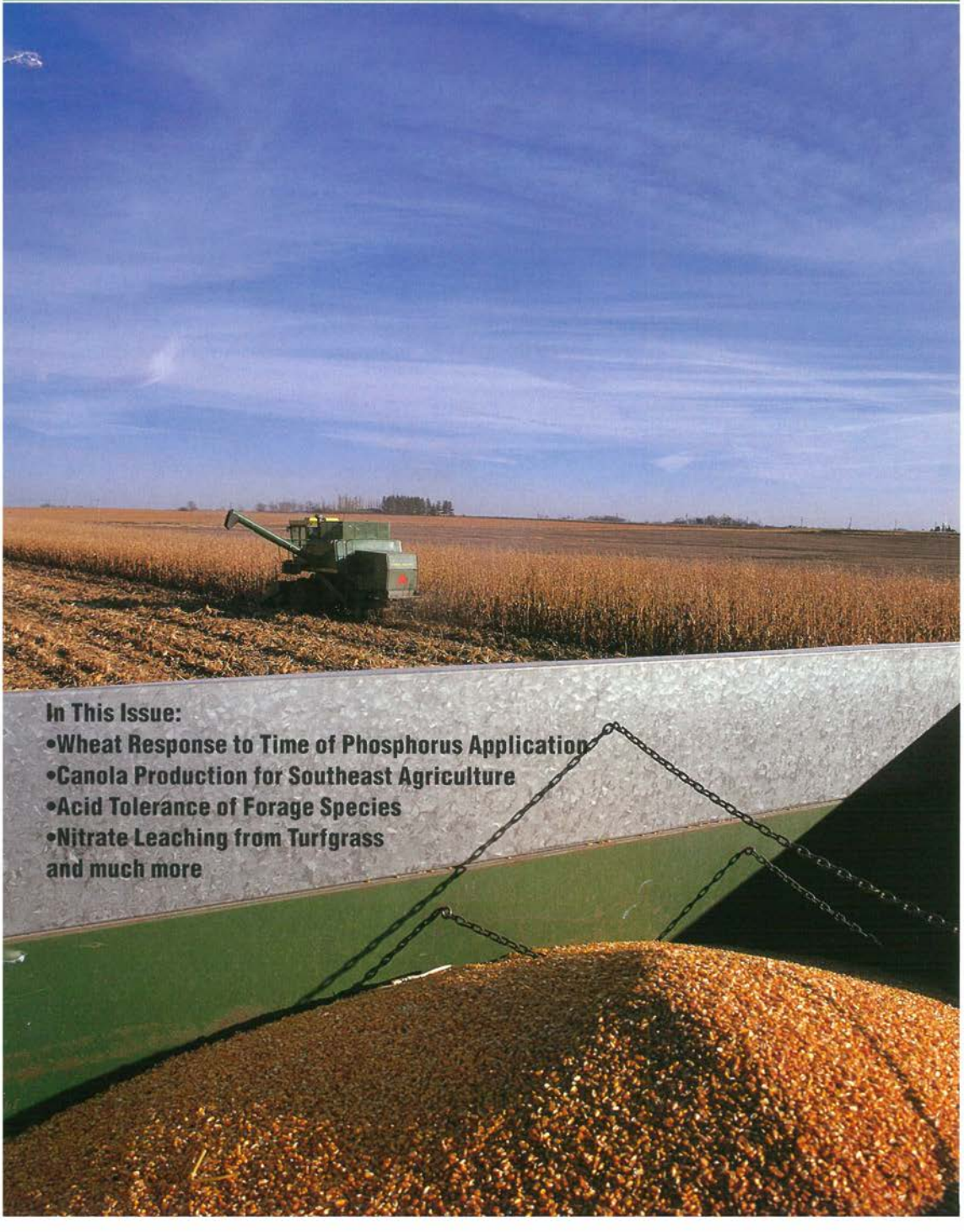
BETTER CROPS
WITH PLANT FOOD

Fall 1993



In This Issue:

- Wheat Response to Time of Phosphorus Application
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- Acid Tolerance of Forage Species
- Nitrate Leaching from Turfgrass

and much more

BETTER CROPS With Plant Food

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Contents

Our Cover: Corn harvest in the Midwest.
Photo credit: Thomas Hovland from Grant Heilman

C.S. Hoffman Elected Chairman, C.E. Childers Vice Chairman of PPI and FAR Boards of Directors

C. STEVE HOFFMAN, Senior Vice President-Marketing, of IMC Fertilizer Group, Inc., has been elected Chairman of the Potash & Phosphate Institute (PPI) Board of Directors. He will also serve as Chairman of the Foundation for Agronomic Research (FAR). Charles E. "Chuck" Childers, Chairman, President and CEO of Potash Corporation of Saskatchewan Inc. (PCS), is the new Vice Chairman of the PPI and FAR Boards.

"We sincerely welcome Steve Hoffman and Chuck Childers to their new leadership responsibilities with the PPI and FAR Boards," said Dr. David W. Dibb, PPI President.

