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Agricultural Research Service

FIELD DAY 2002

April 18, 2002

GRAZINGLANDS RESEARCH LAB

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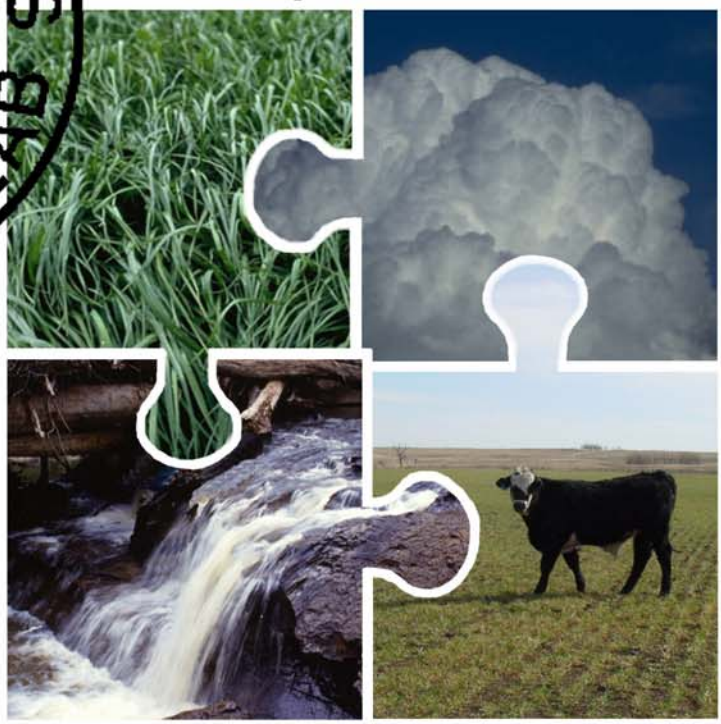

Progress Reports from the
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USDA-ARS

GRAZINGLANDS RESEARCH LABORATORY FIELD DAY

APRIL 18, 2002

Reports of Research Projects and Research in Progress on

CLIMATE AND NATURAL RESOURCES

LIVESTOCK PRODUCTION

FORAGE PRODUCTION

Edited by Charles T. MacKown and Jurgen Garbrecht

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Cover: Pictorial description of integrated research conducted at the Grazinglands Research Laboratory, El Reno, OK. Cover created by Jerry Ramirez.

WELCOME TO ALL

On behalf of the staff of the Grazinglands Research Laboratory and our cooperating institutions, we welcome you to Field Day 2002. We hope that the day proves to be exciting and informative.

The name of the Laboratory reflects our mission. We conduct research across a broad range of scientific disciplines, but each facet of the program is directed at increasing profits and reducing risks by providing new technology and management strategies for livestock production that is based on grazing. We focus the research on the stocker calf component of the Nation's beef production system, and on more efficient approaches to forage production and utilization, especially the elimination of those periods during the year when adequate amounts of high-quality forage are not available for grazing, and on developing knowledge to support sound stewardship of the soil and water resource base that supports agricultural as well as other critical community needs. But we increasingly focus more resources on reducing risks, both economic and environmental, by enhancing our understanding of variability in weather and its impacts on agriculture, and by developing technologies that incorporate new developments in weather forecasting, hydrologic modeling, and remote sensing. At the same time, with the help of our supporters, our Congressional delegation, and the Agency's leadership, we are implementing new projects which may diversify farm and ranch income and enhance environmental quality in agricultural settings.

While the Grazinglands Research Laboratory is a research facility staffed and operated primarily by USDA's Agricultural Research Service, we are fortunate to have many partners who help us achieve our goals. Cooperators with Oklahoma State University, the Oklahoma State Experiment Station and Oklahoma Cooperative Extension Service, have been members of the research team at El Reno for over 50 years. We also place a high value on our relationship with Langston University, where a portion of our staff is assigned. Other institutions, such as the University of Oklahoma's Health Sciences Center, the University of Central Oklahoma, the Noble Foundation, the Natural Resources Conservation Service, and Redlands Community College, participate with the Laboratory staff in a variety of research projects and activities. We acknowledge our debt and dependence on these partnerships.

We express our gratitude to the employees of the Grazinglands Research Laboratory for their hard work in preparing for this event and to the planning committee for organizing the field day.

Herman Mayeux
Laboratory Director

Jeanne Schneider, Co-Chair
Field Day 2002 Committee

Jean Steiner
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GRAZINGLANDS RESEARCH LABORATORY

Research Program

USDA, ARS has operated the Grazinglands Research Laboratory on the 6,700 acres of Fort Reno lands since 1948. The **Laboratory's Mission** is to provide new technology and management strategies which increase the profitability of forage and livestock production, reduce risk, promote sustainability, and conserve the productivity of grazinglands resources in the Great Plains. Emphasis is placed on development of sustainable forage/livestock production systems for the stocker calf component of the U.S. beef cattle industry.

The research is conducted by 17 scientists and 38 support personnel, divided into two units.

The current objectives of the **Forage and Livestock Production Research Unit** are to

- Minimize periods during the year when high-quality forage is unavailable, requiring producers to import purchased feeds at high cost, by developing new varieties of forage grasses and better management techniques for existing forages;
- Increase the profitability of beef cattle production by resolving constraints to rapid weight gain by stocker cattle and developing beef cattle finishing systems that utilize more forages in the diet; and
- Identify, develop, and evaluate biomass/bioenergy crops which will diversity agriculture in the southern Great Plains and reduce dependence on imported petroleum.

Primary objectives of the **Great Plains Agroclimate and Natural Resources Research Unit** are to

- Evaluate and adapt seasonal climate forecasts developed by NOAA's Climate Prediction Center for agricultural applications and incorporate them with other information about variability in climate and weather into risk-based decision and management tools;
- Utilize long-term climatic and hydrological data bases from the 230 square-mile Little Washita Experimental Watershed to define interactions among climate, land use and management, and hydrologic processes to assure availability and efficient use of water;
- Develop new technology to monitor soil water content and forage characteristics using remote sensing (satellite imaging technology); and
- Document changes in soil organic carbon content in response to management and shifts in land-use, to define rates of carbon sequestration.

Both units maintain staff at Langston University, Langston, OK, to address problems unique to small, low capital farms, with emphasis on low-input forage and livestock production and natural resource conservation.

The facilities include renovated laboratories for chemical analyses, instrumented watersheds, and experimental herds of cattle (usually about 1,000) and sheep (600), and 200 acres of irrigated alfalfa, 900 acres of cropland in wheat, 2,000 acres of improved grass varieties, and almost 3,000 acres of native tallgrass prairie, all grazed and used to conduct farm-scale research projects.

MATCHING CROPPING SYSTEMS WITH CLIMATE FOR BETTER SOIL WATER USE, LESS EROSION, AND GREATER PRODUCTIVITY

John Zhang

RATIONALE

Crop and forage production in the Southern Great Plains is largely limited by low and variable precipitation. Most croplands in the region are dryland farming operations, and therefore crop and forage production is dependent upon precipitation. Although precipitation occurrence is beyond our control, we can adapt cropping and tillage systems to climate conditions so that adverse climate impacts like short-term droughts can be alleviated and favorable climate conditions such as above average precipitation can be fully utilized. Adjustment of cropping and tillage systems to climate conditions has potential of making better use of available precipitation and soil water resources as well as maximizing crop and forage production. Before we can make any adjustment of cropping and tillage systems, we must know how much water is needed by a crop or within a cropping system, as well as how much rainwater may be retained in the soil and ultimately becomes available for plant use in each system. This information is needed for making adjustment decisions once reliable climate forecasts become available.

OBJECTIVE

The objectives of this work were to quantify the effects of commonly used cropping and tillage systems on rainwater retention and soil loss reduction, and to evaluate plant available soil water under various climate conditions and cropping and tillage systems.

RESULTS

Experimental data collected since 1977 from the eight Water Resources and Erosion watersheds at the USDA-ARS Grazinglands Research Laboratory were used in the analysis. Land use and cropping and tillage systems included native tall grass, notill winter wheat-summer Hay Grazer or Sudan (notill-double crop with notill drill planting), notill winter wheat-summer fallow (notill-single crop with notill drill planting), conservational tillage winter wheat-summer fallow (disks and harrows), and conventional tillage winter wheat-summer fallow (moldboard plow and disks). Average precipitation at the location in the past 23 years was approximately 33.5 inches. For convenience, years that received above 38 inches of rainfall were arbitrarily defined as wet and those that received below 29 inches as dry, and those between these limits as average years. Based on the seasonal pattern of precipitation and the growth stages of the winter wheat, the year was divided into three distinct periods: spring (March thru June), summer (July thru October), and winter (November thru February of the next year).

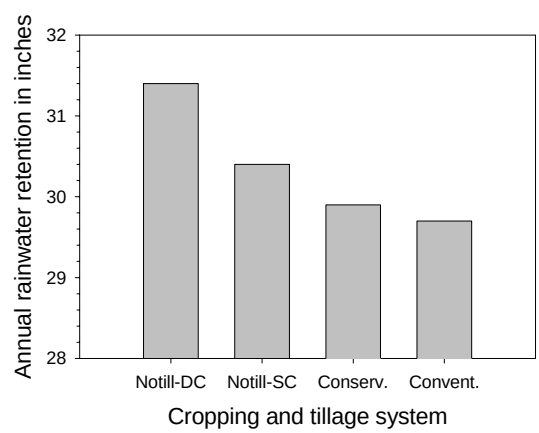


Fig. 1 Average annual rainwater retention by cropping and tillage systems in the winter wheat watersheds (DC=double crop, SC= single crop).

Cropping and tillage systems in the winter wheat-livestock production systems differed in their ability to retain precipitation (i.e. reducing surface water runoff). Notill and conservational tillage, which preserved surface residue cover and reduced mechanical disturbance of surface soil, tended to retain more rainwater than conventional tillage in which a moldboard plow was used and surface residue was turned under (Fig. 1). Surface residue protected soil surface and therefore reduced surface water runoff and soil erosion. As a result, notill systems, on average, had 1 to 2 inches of additional soil water available for plant use compared with conventional tillage systems. Interestingly, notill-double crop (notill-dc), on average, retained about 1 inch more rainwater than notill-single crop (notill-sc). This is because summer crops consumed soil moisture, and the resulting lower soil moisture caused greater water infiltration or retention. These results tell us that for a predicted wet summer, a summer crop should be grown for more water retention and greater productivity.

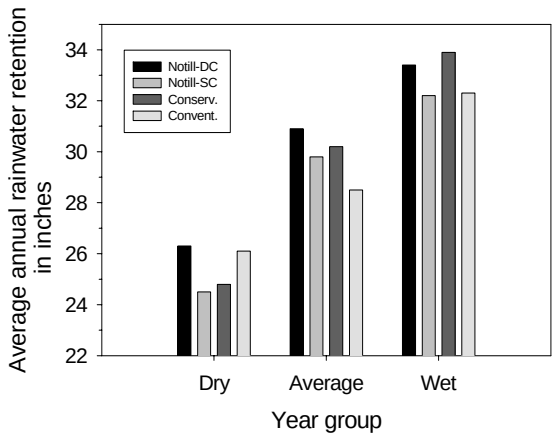


Fig. 2. Annual rainwater retention by cropping and tillage systems and year group.

Average annual rainwater retention of different cropping and tillage systems are plotted with year group in Fig. 2. The maximum difference of annual rainwater retention between cropping and tillage systems was about 2 inches; however, the average difference between wet and dry years was approximately 8 inches. These results indicate that the year-to-year precipitation variation plays a bigger role in determining plant available soil moisture than do the cropping and tillage systems. Thus, adapting cropping systems to climate conditions has great potential of mitigating drought impacts and fully utilizing wetter climate conditions.

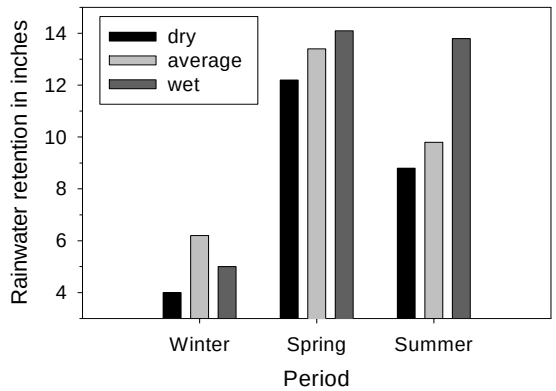


Fig. 3. Rainwater retention in native grass watershed by season/period and year group.

Rainwater retention under native grass prairie during dry, average, and wet years was further broken down into seasons (Fig. 3). Most rainwater retention occurred in the spring period followed by the summer period, which corresponded to the primary and secondary rain seasons in the area. For practical application, note the considerable increase in rainwater retention in the summer period of wet years. The increased soil moisture in wet summer provides a good opportunity for intensive management such as increasing fertilization and intensifying grazing by purchasing more stockers.

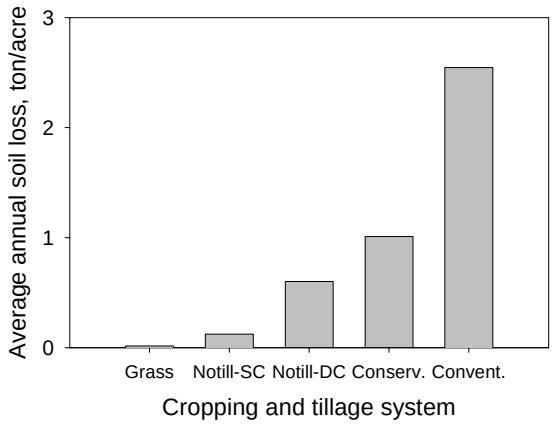


Fig. 4. Average annual soil loss by land use and cropping and tillage systems (DC= double crop, SC= single crop).

In addition to the low and variable precipitation, excessive soil erosion is another major factor that causes severe land degradation, loss of crop productivity, and deterioration of environmental quality. Average annual soil erosion increased dramatically with increasing tillage intensity (Fig. 4). To sustain crop productivity and preserve land resources, the conventional tillage should be reconsidered, especially when the surface slope is above 5%, and the conservation-type of tillage such as notill, reduced tillage, or delayed tillage, which increases rainwater retention and reduces soil erosion, should be adopted instead.

Seasonal distribution of soil loss from the conventional tillage winter wheat watershed is shown in Fig. 5 for different year groups. Obviously, tremendous soil loss occurred in the summer period during wet years. This result further supports the earlier findings that for a predicted wet summer, a summer crop should be grown in summer fallow fields to reduce soil erosion as well as to increase rainwater retention. If this practice is not chosen, then conservation-type of tillage practices should be used.

This work shows cropping and tillage systems differed in their ability to reduce water runoff and soil erosion. Maximum difference in rainwater retention among the cropping systems was about 2 inches per year; however, the average difference between wet and dry years was 8 inches, indicating a dominant role of annual precipitation in influencing plant available soil water. These results indicate the potential of matching cropping and tillage systems with climate conditions for more efficient use of soil water and greater productivity. For example, a summer crop could be grown in a wet summer to alleviate the fall forage shortage while controlling soil erosion. Cropping and tillage systems played a bigger role in reducing soil erosion than rainwater runoff. To prevent excessive soil erosion, conventional tillage should be avoided, and conservation type of tillage such as notill, reduced tillage, or delayed tillage should be practiced instead.

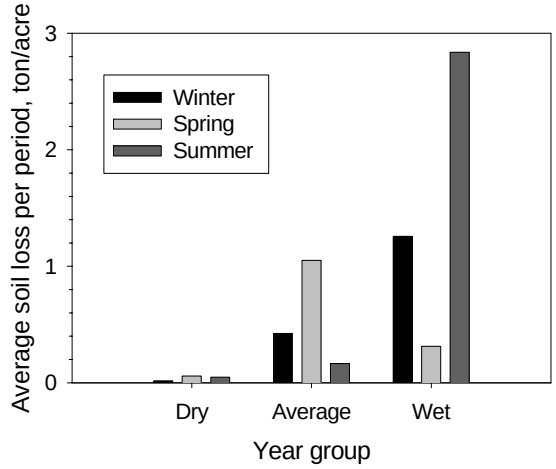


Fig. 5. Soil loss from the conventionally tilled winter wheat watershed by year group and period.

TRENDS IN ANNUAL AND DAILY PRECIPITATION

Jurgen D. Garbrecht and Jeanne M. Schneider

RATIONALE

Trends in annual precipitation occur naturally over a broad range of time scales. An increasing precipitation trend was observed in the Great Plains during the last two decades of the 20th century. The average annual precipitation in Central Oklahoma between 1980 and 2000 was about 5 inches or 17% higher than the average of the 1895-1979 period (Fig. 1). Even though annual precipitation can be used to define wet and dry years, it is the corresponding changes in daily precipitation amount, number of rainy days, and distribution throughout the year that are of particular interest to agriculture. Such changes in daily precipitation values affect surface runoff, soil moisture availability, and

land productivity. Hence, identification of these changes may point to opportunities for adaptation and diversification, and assist the farmer and rancher to move towards a more profitable production.

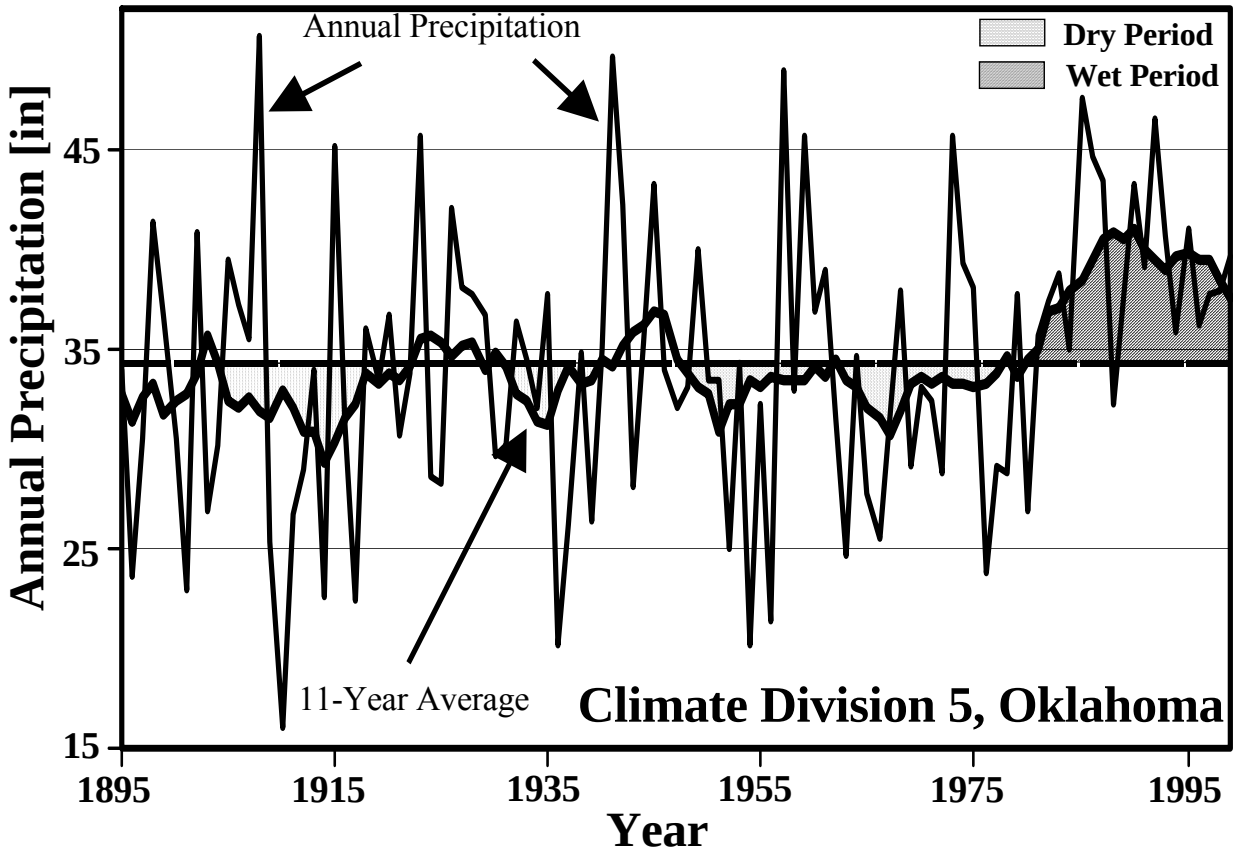


Fig. 1. Annual precipitation (thin line), decade-scale precipitation variations (thick line), and increase in average annual precipitation over the last two decades of the 20th century (hatched area) for Central Oklahoma.

OBJECTIVE

This research was conducted to identify changes in daily precipitation amount and number of rainy days as a result of the observed increasing trend in average annual precipitation at the end of the 20th century.

RESULTS

Changes in daily precipitation during the 1980-2000 trend in average annual precipitation were investigated for a location near Kingfisher in central Oklahoma. The number of rainy days increased from 55.7 to 61.3, for an average increase of 5.6 rainy days per year. Mean precipitation per rainy day increased from 0.521 inches to 0.556 inches, for an average increase of 0.035 inches per rainy day. Based on these results, 60% of the annual increase in precipitation during the 1980-2000 period was to the increase in the number of rainy days, and 40% was attributed to the increase in the daily amount of precipitation. It was also observed that the magnitude and frequency of extreme precipitation events (above 4 inches) increased slightly, but their contribution to the average annual precipitation increase was less than 2% of the annual increase. Thus, the average annual precipitation increase is not due to higher and more frequent extreme precipitation days, but to

daily precipitation events under 3.0 inches that accounted for about 75% of the annual precipitation increase. Hence, the trend towards more rainy days without a significant increase in very high precipitation events is expected to benefit the soil moisture supply for crop production. On a seasonal basis, higher monthly precipitation in spring, early summer and fall were observed (Fig. 2). This slight change in seasonal pattern may benefit primarily winter wheat grazing and spring grain production, whereas summer crops may receive less rain.

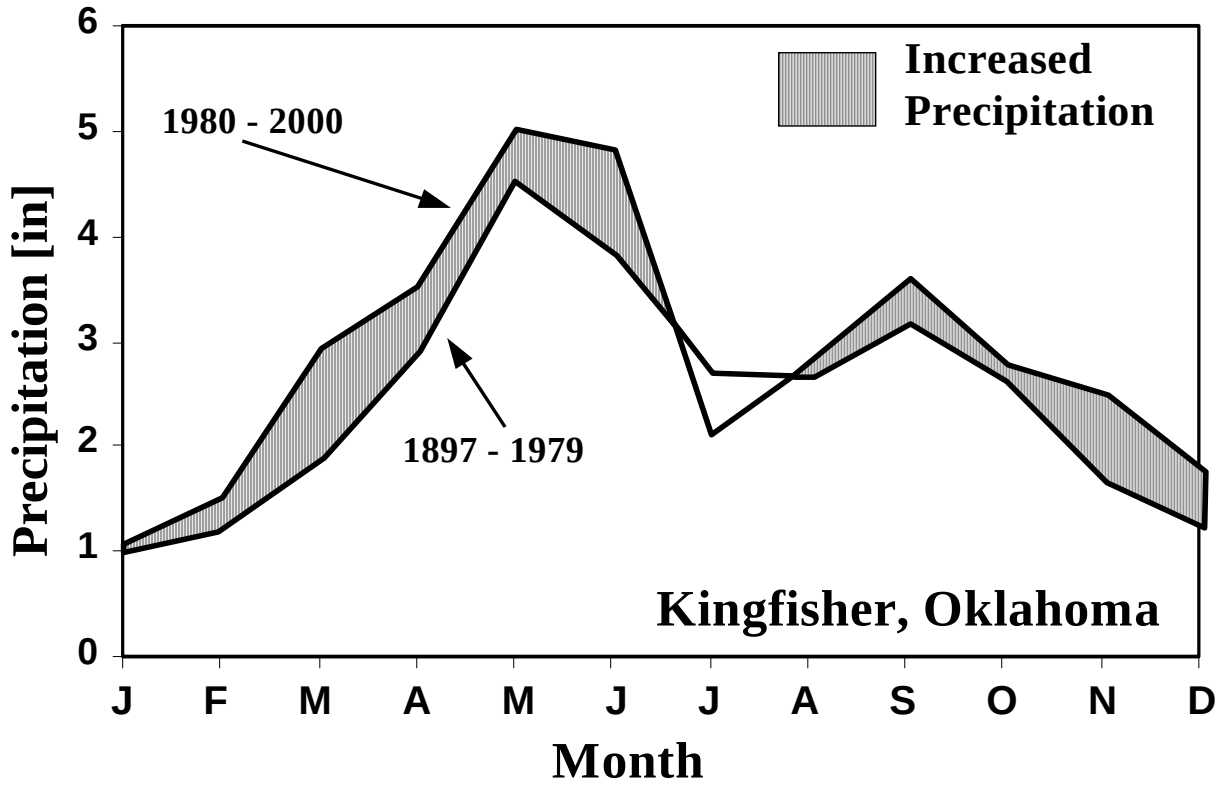


Fig. 2. Annual distribution of average monthly precipitation for the Kingfisher weather station. The hatched area identifies the increase in precipitation.

NOAA'S CLIMATE PRECIPITATION FORECASTS: INITIAL ASSESSMENT OF UTILITY FOR AGRICULTURAL APPLICATIONS

Jeanne M. Schneider and Jurgen D. Garbrecht

RATIONALE

In the Southern Great Plains, the single largest natural risk factor for agricultural production is the large variation in weather and climate, particularly seasonal rainfall. Long range precipitation forecasts may provide producers with the ability to make proactive management decisions based on expected conditions. The National Oceanic and Atmospheric Administration (NOAA) is issuing experimental seasonal precipitation forecasts that could lead to beneficial applications in agriculture. The forecasts are statements of probability, and represent the best current scientific knowledge on predictable aspects of climate. Monthly and seasonal climate forecasts are expressed as departures from conditions experienced over the past 30 years, and are made for the upcoming month and for 3 month periods out to a year in advance. The size of each forecast division is relatively large, roughly 35,000 square miles or about half the size of Oklahoma. The utility of these forecasts for individual agricultural operations is currently unknown.

OBJECTIVE

Effective use of these seasonal precipitation forecasts in agriculture requires first an assessment of forecast characteristics in terms relevant to agriculture. The objective of this report is to briefly describe the forecasts, and three of our initial assessments (usefulness, dependability, and effectiveness) for forecast divisions across the United States.

INTRODUCTION TO THE NOAA SEASONAL PRECIPITATION CLIMATE FORECASTS

Experimental seasonal climate forecasts are issued every month by NOAA's Climate Prediction Center. Among these forecasts, the "probability of exceedance" precipitation forecasts show good potential for application in agricultural decision making. These forecasts specify the changes in probabilities for total precipitation relative to conditions over the previous 30 years. They consist of forecasts for overlapping 3-month periods covering the coming year (13 lead times), for each of 102 forecast divisions across the United States.

Fig. 1 shows the forecast made for the Central Oklahoma forecast division for the 3-month period October-November-December 2001, as issued in mid-September (the shortest lead time). The "Final Forecast" curve shows a prediction for slightly wetter than "Normal" conditions. Each forecast curve is a statement about the probability (on the vertical axis) that particular totals of precipitation (on the horizontal axis) will be exceeded. In this example, the forecast gives a 67% chance (2 in 3 odds) for more than 6.4" of precipitation; a 50% chance (1 in 2 odds) for more than 7.6"; and a 10% chance (1 in 10 odds) for more than 11.8" of precipitation. The slope of the forecast curve is determined by two factors: the historical year-to-year variability in 3-month precipitation, and forecaster expectations about predictability during this 3-month period. A steeper slope represents a more predictable situation, a flatter slope represents a less certain situation. In this example, the forecast curve is a little steeper than for "Normal" conditions, indicating slightly more predictability during this 3-month period.

The probabilistic nature of these forecasts have significant implications for their use. They are a statement of shifts in odds, not a forecast for a particular amount of precipitation. The possibility remains that dry conditions could occur during a wet forecast, or vice versa. This uncertainty is an inherent and unavoidable part of the forecast. A user should not read a single

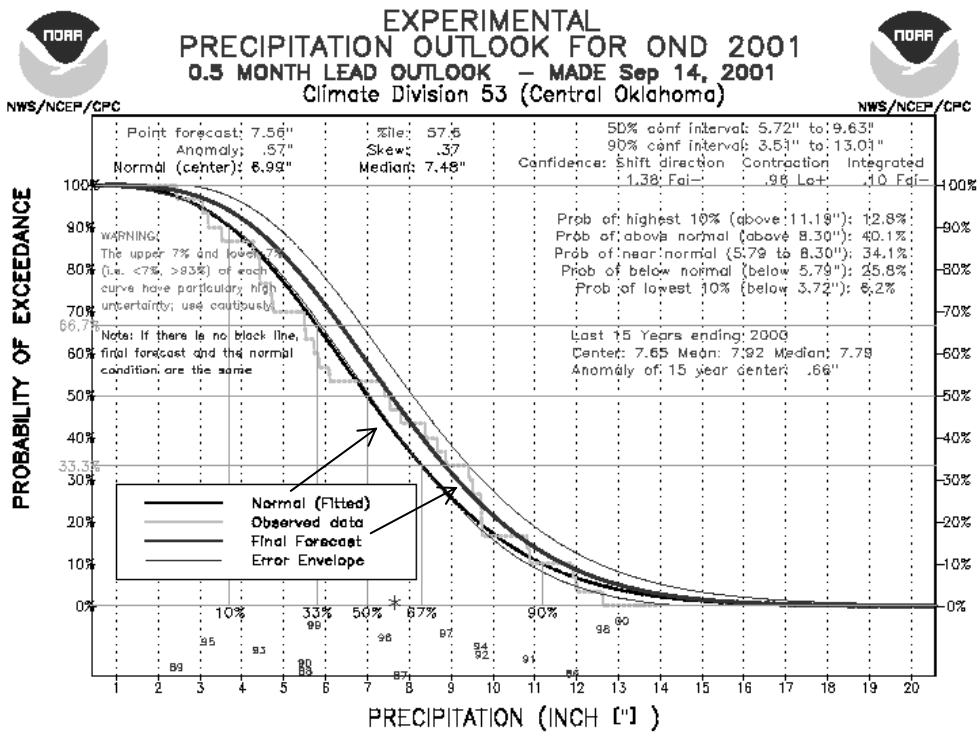


Fig. 1. Probability of Exceedance Forecast for Central Oklahoma for Oct-Nov-Dec 2001. These forecasts a available on the World Wide Web at http://www.cpc.ncep.noaa.gov/Pacdir/NFORdir/HOME3.html.

value from the forecast curve (for example, the "point forecast", or median value) and expect it to be "on the money". Instead, a user should expect the entire forecast *curve* to be a good representation of the odds over a number of forecasts for that 3 month-period. This is one reason we are working to interpret and adapt these forecasts within a risk-based decision-making system for agriculture.

RESULTS

Seasonal precipitation climate forecast performance has been improving by all measures, but the forecasts may or may not be currently useful for all applications at all locations. Forecast utility is an application-specific question, a unique combination of forecast specificity and reliability for each application. However, there are climate forecast characteristics that can be addressed generally, from an agricultural point of view. We have developed a number of different approaches to these issues, and present three examples below that assess forecast usefulness, dependability, and effectiveness.

In this context, "usefulness" is a measure of the size of the forecast departure from historical conditions. How often, and how large, are the differences between the forecast curve and the "Normal" curve? Forecasts of small departures would probably have little usefulness because they represent "business as usual", or typical precipitation. Best management practices are already tuned to typical conditions. To identify the regions with larger and more useful departures, we use the difference along the precipitation axis between the forecast and "Normal" curve, divided by the historical median precipitation, times 100%. For the four years 1997 - 2000, the percent of forecasts with departures larger than an arbitrary threshold of 10% are presented in Fig. 2. In Central Oklahoma, only 4 in 48 forecasts (~ 8% of the forecasts, or 1 per year on average) were larger than 10% of the historical median precipitation. The size and frequency of departures are greater in Texas and central and western Kansas, in the 10-29% range. The region with the most significant departures is the Desert Southwest, where there are relatively strong seasonal

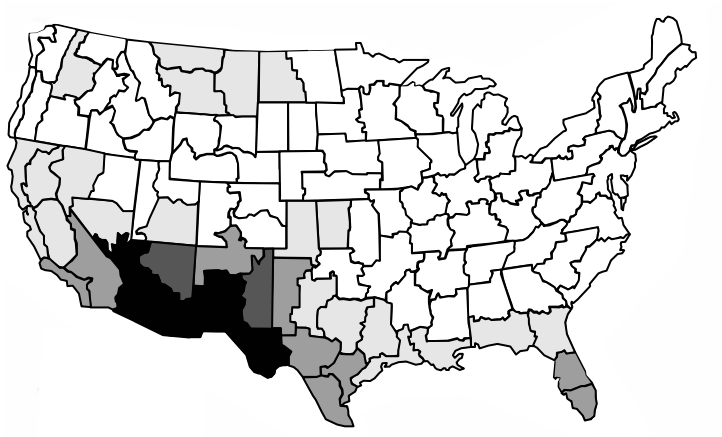


Fig. 2. Usefulness, as percent of forecasts with anomalies larger than 10% ≥40% 30-39% 20-29% 10-19% 0-9%

correlations between local precipitation and sea surface temperatures in the equatorial Pacific (El Niño - Southern Oscillation).

"Dependability" is a measure of the ability of the forecast curve to correctly predict future precipitation probabilities. One initial assessment asks whether or not the forecasts are reliably predicting the shift in direction to wetter or drier conditions. Results of this simple assessment for 1997 - 2000 are shown in Fig. 3. It shows that the forecasts for North Texas, Oklahoma, and Kansas have tended to be too dry over the last four years, while forecasts in southern Texas have been dependable.

"Effectiveness" refers to the ability of the forecast to provide information beyond that offered by random or climatological (a 30 year record) considerations. For this assessment, we measured the reliability of forecasts versus a forecast of "Normal" (climatology) over equal thirds of the forecast curve, for 1997 - 2000. These results are shown in Fig. 4, and indicate that the forecasts have some effectiveness for 43 of 102 forecast divisions across the United States (the solid gray areas on the map). For Central Oklahoma, the effectiveness is modest (difference of 3 forecasts in 48, or 6% of the forecasts better than climatology), but still potentially useful.

