (USDA-NRCS 2006a). At the time of the addition, the NRCS listed 163 National Conservation Practice Standards. Some of the standards contain multiple methods of compliance. Each method was allotted a separate entry to ease searching among the BMP references. For example, several literature resources contain data on the reduced-till conservation tillage method though it is not listed in the National Conservation Practice Standards. It is a part of NRCS Practice code 329, Residue Management/No-Till/Strip Till/Direct Seed. Reduced till is thereby listed as a separate BMP from no-till, strip till, and direct seed, but all of these have NRCS code 329.

Also, physical variables within some BMPs directly influence their effectiveness. For instance, the effectiveness of a vegetative filter strip (NRCS conservation practice code 393) depends on the filter strip's length; the 2-m filter strip and the 15-m filter strip have distinctly different effectiveness. These BMPs require supplementary details visible when documenting effectiveness. BMPs of this type are listed in the BMP Attributes Table multiple times for each different physical variable of the same BMP; therefore a 2-m filter strip would be found as "Vegetative Filter Strip (2-m)" and a 15-m strip as "Vegetative Filter Strip (15-m)." Additionally, the National Conservation Practice Standards' definitions were input to aid in BMP selection from the BMP Attributes Table to allow future users to makes such distinctions.

The References Table received minor modifications. Two fields were inserted: "Issue number" and "Chapter number." An Electronic Address field was also added to accommodate the web address of any internet material found.

The Choices Table was disassembled and restructured

into several, smaller tables. Several small look-up tables increase the query-processing speed and reduce data loss by removing the complicated relationships between the Choices Table and the three other main tables. These tables are smaller and are related directly to the fields in either the primary or secondary tables. This change ensures referential integrity.

Data collection

The scope of this work considers studies completed in the southeastern U.S. (the states of Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia) and studies completed in states adjacent to Arkansas (Missouri, Oklahoma, and Texas). Some of the original references in Gitau et al. (2005) were completed outside the study area and these were removed.

Since Gitau et al. (2005) focused on P reduction, the references were re-evaluated for N and sediment reduction data. A literature review searched for reduction effectiveness of various BMPs applied in Arkansas and the other states. The BMP and agricultural activity for each study were documented for each record of BMP effectiveness. Site conditions and study characteristics, such as HSG, slope, study method, scale, and location, were recorded. Notes on the study method and comments on the study were taken. For each reference, these data were compiled in the database. Details of the full citation were also collected. An abbreviated citation, called "Short Name," was given to each reference.

Fig. 3 shows what data were collected and stored. The citation data are stored in the References Table, while all site and study characteristics and effectiveness data are stored in the Effectiveness Table. These data sets are linked by the Short Name field.

Tool development

Utilizing the BMP database, a BMP effectiveness tool was developed to allow user evaluation of BMPs based on their specified soils and slopes. Data were organized into 14 BMP classes (i.e. alternative water supply, animal-waste systems, barnyard-runoff management, conservation tillage, contour-strip crop, crop rotation, drainage systems, filter strips, nutrient management plan, riparian forest buffers, rotational grazing, stream fencing, terraces, and wetland), and then further segregated into three categories: Barn Yard Management, Erosion Control, and Nutrient Management. The BMP effectiveness data were arranged so that they could be queried by soil group, slope, or combinations of the two. This allows users to determine a mean, range, and standard deviation for individual BMP effectiveness based on specified soil and slope conditions.

The tool was also designed to allow users to search the BMP data in several different manners other than by soil group or slope. Through the tool, the data can be compiled based upon agricultural activity, reduction effectiveness, BMP class, site conditions (soil or slope), or reference citation. The user can further customize the BMP tool with any entries from the BMP database.

An urban BMP effectiveness estimator tool is currently being developed.

RESULTS AND DISCUSSION

BMP tool

According to Gitau et al. (2005), site location, slopes, and soils are the key factors affecting BMP effectiveness. For this tool, data were grouped by HSG, slope, and BMP. Location was considered by restricting data entry to studies in the southeastern states and Missouri, Oklahoma, and Texas. Like the Gitau et al. (2005) BMP tool, the tool's various features are accessed through interfaces.

The main interface is the principal interface; it is automatically opened when the BMP database is launched in Microsoft® Access©. The main interface contains links to general descriptive data on BMPs and BMP classes. Several other interfaces are available from the main interface. The BMP effectiveness estimates interface provides access to the BMP effectiveness estimator, which is the foundation of the BMP tool. This user-driven estimator is written in the query language of Microsoft® Access©, Structured Query Language (SQL). Queries run through SQL are executed at run time, hence outputs are current and reflective of any updates to the database. The estimates are sorted by BMP, a change from the Gitau et al. (2005) database, where the estimates were quantified by BMP class. The estimates are made by averaging the literature data for combinations of HSG and slope if BMP data are available for them. Where the database has no information for a particular combination of BMP class, slope, and soil group, the estimator returns blank fields and refers the user to the Averaged Data interface described in the ensuing paragraph. The procedure to obtain effectiveness results is shown in Fig. 4.

