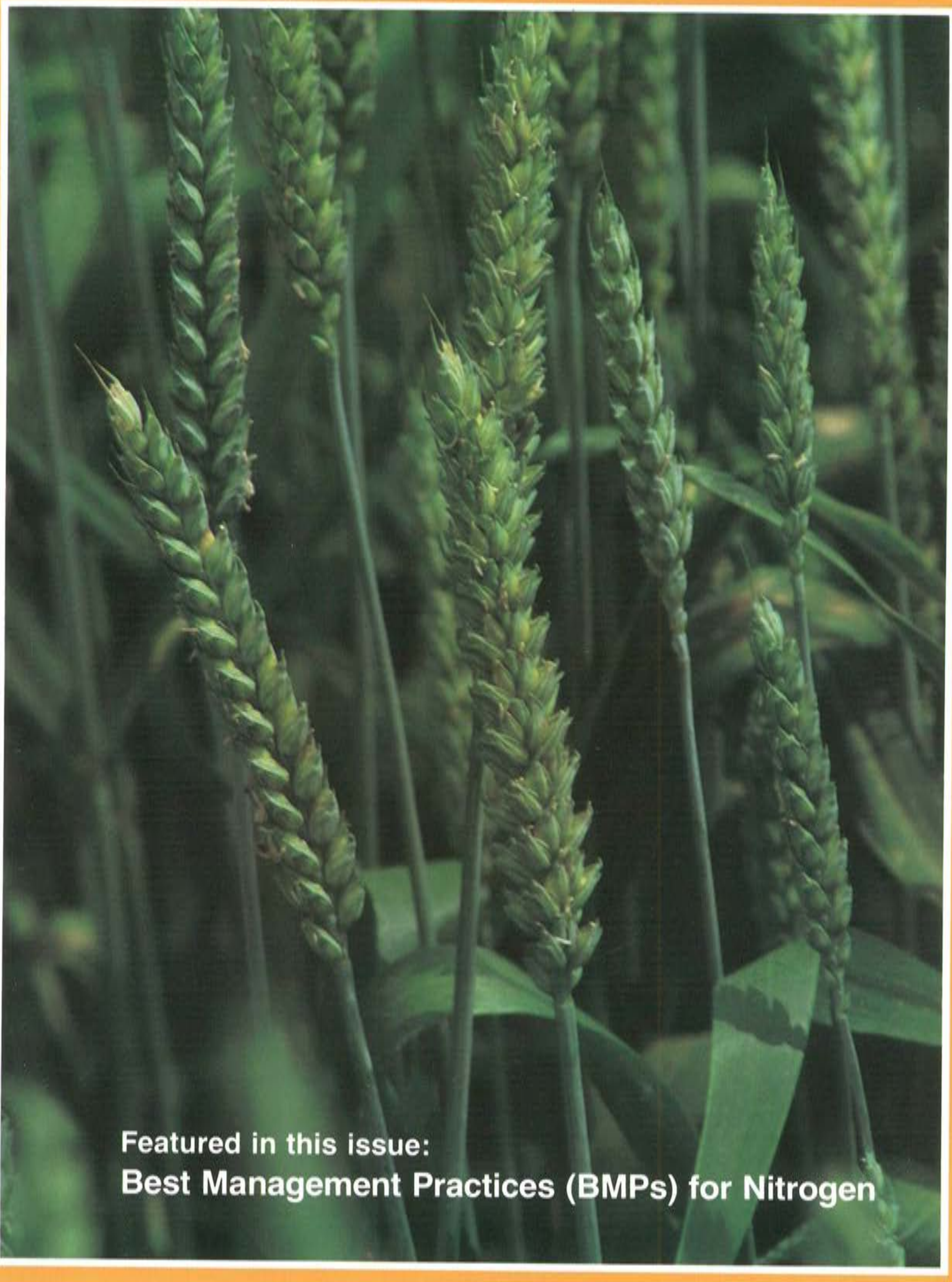
BETTER CROPS WITH PLANT FOOD

Fall 1989



BETTER CROPS With Plant Food

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Contents

Our Cover: A close-up look at wheat in British Columbia research plots.
Photo by Dr. M.D. Stauffer

Nitrogen—Improving Plant Production for Human Health and Environmental Quality

By L.S. Murphy and B.C. Darst

Nitrogen (N) is essential to all forms of plant and animal life. It is involved in photosynthesis, is a part of the proteins and is contained in the nucleic acids, thus playing a vital role in genetic transfer. Crops remove billions of pounds of N from U.S. soils each year. Management of N sources . . . manures, residues, legumes and commercially produced N . . . is critical for economic efficiency and environmental protection.

CORN, WHEAT AND HAY remove nearly 16 billion pounds of N from U.S. soils every year. That represents more than 60 lb for every man, woman and child. Other crops such as cotton, rice, fruits and vegetables also take a heavy toll on our soil N supplies.

Nitrogen is important in the production of crop plants cultivated for human consumption . . . as well as those grown to feed the beef, pork and poultry we eat. Nitrogen is also vital to the human diet. It is a part of all proteins and is a component of RNA and DNA, the "blueprints" that pass genetic characteristics from one generation to the next.

How N Behaves in the Soil

The only part of the soil that supplies N to a crop is organic matter. No soil minerals contain N. Organic matter releases its N slowly. Release rate is controlled by such factors as soil temperature, soil moisture content and soil texture.

As organic matter is mineralized by soil microorganisms, N contained in its complex molecules is converted to more simple inorganic forms . . . ammonium and nitrate. Both the ammonium and nitrate forms of N are highly soluble in soil water and are readily available for crop plant uptake. The ammonium form is attracted to and held by soil particles. Nitrate, on the other hand, remains free and moves downward with soil water. This process is called "leaching" and can lead to nitrate accumulation in groundwater.

Most of the ammonium N not used by the crop is eventually converted to nitrate. The conversion rate can be slowed with the use of nitrification inhibitors and other stabilized N forms. Holding the N in the ammonium form until the crop needs it can be helpful in reducing leaching potential and improving N use efficiency by the crop.

Ammonium and nitrate are the only N forms that can be used by crop plants, no matter what the N source . . . livestock manure, legumes, crop residues, organic matter or commercial fertilizer.

Where Plants Get Their N

- **From the Earth's atmosphere.** There are about 75 million pounds of N in the atmosphere above each acre. This N, though in abundant supply, must be converted to a different form before plants can use it. Most conversion can take place in the soil through a process known as "fixation." However, some N is "fixed" each time there are thunderstorms. Electrical discharge (lightning) forms mineral N which enters the soil with precipitation and other atmospheric reactions.
- **Fixation by soil bacteria.** Legumes also fix N. The process is carried out by certain soil bacteria, and takes place in nodules that develop on

(continued on next page)

Dr. Murphy and Dr. Darst are with the Potash & Phosphate Institute (PPI). This brief article presents main points from *NITROGEN: The Superstar*, a recent publication by PPI, Potash & Phosphate Institute of Canada (PPIC), and the Foundation for Agronomic Research (FAR).

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legume roots. Legumes can convert from a few pounds to hundreds of pounds per acre of atmospheric N into a form crop plants can use. Some free living soil bacteria can also add usable N through fixation, but these amounts are quite limited.

- **From soil organic matter.** Productive soils in the U.S. Corn Belt might contain as much as 3,000 lb of N per acre. Most is tied up in organic matter and becomes available to plants only when the organic matter is decomposed. In general, about 20 to 30 lb of N are released each year from each one percent organic matter in the soil.
- **From animal manures.** Animal manures are another source of N. Where livestock are confined in large numbers . . . poultry barns, dairies and feed lots, for example . . . the accumulation of manure is often significant. Although highly variable in N content, manure is a good source of plant food and can improve the physical condition of the soil when properly applied.
- **From commercially produced fertilizer.** Commercially produced N as a plant food had its beginnings following World War II. The industry developed rapidly in the 1950s and 1960s, and is a vital link in today's food production chain. Its base is the production of anhydrous ammonia, made by combining N from the atmosphere with hydrogen (H) from natural gas or other sources. Using ammonia, other N fertilizers are produced through a variety of processes.

Controlling N Losses from the Soil

Nitrogen can be lost from the soil in several ways. Tremendous quantities are removed in the harvested portions of crops. Erosion accounts for significant N losses because most is present in organic matter in soil surface layers . . . the first part of the soil to be lost by both wind and water erosion. Nitrate can leach out of the soil profile. Volatilization of ammonia gas occasionally results in substantial N losses, particularly when animal wastes are applied to the soil surface and not incorporated. When soil is saturated with water, nitrate can be converted to inert gases and released to the atmosphere. Cultural practices largely control N losses from agricultural soils. This is both economically and environmentally desirable.

Choosing the proper N rates for crops helps reduce the danger of unused nitrate leaching into water supplies. Adequate supplies of phosphorus (P), potassium (K), sulphur (S), and other nutrients must also be available for highest N use efficiency to occur. Decisions on proper rates of N and other nutrients are site specific, requiring a correct yield goal, knowledge of nutrients available in the soil (soil test) and consideration of other best management practices (BMPs).

Applying fertilizer N as close as possible to the time of actual crop use lowers the potential for nitrate leaching. Multiple N applications have been recommended for many years by crop scientists and supply industries. It is widely practiced by farmers.

Certain compounds added to N fertilizer (N stabilizers or nitrification inhibitors) slow the conversion of soil ammonium to nitrate. They can lower the potential for nitrate leaching. Eventually, however, the compounds themselves are broken down by soil bacteria and nitrification continues.

The agronomic BMPs used with soil and water conservation BMPs . . . terracing, grass waterways, strip cropping and others . . . all increase N use efficiency. At the same time, they also reduce the potential for nitrate leaching, thus protecting the environment.

Summary

Both economic and environmental concerns should influence N management in production agriculture. A farmer must realize a fair profit if he is to stay in business and provide a decent standard of living for his family. He must also recognize the environmental implications of his production system and his management decisions.■

Potash Increases Efficiency of Nitrogen for Hybrid Bermudagrass Hay Production

By Marcus M. Eichhorn, Jr. and W.R. Thompson, Jr.