These initial assessments illustrate the limits of recent forecast utility for agricultural applications in the Southern Great Plains. However, the NOAA/CPC seasonal climate forecast procedures are being improved continuously, incorporating relevant research results as soon as possible. This suggests that forecast performance will continue to improve. We plan to be ready to exploit those improvements as they occur. Ongoing and future research at GRL will bridge the gap between the large time and space scales of the forecasts, and the shorter time steps and smaller areas needed to model and estimate crop growth and forage production. This will be followed by demonstrations of the value and impact of the forecasts for agricultural management. The final step will be the development of practical, risk-based decision-making tools that link forecasts to management options.

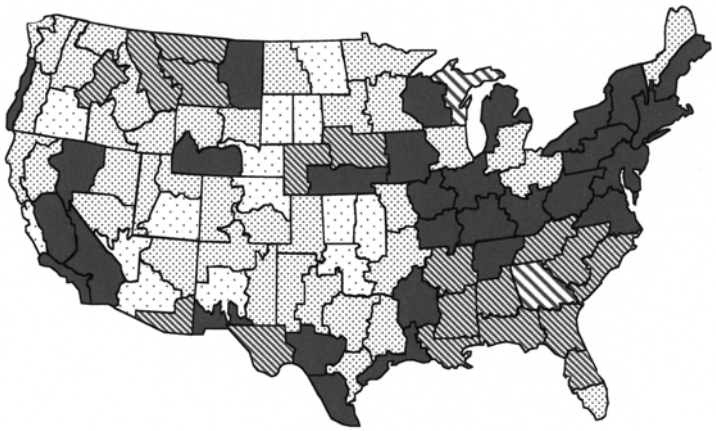


Fig. 3. Dependability of forecast direction. Too dry: > 15% Slightly dry: 5% to 15%
Good match: 5% to -5% Slightly wet: -15% to -5% Too wet: <-15%

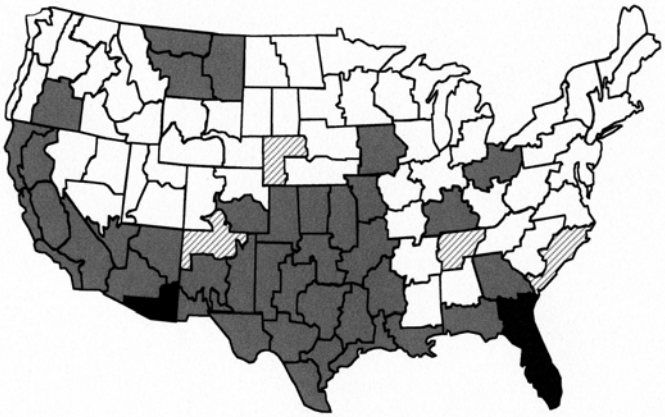


Fig. 4. Effectiveness relative to climatology, with equal effectiveness in white.

Percent of Forecasts Better Than Climatology	Percent of Forecasts Worse Than Climatology
0 to 10%	0 to 10%
10 to 20%	
20 to 30%	

STREAMFLOW PREDICTION OF THE LITTLE WASHITA RIVER EXPERIMENTAL WATERSHED

M.W. Van Liew and J. Garbrecht

RATIONALE

In recent years computer simulation models have been developed to determine how changes in land use or climatic conditions impact water resources on a watershed. An understanding of how these changes affect water resources is important in addressing issues related to downstream water supply, water quality, flood control, and low-flow management. Computer models used for these kinds of studies contain mathematical terms referred to as parameters that must be fine-tuned to give accurate simulations of runoff from the watershed. These parameters are fine-tuned by matching the runoff simulated by the model with the runoff that has been measured on the watershed. This process is referred to as model calibration. Proper calibration of a model is critical to ensure that processes such as runoff, evapotranspiration and soil moisture movement on a watershed are well represented. Once a hydrologic model is calibrated, it should also be tested on other data sets that contain time periods not used in calibration. This process is referred to as model validation, and it is used to verify that the model has been properly calibrated. Model validation is important to help provide a measure of confidence in the predictive capability of the model as scenarios that reflect changes in land management, land use and climate fluctuations are imposed on the watershed.

OBJECTIVES

The objectives of this study were to calibrate and validate a computer model referred to as the Soil and Water Assessment Tool (SWAT) on the Little Washita River Experimental Watershed (LWREW) in Southwestern Oklahoma. Certain portions of the available data set were used for model calibration, while other portions were used for model validation.

RESULTS

In this study SWAT was selected to predict streamflow from a long-term climate record on the LWREW. SWAT operates on a daily time step, and can be used to predict the impact of land management practices on water, sediment and agricultural chemicals exiting large watersheds. The LWREW is characterized as range, cultivated, and forested lands on gently to moderately rolling hills. The USDA ARS has maintained an extensive climatological and streamflow database on the watershed since the 1960s.

Precipitation and runoff data from two subwatersheds within the Little Washita River Experimental Watershed were used to calibrate SWAT. These two watersheds are referred to as subwatershed 526 and 522, and are 62 and 208 square miles in size, respectively. Streamflow measured at gages 526 and 522 (see Fig. 1) is comprised of contributions from surface and subsurface flow on the watershed. Over six years of precipitation and streamflow record were used to calibrate parameters that govern surface and subsurface runoff response in the model, and over nine years of available record were used for subsequent model validation. Calibration of the two subwatersheds involved a multi-step process. A preliminary calibration was conducted to estimate model parameters so that the measured versus simulated yearly and monthly runoff amounts were in agreement for the respective calibration periods. Model parameters were then fine-tuned based on a visual inspection of daily hydrographs and flow frequency curves. The daily hydrograph is a record of the day- to-day changes in the streamflow at gages 526 and 522 on the LWREW. The flow frequency curve represents the cumulative distribution of the streamflow for a given year or number of years. Calibration of the model on a daily basis resulted in a larger proportion of subsurface flow and lower peak

surface runoff rates than were obtained in the preliminary calibration. A comparison of measured and predicted daily hydrographs is presented in Fig. 2 for subwatershed 526 for the period 6/1/92 to 12/31/92. The figure shows that the calibrated model predicts peak flows, recession curves, and subsurface flows with reasonable accuracy. Measured and predicted flow frequency curves are shown in Fig. 3 for the period of record from 1992 to 2000 on subwatershed 526. Similar comparisons of daily hydrographs and flow frequency curves were obtained on subwatershed 522. Good agreement between measured and predicted flow frequency curves suggests that for the selected calibration parameters, SWAT simulated the range in magnitude of daily flows with reasonable accuracy. Results of this study lead to conclude that the model is capable of providing reasonably accurate simulations for hydrologic studies related to the impact of changes in land use, management, and climate fluctuations on water budget and water availability on the LWREW.

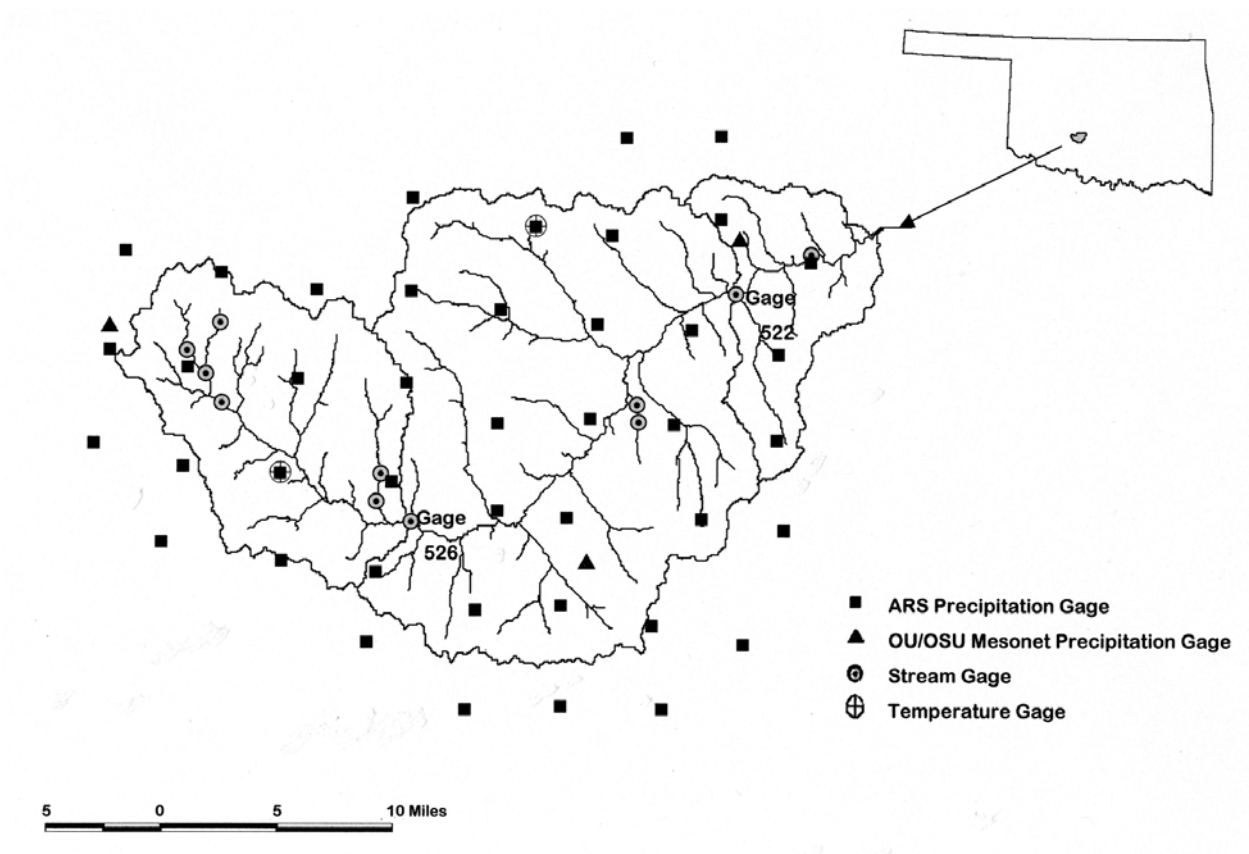


Fig. 1. Location of the Little Washita River Experimental Watershed.

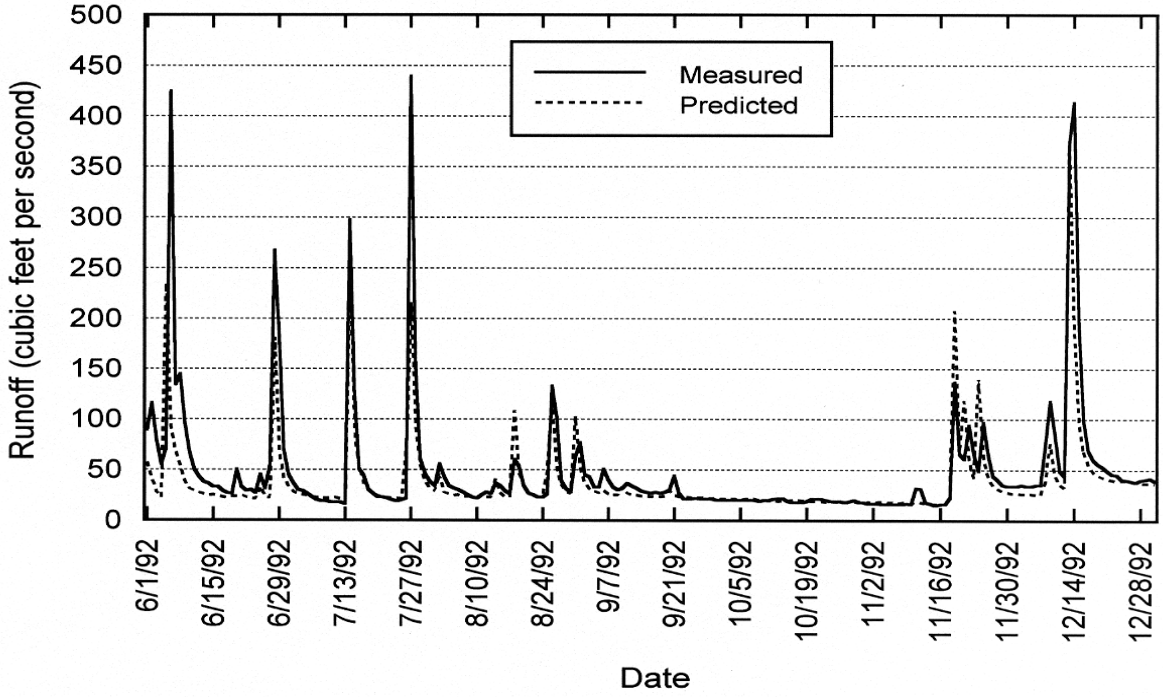


Fig. 2. Subwatershed 526 Daily Runoff Comparison for 6/1/92 to 12/31/92.

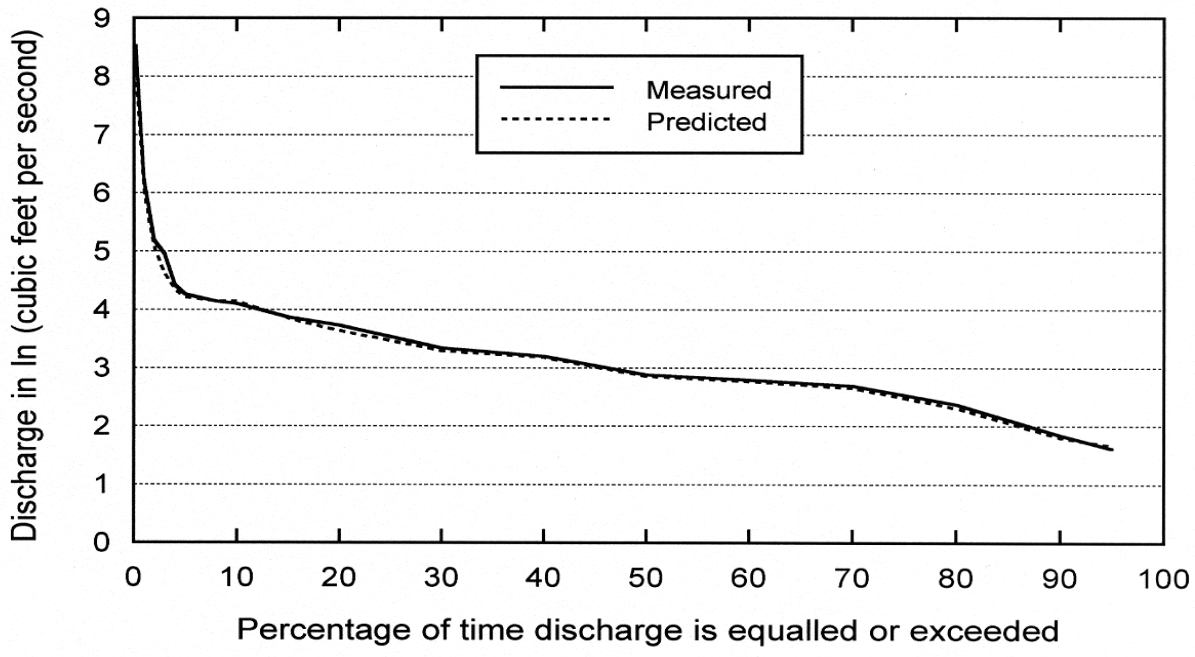


Fig. 3. Subwatershed 526 Comparison of Daily Flow Frequency Curves for the Validation period: 1992 to 2000

HYDROLOGIC RESPONSE OF AN EXPERIMENTAL WATERSHED TO CHANGES IN ANNUAL PRECIPITATION AMOUNTS

M.W. Van Liew and J. Garbrecht

RATIONALE

Decade long precipitation fluctuations lead to changes in the volume of surface runoff and ground water recharge that can either benefit or adversely impact agricultural, domestic, industrial and ecosystem uses. Therefore, management of water supply systems, operation of reservoirs, development of additional water storage capacity, and mitigation strategies that deal with excess or shortage of water must consider the occurrence and size of decade-long precipitation fluctuations. To address these long-term water needs, an improved understanding of the relation between decade-long precipitation fluctuations and water availability must be developed.

OBJECTIVE

The objective of this research was to determine the impact of fluctuations in precipitation on evapotranspiration (ET), and runoff from the Little Washita River Experimental Watershed.

RESULTS

A computer simulation model referred to as the Soil and Water Assessment Tool (SWAT) was used to estimate the effects of precipitation variations on the water budget of the Little Washita River Experimental Watershed (LWREW). Located about 50 miles southwest of Oklahoma City (see previous paper), the LWREW consists of gently to moderately rolling hills on land that is characterized as 66% rangeland, 19% cultivated, 9% forested, and 6% miscellaneous. The average annual precipitation and runoff for the watershed are about 30 and 2.5 inches, respectively. Available historical records of precipitation and runoff for the LWREW were used to calibrate SWAT for estimating the hydrologic response on a 208 square mile area of the watershed. Following model calibration, the climate generator in SWAT was used to simulate a 50-year period to establish a baseline from which to compare changes in precipitation. Next, precipitation amounts were increased or decreased by 20, 40 and 60 percent within the watershed for each month, and a sensitivity analysis was carried out to compare the output variables to their baseline values.

Average monthly precipitation, evapotranspiration, and runoff simulated by SWAT for the baseline climatic conditions are presented in Fig. 1. Evapotranspiration is the process by which water in the land surface, soil and vegetation is converted into water vapor and returned to the atmosphere. The model simulated an average annual precipitation amount equal to 29.6 inches, of which 26 % occurred during the months of April and May and 20 % occurred during the months of September and October. The model simulation shows that ET comprised 91 % of the outgoing water budget, followed by 5 % for surface runoff, and 4 % for subsurface runoff. For all months of the year except June, July, and August, the volume of precipitation exceeded that of evapotranspiration. For the months of June and July, ET exceeded precipitation by about 42 %. Under baseline conditions, SWAT simulated an average surface runoff volume of 2.5 inches. Sensitivity of annual ET to fluctuations in precipitation is shown in Fig. 2. The data show that ET is far less sensitive to increases than it is to decreases in precipitation. A 40 % increase in precipitation results in only a 19 % increase in ET, while a 40 % decrease in precipitation results in a 32 % decrease in ET. Fig. 3 shows the sensitivity of annual runoff to changes in precipitation. The curve reflects the increasing

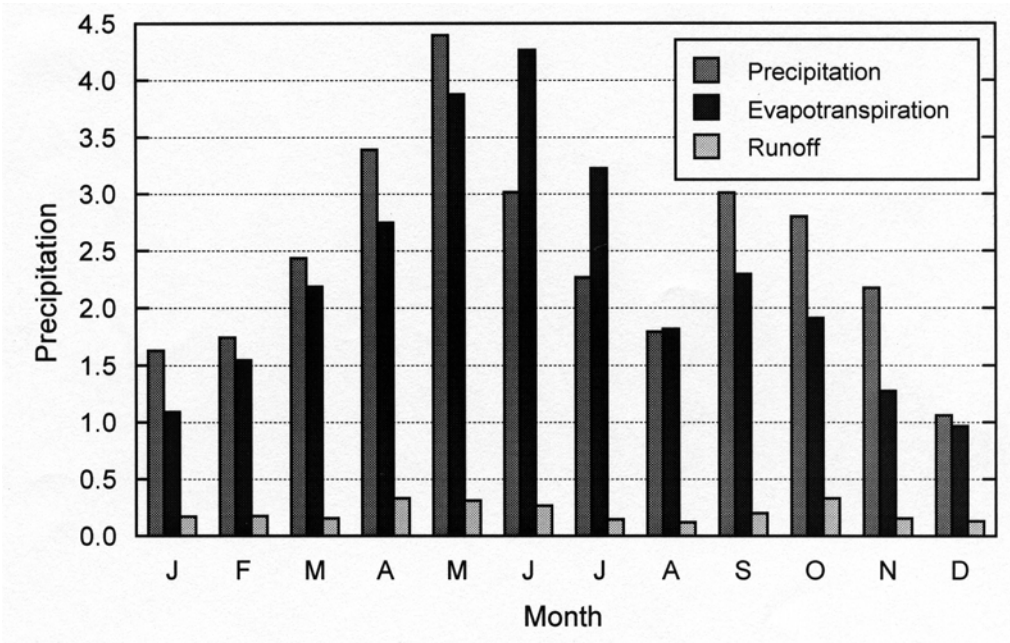


Fig. 1. Average monthly water budget for baseline conditions generated by SWAT for 50-year period.

sensitivity of runoff to incremental increases in precipitation. For example, a 20 % increase in precipitation corresponds to an increase in runoff of 104 %, while a 40 % precipitation increase corresponds to a 248 % increase in runoff. Annual runoff simulated by SWAT was plotted against precipitation ranging from $\pm$ 60 % from the baseline value of 29.6 inches. Fig. 4 shows that precipitation amounts simulated by SWAT range from 11.9 to 47.5 inches. When expressed as percent of precipitation, runoff varies as 0, 8.4, and 27% for a 60% decrease, no change, and 60% increase in baseline precipitation, respectively. In other words, simulated runoff varied from 0 inches for a 60% decrease in the baseline precipitation to 12.8 inches for a 60% increase in the baseline precipitation. For a precipitation range from 28 to 35 inches, simulation results obtained from SWAT show that the sensitivity factor between long-term variations in runoff precipitation is about 4, meaning that a 10% increase in precipitation results in a 40% increase in runoff.

Historical records on the LWREW indicate that for an annual precipitation amount of about 20.3 inches, the corresponding runoff amount is about 0.7 inches. Test results from this study suggest that at very low levels of annual precipitation approaching 16 inches, runoff from the LWREW becomes negligible. A low annual volume of precipitation such as this would result in a severe water shortage with profound implications to society, wildlife, and the aquatic environment.

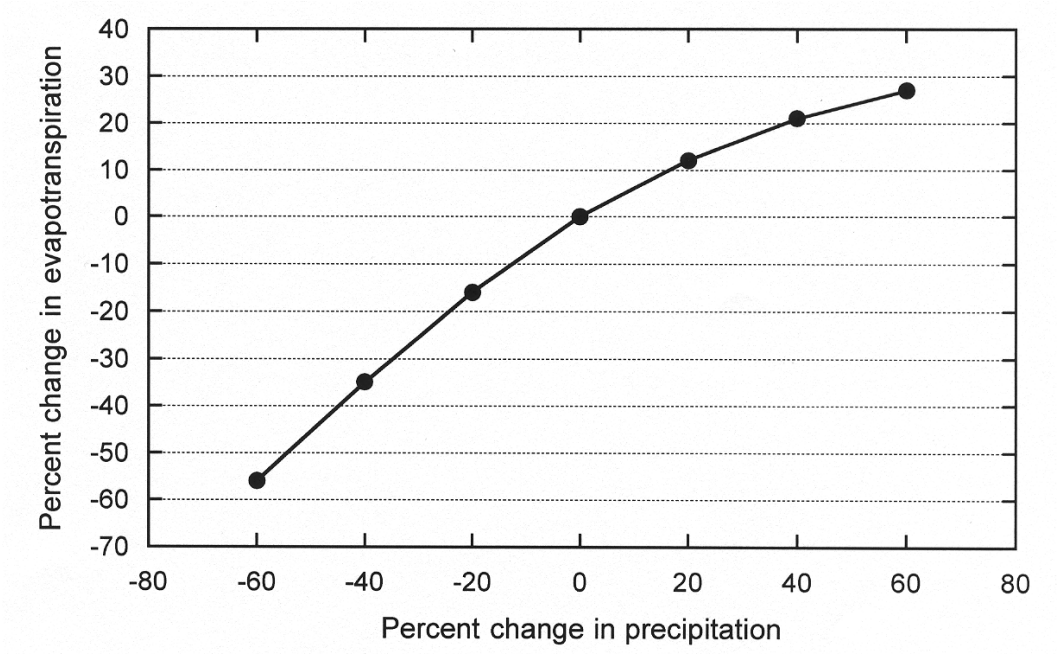


Fig. 2. Sensitivity of evapotranspiration to precipitation.

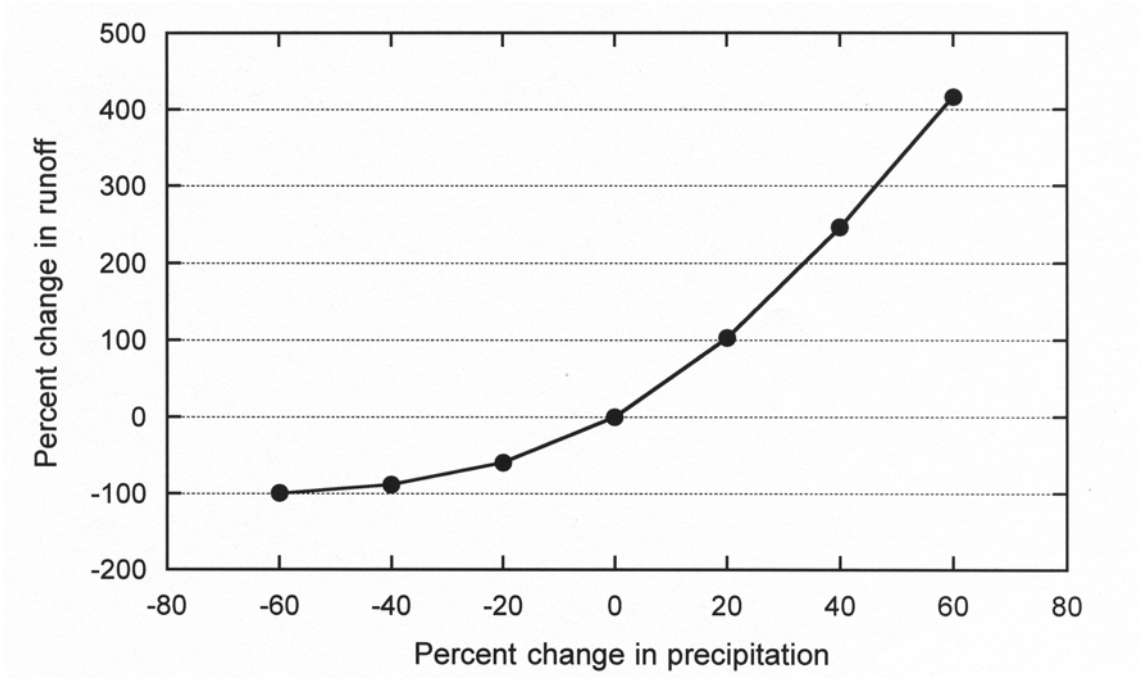


Fig. 3. Sensitivity of runoff to precipitation expressed as a percentage.

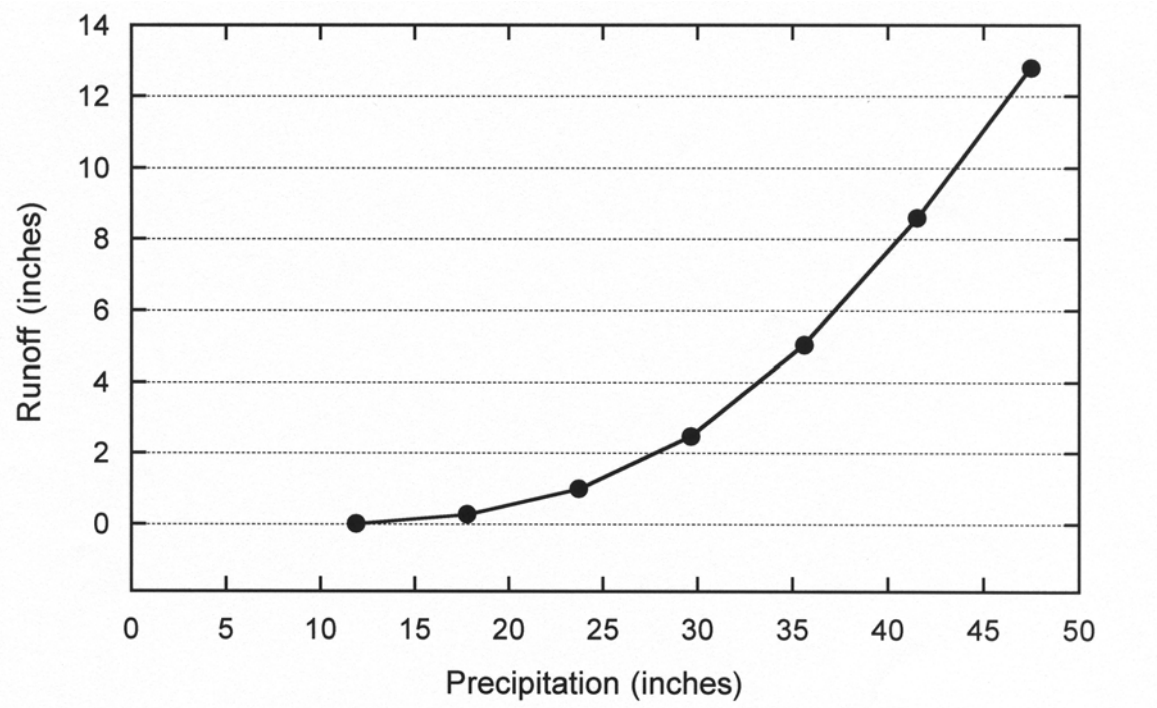


Fig. 4. Sensitivity of runoff to precipitation.

REMOTE SENSING OF FORAGE QUALITY DIRECTLY IN THE FIELD

Patrick J. Starks, Samuel W. Coleman, and William A. Phillips

RATIONALE

Timely assessments of the quality of standing forages would allow more efficient pasture management and feeding of supplements, and could be used to match grazing and calving dates to better optimize the use of available forage protein while maintaining reproductive rates and weaning percentages.

Standard wet chemistry techniques used to determine forage quality parameters, such as percent acid detergent fiber (ADF), neutral detergent fiber (NDF), and crude protein are highly accurate. However, these wet chemistry techniques are labor intensive, expensive, produce laboratory wastes, and may not provide information back to the livestock producer in a timely manner to make beneficial adjustments in livestock feeding operations. Near-infrared spectroscopy (NIRS) is a bench-top remote sensing approach that provides accurate measurements of forage quality, but requires manual sample collection and preparation. A large number of samples would have to be collected and processed in order to provide a realistic assessment of extensive land areas. NIRS analysis of fecal samples likewise requires manual sample collection and preparation, and the results may be animal specific unless a considerable number of samples are collected and processed. A remote sensing approach

applied directly in the field could substantially reduce or eliminate manual sample collection and preparation and provide real-time measurements of forage quality over large land areas.

OBJECTIVE

Our objective was to determine if it is feasible to estimate common forage quality parameters, percent NDF, ADF and nitrogen (N), directly in the field using hand-held remote sensing techniques with similar accuracy to that of NIRS analysis of clipped forages.

RESULTS

A four-acre area of Midland bermudagrass was divided into six equal-sized strips, each receiving one of three fertilizer treatments. The strips were sampled intermittently during the growing seasons of 1999 and 2000, and sampled once per week during the growing season of 2001.

The amount of solar energy reflected from the bermudagrass canopies was measured at selected locations within the strips using a hand-held, remote sensing instrument (radiometer). After the reflectances were measured, a sampling frame was placed around the area viewed by the radiometer, and all vegetation within the frame was clipped, bagged, and dried. After drying, the samples were ground to a fine powder for determinations of percent N, NDF, and ADF using wet chemistry procedures. The wet chemistry measurements are used both to develop prediction equations for the NIRS and radiometer approaches and as reference values for comparison with predictions made from the NIRS and radiometer equations.

All data from the radiometer and NIRS instruments, and laboratory reference values of percent ADF, NDF, and N values were input into commercially available software for development and evaluation of equations to predict forage quality. A total of 77 samples from the three-year study were used. During equation development, the software reserved 1/6 of the samples for evaluating the equation, and this process was repeated six times so that every sample was used for validation. The final equation was calculated using all samples. Due to the small number of samples, no true validation with independent data was conducted. Therefore, these data represent a feasibility study where comparison is made between proven NIRS techniques and the field radiometer approach. Statistical evaluations include the mean, standard deviation, standard error of prediction corrected for bias (SEP(C)), and r^2. (An r^2 of 1 indicates perfect agreement between measured and predicted values, whereas 0 would indicated complete disagreement.)

Table 1 contains composite comparison statistics generated from equation development (6 times through) for percent N, NDF, and ADF. Mean and standard deviation of the laboratory reference values are also included. From these data it is observed that the mean and standard deviations from the predictions are close to one another, and that both prediction methods generate values similar to those measured in the laboratory. In all cases, the SEP(C) of the radiometer predictions are comparable to those from the NIRS, suggesting that the accuracy of the in-field approach is similar to that of the NIRS.

Table 1. Comparison of the summary statistics generated from predictions of N, NDF, and ADF based on benchtop NIRS and hand-held radiometer reflectance data. Laboratory reference values are also included. Seventy-seven samples were evaluated.

Method	Mean	SD†	SEP(C)‡
	% Nitrogen		
Laboratory	1.5	0.8	
Benchtop NIRS	1.5	0.8	0.3
Radiometer	1.5	0.7	0.3
	% Neutral detergent fiber		
Laboratory	64.8	6.1	
Benchtop NIRS	64.9	6.2	2.4
Radiometer	64.9	5.5	2.7
	% Acid detergent fiber		
Laboratory	32.9	4.4	
Benchtop NIRS	33.2	4.0	1.5
Radiometer	33.0	3.9	1.9

†SD, standard deviation.
‡SEP(C), standard error of prediction corected for bias.

Fig. 1 through 3 are plots of the predicted percent N, NDF, and ADF values, respectively, from the final calibration equations from both the NIRS and radiometer approaches versus the laboratory reference measurements. In all cases, the NIRS predictions are closer to the laboratory measurements than those from the radiometer. Nevertheless, the r^2 from the radiometer are all greater than 0.80 meaning that the field remote sensing approach accounts for at least 80% of the variability measured in the laboratory.