Mr. Hoffman, in his present assignment with IMC Fertilizer Group, Inc., is responsible for worldwide sales of potash fertilizers, phosphate rock materials and phosphate chemicals. He joined IMC's Industrial Chemicals Division in 1974. From 1975 to 1978 he was a Field Sales Representative and in 1978 was promoted to District Sales Manager. In 1982, he joined IMC's International Division as Manager, Latin America. He served as Vice President, Domestic Wholesale Marketing in 1989 and 1990, and later as Senior Vice President-Sales.

C.S. Hoffman

A native of Pittsburg, TX, Mr. Hoffman is a 1971 graduate of Stephen F. Austin State University with a Bachelor of Arts degree in business administration. He is currently on the Board of Directors of the Phosphate Chemicals Export Association, the Phosphate Rock Export Association and the Canadian Potash Export Association (Canpotex Limited).

Mr. Childers became President and CEO of PCS in 1987 and was elected Chairman in 1990. He has served as Chairman of Canpotex Limited and also served on the Board of Saskatchewan Potash Producers Association, including two terms as Chairman. He is a member of the Executive Management Group of the International Fertilizer Association (IFA), the American Institute of Mining Engineers, and the Canadian Institute of Mining. Mr. Childers is a member of the executive committee of the Fertilizer Industry Advisory Committee (FIAC) and is currently Chairman of the Board of The Fertilizer Institute (TFI).

C.E. Childers

Mr. Childers graduated from the University of Illinois with a Bachelor of Science Degree in Mine Engineering. He began his career with Duval Corporation in Carlsbad, NM, and subsequently joined International Minerals & Chemical Corporation (IMC). At IMC, he held various senior positions before joining PCS as President and CEO.

In other action of the PPI Board, Mr. John U. Huber, President, Kalium Chemicals, Ltd., was elected Chairman of the Finance Committee. Mr. Jochen Witt of Potash Company of Canada Limited and Mr. Robert F. Clark of Great Salt Lake Minerals Corporation were named to the PPI Board. New members of the FAR Board are Mr. Charles R. Gibson of FirstMiss Fertilizer, Inc., Mr. Barry R. Jarrett of Helena Chemical Company, and Dr. Robert L. Westerman of Oklahoma State University. ■

North Dakota

Flaxseed Is High in Potassium for Human Nutrition

By Jack F. Carter

The potassium (K) content of many grains is not well known in the human nutrition and medical community. Flaxseed is very high in K, much higher than banana on a dry matter basis. The consumption of ground flaxseed and cold-pressed flaxseed oil in baked products and other foods is increasing, adding an important source of K for human nutrition.

WHOLE and ground flaxseed and cold-pressed flaxseed oil are being consumed increasingly by people primarily because of their high content of the omega 3 oil, alpha linolenic acid, and dietary fiber. Flaxseed contains about 35 percent oil, of which 55 percent is alpha linolenic acid, the omega "fish oil" type. About 35 to 40 percent of flaxseed is dietary fiber, of which 10 percent actually is soluble fiber, partially mucilage in the seedcoat. The omega 3 oil and the fiber have the apparent nutritional benefits associated commonly with these two components. Ground flaxseed is consumed either in baked goods, in fruit juice drinks, or sprinkled on cold cereals, salads and other foods.

Data in **Table 1** compare the K content of flaxseed to other foods commonly suggested as good sources of K, including raw banana.

Table 1. Potassium concentrations in selected foods.

Food	K concentration (as is water content), %	Normal water content of product, %
Raw banana	0.39	75
Orange juice	0.20	88
Whole potato, baked	0.42	91
Green beans, frozen	0.11	92
Apple, fresh	0.10	90
Milk, 2%	0.15	89
Flaxseed	0.56-0.92	4
Oatmeal	0.40	4
Oat bran cereal	0.65	4

From USDA and other sources.

(continued on next page)

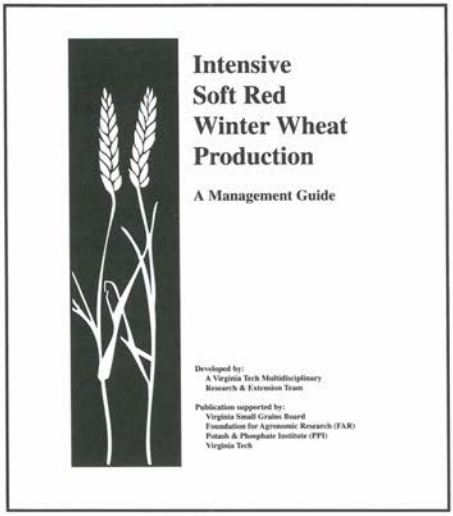
FLAX plants have a characteristic blue flower. The mature seed contains a surprisingly high concentration of K and offers some benefits in human nutrition.

Dr. Carter is Professor Emeritus of Agronomy and President of the Flax Institute, North Dakota State University, Fargo, ND 58102.

Virginia

New Publication, Video and Educational Programs for Intensive Wheat Management

VIRGINIA TECH scientists, in cooperation with the Potash & Phosphate Institute (PPI) and the Foundation for Agronomic Research (FAR), have introduced a new publication and video which give step-by-step guidelines for intensive management of soft red winter wheat. The new guide and video cover the yield-building factors of precision planting, variety selection, plant nutrition and tramline establishment, as well as the yield-protecting factors of pest management, lodging control and harvest considerations. The four-color management guide gives details on growth stages and the importance of their use in successful intensive wheat production. The guide and video are available from Virginia Tech.



