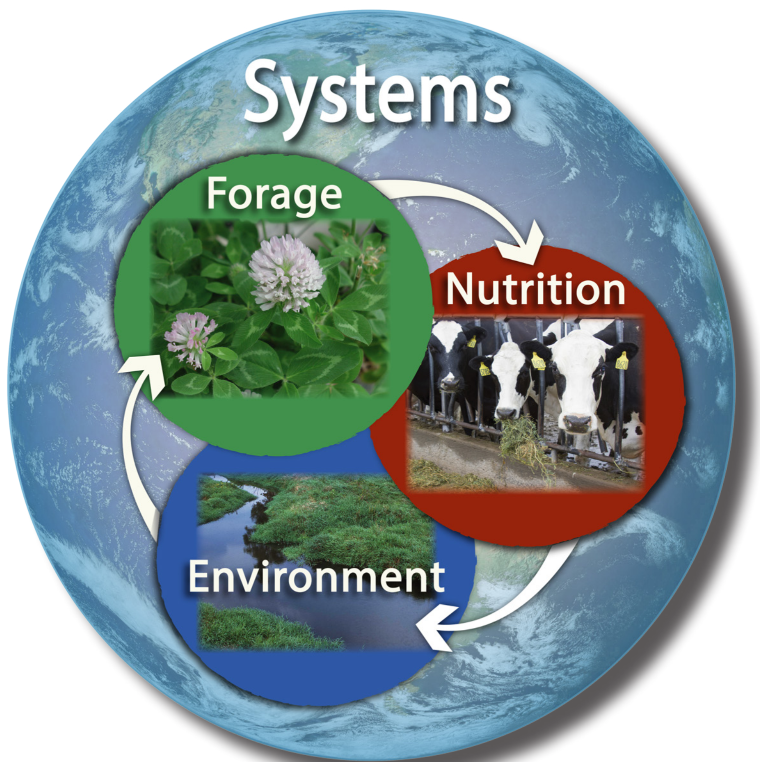
United States Department of Agriculture

U.S. Dairy Forage Research Center

In the News



December 2016 to March 2017

Nitrogen Fertilization, Interseeding Alfalfa, Rumen Microbes & Production Efficiency, Pastures Producing More Milk

Scientists from the U.S. Dairy Forage Research Center

With a multidisciplinary team of 20 scientists, the U.S. Dairy Forage Research Center (USDFRC) in both Madison and Marshfield, WI, is working on a variety of studies to improve the economic and environmental sustainability of dairy forage systems. Here is an update of four projects.

N Fertilization for Improved Forage Yields Has Little Impact on Nutritive Value – *Wayne Coblentz, Marshfield, WI*

Applications of soil amendments or fertilizers containing nitrogen are a routine part of most grass forage management strategies, with the primary goal of improving forage yields. But an increase in yield is usually accompanied by a decrease in nutritive value. In order to better evaluate this tradeoff, we evaluated the effects of nitrogen fertilization on the nutritive value of a single cultivar (ForagePlus) of fall-grown oat fertilized at planting with six different rates of urea (nitrogen) or two rates of dairy slurry.

Concentrations of fiber components increased consistently with nitrogen fertilization, while water-soluble carbohydrates (sugars) exhibited the opposite response. Overall, the forage nutritive value of fall-grown oat declined mildly in response to nitrogen fertilization, but these responses were not nearly strong enough to offset the advantages obtained by improved forage yields. This study provides forage farmers with the knowledge that fertilizing for improved yields will not greatly reduce the nutritive value of fall-grown oat forage fed to dairy cattle.

Workable Corn-Interseeded Alfalfa Production Systems Would Have Many Benefits – *John Grabber, Madison, WI*

According to recent agricultural statistics, alfalfa was planted on 0.44 million acres and harvested from 2.2 million acres, and silage corn was planted and harvested from 1.0 million acres per year in Wisconsin. Because both crops are often grown in rotation, alfalfa could be interseeded at corn planting to serve as a dual-purpose crop for providing groundcover during silage corn production and forage during subsequent growing seasons.