Less precision should be expected in the hand-held method for two reasons. First, the sample of ground forage scanned with the bench-top instrument is very similar to that used to conduct reference chemistry for N, ADF and NDF, whereas the hand-held procedure measures reflectances of the forage sample before it was harvested. Sampling could be a significant factor in the difference between precision of the two procedures. Secondly, the bench-top NIRS approach measures reflectances under controlled lighting conditions, whereas the hand-held approach measures reflectance from a live canopy under variable lighting conditions.

Our objective was to determine if it is feasible to estimate percent N, NDF, and ADF directly in the field using hand-held remote sensing instruments with accuracy similar to that of conventional bench-top NIRS analysis of clipped forages. Our preliminary data analysis for remotely sensed data collected over live Midland bermudagrass canopies indicates that it is feasible to estimate these forage quality parameters.

The study will be expanded so that a more stringent evaluation can be made using an independent data set. Additionally, research findings from some bench-top NIRS studies have indicated that calibration equations are often species dependent. Therefore, additional warm and cool season forage species will be added to the study to determine the general utility of the in-field approach.

Landscape-scale nutritional information coupled with estimates of forage quantity, would provide timely forage status assessments to the rancher/livestock manager to facilitate better management of livestock, forage and feed, and grazing lands.

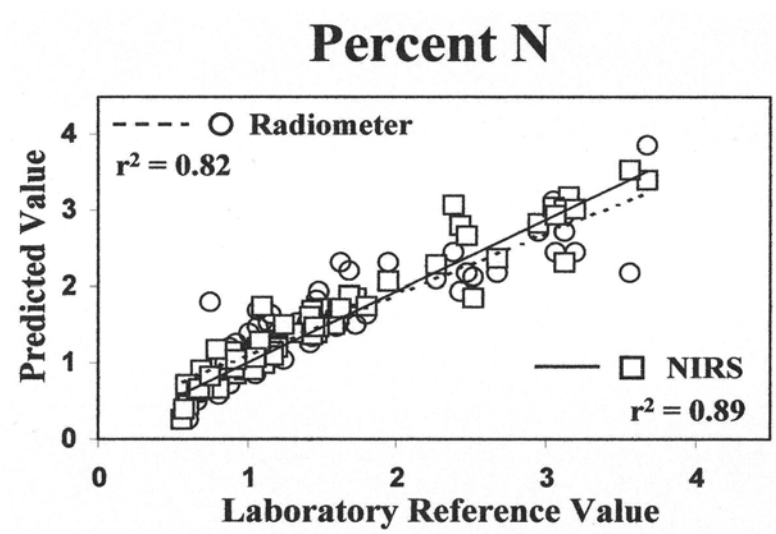


Fig. 1. Plot of predicted percent nitrogen from the NIRS and radiometer approaches versus the laboratory reference value.

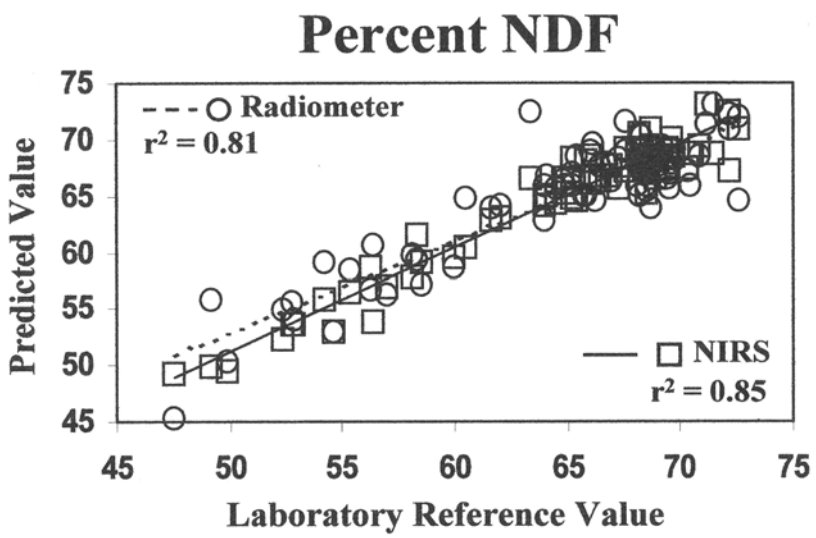


Fig. 2. Plot of predicted percent neutral detergent fiber (NDF) from the NIRS and radiometer approaches versus the laboratory reference value.

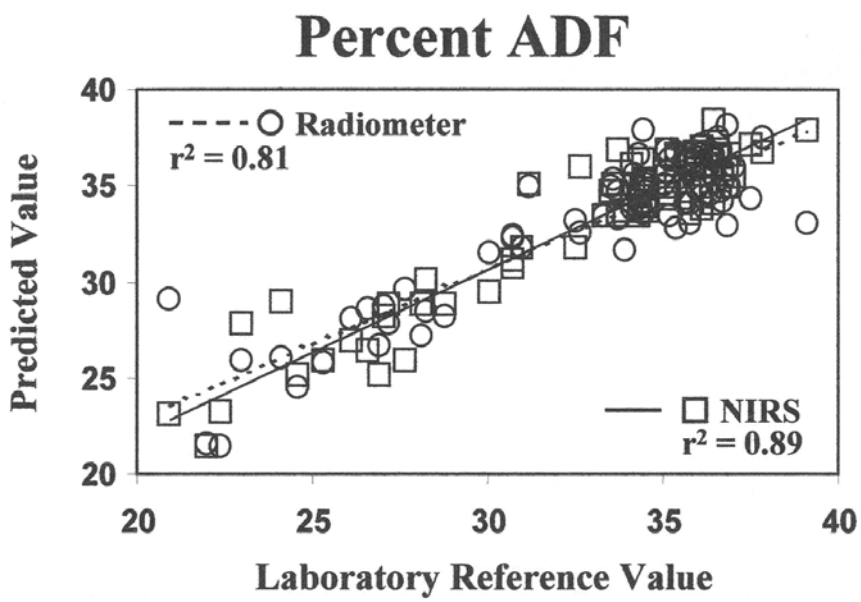


Fig. 3. Plot of percent acid detergent fiber (ADF) predicted from the NIRS and radiometer approaches versus the laboratory reference value.

CLIMATE AND MANAGEMENT IMPACTS ON FORAGE COMPOSITION OF A SOUTHERN TALLGRASS PRAIRIE

Brian K. Northup, John A. Daniel, and William A. Phillips

RATIONALE

Tallgrass prairie is an important resource for livestock producers in central Oklahoma. It is part of the annual grazing system (including wheat pasture and introduced perennial grasses) used to grow stocker cattle. Composition of the plant community is important to the long-term productivity of these prairies. Key warm-season grasses like big bluestem, indiangrass and little bluestem can produce 50 to 75% of any year's total forage. These species are subject to numerous stress factors that affect productivity of the prairie, and persistence of the plant community.

Defoliation of grass plants by grazing or haying can have significant impacts on the condition of prairie. Removal of top growth causes the plants to limit root growth while the leaves become reestablished, which reduces the soil volume the roots exploit for water and nutrients.

Prolonged wet and dry periods have been recorded in the southern Great Plains, such as the wet period that has been noted for 1975-1999. However, variation in annual rainfall can be extreme, and the timing of rains is unpredictable. When taken in combination with grazing, such climatic effects could cause significant changes in pasture composition.

OBJECTIVE

Producers must consider responses of key forage species to management and rainfall to ensure sustainable use. The objective of this research is to show how management and variation in rainfall affect the composition of forage produced by tallgrass prairie during a 16-year period.

RESULTS

In order to show how rainfall and management can affect tallgrass prairie, studies were conducted on five experimental pastures used in watershed research at the Grazinglands Research Laboratory between 1984-2001. Different types of management regimes (Table 1) were applied to individual pastures during 1985-1995: (A) heavy (2 pastures) and; (B) light grazing by stocker cattle; and (C) light grazing with regular applications of broadleaf herbicide and fertilizer. An unmanaged (no burning, grazing or haying) plot adjacent to the experimental pastures has also been maintained for 25 years (1975-2001) for comparison. After

Table 1. Management regimes applied to 4.0 acre experimental pastures on the Grazinglands Research Laboratory during 1984-1995.

Management regime	Stock rate†	Forage use‡	Herbicide§	Fertilizer§
	AUD/acre	-- % --	-- qt/ac --	-- lb/ac --
Heavy grazing	86	62	No	No
Light grazing	46	33	No	No
Light + ag chemicals	46	33	1.0 Grazon P+D	102 lb 46-0-0
Unmanaged	0	0	No	No

†AUD represents forage required to support a 1000 lb cow plus 300 lb calf or equivalent amounts of other grazers per day. Based on 25 lb forage/AUD and average forage production of 3500 lb/acre.

‡Represents planned level of forage utilization of current year's herbage applied during the study.

§Applied every second year of the study.

a year or rest in 1996, three of the grazed pastures were assigned to new grazing treatments with an average grazing pressure of 66 animal unit days (AUD) per acre (where an AUD represents the amount of forage required to maintain a 1000 lb cow plus 300 lb of suckling calf – or their equivalent in other classes of animals - for one day, about 25 lb of forage), and the fourth was hayed in July. All the grazed/hayed pastures were burned regularly throughout the 16 years. Grazing pressure was applied by numbers of stocker cattle (700 to 850 lb) assigned to the pastures (4 to 6 and 8 to 12 head on lightly and heavily grazed pastures, respectively), which varied with annual production.

Plant community responses were determined in permanent ungrazed exclosures within each pasture, and the remainder of the areas that were grazed (or hayed). Percent contribution of the species of plants to forage production was described each year between 1984-95, and in 2001, by estimation techniques and assigned to five forage classes: (1) key warm-season grasses (big bluestem, little bluestem, indiangrass and switchgrass, noted as 'Big 4'); (2) other minor warm-season grasses (16 species, noted as WSG); (3) annual bromes (eg. cheatgrasses); (4) other native cool-season grasses (5 species, noted as CSG); and (5) broad-leaf plants (23 species, noted as forbs). Daily rainfall was recorded by rain gauges located near the pastures.

Species composition of forage produced by all pastures underwent major changes during the study (Fig. 1). The 'Big 4' grasses declined on all pastures in 1988-89, regardless of pasture management. These grasses even declined on the ungrazed exclosures and the unmanaged pasture. Production by the 'Big 4' grasses in 1988-89 was replaced by some combination of other less-common species. Under light grazing, forage produced by 'Big 4' grasses in 1995 had returned to 1984 levels, but was still reduced on the other pastures. Level of production by the 'Big 4' grasses had generally recovered on all pastures by 2001.

Increases in annual bromes were pronounced in the ungrazed exclosures within managed pastures (Fig. 1), and at different times (1988-89, and 2001) on the pasture receiving fertilizer and herbicide. Herbicide and fertilizer applications also resulted in major increases in forage production by minor warm-season

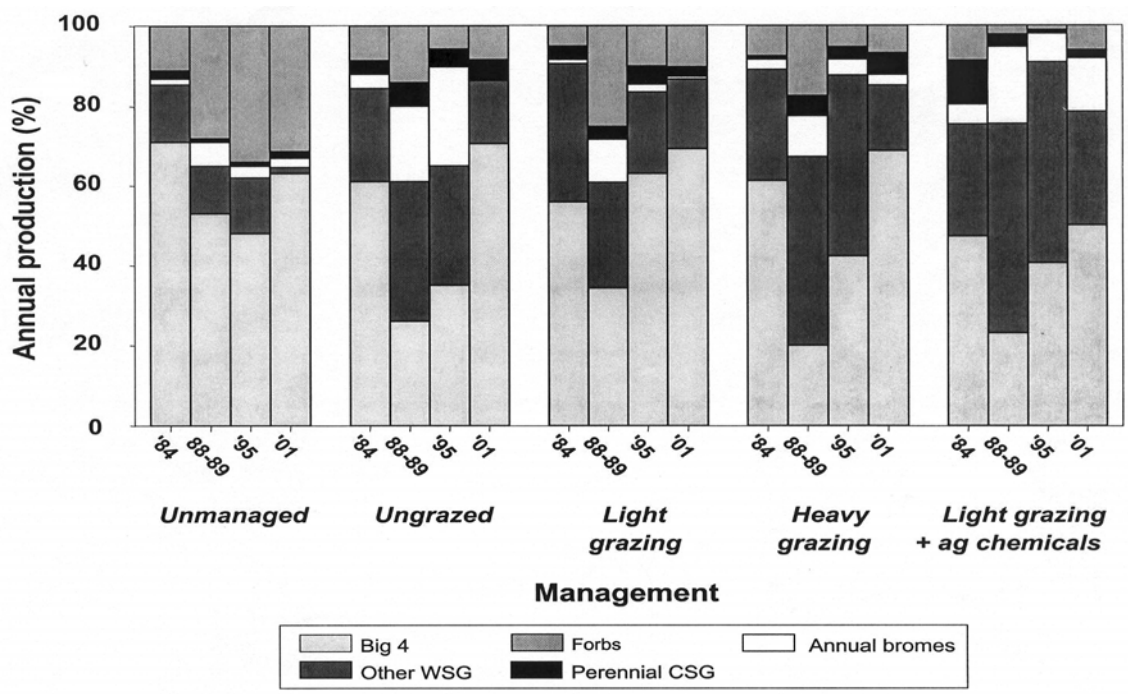


Fig. 1. Composition of forage production under different forms of management during 1984-2001; WSG is other warm-season grasses, CSG is native cool-season grasses, and forbs is broadleaf plants.

grasses through 1995, as did heavy grazing; the most notable increases occurred in amounts of annual foxtails, crabgrass and silver beardgrass (a low-quality perennial grass related to big bluestem).

Forage composition of the unmanaged pasture was radically different from the other pastures by 1995 (Fig. 1). The 'Big 4' grasses were mostly replaced by weedy forbs like thistles, annual sunflower, and mare's tail. By 2001, production by 'Big 4' grasses was near 1984 levels, replacing the minor warm-season grasses, but production by the weedy forbs had not declined. This response shows that lack of management on tallgrass prairie can be as harmful as over-grazing. The build-up of plant litter over the years apparently limited the amount of the sun's energy reaching the surface, which inhibited the capacity of the dominant warm-season grasses to compete with the undesirable species.

The most notable shifts in forage composition occurred in 1988-89, and corresponded to dry periods that occurred during both years (Fig. 2). Total annual rainfall was only 14% below average in 1988, and above average in 1989. However, shortfalls occurred at key times for soil moisture recharge (November-December 1988, January-February 1989) and plant growth (May-August 1988, March-April 1989). These short-term 'droughts' stressed the plant communities and helped drive changes in species composition of the pastures. The dry conditions during these periods had an over-riding impact on the plant community, and led to gaps that were filled by quick-growing and drought-adapted species. As a result, composition of the plant communities within the pastures changed from that at the beginning of the study. When taken in combination with the more-aggressive forms of management (heavy grazing or use of fertilizer and herbicide), the changes in the plant communities towards dominance by less-productive species were marked. Conversely, wet conditions after 1995 (in combination with changes in applied grazing pressures) helped the composition of the plant communities to recover. The above responses underscore the need to recognize the impacts of short-term drought conditions on tallgrass prairie. This is particularly relevant, as the 1988 and 1989 seasonal droughts occurred during a 'wet' period in the last quarter of the 20th century. Since seasonal dry conditions are less predictable than long-term precipitation patterns, drought management should be an integral part of grazing management for tallgrass prairie in the southern Great Plains. Included should be such practices as use of lighter stocking rates, early sale of part of the herd, and switching to alternate sources of forage.

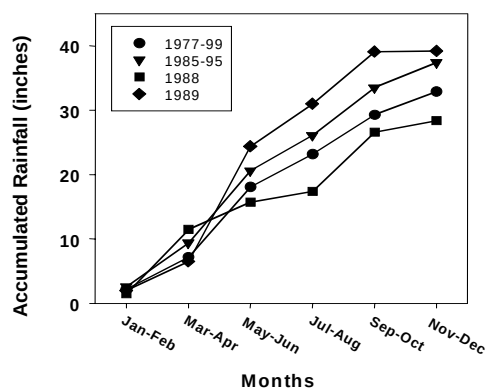


Fig. 2. Accumulated rainfall during the 1977-2001 time period on watershed pastures of the Grazinglands Research Laboratory.

SPATIAL VARIABILITY IN THE DISTRIBUTION OF FORAGE PRODUCED BY A TALLGRASS PLANT COMMUNITY

Brian K. Northup

RATIONALE

Tallgrass prairie in central Oklahoma represents an important resource for livestock producers. If properly managed, it can provide a low-input source of forage for stocker cattle from May through October (though quality can be variable). Species like big bluestem, little bluestem and indiangrass are important parts of plant communities in the region. However, the distribution of native vegetation is not uniform. It tends to be distributed across the landscape in complex mosaics of different species. These distribution patterns represent ecosystem-level processes that vary in both space and time in response to factors like temperature, rainfall, topography and soils. Such processes can influence process-related functions like production, decomposition and nutrient cycling. Defining how key forages are distributed within a plant community is important to understanding landscape function and management responses.

OBJECTIVE

Variations in distribution of plant species and forage production on native prairie create significant challenges for land managers. Such variability must be understood to ensure sustainable use of tallgrass prairie communities. The objective of this study is to describe variation in the distribution of forage production and key forage species on a native tallgrass pasture.

RESULTS

To examine how forage production and distribution of key forage groups were related, a 1.1-acre plot was identified in February 2001 within a 25 acre pasture, located on a loamy prairie site. The pasture was located on a Norge silt loam soil, with 3 to 5% slope and a northwesterly exposure. The plot was situated within the pasture between the top of a ridge and a stream bank. The plant community was dominated by the tallgrasses big bluestem, indiangrass and switchgrass, and the midgrass little bluestem. Little or no grazing pressure was applied to the pasture in the previous 10 years. The pasture received a prescribed burn in early-March, prior to the start of spring growth by the warm-season grasses. The 1.1-acre plot had dimensions of 100 ft across the slope and 498 ft down-slope. Seven transects (oriented down-slope) were spaced across the plot at 14.3 ft intervals and 33 sample points were randomly located along each transect. At each sample location, total forage was collected within 2.7 ft^2 quadrats between June 12-16, and species composition of this forage was determined by estimation techniques. The relative contribution of the different species to total production were then combined into forage groups, based on growth form: (1) 'Big 3'grasses (the tallgrasses big bluestem, indiangrass and switchgrass); (2) bunch-type midgrasses (little bluestem, tall dropseed and sand dropseed); (3) all other grasses (11 species); and (4) broadleaf forbs (15 species). The combination of quadrat location, forage production and species composition were used to develop maps to show the distributions of forage production, and how the different forage species contributed to this production.

Within the 1.1-acre plot, all measured characteristics had wide ranges of values (Table 1). The 'other grass' and 'forb' groups had extremely wide ranges noted in the observed points. The contribution of the 'Big 3' grasses was the least variable, but the range between low and high values was still large. These wide ranges in values indicated that all the measured characteristics were likely distributed within the plot in a patchy, variable fashion. Total forage

production was organized in a series of areas with high and low levels (Fig. 1). Most of these areas were 15 to 65 ft in diameter. High production areas were scattered throughout the plot, and were not correlated with general location on the slope. The 'Big 3' grass group dominated the high production areas, and comprised greater than 60% of the total production on these areas. Conversely, low production areas were largely dominated by the midgrasses. The 'other grass' and 'forb' groups dominated production on small parts of the plot, and were present in minor amounts throughout the area.

High production areas (greater than 2300 lb per acre) covered 27% of the plot (Fig. 1), and generated 38% of the total production (890 of 2330 total pounds) for the entire 1.1 acre plot. Conversely, low production areas (less than 1940 lb per acre) covered a larger part of the plot (51%) but only generated 925 lb of the total forage production of the plot, which was similar to the amount produced by high producing areas. Areas with average levels of production (2120 ± 180 lb per acre) only covered 22% of the plot and generated just 515 lb per acre (22%) of the total forage on the plot.

Spatial variability of forage production and distribution of key species are important components to the productivity and function of southern tallgrass prairie. As such, interactions between management and spatial variability may have consequences that must be understood to ensure sustainable use of the landscape. The map indicated that productivity was dependent on a relatively small area of the entire plot. Management applied to the pasture must ensure that these portions of the area remain healthy to ensure long-term sustainability. Further, a large part of the plot produced amounts of forage that were below the average level of production. This represents a significant challenge for grazing management. Management of native pastures has traditionally been described by use of available forage, based on averages of pasture production. If a grazing system (with a goal of uniform application of grazing pressure to an area) were keyed to the average level of production, then portions of this pasture could be over-grazed by use of best management practices. For example, while a goal of uniformly grazing 50% of available forage (about 1100 lb per acre) in this pasture would have little effect on high production areas, half of the pasture could be over-grazed to some extent. Such potential impacts demonstrate the importance of knowing how (and why) forage is spatially distributed within pastures so that good management practices for southern tallgrass prairie can be developed.

The results reported here represent the first year of a multi-year study. The information generated by this study will help define how forage production in southern tallgrass prairie varies in space and time in response to growing conditions during different years. Additional experiments will be undertaken to help determine why the high (and low) production areas are distributed in small patches across the plot (i.e. changes in soil characteristics, minor variations in topography, etc.). Forage samples collected from the quadrats will be analyzed for nitrogen and phosphorus contents to develop maps of nutrient density, to help explain how cattle might use such pastures. The ultimate goal of these experiments is to improve management and monitoring tools for tallgrass prairie.

Table 1. Average and ranges of forage production and composition of plant materials.

Trait	Average	% variation†	Low	High
Production, lb/ac	2120	45	220	6740
'Big 3' grasses, %	48	65	0	95
Midgrasses, %	35	82	0	88
Other grasses, %	7	142	0	75
Forbs, %	6	133	0	65

†How variable values are relative to the average of 235 observations in the data set.

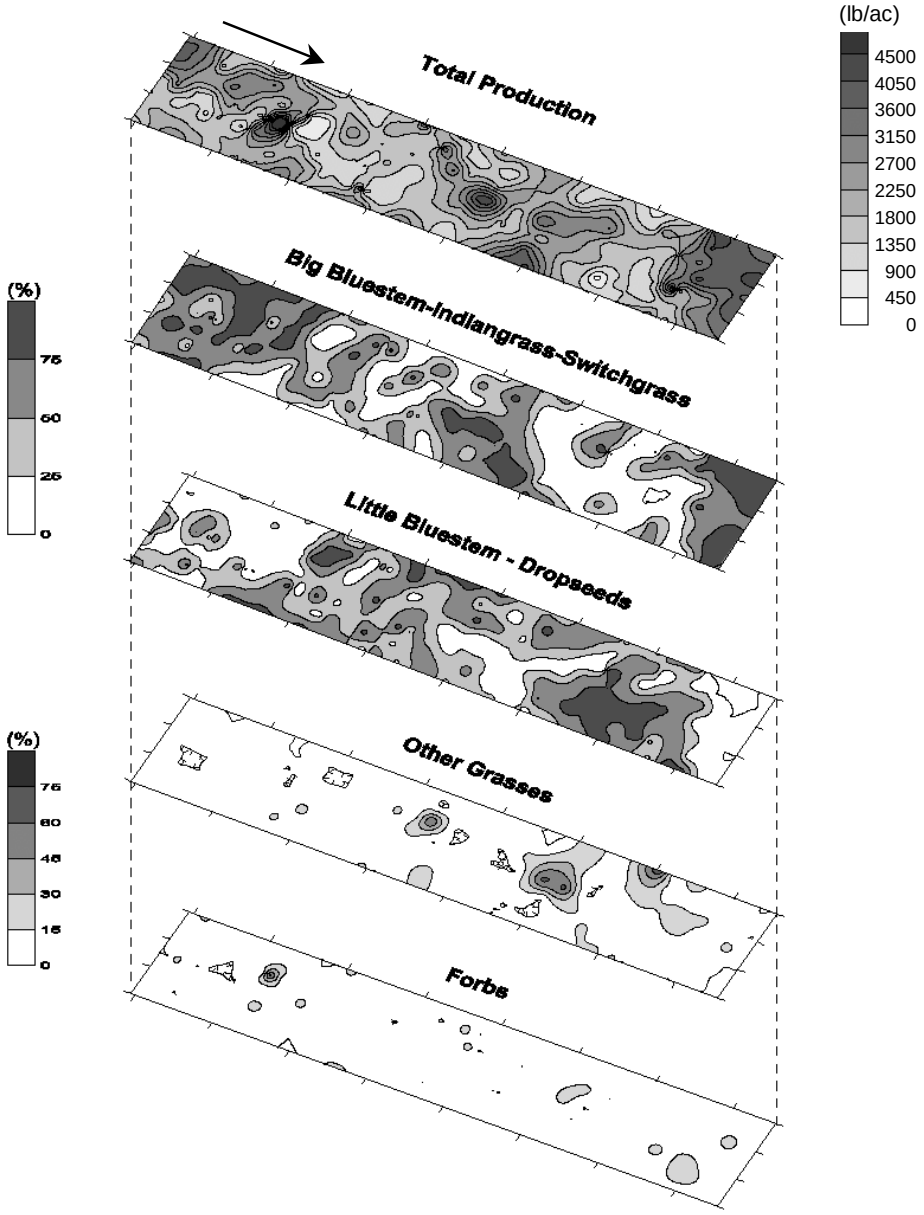


Fig. 1. Interpolated maps of total forage production and percent of forage produced by key forage groups on a 1.1 acre plot (100 x 498 ft); the arrow shows the direction of the slope.

SPATIAL VARIABILITY OF WINTER WHEAT PASTURE AT THE ONSET OF FALL GRAZING

Charles T. MacKown and Brian Northup

RATIONALE

Much of the agricultural economy of the Southern Great Plains is driven by the production of winter wheat and its use as forage for stocker calves. Winter wheat pastures are the primary source of cool-season forage for millions of stocker calves transported into the southern Great Plains. Nearly 6 million acres of winter wheat are planted each year in the western half of Oklahoma, and roughly 50% of this is used to support the production of stocker cattle. In some cases producers use their wheat as a dual-purpose crop for both forage and grain. Wheat grown as a dual-purpose crop offers producers greater flexibility and economic advantages not enjoyed by those that grow wheat for only forage or only a grain crop. Each wheat production system, however, requires different planting and soil fertility management practices to assure success. Wheat used for both forage and grain should be planted earlier, at a greater seeding rate, and be supplied with additional nitrogen (N) fertilizer to offset N removed through grazing.

The majority of stocker calves transported to the Southern Great Plains are produced on more than 200,000 farms across the southern United States under an array of livestock management options, breed types, and forage resources. Because nutrition and weight gain of stockers depends almost entirely on consumption of forage, the foundation of the stocker industry in the Southern Great Plains is dependent on abundant production of high quality forage. Generally, the forage quality of winter wheat pasture is considered excellent, supporting as much as 3 lb of weight gain per animal per day. However, during the first 3 weeks of grazing winter wheat, little or no gain in animal weight may occur. Both plant and animal factors may affect the adaptation of stocker calves to winter wheat pasture.

OBJECTIVES

Determine the spatial distribution of forage biomass, available soil N, and plant N composition in a 5 acre winter wheat pasture at the onset of fall grazing to better understand forage management factors that might affect the adaptation of stocker calves.

RESULTS

The wheat pasture site had been cropped previously with winter wheat for more than 30 years. Wheat was not planted in the fall of 2000 and the site was kept clean fallow. Fallow soil pH and nutrient analyses indicated that adequate N was available for fall growth, but lime, phosphorus (P) and potassium (K) were needed. Lime (effective calcium carbonate equivalent of 2.5 tons acre^{-1}) and fertilizer P (40 1b acre^{-1}) and K (25 lb acre^{-1}) were applied and incorporate into the soil during the year 2000 growing season.

Winter wheat ‘2174’ was planted 18 September 2001. The site was not fertilized with N before planting or collecting forage and soil samples.

Plant and soil samples were collected 29-30 October 2001 at 16.4 ft. increments along a single north-south 623 ft. transect through the middle of the 5-acre pasture. About 3 weeks later, a second set of plant samples was collected 19-21 November 2001 when stockers began grazing a similarly treated adjacent wheat pasture. The plant samples were collected in a modified grid pattern with most of the 212 sample points spaced 16.4 ft apart in eight north-south transects arranged 50 ft apart. Soil samples were collected 26-27 November 2001 at the same grid locations as the plant samples.

At each sample location, wheat vegetation in 1.6 ft. of row was clipped by hand to a height of 2 inches and then dried to constant weight. Soil

cores 12 inches deep were collected for the single transect sampling, while cores 10 inches deep were collected for the second sampling. Soil samples were air dried, crushed, and sieved before analyzing for mineral N. Measurements of forage dry weights and available soil N were used with the grid sample location coordinates to develop interpolated distribution maps of these traits.

Among the forage traits measured 6 weeks after planting, dry matter yield had the greatest variability and total N the least variability (Table 1). Fifty percent of the clipped samples had dry matter less than 520 1b acre^{-1}. The range in tissue NO_3^--N was large with 50% of the samples containing more than 3220 ppm NO_3^--N. Forage containing more than 1000 ppm NO_3^--N may pose a risk for cattle if reduction by rumen microorganisms results in excessive formation and absorption of nitrite into the blood stream. Nitrite in the blood stream inhibits the oxygen transporting capacity of red blood cells by oxidizing the ferrous iron of hemoglobin to ferric iron (methemoglobin). The forage samples we collected contained both leaf and stem tissue, which is known to have substantially higher nitrate concentrations than only leaf tissue. If pasture-stocking rates are high, then the likelihood that consumption of forage containing stem tissues high in nitrate would probably increase and adversely affect the performance of young stocker cattle unaccustomed to high nitrate forage.

Estimations of plant available mineral N in the soil ($NH_4^+ + NO_3^-$) ranged from 65 to 372 lb N acre^{-1} with 50% of the samples containing more than 183 lb N acre^{-1} (Table 1). Most of the mineral N was present as NO_3^- (data not shown). These levels were greater than expected and may be the consequence of past cropping history and microbial conversion of soil organic N to mineral N during the extensive fallow period.

Overall, increases in the levels of forage traits with increases in available N were not significant (forage dry matter) or only weakly correlated (forage total N, $r^2 = 0.26$, $P < 0.001$; forage NO_3^--N, $r^2 = 0.26$, $P = 0.007$). The differences in forage dry matter were unrelated to differences in forage total N ($r^2 = 0.02$, $P = 0.444$), but forage NO_3^--N increased 250 ppm with each 0.1% increase in forage total N ($r^2 = 0.50$, $P < 0.001$).

As with the single transect, forage dry matter and available soil N values of the 212 sample points distributed in a grid pattern across the pasture were variable (Table 2). Differences in forage dry matter were unrelated to available soil N ($r^2 = 0.016$, $P = 0.108$). The interpolated maps depicting the distribution of accumulated forage dry matter and available soil N across the

Table 1. Forage and soil traits of 39 samples collected at the end of October 2001 along a single north-south transect through the center of a 5-acre wheat pasture.

Pasture variable	Mean	Relative SD (%)	Minimum	Maximum	Median
Forage dry matter, lb acre^{-1}	488	50	53	949	520
Forage total N, %	5.04	5	4.50	5.45	5.04
Forage NO_3^--N, ppm	3130	29	732	4350	3220
Available soil N, lb acre^{-1}	192	41	65	372	183

Table 2. Forage and soil mineral N values of samples collected 19-21 November 2001 212 locations arranged as a modified grid pattern in a 5-acre wheat pasture.

Pasture variable	Mean	Relative SD (%)	Minimum	Maximum	Median
Forage dry matter, lb acre^{-1}	1600	35	63	3560	1580
Available soil N, lb acre^{-1}	96	57	21	334	85

wheat pasture demonstrate the extensive variability for these two traits (Fig. 1). These maps illustrate the regional diversity in the amounts of forage dry matter and available soil N that can be encountered within a small pasture. For these traits, the poor replication of the map patterns portrays the lack of association between forage biomass and available soil N measured at the onset of grazing.

These results demonstrate that assessment of wheat forage availability and quality on the initial performance of stocker cattle will require extensive sampling. Producers using rotational grazing practices should carefully evaluate their pastures for obvious variability in forage availability to insure that stocking rates do not lead to excessive grazing pressure and consumption of the high nitrate wheat stems. The construction of pasture maps showing distribution patterns of available forage and N composition could be used in combination with maps of grazing behavior to offer insights into factors affecting stocker cattle adaptation to wheat pastures.

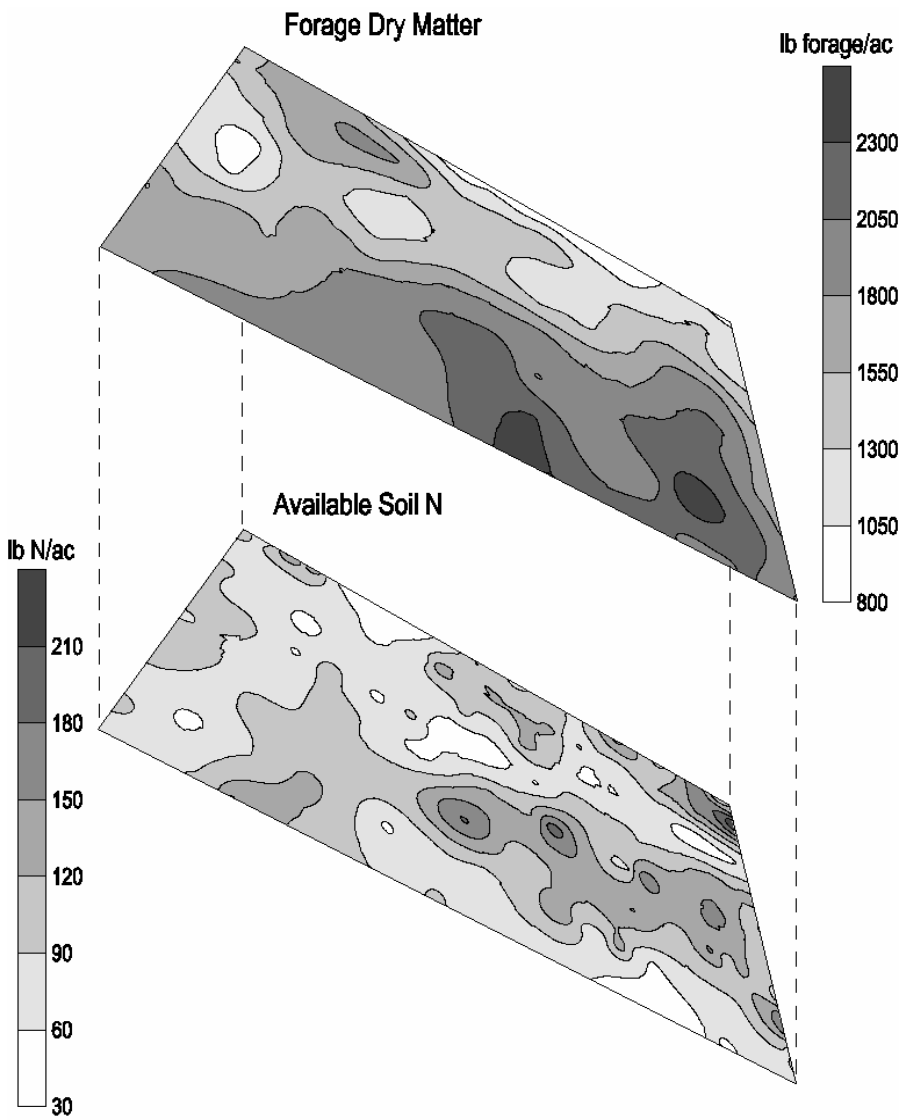


Fig. 1. Contour maps of forage dry matter and available soil N measured in a 5-acre wheat pasture at the onset of grazing.