To supplement the new educational materials, the Virginia Tech research and Extension team is offering an intensive wheat management training series via satellite TV. The first broadcast, on September 29, covered precision planting and fall management considerations. There were more than 40 known down-link locations in seven states which viewed the telecast. Individuals with access to a satellite dish also participated. Future broadcasts will be on January 12 and March 30 at 8:30 a.m., Eastern Standard Time. The coordinates for the broadcast are C-Band, Telstar 301, and Channel 19. For further information contact, Dr. Bill Griffith, Eastern Director, PPI, at (703) 450-4835.

The publication, *Intensive Soft Red Winter Wheat Production – A Management Guide* (No. 424-803), and the videotape are available for purchase at $15.00 each. As a set, in a 3-ring binder, the purchase price is $25.00 which includes shipping. Checks payable to "Treasurer, Virginia Tech" should be sent with orders to:

Virginia Tech Cooperative Extension
Distribution Center
112 Lansdowne Street
Blacksburg, VA 24061-0512
Telephone (703) 231-6192. ■

Flaxseed . . . from page 4

The high K content of flaxseed relative to human nutrition has been recognized by some of the medical profession, especially some cardiologists, based on their concept of the importance of K in the blood electrolyte system.

A review article, "Flaxseed in Human Nutrition," including a discussion of K in flaxseed, appears in the October 1993 issue of *Cereal Foods World,* a publication of the American Association of Cereal Chemists. ■

Fertilization and Legumes Influence Spring Wheat Yield Trends

By C.A. Campbell, G.P. Lafond and R.P. Zentner

A 34-year crop rotation study on a heavy textured thin Black Chernozem soil in Saskatchewan has shown that adequate fertilization with nitrogen (N) and phosphorus (P) is necessary to sustain long-term yields of spring wheat. Using a legume green manure in a 3-year wheat rotation produces better yields than fallow in unfertilized systems, but cannot sustain long-term yields because the green manure provides no P.

CAN LONG-TERM cereal yields be maintained without proper fertilization? Can legumes replace N fertilizers? The relative benefits and environmental impacts of fertilizers compared to legumes for maintenance of sustainable agriculture systems are important considerations.

A 34-year study (1958-1991) on a heavy textured, thin Black Chernozem soil at Indian Head, SK, has shown the long-term impact of fertilizer and legumes on spring wheat yield trends. This rotation study included fertilized (N and P) and unfertilized continuous wheat (Cont W) and fallow-wheat-wheat (F-W-W), and unfertilized sweet clover green manure-wheat-wheat (GM-W-W) cropping systems. Fertilizer N and P were applied according to general recommendations for the first 17 years and according to soil test recommendations thereafter. Soil test N rates in the latter period were triple that of the first 17 years, but P rates were generally similar for the two periods.

The positive influence of N and P fertilizers on yields of wheat grown on stubble is shown in **Figures 1 and 2**. The 34-year average fertilizer-induced rate of increase in wheat yield grown on stubble (wheat after wheat) was about 0.5 bu/A/year in both F-W-W and the Cont W rotations.

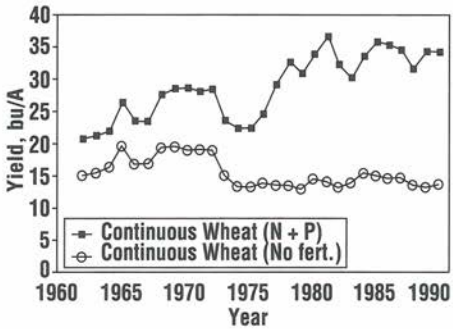


Figure 1. Yield trends of continuously grown hard red spring wheat as influenced by fertilizer. The points are 5-year running means. (Indian Head, SK).

The increasing difference between fertilized and unfertilized systems was partially due to an increase in N rate since 1978 when recommendations were based on soil tests and partially due to a gradual decline in natural soil fertility in the unfertilized system. The unfertilized F-W-W system had lower soil organic matter and less N-supplying power than the unfertilized Cont W system.

Legume green manure increased yields of wheat grown on stubble by an average of 6 bu/A more than the unfertilized F-W-W rotation (**Figure 2**) and supplied 56 percent more N, likely because of N fixa-

The authors are research scientists with Agriculture Canada, located at Swift Current Research Station, Saskatchewan, Canada.

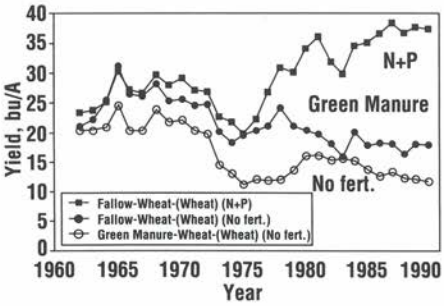


Figure 2. Yield trends of hard red spring wheat grown on stubble (wheat after wheat) in a fallow-wheat-wheat rotation, showing the influence of sweetclover green manure and of N + P fertilizer. The points are 5-year running means. (Indian Head, SK).

tion. Even so, the yield trends for wheat grown on stubble in this green manure system still declined at a rate of 0.39 bu/A/year. This downward trend was probably because legumes do not supply P, and more P was exported in the grain produced from this system.