The Averaged Data interface, another addition to the BMP tool, is directly accessed through the main interface. This interface provides average BMP effectiveness values regardless of site, soils, and slopes. This interface references the NRCS code for the BMP and its NRCS descriptive definition. The averages are arranged by BMP class and only the BMPs with quantitative effectiveness data are listed.

The View Summaries interface opens a summary for each nutrient and sediment. These reports show the reduction effectiveness categorized by BMP class. For each BMP class, statistical properties, such as average, minimum, maximum, standard deviation, and count of records of the data, are returned. Only the BMP classes that contain quantitative effectiveness data are shown.

The Effectiveness Details interface lists all the individual data under the short name of its citation. This interface provides an easy way to search the specific effectiveness records without toiling through the complete Effectiveness Table. The BMP, site, and study characteristics are given. Access to the full citation is also provided. Similarly, the Search by Authors interface lists the citations for all the data. It provides a user-friendly forum to directly search the citations referenced in the tool rather than the References tables. The Access filters can also sort and search the fields in both interfaces.

The Updater interface updates the different database tables. All data, citation or effectiveness, can be edited from the Updater interface. Several of the different fields (BMPs, BMP class, journals, and agricultural activities) used in the look-up tables are updated here.

Data summary

Table 1 lists some of the effectiveness estimator results. The negative values indicate a decrease in BMP effectiveness; blank values mean there are no data for the given site conditions. Total sediment reduction had the most entries for any BMP and also the greatest ranging percentage reduction (from 19 to 97%). There were only four estimates for particulate P (PP%). For the data shown, most data collected thus far were for vegetative filter strips or no-till with 17 and 23 results for all slope and soil group combinations, respectively. No-till with 3-8% slopes and type C soil had the greatest number of references; its effectiveness estimates for total sediment, TP, and TN were 78, 84, and 90%, respectively.

Example application

A farm, with hydrologic soil-group C soils and a slope between 3-8%, in eastern Arkansas has been designated as having contributed to sediment pollution. This farm cultivates row crops. The farm's planners feel they need to install BMPs in order to control their sediment problem. However, choice of the BMP is not clear.

Using the tool, the farm planners select site conditions similar to their own. They choose the BMP category they are interested in (in this case, erosion control). They are able to determine which BMPs are the most effective in preventing sediment pollution. Under these conditions, estimates of BMP effectiveness are obtained for four BMPs (Fig. 4).The most effective BMP to reduce sediment pollution is reduced tillage, which has a 92% effectiveness estimate for sediment reduction. The blank fields in Fig. 4 indicate no nutrient data are available for reduced tillage. No-till or pasture and hay planting have estimates of 57 and 59%, respectively. Fig. 5 shows the results graphically. Estimates for different soil and slope combinations can be obtained similarly, thus facilitating BMP selection.

This tool is an aide to effectiveness-based BMP selection. It allows effectiveness estimates to be determined for combinations of hydrologic soil-group and slope, averaged general BMP effectiveness estimates, or nutrient and sediment summary reductions. This tool will be made accessible to local and state agencies and will aid rural and urban planners in developing management solutions for nutrient and sediment control. The tool was designed for Arkansas conditions; but because its base data were derived from a variety of site conditions within the southeastern U.S., it would be appropriate for use within the surrounding region where site conditions and management interventions are similar to those in Arkansas. With a few modifications and additional data entry, the tool could be applicable elsewhere in the U.S.