VARIATION IN SOIL PH OF CROPLAND PLANTED TO CONTINUOUS WINTER WHEAT

Brian K. Northup, Charles T. MacKown, and John A. Daniel

RATIONALE

Nearly 6 million acres of winter wheat are planted annually in the western half of Oklahoma. Roughly 50% of this crop is used to grow stocker calves prior to entering the feedlot. Wheat production systems require some degree of annual tillage and fertilizer application, particularly nitrogen. Long-term, continual tillage by conventional techniques (e.g. burning stubble, plowing and disking) can have significant impacts on soil condition. They alter the input of plant residues and decomposition of organic matter in the soil. Organic matter, and its' decomposition, are important components of soil activity, and affect nutrient cycling and buffering of soil reactivity (pH) through its input of carbon and hydrogen atoms.

Soil pH (the acidity or alkalinity of soil) affects the availability of nutrients for plant growth (Fig. 1), the activity of soil microbes (important for the recycling of nutrients in organic matter), and root growth by plants. Active plant growth occurs throughout the pH range of 4.0 to 8.5, though plant responses are species and variety specific. In the low pH range, the concentration of aluminum or manganese is often toxic to plants. Most nutrients are available in adequate amounts to support plant growth in the range of pH 6 to 7. However, as pH becomes lower the availability of many nutrients important to plant growth become limiting. Below a pH of 6.0, potassium (K), phosphorus (P), calcium (Ca) and magnesium (Mg) are less available. Further, soil microbial activity becomes reduced at pH below 5.5, and root growth of many forage species becomes reduced below pH 5.0.

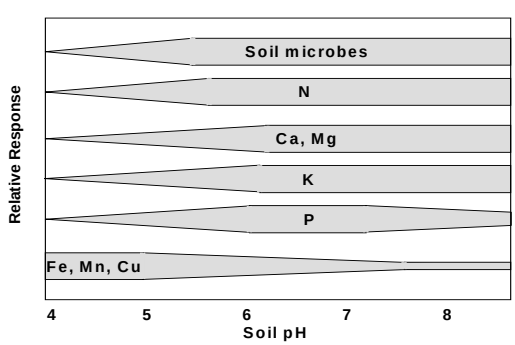


Fig. 1. Illustration of the relationship between soil pH, microbial activity and availability of nutrients.

In time, the conventional tillage, stubble management, and grazing techniques used in the production and harvest of winter wheat forage in Oklahoma can affect soil pH. Native prairie and cultivated soils are generally not uniform, and vary in structure and composition within pastures. As such, soil acidity will vary in its distribution, and in its responses to management.

OBJECTIVE

Soil pH impacts forage production through its effects on root growth, microbial activity and nutrient availability. Producers need to understand variability in soil pH within wheat pastures to better identify the needs for specific management practices that can improve productivity. This study was undertaken to examine the level of variability that exists in soil pH of a wheat pasture farmed under continuous wheat over several decades.

RESULTS

In fall 2000, a 5-acre wheat pasture (348 x 625 ft) was identified within an area previously cropped in continuous winter wheat for over 30 years and in wheat or row crops for 20 years prior to continuous wheat. The soil was a Dale silt loam, less than 1% slope, with a described pH range of 6.1 to 7.4 in the upper 24 inches of the soil horizon. The area was fallow for all of year 2000 and tillage plus herbicides were used to control weeds. Preliminary soil test were conducted during year 2000 to determine

nutrient deficiencies and soil acidity. These initial tests indicated available soil N was in excess of requirements for grasses (more than 60 lb per acre), while soil P, K and acidity (an average pH of 5.7) required adjustments. Lime (effective calcium carbonate equivalent of 2.5 tons per acre), and fertilizer P (40 lb per acre) and K (25 lb per acre) were applied and incorporated into the soil during the 2000 growing season. The acid-tolerant, winter wheat variety '2174' was planted on 18 September 2001, and no N fertilizer was applied at planting. Plant and soil samples were collected during 29-30 October, roughly 40 days after plant emergence. Samples were collected at 16.4 ft increments along a single north - south, 625 ft transect through the center of the pasture. At each sample location, forage in a 1.6 ft row was collected by clipping to a stubble height of 2 inches, and used to define amount of dry forage. Also, 12-inch deep soil cores were collected at each location, divided into two segments (0-4 inches, 4-12 inches), and analyzed for both available soil N and pH.

Data were used to describe variation in the distribution of soil pH and forage production at two scales. 'Local' variation considered how pH and production changed between neighboring sample points (16 ft diameter areas), and represented changes across individual soil pedons (smallest volume of the profile that can be defined as a soil). 'Patch' scale variation defined differences among groups of neighboring pedons (80 ft diameter areas) and identified larger-scale features related to the organization of pH and production within the pasture (soil differences, topography, etc.). Measurements of forage production and soil N were variable, while soil pH was less variable (Table. 1). Available soil N ranged from 65 to 372 lb N per acre, which was above the fall requirements of wheat (see MacKown et al., this publication for N distribution). These levels of N were much higher than expected, and probably due to some combination of past management (annual application of high levels of mineral fertilizer) and microbial conversion of organic N sources to mineral forms during the 2000 fallow period. Soil N was uncorrelated (r = 0.12) to forage production at the different sample points.

The upper four inches of the soil had a lower average pH, and a slightly wider range of levels than the 4-12 inch zone (Table 1). Soil pH was only weakly correlated to forage production (r=0.33) at the sample points. The low pH levels we recorded were somewhat surprising, given the amount of lime that was applied to the pasture during the previous year. It would appear that some of the areas sampled to define amount of lime to apply had higher pH than much of the remaining area of the pasture.

The majority of the topsoil (0-4 inch depth) had pH levels (Fig. 2) that no longer fit the description of the mapped soil (pH range of 6.1 to 7.8). For the top four inches, about 75% of the locations had values less than pH 6.1, while roughly 45% of the soil at the 4 to 12 inch depth had pH values below the lowest level of a Dale silt loam. These low pH levels may be related to the farming practices applied to the area for over 30 years (conventional tillage techniques and high levels of inorganic N fertilizer were applied each year).

'Local'-scale variability was extreme (Fig. 2). Soil samples 16 ft apart showed large swings in acidity at both depths, as did forage production. High forage production was not

Table 1. Soil pH and forage production along a 625 ft transect within a 5.0-acre pasture farmed in continuous wheat for over 30 years.

Characteristic	Average	% Variation†	Minimum	Maximum
Soil pH, 0-4 inch	5.6	11	4.6	7.0
Soil pH, 4-12 inch	6.2	9	5.3	7.4
Soil N, lb/acre	192	41	65	372
Production, lb/ acre	488	51	52	950

†How variable the recorded values of the 39 observations were in relation to the average.

consistently associated with soil acidity along this transect. In some cases 'peaks' in forage production occurred where soil pH was lower, and accounted for the low correlation between these variables. This response could be some local effect related to the interaction between pH, liming treatment, and the acid-tolerant wheat variety used.

Variations were also present at the 'patch' scale, though changes were more gradual (Fig. 2). A general increase in soil acidity from the north end (0 ft) to the south end (625 ft) was noted, with 'peaks' and 'valleys' showing larger-scale features of the wheat pasture. For example, the pH 'valley' at 175 ft represented an area dominated by an exposed and eroded knob (with a shallow topsoil layer), while the neighboring 'peak' (235 ft) was an area best defined as a small drainage channel (e.g., a wet area). The area from 235 ft to 625 ft, which had pH below the pasture average, was located on a gentle incline, with station 625 near the top of the slope. Patch-scale production was above the average for most of this section.

Soils of perennial grasslands are generally more acidic than soils of cultivated ground, though that distinction appears absent in this case (continuous wheat grown for forage). Fig. 2 illustrates the complex local diversity that can occur in forage production and soil pH within a small area, and how forage production can be influenced by several interacting factors.

The results highlight the effect of spatial variability on management requirements for wheat pasture. Soil acidity will limit the choices among available species that could be planted on this area. It would be difficult to get most types of cool-season forage legumes to establish and grow without significant inputs of lime. Also, given the current level of acidity, only the most-acid tolerant varieties of annual cool-season cereal crops or perennial grasses should be used. However, there is no guarantee that such varieties will be the most uniformly productive in terms of forage yield. Future research will compare these results to the degree of acidity, and level of variability, that exists in soil pH of a pasture planted to perennial grasses during the past three decades.

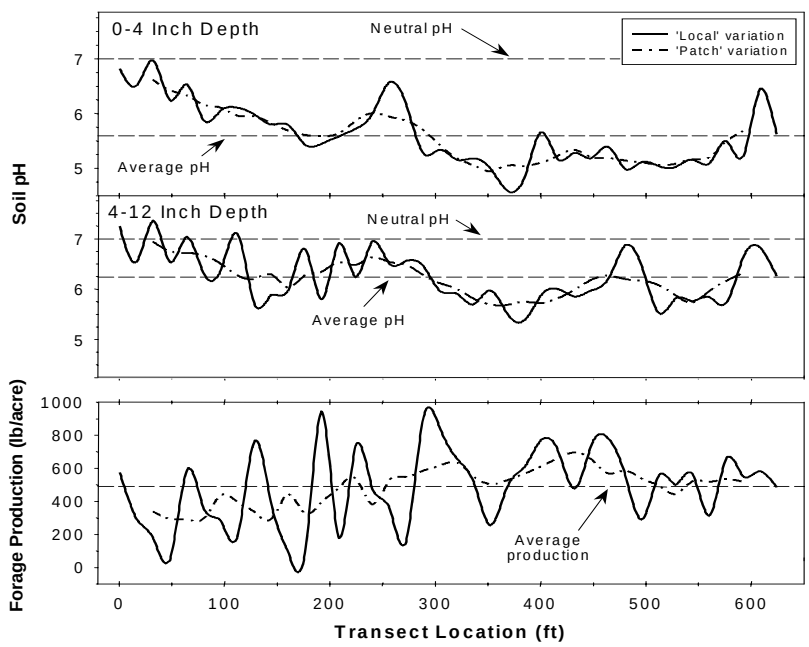


Fig. 2. Variation in level of soil pH in two layers of the soil profile, and forage production, at different locations along a 625 ft transect within a 5.0 acre pasture.

COMPANION CROPPING PERENNIAL COOL-SEASON GRASS FORAGES WITH WINTER WHEAT

Bryan Kindiger and Terry Conley

RATIONALE

Domestic wheat is the standard winter and spring forage of the Southern Great Plains forage-livestock production system; however, cool-season perennial forage grasses can also become an integral component of this grazing system for livestock producers. Companion crops, also known as nurse crops, are usually established at the time of sowing with the primary species. The selection and sowing of a companion species are carefully selected so as to provide weed control, provide a high-quality supplemental forage, and provide protection for the adjacently sown species. Because annual companion species such as wheat, rye, oats, etc., are more productive than first year of growth of perennial cool-season grass forages, such companion crops can become an overwhelming competitor for soil nutrients, light and moisture and a detriment toward the establishment of the primary sown species, if the companion species is not well selected.

Due to the limited number of cool-season growing days in this region, information regarding appropriate germplasm, methods for successful establishment of the perennial cool-season grass forage species, and methods for optimum utilization of the land resources by the livestock producer are required. In addition, a system for beneficial companion crop planting with perennial cool-season grass forages is poorly documented in this area and represents a relatively new endeavor for livestock producers in the southern Great Plains.

OBJECTIVES

In recent years, there has been substantial producer interest in options that would reduce the annual expense associated with the planting of wheat pasture and thereby enhance long-term sustainability of the land and its natural resources. In addition, the identification and utilization of cool-season grass pasture establishment systems that would reduce summer tillage operations, could reduce soil loss during these summer fallow periods and offer long term soil sustaining benefits to the region's landowners.

Establishment of cool-season forage grasses in the Southern Great Plains is performed typically by establishing the perennial cool-season grass forage as a solitary crop. Establishment is generally most successful when the cool-season species are sown in September or October, which is also the typical time for sowing winter wheat in this region. Rapid spring growth of the perennial cool-season grasses begins about 2-4 weeks later than wheat, but the perennial cool-season grasses may continue to produce quality forage through June, well after annual wheat has reached maturity.

The objective of this study was to sow an array of commercial, public and experimental perennial cool-season grass forage germplasm utilizing winter wheat as a companion crop to identify germplasm resources compatible with companion crop establishment.

RESULTS

The experimental location was established on September 20, 1999, on a Brewer silty clay soil type (fine, mixed, superactive, thermic Undertic Argiustoll) at the Grazinglands Research Laboratory, El Reno, OK. The experiment was conducted utilizing eighty-two perennial cool-season experimental or varietal cultivars representing eleven species. Cultivars consisted of selections of crested wheatgrass, Basin wildrye, Altai wildrye, Russian wildrye, bluebunch wheatgrass, Snake River wheatgrass, western wheatgrass, thickspike wheatgrass, intermediate wheatgrass, tall wheatgrass, and smooth bromegrass. The perennial cool-season grass forages and the wheat companion crop were sown in a field previously sown to wheat in

1998. The prepared seedbed was firm and well-packed and resided on a level, well-drained site with a relatively low degree of prior weed infestation. Prior to seeding, soil test indicated availability of 39 ppm NO3-N, 51 ppm P2O5 and 403 ppm K2O with a pH of 6.9. As a consequence, no N, P, or K was added at sowing.

In central Oklahoma the traditional standard planting rate for winter wheat is 90 lbs/ac. For this study, the seeding rate was reduced to approximately 20% of the normal winter wheat seeding rate. The companion wheat crop, wheat cultivar 2613, a popular local variety, was broadcast sown at approximately 12 lbs/ac then lightly cultivated into the soil. Winter wheat was selected for this study due to its widespread use in the Southern Great Plains region. The perennial cool-season forage entries were sown in six 16 foot rows at an 8 inch row spacing through a six row Hege cone planter at an approximate depth of 1.5 inches and at a seeding rate of 40 PLS (Pure Live Seed) per ft2. The high sowing rate for the perennial cool-season forages was chosen to provide each entry the maximum opportunity to completely establish itself in the plots. In October 2000, granular nitrogen was applied at a rate of 40 lbs/ac by a calibrated broadcast spreader.

When the entries reached an approximate height of 18 inches, they were clipped to a uniform height on November 14, 1999, January 18, 2000, March 31, 2000, and April 25, 2000. Clipping was performed with a Hege forage harvester set at a height of 2-3 inches to simulate rotational grazing. All entries were exposed to a final cutting in June-July, just below the seed heads, to allow for seed removal and prevent seed maturation. This seed removal step was performed to remove the opportunity for additional plants to establish themselves in the plots during the second growing season. As a consequence, stand counts measured in March 2001, are true representations of actual stand survival or are results of rhizomatous spreading. Plots were not irrigated during the research study. Forage accumulation data was not obtained on the plots because determination of forage yields was not a parameter of the study; forage data for most entries utilized in this study can be found elsewhere.

Two weeks following sowing (September 1999), stand counts were measured on the cool-season grass forages. Seedling stand counts were estimated by counting the number of plants in a 1-ft row and then following guidelines of the Association of Official Seed Certifying Agencies. In the following spring, stand counts were performed on March 21, 2000. On March 14, 2001, stand counts were again performed to determine stand establishment for the second growing season.

Generally, cool-season perennials were dwarfed by the vigorous growth of the annual wheat. Stand counts the following spring of 2000 indicated that all the perennial cool-season entries exhibited a stand reduction from their original population density. However, several entries representing the Western wheatgrass, intermediate wheatgrass and tall wheatgrass exhibited excellent stand counts with little stand reduction, because their rhizomatous nature allows them to fill in vacant areas in the nursery plots.

Comparisons between stand counts from spring 2000 with those of spring 2001 indicate that several varieties exhibit the ability to fill in vacant areas in the plots. Specifically, entries representing Western wheatgrass, were observed to be superior in recovering from stand reductions. In addition, the performance of entries representing the tall and intermediate wheatgrass entries and the smooth bromegrass were only moderately less successful in their ability to recover from stand reductions. In Oklahoma, the USDA-NRCS has suggested that a satisfactory stand for a perennial forage pasture should have 0.5 plants per square foot. Available varieties that fit these criteria either through stand maintenance following competition with winter wheat following the winter of 1999 and spring of 2000 or stand recovery in the spring of 2001 are provided in Table 1. Varieties representing those species were smooth bromegrasses ‘Lincoln’ and ‘Mahchar’; tall wheatgrasses ‘Alkar’ and ‘Jose’, intermediate wheatgrasses ‘Luna’, ‘Greenar’, ‘Reliant’, ‘Manska’, and ‘Oahe’; and Western wheatgrasses ‘Rosana’, ‘Arriba’, and ‘Rodan’.

Table 1. Species exhibiting superior stand count and plot recovery.

Genus species	Common name	Stand count†
		-- plants/ft^2 --
Pascopyrum smithii	Western wheatgrass	9.75
Elytriga intermedium	Intermediate wheatgrass	9.24
Elytriga elongatum	Tall wheatgrass	8.25
Bromus inermis	Smooth bromegrass	8.00
Elymus lanceolatus	Snake River wheatgrass	6.35
Elymus junceus	Russian wildrye	6.19
Agropyron cristatum	Crested wheatgrass	5.82
Elymus angustus	Altai wildrye	5.18

†The OK USDA-NRCS suggests that a stand count of 0.5 plants/ft^2 is satisfactory

Entries representing Western wheatgrass, smooth bromegrass and intermediate and tall wheatgrass species were notable in their ability to increase the population density and thicken the vegetative cover the second season due to their rhizomatous growth and high tillering rates.

The system of multiple clippings utilized in this study simulates how livestock producers of the region utilize the rotational grazing style on winter wheat pasture. By periodically submitting the plots to multiple clippings, removal of the winter wheat vegetative canopy provided an advantage to the perennial cool-season entries by reducing the competitive pressures applied by the companion crop. This allowed for more vigorous growth of the slower establishing perennial cool-season forage entries.

This study identified that by inter-seeding perennial cool-season species with winter wheat, a good stand establishment for a wide range of perennial cool-season grass forages can be achieved in the Southern Great Plains. In addition, it is evident from the multiple clippings that the seeded pasture could also be moderately utilized as a forage resource for grazing livestock during the first year of perennial cool-season forage establishment. Benefits relative to reducing winter kill of young perennial cool-season grass forages and enhancing erosion control are also likely gains from this type of system. This study also identified several varieties/cultivars and new experimental germplasm that can compete successfully and survive when sown in a highly competitive high population density environment.

One primary advantage of sowing perennial cool-season grass forages verse sowing annual wheat is that once the perennial cool-season grass forage is established, it can provide forage in September and October whereby the winter wheat seeded in September is not available for grazing livestock until November. As a consequence, livestock producers with a perennial cool-season pasture can obtain at least a 30-day jump over newly sown wheat pasture.

The described method of inter-seeding perennial cool-season grass forages with wheat provides preliminary information regarding the opportunity for livestock producers to graze their pastures via wheat stand establishment and simultaneously develop a stand of a perennial cool-season grass forage. The use of this method to establish perennial cool-season pastures should assist in providing an economically and environmentally sustainable livestock production operations and allow for development of superior perennial cool-season genotypes.

SEEDLING GERMINATION, GROWTH, AND N UPTAKE BY DESIRABLE PERENNIAL AND INVASIVE COOL-SEASON GRASSES: EFFECTS OF N SOURCE

Charles T. MacKown, Douglas A. Johnson, Thomas A. Jones, and Margaret G. Redinbaugh

RATIONALE

The exotic undesirable annual cool-season grasses cheatgrass and medusahead infest nearly 1.6 million ha of rangelands in the Intermountain West and large areas of grazingland in the Great Plains. Annual weed infestation is often a problem during establishment of cool-season perennial grasses on grazinglands', particularly on disturbed rangeland. Infestations diminish biological diversity and abundance of desirable forages for livestock and wildlife, increase the frequency and severity of wildfires leading to reduce forage productivity, destabilize watersheds, and intensify weed dominance. Native perennial grasses are vital for renewal of ecosystems and reclamation of disturbed lands, but biological processes underlying successful restoration are poorly known.

Desirable native grasses reportedly compete better with annual invasive cool-season grasses during establishment when available mineral N is primarily in the form of ammonium rather than nitrate, the final form of mineral N produced in the biological conversion of soil organic N to mineral forms of N used by plants. The functional basis for differences in competitive behavior among undesirable exotic and desirable native grasses exposed to different sources of available N has not been thoroughly explored. If a functional basis for an available N effect is discovered, this could lead to refinements in management strategies to improve seed germination and early growth of desirable perennial species.

OBJECTIVES

Conduct controlled N nutrition experiments to determine effects of availability and forms of mineral N on seedling germination, N uptake, and growth responses of desirable perennial and weedy annual cool-season grasses.

RESULTS

Two annual cool-season grasses, cheatgrass and medusahead, and five perennial cool-season grasses (‘Goldar’ bluebunch wheatgrass; ‘Sand Hollow’, ‘1171’, ‘1206’, and ‘1219’ squirreltail grasses) were germinated and grown in the laboratory using a hydroponics (soilless) culture system. Treatments included four different aerated nutrient solutions: (1) N-free (control), (2) equal N levels of ammonium and nitrate (NH_4NO_3), (3) ammonium-only (NH_4^+), and (4) nitrate-only (NO_3^-). All nutrient solutions contained nonlimiting amounts of other essential macro- and micro-nutrients and were maintained at pH 6.1. Light was provided 16 hours per day by a combination of high intensity discharge lamps. Temperature was that of the laboratory. Use of the hydroponics culture system made it possible to accurately determine the effects of N sources on germination, N uptake and dry-matter accumulation and partitioning between roots and shoots, factors that can affect competition for resources (light, water, nutrients) and establishment. The perennials chosen for the study possess beneficial traits that make them desirable for disturbed rangeland and include four accessions of native squirreltail and one accession of bluebunch wheatgrass.

Germination, based on the appearance of shoot and root organs of seeds placed on media of the same nutrient composition as the hydroponics solutions, was unaffected by the availability as well as the form of mineral N supplied (Table 1). Germination means of the four nutrient treatments ranged between 87 and 91% of the seeds planted. It is unlikely field

Table 1. Germination percentage based on appearance of root and shoot organs.

Entry	Nutrient treatment				Mean
	N-free	NH_4NO_3	NH_4^+	NO_3^-	
	% germination				
Medusahead	94	94	89	100	94
Cheatgrass	83	78	67	72	75
'Goldar'	94	89	100	83	92
'Sand Hollow'	78	89	94	83	86
'1171'	100	83	94	100	94
'1206'	100	94	100	100	99
'1219'	89	78	83	89	85
Mean	91	87	90	90	

ANOVA

Source	$P > F$	$LSD_{0.05}$
N treatment (N)	0.520	--
Entry (E)	0.0006	10
N X E	0.710	--

differences in establishment success of any of the grasses studied is linked to an effect of N form or availability.

Seedling growth at 10 days after planting was markedly different among the grasses and nutrient treatments. The responses of all grasses to the different nutrient treatments were not similar. Root lengths of the weedy annual grass medusahead and cheatgrass were about 9.4 inches and exceeded those of the desirable perennial grasses by 41 to 56%, regardless of the nutrient treatment. In addition, root lengths of the annual grasses supplied N-free solution exceeded those supplied N (Fig. 1), whereas this response was often not observed for the perennials. Nitrogen enhanced maximum shoot length at 10 days after planting, particularly when supplied as NH_4NO_3 or as NO_3^--only. Shoot lengths among the grasses and within a nutrient treatment were uniform, except that the N-free solution was particularly detrimental to shoot length of cheatgrass (Fig. 1). The overall apparent greater root growth of the annuals should offer an advantage to their establishment and access to soil nutrient and water resources. The reduced shoot growth of cheatgrass with N-free nutrients would appear to favor interception of light by the perennials when plant available N is limited.

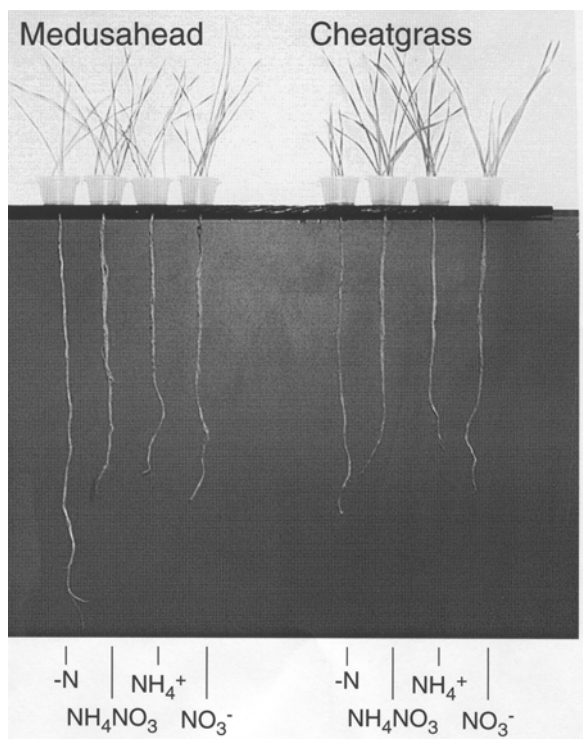


Fig. 1. Appearance at 10 days after planting of medusahead and cheatgrass supplied four different nutrient solutions that varied in availability and form of N.

When we terminated the experiment at 21 days after planting, maximum root length of medusahead and cheatgrass had increased to nearly 17.4 inches and exceeded those of the desirable perennial grasses by 20 to 29%. Seedlings grown with N-free nutrient solution still had roots (overall mean of 17.0 inches) that were 21% longer than did those grown with mineral N. In contrast, a maximum shoot length of 12.9 inches was obtained with NH_4NO_3 and NO_3^--only nutrient solutions, which was 15% greater than ammonium-only and 116% greater than N-free grown shoots. Biomass of annual grass seedlings supplied a mixture of ammonium and nitrate was 13% more than nitrate-only, 29% more than ammonium-only, and 75% more than that of N-free grown seedlings. With medusahead the NH_4^+-only nutrient solution was particularly detrimental to biomass accumulation (31% less than other nutrient treatments containing N). Among the nutrient treatments containing N, biomasses of a perennial grass were usually equivalent. Shoot to root biomass ratios in the presence of N ranged from 2.0 to 4.2, with lower values most often associated with ammonium-only nutrient solution. In the absence of N, the distribution of biomass between shoot and root organs was nearly equal except for seedlings of cheatgrass, which had root weights that were twice as much as shoot weights.

In another set of experiments we measured seedling dry weight and steady-state N uptake rate of 28-d-old seedlings. Total dry weight of cheatgrass was as much as 4.2-fold more than any of the other grasses and was > medusahead ≥ 1219 = other perennials (Fig. 2). Total dry weights of seedlings cultured with NO_3^--only and NH_4NO_3 were 65% greater than those cultured with NH_4^+-only nutrient solution. Compared to annuals the growth of the perennials was not favored by excluding NO_3^-. The overall seedling vigor of the annuals was greater than that of the perennials.

Cheatgrass had a 1.2- to 2.4-fold greater NO_3^- uptake activity than the perennials, while NH_4^+ uptake of medusahead was 1.3- to 1.7-fold less than Sand Hollow and 1219 squirreltail grasses (Fig. 3). The potential for accumulating N resources by cheatgrass was equal to or superior to that of the other grasses. The perennials did not have consistently more favorable NH_4^+ uptake activities than the annuals.

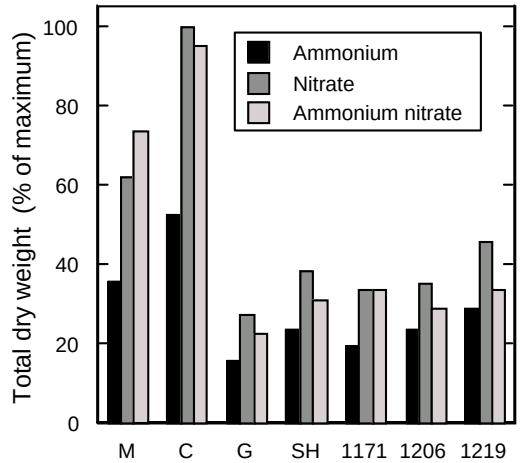


Fig. 2. Relative total dry weight of the two undesirable annuals medusahead (M) and cheatgrass (C) and five desirable perennials Goldar (G) bluebunch wheatgrass and Sand Hollow (SH), 1171, 1206, and 1219 squirreltail grasses grown with three different N sources.

The competitive advantages leading to unfavorable establishment of invasive annuals instead of desirable native perennial grasses appears to be determined more by the greater vigor of the annuals than factors associated with differences in the response of the cool-season grasses to N supply or form of mineral N. Even though the growth of medusahead but not the perennials was adversely affected by NH_4^+-only nutrient solution, the growth of medusahead was still much greater than that of the perennials. Additional research is required before the underlying basis is identified for enhanced establishment of desirable native perennials following management practices of disturbed rangeland sites that limit N availability and conversion of NH_4^+ to NO_3^-.

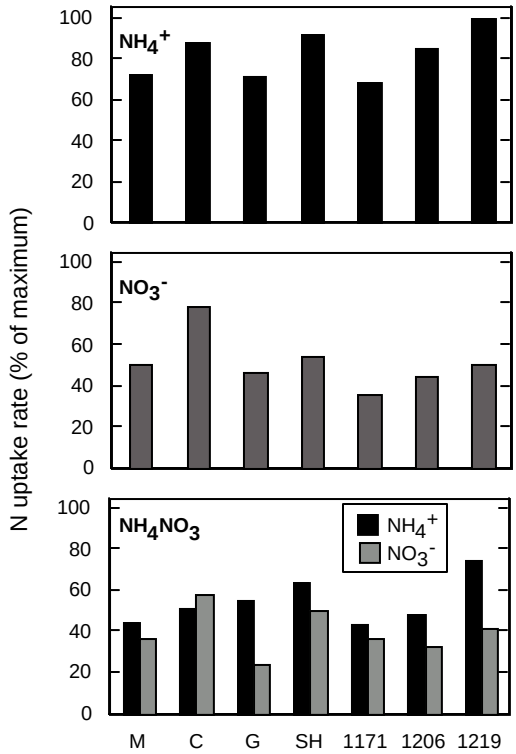


Fig. 3. Relative N uptake rates of the two undesirable annuals medusahead (M) and cheatgrass (C) and five desirable perennials Goldar (G) bluebunch wheatgrass and Sand Hollow (SH), 1171, 1206, and 1219 squirreltail grasses grown with three different N sources.

ACCUMULATED TEMPERATURE EFFECTS ON GROWTH AND DEVELOPMENT OF COOL SEASON GRASSES

Paul W. Bartholomew and Robert D. Williams

RATIONALE

As feed costs rise, farmers are increasingly interested in the use of forage for livestock production and particularly in use of grazed forages. This in turn has led to efforts to extend grazing seasons later and earlier in the year, either by use of stockpiled forage or by inclusion in the production system of forages that can grow in the cooler temperatures characteristic of late fall and early spring. An extended growing and grazing season is commonly achieved by using sequences of cool and warm season forages.

Combining crops with different seasonal growth patterns can improve the seasonal distribution of forage production, but it can also lead to problems of management, whether crops are grown in a sequence of crops or in mixtures.

Competition between components of warm- and cool-season forage crop mixtures or sequences can reduce regrowth of warm season crops in spring or cool season crops in fall and may reduce long-term persistence.

OBJECTIVES

In the work reported here we have begun to look at the possibility of using a simple temperature index as an aid to management of forages during the transition between warm and cool seasons.

Accumulated temperature expressed as ∑{(Tmax+Tmin)/2}-Tbase, or accumulated Growing Day Degrees (GDD), has been shown to relate closely to plant development in a range of crops, and has been used as an aid in timing of fertilizer or herbicide application and crop harvest date. The temperature scale used to calculate the GDD is centigrade rather than Fahrenheit.

The broader objective of our research in this area is to determine whether accumulated GDD measures may be used to predict the onset and termination of growth in a range of forage species, and whether this will allow us to develop guidelines for improved management of transitions between warm- and cool-season forage cropping, based on accumulated temperatures.

Our immediate concern, however, is to establish whether GDD and plant development relations are consistent through temperatures which approach the lower limits to growth of cool season grasses, at around 0ºC.

To examine this question we grew seedlings of Italian ryegrass (IRG; *Lolium multiflorum*), tall fescue (TF; *Festuca arundinacea*) and tall wheatgrass (TWG; *Elytrigia elongata*) in controlled environment chambers and measured their development in terms of cumulative leaf appearance, under four temperature regimes.