Unfortunately, this system has been unworkable because competition between the co-planted crops often leads to stand failure of interseeded alfalfa. At the USDFRC, we are conducting a long-term research project to develop a system that works on the farm. Earlier studies demonstrated properly timed foliar applications of a plant growth inhibitor on appropriate alfalfa varieties could increase plant survival of interseeded alfalfa by up to 400%. When successfully established, the average dry matter yield of interseeded alfalfa the following year was two-fold greater than conventionally spring-seeded alfalfa.

Preliminary economic analyses suggest using interseeding in place of conventional spring seeding for alfalfa establishment could improve net returns of first year alfalfa by about $100/ac. Other studies revealed interseeded alfalfa reduced fall and spring runoff of water and phosphorus by 60% and soil erosion by 80% compared to cropland containing only silage corn residues and weeds. These improvements in crop yields, profitability, and soil and water conservation are powerful incentives for continuing research to develop reliable and workable corn-interseeded alfalfa production systems for use on farms.

Rumen Bacterial Community Affects Milk Production Efficiency – *Paul Weimer, Madison, WI*

Improving the milk production efficiency of dairy cows is essential to both the profitability and environmental sustainability of dairy farms. Cows differing in milk production efficiency are known to have different rumen microbial communities, but a direct role of the microbial community in dictating efficiency is lacking.

In this collaborative study (USDFRC and University of Wisconsin), we demonstrated that near-total exchange of rumen contents between pairs of cows differing in milk production efficiency resulted in a temporary change in their efficiency to more closely resemble the donor cow before gradually returning to the milk production efficiency of the host cow over a period of approximately one week. Likewise, the composition of the bacterial community reverted to that of the host cow over about the same time period.

These results provide the first direct evidence that milk production efficiency can be altered, at least transiently, by substitution of the rumen bacterial community from a cow of different milk production efficiency. Future experiments will attempt to establish "high-efficiency" communities in cows by early-stage (birth through weaning) inoculations of rumen contents into calves, using rumen contents from high-efficiency cows. If successful, this strategy may be useful to dairy farmers as a facile means of improving the profitability and environmental sustainability of their herds.

Milk Production of Grazing Cows Most Highly Associated with Pasture Legumes & Grazing Height – *Geoffrey Brink, Madison, WI*

Organic dairies may have lower milk production as a result of poor pasture production. This collaborative study (USDFRC and University of Wisconsin), determined pasture management factors associated with potential milk production on 20 Midwestern organic dairies.

At each farm, two pastures considered either productive or unproductive were sampled before grazing for species composition, productivity, and nutritive value in June and September. Soil samples and management information were collected in October. Potential milk production was calculated based on forage productivity, nutritional value, and anticipated consumption by grazing cows.

Higher milk production is most highly associated with 1) proportion of improved legumes in the pasture and 2) making sure cattle do not graze shorter than 4″.

We found higher milk production of grazing cows was most highly associated with 1) proportion of improved legumes such as red clover and alfalfa, which have greater nutritional value than other pasture species, and 2) making sure cattle do not graze the pasture shorter than 4″, which ensures rapid regrowth by grasses after grazing. Conversely, lower milk production was negatively associated with the proportion of unimproved grasses such as Kentucky bluegrass, which have lower productivity and nutritional value.

Legumes improve forage quality and reduce nitrogen inputs in a pasture-based system.

Applying manure impacts pasture yield, composition

by Geoff Brink

GRAZING-based livestock producers frequently overseed cool-season grass pastures with legumes such as red clover, white clover, or alfalfa to increase forage quality, improve the seasonal distribution of forage production, and reduce the need for supplemental nitrogen (N). However, solid manure collected from bedded packs or liquid manure collected in pits must also be utilized on the farm, and nutrients contained in manure will improve pasture productivity.

The effects of applying manure to grass-legume pastures and the subsequent effects on legume persistence should be carefully considered because the forage quality benefits imparted by legumes may be more important than a boost in pasture productivity attributed to the manure. Determining how manure type, date of application, and pasture management influence pasture productivity and legume persistence will provide management guidelines for utilizing manure efficiently and maintaining legumes in rotationally-grazed pastures.