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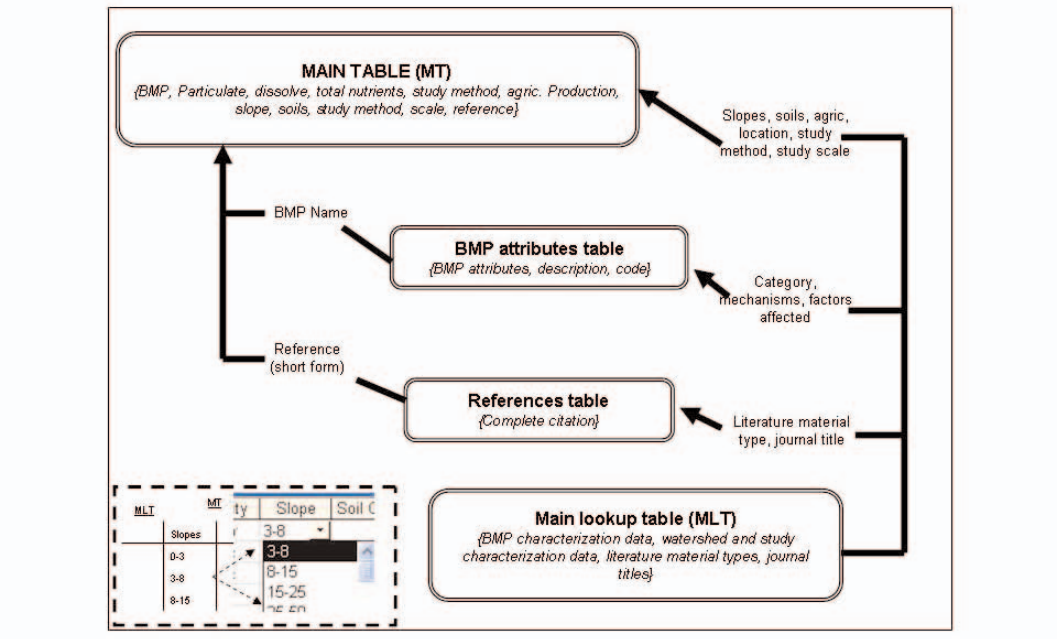

Fig. 1. Database schematic showing component tables, contents, and table linking (Adapted from Gitau, et al. 2005).

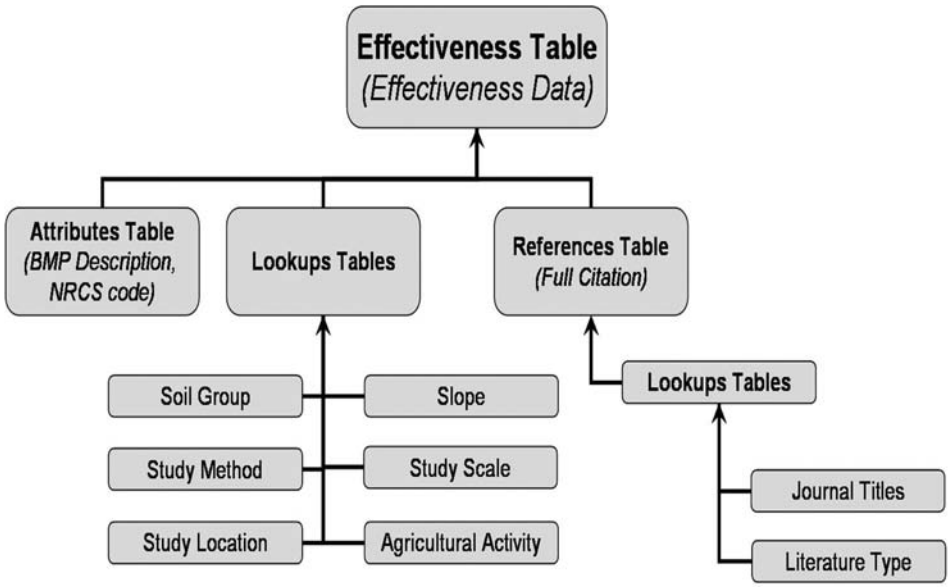

Fig. 2. Database schematic.

References table:

Authors	Journal title	Volume number	Book title	Has BMP data?
Year	Article title	Issue number	Publisher	Combined BMP data
		Chapter number	Address	Ag or Urban BMP
Short name		Pages numbers	Web address	

Effectiveness table:

Bmp name	Agricultural activity	Study method	**Reduction effectiveness in:**
Bmp class	State	Study scale	Dissolved P
	Detailed location	Method description	Particulate P
	Slope	Comments	Total P
Short name	Soil group		Ammonium N
			Nitrate N
			Total N
			Total Sediment

Fig. 3. Data taken from the literature, showing how the References and Effectiveness Tables are connected. P = Phosphorus; N = Nitrogen