These temperature regimes consisted of day and night temperatures of 22.5 and 7.5, 17.5 and 12.5, 15.0 and 0.0, 10.0 and 5.0ºC. These regimes correspond to two levels of average temperature, 7.5 and 15.0ºC at each of two ranges in daily temperature, 5 and 15ºC. Seedlings were grown in a 13-hour light and 11-hour dark cycle, with a light input of 285 µE m^{-2} sec^{-1}.

At each temperature regime we measured cumulative leaf appearance on the mainstem and tiller T0 (first daughter tiller) of each seedling, up to 350 GDD after mainstem or tiller emergence. Effects of average temperature and temperature range on rate of leaf appearance were analyzed by comparison of linear regressions, with cumulative leaf appearance as the dependent, and post-emergence accumulated temperature above a base of 0ºC as the independent variable.

RESULTS

In all species tested, the rate of leaf appearance showed a highly significant ($P < 0.001$) linear relation with post-emergence accumulated temperature. The rate of leaf appearance in IRG was significantly greater than that of TF and TWG, (Fig. 1.) and the interval between successive leaf appearance (phyllochron) for each species was estimated at 67, 89 and 93 GDD for IRG, TF and TWG, respectively. The relation between cumulative leaf number and accumulated GDD post-emergence for each species was described by the following linear equations:

IRG:
leaf number = 0.0150GDD – 0.1571 ($r^2 = 0.94$)

TF:
leaf number = 0.0115GDD – 0.0236 ($r^2 = 0.88$)

TWG:
leaf number = 0.0108GDD – 0.0101 ($r^2 = 0.93$)

Among the three species, leaf appearance response to accumulated GDD was not significantly affected by either average temperature or by temperature range.

From these data we can conclude that over temperatures ranging from 0 to 22.5ºC the rate of leaf appearance in the three grasses tested maintains a close relation to accumulated temperature. Thus, accumulated GDD may be a consistent indicator of plant development, even at lower temperatures. Further work will be undertaken to validate this conclusion in the

field and to examine the grass development response to GDD when seedlings are subject to different levels of exposure to minimum temperatures below 0ºC.

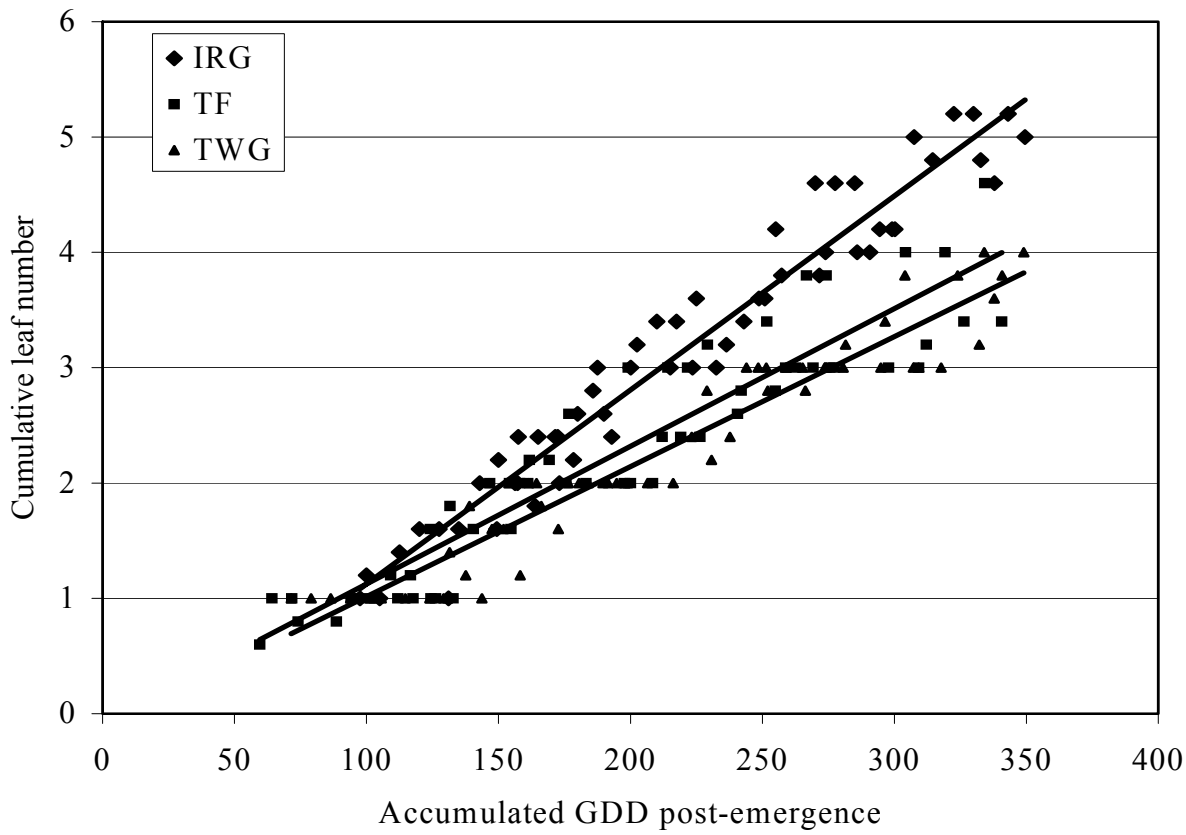


Fig. 1. Cumulative leaf appearance and post-emergence Growing Day Degrees (GDD) above 0°C for three cool season grasses.

SIMPLE PRECIPITATION MODELS AS DECISION AIDS FOR OUTREACH SPECIALISTS

Robert D. Williams and Paul W. Bartholomew

RATIONALE

Establishment of cool-season forages in either the fall or spring requires sufficient rainfall to insure seed germination and seedling survival. Given a window of opportunity for planting what are the odds of having sufficient rainfall for crop establishment? As shown in Fig. 1 the amount of average annual precipitation decreases from east to west across Oklahoma ranging from 52 inches in the southeastern corner of the state to less than 16 inches in the panhandle.

In addition to varying across the state, the annual precipitation can also vary throughout the year. Greater rainfall may occur in the spring than in the fall or winter at some locations in the state, while the fall-winter precipitation may be greater at other locations.

OBJECTIVE

Here we examine two simple rainfall models and 30 years of historical climate data to predict the probability of rainfall amounts during specified periods in the fall and spring for 14 Oklahoma counties. The precipitation models used were: HOWOFTEN, and HOWMUCH.

HOWOFTEN identifies how often a specified amount of rain will fall during a specified period. HOWMUCH provides the distribution of rainfall over a specified period. David Freebairn and his associates at the Agricultural Production Systems Research Unit, DPI/DNR/CSIRO, Toowoomba, Australia developed the models. Each model was used to estimate the conditions in Central Oklahoma

The objective was to determine the probability of accumulated rainfall amounts for the fall between September 15 and October 15 or October 31, and between October 1 and October 31. The Spring scenario examined the period between April 15 and May 15.

RESULTS

The Oklahoma counties selected for the study are presented in Fig. 2. The counties are part of the target area for the Grasslands Center of Excellence Outreach Program at Langston University. Counties selected for the study ranged from 52 inches to 32 inches of precipitation annually.

HOWOFTEN was used to determine the probability of accumulated precipitation exceeding 0.25, 0.5 and 1.0 inches during two 10-day planting periods in spring planting dates (February 24 to April 15, and April 15 to May 15) for each of the 14 counties. As shown in Fig. 3A, there is a 90% probability or greater of receiving precipitation to less than or equal to 1 inch during the first planting period.

If the planting date and establishment period was moved to April 15 to May 15, all the counties exceeded an 85% probability of receiving 1 inch of precipitation and 75% probability of exceeding 2 inches of precipitation (Fig. 3B).

When a fall planting and establishment period was considered, the probability of exceeding 1 inch of accumulated rainfall from September 15 to October 15 was 75% or greater. The probability of accumulated rainfall of 2 inches ranged from 53 to 75% (Fig. 3C).

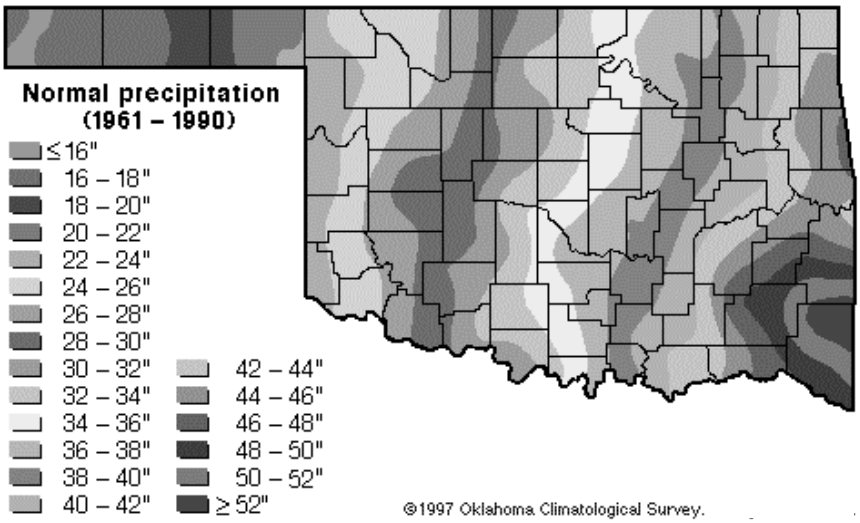
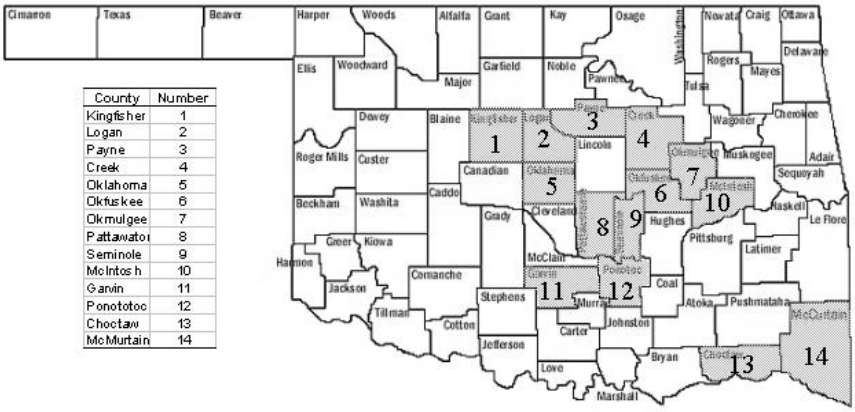


Fig. 1. Annual precipitation pattern across Oklahoma.



County	Number
Kingfisher	1
Logan	2
Payne	3
Creek	4
Oklahoma	5
Okfuskee	6
Okmulgee	7
Pattawatomie	8
Seminole	9
McIntosh	10
Garvin	11
Ponototoc	12
Choctaw	13
McMurtain	14

Fig. 2. Oklahoma counties included in the study of precipitation models HOWOFTEN and HOWMUCH.

If the planting-establishment period was extended from September 15 to October 31 the probability of exceeding 1 or 2 inches of accumulated rainfall was generally greater than 75% (Fig. 3D). When the planting-establishment period is delayed until October 1 through October 31, the probability of exceeding 1 and 2 inches of rainfall are 80% and 65%, respectively.

Although these results are preliminary, they indicate that the fall precipitation tends to be more variable than the spring. The purpose of the model is to evaluate the chances of rainfall exceeding a given amount during a specified period of time based on historical data. It does not account for soil moisture that may have accumulated in the soil profile before planting. This is a limitation of this approach.

Unlike HOWOFTEN that provides a probability of rainfall, HOWMUCH gives the distribution of precipitation during a specified period of time. Using historical rainfall records HOWMUCH provides the average, maximum and minimum rainfall amounts recorded for a location over a given period of time. This model was used to determine the distribution of rainfall during the spring and fall. HOWMUCH can also be used to estimate crop yield based on the crop's water use efficiency and soil water content available to the plant, and the user can stipulate times or periods during the crop development when water stress is critical (e.g. flowing or seed set). Here HOWMUCH was only used to determine the variability during the planting periods. Typical HOWMUCH results for Ponotoc County are given in Table 1.

As shown in the table above the average precipitation occurring during the winter and spring in Ponotoc County ranges from 1 to 9 inches, while in the fall it ranges from 1 to 5 inches. Comparing the average to the maximum and minimum rainfall amounts for the same periods of time provide us with an indication of the variability encountered in the 30-year historical rainfall data.

The results appear to favor spring planting regardless of location. Probabilities for spring rainfall were greater than 94% for 1 inch and 75% for 2 inches of rainfall. When we look at the fall rainfall from September 15 to October 15, all the counties had a greater than 75% probability of having 1 inch of accumulated rainfall, while only four of the counties had a 70% probability of receiving an accumulation of 2 inches of rainfall. Most of the counties were in the 50 to 70% probability range for equaling or exceeding 2 inches of rain. Extending the planting and establishment period by 2 weeks until October 31 slightly improved the odds. Results from October 1 to October 31 time period were similar to the results for the September 15 to October 15 time-frame.

HOWOFTEN was very useful for quickly examining historical rainfall records and determining the probability of a rainfall event and the amount of rain during a specified period. HOWMUCH is a useful model in that it quickly examines the distribution of rainfall during critical periods of crop growth and development. Information gained from these simple models can help extension personnel advise farmers on planting cool-season forages.

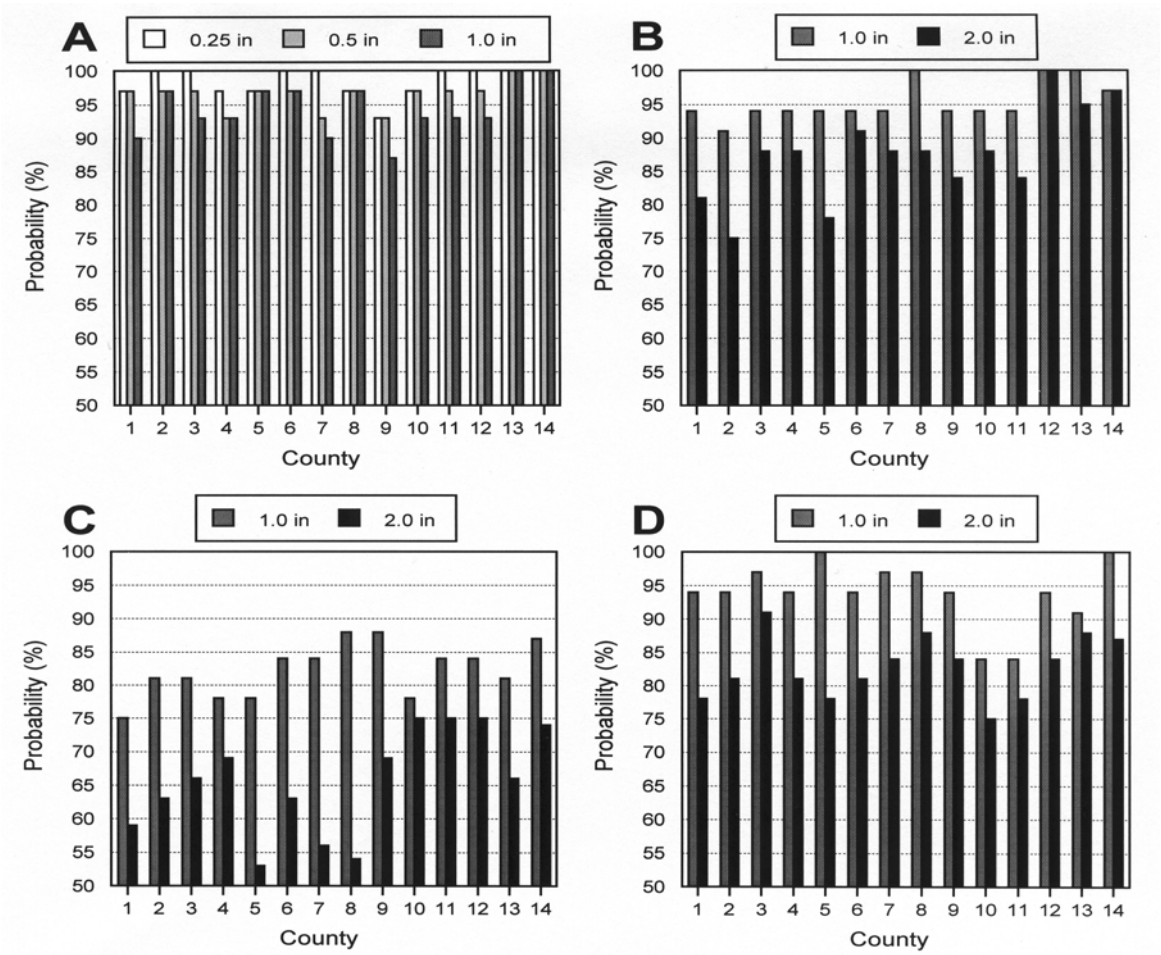


Fig. 3. Probability of exceeding minimum precipitation limits from February 24 to April 15 (A), April 15 to May 15 (B), September 15 to October 15 (C), and September 15 to October 31 (D).

Table 1. Average, maximum and minimum precipitation during the spring and fall for Ponotoc County from 1961 to 1990.

Season	Date	Average	Maximum	Minimum
		---------- inches ----------		
Spring	Jan 1 – Feb 23	5	11	2
	Feb 24 – Mar 6	1	4	0
	Mar 7 – Apr 30	6	11	2
	May 1 – Jul 1	9	16	2
Fall	Aug 1 – Sep 14	5	20	0
	Sep 15 – Sep 21	1	4	0
	Sep 22 – Oct 21	3	11	0
	Oct 22 – Nov 1	2	6	0

PERFORMANCE OF STEER CALVES REARED IN TEMPERATE OR SUB-TROPIC ENVIRONMENTS AND USED AS STOCKER CALVES ON WINTER WHEAT PASTURES

William A. Phillips, Samuel W. Coleman, Elaine E. Grings, David G. Riley, Chad C. Chase, Robert E. Short, Herman S. Mayeux, and Rod K. Heitschmidt

RATIONALE

Each fall millions of stocker calves are brought into the southern Great Plains region to graze winter wheat pasture before entering a feedlot for finishing. Rather than owning the calves, producers may decide to act as subcontractors who are paid by the amount of gain accumulated by each calf. Motivated by price and availability, stocker calves may be purchased from regions of the U.S. that differ in climatic conditions to those found on the southern Great Plains. Calves from temperate and sub-tropical environments may respond differently as stockers grazing winter wheat pastures, which would affect the amount of gain per calf.

Tropical adaptation is a desired trait for mother cows located in the sub-tropical regions of the U.S.A., including the Gulf Coast and most of the Southeast. Zebu breeds have traditionally been used for this area, but have some limitations such as reproduction and carcass quality. Criollo cattle from South America, such as the Romosinuano, have been reported to have good reproduction and carcass merit under tropical and sub-tropical conditions. However, the performance of Romosinuano calves as winter wheat pasture stockers has not been determined.

OBJECTIVE

The objective of this experiment was to compare the weight gains of steers from temperate and sub-tropic environments as stockers for grazing winter wheat pastures.

RESULTS

A herd of Romosinuano cattle was established by embryo transfer at USDA, ARS, Subtropical Agricultural Research Station in Brooksville, FL. The station also has a resident Angus herd to represent the temperate breeds. Purebred calves from both herds were born in the spring and weaned in the fall. On October 23, 2000, after a 21-day pre-conditioning period, 34 Angus and 36 Romosinuano steers were transported 1350 miles from Brooksville, FL, to El Reno, OK.

For calves bred and reared in a more temperate environment, 53 steers from the USDA, ARS Fort Keogh Livestock and Range Research Laboratory, Miles City, MT were selected. These calves were born in February, April, or June, and weaned in October to create calves of different ages and body weights. Following a pre-conditioning period, the calves were shipped 1140 miles from Miles City to El Reno on November 14, 2000.

Because winter wheat pasture was limited due to drought conditions, all steers were combined into a single group and placed in a dormant warm season grass pasture. The steers had ad libitum access to hay and a mixed diet in a self-feeder. The mixed diet was formulated to have a crude protein concentration of 14% and a total digestible nutrient (TDN) concentration of 79%. A buffer was added to the mixed diet to prevent acidosis and an ionophore was added to increased performance. The combination of mixed diet and hay was calculated to result in an average daily gain (ADG) of 1.7 lbs, which would be similar to the anticipated ADG on wheat pasture. In April, wheat pasture was available. The steers were sorted by source

(Montana or Florida) and placed on winter wheat pastures for a 63-day grazing period.

Performance of Angus and Romosinuano steers are shown in Table 1. Angus steers were 26 lbs heavier than Romosinuano steers upon arrival at El Reno. In general, the winter of 2000-2001 was colder and wetter than an average winter. From visual observations the Angus steers were shorter, thicker and heavier muscled than the Romosinuano steers and had heavier coats of hair. It is not surprising that during the 160-day winter period (October to April), Angus steers gained more weight than the Romosinuano steers. The amount of weight gained during the spring was lower than during the winter because the spring period was shorter and forage quality and quantity became a limiting factor during the later part of the period. During the spring (April and May), daily temperatures were warmer than during the winter and the Romosinuano steers gained more weight than the Angus steers. However, the Angus steers were still heavier than the Romosinuano steers (757 vs 666 lbs) by the end of the grazing period.

Table 1. Stocker performance of Angus and Romosinuano steers during the winter and spring.

Breed of steer	Initial body wt.	Winter wt. gain	Spring wt. gain
	---------- lbs ----------		
Angus	433	298	26
Romosinuano	407	222	37

Performance of cross-bred calves from Montana weaned at 4, 6 or 8 months of age are shown in Table 2. The calves from Montana arrived later than the calves from Florida, but they gained more weight during the winter period under the same environmental and nutritional conditions. The amount of winter gain decreased as the initial body weight and age at weaning decreased. Gains during the spring were similar to those observed for the Florida calves. During the spring grazing period, the younger, lighter Montana calves gained weight more rapidly than the older, heavier calves. By the beginning of the spring grazing period, the older February born calves weighed over 800 lbs, while the younger June born calves weighed just over 650 lbs. The June calves probably had to expend less energy for maintenance, so they could gain weight more rapidly. Because the value of gain is greater for lighter calves than for heavier calves, owning the June-born calves would probably be more profitable than being paid for the gain as a sub-contractor. The opposite would be true for the February-born calves. Because the February born calves were heavier at arrival and gained more weight during the winter than the younger calves, being paid for the gain would be more economical.

While direct comparison of performance of stocker calves from Florida and Montana is difficult, we can draw some conclusions. Stocker calves born and reared in a temperate climate will probably out-perform stockers selected for production in a sub-tropical environment. Stocker calves from a temperate breed but reared in a sub-tropic environment performed as well as steers born and reared in a temperate environment. Initial body weight should be considered when deciding whether to own stockers or to be paid based on the amount of gain.

Table 2. Performance of steers from temperate breeds weaned at 4, 6 or 8 months of age.

Month of birth	Age at weaning	Initial body wt.	Winter wt. gain	Spring wt. gain
	months	---------- lbs ----------		
February	8	538	307	32
April	6	433	282	47
June	4	386	272	56

WHEAT PASTURE ADAPTATION OF DORSET, ST. CROIX AND CROSSBRED LAMBS

Mike A. Brown, Lisa A. Appeddu, and William A. Phillips

RATIONALE

Wheat pasture plays a major role in the stocker industry in the southern Great Plains. In most stocker operations, animals are purchased rather than raised and placed on winter wheat pasture with intent of producing low-cost weight gain. Stocker operators have observed and research at the Grazinglands Research Laboratory has substantiated a period of adaptation when gains are minimal or negative for the first 21 days after animals are placed on winter wheat pasture. Shortening the adaptation period could result in substantial increases in net income for stocker operators. However, little is known about factors that may influence this adaptation period, and these factors must be identified before strategies can be developed to mitigate problems with initial stocker performance on wheat.

OBJECTIVE

The objective of this research was to evaluate the period of lamb adaptation to wheat pasture and to determine if breed differences in adaptation times or magnitudes are important.

RESULTS

In a 2-year study, four breed groups of fall-born lambs (Dorset x Dorset, St. Croix x St. Croix, Dorset x St. Croix, St. Croix x Dorset; sire breed listed first) were weaned in December and placed in drylot. Dorset are medium-frame wool sheep, while St. Croix are small-framed tropically adapted hair sheep. When winter wheat was available for grazing (mid-January, 2000; early March, 2001), one-half of each breed group was moved from drylot to wheat pasture. Lambs in drylot were fed a 50% roughage ration balanced to approximate expected animal gains on wheat pasture (Table 1). Weight gains in drylot and wheat pasture lambs were measured for 6 weeks after initiation of wheat pasture grazing, after which drylot lambs were placed on wheat pasture on Feb. 29, 2000, and on April 18, 2001. Wheat pasture lambs remained on wheat pasture. Gains were again measured for an additional 3 (2001) or 4 (2000) weeks to observe the adaptation of the drylot treatment to wheat pasture.

Table 1. Ration for drylot treatment lambs.

Ingredient	Fraction of ration	Crude protein	Total digestible nutrients
	----------	%	----------
Molasses	5.0	0.2	4.0
Limestone	0.5		
Dical phosphate	0.5		
Corn	35.5	3.6	31.6
Alfalfa hay	50.5	8.6	28.3
CSM	8.0	3.5	6.2
Total	100.0	15.9	70.1

Weekly average daily gains (ADG) in years 2000 and 2001 for each postweaning treatment are shown in Fig. 1. Averaged over breed group, lamb gains on wheat pasture were less than drylot lambs for the first 3 weeks of the trial in 2000 and for the first week of the trial in 2001. Thereafter, until 6 weeks later, gains were similar between postweaning treatments in both years, indicating adaptation had occurred. Consequently, it appears a 3 week adaptation period is required for lambs in the early spring and less time is required later in the spring. Similarly, there was a significant adaptation period for the drylot lambs after being moved to wheat pasture, but it was only for 1 week in both years of the study.

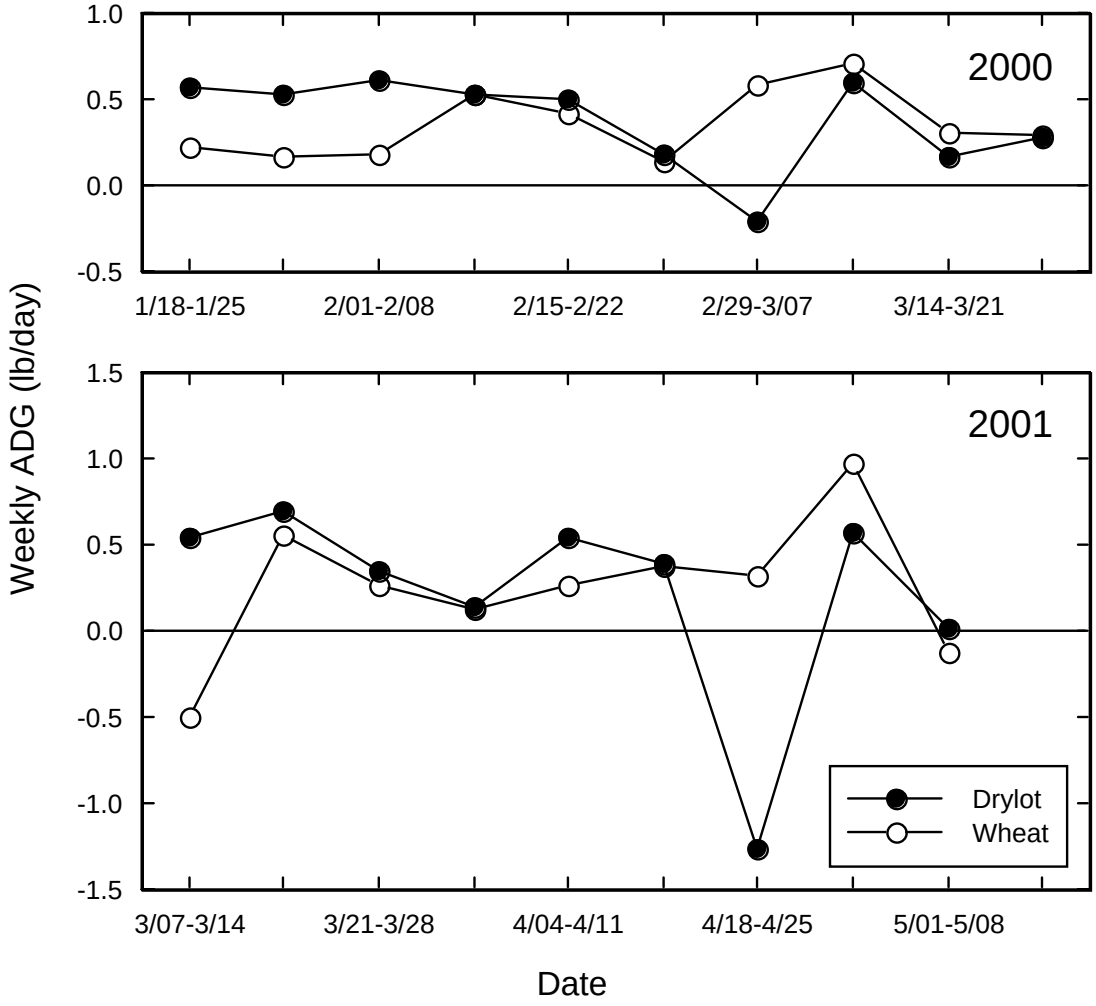


Fig. 1. Weekly average daily gain (ADG) for wheat pasture and drylot lambs in years 2000 and 2001.

Data were categorized and summarized into three time periods for purposes of breed group comparisons (Tables 2 and 3). The initial 21 days was made up first time period, when the wheat pasture lambs were adapting. The second time period consisted of the next 21 days, when the wheat pasture lambs were adapted to wheat pasture. The last 21 day (2001) or 28 day (2000) period was associated with the adaptation of drylot lambs to wheat pasture.

In 2000, there were obvious breed group differences in the drylot lambs during period 1, with Dorset and St. Croix x Dorset having higher ADG. However, there was little evidence of breed group differences in the wheat pasture treatment. By period 2, adaptation to wheat pasture was evident in all breed groups. Breed differences in adaptation of drylot lambs to wheat pasture was evident in period 3, with the St. Croix x Dorset drylot lambs having lower gains than the other drylot breed groups.

In 2001, there was more evidence of differences among breed groups on wheat pasture during period 1, with St. Croix-sired lambs most negatively affected. Gains of lambs in drylot during period 1 were similar for Dorset, Dorset x St. Croix and St. Croix x Dorset but lower for St. Croix. There was some evidence in period 2 that the St. Croix x Dorset lambs required additional time for adaptation, as suggested by lower gains during

this period. Breed differences during adaptation of drylot lambs to wheat pasture were evident in period 3, with St. Croix drylot lambs seemingly least negatively affected.

From these preliminary data, we can conclude that approximately 1 to 3 weeks are required in lambs to adapt to wheat forage, depending on the time of year. There may be genetic differences in adaptation, which relate to rate of gain at different production stages, but differences were not consistent across years. Further research is needed to define adaptation x year interaction.

Table 2. Average daily gains for three periods for each breed group and postweaning treatment in year 2000.

Breed[†]	Postweaning treatment	Jan 18 - Feb 8[‡]	Feb 8 - Feb 29	Feb 29 - Mar 28
		---------- lb per day ----------		
D x D	Drylot	0.76	0.50	0.34
	Wheat pasture	0.17 (0.59)[§]	0.43 (0.07)	0.62 (-0.28)
D x S	Drylot	0.39	0.34	0.25
	Wheat pasture	0.21 (0.18)	0.36 (-0.02)	0.45 (-0.20)
S x D	Drylot	0.71	0.40	0.10
	Wheat pasture	0.21 (0.50)	0.33 (0.07)	0.56 (-0.46)
S x S	Drylot	0.43	0.33	0.19
	Wheat pasture	0.18 (0.25)	0.32 (0.01)	0.29 (-0.10)

[†]D x D=Dorset, D x S=Dorset x St. Croix, S x D=St. Croix x Dorset, S x S=St. Croix, sire breed listed first.

[‡]Jan 18 – Feb 8, Period 1, initial adaptation period; Feb 8 – Feb 29, Period 2, lambs maintained on wheat pasture or in drylot; Feb 29 – Mar 28, Period 3, adaptation period for drylot lambs to wheat pasture.

[§]Numbers in parentheses are drylot-wheat pasture ADG.

Table 3. Average daily gains for three periods for each breed group and postweaning treatment in year 2001.

Breed[†]	Postweaning treatment	Mar 7 - Mar 28[‡]	Mar 28 - Apr 18	Apr 18 - May 8
		---------- lb per day ----------		
D x D	Drylot	0.69	0.44	-0.20
	Wheat pasture	0.23 (0.46)[§]	0.38 (0.06)	0.43 (-0.63)
D x S	Drylot	0.57	0.43	-0.18
	Wheat pasture	0.13 (0.44)	0.30 (0.13)	0.39 (-0.57)
S x D	Drylot	0.601	0.45	-0.20
	Wheat pasture	0.04 (0.56)	0.22 (0.23)	0.45 (-0.65)
S x S	Drylot	0.30	0.12	-0.05
	Wheat pasture	0.06 (0.24)	0.08 (0.04)	0.32 (-0.37)

[†]D x D=Dorset, D x S=Dorset x St. Croix, S x D=St. Croix x Dorset, S x S=St. Croix, sire breed listed first.

[‡]Mar 7 - Mar 28, Period 1, initial adaptation period; Mar 7 – Apr 18, Period 2, lambs maintained on wheat pasture or in drylot; Apr 18 – May 8, Period 3, adaptation period for drylot lambs to wheat pasture.

[§]Numbers in parentheses are drylot-wheat pasture ADG.

INCREASING THE PERFORMANCE OF STOCKER CALVES ON WINTER WHEAT PASTURE

William A. Phillips, Elaine E. Grings, J. William Holloway, Robert E. Short, Bobby Warrington, Herman S. Mayeux, and Rod K. Heitschmidt

RATIONALE

In the past we had conducted experiments to develop management strategies to help reduce the amount of stress calves were subjected to during assembly and transit. Our goal was to help these calves recover from the stressful events as soon as possible so that they could remain healthy and begin to gain weight. One of the factors used to gage success was feed intake. Without adequate feed intake calves were nutritionally deprived, which hampered mounting an adequate defense against bacterial and viral infections and the ability to begin to gain weight.