Liquid versus solid

Several factors influence how a mixed, cool-season pasture responds to manure application. The N in solid manure is primarily in nitrate form because much of the ammonia has been lost as a gas during storage. Conversely, the N in liquid manure is primarily in the ammonia form, which can be lost during application, particularly if the air temperature is high. An advantage of liquid manure is that it can enter the soil relatively quickly, potentially reducing N losses. An advantage of solid manure is its relatively slow rate of decomposition, which makes the N available to plants over a longer time period.

Plants can absorb N in either the nitrate or ammonia form, but typically take up nitrate-N more readily than ammonia-N. Grasses absorb N more efficiently than legumes due to their fibrous root system, and they exhibit a more rapid growth response. The manner in which the pasture is managed after manure is applied may also influence legume growth and persistence; harvesting a pasture for hay may impose further competitive stress on the legume.

Given these factors, scientists at the U.S. Dairy Forage Research Center, USDA Agricultural Research Service, conducted experiments to determine the response of an orchardgrass-red clover mixture to manure type and application date, and to pasture management. Orchardgrass was overseeded

Manure source	Application date	Management
None		Graze at vegetative stage
Solid manure	April	Graze at vegetative stage
Liquid manure	April	Graze at vegetative stage
None		Hay harvest; graze at vegetative stage
Liquid manure	April	Hay harvest; graze at vegetative stage
Solid	June	Graze at vegetative stage
Liquid	June	Graze at vegetative stage
Solid	August	Graze at vegetative stage

GEOFF BRINK

The author is a forage researcher with the USDA-ARS, U.S. Dairy Forage Research Center in Madison, Wis.

with red clover and clipped monthly the year before manure was applied. All treatments were supplied 60 pounds of N per acre except the None treatment (no N). Plots were grazed at the vegetative stage (three to four grass leaves) five times during the growing season, or harvested for hay (grass head emerged) in spring and then grazed at vegetative stage three times.

Higher productivity

The mean annual forage yield of an orchardgrass-red clover mixture grazed five times each year at vegetative stage and not fertilized with manure was 7,100 pounds of dry matter (DM) per acre. At the end of the grazing season, red clover was found in half of the rows in which it was seeded (50 percent stand). Applying either solid or liquid manure in April and grazing throughout the season enhanced annual forage yield by 500 pounds of DM per acre, a 7 percent improvement in productivity.

A red clover-orchardgrass mixture fertilized with solid or liquid manure in June or August produced 400 to 700 pounds of DM per acre less than a mixture receiving no manure. Whether manure was applied in April, June, or August, persistence of red clover that was grazed during the season at vegetative stage was reduced from a 50 percent stand (no manure applied) to a 30 to 45 percent stand. Mixtures receiving manure in the spring had greater annual yield due to greater grass growth, and mixtures receiving manure in mid- to late summer had lower annual yield due to a loss of clover.

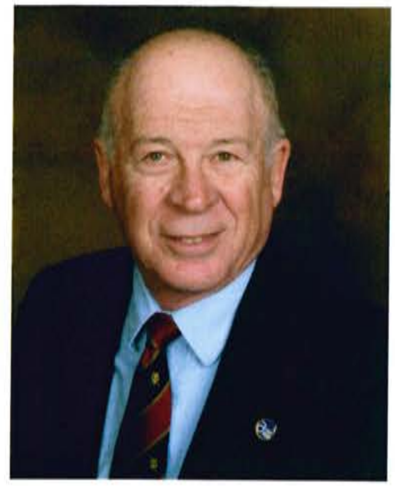
Legume persistence suffers

A red clover-orchardgrass mixture harvested for hay in the spring and grazed at vegetative stage the rest of the season was equally productive as that grazed at vegetative stage throughout the season (7,100 pounds of DM per acre). Delaying harvest in the spring to hay stage, however, reduced clover persistence from a 50 percent stand (no haying or manure) to a 40 percent stand. Applying liquid manure to the mixture and following the same harvest regime reduced annual yield by 300 pounds of DM per acre due to a further decline in red clover persistence (50 to 30 percent).