When fertilized with N and P according to soil test recommendations, the F-W-W system maintained higher yields of wheat grown on stubble than the unfertilized GM-W-W system, indicating that the latter system is not sustainable. The lower yields in the GM-W-W system were related to lower soil test P. In 1991, that system had only half as much bicarbonate extractable P (Olsen-P) in the soil profile (0-4 ft) as the fertilized F-W-W system (i.e., 23 lb/A vs. 50 lb/A).

Summary

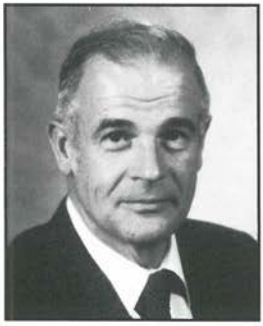
Replacing fallow with a legume green manure crop in a 3-year, unfertilized wheat rotation will produce higher wheat yields. However, neither fallow nor green manure will sustain wheat yields in the long-term without adequate fertilization, because neither system can meet the long-term P requirements of wheat. Proper fertilization with N and P can sustain and increase long-term wheat yields in both continuous- and fallow-wheat rotations. ■

Dr. J.D. Beaton Receives WCFA Award of Merit

THE Western Canada Fertilizer Association (WCFA) recently presented its Award of Merit to Dr. James D. Beaton, Senior Vice President, International Programs, of the Potash & Phosphate Institute (PPI) and President of the Potash & Phosphate Institute of Canada (PPIC). The recognition was given during the recent 1993 annual meeting and convention of WCFA.

The organization also welcomed PPIC as an affiliate member of WCFA, recognizing several years of cooperation.

A native of British Columbia, Dr. Beaton earned his B.S.A. and M.S.A. degrees from the University of British Columbia and gained his Ph.D. at Utah State University. He later worked as a researcher with Agriculture Canada, as an industry agronomist, and then as Chief Agronomist with The Sulphur Institute.



Dr. Beaton

He joined the staff of PPI/PPIC in 1978 as Western Canada and Northwest U.S. Director. In 1988, Dr. Beaton was named Vice President, International Programs, PPI, and President, PPIC. He served two terms as WCFA President, in 1977-78 and 1978-79.

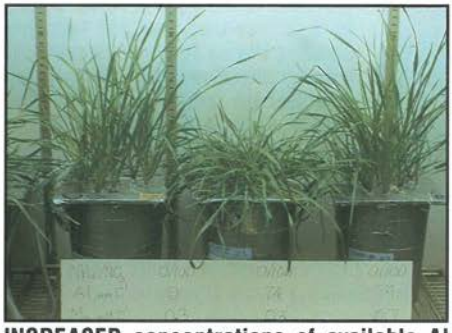
Dr. Beaton is co-author of the widely used textbook, *Soil Fertility and Fertilizers*, now in its fifth edition. ■

Acid Tolerance of Forage Species

By D. L. Robinson, A. E. Castillo and T. Kong

Louisiana studies have emphasized the varying sensitivity of cool-season and warm-season forage species to soil acidity and exchangeable soil aluminum (Al). Liming to reduce soil acidity and lower exchangeable Al is a crucial forage best management practice that has dramatic effects on the growth of most species, particularly legumes.

IN THE SOUTHEASTERN U.S., a wide variety of forage species is important for livestock production, many grown on highly acid soils. While some forage grasses are rather acid tolerant, many legumes are sensitive to high levels of soluble and exchangeable Al, the major factor restricting root growth and crop yields in acid soils. Yet, there is a continual interest in expanding legume production in order to increase forage quality and resultant animal productivity while reducing the use of nitrogen (N) fertilizers. If forage legumes or grasses are to be grown successfully on highly acid soils, their relative acid tolerance should be known so lime needs can be met as efficiently and economically as possible.



INCREASED concentrations of available Al associated with low soil pH dramatically decrease growth of annual ryegrass and other forages. From left to right, Al concentration in the pots was 0, 74 and 74 μmol/liter. Increased concentrations of available magnesium (Mg), however, offset the negative effects of Al. Magnesium concentrations left to right were 0.3, 0.3 and 0.7 mmol/liter.

Louisiana Studies

At Louisiana State University we conducted a greenhouse study to evaluate the relative Al tolerance of various forage grasses and legumes. A highly acid Stough fine sandy loam soil of the Flatwoods area with high levels of exchangeable Al and relatively low levels of soluble iron (Fe) and manganese (Mn) was selected. Thus acid soil toxicities could be attributed to exchangeable Al levels. Seven species of cool-season forages were grown at six levels of lime application: 0, 1.5, 3, 6, 12 and 24 tons/A. The experiment was repeated with seven warm-season species. Forage yields were then related to the resulting soil pH values and exchangeable Al levels.