Optimum nitrogen (N) rates, balanced with adequate rates of potash (K) and other nutrients, can increase nutrient use efficiency while producing profitable yields of hybrid bermudagrass.

COASTAL and other hybrid bermudagrasses grown for hay production need high rates of N and K for sustained and profitable yields. A study at the Louisiana Hill Farm Research Station found that a K_2O rate of 400 lb/A produced the top yield of hay, replenished and sustained grass stands, and improved uptake and use efficiency of the applied N fertilizer. Higher K rates also increased hay yields, but not as economically as did the 400 lb rate.

Earlier research at this station found that the N rate of 400 lb/A produced the maximum economic yield (MEY) of Coastal bermudagrass hay. The 400 lb N rate, coupled with 150 lb/A of phosphate (P_2O_5), 90 lb/A of sulphur (S), and 2 lb/A of boron (B), were applied in the K rate study conducted from 1980 through 1984.

Nitrogen uptake and use efficiency were maximized with the 400 lb/A K_2O rate. The previously depleted Coastal bermudagrass stand was replenished and then sustained by the K application. Soil K levels were nearly balanced between K applied and removed. A K_2O rate of about 600 lb/A was required to build soil K levels **(Table 1).**

For sustained, profitable hybrid bermudagrass hay yields, and greatest N use efficiency, a balanced N:K ratio (1:1) and adequate levels of other nutrients are required.■

Table 1. Effect of K_2O rates on Coastal bermudagrass yield, nutrient uptake, stand, and soil test.

	K_2O, lb/A				
Factor	**0**	**100**	**200**	**400**	**600**
Yield, tons/A	4.46	6.05	6.69	7.10	7.19
Nitrogen					
Rate, lb/A	400	400	400	400	400
Uptake, lb/A	200	265	288	307	308
Removal, %	50	66	72	77	77
Spring Stand, %					
1980	57	24	35	42	36
1985	29	66	84	93	94
Soil K, ppm, 0-6 inch depth					
1980	47	31	37	41	30
1984	11	12	16	22	42

Louisiana

Dr. Eichhorn is Associate Professor, Hill Farm Research Station, LSUAC, Homer, Louisiana. Dr. Thompson is Midsouth Director, Potash & Phosphate Institute, Starkville, Mississippi.

In British Columbia

Winter Crops Management Offers Better Environmental Protection

By Art Bomke and Wayne Temple

In 1988, research investigating ways to reduce soil quality losses in high rainfall areas resulted in a record Canadian wheat yield. Protecting soil from the harmful effects of high rainfall and wind erosion requires a fall seeded crop receiving best management practices (BMPs). This article explains that proper crop management provides for environmental security. In addition, it is setting the stage for better profitability for farmers in south coastal British Columbia.

IN HIGH RAINFALL AREAS such as coastal southern British Columbia, winter crops provide a much better "crop-environment fit" than the traditional spring crops. Several benefits result.

Winter crops protect the structure of surface soil from heavy rainfall and wind erosion during the winter months **(Figure 1).** In addition, soil compaction caused by various farming operations is greatly

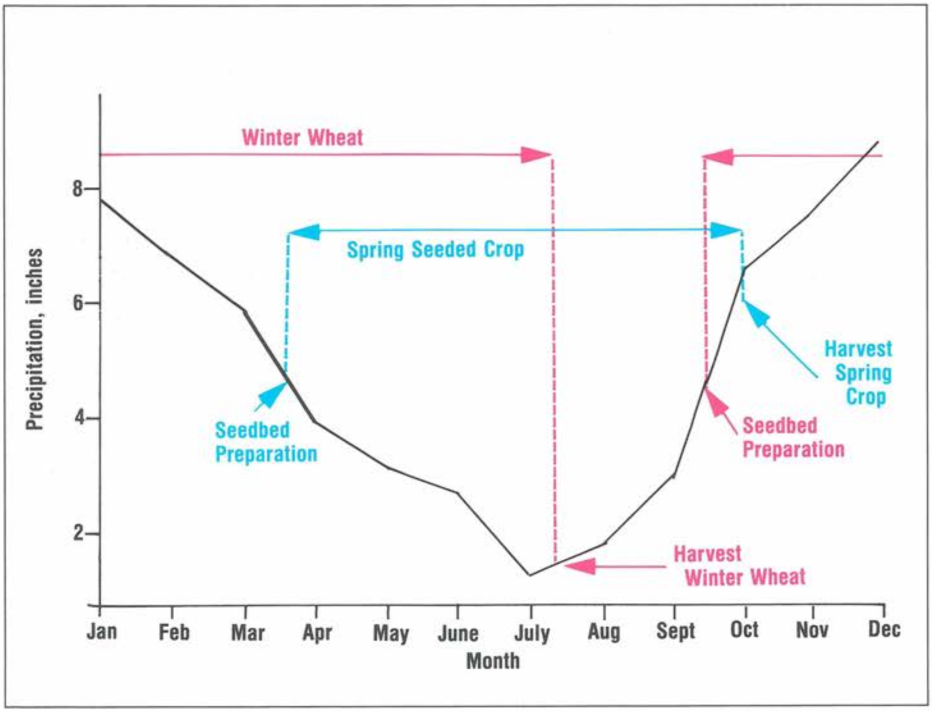

Figure 1. Precipitation curve as related to management practices for spring and winter crops.

The authors are with the Department of Soil Science, University of British Columbia.

205 bu/A Wheat Yield Is Canadian Record

THE 205 bu/A (13.8 t/ha) wheat yield achieved in 1988 by researchers Art Bomke and Wayne Temple is considered a record high for Canada.

"The yield of 205 bu/A indicates the suitability of winter wheat to the climate and soils of southern coastal British Columbia," Dr. Bomke notes.

Development of site-specific intensive management systems in very high potential production regions challenges the knowledge of limiting factors and interaction among inputs.

The BMPs for profitable yield goals must also be environmentally sound, the researchers emphasize.

Nitrogen management aspects of this research were funded by the China/Canada Potash Agronomy Program.■

— Dr. Mark D. Stauffer, PPI

minimized because traffic on fields is shifted to comparatively drier periods in the growing season.

Farming systems built around environmental concerns must, however, be both practical and profitable. Winter wheat has shown good potential for southern coastal British Columbia. Management components are now being evaluated and adapted for compatability in maximizing economic production while protecting the environment. Careful nitrogen (N) management is necessary during cool, wet winter months when mobile nutrients leach from the rooting zone. Also, disease and lodging susceptibility of winter wheat during the rapid growth period of March through June demand precise N managment.

Currently, BMPs for fertilizer N, fungicide and anti-lodging compounds are being investigated to determine their effects on grain yield, milling quality and cost-benefit ratios for producers. This interim report summarizes studies on developing high management systems for winter crop production in our area.

Nitrogen Management

A grain yield of 120-150 bu/A (8-10 t/ha) with adequate protein content for milling requires approximately 268 lb N/A (300 kg N/ha). Winter wheat, seeded in September-October, resumes growth in mid-February to early March. By mid-April (Zadoks growth stage 31-33, jointing), it is severely N-deficient because heavy winter rainfall leaches residual NO_3-N from the root zone. Significant crop growth occurs before N mineralization in soil has begun. In these coastal soils, soil organic matter supplies about 90 lb/A (100 kg N/ha) throughout the growing season, but the amount is insufficient to meet high yield and protein content goals.

In high rainfall areas, determining the correct timing and rate of fertilizer N application is complicated by increased N leaching and denitrification losses when crop demand is highest. Dramatic and rapid visual responses to 45 lb N/A (50 kg N/ha) applied when spring growth (tillering) begins are common. However, in these studies split N application, with the first application providing 45 lb N/A (50 kg N/ha) preplant or at tillering, gave best yields at only one of four test locations in 1988 **(Table 1).**

At the other sites, including the 205 bu/A yield site, the highest yields occurred when N application was delayed until stem elongation (growth stage 31).

(continued on next page)

Table 1. Winter wheat yield response to nitrogen (urea) fertilizer inputs in 1988.

N Applied, lb/A at various growth stages[1]				Yield, bu/A (13.5% moisture)			
11/	22+/	31/	37	Costal Site 1	Coastal Site 2	Inland Site 1	Inland Site 2
0/	0/	0/	0	134	37	72	73
0/	0/	200/	0	199	96	115	77
0/	0/	156/	45	205	104	120	83
0/	45/	156/	0	—	84	107	66
0/	45/	111/	45	—	90	124	73
45/	0/	90/	67	181	—	—	—
45/	45/	67/	45	183	—	—	—

[1]Zadoks scale growth stages are indicated as follows:
11 = first leaf expanded, second leaf emerging
22+ = at least two tillers
31 = initiation of jointing
37 = flag leaf emerged

Winter Crops . . . from page 7

Variation in responses to early N application occurred because of several factors, including wild fowl winter grazing, N leaching losses, or plant disease. Early N application encouraged rapid growth and a dense crop canopy which was vulnerable to disease infestation. The best N management practice appears to be one which delays the main N application until jointing (growth stage 31) followed by an additional 45 lb N/A (50 kg N/ha) just prior to flag leaf emergence.

An early application of 22 lb N/A (25 kg N/ha) is currently being evaluated since it appears likely that a small amount of "wake up" N may be needed. The amount of N applied at jointing will be determined by plant population and other factors affecting yield potential, such as disease.

Crop Protection

Winter wheat in a humid, high yield environment is susceptible to leaf, stem and root diseases. Fungicides are required to protect the crop. In British Columbia, disease pressure is worse at inland locations. Fungicide responses were larger at these sites (**Table 2**). Reasons are not clear, but higher spring/summer temperatures and precipitation and lower soil and crop tissue chloride contents may be involved.

Table 2. Winter wheat yield[1] response to fungicides, 1988.

	Yield, bu/A	
Fungicide Treatment	Coastal Site	Inland Site
None	158	68
"Bayleton" at 1st node plus "Tilt" at flag leaf plus "Tilt" at flowering	183	108

[1]Grain moisture at 13.5%

Fungicide application is a BMP essential for high yield cereal production. The fungicides "Bayleton" and "Tilt" improved yields significantly at most sites by controlling leaf rust, Septoria leaf spot and powdery mildew. However, inadequate drainage produced root and stem rots which caused lodging and yield reductions which could not be prevented by fungicide application.