The results indicate that there is no difference between solid and liquid manure with respect to their effect on pasture growth and legume persistence: Applying manure in the spring to a grazed grass-legume mixture will improve annual productivity, but at the expense of legume persistence. Applying manure in mid- to late summer did not improve annual production and further reduced legume persistence.

Producing hay from grass-legume pastures has a detrimental effect on legume persistence, but persistence is further reduced when manure is applied. Since one of the primary benefits of adding legumes to pasture is improved forage nutritive value, don't apply manure to pastures with good legume stands, which is generally in the seeding year and the following year. ●

Orchardgrass-red clover plots at the U.S. Dairy Forage Research Center received eight different treatments in the study.



Neal Martin

A former Minnesota forage extension specialist and director of the U.S. Dairy Forage Research Center. He and his wife now operate an Ohio blueberry farm.

HFG: What experience or person was most instrumental in your decision to make the forage industry a lifelong career?

NM: Walter Wedin. Starting my master's degree at Iowa State University I wanted to become a soybean physiologist, but Walt was the only professor who would accept me. During a discussion about future direction and my career, he asked me what part of dairy farming and undergraduate studies at Ohio State I liked. My answer was forage crops. After completing my master's degree, Walt offered a three-quarter-time associate position, and I decided to pursue a joint Ph.D. program in agronomy and animal science with Walt and Richard Vetter.

HFG: During those years in Minnesota, it must have been enjoyable to work through a period when major changes were occurring in terms of alfalfa cutting schedules and forage testing. Tell us about that.

NM: I am blessed to have been able to work in Minnesota with a strong research team on campus, an interdisciplinary group of extension specialists, great county agents who welcomed field projects, and many innovative farmers. One of my first dairy meetings was with Mike Hutjens. I was fully armed with new data from Gordon Marten (three-cut schedules to maximize protein yield). On the way back to St. Paul, Mike said, "If you're going to continue doing dairy meetings, you have to get rid of that cutting study. Dairy farmers need to know how to reduce the fiber and enhance the energy from alfalfa."

From that point, I was driven to find a better answer, and several cutting schedule studies that were done in Minnesota helped me reach that end. We recognized that forage quality (relative feed value, at the time) dropped rapidly in those first two cuttings and that they needed to be cut early for high-energy feed.

Forage quality changes were more dynamic. Some highlights included serving on the 1978 Alfalfa Hay Quality Standards Committee, initiating the National Hay Testing Association, and receiving a USDA grant to partially support the purchase of a near-infrared reflectance spectroscopy (NIRS) testing van for Minnesota. The van project provided a tool for agents, farm advisers, industry reps, and farmers to enhance harvested forage quality and assess feeds before being fed. It also led to the initiation of quality-tested hay auctions in the state.

HFG: Compared to your Minnesota years, university extension and forage research positions have been drastically cut across the United States. Does this concern you?

NM: Since I started at the University of Minnesota, forage teaching and research faculty in the department of agronomy and plant genetics declined from four to one; USDA-ARS positions have experienced significant declines as well. The problem-solving programs we used in my days are now limited or nonexistent. At the same time, ruminant livestock and perennial forages are key elements to global sustainability in terms of land preservation and water quality.

HFG: Following your career in Minnesota, you accepted the director position at the U.S. Dairy Forage Research Center in Madison, Wis. How did your extension career make you a better research director?

NM: My Minnesota experience taught me that to solve problems there needed to be key people involved in the planning, execution, and dissemination of solutions. The U.S. Dairy Forage Research Center (USDFRC) had the ideal mission to implement this model. During my tenure as director, I started to incorporate industry collaboration and input from innovative farmers. Clive Holland, retired forage production manager from Pioneer-DuPont, helped establish an active USDFRC stakeholder committee to support development of multidisciplinary problem-solving research of national significance.