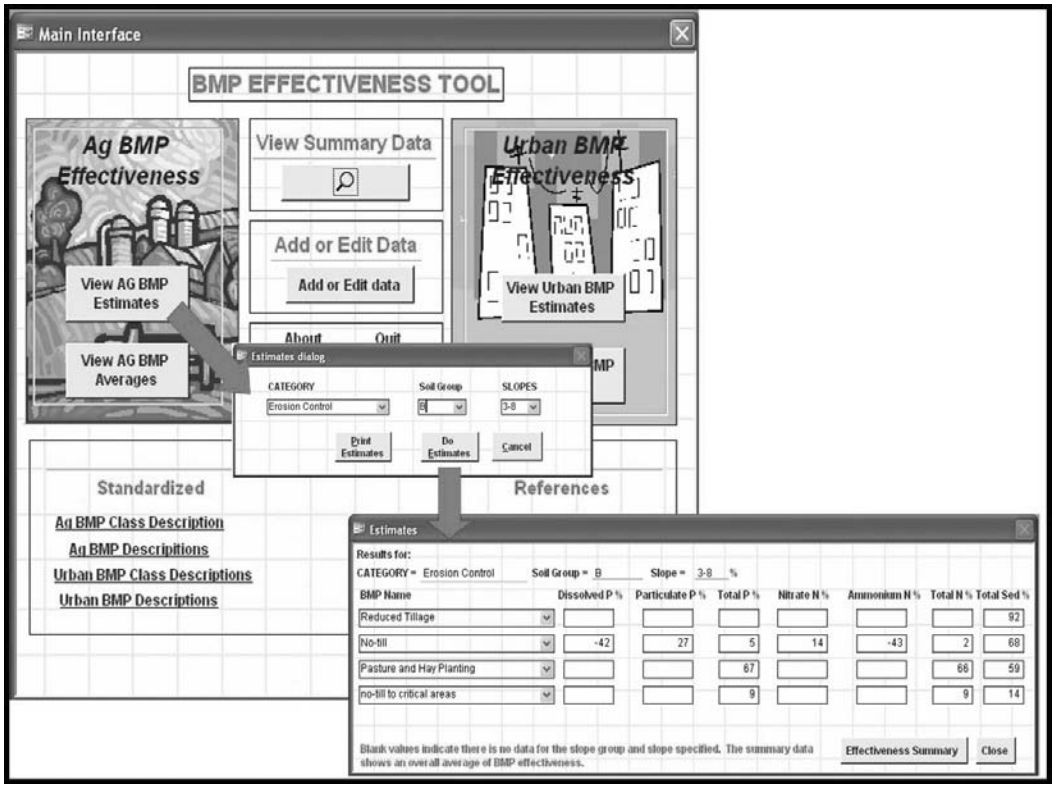

Fig. 4. Schematic of the Effectiveness Estimator.

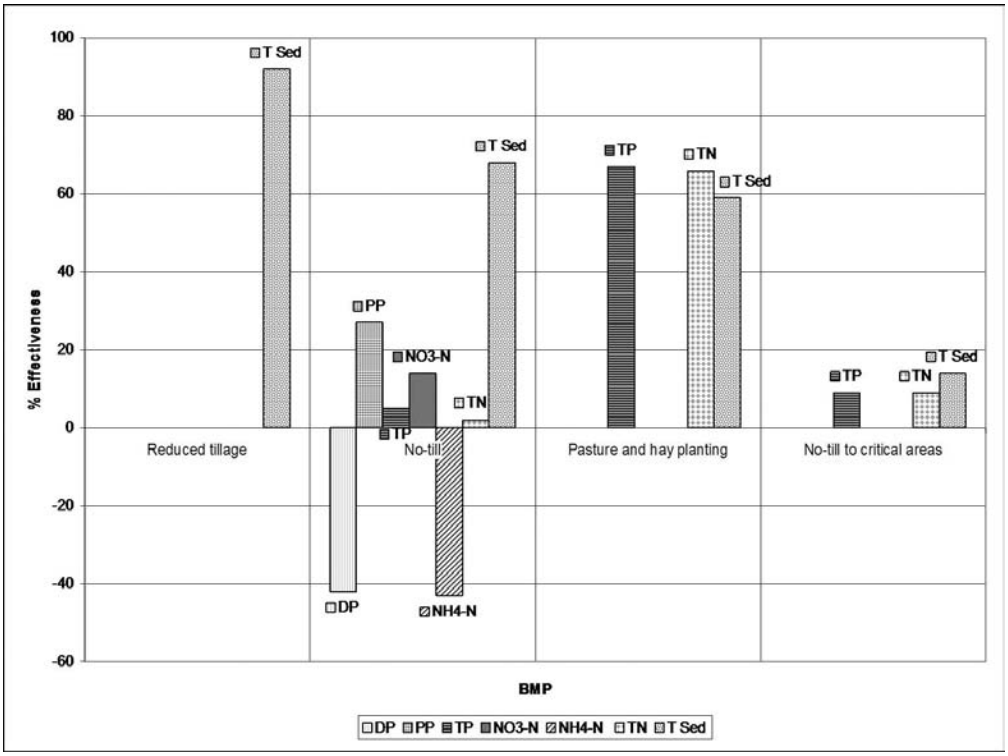

Fig. 5. Graphical results of the Effectiveness Estimator. DP = Dissolved Phosphorus, PP = Particulate Phosphorus, TP = Total Phosphorus, NO_3-N = Nitrate Nitrogen, NH_4-N = Ammonium Nitrogen, TN = Total Nitrogen, and T Sed = Total Sediment.

Table 1. Selected BMP effectiveness estimates based on slope and soil group.