Table 3. Plant height and grain yields[1], with and without "Cycocel Extra" (plant growth regulator).

	Without "Cycocel Extra"		With "Cycocel Extra"	
Site	Height, in.	Yield, bu/A	Height, in.	Yield, bu/A
Coastal Site 1	42	174	35	183
Coastal Site 2	46	108	43	116
Inland Site 1	47	108	39	107
Inland Site 2	44	41	42	58

[1]Grain moisture at 13.5%

IN WHEAT RESEARCH plots in British Columbia, various production inputs are evaluated in systems of best management practices. Shorter wheat height in some plots is due to plant growth regulators.

There is some evidence that potash (K) fertilizers help suppress the severity of these rots.

Plant Growth Regulators (PGR)

Use of PGR "Cycocel Extra" permitted higher N applications by reducing plant height and increasing stem strength **(Table 3).** Although lodging was not a consistent problem (probably because the variety Monopol is lodging resistant) PGR was used as an insurance factor. Higher yields and the higher N requirement to achieve them necessitate consideration of PGR use in a BMP program. But disease incidence may increase when PGRs are used since a shortened crop increases canopy density and the relative humidity levels within the canopy. Consequently, the fungicide importance may increase with the use of both higher N and PGRs.

Other Management Factors

Developing high yield environments for winter wheat requires BMPs for each factor contributing to high yield. Important management factors not intensively evaluated to date include variety selection, seeding rate, seeding date, weed control, tillage, drainage requirements, and the requirements for phosphorus (P), K and sulphur (S). Presently, the use and rates of each factor in our studies are based on information from the literature. They have not been investigated in our research. The 1988 experiments indicate that 135 lb/A (150 kg/ha) of exchangeable K may be inadequate and yield limiting, especially on coarse textured soils.

Summary

This research defines some of the factors limiting winter wheat production in high rainfall, long day-length environments.

Best management practices to produce high yields must also be environmentally sound. The evidence to date from these studies indicates that constructing high-yielding crop production systems to fit the environment provides the best opportunity for protecting the soil, increasing water infiltration and improving N-use efficiency. Just as importantly, the collective benefits of each BMP provide maximum economic yield (MEY), the best profitability.■

Cutting Nitrogen Rates Below Optimum Levels Reduces Irrigated Corn Profits in Long Term

By A.B. Onken and A.L. Stoecker

Cost reduction is heavy on the minds of farmers today because of the uncertainties of farm prices and the impact of recent droughts across much of North America. Cutting back on purchased inputs such as fertilizer to save money and protect the environment is also being strongly promoted by environmentally concerned groups. This article takes a look at fertilizer nitrogen (N) and residual soil N from the standpoint of maximizing grower returns from applied N. It suggests that crop prices and N prices do not influence optimum fertilizer rates as strongly as does residual nitrate-N (NO_3-N) levels.

CONSIDERABLE emphasis continues on reducing the cost of crop production because of uncertainties of farm prices and the related farm credit crisis. Further, the focus on reducing off-farm purchases is an integral part of the low-input sustainable agriculture (LISA) movement. Fertilizers present a tempting place to cut costs. However, adjustments in fertilizer expenditures should be made with an awareness of the appropriate fertilizer application rate for the crop in question and the economic consequences of those adjustments.

Fertilizer N and residual NO_3-N in the soil profile interact in their effects on crop yield. Our study was conducted to examine the effects of residual soil NO_3-N levels on the optimal use of applied fertilizer N for irrigated corn and to examine the effects of fertilizer N limitations on producer returns for soils in which N accumulation has been shown to occur. Data for the economic analyses were obtained from four years of N fertilizer response research with irrigated corn grown on a Pullman clay loam, a major soil series in the southern High Plains of Texas.

Fertilizer N was applied at 0, 40, 80, 120, 160 and 200 lb/A. Over the course of the study, NO_3-N levels varied from 12 to 70 lb/A in the 0-6 inch increment and average grain yields from 52 to 183 bu/A.

Profile nitrate measurements made over years indicate fertilizer rates influence the amount of carry-over nitrate and, therefore, potential corn yield response to applied fertilizer N in subsequent years. If this is the case, fertilizer applications in a given year influence responses to fertilizer applications in subsequent years. Appropriate economic analysis must take this into account.

Given the possibility of cost cutting by reducing fertilizer application, questions arise concerning the effects of suboptimal application levels of fertilizer N, not only on the current crop, but on subsequent crops as well and the effective length of crop planning. For example, should the tenant farmer with a one-year lease apply the same amount of fertilizer N as a producer who has an assurance of continued land use, such as an owner-operator?

During the study, fertilizer N rates necessary to optimize net returns for the investment in fertilizer for long-term production (for example, 10 years) of irrigated corn on clay loam soils that accu-

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mulated unused NO_3-N were found to be relatively independent of changes in crop prices, fertilizer costs and interest rates.

Table 1 shows N rates which maximize profit for a single-year plan and the first year of a 10-year planning period. Comparisons are made for three corn prices, three N prices and two residual soil NO_3-N levels. The following points can be made from the data shown.

- Optimum N rates vary little with changes in corn and N prices. For example, in the first year of a 10-year planning period with 10 lb/A residual soil NO_3-N, optimum rates range from 171 lb/A ($2.25 corn; $.35 N) to 186 lb/A ($3.25 corn; $.25 N), a change of less than nine percent.
- Residual soil NO_3-N and fertilizer interact. When soil residual NO_3-N increased from 10 lb/A to 30 lb/A, optimum fertilizer N rates dropped by about 18 lb/A. This tells us that the residual soil NO_3-N is about as effective in boosting grain yields as is fertilizer N.
- Nitrogen rates necessary for maximizing profits for long-term production are 12 to 14 lb/A more than the rates for a single year. This is due to the effect of residual NO_3-N on grain yield, the need to bring it to an optimum level over time and having a sufficient number of crops to take advantage of the optimum level of residual soil NO_3-N.

Soil Test

Residual NO_3-N and applied fertilizer N interact in grain production and influence the level of residual NO_3-N left in the soil profile at the end of the season. Therefore, it is extremely important to have an annual soil test to determine the residual NO_3-N level in order to calculate the correct amount of N to be applied.

Summary

Even small reductions in applied fertilizer N below that required for optimal long-term profit resulted in substantially greater reductions in revenue than savings in fertilizer cost. Due to the carry-over effect, below optimum rates of fertilizer N application not only affect net returns in the current year, but also in subsequent years.

Our analyses indicate that a producer could afford to borrow money at very high rates of interest in order to apply the optimum rate of fertilizer N such that net returns would be maximized over the long term.■

Table 1. Comparison of profit-maximizing N recommendations which would be made for single-year planning and in the first year of a 10-year planning period (annual interest rate of 12%).

	N Price, $/lb					
	0.25		0.30		0.35	
	Planning Period		Planning Period		Planning Period	
	1 Yr	10 Yr	1 Yr	10 Yr	1 Yr	10 Yr
	NO_3-N Soil Test = 10 lb/A					
Corn $/bu	N, lb/A					
2.25	166	180	162	175	158	171
2.75	170	183	166	180	163	177
3.25	173	186	170	182	167	180
	NO_3-N Soil Test = 30 lb/A					
	N, lb/A					
2.25	149	162	145	158	141	153
2.75	153	165	150	162	146	158
3.25	156	168	153	165	150	162

Nitrogen Management for Turf

By Tom Voigt and David Wehner

In most situations, turf fertilization should not consist solely of nitrogen (N) applications. Soil tests can determine the need for additional nutrient applications, especially potassium (K), phosphorus (P) and lime.

ALTHOUGH turfgrasses are important erosion controls and play surfaces, many acres of turf are grown solely for ornamental appeal. A common perception is that a turfgrass must be dark green to be attractive and of high quality. Turf color is related to the species and cultivar in use, the presence of disease or weeds, and the fertility of the soil. Nitrogen mineral fertilization is often used to enhance green color and improve turf appearance.

Turfgrass fertility management often revolves around the quantity and timing of N applications. Nitrogen is the most important element in turfgrass culture because it is present in larger percentages than other minerals in turf tissues, and it elicits the strongest growth response of any element.

Nitrogen Forms

Turf N fertilizers are usually classified as quick release or slow release. Quick release sources are water soluble (e.g. ammonium nitrate, urea, and ammonium sulphate); they will release N into the soil solution rapidly with rainfall or irrigation. They produce a relatively short-lived flush of growth, and can burn the grass leaves if applied incorrectly. However, in most cases, they cost less than slow release forms.

Slow release forms of N include natural organic materials such as activated sewage sludge and animal by-products, synthetic organic materials such as isobutylidene diurea (IBDU) and ureaform, and coated materials such as sulphur-coated urea (SCU). These materials release N over a period of time.

Natural organic materials and ureaform are broken down slowly by soil microorganisms, while IBDU has a slow release by virtue of its low water solubility. As the name indicates, SCU is urea that is encapsulated with S to slow N release. Since urea particles are not coated evenly, SCU is approximately one-third quick release and two-thirds slow-release. This gives the advantage of initial response to application combined with additional long-term benefits. Slow release materials are more expensive than soluble N sources and are less likely to cause fertilizer burn. These materials can be useful for extending the response to N fertilization and are useful during periods of dry weather.

How Much and When?

Nitrogen is used by turf plants in large quantities, and because it is mobile in the soil, it should be applied two to four times per year. Most turf fertility recommendations will indicate the rate in pounds of actual N to be applied per 1,000 square feet of turf per year. How much N a turf receives is determined by a number of factors.

First, the cultivar and/or species grown will indicate, in some part, the quantity applied. See **Table 1** for optimum application rates for common turf species.

Second, the level of quality and intensity of color desired will dictate how much N to use. Nitrogen will provide longer periods of dark green color when applied three or four times annually at the higher end of the recommended rates.

Finally, N should be available for turfgrass utilization during periods of active turfgrass growth. For cool season turf-

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Table 1. Optimum N application rates for turf.