USDFRC scientists were interdisciplinary, but many disciplines were needed to solve forage production and dairy utilization problems. We were able to build needed discipline expertise and establish the Institute for Environmentally Integrated Dairy Management in Marshfield, Wis. Most of the new hires during the expansion of the USDFRC effort had a strong outreach component in their background, and I wanted to participate in outreach myself.

In each issue of *Hay & Forage Grower,* we talk to a forage industry newsmaker to get their answers on a variety of topics.

HFG: Does any accomplishment stand out while you were at the USDFRC?

NM: Consortium for Alfalfa Improvement. Redesigning alfalfa for dairy cattle needed an industry-public-private partnership. It was a pleasure working with Mark McCaslin from Forage Genetics International and Richard Dixon at the Noble Foundation to form the consortium. USDFRC scientist involvement within the team to improve forage digestibility (reduced lignin) and protein utilization (reduction of proteolysis and the addition of tannins) of alfalfa for dairy cattle was essential. Being part of the excitement of basic scientists developing gene silencing when proof of concept feeding trial results first appeared was second to none; more important will be farmer discovery.

HFG: Looking back on your career, where do you feel the forage industry has made its greatest advances that have translated to farm profitability?

NM: Application of NIRS to standardize, describe, and value forage quality needed by each livestock class.

HFG: Where do you feel there is still a significant forage knowledge gap that needs to be addressed?

NM: We need animal digestion data. We have used too much modeling based on outdated nutrition data to develop forage, feed, and supplement diets, especially for high-producing dairy cows. Using new knowledge related to digestive microbiology and rapidly changing animal genetics, it's time to research and rewrite our body of knowledge pertaining to animal nutrition. USDFRC is well positioned to do this.

HFG: What new forage technology is particularly exciting to you?

NM: It would have to be advances in harvest technology — leaf-strippers, in-line quality analysis on balers, and yield monitors on balers and choppers. We need equipment to enable better utilization of redesigned alfalfa. More important, we need to improve alfalfa yields. A state yield average of 3.0 to 3.5 tons per acre is shameful.

HFG: Has operating a blueberry farm in retirement taught you any new agricultural lessons?

NM: The necessity to make production decisions without having all detailed information has been huge for me. I have a greater appreciation for the time that's required to improve production. I am still learning after 13 seasons, and my respect for farmers and farming has been enhanced.

HFG: Favorite food?

NM: Yellow perch. •

Comparing Sudangrass & Sorghum-Sudangrass in the Field & in Dairy Cow Diets

Geoffrey Brink, Kenneth Kalscheur, Lori Bocher, U.S. Dairy Forage Research Center

One of the "big picture" goals at U.S. Dairy Forage Research Center (USDA Agricultural Research Service) is to increase the amount of forages in dairy cattle diets without affecting milk production or milk production efficiency. Potentially, there are many ways this could be accomplished, so the "big picture" must be built from several smaller pictures, including a better understanding of alternative forages and how they can be combined in rations to bring about the desired result.

Sudangrass and sorghum-sudangrass are alternative forages that use less water, are high in digestibility, and are already being grown in drier regions of the U.S. or as emergency forages. The USDFRC chose to study these grasses from an agronomic perspective and a dairy cattle diet perspective. Preliminary studies show sorghum-sudangrass performs better with a single harvest, and sudangrass performs better with multiple harvests, including grazing; and up to 10% of corn silage and alfalfa haylage in dairy cattle diets can be replaced with sudangrass silage with no detrimental effect on milk production. The following are brief summaries of this ongoing research.


Sudangrass harvest at the Prairie du Sac location.

In the Field

The objective of the agronomic study (Brink) was to compare yield and regrowth potential of brown mid-rib (BMR) sudangrass and BMR sorghum-sudangrass grown at two locations. At Prairie du Sac in south central Wisconsin, plots were seeded on June 6, 2016, and harvested on July 25 and September 19. At Marshfield in central Wisconsin, plots were seeded on June 8 and harvested on August 4 and October 6.