BMP name	Slope %	HSG[a]	T Sed %[b]	PP %	DP %	TP %	NO_3-N %	NH_4-N %	TN %	Count[c]
Contour buffer strips (3- m)	3-8	B				30	10		17	2
Contour buffer strip (4.5-m)	0-3	D	19			26	39	32	20	1
	3-8	D	19			26	39	32	20	1
No-till	0-3	B	86							1
	0-3	C	68							2
	3-8	B	68	27	-42[d]	5	14	-43	2	5
	3-8	C	78			84			90	11
	3-8	D	16							1
	8-15	C	87	71	71	78	37	57	91	3
Pasture and hay planting	3-8	B	59			67			66	1
Reduced tillage	3-8	B	92							1
	3-8	C	75							2
	3-8	D	14							1
Riparian forest buffer	0-3	B/D		63		56	59	48	37	1
Use exclusion/stream protection	8-15	B	82			76	33		-78	1
	8-15	C	82			76	33		-78	1
Vegetated filter strip	3-8	C	31		-3	35	-82	38	37	3
	3-8	D	95	90	71		68	73		1
	8-15	C	87		-20	63	-36	34	64	1
Vegetative filter strip (4.6-m)	3-8	C	83		69	85	72	74	84	1
	8-15	C	86		-83	73	2	57	73	1
	15-25	C	65		-50	51	5	-6	58	2
Vegetative filter strip (6.1-m)	3-8	C			55	42		48	37	2
Vegetative filter strip (9.1-m)	3-8	C	76		40	53	-43	37	45	2
	8-15	C	97		39	87	41	79	87	2
	15-25	C	79		-41	61	20	4	66	2
Waste storage facility	3-8	B				27			29	1
Watering facility	8-15	B	38			-10	41		-27	1
	8-15	C	38			-10	41		-27	2
Winter cover crop	0-3	D	91		37		75	37		3

[a]Hydrologic Soil-Group.
[b]Abbreviations of pollutants are as follows: T Sed = Total Sediment, PP = Particulate Phosphorus, DP = Dissolved Phosphorus, TP = Total Phosphorus, NO3-N = Nitrate Nitrogen, NH4-N = Ammonium Nitrogen, and TN = Total Nitrogen.
[c]Number of literature references for each BMP for the given conditions.
[d]Negative Values indicate a decrease in BMP effectiveness.

Drying of post-harvest rough rice with silica gel: A preliminary investigation

Stephen J. O'Brien[*] *and T. J. Siebenmorgen*[†]

ABSTRACT

Rice drying operations can encounter problems of over drying and losses in head rice yield (HRY) through the formation of fissures. Typical rice drying methods also utilize large volumes of expensive fossil fuels to dry the kernels. Drying of rice with a solid desiccant such as silica gel has several potential advantages that avoid some of these problems. Two cultivars of long-grain rough rice, 'Cheniere' and 'Wells' with harvest moisture contents of 17.8% and 22.0%, respectively, were dried over a 48-h period with various ratios of rough rice-to-silica gel. It was found that an intimate mixture of 3:1 rough rice to silica gel was sufficient to dry these rice lots to 12.5% and 14.3% within 12 h, respectively. Head rice yields of desiccant-dried rice showed no considerable differences from the control. Rough-rice drying curves for all rough rice-to-silica gel mixtures followed exponential relationships.

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[†] Terry J. Siebenmorgen, teacher and faculty mentor for rice processing, is a professor in the Department of Food Science.

INTRODUCTION

The drying of rough rice, like many other crops, is one of the most energy consuming activities in agricultural production. Once harvested, rice must be immediately dried to a moisture content (MC) near 12.5% (w.b.) to prevent damage by microorganisms and respiration (all moisture contents are expressed on a wet basis). The use of ambient air is typically too slow a process; so heated air is typically used to effectively dry rough rice. Unfortunately, the most common form of energy used in these systems is fossil fuel, an increasingly expensive source of energy. It is also widely accepted that under some situations, drying of rice at elevated temperatures can cause fissured kernels and thus lower milling yields. Moreover, increased harvesting and transportation capabilities of rice producers are placing increased pressure on commercial drying and storage facilities to receive and dry rice on a timely basis. A possible means of alleviating the pressure placed upon commercial driers is to pursue on-farm drying methods that are effective and practical in drying rough rice.

Silica gel is a commercially available desiccant that has long been used in many industrial applications as a dehydrating agent. It is an inert granular solid that is ideal for air-drying. Comprised of amorphous silicon dioxide, this desiccant's large surface area acts to readily ad-sorb water molecules. Silica gel can adsorb up to 40% of its weight in moisture at 100% relative humidity (RH). It remains dry and free-flowing when water-saturated. Silica gel is resistant to attrition and is regenerated by heating to an elevated temperature.