Turf Species	N Rate/Year lb/1,000 sq. ft.
Fine-leaf Fescues	1-2
Tall Fescue	2-4
Perennial Ryegrass	2-4
Improved Kentucky Bluegrass	2-4
Zoysiagrass	2-4
Improved Bermudagrass	4-8
St. Augustinegrass	2-4

Split the annual number of pounds of nitrogen to be applied equally into each application. Do not exceed one pound of nitrogen in a quick release form at any one application.

grasses (e.g. Kentucky bluegrass, perennial ryegrasses, and the fescues), active growth occurs in mid-spring to early summer and again in late summer through mid-fall. By following the application schedule in **Table 2** for three or four applications per year, turf of moderate to high quality can be maintained. Making applications only once or twice a year can produce acceptable turf when quality expectations are lower. As a general rule, never apply more than one pound of actual N per 1,000 square feet from a quick release N source during any one application. Following this recommendation will reduce the possibility of fertilizer burn.

Table 2. Application schedule for N on cool season turfgrasses.

Number of N Applications/Year	Time of Application
1	Early Sept.
2	Early Sept. + Early May
3	Early Sept. + Early May + Late Fall
4 (with summer irrigation)	Early Sept. + Early May + Late Fall + Mid-June

Late fall application should be applied approximately one week following the final mowing of the season.

Warm season turfgrasses (e.g. zoysiagrass, bermudagrass, St. Augustinegrass) grow actively when temperatures are warmer, usually from mid-spring through mid-fall, depending on latitude. Warm season grasses are usually fertilized at least once per year in the spring at the initiation of growth. Successive applications can be made monthly during active growth.

NITROGEN fertilization helps turf compete with weeds. Note the decreasing dandelion populations related to N application in these plots. From left, the N rates were zero, 2, 4 and 8 lb/1,000 sq. ft.

Fertilizer Selection

In most cases, turf fertilization should not consist solely of N applications. Soil tests can determine the need for additional mineral applications, especially K, P and lime. In lieu of having soil tests, select turf fertilizers with N-P-K analysis ratios of 4-1-2, 5-1-2, or 3-1-2.

Fertilizers can also be combined over an annual N fertility program. For instance, an early September and late fall application may be made using a quick release source, the early May and the late June applications may be made using slow release forms. When selecting N fertilizers for a specific application, consider budget, the amount of mowing and irrigation required, and the N form that will best fit into this program.

Very often, N applications are made in excessive amounts or at times when not beneficial to the plant. Obvious results of excessive or improper timing of N applications include: turf that is prone to some patch and leaf spot diseases; thatch production; increased water usage; and increased growth rate, requiring more mowing. Some problems that are not so obvious include reduced root, rhizome, tiller, and stolon growth, as well as reduced heat and drought tolerance. Through proper N applications, not only turf color, but also density and health can be managed. ■

Nitrogen Use Efficiency in Grain Sorghum: A Focus on Phosphorus and Potassium

By David Whitney and Ray Lamond

Grain sorghum requires large amounts of nitrogen (N). Too often, however, the crop does not receive needed phosphorus (P) and potassium (K), or application rates are too low. As a result, yields suffer, water use efficiency is restricted, profitability is low, and nitrate N accumulates in the soil.

USE OF ADEQUATE N fertilizer improves efficiency and profitability of grain sorghum. Recommendations for N use must be based on sound research and production practices to produce the most profitable yield, give the greatest net return, and protect the environment.

Applying N balanced with P and K helps reach those goals. Nitrogen use efficiency can be expressed in several ways: as pounds or bushels of grain per pound of applied N; as N removed in the grain; or as applied N remaining in the soil after harvest.

Let's see how N, P and K interact in grain sorghum production.

Nutrient Requirements

Grain sorghum is a large N user. But its most efficient N use occurs when the crop has enough P and K.

Nitrogen, P and K needs of grain sorghum can be estimated by soil testing. It's a good tool for improved sorghum management. Remember that residual soil nitrate-N should be included in determining fertilizer needs.

Table 1. N x P interactions increase grain sorghum yields.

Treatment	Yield bu/A	Yield lb/A	Yield Increase %
No N or P	82	4,592	—
N only (120 lb N/A)	97	5,432	18
P only (80 lb P_2O_5/A)	90	5,040	10
N and P	132	7,392	61

Soil test P: Low — Herron: Kansas

The authors are with Kansas State University.

Grain Yield

Data in **Table 1** demonstrate how N x P interactions can boost grain yields with good moisture conditions on a soil testing low in P.

Translating yield increases from P fertilization into net returns emphasizes the importance of P management. Note in **Table 2** how production costs per 100 lb of grain dropped as yields increased, even though production costs per acre increased. At the same time, net return went up.

Table 2. Fertilizer results in lower costs per unit of production and higher profitability for grain sorghum.

N (lb/A)	P_2O_5 (lb/A)	Yield (lb/A)	Production costs $/A	Production costs $/100 lb	Net Return $/A
80	0	4,480	160	3.57	19
80	18	6,216	171	2.75	78
80	36	6,552	177	2.70	85

Sorghum, $4/100 lb. N, 20¢/lb. P_2O_5, 25¢/lb. Costs of harvesting, hauling extra grain, 39¢/100 lb. Soil test P: Low. — Kansas

Nitrogen Recovery

Phosphorus is essential for profitable grain sorghum production and for efficient utilization of other nutrients. Kansas data (**Table 3**) show no net carry-over of applied N when adequate P was applied under dryland conditions. Nitrogen removal in grain increased 36 percent with P fertilization.

Table 3. Supplying P helps improve grain sorghum yield, decreases N carry-over in the soil.

P_2O_5	Grain Yield		N Removed in Grain	Net Carry-over N
lb/A	bu/A	lb/A	lb/A	lb/A
0	78	4,340	64	16
18	93	5,230	79	1
36	103	5,762	87	-7

Soil test P: Very Low; P applied banded at seeding. N applied at 80 lb/A. Kansas

Getting grain sorghum off to a good start can carry through to improved yields, high N use efficiency and higher profitability. Starter P can help provide that good start.

Another dryland study of starter P effects on grain sorghum yields demonstrated how dramatic yield responses can be (**Table 4**).

Table 4. Small amounts of starter P improve grain sorghum yields and N use efficiency on low P soil.

P_2O_5	Grain Yield		Plant P		N Removed in Grain
lb/A	bu/A	lb/A	6-leaf	boot	lb/A
			------ % ------		
0	55	3,080	0.17	0.17	67
12	93	5,208	0.19	0.24	112
18	99	5,544	0.21	0.25	120

Soil test P: Very Low; P in direct seed contact. N applied at 80 lb/A. Kansas

Small amounts of P placed in direct seed contact on a very low P testing soil increased yields almost 2,500 lb/A (44 bu/A) and almost doubled N removal in the grain.

Direct seed placement of starters for grain sorghum can be effective at low rates. Sorghum is sensitive to soluble salt damage to germination and rates should be kept low. Higher rates may be possible with plenty of soil moisture, but increase the risk of germination damage. Starter side-banding or placement below the seed would be preferable.

PROVIDING adequate P can significantly advance grain sorghum maturity, lowering grain moisture content and decreasing drying costs while increasing yields.

Adding needed K also serves to improve grain sorghum responses to N and lowers stalk rot and lodging (**Table 5**). Using N alone without sufficient K on low K soils tends to increase lodging and lowers N recovery efficiency. However, supplying K needs in the fertilizer program can have dramatic effects. Nitrogen response with added K increased over 1,100 lb/A (20 bu/A) and lodging was negligible. Nitrogen removal was increased 30 percent over the amount removed by plants receiving no supplemental K.

Summary

Profitable and efficient grain sorghum production requires attention to all nutrient needs. Soil testing clearly is the basis for best fertilizer management practices for this crop. Don't let sorghum yields and profitability be cut short by inadequate plant nutrition.■

Table 5. Adequate K increases grain sorghum yield and N recovery, decreases lodging.

Applied K	Yield lb/A		Lodging, %		N Removal in Grain, lb/A	
lb K_2O/A	No N	N	No N	N	No N	N
0	3,808	3,528	4	29	57	53
80	3,864	3,920	2	16	58	59
160	3,752	4,872	2	4	56	73

Soil test K: Low. N applied at 160 lb/A. Kansas

Best Management Practices: The Ultimate Land Substitutes

By Robert Aukes

While the amount of prime farmland worldwide is decreasing, demand for the food, feed and fiber it produces continues to increase. In this article, the author points out how other inputs and/or improved management might substitute for more land.

WITH THE WORLD'S POPULATION increasing at 1.6 percent, food consumption is expected to grow by 2 percent to 2.5 percent annually. Meanwhile, millions of acres of U.S. farmland are lost each year to nonagricultural uses, to erosion and to soil deterioration. However, the old expression, "They're not making anymore of it", isn't necessarily true today. If one acre now grows as much food as two acres did yesterday—haven't we really created an extra acre of land?

Although some farmland **is** created each year through drainage, clearing and irrigation practices, farmland creation is costly. A powerful motivation to buy farmland continues to be the idea—or myth—that "they're not making any more of it." But **substitutes** for farmland are being created all the time.

Substitutes for Farmland

Irrigation, soil drainage, soil conservation practices, improved transportation and grain storage are all land substitutes. Many elements of best management practices (BMPs) including improved seed varieties, optimal fertilizer, pesticide and herbicide usage, and even newer biotech innovations, along with better machinery and improved crop production management, are all land substitutes that stretch the supply of land. Acreage reduction programs of the federal government continue to be stymied by producers who substitute these inputs for acres, and the productivitiy of these substitutes just keeps increasing.

Figure 1 shows the impact of modern production techniques on corn, soybean and wheat yields. Since 1930, U.S. corn yields have increased more than 350 percent, soybean yields about 100 percent and wheat yields more than 180 percent.

The combined production of corn, soybeans and wheat is shown in **Figure 2.** From 1930 to 1985 production increased 408 percent while harvested acreage increased less than 22 percent. The number of acres can't account for the large increase in production.