At the more southern location, forage production of sudangrass and sorghum-sudangrass was relatively equal for the first and second harvest period because the climate is conducive to growth of both warm-season grasses. At the more northern location, sorghum-sudangrass had higher yield potential than sudangrass for the first harvest period, but lower yield potential for the second harvest period. At the more southern location, both sudangrass and sorghum-sudangrass had a higher regrowth potential compared to the more northern location; regrowth will be better the farther south the crop is planted.

The USDFRC will be conducting a similar study in 2017. But the take-home message from this first year of data can be summarized as follows. If a farmer wants multiple harvests, as in a grazing system, sudangrass has higher yield potential because of its improved regrowth. But if a farmer wants maximum yield with a single harvest, such as when used as an emergency forage crop or as a replacement for corn silage, sorghum-sudangrass has higher yield potential.

In the Diet

The objective of the dietary study (Kalscheur) was to evaluate the replacement of corn silage and alfalfa haylage with increasing concentrations of sudangrass silage in the diets of lactating dairy cows. Sudangrass was chosen for the study because there is less research on it compared to sorghum-sudangrass and sorghum. A BMR sudangrass variety was chosen for the feeding trial because of its higher digestibility.

In the study, 48 Holstein cows in mid-lactation were assigned to treatments in a randomized complete block design. Diets were formulated to contain 40% corn silage, 20% alfalfa haylage, and 40% concentrate. Sudangrass silage was included in experimental diets at 0, 10, 20, and 30% of the diet dry matter (Table 1). Proportionally, sudangrass silage replaced two parts corn silage and one part alfalfa haylage. All other ingredients (e.g., high-moisture corn, canola meal, roasted soybeans, soyhulls, minerals and vitamins) were included equally for all diets, and crude protein levels were similar for all diets.

Table 1. Experimental sudangrass silage diets.

	Percent sudangrass silage in the diet			
	0%	10%	20%	30%
DMI, lb/day	62.4	57.8	57.1	55.3
Milk, lb/day	95.0	94.8	88.2	86.4
ECM, lb/day	99.0	100.8	93.5	90.0
ECM/DMI*	1.60	1.74	1.65	1.63

*Measure of feed efficiency

As expected, dry matter intake (DMI) decreased linearly as sudangrass silage replaced corn silage and alfalfa silage. Similarly, milk production decreased from 95 lbs/day for cows fed 0% sudangrass silage to 86 lbs/day for cows fed 30% sudangrass silage. However, even though DMI decreased from the 0% sudangrass ration to the 10% ration, pounds of milk produced stayed nearly the same (95.0 and 94.8 lbs/day), and energy corrected milk (ECM) increased slightly (99.0 and 100.8 lbs/day).

Feed efficiency, defined as ECM/DMI, was not affected by changes in forage because milk production changes and DMI changes were the same. While it was expected increased digestibility of the BMR sudangrass silage (compared to regular sudangrass) would benefit the dairy cow, it is possible the increased fiber in the sudangrass diets limited intake, resulting in a linear decrease in milk production.

◄ Research Updates continued from page 18

WISCONSIN-Utility of Alfalfa Stemlage for Feeding Dairy Heifers

Huawei Su, Matt Akins, Nancy Esser, University of Wisconsin; Wayne Coblentz, Robin Ogden, Ken Kalscheur, Ron Hatfield, U.S. Dairy Forage Research Center

Dairy heifers are typically offered high-forage diets to control weight gains; however, forage-based diets often contain significant portions of corn silage or other high-quality forages with low fiber content. Inadequate dietary fiber can lead to greater feed and energy intakes, causing excessive weight gains (>1.8-2.2 lbs/day) and overconditioning, especially for pregnant heifers having higher potential intakes but relatively low energy needs. For farmers with confinement housing, and reduced weather and mud exposure, overconditioning can be further complicated by limited exercise. Excessive body condition (>3.5 on 5-point scale; ideal is 3-3.5) can lead to difficult calving and metabolic problems after calving. Typically, they will eat about 1% of bodyweight in neutral detergent fiber (NDF), so by increasing dietary NDF, you can reduce feed intake. This led to much research at the University of Wisconsin Marshfield Agricultural Research Station on using high-fiber, low-energy dilutant forages (e.g., wheat straw, eastern gamagrass, corn stover, tropical corn silage, forage sorghums) to increase fiber and lower energy content of diets to better control weight gain.