Although previously not applied to rice, this desiccant has shown promise in drying corn, soybean, and other crops. Danziger et al. (1972) have reported that a 3:1 mixture of corn to silica gel effectively dried corn from 24.9% to 14.6% within 24 h. Moreover, research by Wright and Warnock (1983) on the effects of vapor pressure difference between rough rice kernels and drying air have indicated that at low drying air temperatures (52 and 57°C), representative of those experienced with desiccant drying, vapor pressure does not significantly affect milling yields.

The capability to more effectively and efficiently dry rough rice on-farm during the rice harvest season could dramatically improve the rice industry's ability to dry rice at an increasingly rapid pace. The objective of this study was to first evaluate the drying potential of an intimate mixture of rough rice and silica gel by observing the latter's drying capabilities and characteristics. Second, this study sought to distinguish if desiccant drying has any deleterious effects on the milling yield of rough rice.

MATERIALS AND METHODS

Long-grain rice cultivars 'Cheniere' and 'Wells' were harvested at MCs 17.8% and 22.0%, respectively, from the University of Arkansas Rice Research and Extension Center Stuttgart, Ark. in 2005. Immediately after harvest, the rice was cleaned and stored in plastic bags at 4°C.

Silica gel (Type A; 1-3 mm beads, AGM Container Controls, Tucson, Ariz.) was provided to the University of Arkansas Rice Processing Program. This bead size was chosen due to the ease of separation from rough rice when intimately mixed. Additionally, the bead size provides a large surface area-to-volume ratio compared with a larger bead size. Silica gel was activated by drying at 135°C for 24 h in a forced-air oven.

Preliminary experiment

Preliminary experiments were conducted to evaluate the drying capabilities and characteristics of silica gel when intimately mixed with rough rice. Mason jars (Quart, Golden Harvest) were used to seal mixtures of rough rice and silica gel. Based on literature findings with other crops, mixture ratios of 9:1, 3:1, and 1:1 rough rice to silica gel were evaluated for 'Cheniere' and mixtures of 9:1 and 3:1 were evaluated for 'Wells.' For each cultivar and ratio a single trial was conducted by placing 100 g of rice and the respective mass of desiccant into each of 10 jars. Once filled and sealed, the jars were held in a room at 22?C for 48 h. At regular intervals during the 48-h drying trials, separate jars were randomly selected and opened. The jar contents were separated using a no. 7 U.S. standard sieve. Fifteen-gram rough rice samples in duplicate from the separated rice were immediately taken for MC determination. Moisture content was determined by drying rough rice in tins with a convection oven at 130?C for 24 h.

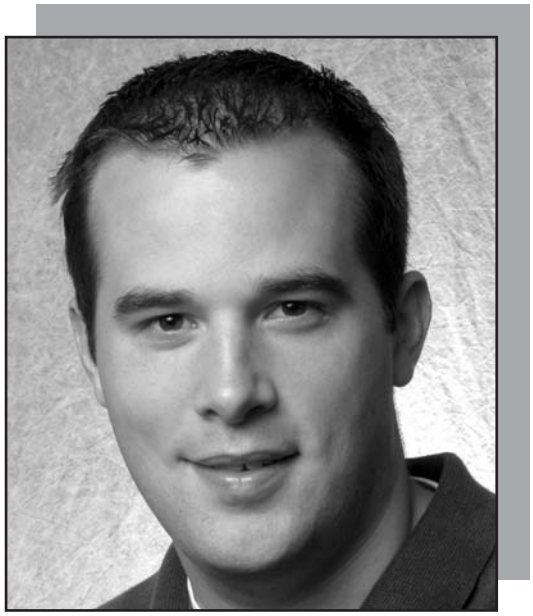
For both cultivars, the 3:1 rough rice-to-silica gel ratio best exhibited the ability to dry rough rice to near typical dried MCs of 12.5% and was applied in all further experimentation.

Further experimentation

Further experimentation was conducted to explore drying kinetics and to evaluate the effect of drying rough rice with silica gel on milling yields. The drying procedure previously mentioned was used.

A larger amount of rice, 430 g, and desiccant, 142 g, were used to produce the 3:1 rough rice-to-silica gel mixture. Sensors (HOBO, Onset Computer Corporation, Bourne, Mass.) equipped with temperature and RH probes were placed in each jar to measure the inter-kernel air temperature and RH throughout the drying trial. For each jar selected at the given intervals