Cool-Season Forage Yields

Forage yields clearly showed that Marshall ryegrass was more tolerant of a wide range in soil pH and Al values than were the clovers. It also produced about twice the maximum yield (**Table 1**). Ryegrass yield at pH 4.6 and 111 parts per million (ppm) Al where no lime was applied was only 21 percent of the maximum yield, while yields at all other pH values ranged from 78 to 96

Dr. Robinson is Professor and Dr. Kong is Research Associate at Louisiana State University, Baton Rouge. Ms. Castillo is in Agronomic Sciences at the National University of the Northeast, Corrientes, Argentina.

Table 1. Effects of soil pH and soil exchangeable Al on yields of cool-season forage species.

Soil pH	Soil Al, ppm	Ryegrass MRG[1]	Clovers OSC	S-1	SUB	DIX	CHF	BBS
		grams/pot						
4.6	111	2.1d	0.2c	0.0c	0.1c	0.0c	0.0d	0.0c
4.7	77	8.5bc	2.4b	2.8b	3.3b	1.9b	1.3c	1.5b
5.2	36	10.2a	4.6a	4.8a	5.7a	5.8a	5.2a	3.8a
6.2	< 2	9.1abc	4.6a	4.2ab	3.9b	6.1a	4.2b	3.1a
7.5	< 1	9.8ab	0.8c	0.7c	0.1c	0.2c	0.0d	0.2c
7.8	< 1	8.0c	0.5c	0.6c	0.1c	0.1c	0.1d	0.2c

[1]MRG = Marshall ryegrass; Clovers: OSC = Osceola white; S-1 = La S-1 white; SUB = Mt. Barker subterranean; DIX = Dixie crimson; CHF = Chief crimson; and BBS = Bigbee berseem.

Table 2. Effects of soil pH and soil exchangeable Al on yields of warm-season forage species.

Soil pH	Soil Al, ppm	Grasses COM[1]	DAL	BAH	Legumes AES	SER	176	ALY
		grams/pot						
4.4	91	18.4ab	13.6b	14.9ab	2.8a	0.0b	0.4b	0.2c
4.5	59	18.3ab	16.8a	16.4a	2.8a	3.8a	2.5a	2.2b
4.8	39	20.1a	15.2ab	15.3a	3.4a	4.7a	3.0a	2.4b
5.7	4	15.8b	15.6ab	12.8b	4.6a	4.8a	3.8a	5.8a
7.2	<1	18.8a	5.4c	1.9c	0.7b	0.0b	0.3b	0.1c
7.6	<1	19.3a	0.7d	0.0c	0.0b	0.0b	0.0b	0.0b

[1]COM = common bermudagrass; DAL = dallisgrass; BAH = Pensacola bahiagrass; AES = Aeschynomene; SER = Serala lespedeza; 176 = Interstate 76 lespedeza; and ALY = alyce clover.

percent of the maximum yield. All cool-season species produced the highest yield at pH 5.2 and 36 ppm Al, except Dixie crimson clover, which produced the highest yield at pH 6.2 and 1 ppm Al. However, Dixie produced 95 percent of the maximum yield at pH 5.2.

Mt. Barker subterranean and Chief crimson were the only clovers that produced significantly less forage at pH 6.2 than at pH 5.2. The most Al-tolerant clovers were Mt. Barker subterranean, Osceola white, and La S-1 white, which still produced 53 to 59 percent of their maximum yields at pH 4.7 and 77 ppm Al. The crimson clovers and Bigbee berseem clover were least Al tolerant and produced only 24 to 40 percent of maximum yield at 77 ppm Al.

The surprisingly high levels of Al tolerance of all the cool-season clovers are possibly related to the high organic matter content (3.9 percent) in this soil. None of the cool-season clovers produced acceptable yields without lime application at pH 4.6 and 111 ppm Al or at pH values above 7.0.

Warm-Season Forage Yields

Warm-season forage grasses were much higher yielding and more Al tolerant than were the forage legumes (**Table 2**). Common bermudagrass produced satisfactory yields over the entire pH range from 4.4 to 7.6, with Al levels up to 91 ppm.

Dallisgrass and bahiagrass each produced maximum yields at pH 4.5 and 59 ppm Al and showed very little yield fluctuations at other acid pH values. Dallisgrass produced 81 percent of maximum yield at pH 4.4 and 91 ppm Al, and bahiagrass produced 78 percent of maximum yield at pH 5.7 and 4 ppm Al, both yields being significantly lower than the maximum yield. Other yield differences of either species were not significant at acid pH values. Neither grass produced acceptable yields at pH values above 7, although dallisgrass appeared somewhat more alkaline tolerant than did bahiagrass.

Each of the warm-season forage legumes produced the maximum yield at pH 5.7 and 4 ppm Al. Aeschynomene

(continued on page 11)

Liming Acid Soils Is Essential for Ryegrass Forage Production

By M.M. Eichhorn and Paul Bell

Louisiana field research indicates the importance of liming to correct soil acidity for ryegrass forage production. Substantial differences in varietal responses to soil acidity and liming were recorded.

THE EFFECTS of soil acidity on seven varieties of ryegrass were studied at the Hill Farm Research Station at Homer, LA. Initial soil pH at the test site was 4.2. Exchangeable aluminum (Al) was 118 parts per million (ppm) on the control plots at the outset of the study (**Table 1**).