The project objective was to evaluate inclusion of alfalfa stemlage or wheat straw in pregnant dairy heifer diets, and to compare subsequent voluntary intakes and weight gains of those heifers consuming a control diet with no dilution. It was thought stemlage may help control intake and weight gains similar to straw, which previously was demonstrated. Alfalfa stemlage was produced by a novel leaf-stripping technology developed at the USDA Dairy Forage Research Center. The stripper removed a majority of alfalfa leaves to be used as high-quality feed for lactating cows or potentially as protein sources for other livestock (e.g., poultry, swine, fish) or for human use. Stems remaining in the field were cut, wilted overnight, baled into large square bales, and individually wrapped. Stemlage nutrient composition was 63% dry matter (DM), 11% protein, 65% NDF, and 40% total digestible nutrients (TDN). Stemlage diet had about 32% stemlage, 35% corn silage, and 33% haylage; straw diet had 31% straw, 30% corn silage, and 39% haylage; and control diet had 56% corn silage and 44% haylage. Diets had similar protein contents (12.8% CP), but stemlage and straw diets had 44-46% NDF and 59-61% TDN compared to 40% NDF and 67% TDN for the control. Each diet was fed to 3 pens of 8 pregnant dairy heifers (total - 9 pens, 72 heifers) for 56 days with intakes recorded daily and weights and body measurements taken at the beginning and end of the study.

Inclusion of stemlage or straw dilutant forage effectively reduced daily feed and energy intakes (average of 22.8 lbs DM and 13.9 lbs TDN) compared to control (24.9 lbs DM and 16.7 lbs TDN). NDF intakes were similar across the 3 diets at about 10 lbs/day with heifers eating approximately 0.9% of bodyweight in NDF each day. Lower energy intakes resulted in more desirable weight gains for heifers fed stemlage and straw (2.2 lbs/day) than heifers fed control (2.9 lbs/day). As a result, heifers fed the corn silage/haylage control diet gained more condition than heifers on diluted diets even within the short 56-day study. Digestibility of control and straw diets were greater compared to stemlage diet with heifers fed stemlage, excreting 11.8 lbs fecal DM (72 lbs wet feces) compared to about 9 lbs fecal DM (60 lbs wet feces) for both control and straw. Increased fecal amount may be problematic when feeding high-fiber, low-digestibility forages since some dairies have limited manure storage. Sorting against straw and stemlage was observed. Harvesting stems as chopped silage or as dry hay and then bale grinding would likely reduce sorting. Overall, alfalfa stemlage had similar positive results on performance as straw and can be a useful dilutant in heifer diets to control intake and growth.

UNIVERSITY OF WISCONSIN–MADISON NEWS

Study quantifies role of 'legacy phosphorus' in reduced water quality

March 14, 2017 | By Jenny Seifert | For news media ⊞

Wind turbines and farm fields near Springfield Corners, Wisconsin. Cropland in the Yahara watershed has an overabundance of soil phosphorus, and researchers say that makes clean lakes and rivers possible only with a revolution in land and water management. COURTESY OF UW–MADISON WATER SUSTAINABILITY AND CLIMATE PROJECT

For decades, phosphorous has accumulated in Wisconsin soils. Though farmers have taken steps to reduce the quantity of the agricultural nutrient applied to and running off their fields, a new study from the University of Wisconsin–Madison reveals that a "legacy" of abundant soil phosphorus in the Yahara watershed of Southern Wisconsin has a large, direct and long-lasting impact on water quality.

Published March 13 in the journal Ecosystems (https://link.springer.com/journal/10021), the study may be the first to provide quantifiable evidence that eliminating the overabundance of phosphorus will be critical for improving the quality of Wisconsin's lakes and rivers.