Figure 3 explains some of the increase in yields and total production. From the early 1950s to the early 1980s, fertilizer use went up more than 250 percent! Also, over the past two decades, herbicide use has gone up dramatically. Not shown in **Figures 2 and 3** is the effect of hybrid seed. Improved hybrids are usually credited for more than half of recent yield increases. So, through better genetics, more and better fertilizers, pesticides and herbicides, and other BMPs which properly combine these high-powered inputs, the acreage base of major field crops is effectively expanded many times over.

As the supply of land is stretched through the improved use of inputs, the

Dr. Aukes is President of Ferguson Group (Des Moines) Ltd., an Iowa-based firm specializing in management, financial and planning advice. In a guest editorial in the mid-January 1989 issue of *Farm Journal* magazine, Dr. Aukes presented these ideas under the title, "Who says there's no substitute for land?" This article was adapted to emphasize the role of best management practices in modern crop production.

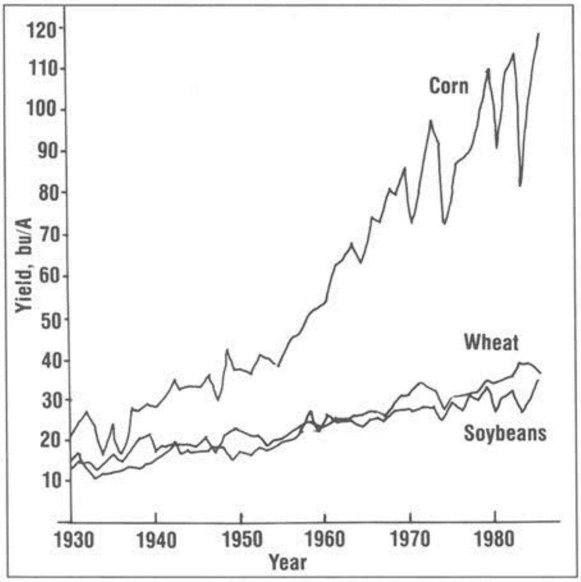

Figure 1. U.S. average yields of corn, wheat, and soybeans.

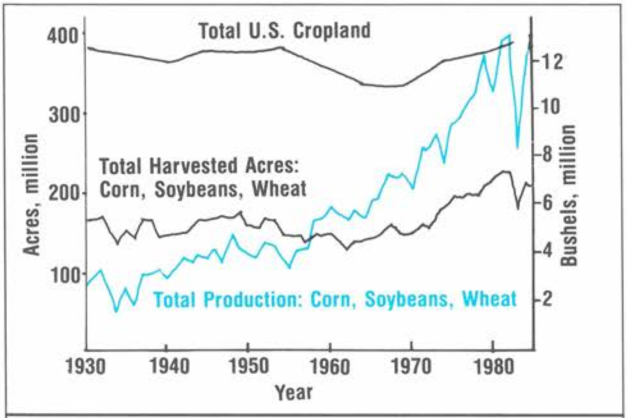

Figure 2.
Total U.S. cropland compared to harvested acres and producton of corn, soybeans and wheat.

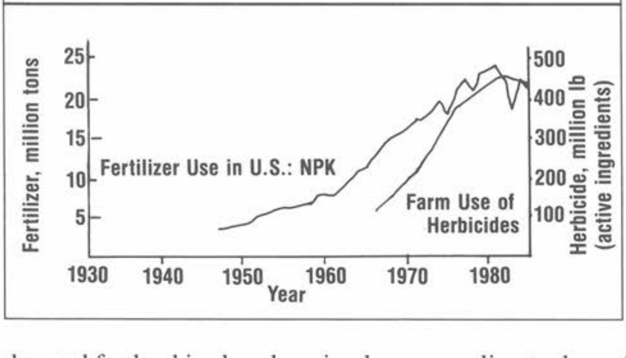

Figure 3.
U.S. fertilizer (NPK) use and farm use of herbicides.

demand for land is also changing because of new methods of livestock production. Improved breeding and husbandry practices continue to increase the efficiency of livestock production. For example, higher quality, faster growing hog and beef hybrids require less feed per pound of gain

(continued on next page)

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than ever before. Also, recent biotech advances in pork and bovine growth hormones promise big increases in the efficiency of feed grain conversion, reducing the demand for feed grains and, hence, for farmland.

The Key Land Substitute

The most important land substitute is management. Topnotch managers outproduce the rest at lower cost per unit of production. New technologies will only widen this gap. New technologies also require greater access to production capital, and that requires even better management: better production management; better accounting and financial management; better personnel management.

For example, the best combination of high-powered seed, fertilizer, herbicide and land will generate higher yields. This raises land prices and further increases the demand for capital. To gain access to capital, better accounting and financial management are being required. It all comes back to management.

The Future for Farmland

So, how much land does U.S. agriculture need? In the 1970s land seemed to be growing scarce, while in the 1980s tens of millions of acres were pulled out of production. Excess production capacity is being used to "mothball" the more marginal land or areas that may be more susceptible to environmental problems.

Researchers estimated "excess capacity" in agriculture at 44 million acres in 1985 and have projected that 231 to 339 million acres of cropland would be needed in the U.S. in the year 2030, depending upon export demand and technology. Another doubling of feed grain, soybean and wheat yields is expected by the year 2030, and livestock productivity should go up another 60 to 70 percent.

Farmland—they're not making any more of it, but they **are** making new and better substitutes all the time. There is excess supply now, and that excess supply could easily grow. However, there is no excess supply of **high-quality** land. The competition for this land is very intense today, because it uses all of the other inputs most efficiently. The demand will undoubtedly remain strong for all high-quality farm inputs, whether for the best land or for land substitutes, such as hybrid seed, fertilizer, herbicides, etc., and most importantly, the management ability to combine these inputs most efficiently.

The Problem IS The Solution

So where does this leave us? Should we buy land? Sell land? When? All this talk about myths and land substitutes only muddies the water. How can we use this information?

First, don't panic. Land substitutes have been coming on line for the past many decades, and meanwhile, land prices have gone both up and down. Land substitutes aren't going to break the land market next week—but they will continue to impact the land market. That may appear to be a problem to some farmers or landowners—but it is also the solution! Highly productive land substitutes can be much more cost effective inputs than land—that's why they are coming on line. And BMPs are undoubtedly the most cost effective land substitutes. So producers can either worry about land substitutes—or use them!

The question of scarcity of farmland and whether land prices are going up or down—that's important to the land speculator. It is not relevant to tomorrow's successful farm operator. In the 1970s many of us thought "they're not making any more farmland," and that kind of tunnel vision distracted us. Tomorrow's successful operators don't dare base important strategic decisions on such myths—or such broad forces that are outside their control. . . "Outside the line fence."

Successful farm operators buy land—or herbicides, or fertilizer, or hybrid gilts, or any input—if it fits into their business plan, if it's profitable and not too risky, and if they can successfully finance it. To operate this way, farmers have to know themselves, their goals and their business—inside and out. They must have detailed financial information and analysis of every phase of their operations. Without this information, myths can lead us astray.■

The Private Crop Consultant and BMPs: Combining Production and Sustainabililty

By Bob Narem

A crop consultant describes the process of working with farmers to evaluate and improve crop production systems, with concern for profit as well as environmental effects.

THE TERM best management practice (BMP) is becoming more familiar in the agricultural community. It describes various specific practices to minimize erosion and surface and groundwater pollution, while maximizing efficiency of seed, fertilizer and pesticide inputs.

Though the term has not been part of my business vocabulary in the past, as a private agronomic consultant I am, in effect, paid to install BMPs on contract acres. It has always been a central idea to the business that prudent ecological decisions must coincide with prudent business decisions. BMPs address both concerns.

Some tools used to make these decisions are: soil fertility tests; soil series mapping; weed and insect scouting reports; observations of soil physical properties; and development of proper yield goals for each field.

My service area is in northeastern South Dakota, an area combining characteristics of the Corn Belt and the northern spring cereal region. My customers are mostly 30 to 50 years old and farm 800 to 1,500 acres. Gross farm income for most would range from $150,000 to $250,000 per full time family operator (some are multiple family operations). Therefore, my customers are slightly younger than average, with larger than average acreage. Their concerns, however, are also the concerns of most farmers in this region.

The major change I usually advise in working with a farmer is the individualization of programs by field rather than by crop. The following general observations encompass these individual programs.

1) Very little change in total fertilizer use, but large changes in how and where fertilizers are applied.

While all my customers grow corn, soybeans and wheat (along with smaller amounts of other crops), corn has traditionally been most emphasized.

It has been assumed that corn needs a tremendous amount of fertilizer in comparison to other crops. We have found that corn may need no more than a wheat or a soybean crop. Some of this is due to soil testing, and some to a reevaluation of yield goals and total crop needs. This approach can reduce nutrient loss through leaching, denitrification and erosion.

More of the phosphorus (P) is being applied as a starter band on both corn and wheat, and nitrogen (N) applications are split on much of the corn and increasingly on some fields of wheat. Most soybeans on soils with low to medium P tests are now fertilized. For the most part, total fertilizer use has changed very little among my clients.

2) Much less tillage.

The trend to conservation tillage appeals to most farmers. However, we have accelerated changes for many farmers by providing assurance that they can react to the new situations.

About 20 of my 30 customers have significantly reduced tillage recently, half of these moving toward no-till or ridge-till. Without plowing, management re-

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Mr. Narem operates a crop consulting service in South Dakota.

Nitrogen Fertilizer Use: Its Impact Upon Texas Groundwater

By Dale Pennington

Texas has groundwater in some regions containing nitrate levels that exceed the 10 parts per million (ppm) of nitrogen (N) established by the United States Environmental Protection Agency (EPA) as being safe for human consumption. The problem is often blamed on N fertilization. However, the groundwater problem is more complex than that, and deserves careful examination of existing facts. The author examines some of those facts in this article.

NITROGEN fertilizer has been utilized in some regions of Texas since 1908 when statewide total use of N, phosphorus (P), and potassium (K) was only 21,850 tons, exclusive of cottonseed meal. The principal high N fertilizer source was nitrate of soda which was guaranteed to contain 15 percent N.

Technology, developed along with the events of World War I, was eventually adapted by agriculture. Nitrogen analysis reflected these trends, and the use of urea (42-0-0) was reported and first sold in 1939. Ammonium nitrate sales were first reported in 1942 when 1,170 tons were used in Texas.