From our most recent research, we have discovered that winter wheat forage is not readily consumed, so weight gains during the first 2 to 3 weeks of grazing could be negative or just slightly positive. Why stockers don't readily consume wheat forage is not known, but it may be due to the rapid release of nitrogen or the high content of soluble carbohydrates. We wanted to explore management options that had been successful in stimulating the appetite of stressed calves on stocker calves when they were first turned out on winter wheat pasture.

OBJECTIVE

The objective of this experiment was to determine the impact of an intake-stimulating product on the performance of stocker calves grazing winter wheat pastures for the first time.

RESULTS

In the spring of 2000, 241 cross-bred steers were assembled at a feedlot in Southern Kansas, pre-conditioned for 30 days and then shipped to El Reno, OK for grazing winter wheat. Calves were implanted and treated for internal parasites and randomly assigned to one of two pastures. Within each pasture group, approximately half of the steers received 0.53 oz of an oral paste that contained yeast products. The paste was a commercial product that contained at least 284 million colony forming unit (CFU)/oz of product. Steers were individually identified and weighed at the beginning (March 7) and end (May 26) of the grazing period.

In the fall of 2001, 61 steers born in February, April or May and reared at the USDA-ARS Fort Keogh Livestock and Range Research Laboratory, Miles City, MT were weaned in October, pre-conditioned for 21 days, then shipped to El Reno on October 30. On November 6, calves were blocked by month of birth. Half of the calves in each group received the oral paste previously described. All 61 steers grazed the same pasture which was seeded with a combination of wheat (75lb/ac), ryegrass (20 lbs/ac) and triticale (45 lbs/ac). Calves were individually weighed at the beginning (November 6) of the grazing period and 35 days later.

In the fall of 2001, 76 cross-bred spring born heifers were weaned and shipped from the Texas A&M Extension and Research Center in Uvalde, TX to El Reno, OK on November 14. Two days after arrival 20 heifers were selected to graze a single wheat pasture. The remaining 56 heifers grazed a single field of wheat-ryegrass-triticale. Half of heifers in each pasture received the oral paste prior to grazing. The cattle were individually weighed at the beginning (November 16) and end (December 19) of the experimental period.

The initial body weights and the amount of weight gained for each of the three experimental groups are shown in Table 1. The steers from Kansas had an average weight of 631 lbs at the beginning of the 78-day spring grazing season. Steers that were treated with the oral paste gained 13 lbs more than those not treated. At a cost of $1.00/steer for oral paste, the additional gain had a cost of 8 cents/lb. Overall, these steers had a very good average daily gain of 2.28 lbs for the

grazing season, although we kept them on the pastures longer than was optimum.

The steers from Montana averaged 546 lbs in body weight at the beginning of the experiment. The calves born in February weighed 619 lbs and were heavier than the calves born in April (532 lbs) or June (419 lbs). Although steers that received the oral paste gained more weight than the control group, the response to oral paste was about half of that observed in the steers from Kansas. This may have been due to the short length of the fall grazing period (35 days) as compared to the spring (78 days). Also, stocker calf performance on fall wheat is usually less than that observed on spring pastures.

The heifers from Texas had the lowest rate of gain of all three groups. These heifers were from Southwest Texas and at least half of their genetic make-up was from tropically-adapted breeds of beef cattle. Therefore, they may have been under more environmental stress than the steers from Montana.

From these data, we conclude that stocker calves used to graze wheat pastures or other annual cool season grasses may go through a dramatic change in diet when turned out on pasture for the first time. Dosing these calves with 0.53 oz of a paste containing yeast product prior to turn out appeared to help calves make this transit more smoothly, resulting in an increase in weight gain.

Table 1. Performance of stocker calves grazing annual cool-season pastures in the fall or spring.

Season	Source	Days on grass	Gender of calf	Treatment	Initial body wt.	Number of calves	Weight gain
					-- lbs --		-- lbs --
Spring	Kansas	78	Steer	Control	632	126	171
				Paste	631	115	184
Fall	Montana	35	Steer	Control	541	30	61
				Paste	553	31	68
Fall	Texas	33	Heifer	Control	541	35	40
				Paste	510	41	36

USE OF INTAKE AND DIGESTIBILITY MARKERS IN STOCKERS GRAZING WHEAT

Lisa A. Appeddu and Mike A. Brown

RATIONALE

Changes in intake and digestibility may contribute to the low or negative gains commonly observed during the first 21 days in stockers grazing wheat pasture. While intake and digestibility may be measured directly under confined conditions, changes in growing forage cannot be duplicated. In the field, it is difficult to obtain accurate estimates of forage intake and normal grazing behavior is disrupted.

Animal handling may be reduced by using a bolus, which gradually releases a known amount of alkane markers (Captec, Ltd., Auckland, New Zealand). Alkanes are long chain, saturated carbon compounds which are not well-digested by the animal, allowing them to be recovered in the feces. Fecal output can be estimated by dividing the amount of marker administered per day by its concentration in the feces. From this, intake can be calculated by dividing fecal output by forage indigestibility, as determined from alkane concentrations naturally found in plant wax. While this technique shows promise, it has not been validated in stockers grazing wheat pasture.

OBJECTIVE

The objective of this research is to determine alkane bolus release rate and alkane marker recovery in stockers introduced to wheat pasture.

RESULTS

Twelve steers (initial weight = 618 ± 36.0 lbs) were weaned on October 30, 2001. Steers had unlimited access to prairie grass hay and were fed 2 lbs of high protein pellets per head per day in a drylot. Prior to being placed on fall wheat pasture, steers were divided into three groups, which would receive an alkane bolus at three different times. Steers in the first group received an alkane bolus 6 days before being placed on wheat pasture; steers in the second group received an alkane bolus 6 days after grazing wheat pasture; and steers in the third group received an alkane bolus on the day they were introduced to wheat pasture. This protocol was used to investigate the effect of diet change on the ability of the alkane bolus to predict fecal output during steer adaptation to wheat pasture.

Steers in groups 1, 2, and 3 were introduced to fall wheat pasture on November 13, November 14, and December 5, respectively. Sample collection started 10, 7, and 5 days after boluses were administered. As recommended by the manufacturer, sample collection did not begin until 5 or more days after the bolus was administered to let alkane marker concentration stabilize in the feces. Total fecal collections were conducted by fitting fecal bags and harnesses to steers on 4 to 8 days, 13 to 16 days, and 5 to 9 days after steers were introduced to wheat pasture in groups 1, 2, and 3, respectively. Bags were changed twice daily and weighed to determine average daily fecal output. Subsamples were taken from fecal bags. Fecal grab samples were taken at the same times that bags were changed. All fecal samples were freeze-dried for further analysis. Fecal alkane concentration will be determined in freeze-dried samples. Alkane recovery will be calculated by multiplying fecal alkane concentration with fecal output. This will be compared to the labeled alkane release rate to determine the consistency of marker release during steer adaptation to wheat. Differences between steers and between bolus groups will be compared. Actual fecal output will be compared to fecal output calculated from the alkane concentrations determined in fecal grab samples. The ability to use fecal grab samples would allow a larger number of stockers to be bolused and intake estimated without fecal bags. Future research will involve alkane bolus

marker recovery in steers adapting to spring wheat and in steers already adapted to wheat pasture. Wheat pasture was clipped during fecal collections so that the ratio of plant alkane concentrations in the feed and feces can be used to estimate forage indigestibility. This will be compared to standard digestibility estimates as determined *in vitro*, by incubating forage in a rumen fluid-based solution for 48 hours at 102.2°F. Future research will focus on evaluating plant alkane recovery under confined conditions by measuring actual plant alkane intake and output in stockers consuming wheat silage and hay.

In a second experiment, alkane boluses were placed in the rumen of two cannulated steers (initial weight = 1016 lbs) to allow direct observations of the bolus itself over four bolus release periods during steer adaptation to wheat pasture. Two alkane boluses were introduced into each steer at 16 days before (November 15), 5 days before (November 26), on the day of (December 1), and 5 days after (December 6) being placed on wheat pasture. Alkane boluses were weighed prior to and after removing from the rumen. The length of alkane level in each bolus was visible and could be measured with a ruler prior to, during, and after being placed in the rumen. Boluses were secured on a 4 ft string so that they could move freely in the rumen, but be easily recovered for measurement. Two measures were made at each time per bolus, and the average value was recorded. Boluses were removed from the rumen before the entire alkane marker had been released. Boluses were rinsed to remove rumen debris and air-dried before final weight and length measurements were made.

Initial weights (1.55 ± 0.001 oz) and alkane levels (2.49 ± 0.004 in) were similar across boluses. Daily alkane release rate for each bolus release period was determined by using linear regression between initial and final weights, or across measures of alkane marker level (Table 1). Similar trends were found whether boluses were weighed or measured. The two boluses within each steer did not have a different release rate ($P \geq 0.24$).

However, release rates were different between steers ($P < 0.01$), with the largest numerical differences found in the second and third bolus release periods (when alkane boluses were introduced five days prior to and on the day of placing steers on wheat pasture).

Release rates were different across bolus release periods ($P < 0.01$). On average, rates decreased from the first bolus release period to the second and third periods (Table 1). This decrease was visible in bolus measures (Fig. 1), occurring after steers were placed on wheat

Table 1. Rate of disappearance of alkane marker from a bolus as determined by changes in bolus weight and alkane marker length.

	Alkane bolus release period			
Steer	-16 to 0 day	-5 to 9 day	0 to 16 day	5 to 19 day
	oz/day			
1	0.045 [a]	0.040 [b]	0.039 [b]	0.045 [a]
2	0.044 [a]	0.044 [a]	0.042 [b]	0.047 [c]
SEM [†]	0.0002	0.0003	0.0007	0.0002
Steer difference (*P*)	0.09	0.01	0.09	0.03
	in/day			
1	0.146 [a]	0.126 [b]	0.123 [b]	0.145 [a]
2	0.143 [ab]	0.139 [ac]	0.133 [c]	0.148 [b]
SEM [†]	0.0009	0.0007	0.0018	0.0008
Steer Difference (*P*)	0.14	0.01	0.06	0.13

[†] Standard error of the mean.
[abc] Values with different superscripts across a row are different ($P < 0.01$).

pasture. Differences between steers and periods support the manufacturer's warning of the potential for disrupting bolus release rates, if animal diet is changed. In contrast, alkanes were released at similar rates in the first and fourth periods. This suggests introducing alkane boluses at 5 days after placing steers on wheat pasture would cause alkane delivery from boluses to be similar to when steers consumed prairie grass hay. Although only two steers were compared, preliminary results suggest the most changes and variation in alkane marker release from boluses occurs when day of placing steers on wheat pasture. However, waiting to administer boluses to steers until 5 days after they are placed on wheat pasture does not allow indirect measures of intake during the first week of steer adaptation to wheat pasture. Actual fecal alkane recoveries determined from fecal bag collections will dictate the overall repeatability and accuracy of the use of alkane boluses for estimating forage intake in stockers.

boluses are introduced just prior to and on the

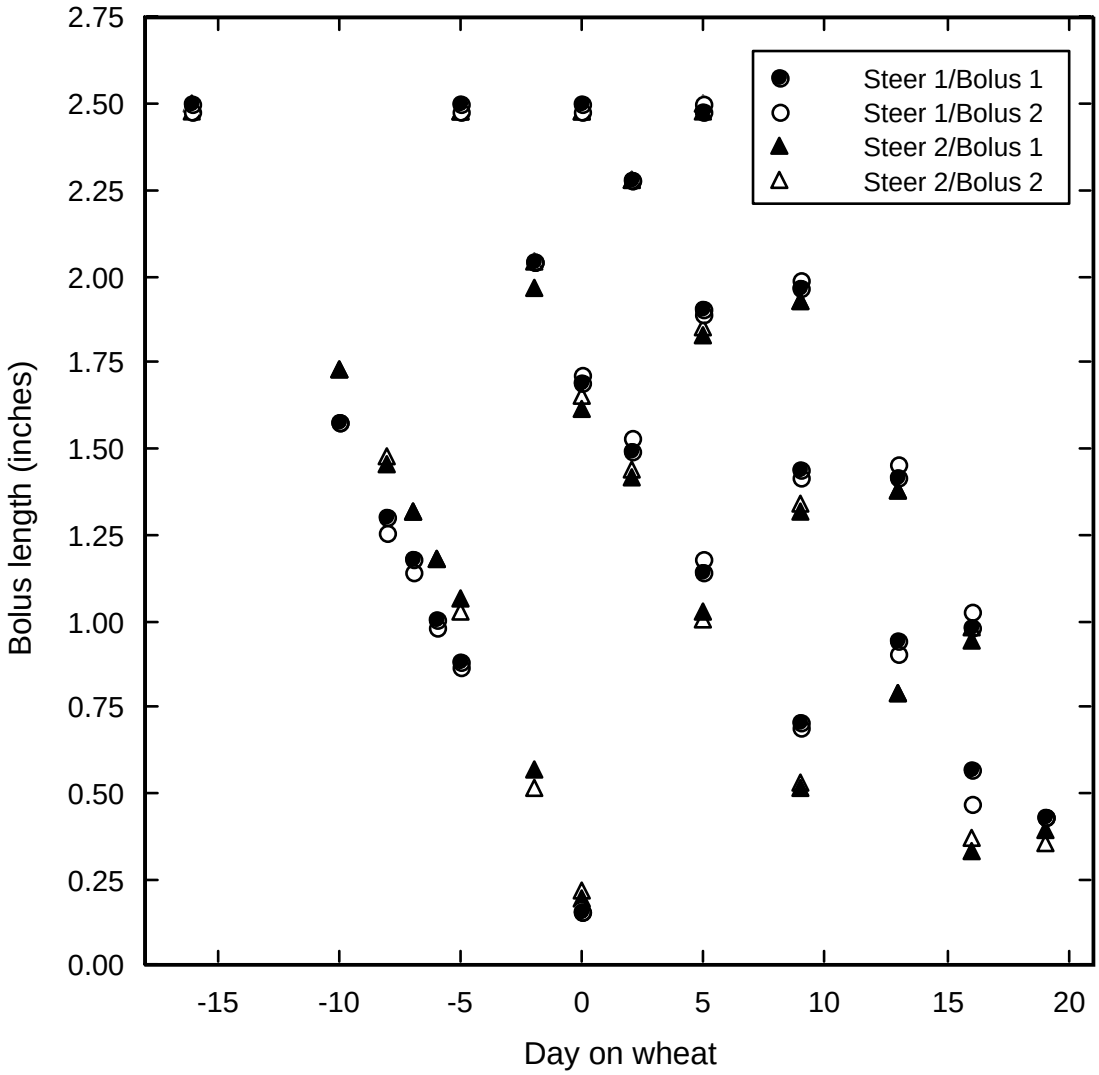


Fig. 1. Alkane bolus disappearance in rumen cannulated steers.

STOCKER RESPONSES TO MANAGEMENT SYSTEMS ON THE GRAZINGLANDS RESEARCH LABORATORY EXPERIMENTAL WATERSHEDS

Brian K. Northup, William A. Phillips, and John A. Daniel

RATIONALE

Millions of stocker calves are brought into Oklahoma each year to gain weight prior to entering feedlots for finishing. Winter wheat and different types of warm-season perennial grasses are the foundation of management systems used to grow stocker cattle in the region. Changes in animal maturity, quality and availability of forage, and climate with time of year can all affect gains.

Native prairie has the lowest costs of production of the available warm-season forages in Oklahoma, and can promote good gains by stocker cattle, if properly managed. However, stocker cattle on native prairie have lower average daily gains (ADG) during the last half of the summer (July-September), as compared to the first half of the summer. Supplemental protein is needed to improve ADG during late summer. These supplements are generally based on different oil-seed meals and can be expensive inputs. Inter-cropping an annual summer legume into winter wheat fields could be a viable alternative in wheat-warm season production systems, particularly if the price of concentrate supplements is high. Such a crop can also serve as an organic source of N fertilizer that could be available for a following cereal crop.

Korean lespedeza, an annual summer legume, inter-cropped into wheat has been shown to provide high-protein (18-20%) forage in late summer. It could be coupled with a more aggressive form of management of native pasture to improve gains by stocker cattle and reduce the costs of production. Intensive early stocking (IES) is an aggressive management option that uses higher stocking rates for the first half of the summer, then rests the pasture for the remainder of the summer. The IES approach takes advantage of the higher quality forage that exists early in the growing season. However, stockers must be moved to another pasture for the second half of the summer to prevent over-grazing.

OBJECTIVES

Grazing Korean lespedeza in conjunction with IES on native prairie might provide summer-long grazing for stocker cattle, and reduce the costs of production. The objective of this study was to compare weight gains by stocker cattle on native prairie under management systems that included different forms of supplement and grazing regimes.

RESULTS

During 1999 and 2000, different grazing systems were established on eight, 4.0 ac experimental watersheds on the USDA-ARS Grazinglands Research Laboratory, four of which were native prairie and four that were cultivated ground. Management systems (Table 1) applied to the native pastures were: (1) season-long grazing at a conservative stocking rate; (2) season-long grazing at a conservative rate with protein supplement supplied (0.5 lb/head/day, fed in 3 meals/week) during the second half of the summer; and (3) intensive early stocking (IES) in which the stocking rate was doubled for the first half of the summer and the cattle were removed from native prairie for the second half. A fourth native pasture was hayed to describe forage production. Cultivated pastures were planted each year to winter wheat and grazed by stocker cattle in the winter and spring. Two of the cultivated pastures were inter-seeded with Korean lespedeza in March, and stocker cattle from the IES pasture were shifted to these pastures for the second half of the summer (July-August). Weight gains of the stocker cattle were measured at key times during

the grazing seasons and used to describe ADG and gains per acre. Costs of grazing cattle under the different grazing-cultivation systems were also tabulated.

Average daily gains during the first half of the grazing seasons varied (Table 2), most likely due to differences in forage quantity and quality. Average daily gains in the second half of the summer were lower in the season-long – no supplement system. Calves on native pastures with supplement, or those shifted to lespedeza pastures, produced higher ADG with levels similar to those reported in the first half of the grazing season.

Gains per acre from the four systems were variable but decreased for calves that were not supplemented, or those shifted to lespedeza, during the second half of the season. The highest gains were noted for the IES systems during the first half of the season. The system including lespedeza generated higher gains per acre during the second half of the season, as compared to season-long grazing. Supplements in combination with native prairie produced higher gains per acre during the second half of the summer than the non-supplemented system, but only represented a 22 lb/acre improvement. On a seasonal basis, IES + lespedeza and IES alone produced higher gains per acre than the season-long systems; supplements did not generate any increases over the non-supplemented system.

Table 1. Timing, duration and stocking rates of management systems applied to native grass pastures located on the Grazinglands Research Laboratory watershed site during 1999 and 2000.

Management†	Grazing duration	Time of grazing‡			Stocking rate
		1st half	2nd half	Season	
		---------- days ----------			acre/head
Season-long	Jun-Sep	49	47	96	0.90
Season-long + protein supplement	Jun-Sep	49	47	96	0.90
Intensive early stocking (IES)	Jun-Jul	49	--	--	0.43
IES + wheat with lespedeza	Jun-Aug	49	31	80	0.74

†Cost of protein supplement was $0.53/lb of gain. Stocking rates for IES + wheat with lespedeza treatment included 0.43 acre/head on native prairie (1st half) and 0.31 acre/head on lespedeza (2nd half) inter-seeded into wheat (2nd half, July-Aug).

‡First and second halves represent portions of the grazing season.

Table 2. Summary of weight gains of stocker cattle grazing different forages under different management systems during 1999 and 2000.

Management†	Grazing duration	Average daily gain			Gain/acre		
		1st half‡	2nd half	Season	1st half	2nd half	Season
		---------- lb ----------					
Season-long	Jun-Sep	1.95	1.28	1.63	110	66	176
Season-long + protein supplement	Jun-Sep	1.61	1.70	1.66	90	88	178
Intensive early stocking (IES)	Jun-Jul	1.80	--	1.80	203	--	203
IES + wheat with lespedeza	Jun-Aug	1.80	1.81	1.80	203	129	332

†Cost of protein supplement was $0.53/lb of gain. Stocking rates for IES + wheat with lespedeza treatment included 0.43 acre/head on native prairie (1st half) and 0.31 acre/head on lespedeza (2nd half) inter-seeded into wheat (2nd half, July-Aug).

‡First and second halves represent portions of the grazing season.

Costs per acre (not including the costs of land) for the IES + lespedeza and supplemented systems were considerably higher than season-long or IES grazing alone (Fig. 1). The cost of grazing native prairie either season-long or by IES was only $3/acre, as compared to $16 and $29/acre for supplements or lespedeza. One cost not included in the analysis was the potential loss of wheat pasture in parts of November through March when using lespedeza. Lespedeza inter-seeded into wheat pasture can result in reductions in soil moisture available to support the next years' wheat crop, because of summer growth by lespedeza. As such, fall and some winter grazing may be lost due to the delay in establishment of the wheat crop. The usefulness of lespedeza, therefore, depends on amount of rainfall during the second half of the summer growing season and early fall. As an example, attempting to use lespedeza during 2000 or 2001 was risky, due to the dry conditions that prevailed in central Oklahoma. In contrast, above average rainfall during the mid-1990s made the use of lespedeza as a summer-fallow crop in rotation with wheat viable during that time period.

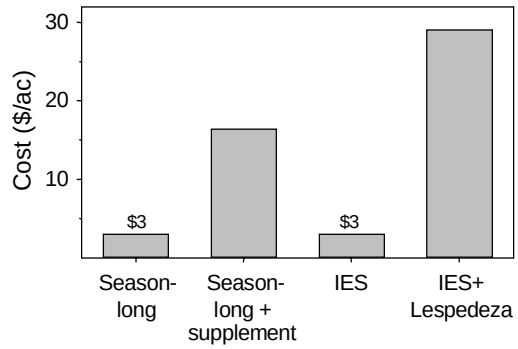


Fig. 1. Production costs of different grazing systems applied to native pasture, and forms of supplement N.

Using alternative forms of grazing management or including a 'green' source of supplemental N could be useful options for producers growing stocker cattle in the southern Great Plains. Producers must decide if the costs of including such approaches when grazing native prairie could be offset by improved animal gains. When combined with returns from wheat pasture, some of these systems for grazing native prairie, or native prairie in combination with inter-seeded lespedeza, could produce improvements in farm income.

RELATIONSHIP OF GENETIC POTENTIAL FOR MILK TO ACTUAL YIELD IN BRANGUS

Mike A. Brown, Lisa A. Appeddu, and William A. Phillips

RATIONALE

Stocker cattle are traditionally 6 to 12 months of age when transported to the southern Great Plains for grazing. Because stockers have spent a significant portion of their life dependent on the cow the preweaning environment can influence postweaning performance. Factors such as climate in which calves were raised, preweaning forage type, preweaning exposure to microorganisms, preweaning management, and preweaning maternal environment can impact postweaning growth. The preweaning maternal environment includes the amount and quality of milk produced by cows. While milk production levels consistent with production environment are desirable for cow-calf production systems, the effects of higher levels of milk production and/or quality on postweaning growth in calves are less well understood.

OBJECTIVE

The objective of this research is to evaluate the effects of level and quality of milk production on preweaning and postweaning

growth in Brangus and Brangus-cross calves, and to associate actual levels of milk production with estimated genetic potential for maternal performance.

RESULTS

Fifty Brangus cows were selected from a herd of 125 to estimate milk yield and quality in the spring of 2000. Cows were selected to include a wide range of sire estimated progeny differences (EPD) for milk. Sire milk EPD's in this sample of cows ranged from -13.8 lb to 17.5 lb. The difference in sire milk EPD's can be interpreted as the expected difference in weaning weight of calves from daughters of the sires, due to differences in mothering ability. In this sample of cows, the expected weaning weight difference would be 31.3 lb between cows with the lowest and highest sire milk EPD. Milk yield was estimated by milking cows after a 14-hour separation from calves using a single-cow milking machine. Milk quality was estimated by a commercial laboratory (Heart of America DHIA, Manhattan, KS) from samples taken at milking. Milk production estimates were conducted at an average 58, 86, 114, 142, 177, and 204 days post-calving with cows grazing tall grass prairie.

Average milk yields were relatively consistent for the first four collections (Fig. 1), but declined by day 177 and 204 (August and September, 2000). This decline coincides with the typical decline in forage quality in late summer. It also reflects the lack of rainfall received in July and August 2000. Estimates of milk fat were lower at 58 days post-calving than on other days (Fig. 2), but generally reflected the higher milk fat expected in Brahman-cross cattle that is reported in the literature. Milk protein was lower on 86 and 114 days post-calving, but relatively constant thereafter (Fig. 2). Calf birth weights averaged 84 lb and weight at 204 days averaged 532 lb (Fig. 3). Preweaning average daily gain (ADG) was calculated as 2.19 lb/d. The simple correlation of total milk yield to ADG was 0.52, indicating that calves from cows with higher milk yield tended to gain faster while on the cow.

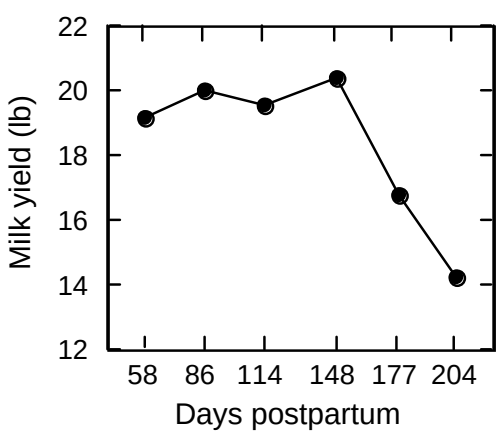


Fig. 1. Daily milk yield of Brangus cows.

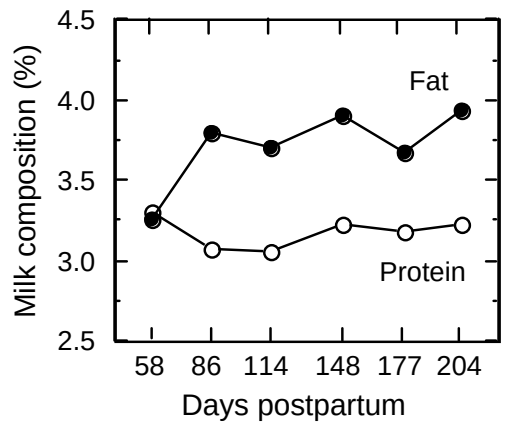


Fig. 2. Fat and protein concentrations of Brangus cow milk.

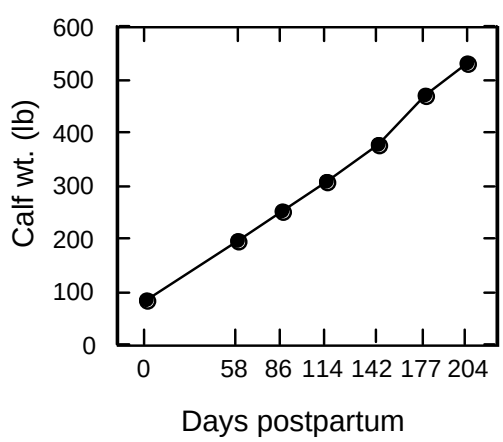


Fig. 3. Calf preweaning weight.

Cows were divided into two groups: one with sire milk EPD's greater than zero and the other with sire milk EPD's less than zero. Milk yields of the two groups for each of the monthly estimates are given in Fig. 4. Cows with sire milk EPD's greater than zero tended to have higher milk yields early in lactation compared to cows with sire milk EPD's less than zero. The milk yield of all cows was similar in late lactation. We believe that sire milk EPD's may be more predictive of actual differences in milk yield early in lactation, but not in late lactation. This may result from the decline in forage quality over the summer into fall causing nutritional levels to be below the requirements needed to support differences in genetic potential for milk yield.

Future work will determine the relationships of sire EPD for milk to actual milk yield and quality in different production systems and nutritional levels, as well as relationships to calf preweaning and postweaning growth.

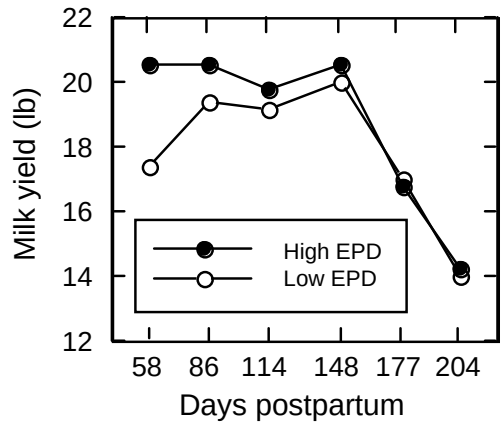


Fig. 4. Daily milk yield of Brangus cows from high and low estimated progeny different (EPD) sires.

INFLUENCE OF HARVEST TIME OF WARM SEASON HAY ON STOCKER PREFERENCE AND FORAGE QUALITY

Lisa A. Appeddu and Mike A. Brown

RATIONALE

Previous research conducted at the Grazinglands Research Laboratory documented the potential to improve stocker lamb preference of cool season forages harvested in the afternoon as compared to in the morning. Most improvement was observed in 'Jose' tall wheatgrass and 'Triumph' tall fescue hays as compared to 'Luna' pubescent wheatgrass and 'Paiute' orchardgrass hays. This preference is influenced by the increase in plant sugars, which occurs over the course of a day. Harvesting forages later in the day captures soluble carbohydrate changes, which may result in a hay having the potential to increase stocker intake and weight gain. Because warm season grasses have a different carbon metabolism during photosynthesis than cool season grasses, it is not known how harvesting warm season forages at different times of the day impacts stocker preference and performance.

OBJECTIVE

The objective of the research was to determine the effect of harvest time on the nutrient composition of Old World bluestem, a mixture of native prairie grasses, and Bermudagrass grown in the southern Great Plains.

RESULTS

In preparation for summer harvest, established stands of Old World bluestem and native prairie forage were burned in spring 2001. Old World bluestem was fertilized with 70 lbs N/acre. Old World bluestem was cut for hay at

0630, 1230, and 1830 (2 ac per harvest time) on June 12. Samples were collected from swath rows at the time of harvest on June 12 and at the time of baling on June 18. Random clip samples were taken from an adjacent unharvested area at 0630, 0930, 1230, 1530, 1830, and 2130 on June 12, and at 0030, 0330, and 0630 on June 13. At each time, the sample was divided into representative subsamples. One part was oven-dried to determine field dry matter content, and three (clip and swath) or four (bale) subsamples were freeze-dried.

A similar protocol was followed for native prairie grasses, which was cut on July 9 and 10 and baled on July 12. The native prairie pasture was composed primarily of big bluestem, little bluestem, Indiangrass, and switchgrass. Minor forages included sideoats grama, tall dropseed, annual sunflower, Canadian rye, sedge, sensitive briar, mare's tail, bull nettle, milkweed, ragweed, scribners panicum, and gammagrass. Field dry matter content was determined from one subsample. Four clipped, swathed, and baled subsamples were freeze-dried from each collection time.

Freeze-dried subsamples were finely ground and analyzed for organic matter, neutral detergent fiber (NDF), acid detergent fiber (ADF), and crude protein contents. Organic matter is made up of the percentage of dry matter determined in the laboratory corrected for the inorganic material called ash (soil contaminants and minerals). Fiber procedures remove the readily digestible cell contents. The NDF content is composed of the more (hemicellulose) and less (cellulose and lignin) digestible cell wall components, whereas ADF contains only cellulose and lignin. *In vitro* organic matter digestibility was determined as an initial indicator of nutrient availability to the animal.

Chemical composition of clipped (average), swathed, and baled samples for Old World bluestem are presented in Table 1. Time of harvest did not change ($P \geq 0.07$) crude protein and NDF contents. The change in organic matter digestibility of clipped samples over time ($P < 0.02$) was due to the lower digestibility value found for the sample taken at 1530 as compared to other times (Fig. 1). This finding will be further investigated when Old World bluestem is harvested again in summer 2002. It is unlikely that changes over time detected for the organic matter content of clipped samples ($P < 0.02$) would affect palatability, due to the narrow range (86.1 to 87.7%) observed (data not shown).

In native prairie forage, the ADF in clipped samples varied ($P < 0.02$) over the course of the day (Fig. 2). Results suggest afternoon (> 1230 samples had lower levels of less digestible cell wall components. *In vitro* organic matter digestibilities also varied over time for clipped samples ($P < 0.01$; Fig. 1) and for samples collected at baling ($P < 0.05$; Table 2). Some variation in forage nutrients may be expected

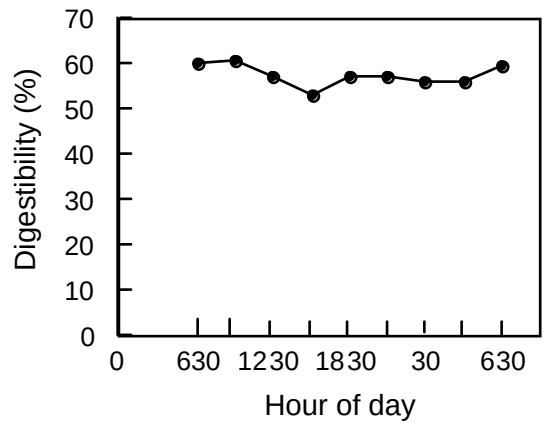


Fig. 1. *In vitro* organic matter digestibility of Old World Bluestem from June 12-13, 2001.une 12-13, 2001.

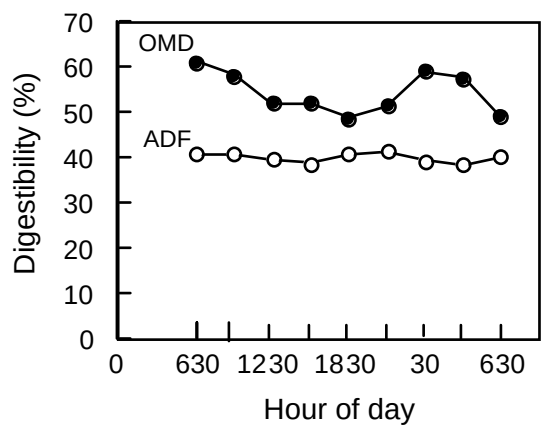


Fig. 2. Acid detergent fiber (ADF) and *in vitro* organic matter digestibility (OMD) of native prairie forage from July 9-10, 2001.

due to the difficulty of collecting a representative sample in native prairie pastures. However, the time of highest digesitibility for clipped (0630), swathed (0630), and baled samples (1230) were different. Results suggest both time of harvest and drying may have influenced *in vitro* organic matter digestibility. No other differences ($P \geq 0.05$) were found for nutrients analyzed in native prairie samples (Table 2).