MEET THE STUDENT-AUTHOR



Stephen J. O'Brien

I graduated from Fayetteville High School in 2001 and enrolled at Trinity University in San Antonio, Texas. Trinity is a nationally competitive private university that prides itself as being one of the few schools in the south with 'ivy league' standards. However, after my sophomore year, I transferred to the University of Arkansas because of its research-oriented focus. While finishing my undergraduate degree in biochemistry, I have been working with Dr. Ya-Jane Wang, a professor in Food Science, on an independent study project. My work on that project, concerning "The Effects of Chemical Composition and Granule Organization on Enzymatic Hydrolysis of Starches", has allowed me to be selected as an Undergraduate Research Paper Competition finalist competing at the Institute of Food Technologist's (IFT) annual meeting and food exposition. Meanwhile, I've also have been working with Dr. Terry Siebenmorgen, a professor in Food Science, on this research project to gain a better understanding of the engineering principles involved in food processing. I also competed in the Ozark Food Processors Association's Food and Beverage Innovations Competition and was awarded 1st place for a unique soluble fiber-enriched beverage. Upon graduating in 2006, I plan to enroll in graduate school and further my study in field of Food Science at the University of Arkansas.

throughout a drying trial, rice moisture content was measured as before and the remaining rice was placed into a chamber maintained at 21°C and 55% RH to gently equilibrate to 12.5% MC. Those samples that were dried below 11% MC were not included in this equilibration procedure or the subsequent milling analysis. These over-dried samples were removed from further analysis due to the general acceptance that abnormally low MC can cause inconsistent milling characteristics and skew the true head rice yield (HRY). The 'Cheniere' desiccant drying trial was replicated. The drying of the 'Wells' was not replicated due to rice unavailability.

After the rice was equilibrated to 12.5% MC, milling tests were conducted in order to measure HRYs. Replicate 150 g rough rice samples were dehulled using a laboratory huller (THU-35A, Satake Engineering Co., Tokyo, Japan). Brown rice was then milled for 30 s in a lab mill (McGill no. 2, Brookshire, Texas). The mass of the head rice was determined using an image analyzer (Graincheck 2312, Foss North America, Minneapolis, Minn.) and HRY was calculated as the mass fraction of complete kernels of rough rice remaining as head rice kernels. The head rice was then separated from brokens by hand and measured for whiteness using a whiteness meter (C-300, Kett Electronic Laboratory, Tokyo, Japan) as an indication of degree of milling.

To serve as a control, replicate samples of each cultivar were sealed in jars without desiccant for the 48-h duration of each trial and then gently dried in the EMC chamber from the HMC to 12.5% MC, resulting in minimal breakage and consequently a high HRY. The HRYs of the samples having been desiccant-dried were then compared against the HRY of the control samples.

RESULTS AND DISCUSSION

Preliminary Experiment

Results from the preliminary experiment indicated that all rough-rice drying curves exhibited a typical exponential drying relationship (Fig. 1). The most extensive drying occurred within the first 24 h. Slightly different asymptotes were observed for the cultivars when dried with the same rough rice-to-silica gel ratios. The cultivar with the lower harvest moisture content

(HMC), 'Cheniere', was dried to a lower MC than 'Wells' using the 9:1 and 3:1 ratios. For example, using the 3:1 rough rice-to-silica gel ratio, 'Cheniere' was dried from 17.8% to 9.6% MC in the 48-h drying cycle while 'Wells' was dried from 22.0% to 11.3% MC. This trend is speculated to be due to the desiccant's drying capacity. Again, rough-rice drying operations target the final MC of their rough rice at approximately 12.5%. For both cultivars, the 3:1 rough rice-to-silica gel ratio best exhibited a drying "capacity" to lower rice MC near this value within 48 h.

Further experimentation

Results from further experimentation using a larger volume of rough rice and the 3:1 rough rice-to-silica gel ratio can be seen in Fig. 2. The drying trends, particularly the asymptotic MC values reached in the previous experiment and this further analysis, were in close agreement despite the differing amounts of rice and silica gel used. Further observations of drying rough rice with silica gel (Fig. 2) confirm that most of the drying occurred within the first 24 h. 'Cheniere' rough rice was lowered to 12.5% MC in approximately 12 h whereas 'Wells' rough rice MC was lowered to 14.3% MC in approximately the same drying duration. These results support work done by Danziger, et al. (1972) and demonstrate that silica gel can quickly dry high-MC rough rice.

The silica gel first acted by dramatically decreasing the RH of the inter-kernel air within the first 2 h of drying. Then beyond 2 h, the RH of the inter-kernel air rebounded. This demonstrates that a MC gradient had been quickly established between the high-MC rough rice and the dry inter-kernel air. As the rough rice moisture is drawn to the surrounding inter-kernel air, it is taken up by the desiccant and additional moisture from the kernel interior is transferred to the air. Once the desiccant begins to reach its saturation, a slight increase in the inter-kernel air RH is observed. By 18 h into drying, the MC gradient between the inter-kernel air and the kernel had effectively diminished. Again, different asymptotes were observed for the two cultivars. For the cultivar with the lower HMC, Cheniere, the inter-kernel RH stabilized near 30% and a kernel MC of 9.6% after the 48-h drying period. This observed value corresponds to a theoretical equilibrium moisture content of 9.0% predicted by the Chung-Pfost equation (ASAE Standards, 2005) using 30% RH and 22°C. Similarly, Wells' inter-kernel RH stabilized near 40% and a kernel MC of 11.3% MC. This observed value also corresponds to a theoretical equilibrium MC of 10.0% predicted by the Chung-Pfost equation using 40% RH and 22°C.