An education and research program to introduce anhydrous ammonia in the Rio Grande Valley of Texas was initiated in 1948. In the mid 1960s extensive liquid fertilizer tonnages were sold in the state and brought about the use of large broadcast applicators. Before that, most of the fertilizer was banded.

Nitrogen Use Trends in Texas

Knowing the dates when fertilizer N was introduced is essential to correctly interpret groundwater nitrate data. It is also important to establish the tonnages of N used in Texas and the trends in N consumption. Data presented in **Table 1** show N tonnage trends since 1953. The data indicate that N use has stabilized at around 700,000 tons per year during the last 20 years.

Table 1. Nitrogen use trends in Texas, 1953 – 1987.

Year	N Use tons (000)
1953	69
1958	144
1963	316
1968	776
1973	703
1978	685
1982	687
1987	749

Evaluation of Groundwater Nitrate-N

With the preceding background of N fertilizer use in Texas, it is appropriate to examine the available information on groundwater nitrate levels in those regions of the state where nitrate-N levels exceed the 10 ppm level established by EPA.

Data developed by the Texas Board of Water Engineers in 1948 included more than 20,000 determinations for nitrate-N in groundwater samples. About 3,000 of these samples, 15 percent, had more than 20 ppm nitrate (4.4 ppm nitrate-N).

In 1952, the Texas Agricultural Experiment Station and the Office of the State Chemist at Texas A&M University accumulated 51 years of recorded fertilizer sales. Data from these records were examined during the 1946 groundwater nitrate sampling

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era and the 1952 era, just as fertilizer use began to develop. Nitrogen fertilizer sales (1946 and 1952) in 21 counties reporting high groundwater nitrate levels are shown in **Table 2**. The data indicate that no N fertilizer was sold or applied in 16 of the counties with groundwater nitrate problems in 1946. Even in 1952, with N fertilizer use increasing in some areas of Texas, only eight of the 21 counties were reporting N use greater than 20 tons per year for the entire county.

Data in **Table 2** provide strong evidence that N fertilization is **not** the cause of the groundwater nitrate problem reported in Texas. This evidence shows that no fertilizer or only small amounts were applied or sold in this region during a time when nitrates were identified as a water quality problem. Therefore, one can conclude that the existing groundwater nitrate problem is a naturally occurring phenomena or is influenced by tillage, or both.

Table 2. Nitrogen sales for 1946 and 1952 in 21 selected counties with reported high nitrate levels in groundwater.

County	Nitrogen fertilizer sales, tons/year 1946	1952
Baylor	0.34	18.29
Blanco	-0-	7.16
Cass	225.73	421.50
Childress	-0-	-0-
Coleman	-0-	-0-
Cottle	-0-	-0-
Dickens	-0-	42.69
Fisher	-0-	-0-
Hardeman	-0-	7.28
Haskell	-0-	42.62
Hays	-0-	28.32
Jones	-0-	2.12
King	-0-	-0-
Knox	-0-	11.52
Mason	-0-	14.94
Runnels	-0-	0.85
Stonewall	-0-	1.72
Travis	5.69	34.71
Wichita	8.33	135.63
Wilbarger	8.31	39.94
Williamson	-0-	43.75

Summary and Conclusion

Texas introduced N use later than other states and has applied N with a different set of criteria. Efforts in Texas to control high N rates were initiated in 1970 with the introduction and adaptation of the nitrate electrode in soil analysis. It has prevented soil nitrate levels from accumulating in farmland for the past 18 years in the Texas High Plains. This same technique was adapted in 1983 for the remaining 154 counties in Texas. The procedure has been recently improved through the use of automated soil nitrate analysis. Other states are just now beginning to introduce this technology into their fertilizer recommendation programs.■

Consultant and BMPs . . . from page 19
quirements increase greatly. If short-term profitability is kept constant or improved, the savings in soil can then be viewed as an investment which will pay off in the future.

The challenge becomes turning the increase in soil water (through less evaporation and more snow catch) into higher yields and greater profits.

3) Reduced herbicide and insecticide use.

Less tillage, higher yield goals and more intensive management would seem to mean increased chemical use, but that has not been the case with most of my clients. Regular field scouting means only **actual** problems are addressed. Also, a well-fertilized, well-rooted, healthy crop grown in an appropriate rotation is more resilient to pest attacks.

Tillage can sometimes replace herbicide use and rotations can reduce or eliminate insect and disease problems. Finally, a consultant's technical knowledge and experience can allow the choice of chemicals with more consideration of possible toxicity to both the applicator and the environment.

A system of BMPs can include a myriad of possible combinations of practices. It is, on the other hand, specific enough to require considerable investments in time and energy on each farm and each field. A consultant can bridge the gap between research information and each farmer's particular field situation. The result is increased profitability for individual farmers, while attaining the goal of "sustainability" of crop production and the health of our land and water resources.■

Livestock Manure— A Limited Resource

By W. K. Griffith

Animal manures are an integral part of low-input sustainable agriculture (LISA). Use of manures is widely promoted as an alternate nutrient source for crops. The author discusses the use of manures, comparing efficiency and environmental impact to those of commercial fertilizers.

ANIMAL MANURES are a valuable plant nutrient source and should be utilized efficiently by those who produce both crops and livestock. Nutrients supplied from manure in plant-available form are no different than those contained in commercial fertilizers.

Animal manures can "leak" nitrates through the groundwater and losses can occur in runoff. Some significant environmental problems are also associated with their storage and distribution. The use of animal manures has no environmental advantages compared to commercial fertilizer, and should be based on current availability and economic efficiency.

Availability

Usable nitrogen (N) from animal manures represents only 18 percent of the annual consumption of commercial fertilizer N in the U.S. However, in the 12 Corn Belt states, where grain production is the most concentrated, the percent of available animal N used compared to commercial fertilizer N is even less (**Table 1**).

Tremendous increases in animal numbers, and huge costs in labor, energy and equipment would be required to get the manure in place to satisfy the nutrient needs of Corn Belt crop production.

Table 1. Distribution of available N from manure and from commercial fertilizer.

Area	Total Available N from Manure tons (000)	Fertilizer N Used tons (000)	Percent Manure N: Fertilizer N (%)
United States	1,900	10,350	18
Corn Belt	643	5,749	11

Environmental Risk

Manure contains N in organic compounds which are decomposed gradually by soil microbes. Manure applications add large amounts of this organic N to the soil where some accumulates and all is gradually converted into ammonium and eventually into nitrate-N. But many factors control the release of that N and its release may be gradual.

While scientists have found that animal manure can be at least as effective as chemical fertilizer in improving yields, it is also more of a pollution risk. This is because plots receiving manure regularly contain more nitrate-N in the soil after harvest in the autumn than plots receiving chemical fertilizer. There is more organic-N for microbes to break down and it comes from both past and current year additions of manure.

Table 2 shows the results of a Minnesota study. According to researchers (see footnote), 75 percent of the organic N in hog manure or 118 lb/A was assumed not to be available in the year of application. Researchers are evaluating the possible fate of N. One could say with some certainty, however, that since the remaining manure N continues to be mineralized after the crop matures and crop N

Dr. Griffith is Eastern Director of Potash & Phosphate Institute, Great Falls, Virginia.

Table 2. Corn yield and nitrate (NO_3-N) concentration in soil water as influenced by N treatments.

N Form	N Rate lb/A	Time Applied	2-Yr. Avg. Yield, bu/A	Nitrate Content in Soil Water, ppm[2]
Anhydrous Ammonia	150	Spring	177	12
Anhydrous Ammonia	75+75	Spring+ Sidedress	173	10
Hog Manure	196[1]	Spring	184	41

Minnesota

[1] Estimated available N. Total N applied was 315 lb/A, half being inorganic and half organic. Reseachers assumed 100 percent availability from inorganic N in year of application.
[2] Measured at 5-foot depth by suction lysimeters at end of second year.

needs are met, there is considerable potential that some of it could find its way into the groundwater.

There are other environmental problems associated with animal manure use and low-input systems:

- Soil compaction from repeated heavy loads of manure increases runoff, restricts root growth, reduces nutrient and water use efficiency and lowers yield.
- Variable nutrient content makes it difficult to determine proper rates for yield goals and nutrient efficiency.
- Limited application time means that manure is often applied at times other than when crop demand is high.

Considerations

Farmers who might consider switching to animal manures as the main nutrient source should consider the following:

- Economics often favor commercial fertilizer because of the high cost of transporting manure.
- It is difficult to fine-tune the amount, or timing, of N release from animal manure, forage legumes, and other types of organic wastes.
- Animal manures are bulky, low-grade organic materials of variable composition. The potential for soil compaction is great because of the heavier loads needed to obtain the same nutrient input as from commercial fertilizers. This increases the potential for runoff to streams.
- Optimum rates of manure applications are not easy to predict. Nutrient variability makes it difficult to apply appropriate rates for both yield and environmental considerations.
- It is difficult to balance manure applications in terms of nutrient requirements of the crops to be grown. Because of their low and variable nutrient content, manures cannot be applied in exact nutrient ratios to meet specific crop needs as accurately as commercial fertilizer.
- Farmers not now involved in animal production would need to learn new management skills for the animal-based system.

The Best Approach

Use both animal manures and commercial fertilizer in the most efficient manner possible. Integrate the use of both nutrient sources with other best management practices (BMPs) to obtain maximum economic yields (MEY) and minimize environmental impact.

There are limited advantages in promoting the widespread conversion of conventional farming to low-input agriculture where animal manures and legumes are advocated to replace commercial fertilizer. If such a transition occurred, there would be a decrease in the productive capacity of most current cash crop farms. The ability of U.S. agriculture to compete in the world market would be severely curtailed.■

Phosphorus and Potassium Help Nitrogen Use Efficiency in Bromegrass and Fescue

By Ray Lamond and Richard Mattas

Bromegrass and fescue have broad adaptability across North America. These cool season grasses provide the major forage production system for hay and grazing in Missouri, Kansas and several adjacent states.