Future analysis includes analyzing samples for sugar content. Bermudagrass will be sampled and cut for hay in summer 2002 due to poor stand establishment in summer 2001. The effects of harvest time of Old World bluestem, native prairie grasses, and Bermudagrass hays on stocker preference and performance will follow.

Table 1. Characterisitics of Old World bluestem clip (average), swath, and bale samples.

Sample	Time†	Field dry matter (DM)	Organic matter (OM)	Protein	NDF‡	OMD‡
		%	% of DM	---------- % of OM ----------		
Clip		32.8	86.9	8.4	75.7	57.7
SEM§		--	0.42	0.46	0.79	1.60
Swath	0630†	32.3	86.8	7.9	76.2	57.0
	1230	40.1	87.2	8.0	75.2	58.8
	1830	35.9	87.6	7.4	75.5	58.1
SEM		--	0.10	0.42	0.66	1.41
Bale	0630†	62.1	87.7	7.5	79.8	55.3
	1230	65.9	88.2	8.0	78.6	54.0
	1830	72.7	87.9	8.0	79.8	52.5
SEM		--	0.26	0.32	0.45	0.88

† Time forage was swathed in the field on June 12 and 13, 2001, and collected before being baled on June 18, 2001.

‡NDF, neutral detergent fiber; OMD, *in vitro* organic matter digestibility.

§SEM, standard error of the mean.

Table 2. Characterisitcs of native prairie forage clip (average), swath, and bale samples.

Sample	Time†	Field dry matter (DM)	Organic matter (OM)	Protein	NDF‡	OMD‡
		%	% of DM	---------- % of OM ----------		
Clip		38.3	88.3	6.82	73.9	54.5
SEM§		--	0.29	0.28	0.74	2.45
Swath	0630†	34.3	88.6	6.0	75.3	57.9
	1230	41.6	89.4	6.0	75.2	51.7
	1830	42.2	87.2	7.3	71.5	52.0
SEM		--	0.67	0.50	1.89	2.32
Bale	0630†	89.1	88.6	6.0	76.7	52.1[ab]
	1230	86.8	88.7	6.2	77.0	57.2[a]
	1830	88.4	89.2	6.0	75.1	47.7[b]
SEM		--	0.15	0.23	0.98	2.21

†Time forage was swathed in the field on June 12 and 13, 2001, and collected before being baled on June 18, 2001.
‡NDF, neutral detergent fiber; OMD, *in vitro* organic matter digestibility.
§SEM, standard error of the mean.
[ab]Values with different superscripts within a column are different ($P < 0.02$).

CHANGES IN DIGESTIBILITY AND SERUM MEASURES IN STEERS CONSUMING MIXED GRASSPEA HAY

Lisa A. Appeddu, Brian K. Northup, and Srinivas C. Rao

RATIONALE

Grasspea (*Lathyrus sativus*) is a warm season annual legume primarily grown for human grain consumption, as a cover crop, or fed as a forage to draft and dairy animals in areas outside North America (India, Africa, Asia, and the Middle East). It is also grown as a green manure crop in North America (Canada, North Dakota, and South Dakota). Over the past decade, grasspea has received increasing attention due to its ability to grow under arid conditions. It is also high in protein, a feed nutrient that is expensive in the United States and increasingly hard to acquire in many developing countries.

Despite its potential benefits, grasspea contains small amounts of neurotoxins in its mature seed. While this could cause problems if fed in large quantities to cattle over an extended period of time, new varieties of grasspea have been developed with lower levels of neurotoxin in the seed. Other antiquality factors in grasspea forage have not been reported except for phenols and tannins. It is not documented how feeding the new grasspea variety as a forage impacts intake, digestibility, and metabolism in growing cattle and sheep.

OBJECTIVE

The objective of this research was to initially evaluate the palatability, digestibility,

and metabolic effects of grasspea when steers were offered a mixed grasspea hay. Metabolic effects were evaluated by looking for large changes in blood metabolites, proteins, and enzymes outside of normal levels.

On average, steers consumed 26.9 lbs and 28.3 lbs of dry matter per day of the first and second round bale, respectively. No apparent palatability problems were observed, and grasspea was not sorted out of the hay. Organic matter digestibility (59 ± 2.5%) and fiber digestibility (54 ± 2.2%) did not significantly change over time ($P > 0.40$), whereas nitrogen digestibility fluctuated ($P < 0.01$) over collection dates (Fig. 1). While nitrogen digestibility measures can be affected by nitrogen recycling and secretions within the animal, the decline observed on July 12 coincided with the time when steers were finishing the first hay bale. This may have affected their ability to "select" plants from the bale as high in nitrogen quality as during the previous collection dates. A similar decline was not observed on the last collection date, when steers were still able to consume the second bale for 5 more days. It is most important to note that no consistent declines in digestibilities were detected, which would be expected if hay antiquality factors interfered with rumen function and digestive processes.

Table 1. Chemical composition of grasspea (whole plant) and mixed grasspea hay.

Forage source	Field dry matter (DM)	Organic matter (OM)	ADF†	Nitrogen	*In vitro* digestibility
	%	% of DM	----------	% of OM	----------
Grasspea	14.6	77.4	30.1	4.9	82.5
Mixed grasspea hay	81.4	81.3	41.2	2.5	65.8

†Acid detergent fiber.

RESULTS

Grasspea was planted March 20, 2001 with minimum tillage in an area traditionally used to grow winter wheat. Phosphorus (40 lbs per acre) and potassium (20 lbs per acre) were broadcast applied prior to seeding. Annual warm season grasses (foxtail, barnyard grass, goose grass, crabgrass, and Johnsongrass) grew among the grasspea plants. The area was swathed on June 7, 2001 and two round bales composed of approximately 30% grasspea were made. At this time, the grasspea plant had reached growth stages ranging from late flowering to having pods with immature seed. The chemical composition of the fresh grasspea plant and mixed grasspea hay are presented in Table 1.

Two mature Holstein steers (average 1526 lbs) were penned and group-fed the mixed grasspea hay. Prior to this, steers had been grazing a similar mixture of grasses that did not contain grasspea. Initial fecal and blood samples were collected on June 20, 2001. Steers were sampled on June 28, July 6, July 12, July 18, July 25, and August 2. Steers finished consuming hay by August 7. Grasspea plant, hay, and fecal samples were dried, ground, and analyzed for organic matter, acid detergent fiber, and nitrogen. Indigestible acid detergent fiber was used as an internal marker to calculate apparent nutrient digestibilities. Serum was harvested from blood samples and frozen until sent to Spectra-Lab, Inc. (Oklahoma City) for analysis.

Average values and the biological role of blood metabolites, proteins, and enzymes are reported in Table 2. Except for low calcium and phosphorus, blood values were within the normal range expected for cattle. A low calcium and phosphorus status can be corrected with a mineral supplement in growing stockers and producing cows. Creatine kinase increased (100 vs 122 U/L; $P < 0.01$) but remained within the normal range after the initial collection date as compared to the average value determined while steers consumed the mixed grasspea hay. Other serum values did not change over time ($P \geq 0.06$) and were within levels expected for cattle. These initial results suggest adding grasspea to a forage diet does not negatively affect

palatability, decrease nutrient digestion, or alter metabolism. Future research will investigate the intake and growth rate of stockers fed grasspea to determine its potential as an annual pasture or hay source in the southern Great Plains.

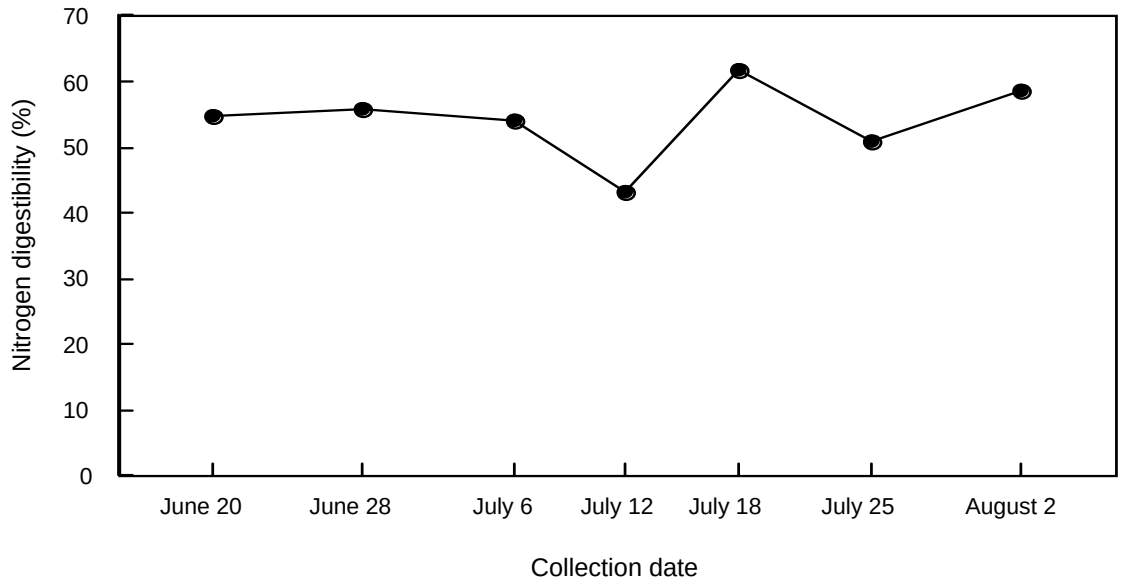


Fig. 1. Nitrogen digestibility of mixed grasspea hay in steers.

Table 2. Average blood analysis of steers fed mixed grasspea hay.

Blood factor	Biological meaning	Average	Normal range†
Metabolite			
Glucose (mg/dL)	Energy status/regulation	70 ± 2.3	44 to 78
Urea nitrogen (mg/dL)	Feed or body protein breakdown	19 ± 1.0	5 to 30
Creatinine (mg/dL)	Kidney function	1.4 ± .04	1.0 to 2.0
Cholesterol (mg/dL)	Energy status	82 ± 4.2	80 to 120
Sodium (mmol/L)	Electrolyte balance	139 ± 1.0	132 to 152
Potassium (mmol/L)	Electrolyte balance	4.6 ± 0.08	3.9 to 5.8
Chloride (mmol/L)	Electrolyte balance	101 ± 0.8	97 to 111
Magnesium (mEq/L)	Mineral status	2.0 ± 0.06	1.8 to 2.3
Calcium (mg/dL)	Mineral status	8.9 ± 0.17	9.7 to 12.4
Phosphate (mg/dL)	Mineral status	3.2 ± 0.21	5.6 to 6.5
Protein (g/dL)			
Albumin	Dehydration or protein status	3.1 ± 0.01	2.8 to 3.6
Globulin	Elevated in immune response	2.8 ± 0.11	3.2 to 5
Total protein	Water, electrolyte, protein balance	6.0 ± 0.09	5.8 to 7.5
Enzyme (IU/L)			
Alkaline phosphatase	Released in liver damage	33 ± 3.0	27 to 107
Lactate dehydrogenase	Liver, heart, muscle damage	880 ± 51	839 to 1283
Aspartate aminotransferase	General tissue breakdown	55 ± 1.9	43 to 132
Glutamyl transferase	Released in liver/bile disorders	25 ± 1.4	6 to 39
Creatine kinase	Released in muscle breakdown	120 ± 6.0	56 to 409

†Spectra-Lab, Inc. (Oklahoma City)

MODELING DAILY PRECIPITATION OF SEASONAL FORECASTS

Jurgen D. Garbrecht, Jeanne Schneider, and John Zhang

RATIONALE

Farming and ranching in Oklahoma are subject to seasonal climate and weather variations that result in year-to-year forage and crop yield variations. The unpredictable character and size of seasonal climate and weather variations have resulted in an inflexible agricultural system with few planning options and a reactive management approach. Over the last two decades the scientific understanding of the atmospheric system, teleconnections such as the El Nino-Southern Oscillation (ENSO), global climate change, and climate predictability has greatly increased. This improved understanding of the global ocean-atmosphere-land system has led to the development of seasonal climate forecasts up to 12 months into the future. These advances provide opportunities for agriculture to incorporate climate forecasts into planning and management decisions, and consequently to move away from a reactive management style towards a proactive and flexible management approach. However, the forecasts are provided at seasonal time scales, while daily time scales matter most for agricultural applications. It is daily precipitation that affects surface runoff, soil moisture availability, and land productivity. Hence, identification of daily precipitation values associated with the seasonal forecasts is required to uncover, through computer modeling of crop yields and environmental impacts, opportunities for adaptation and diversification, to determine risk at the planning level and in management decision making, and to assist the farmer and rancher to move towards a more profitable and environmentally friendly production.

OBJECTIVES

Downscale seasonal forecasts for farm and field applications, and develop a computer program that generates daily precipitation that is representative of seasonal precipitation forecasts and that can be used with traditional crop yield and natural resources models.

METHODS

This work will build on previous weather generators developed by the Agricultural Research Service (ARS) for crop productivity modeling. Elements of those weather generators will be used, validated, improved, and assembled with new components to account for the forecasts on a month-by-month basis. The format of current ARS weather generators is not suited for this task. The computer program that is developed by this project will consider changes in the amount of daily precipitation and number of precipitation days associated with the forecasts. Improvements in the estimation of extreme precipitation events will also be investigated.

EXPECTED BENEFITS

This “forecasted daily weather” will be used with crop yield and natural resources models to demonstrate how and to what degree farmers and ranchers can benefit from the seasonal forecasts. The work will investigate the potential for diversification and increased profitability under favorable seasonal forecasts, suggest mitigation needs under unfavorable seasonal forecasts, and determine risk associated with the uncertainty of the forecasts.

NOAA'S CLIMATE PRECIPITATION FORECASTS: DOWNSCALING TO FIELD SCALES

Jeanne M. Schneider and Jurgen D. Garbrecht

RATIONALE

Long range experimental seasonal precipitation forecasts are being issued by the National Oceanic and Atmospheric Administration (see earlier article "NOAA's Climate Precipitation Forecasts: Initial Assessment of Utility for Agricultural Applications"). Unfortunately, the forecasts are statements about the probability of total average precipitation occurring over large areas (about 35,000 square miles) during 3 month periods. In many regions, historical precipitation varies considerably within these large areas. In Oklahoma, for example, there is a typically a strong gradient from wetter conditions in the southeast to drier conditions in the northwest. This means that an average total may not have much relevance to any single location within that area. Further, since computer model predictions of crop yields use daily precipitation, a 3 month probability prediction of total precipitation is of limited use in such applications. Methods need to be developed to correctly transfer the information in the precipitation forecasts to field and daily scales. Research on the first step, downscaling the area forecast to a specific location, is outlined in this report.

METHODS

The forecast quantity that can be downscaled is the probability anomaly, the difference between the division Normal curve (representing area average conditions over the previous 30 years) and the forecast curve. The forecast anomaly from the division forecast can be added to a curve representing conditions at a single location over the previous 30 years (the location Normal) to produce a local forecast.

Downscaling can be done graphically or numerically. Here we provide a graphical example (Figures 1 through 4). In this hypothetical situation, the location Normal (the gray curve) has about the same average value as the forecast division Normal, but has a significantly different slope over the wet half of the distribution (Figure 1). This means that the location has received more heavy precipitation events than the division average over the previous 30 years.

The first step is to define the difference between the division forecast and the division Normal. A set of probability values is chosen; in this example, we use 10% increments between 10% and 90%, and the forecast anomaly is defined at each of these probabilities (the small black arrows in Figure 2). The forecast anomalies at 100% and 0% are zero by definition.

The second step is to add this set of probability anomalies to the location Normal at the matching probability points (Figure 3). A curve drawn through the set of new points is the downscaled location forecast (Figure 4). This downscaled forecast accurately reflects the predicted shift in probability relative to local historical precipitation.

EXPECTED BENEFITS

Downscaled forecasts will make it possible to use these experimental seasonal precipitation forecasts in decision support systems for specific locations. With the addition of methods to further downscale the forecasts to single months, the forecasts can also be used as input for specialized weather generators to generate predictions of daily precipitation for computer modeling of crop yields (see "Modeling Daily Precipitation of Seasonal Forecasts").

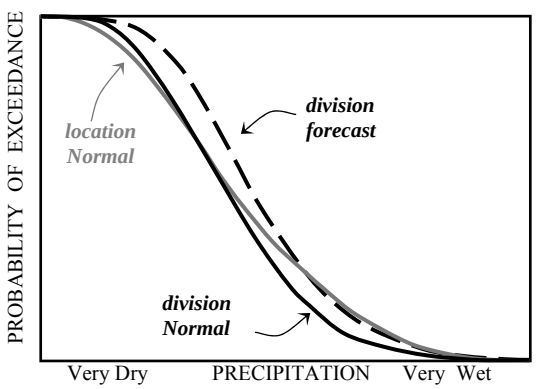


Fig. 1. Sketch of forecast and division and local Normals.

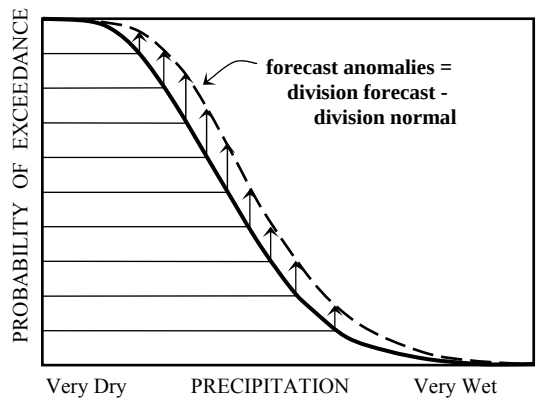


Fig. 2. Subtraction to get forecast anomalies.

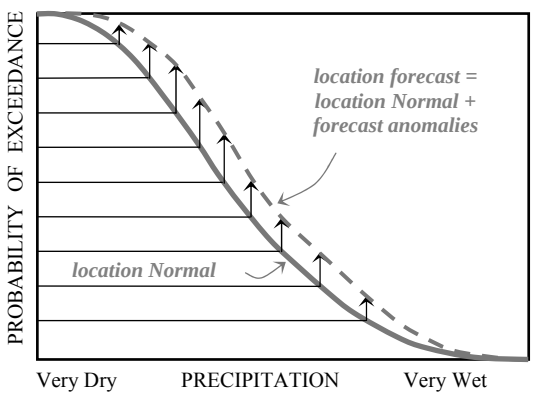


Fig. 3. Addition of forecast anomalies to location Normal.

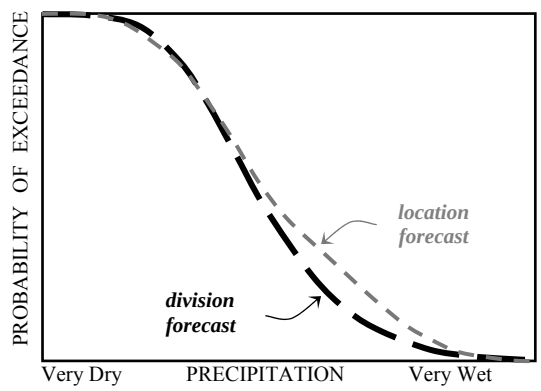


Fig. 4. Downscaled location forecast compared to original division forecast.

MITIGATION OF LIVESTOCK EFFLUENTS BY SURFACE IMPOUNDMENTS

John A. Daniel

RATIONALE

Public concern over agriculture's impact on water quality has prompted the formulation of regulations to restrict and reduce nutrient movement in surface water and prevent environmental damage. Some of these environmental problems are caused by increased phosphorus in surface runoff from confined animal feeding operations (CAFO's), which lead to water impairment, lake eutrophification and fish kills. Such problems are difficult to treat and costly to rectify. In addition, the livestock industry is concerned that environmental regulations and restrictions for water quality imposed on CAFO's will be

expanded to include grazed pastures and other agricultural lands. In order to address this problem, a study was started to compare phosphorus levels of successive surface impoundments within two small grazed watersheds with different combinations of land management applied to pasture and cultivated land.

METHODS

Two mixed land-use agricultural watersheds located at the USDA-ARS Grazinglands Research Laboratory (GRL) were used in this study. Both sites are typical of agricultural land-use and are representative of the tall grass prairie region of Southern Great Plains. The upper end of each watershed lies outside the boundary of the GRL and directly drains as stream channels (inlets) situated on the GRL. Four successive surface impoundments lie within the drainage of each watershed. Both watersheds are mixed land-use of grazed rangeland and winter-wheat, with one watersehd containing a dairy operation in the headwaters. An impoundment that is situated on a tributary of the dairy watershed but separate from the primary drainage impacted by the dairy operation was used as a control.

Beginning in January 2001, water samples were collected monthly from the surface impoundments on both watersheds. Samples were also collected at the point where the stream channels enter the GRL portion of the watershed to represent the phosphorus contribution from the respective upstream agricultural management practices. Samples were analyzed for water-soluble phosphorus (WSP) and bioavailable phosphorus (BAP) because these nutrients are largely responsible for lake eutrophication.

RESULTS

Concentrations of water-soluble phosphorus (WSP) were greater for impoundments in the dairy watershed than for the grazed watershed as can be seen by the general observation of Figure 1. The Y-axes scale of diagrams in Figure 1 are equivalent to allow the comparison in WSP magnitude between the two watersheds. WSP concentrations, in most instances, decreased downstream of the dairy operation with each successive impoundment. For example, for January 2001, WSP levels for the dairy watershed dropped from 569 ppb (parts per billion) at the inlet to 163 ppb at the first impoundment, to 81 ppb at the second, 33 ppb at the third and 12 ppb at the fourth impoundment. This dropped the phosphorus levels to less than 40 ppb, the EPA limit. An increase in WSP levels was found late in the spring and summer (Figure 1) probably due to the low water levels and movement in the drainages. The concentrations of WSP in the impoundments from the grazed watershed were much lower than the dairy watershed.

Bioavailable phosphorus (BAP) concentrations were greater for the impoundments in the dairy watershed than for the grazed watershed, but the relation between impoundment location and BAP concentration was not well defined. The Y-axes scale of diagrams in Figure 2 are equivalent to allow the comparison in BAP levels for the two watersheds. When sampling first began, the upstream sites (the inlet, impoundment 1, and impoundment 2) had concentrations of 34, 48, and 18 ppb, respectively, while BAP levels downstream at impoundment 3 decreased to 6 ppb. As the summer progressed, BAP concentrations for the grazed watershed increased to levels equivalent to the dairy watershed. However, different relationships were found for the grazed watershed compared to the dairy watershed. For the grazed watershed, the concentration of BAP in a sample was not related to the downstream order of the impoundments (1, 2, 3, etc.). BAP distributions for the dairy watershed, on the other hand showed that during the period of surface runoff in the late winter and early spring, upstream impoundments had greater BAP concentrations and decrease downstream. These results suggest that the surface impoundments are partially successful in restricting the downstream movement of BAP.

Preliminary results of nutrient movement in these watersheds suggest that water quality was impacted by the dairy operation more than the grazed agricultural watershed. Bioavailable and water-soluble

phosphorus concentrations were greater in the watershed associated with the dairy operation and above the recommended target goal of 40 ppb established by the EPA. However, surface impoundments downstream of the dairy operation mitigated some of the impacts of bioavailable and water-soluble phosphorus on water quality and may provide producers a low cost approach to reduce off-site effects of their production systems.

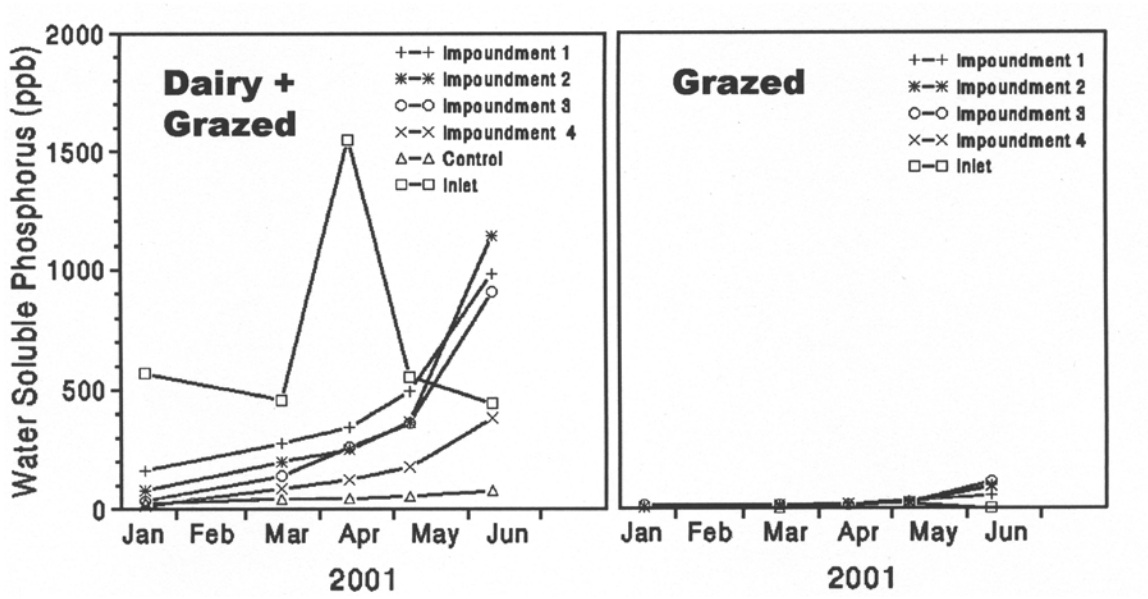


Fig. 1. Temporal distribution of water soluble phosphorus. Y-axes for both diagrams are equivalent for comparison purposes for the watersheds.

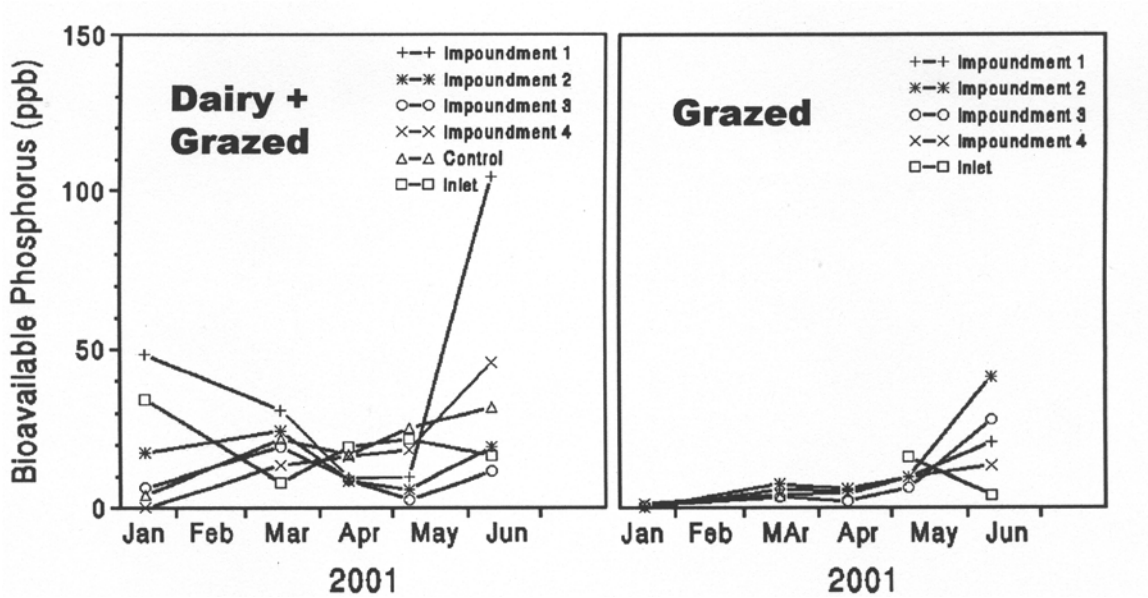


Fig. 2. Temporal distribution of bioavailable phosphorus. Y-axes for both diagrams are equivalent for comparison purposes for the watersheds.

CARBON SEQUESTRATION ON GRAZINGLANDS

Herman S. Mayeux, Jean L. Steiner and Patrick J. Starks

RATIONALE

Atmospheric concentrations of greenhouse gases have increased to levels which may alter Earth's climate. These greenhouse gases, especially carbon dioxide, are generated by combustion of fossil fuels, burning forests, and, to a smaller extent, by various agricultural activities. The rate at which greenhouse gases accumulate in the atmosphere may be reduced in two ways. We can reduce emissions by the energy, transportation and manufacturing industries. And we can remove carbon dioxide from the atmosphere by the process of photosynthesis and store it in vegetation and in soils as organic matter; this is called carbon sequestration.

Sequestering soil carbon on agricultural lands (crop and grazinglands) is a topic of considerable interest to both policy makers and land managers. Policy makers are interested because it creates a potential win-win situation whereby they can address national and international concerns about climate change, while also providing other environmental benefits. Agricultural land managers are interested because of possible carbon payments from either the government or private sector (e.g., utilities) and because increasing soil organic matter almost always enhances soil quality and tilth, nutrient and water holding capacity, and productivity.

Several years ago, Dr. Thanh H. Dao and other scientists working at our laboratory reported that shifting from conventional moldboard plowing to no-till wheat production increased soil organic carbon content. Organic carbon in the top few inches of soil increased by 65% after 11 years of no-till soil management. Smaller increases occurred at deeper in the soil. Similar studies are required to document the carbon sequestration potential of other practices, including those associated with production of forages and bioenergy/bioproduct crops.

OBJECTIVES

The overall goal of a series of studies is to document changes in amounts of organic carbon in rangeland, pasture and crop land soils subjected to different management practices, in order to determine potential rates and amounts of carbon sequestration in soils of the southern Great Plains. Emphasis is placed on monitoring changes in soil organic carbon associated with more sustainable forage and livestock production practices, compared to carbon contents in soils maintained under conventional management. In addition, measurements of carbon dioxide movement into native prairie vegetation and soils were begun in 2001 to determine how much carbon enters or leaves native pastures through the atmosphere each year in our geographic area, how management with fire and grazing affects the amounts of carbon dioxide that enter prairie vegetation and soils, and to compare results obtained with two kinds of equipment commonly used to continuously measure carbon dioxide fluxes.

METHODS

Examples of situations in which changes in soil carbon contents will be monitored are given below. In each case, soils will be sampled periodically with a 2- or 3-inch diameter tubular probe on a truck-mounted hydraulic coring device to a depth of at least 3 feet, and organic carbon contents determined at appropriate depth increments by analysis in the laboratory.

Soil carbon contents will be documented on a field where soil organic matter has been depleted by decades of wheat production under conventional tillage that is being converted into a study of the persistence and productivity of perennial cool-season grasses. The forage and livestock production aspects of that study are described elsewhere in this publication. Five-acre pastures planted to "Jose" tall wheatgrass, "Manska" intermediate wheatgrass, "Lincoln" smooth brome, or maintained in wheat will be fertilized at three different nitrogen levels and subjected to two levels of grazing intensity for a period of

several years. Soils will be sampled in each pasture periodically to determine management impacts on changes in soil organic carbon.

Congress directed in the 2002 appropriations bill that the Grazinglands Research Laboratory will participate with ARS laboratories in other regions in a coordinated national research effort to develop biomass production systems that can be combined with conservation plantings to reduce negative impacts of agriculture on the environment while diversifying farm income and reducing the Nation's dependence on imported energy. Changes in soil organic mater will be documented where annual crops are grown on marginal soils to produce biomass, bioenergy, and bioproduct crops, and where perennial grasses are established as buffers, on CRP lands, and in other conservation contexts. These conservation plantings will be managed in such a way that they also provide harvested plant biomass to be used as feedstocks for bioenergy and bioproducts. This project will also be coordinated with on-going research on biofuels production conducted by colleagues in the Department of Biosystems and Agricultural Engineering, Department of Plant and Soil Sciences, and others at Oklahoma State University.

Beginning last year, with assistance from the ARS National Program Staff and Dr. William A. Dugas of the Texas Agricultural Experiment Station at Temple, TX, the laboratory obtained and began operating two sophisticated systems of meteorological and other sensors which continuously measure and record the net rate of movement (flux) of carbon dioxide into and out of vegetation. One system uses the Bowen ratio/energy balance approach to provide the information necessary to calculate the carbon dioxide fluxes. The Bowen ratio systems have been used at Woodward, OK, and nine other ARS research facilities located across the central and western U.S. to compare carbon dioxide fluxes on rangelands, the ARS Rangeland CO_2 Flux Network. The other system, called eddy covariance, is typical of the units used by another network which mostly measures carbon dioxide fluxes in forests, the AmeriFlux Network. Operating the two measurement systems at the same site will allow us to determine whether the fluxes determined by the rangeland and forest networks are the same or different. If the fluxes are different, we will determine why the units do not provide the same results, and how to account for any difference. The purpose of the comparison is to ensure that we can directly compare grasslands and forests in terms of the significance of their roles in the global carbon cycle. In addition, because the annual net flux of carbon dioxide is a good measure of whether land lost or sequestered organic carbon, the studies will allow us to compare carbon sequestration rates in forests and grasslands.

The carbon dioxide fluxes are being measured on a native prairie pasture which has not been burned for many years. Little research has been conducted on the value of prescribed burning as a management practice for enhancing carbon sequestration, and the results are conflicting. After we have established the flux rates in the absence of burning, which may require several years, we will initiate a schedule of periodic burning and continue the measurements to determine whether the higher productivity of burned prairie increases rates of carbon sequestration. Interacting effects of burning and grazing on carbon sequestration will be explored in the same manner.