For example, the results indicate that a 50 percent reduction in soil phosphorus in the Yahara watershed's croplands would improve water quality by reducing the summertime concentration of phosphorus in Lake Mendota, the region's flagship lake, by 25 percent.

Melissa Motew

Christopher Kucharik

"If we continue to apply phosphorus at a greater rate than we remove it, then phosphorus accumulates over time and that's what's been happening over many decades in the Yahara watershed," says Melissa Motew (https://wsc.limnology.wisc.edu/node/21), the study's lead author and a Ph.D. candidate in the UW–Madison Nelson Institute for Environmental Studies (https://nelson.wisc.edu/).

Phosphorus seeps into soils primarily by way of fertilizer and manure, and what crops and other plants don't use to grow then leaks into waterways with rain and snowmelt runoff. Scientists have long believed that excess soil phosphorus is a culprit behind the murky waters and smelly algal blooms in some of Wisconsin's lakes and rivers.

Conventional efforts, like no-till farming and cover crops, have tried to address nutrient runoff by slowing its movement from soils to waterways. However, the study shows that simply preventing runoff and erosion does not address the core problem of abundant soil phosphorus, and this overabundance could override conservation efforts.

"Solutions should be focused on stopping phosphorus from going onto the landscape or mining the excess amount that is already built up," says co-author Christopher Kucharik (http://agronomy.wisc.edu/christopher-kucharik/), a professor of agronomy and environmental studies at UW–Madison.

Peter Vadas' Annual Phosphorus Loss Estimator (APLE)

Using newly advanced computer models, the study shows the watershed has about four times more phosphorus in its soil than is recommended by UW-Extension, which writes the state's nutrient management recommendations based on what crops need and a landscape's potential for nutrient runoff.

Moreover, the study indicates that if soil

Crops, such as these young rows of corn, use some of the abundant soil phosphorus reserves, but not enough to draw down the surplus. SAMUEL ZIPPER/UW-MADISON WATER SUSTAINABILITY AND CLIMATE PROJECT

phosphorus levels continue to increase as the climate also changes and becomes wetter, there will be more runoff and further decline in water quality. Reducing the surplus could mitigate this risk, Motew says.

Currently, the only method known to draw down soil phosphorus is harvesting crops, but Kucharik explains that plants take up only a small amount of the surplus each year.

“It is unlikely that any cropping system will quickly draw down the excess,” he says.

It will require working with farmers to practice better nutrient accounting and counter the tendency of some to apply more fertilizer, as an insurance measure, than is needed.

“Farmers have many different decisions to make and priorities that they have to juggle. If we want to address the legacy phosphorus problem, nutrient and manure management will need to become a higher priority,” says Motew, who adds that the pressures of farming and demand for products like meat and milk underlie the problem.

But food production need not be compromised by potential solutions, Kucharik says. There is enough excess phosphorus in our soils “to support plant nutrient needs for a long time.”

> **“While we’ve long known that too much phosphorus is bad, the models allow us to quantify just what ‘bad’ means.”**
>
> — Melissa Motew

Innovation in manure disposal would also help. Throughout Wisconsin, farmers have more manure than they know what to do with, and the primary way to get rid of it is to spread it on their land, where its phosphorus just adds to the surplus.

“Support for manure digesters, the removal of phosphorus from lake and stream sediment, and other actions to recycle the phosphorus already in place would be beneficial for reducing the concentrations in our soils over the long term,” says Kucharik.

Also key to finding solutions is the use of state-of-the-art computer models, like those developed by the research team for the study, which allowed them to identify direct relationships between soil phosphorus and water quality — a feat virtually impossible using scientific observations alone.

"While we've long known that too much phosphorus is bad, the models allow us to quantify just what 'bad' means," says Motew. While the study method doesn't provide a blueprint for achieving clean lakes, putting numbers behind a common-sense understanding of a complex system is a step in the right direction, she says.

The research is part of UW–Madison's Water Sustainability and Climate (https://wsc.limnology.wisc.edu/) project and is funded by the National Science Foundation.