Many studies and reports have emphasized the response of both of these species to nitrogen (N) fertilization. But, in recent years, production per acre has declined in many areas and producers have become concerned. On some occasions, fertilized brome and fescue fail to produce either adequate forage or seed. This situation is especially apparent where N has been the only nutrient used. In some cases, years of good forage production have probably lowered soil phosphorus (P) and potassium (K) tests as cool season grasses remove nearly 10 lb of P_2O_5 and 30-35 lb of K_2O per ton of forage.

Kansas and Missouri studies indicate that P and K, along with N, are essential for increased forage yields and quality. The research has shown that full benefit of N fertilization cannot be obtained without the use of P and K on low testing soils.

In Kansas

KANSAS studies have shown consistent fescue and brome responses to N fertilization for the past 25 years. But, in practice, grower returns to N fertilization are frequently limited by inattention to P, K and S needs. Data from northeast Kansas emphasize the effects of P fertilization on brome responses to N and to N removed in the crop (**Figure 1**).

Nitrogen alone increased yields about 2 tons/A. But providing P produced an additional ton of forage per acre. Figuring hay at a conservative \$60 per ton and P_2O_5 at 25¢/lb, that's about a 4.8 to one return for investment in P at the highest P rate (50 lb P_2O_5/A) and the optimum N rate. Actually, return to P was even better since the 25 lb/A P_2O_5 rate was frequently adequate in these studies.

Nitrogen use efficiency improved dramatically when needed P was supplied. Nitrogen removed in the harvested hay increased about 30 to 50 lb/A with the application of P. That means more purchased N was recovered, protein production per acre increased and N left in the soil to move with percolating water was diminished. Occasionally, P improved protein concentration.

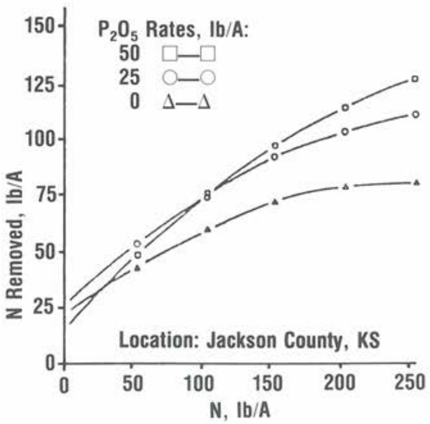

Figure 1. Nitrogen recovery in bromegrass is much higher with applications of needed P. Soil test P was low at this Kansas location. Protein production per acre is an exact image of these curves.
Source: Gruver.

Other Kansas studies have provided similar information. Data from another northeast Kansas location emphasize the importance of P in improving N re-

Dr. Lamond is with the Department of Agronomy, Kansas State University; Mr. Mattas is with Southwest Research Center, University of Missouri.

Table 1. Nitrogen placement and P applications improve N efficiency in fescue.

N	P_2O_5	K_2O	Application Method	Yield	Nutrients Removed, lb/A		
lb/A				tons/A	N	P_2O_5	K_2O
12	0	0	Broadcast	1.26	30	11	43
12	0	0	Knifed	1.76	43	15	57
100	0	0	Broadcast	2.64	80	21	91
100	0	0	Knifed	2.90	92	22	108
100	40	0	Broadcast	3.07	92	30	100
100	40	0	Knifed	3.14	105	29	106
100	40	40	Broadcast	2.70	72	24	103
100	40	40	Knifed	3.40	125	33	132

Soil test P and K: Low. Lamond and Moyer: Kansas
Knifed applications on 15-inch centers.

sponses and N use efficiency. Without P, recovery of added N was about half that applied. With P applied, N recovery was actually greater than that applied at both 60 and 90 lb/A N rates. Phosphorus removal in the first crop accounted for about 32-50 percent of the applied P. At the highest P rate, 60 lb/A P_2O_5, soil test values should be expected to increase slowly if P applications were continued. But with substantial percentages of P removed in the first crop (25-40 percent), growers cannot count on long-term effects from a single P application. Continued soil testing will give an indication of soil P status and need for additional P applications.

Responses to applied N, P and K can be affected by methods of application. Kansas studies with fluid fertilizer materials indicate that broadcast applications on fescue were not as effective as those knifed into the soil or applied in surface bands. Data in **Table 1** demonstrate the trend of those differences and also emphasize the effects of P and K on N use and on nutrient removal in general. It's the same story: use efficiency of N was greatly improved by P applications. Nitrogen recovery was increased 12 to 30 lb/A by application of P. Nitrogen removal in the forage was actually above the amount applied with the more efficient knifed placement. Even though K responses were small, note that K removal is essentially equal to that of N.

In Missouri

Seven years of studies in Missouri involved topdressing tall fescue with N, P and K. Optimum yields in these studies were targeted at the level which could be utilized as grazable forage under good management conditions.

The Missouri studies strongly emphasize the importance of supplying all

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Table 2. Phosphorus and K are essential for top fescue yields.

N	P_2O_5	K_2O	Yield	Nutrients Removed/Year, lb/A	
lb/A			tons/A	P_2O_5	K_2O
100	0	0	1.47	6	42
200	0	0	1.67	9	50
100	60	0	1.87	19	60
200	60	0	2.63	31	72
100	60	100	2.14	22	104
200	60	100	3.56	32	131

Initial soil tests P and K: Low. Missouri

Sulphur Improves Nitrogen Use Efficiency in Bermudagrass Production

By J.M. Phillips and C.C. Curtis

Arkansas research with nitrogen (N) and sulphur (S) on Coastal bermudagrass growing on a Rilla silt loam found both N and S increased forage yields. Nitrogen recovery was greater with S, and S recovery was greater with N.

BERMUDAGRASS is grown on approximately two million acres in Arkansas. Most of the production is in the southern part of the state on Coastal Plain soils and consists of both common and hybrid types. Soils in this region are highly weathered, mature, usually quite acid, low in fertility and low in base saturation. Fertilization is generally essential for efficient production of warm-season grasses in the southeastern U.S.

Our study was conducted in 1986 and 1987 near Texarkana, on a Rilla silt loam that had been in Coastal bermudagrass production for approximately 15 years. Sulphur was applied as either gypsum or wettable S at 90 lb/A S following the initiation of spring growth (early May). Nitrogen fertilizer was applied in early May and at 28-day intervals following each harvest through the growing season. The rates were 0, 50, and 100 lb/A per application. The N sources were ammonium nitrate (NH_4NO_3), urea, and 32 percent UAN solution.

Forage production increased as N fertilizer rates increased. The highest yield was obtained in the study when NH_4NO_3 was applied at the high N rate (400 lb/A) with gypsum in 1986 and with wettable S in 1987.

Nitrogen recovery increased quite markedly when S was added. Sulphur is a component of the essential amino acids (methionine, cystine and cysteine) and is, therefore, critical to the synthesis of proteins in plant tissue. In S-deficient soils,

RESPONSE of Coastal bermudagrass with S application was recorded in these plots.

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Table 1. Dry matter (DM) forage yields and recovery of N and S with Coastal bermudagrass.

N Rate	Sulphur Applied	Forage Yield DM, lb/A	Nitrogen		Sulphur	
			Uptake lb/A	Recovery %	Uptake lb/A	Recovery %
0	No	4,743	81	0	6	0
	Yes	5,274	88	0	23	18
200	No	9,216	186	53	12	0
	Yes	10,426	223	72	33	39
400	No	10,259	236	39	26	0
	Yes	12,238	306	56	36	47

S source was gypsum at rate of 90 lb/A S.

N recovery could be less, due to the low levels of S. At the moderate N rate (200 lb/A) in 1986, N recovery was only 40 percent when no S was applied. When S was added at the moderate N rate, 78 percent and 69 percent N recovery was realized with gypsum and wettable S, respectively.

Summary

A field study conducted in 1986 and 1987 evaluated N and S recovery on Coastal bermudagrass where S was a nutrient limiting forage growth on a Coastal Plain soil. The addition of S resulted in increased forage yields. Nitrogen recovery was highest when S and N were applied at the 200 lb/A N rate.

Sulphur recovery increased with increasing N rates. Fertilizer application including S should be considered to increase forage yield and improve N recovery and forage quality on deep sandy and silt loam soils in the Coastal Plain soils that are low in organic matter. Additional studies are underway to better define rates and timings of S fertilization. ■

Fescue . . . from page 25

needed nutrients for fescue. For instance, increasing the N rate from 100 to 200 lb/A produced only a 0.2 ton/A yield increase (**Table 2**). However, when adequate P and K were applied, the additional N increased yields as much as 1.4 tons/A. That is a tremendous improvement in N efficiency, identical to the Kansas reports.

Other Missouri data suggest that split N applications for the spring and fall growth of fescue can improve N use efficiency.

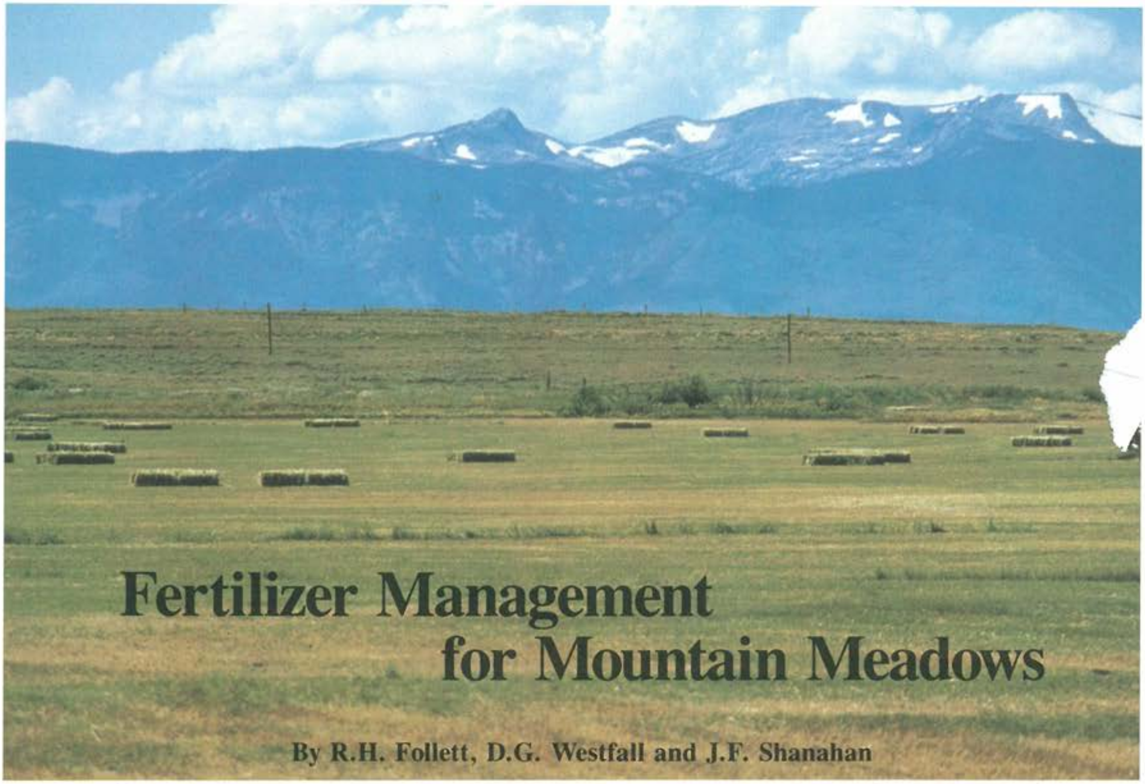
Supplying P without needed K was also inefficient. When P was supplied along with adequate N, yields increased about 1.0 ton/A. But when P and adequate K were applied in addition to adequate N, yields doubled, an increase of nearly 1.8 tons/A.