EXPECTED BENEFITS

Both policy makers and land managers require science-based information in order to develop policies and select practices that enhance carbon sequestration in agricultural systems. We know that many conservation practices increase organic carbon content in the soil, but we lack sufficient information to determine how much carbon could be sequestered in southern Great Plains agricultural systems by modifying management and changing land uses.

THE UTILITY OF INTRODUCED PERENNIAL COOL-SEASON GRASSES IN STOCKER PRODUCTION SYSTEMS OF THE SOUTHERN GREAT PLAINS

Brian K. Northup, William A. Phillips, and Herman S. Mayeux

RATIONALE

No single forage in the Southern Great Plains can supply stocker cattle with year-round feed. Current grazing systems rely on summer pastures of introduced or native warm-season grasses, and wheat in the fall, winter, and spring (Fig.1). This two-component system has several production problems. Depending on how wheat is managed, gaps in availability of quality forage occur at different times, mostly between mid-March and mid-June when warm-season grasses are not available. In addition, green forage is limited in September through November, because quality of warm-season grasses is poor and wheat pasture is not ready. Finally, moving stockers among different forages can decrease animal performance and increase production costs, because animals need time to adjust to new forages.

Winter wheat can be used as a dual-purpose forage and grain crop. It is an attractive alternative to grazing or grain-only systems, but has its own problems related to management. When used as a dual-purpose crop, wheat requires additional N fertilizer, and should be planted earlier (mid-September) and at a greater density. Significant problems with the use of wheat as forage are the uncertainty of fall grazing, late turn-on date, and declining forage quality during a relatively short period of grazing in the spring. Perennial cool-season grasses (CSG) could partially fill the gaps in the two-component forage system (Fig.1). In the fall they can take advantage of stored soil water and begin growth earlier than wheat, reduce uncertainties about early forage availability, and produce green forage for a longer time in the spring (Fig. 2). However, they are not entirely adapted to the southern Great Plains. Hot summers, dry conditions, and occasional severe winters can combine to reduce their persistence and productivity.

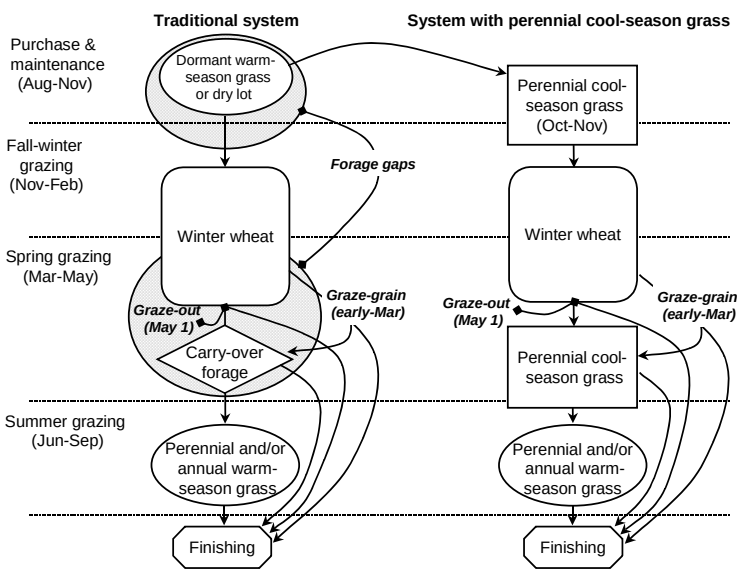


Fig. 1. Traditional stocker production system and the traditional system modified to include perennial cool-season grass.

The ability of perennial CSG to support the production of stocker cattle alone or in combination with wheat and other forages is not fully understood. Small-plot research at our laboratory indicated that hay produced by eight species of CSG varied in protein content and amount over their growing season (Fig. 2). Protein contents were similar to wheat and levels of production approximated wheat, but took a longer period of time to reach maximum level of green forage. Persistence in response to climate and

management also varied; some species survived over 10 years, while other did not persist past five years. If properly managed, such grasses could produce forage for a longer time in the spring, and provide early-fall forage to help condition stocker cattle for grazing wheat pasture. A systems-level study must be used to determine if perennial cool-season grasses used in the southern Great Plains will act in concert with other forages, and forage management systems, to increase weight gains by stocker cattle and profits for the producer.

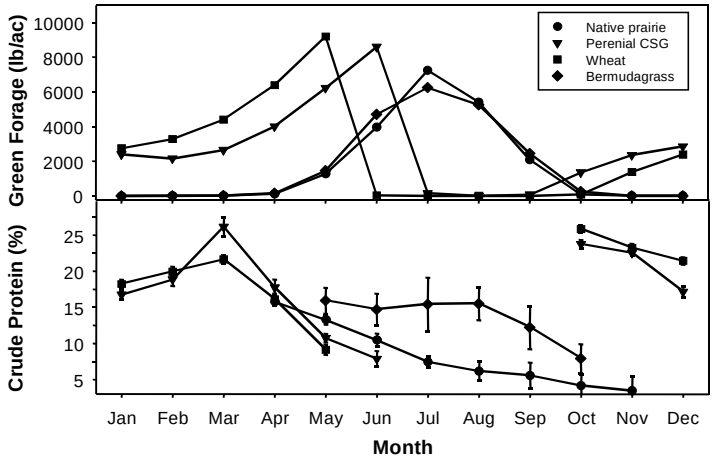


Fig. 2. Available green forage (top) and protein content of native prairie, perennial cool-season grasses (CSG), wheat, and bermudagrass grown in central Oklahoma.

METHODS

Experiments will be conducted during 2002-2007 to examine the function of perennial CSG in integrated forage-livestock production systems in Oklahoma. Each year, a group of genetically similar stocker cattle (to reduce confounding related to animal responses) will be divided into three sets of animals prior to fall grazing. During fall and spring grazing, these animals will be assigned to pastures planted to one of three perennial grass species ('Lincoln' smooth brome, 'Jose' tall wheatgrass, and 'Manska' pubescent intermediate wheatgrass) or wheat, under one of three levels of N fertilization above a fall application of 40 lb/ac (no additional fertilizer, 40 lb/ac, and 80 lb/ac), noted as low, medium and high input. The groups of cattle will be grazed on wheat during winter and other carry-over forages as needed during late spring (Fig.1). Thereafter, the sets of cattle (as per the three levels of fertilizer input) will be sorted and assigned to one of three production paths that end in finishing the animals on high grain diets. After the cool-season grazing period, one-third of the animals from each grass and fertilizer level will be directly shipped to a conventional feedlot for finishing. The remaining two-thirds will be retained for summer grazing and managed in an intensive-early stocking system (twice the normal stocking rate) on introduced warm-season grass for the first half of the summer, under the fertilizer level they were originally assigned to. After summer grazing, one-half of each set will be assigned to either conventional feedlot finishing or provided access to a high grain diet while still on pasture. Data pertaining to the adaptation of cattle to the forages (gain, forage utilization, effective stocking rates) will be collected. Quantity and quality of forage will be measured at key times to describe potential hay production in lieu of grazing cattle, and grain production will be determined on ungrazed exclosures within the wheat pastures. Input costs of different combinations of cool- and warm-season grasses, fertilizer management, and finishing systems will be collected, and potential returns from livestock, forage or grain sales calculated.

EXPECTED BENEFITS

These data will be used to produce economic analyses of the traditional two-component system and the traditional system modified to include perennial CSG. The analyses will provide an assessment of risks and potential outcomes for different grain, forage and livestock production scenarios.

PERSISTENCE AND SUSTAINABILITY OF INTRODUCED PERENNIAL COOL-SEASON GRASSES IN THE SOUTHERN GREAT PLAINS IN RESPONSE TO MANAGEMENT

Brian K. Northup, William A. Phillips, Charles T. MacKown, Herman S. Mayeux, Jean L. Steiner, Lisa A. Appeddu, John A. Daniel, and Patrick J. Starks

RATIONALE

The southern Great Plains is a diverse region, characterized by high variability in precipitation, temperature, and evapo-transpiration, all of which place stresses on forage plants. Winter wheat is a key component of the traditional forage-livestock production system used to grow stocker calves in the region. It serves as the primary forage from late-fall through spring, and is used for grain production in certain situations. Replacing wheat with perennial cool-season grass may be a viable alternative for producers in the region, to reduce risks and feed costs. With proper management they could play important roles in the production of stocker cattle. Perennial cool-season grasses can provide forage earlier in the fall than winter wheat, and generate forage for a longer period in the spring to fill the forage gap between wheat and warm-season grasses. However, constraints presented by the environment of the region, and a shortage of information on sustainable forage management and animal responses, are serious drawbacks to the use of perennial cool-season grasses. Some perennial cool-season grasses are not well suited to the climate of the region, and grazing pressure may negatively affect species that do persist under climatic extremes. The capacity of perennial cool-season grasses to function in stocker production systems in the region must be evaluated with multi-disciplinary studies, to examine plant, animal and soil responses to management. This study tests hypotheses related to the effects of soil type, nitrogen fertilization, and grazing pressure on: (1) persistence of introduced cool-season grasses; (2) stocker cattle adaptation to forages and gain; (3) nitrogen use and mobilization by plants; (4) soil carbon sequestration; (5) nitrate movement within the soil; and (6) the capacity of remote sensing to predict amount and quality of cool-season forage.

METHODS

Perennial cool-season grass and wheat pastures were established in September 2001 on an area formerly farmed to continuous winter wheat for over 30 years. Fifteen-acre fields of four different grasses (Fig.1) were planted on each of three different soil types (sandy loam, silt loam, and areas with mixtures of sandy and silt loam soils). Grasses included winter wheat (as a control), 'Lincoln' smooth brome, 'Jose' tall wheatgrass, and 'Manska' pubescent intermediate wheatgrass. These perennial grasses have been used throughout the Great Plains, and vary in their palatability to cattle and persistence to grazing and climate. Each 15-acre field will be subdivided into 5-acre pastures that receive different levels of N fertilization (0, 40, and 80 lbs/acre) above a fall application of 40 lbs/acre, and be grazed by stocker cattle beginning in the fall of year 2002. The perennial pastures will be grazed to attain 65% use of current forage growth each year, to apply the stress required to identify persistent grasses. Additional effects of grazing pressure will be created with fenced exclosures used to attain no grazing and 33% utilization of growth. An initial set of experiments will be conducted on these pastures over a 5-year span, beginning in 2002, to describe responses of different components of the grazing system.

Experiments:

1. *Persistence of introduced perennial cool-season grasses.* Densities and frequencies of occurrence of the different grass species will be measured to determine effects of N fertilizer and grazing pressure on stand persistence.
2. *Stocker cattle response to perennial cool-season grasses*. Changes in body weight of stocker calves as they adapt to the different forages will be monitored during the fall, winter, and spring grazing periods and as they are shifted between wheat and perennial grass pastures.
3. *Nitrogen use and mobilization by introduced cool-season grasses.* Effects of N fertilization and grazing on root reserves available to initiate plant regrowth will be examined, and levels of various forms of soluble N in forages will be described at different times during the fall grazing period.
4. *Effects of cool-season grasses and their management on soil condition*. Soil cores will be collected at different times to a depth of 5.0 ft in ungrazed exclosures and grazed parts of pastures receiving high and low fertilizer levels. These cores will be analyzed to define changes in carbon content within the soil profile in response to grass species, fertilization and grazing.
5. *Effects of grass species and management on nitrate movement in the soil profile.* Nitrate levels in soil water under selected pastures of perennial cool-season grasses, receiving different levels of N fertilizer, will be monitored.
6. *Remote sensing of forage production and quality.* From the start of spring growth to summer decline, remotely sensed (with hand-held systems) and clipping data will be collected within wheat and perennial grass pastures to develop tools for the rapid prediction of productivity and forage quality.

EXPECTED BENEFITS

Information generated by these studies will be used to test how stands of the different grasses were affected by fertilizer management and grazing pressure, and how the management components affected the animal-plant-soil interface of the grazing system. The experiments will ultimately help describe the value of introduced perennial cool-season grasses to producers in the southern Great Plains.

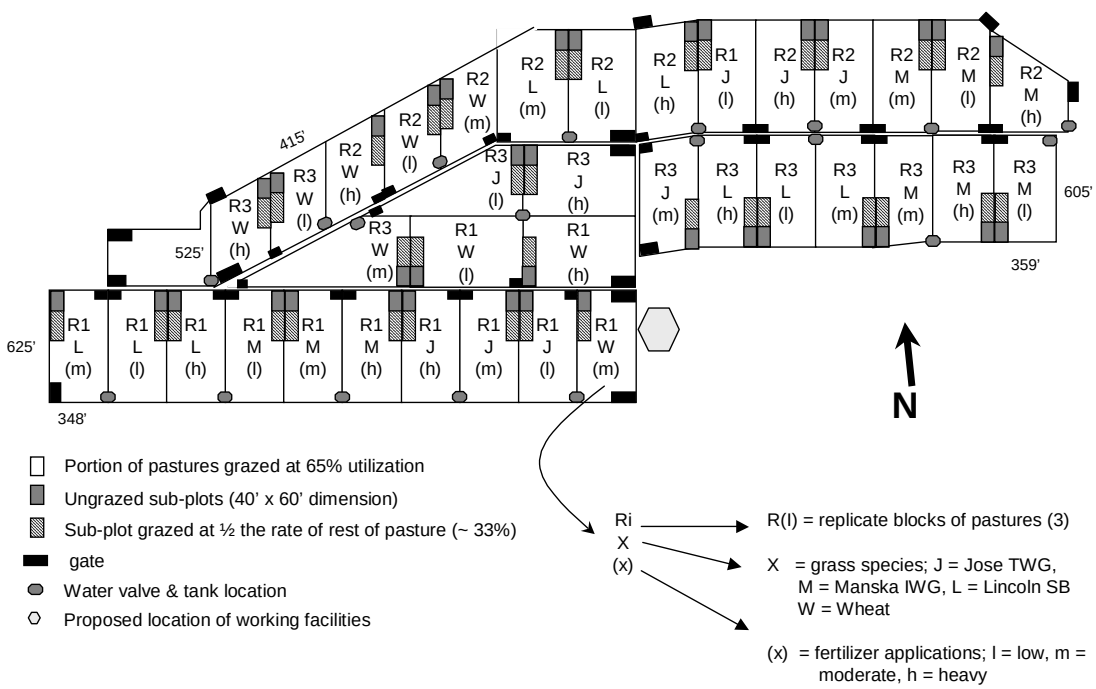


Fig. 1. Layout of study area and pasture design for grazing experiments on perennial cool-season grasses.

IS THERE ENOUGH SOIL MOISTURE FOR GROWING A SUMMER CROP?

John Zhang, Srinivas C. Rao, and Patrick J. Starks

RATIONALE

High quality wheat forage for stocker livestock is often lacking from September to November due to limited wheat growth. This potential forage deficit combined with low quality of warm-season grasses during this period can limit the profitability of stocker livestock enterprises in the Southern Great Plains. Summer crops such as sorghum or legumes, grown either for silage or grain production, are an option for filling in the fall forage gap. Unfortunately, summer crops cannot be grown each year due to the low and variable precipitation in the area. However, due to large year-to-year precipitation variation, there are some years when precipitation is sufficient to grow a summer crop without adversely impacting winter wheat production. To make informed decisions on when and what to grow in the summer, water requirements of certain crops as well as future precipitation distribution must be known. The National Oceanic and Atmospheric Administration issues seasonal climate forecasts for the continental US. Assuming that seasonal climate forecasts will becomes reliable and dependable for agricultural application, information on soil water use and water demand of certain summer crops is definitely needed for making summer cropping decisions.

OBJECTIVE

The objectives of this study are to determine the effects of two legume crops on changes in soil moisture during the growing season and their impact on availability of soil water for subsequent winter wheat production. In addition, water use efficiency and crop productivity of the two crops will be measured.

METHODS

The study is being conducted in field plots on the Agronomy Farm at the Grazinglands Research Laboratory. The treatments include control (annual winter wheat-summer fallow), deep-rooted Pigeon Pea (winter wheat-summer Pigeon Pea), and shallow-rooted 'Chinese Red' Cowpea (winter wheat-summer Cowpea). Soil samples and intact soil cores will be taken from various locations to characterize basic soil properties. Particle size distribution, saturated hydraulic conductivity, and soil moisture-water potential relationship will be determined in the laboratory.

Soil moisture is measured by a Time Domain Reflectometry probe, and soil water potential by 1-bar tensiometers. Soil moisture is monitored at three locations for each treatment on a weekly basis and at the 4, 12, 20, 28, 36, and 44 inches depths at each location. Additional soil moisture measurements following large storms will also be made. Daily precipitation is recorded with an electronic rain gauge. The above ground biomass of the two legumes and winter wheat is measured at various development stages. Soil water uptake by crops will be approximated by changes in soil moisture between measurements.

EXPECTED BENEFITS

The outcome of this research will be an increased understanding of how the two summer legumes (deep- and shallow-rooted pea species), compared with summer fallow, affect the soil water balance and the relationships between available soil moisture levels and plant growth performance of the two legumes and winter wheat. This information will be useful for making management decisions on whether a

summer crop should be grown for more efficient use of soil water and greater crop and forage productivity for a given climate forecast. Data can also be used to estimate shallow ground water recharge rates through deep percolation. Shallow ground water reserves could be critical for the survival of deep-rooted annual plant species during a prolonged dry period.

GRASSPEA - A NEW GRAIN LEGUME FOR THE SOUTHERN GREAT PLAINS

Srinivas C. Rao, William A. Phillips, and Brain K. Northup

RATIONALE

A primary goal of grazing-based forage production systems is to provide high quality forage year-round and to reduce the costs of using harvested stored or purchased feeds. The primary forage resources for livestock production in the southern Great Plains are winter wheat and warm-season perennial grasses (Bermudagrass, native prairie, and Old World bluestem). Wheat pasture is available for grazing from November to mid-March if a grain crop is harvested or late April to early-May, if no grain crop is desired. The second major forage resource is warm-season grasses, which are grazed from June through August. The standard grazing system in the southern Great Plains has voids during two critical times of the year. One is in the early fall (August to November) when quality and quantity of warm-season perennial grasses are declining and winter wheat is not yet ready for grazing. The second is in late spring and early-summer (May to June) when the quality of wheat declines rapidly and warm-season perennial grasses are not available for grazing. There is a need to find new plant species that can fill the late spring and early summer forage gap with dependable, high quality forage that will enhance a sustainable forage-livestock production system in the southern Great plains region. Among the grain legumes, Grasspea (*Lathyrus sativus*, also known as Chickling vetch) has been observed for its tolerance to dry conditions and its adaptability to difficult environmental conditions. It has been widely used in East Africa and India as both forage and feed crop. Mature grasspea seed contains a small amount of neurotoxins and may cause problems if fed in large quantities to grazing animals over an extended period. Over the past decade, this crop has received increased interest as a green manure crop and is adapted to such arid environments as the Great Plains, Canada, and South Dakota. Grasspea forage and seed contains high levels of proteins, a component that is increasingly becoming hard to acquire in many developing countries. A preliminary trail conducted at the Grazinglands Research Laboratory indicated that quality of grasspea forage was exceptionally high in crude protein (30 %) at early pod development stage (see Appedu et al, in this publication). However, its adaptability and forage production patterns in the southern Great Plains region is not known, as is its acceptability to grazing animals.

METHODS

A series of experiments will be conducted over the next three years to determine management strategies, forage production patterns and nutritive value of grasspea. Grasspea will be seeded replicated plots in existing bermudagrass and tall grass native prairie plots in the mid-March and mid-August of each year. No nitrogen fertilizer will be applied to plots seeded with grasspea. Another set of replicated control plots without grasspea will be fertilized with 0, 40 or 80 lbs of nitrogen per acre in one application. All plots will receive 60 lbs. of phosphorous per acre. Grasspea seeds will be inoculated and seeded in rows spaced of 2 feet apart. Whole grasspea samples will be collected every 2 weeks beginning 30 days after seeding and the samples will be dried and ground for chemical analysis. In the month of

June and July grasspea samples along with bermudagrass and tall grass native prairie will be collected to determine the contribution of grasspea nitrogen to the companion grasses.

A second experiment similar to that described above will be conducted using conventional tillage methods to determine the performance of grasspea as a sole crop. The conventional tillage plots will be monitored to determine the contribution of grasspea nitrogen to the soil.

EXPECTED BENEFITS

This research will generate information about the availability and quality of forage for filling forage deficit periods and contribute to the sustainability of forage production systems by replacing inorganic nitrogen fertilizers

OVERSEEDING COOL-SEASON GRASSES AND WARM-SEASON LEGUMES INTO UNIMPROVED WARM-SEASON PASTURE

Paul W. Bartholomew and Robert D. Williams

RATIONALE

A survey undertaken by the Langston University Grasslands Center of Excellence in 1999 showed that because of limited forage production small and resource-poor livestock producers in Oklahoma may have to use purchased hay or feed concentrate for their livestock for up to 5 months of the year. For these small farmers, shortfalls in forage availability during the cool season and in late summer are primary contributors to low farm income, through direct effects on livestock performance or through inflation of production costs as a result of expenditures on supplementary feed.

Small and resource-poor farming systems present particular problems for development of more productive forage cropping methods, because approaches acceptable for larger and better capitalized enterprises may not be appropriate for small livestock producers. For example; since many small producers are part-time farmers, forage production systems need to be adapted to low management input. Small livestock farmers frequently do not have easy access to field equipment and therefore face problems in growing forages that require annual planting. This would limit the possible use of productive cool or warm-season annual crops to increase forage production and increases the importance of persistence in productive forages. A lack of hay-making equipment on small farms also places greater importance on grazing for harvesting of forage and means that increased forage output through an extended growing season, with a more even seasonal distribution of production, is likely to be more valuable than an increase in warm-season surplus. Such considerations dictate the type of forage production system that is likely to be appropriate for small and resource-poor farmers. Because unimproved natural pasture systems are productive for only a few months in spring and summer, the need for improved seasonal distribution of forage production is most likely to be met by development of sequences or mixtures of crops that can grow at different times of the year. In low-input systems it is important that the components of forage mixtures or sequences are persistent and that their growing seasons are compatible, to minimize the need for reseeding and to avoid permanent changes in pasture composition as a result of competition between different species. Work with cool- and warm-season grass sequences has generally used improved species in each season. Although such combinations may be productive, their overlapping seasonal growth patterns require careful management in order to minimize the effects of competition between species during changes of season. The integration of cool-

season grasses or warm-season legume in sequence with unimproved natural pasture has received little research attention, but the combination in sequence of species of contrasting seasonal growth pattern may provide improved output above natural warm-season pasture, without a need for significantly increased management input.

METHODS

The effects on forage productivity and species persistence of sequences of cool-season grass, warm-season legume and degraded or unimproved natural pasture will be measured with six species of cool-season grass and three species of warm-season legumes. Cool season forage production treatments consist of no oversowing and oversowing with six cool season grass species: tall fescue (*Festuca arandinacea)*, Italian ryegrass (*Lolium multifloram)*, tall wheatgrass (*Elytrigia elongata*), smooth brome (*Bromus inermis*), intermediate wheatgrass (*Elytrigia intermedia*), and a creeping wheatgrass-bluebunch wheatgrass (*E. repens* x *Pseudoroegneria spicata*) hybrid. These cool season forages will be oversown on ground previously cropped with three warm season legumes [Korean lespedeza (*Lespedeza stipulacea*), Verano stylo, (*Stylosanthes hamata*), or butterfly pea (*Clitoria ternatea*)] and on dormant unimproved natural pasture or on ground clean tilled from unimproved natural pasture.

Cool-season grasses were oversown in fall of 2001 with a no-till seeder into the trimmed stubble of warm-season legumes or natural pasture, or drilled directly into cultivated soil on clean-till treatments. The seed rates used follow standard recommendations (fescue and ryegrass sown at 28 $lb.ac^{-1}$, brome and wheatgrasses at 15 $lb.ac^{-1}$. Warm-season legumes will be oversown in early April of 2002, to ensure legume growth during the summer. The pasture will be managed to encourage self-seeding of the warm season legumes and there will be no further overseeding after early April 2002. Lespedeza, stylo, and butterfly pea will be sown at 30, 6 and 20 $lb.ac^{-1}$, respectively.

Legume seed will be scarified and inoculated according to standard recommendations for each crop. A spring nitrogen application of 50 $lb.ac^{-1}$ will be made in February, to stimulate cool-season grass production. Forage productivity of the various sequences will be estimated by harvests taken at 6-week intervals starting in late March and continuing to the end of November in each year of this 3-year experiment. We will measure the contribution of cool-season grass, warm-season legume and warm-season grass to yield at each harvest and will compare the persistence of grass and legume components in the different crop sequences.

EXPECTED BENEFITS

Results from this study will identify forage sequences that extend the productive grazing period of unimproved or degraded natural pastures and are adapted to limited-resource and low-input farming systems. The results will allow us to examine the trade-off between establishment of cool-season grasses on clean-tilled land, which may accelerate establishment and fall growth, but through destruction of warm-season pasture may reduce output of summer forage. The focus of the work on low-input approaches to year-round grazing will contribute to development of economically and environmentally sustainable forage systems appropriate for resource-limited livestock producers, or for those who wish to operate low-input livestock production enterprises.

FORAGE PERFORMANCE OF WINTER WHEAT POPULATIONS SELECTED FROM GRAIN-ONLY AND DUAL-PURPOSE ENVIRONMENTS

Charles T. MacKown, Brett F. Carver, and Eugene G. Krenzer, Jr.

RATIONALE

Winter wheat is the foundation of agricultural enterprises in the southern Great Plains. Depending on the producer's goals and market conditions, wheat crops are managed for grain-only, full season forage-only, and as a dual-purpose crop that is grazed by stocker calves until appearance of the first hollow stem (jointing) followed by grain production. Nearly 8 million acres of wheat are grazed each year in the southern Great Plains. As much as two-thirds of the Oklahoma wheat acreage may be planted as a dual-purpose crop. Traditionally, wheat breeders in the southern Great Plains have selected new hard red winter wheat varieties based on performance in a grain-only production environment rather than a dual-purpose or a full season forage-only production environment. Because of genotype by production environment interactions, cultivar development based solely on selections in a grain-only production environment may compromise gains in genetic improvement of desirable traits for wheat used in dual-purpose production.

OBJECTIVE

The effects of grain-only and dual-purpose production environments on fall forage traits of selected winter wheat populations will be measured to assess the benefit of tailoring wheat breeding programs for dual-purpose wheat.

METHODS

In the greenhouse F1 hybrids were created using parents consisting of released and experimental winter wheat genotypes. Seed from these crosses were increased in the greenhouse and used for population bulk selections from grain-only (GO) and dual-purpose (DP) production environments. Recommended management practices were used for these production environments. In the fall of 2001 two separate nurseries of breeding materials were evaluated. The nurseries contained 24 triplicate sets (i.e., 24 unique pedigrees) of sub-populations, in which each set originated from the same F2 source. Each set was represented by a non-selected F3 bulk population, an F5 bulk population selected only in a GO environment since the F2, and an F5 bulk population selected only in a DP environment since the F2. In addition, three check cultivars (2174, Jagger, and Custer) were evaluated. The populations and checks were planted 10 September 2001 at Oklahoma State University's Marshall Wheat Pasture Center located 35 miles east of Stillwater, OK. Dual-purpose wheat was planted earlier and at a seeding rate greater than that of GO wheat. Additional nitrogen (N) was applied to DP wheat to account for N removal in forage consumed by livestock that grazed the DP wheat until the appearance of first hollow-stem. Management practices recommended for DP wheat were used. Each entry was replicated three times in randomized complete block experiments. Entries were planted in plots about 10 ft in length with five rows spaced about 9 inches apart. Between 5 to 8 November 2001, about one week before grazing began, forage samples were clipped for measurement of dry weight, total N, and nitrate-N concentrations. From an interior row in each plot three 1.6 ft lengths of row were hand clipped to a height of about 2 inches. Samples were oven dried at 140°F and weighed. Samples will be ground for N analyses.

EXPECTED BENEFITS

This research should reveal if the effects of a DP selection environment have an impact on fall forage traits of winter wheat breeding material. This is important, because direct selection in both GO and DP environments requires additional resources that may not be justified if genetic improvement of wheat for DP is not enhanced. Preliminary analyses of the forage dry weights from the two nurseries indicate that the effect of production system used to make selections was significant at probability levels of 0.093 and 0.068. We believe that even at these levels of significance, there will be a benefit to using DP selection pressure to develop superior DP genotypes.

COMPARISON OF LABORATORY AND QUICK-TEST METHODS FOR FORAGE NITRATE

Charles T. MacKown

RATIONALE

Forages containing greater than 1000 ppm nitrate-N (dry weight basis) can pose a risk for cattle. Nitrate in the forage is converted to nitrite by rumen microorganisms. Nitrite absorbed into the blood stream inhibits the oxygen transporting capacity of red blood cells by oxidizing the ferrous iron of hemoglobin to ferric iron (methemoglobin). Both animal (rumen microflora, animal age and condition, environmental stresses) and plant factors (nutrient management, species, growth stage, environmental stresses, nonstructural carbohydrate level) affect nitrate risk for livestock.

Typically, tissue nitrate levels of cool-season grass increase with increasing amounts of nitrogen (N) fertilizer applied. The primary cool-season forage used by stocker livestock producers in the southern Great Plains is winter wheat. In many cases, producers grow wheat as a dual-purpose crop for both forage and grain. Dual-purpose winter wheat diversifies farming choices and may reduce economic risks, but requires its own set of management practices to assure success. Dual-purpose and graze-out wheat is planted earlier than grain-only wheat and receives additional N fertilizer to assure early fall growth and account for N removal in consumed forage. Published research by Oklahoma State University scientist Bill Raun and Robert Westerman demonstrated that wheat fertilized with 0 to 150 lbs N/acre had leaf nitrate-N values that ranged from 99 to 7960 ppm.

Nitrate in plant tissue is water-soluble and is most often extracted from samples that have been oven dried and finely ground. In some cases, fresh tissues are pressed to release sap for nitrate analyses; less often, fresh field samples are extracted directly for nitrate. Relating nitrate in tissue of fresh plant samples to that of dried samples requires measurement of the water content of the plant sample. Once the tissue extract is obtained, the analysis for nitrate should not be delayed unless the extract is preserved to prevent changes in nitrate concentration as a consequence of microbial activity. There are many methods available for quantifying nitrate in extracts. The most popular and sensitive methods are those that convert nitrate to nitrite followed by a chemical reaction to form a colored complex. The intensity of the color is directly related to the amount of nitrate and is measured using instruments that detect differences in absorption (spectrophotometer) or reflectance of light at a specific wavelength. The other common method is detection of nitrate using an instrument equipped with an ion electrode specific for nitrate. Some of the methods have been adapted for field quick-test of water and plant samples using small hand held instruments, others are being developed for this application and should allow a farm consultant or

producer to rapidly perform their own field test of a forage for nitrate. Before acceptance though, research will be required to demonstrate the accuracy and user friendliness of the quick-test methods.

OBJECTIVE

The objective of this research is to compare a standard laboratory nitrate assay protocol to a novel biochemical linked laboratory and field-test method, and two quick-test methods that use small hand held instruments. In addition, the accuracy of a nitrate field-extraction method suitable for wheat pasture samples will be evaluated and compared with standard laboratory extraction of oven dried and ground wheat samples.

METHODS

Winter wheat forage samples were collected from plots in a wheat field that were fertilized with N to provide a range of tissue nitrate levels. Wheat plants were cut to a height of about 2 inches in early April, about 3 weeks past the date when cattle would have been removed from dual-purpose wheat. Tissue was cut into pieces less than 0.5 inch and divided into tissue that would be immediately extracted (fresh) or oven-dried at 140°F and finely ground for later extraction. The oven-dried tissue was weighed before and after drying to measure water content. Fresh tissue was macerated in 5% propyl alchohol at room temperature using a hand held high speed (11,600 rpm) electric blender. Oven-dried and ground tissue was extracted with hot (208°F) water in a screw-cap test tube.

Extracted nitrate was analyzed using a standard laboratory and selected hand held instrument quick-test methods. Characteristics of the methods are listed in Table 1. Samples were diluted with deionized water to fall within the nitrate assay range of each method.

Table 1. Laboratory and quick-test methods and measurement ranges used to assay nitrate in tissue extracts.

Method	Nitrate detection principle	Range
		ppm NO_3^--N
Laboratory		
FIA (flow injection analyzer)	Cu-Cd column conversion of nitrate to nitrite with color reaction and absorbance measurement	0.01 – 2.0
NaR (microplate nitrate test kit)†	Enzyme conversion of nitrate to nitrite with color reaction and absorbance measurement using microplate	1 - 10
Quick-test		
ISE (compact ion meter)	Ion specific electrode	14 - 1400
TSR (test-strip reflectance)	Test strip chemical conversion of nitrate to nitrite with color reaction and reflectrometry measurement	1.1 – 50.8
FN-NaR (field nitrate test kit)†	Enzyme conversion of nitrate to nitrite with color reaction and visual rating or absorbance measurement	1 - 10

†Kits developed and marketed by The Nitrate Elimination Company, Inc., Lake Linden, MI.

The protocol for extracting nitrate from fresh tissue resulted in values strongly correlated (FIA method, $r^2 = 0.95$, $P < 0.001$; NaR method $r^2 = 0.99$, $P < 0.001$) to those extracted from dry tissue. Using the FIA method, fresh tissue nitrate (expressed on a dry weight basis) was about 12% greater than that of dry tissue, while fresh tissue nitrate was nearly 30% less than the nitrate in dry tissue extracts using the NaR microplate nitrate test kit. The apparent discrepancy in extraction efficiencies may be related to substances in the extracts that have interference effects specific for each nitrate assay method. Additional laboratory study will be required to identify and eliminate these possible interferences. Overall,

preliminary data analysis indicates good agreement among the two laboratory methods and the TSR and FN-NaR quick-tests. The ISE method, however, often overestimated nitrate concentrations. Additional experiments will be undertaken with new prototypes of the FN-NaR test kit that handles a wider range of nitrate concentrations.

EXPECTED BENEFITS

This research should provide information required for reliable and accurate quick-tests of nitrate in forage and hay samples. Recommendations for sample extraction and method of analysis will be developed that allow farm consultants and producers to easily evaluate potential nitrate risks of feed for livestock.

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