Desiccant-dried HRYs were comprised of 10 samples each while the controls were done in duplicate. No desiccant-dried sample had a HRY below that of the control (Table 1). The average HRYs for desiccant-dried samples were similar to those of the controls. Average whiteness values were included to verify that sample sets were equitably milled and HRYs could be compared. 'Wells' HRYs were not different and can be compared since whiteness values are close. A slightly higher whiteness value for the 'Cheniere' control sample indicates that the rough rice had been milled to a greater degree. This greater degree of milling would correspond to a decrease in HRY as more bran would have been removed from the kernel. Given the expected slightly lower HRY of the 'Cheniere' control samples due to greater inherent whiteness, the HRYs of the 'Cheniere' desiccant-dried samples were similar to the control HRYs.

These data support the findings (Wright and Warnock (1983)) that at low drying-air temperatures, vapor pressure caused by a MC gradient between the rice kernels and drying air does not significantly affect milling yields. This study warrants further research, including the quantification of silica gel carried over after rice polishing.

ACKNOWLEDGEMENTS

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Table 1 – Head rice yields (HRYs) and whiteness of desiccant-dried Cheniere and Wells rough rice.

Cultivar	Average HRY	Whiteness
Cheniere (desiccant dried)	65.2 ± 0.34	43.8 ± 0.57
Cheniere (control)	64.4 ± 0.18	45.1 ± 0.71
Wells (desiccant dried)	61.5 ± 0.42	38.1 ± 0.50
Wells (control)	61.1 ± 0.08	38.2 ± 0.71

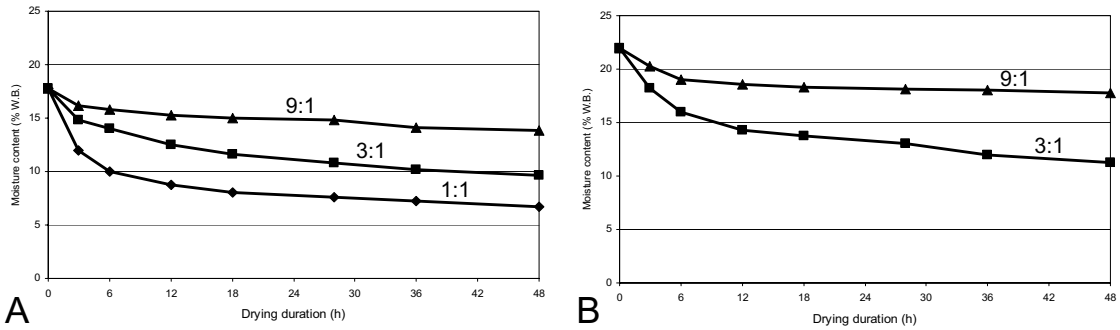

Fig. 1. Preliminary experimentation using 100-g samples of A) 'Cheniere' and B) 'Wells' rough rice to evaluate drying kinetics for the indicated rough rice to silica gel ratios (w/w).

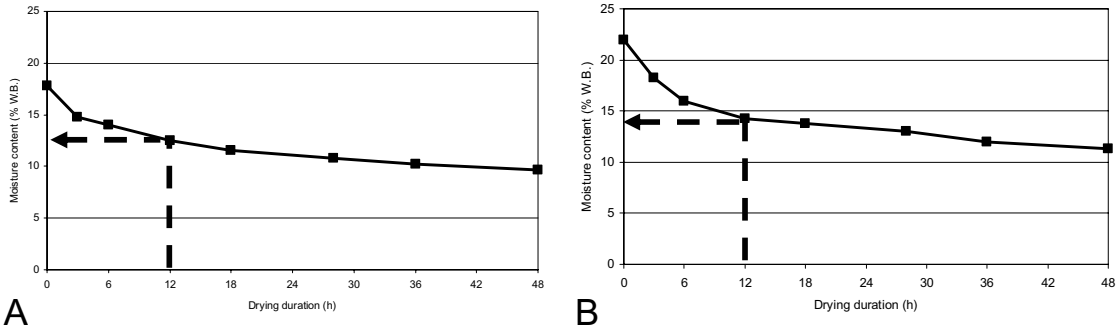

Fig. 2. Moisture contents of 430 -g samples of A) 'Cheniere' and B) 'Wells' rough rice during silica gel drying using a 3:1 rough rice to silica gel ratio.

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