Phosphorus is a significant factor in the nutrition of beef and dairy cattle and affects both the animal and the nutrition of rumen bacteria. Animals consuming low P forage would require significantly more supplemental P in their rations.

Missouri data show that K removal in the forage increased as yields rose, with and without added K. It is important for producers to recognize that K in the forage is an important source of K for animals. It's also important to remember that continued harvesting of forage for hay is a much more serious drain on soil K reserves that will need to be replaced. Without supplemental K, yields will be lower.

Summary

Soil testing is the key to knowing where P and K are needed, and when fields need to be limed. Good fertility management can substantially improve yields and forage quality. Protein production and nutrient content of the forage are both improved by providing adequate plant nutrients. Perennial cool season grasses can provide many years of high yielding, high quality forage when nutrient needs, including P and K, are provided. ■



Fertilizer Management for Mountain Meadows

By R.H. Follett, D.G. Westfall and J.F. Shanahan

Mountain meadows play a vital role in livestock production in Colorado, Wyoming and Montana. Research in that area shows that net returns from mountain meadows can be substantially improved by proper use of fertilizer.

FERTILIZATION is one of the best ways to boost forage production on irrigated meadows in the intermountain area. Presently, unfertilized meadows yield only 1.3 tons of hay per acre. Virtually all irrigated mountain meadow soils are nitrogen (N) deficient and will produce more, better quality hay with adequate fertilization. Research has also shown that the addition of phosphorus (P), potassium (K) and sulphur (S) can also improve meadow production and profitability.

In the past, ammonium nitrate was the most commonly used N fertilizer for mountain meadows. Presently, urea is emerging as a leading solid N source because of its higher analysis (46 percent N) and lower transportation costs.

In some areas, N is applied on meadows in the fall because of better spreading conditions. But, questions have been raised about risks of N loss from fall applications due to leaching during the winter and early spring. Little information has been available on this point.

Much of the fertilization research in the mountain meadow areas of the west has dealt with N. Earlier Colorado data have also shown excellent responses to P. Recent soil tests from mountain meadows in the region have shown that many soils are medium to low in both P and K. As nutrient removal continues through annual harvesting and as yield goals increase, more attention is being focused on needs for P, K, S and other nutrients.

Current Studies

In 1987, we initiated a three-year study of meadow fertilization practices near Saratoga, Wyoming, at an elevation of approximately 7,200 feet. The grass mixture at the site was timothy, smooth bromegrass and meadow bromegrass. Soil at this location was a sandy loam (6

The authors are with the Department of Agronomy, Colorado State University.

to 8 inches) over mixed sand and gravel. The objectives of the study were to:

- evaluate the annual and long-term N fertilizer requirements for mountain meadow hay production;
- compare the effectiveness of ammonium nitrate and urea;
- compare fall and spring applications of N;
- study meadow responses to P, K and S on soil testing low to medium in these nutrients.

Nitrogen

Nitrogen fertilization consistently increased mountain meadow hay yields. Spring applied N produced more forage at all but the highest rate of fertilization **(Figure 1).**

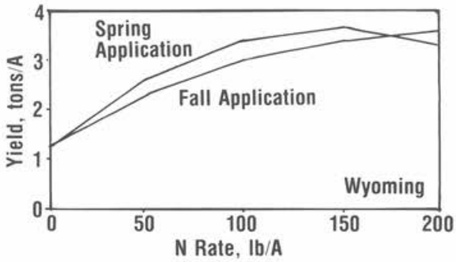


Figure 1. Nitrogen fertilization consistently increased mountain meadow hay yields. Spring N applications were slightly more effective in these studies.

Nitrogen substantially improved not only hay yield but also hay quality by increasing the crude protein content. Protein increased from about 8 percent for areas receiving no N to more than 11 percent with spring applications of both urea and ammonium nitrate.

Nitrogen fertilization had a tremendous influence on the amount of total protein produced per acre. For example, the 100 lb/A N rate more than tripled total protein production compared to no N (600 lb/A versus 200 lb/A). Spring N applications tended to have the greatest effect on protein production.

Rate comparisons indicated that yields and net returns were greatest at 100 lb/A N. Net returns rose from a low of $72 per acre where no N was applied to $178 per acre for urea and $170 per acre for ammonium nitrate at the 100 lb/A N rate.

Nitrogen fertilizer efficiency at rates up to 100 lb/A was remarkably good for spring N applications, ranging between 76 and 78 percent for both N sources. Nitrogen recovery from fall application ranged between 45 and 70 percent, reflecting lower yields and lower protein.

Phosphorus, Potassium and Sulphur

Applications of P, K and S significantly increased yields over N alone **(Table 1).** At this location, increases were relatively small despite the initial low P soil test value. However, P response may occur in following years and those responses should be calculated against the initial costs. Research in Gunnison County, Colorado, showed that the meadow forage continued to respond to single P applications (40 to 120 lb/A P_2O_5) for at least three more years.

Table 1. Providing other needed nutrients besides N boosts mountain meadow hay production.

Fertilizer Rate $N - P_2O_5 - K_2O - S$	Yield	Protein
-------- lb/A --------	tons/A	%
100 - 0 - 0 - 0	3.3	9.4
100 - 40 - 0 - 0	3.5	9.0
100 - 80 - 0 - 0	3.5	9.1
100 - 80 - 60 - 0	3.6	9.3
100 - 80 - 60 - 20	3.8	9.4
100 - 80 - 60 - 40	3.9	9.0

Sulphur availability on coarse meadow soils may also be limiting in early spring growth because of the mobility of sulphate-sulphur in water and the slow release of S from organic matter in cold, mountain soils. Sulphur produced both visible growth effects and a small but significant yield increase in this study. Montana studies have also demonstrated S responses on irrigated mountain meadows.

(continued on next page)

Mountain Meadows . . . from page 29

THE AREA at right in this photo received P fertilizer. Studies show good residual effects in mountain meadows. Soil tests can indicate when nutrients other than N are limiting.

Summary

Based on these and other studies, we would suggest the following points to improve mountain meadow profitability through fertilization.

- Soil test to provide a basis for beginning a fertilizer program. Know where nutrients are needed.
- Don't waste money and fertilizer on droughty, poorly irrigated, weedy meadows. Similarly, fertilizer responses may be poor in wet, boggy areas.
- Grassy meadows will give good yield increases or higher protein hay with applications of N, especially those with good stands of smooth bromegrass, timothy, slender wheatgrass, intermediate wheatgrass, meadow foxtail, meadow bromegrass and other productive species.
- Urea and ammonium nitrate are essentially equal as N sources.
- Spring applications of N are somewhat more effective than fall applications, but differences will vary among locations. Ease of application in the fall may be a factor to consider.
- With a single, late-cutting system, the most economical responses to added fertilizer N will be when N is applied at about 100 lb/A.
- If you use a two-cutting system, split your N application and apply about two-thirds of the N in early May for the first cutting and one-third after the first cutting.
- Fertilizer N is taken up rapidly by grasses. In order to get maximum yields, do not graze mountain meadows in the late spring.
- If legumes are present, P fertilization can increase not only yield but also protein content of the hay, by stimulating legume growth.
- Phosphorus fertilization has a good residual effect and can affect plant growth for several years. Remember, supplying other needed nutrients such as P, K and S helps improve N use efficiency and overall meadow profitability. ■

"Profitable High Plains Cotton Production" — Video Available

A VIDEOTAPE targeted specifically for cotton producers in the Texas High Plains is now available from Texas Tech University. The 70-minute program features nine separate segments emphasizing new research and new production techniques, notes James R. Supak, Texas Agricultural Extension Service (TAEX) cotton specialist. About one-fourth of U.S. cotton production is grown in the region.

Information in the program was written and presented by experts on the various topics. The video project is a joint effort including TAEX, the Texas Agricultural Experiment Station, Texas Tech University College of Agricultural Sciences and USDA-ARS. The Foundation for Agronomic Research (FAR) funded the video project.

For more information or to obtain a VHS copy, write to: Cotton Video, Texas Tech, News and Publications, Broadcast Bureau, Lubbock, TX 79409-2022. A $10.00 check payable to Texas Tech University covers the cost of the videotape and postage. ■

Information Materials from PPI

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Capitalizing on Opportunities for 1990
Building and/or maintaining soil fertility, especially for phosphorus (P) and potassium (K), continues to make good economic sense. This new folder gives clear, concise suggestions on managing for crop profits. **Cost: 20¢ (MC* 10¢)**

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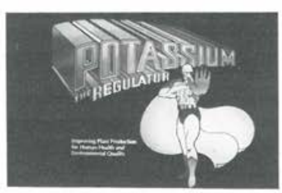

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