Table 1. Effects of agricultural limestone on soil pH and soil chemical properties.

Lime rate, tons/A	Before cropping Aug '92	Before harvest Nov '92	After harvest May '93	Prior to planting Aug '93
	---------- Soil pH ----------			
0	4.2	4.0	3.8	3.8
1	4.1	4.4	4.4	4.4
2	3.9	5.2	4.9	4.9
4	3.9	5.9	5.8	5.7
8	4.1	6.6	6.5	6.6
	------- Exchangeable Ca, ppm -------			
0	162	79	82	83
2	81	414	384	424
8	100	1,021	1,051	1,117
	-------- Exchangeable Al, ppm --------			
0	118	106	83	114
2	91	24	24	26
8	91	2	1	3

Fine, high quality agricultural lime (100.2 percent effective calcium carbonate equivalent) was applied at rates of 1, 2, 4 and 8 tons/A in August 1992 and incorporated to a depth of 6 inches. Ryegrass was drill-seeded in October 1992. The crop received nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) fertilization in four applications for total rates of 328 lb/A N, 162 lb/A P_2O_5, 464 lb/A K_2O and 72 lb/A S. The ryegrass was harvested seven times in the October 1992 to May 1993 growing season: December 1, February 1, February 24, March 25, April 13, May 3 and May 26.

Significant Results

Soil pH values were increased by all rates, but lime application at 8 tons/A was required to raise the soil pH to 6.5 (**Table 1**). Liming substantially increased exchangeable calcium (Ca) and lowered exchangeable Al, which contributed to significant forage yield responses at the lowest rate of lime application (**Table 2**).

Table 2. Effects of liming on Marshall ryegrass dry matter yields.

Lime rate, tons/A	Dry matter, lb/A --------- Harvest --------- 1	3	5	7	Total of 7 harvests
0	0	124	819	283	2,812
1	658	869	1,519	673	8,723
2	709	936	1,606	719	9,672
4	868	757	1,679	646	8,142
8	793	821	1,678	914	8,828

Low soil pH delayed harvests and reduced yields. None of the seven varieties produced harvestable forage on the acid control plots at the first harvest

Dr. Eichhorn is Professor of Agronomy, LSU Agricultural Center, Hill Farm Research Station, Homer, LA; Dr. Bell is Assistant Professor, Dept. of Agronomy, LSU Agricultural Center, Baton Rouge, LA.

GROWTH of ryegrass was severely limited where no lime was applied (at left). Plot shown at right received 1 ton/A lime application, which increased yield and soil pH.

date. In contrast, Marshall variety produced 658 lb/A dry matter at first harvest on plots receiving 1 ton/A lime and 868 lb/A on the 4 tons/A lime plots. Marshall, Tetragold, Surrey and Jackson varieties produced significantly higher yields with liming than did Gulf, Florida 80 and TXR-91-A7EF.

Summary

Fall applications of good quality agricultural lime to acid soils prior to ryegrass seeding is an important management practice for acceptable forage yields. Liming increased soil pH, increased exchangeable Ca, lowered exchangeable Al, advanced forage harvest and increased yields. ■

Acid Tolerance . . . from page 9

was the most Al-tolerant legume in that it produced 60 percent of the maximum yield at pH 4.4 and 91 ppm Al, while other legumes produced very little growth at that Al level. However, Serala lespedeza produced more growth at 39 and 59 ppm Al than did aeschynomene. Serala also produced more growth than did Interstate 76 lespedeza at all Al levels. Alyce clover was the least Al-tolerant species, producing only 41 and 38 percent of maximum yield at 39 and 59 ppm Al. None of the legumes produced significant growth at pH values above 7.

Summary

Common bermudagrass and Marshall ryegrass were both tolerant of highly acid and alkaline soil, although ryegrass yield was severely depressed at pH 4.6 and 111 ppm of exchangeable Al. Dallisgrass and bahiagrass were highly Al tolerant, but yields were greatly reduced in alkaline soil. None of the legumes grew well at alkaline pH values. Cool-season clovers produced maximum yields at pH 5.2 and 36 ppm exchangeable Al while warm-season legumes, which are generally considered more acid tolerant, produced maximum yields at pH 5.7 and 4 ppm exchangeable Al. Reasons for these differences are being investigated. It is encouraging that legumes can be productive on this highly acid Flatwood soil with as little as 3 tons/A of applied lime. ■

Ohio

Study Shows Little Nitrate Leaching from Turfgrass on Fine Texture Soil

By Curt Geron, Karl Danneberger, Sam Traina, Terry Logan and John Street

Ohio studies indicate that soil disturbance during establishment is a primary source of nitrate-N (NO_3-N) in leachate from bluegrass turf. Nitrogen fertilization practices had little if any effect on NO_3-N leaching from established turf.

RECENTLY, NO_3-N leaching from turfgrass has been of concern due to increased desire to protect groundwater from surface contaminants. Studies have shown that quick release fertilizers, heavy irrigation and high rates of fertilizer nitrogen (N) on sandy soils can cause significant nitrate leaching losses from turfgrass.

However, many leaching studies have used a sand medium in order to easily observe differences in treatments. In addition, studies usually involved heavy rates of N fertilization and excessive irrigation. That resulted in data that were not representative of nitrate losses from turfgrass in most areas and under typical management schemes.

Ohio Studies

To meet the needs for more representative information, we established a study to determine loss of NO_3-N from a fine textured soil. Field experiments were conducted to determine the effects of Kentucky bluegrass (cultivar "Baron") establishment methods (sodded and seeded) on nitrate-N leaching. Additionally, late season fertilization practices were compared with a more traditional fertilization program. Moderate rates of slow release and quick release N fertilizers were also examined.

The rhizotron-lysimeter facility at The Ohio State University Turfgrass Research Center was utilized for this project. The rhizotron consists of lysimeters measuring 24 x 24 x 30 inches. A 1/4-inch thick sheet of porous polyethylene plastic at the base of each lysimeter allowed water and nutrients to percolate while preventing soil loss. Leachate from each lysimeter was collected in glass 5 gallon bottles.

For this study, twenty-eight lysimeters were filled with Miamian silt loam. The A, B and C horizons were mixed in equal volumes off-site to simulate land disturbances common in newly constructed turfgrass sites.

LYSIMETERS at Ohio State University provide the opportunity to study leaching of nutrients from turfgrass.

Mr. Geron is a former graduate assistant, Dept. of Agronomy; Drs. Danneberger, Traina and Street are Associate Professors of Agronomy, and Dr. Logan is Professor of Agronomy, The Ohio State University, Columbus, OH.

Maintenance programs simulated normal fertilizer practices utilized in the Midwest. Turfgrass was maintained at a 2-inch mowing height and grass clippings were returned to the plots. The plots were irrigated to prevent wilt. Irrigation did not result in percolation to collection depth except on one occasion.

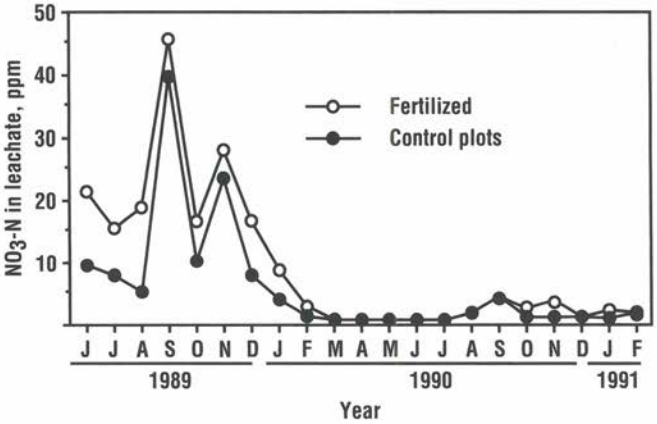


Figure 1. Nitrogen fertilization initially increased NO_3-N leaching from seeded bluegrass turf, but had little effect on NO_3-N leaching from established turf.

Fertilization treatments included a) spring/summer fertilization (SSF) involving N applications of 1.0, 1.0, 0.5, 1.0, and 1.0 lb/1,000 sq.ft. in April, June, July, August and September, respectively, and b) late season fertilization (LSF) which consisted of N applications of 0.5, 1.0, 0.5, 1.0, and 1.5 lb/1,000 sq.ft. in April, June, July, September and November, respectively. Nitrogen sources used were urea and resin coated urea, a slow release N source. Plots were seeded at a rate of 1.0 lb/1,000 sq.ft. and sod was cut to a depth of 1 inch and to the dimensions of the cells (May 1, 1989). Two sod plots and two seed plots were established for controls which received no fertilizer treatments throughout the study.

Fertilizer applications were made on the 15th of the month indicated. Following rain events, percolate volumes were measured and subsamples were removed and frozen until filtering and NO_3-N determinations could be completed. Rainfall was recorded and collected for NO_3-N analysis in order to determine the amount of NO_3-N supplied by rainfall.

Results

Percolate NO_3-N concentrations were high from June 1989 to March 1990 (year 1). Average nitrate-N concentrations for this period ranged from about 10 to 20 parts per million (ppm) NO_3-N depending upon treatments (**Figure 1**). During this time, the average percolate concentrations for all fertilized and unfertilized treatments exceeded 10 ppm NO_3-N (maximum concentration for drinking water standards). It is suspected that high levels of NO_3-N in percolates resulted from soil mixing when each lysimeter was filled. This soil disturbance stimulated degradation of organic matter and N mineralization. High N mineralization occurred since the soil was taken from a grassland high in organic N.

Lower NO_3-N concentrations in late winter of 1990 and early spring of 1990 indicated that the excessive mineralization of N due to soil disturbance had ceased and that the lysimeters had stabilized during the winter. Ninety-one percent of the precipitation events in the first year yielded percolate NO_3-N levels higher than drinking water standards; this dropped to 16 percent in the second year.

There are important factors related to soil disturbances which should be considered when land is being developed for golf courses, real estate or any other uses. Soil disturbance in golf course or housing development could result in temporary high losses of NO_3-N, higher than would be observed on a mature site. However, the long-term effect of NO_3-N contamination of the environment is minimal. Evidence from this study indicates that high losses of

WITH appropriate fertilization and other typical management practices, there is generally no threat to groundwater from nutrients leaching where established lawns are on fine-textured soils.

NO_3-N will subside in approximately one year. Data for the second year are more representative of a stable turfgrass environment. Average concentrations on treated plots ranged from about 1 to 4 ppm NO_3-N.

The greatest NO_3-N leaching occurred during late summer and early fall. Highest leachate mean NO_3-N concentrations (above 10 ppm) occurred in sodded plots in September. Seeded treatments also generated higher percolate NO_3-N concentrations from August to November.

These high NO_3-N leachate levels in early autumn occurred after substantial N fertilizer applications in June, July, August and September. However, NO_3-N losses cannot be attributed to these applications alone since maximum leaching losses in the control plots were also recorded during late summer and early fall, suggesting a high rate of mineralization or organic N and less NO_3-N uptake during these warm months.

Seed versus Sod. High concentrations of NO_3-N in leachate immediately after establishment were not surprising. More NO_3-N leached from seeded than sodded turf during the first summer of the study. Percolates from seed and sod turfgrass averaged 16 and 9.5 ppm NO_3-N, respectively.

Percolate NO_3-N concentrations from seed and sod plots were similar from September through December of 1989, but concentrations from sod turf began to exceed seed turf during the winter months of 1990. Nitrate-N leaching from sodded plots remained higher throughout the remainder of the study.

Root measurements at the termination of the leaching study showed greater root mass in the top 15 in. of soil under seeded turf. These data suggest that root penetration in sodded turf was inhibited at the sod-soil interface, restricting rooting in the soil below. This may account for greater leaching losses of NO_3-N under sodded turf, since it is likely that less N was intercepted by the restricted root system. It is important to note that even though NO_3-N losses in sodded plots were higher than seeded plots, mean NO_3-N concentrations were well below drinking water standards.

During most of the study, percolate NO_3-N concentrations were not affected by the use of resin coated urea. Leachates from urea were slightly higher in NO_3-N during the second winter of the study. Our study showed that N source does not affect NO_3-N loss in turfgrass.

Late Season versus Traditional Fertilization. All fertilizer applications in the spring-summer fertilization (SSF) program were made between April and September. The late season fertilization (LSF) program included an application of approximately one-third of the annual N during November. The only period where LSF impacted NO_3-N concentrations was during the winter of 1991 when average leachate NO_3-N concentrations were slightly higher, 3 and 2 ppm LSF and SSF, respectively. In effect, LSF had little or no impact on groundwater quality.

Summary

The highest concentrations of NO_3-N leaching from turfgrass resulted from

Crop Removal of Chloride

By P.E. Fixen

IT IS OFTEN useful to farmers and their advisors to be able to estimate the amount of chloride (Cl) removed in harvested crops. Crop removal and leaching below the root zone are the only significant losses of Cl from cropping systems.

Table 1 below indicates that very little Cl is removed in grain. For example, a 60 bu/A wheat crop removes less than 2 lb of Cl in the grain. Harvest of grain and straw (assuming the straw hasn't been rained on extensively) could remove 10 to 30 lb/A, depending on soil level and the level of Cl applied.

Plant material with a high water content at harvest usually contains substantial amounts of Cl. A 6 ton/A alfalfa crop would remove approximately 45 lb of Cl using the levels in the table. Soil or applied Cl levels can markedly alter Cl removal in forage crops. Plant analysis is the only means of accurately determining removal.

The removal values in **Table 1** are based on limited data and should be viewed as rough estimates only. For further information on the subject, a review of the references listed below is suggested. ■

Table 1. Chloride removal by selected crops.

Crop	Plant part	Cl content	Reference
Alfalfa	Shoot	7.6 lb/ton (dry wt)	NRC, 1981
Barley	Grain	0.024 lb/bu[1]	Fixen, 1993
Potatoes	Tubers	0.06 lb/cwt	Saffigna et al., 1977
Sweet clover	Shoot	7.4 lb/ton (dry wt)	NRC, 1981
Wheat	Grain	0.026 lb/bu	Fixen, 1993
Wheat	Grain + straw		Schumacher, 1988
	Low soil Cl	0.17 lb/bu	
	High soil Cl	0.44 lb/bu	

[1]Calculated using same concentration as wheat.

Fixen, P.E. 1993. Crop response to chloride. In (Sparks, D.L. ed.) Advances in Agronomy, Vol. 50. p. 107–150. Academic Press, Inc. San Diego, CA.

National Research Council (NRC). 1981. US/Canada tables of feed composition. National Academy Press. 2101 Constitution Ave. NW. Washington, DC 20418.

Saffigna, P.G., D.R. Kenney and C.B. Tanner. 1977. Nitrogen, chloride, and water balance with irrigated Russet Burbank potatoes in a sandy soil. Agron. J. 69:251–257.

Schumacher, W.K. 1988. Residual effects of chloride fertilization on selected plant and soil parameters. MS Thesis, South Dakota State University.

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soil disturbance during establishment. Soil disturbance stimulates organic matter degradation and N mineralization.

After sod establishment, percolate NO_3-N concentrations decreased to levels well below drinking water standards, indicating that N fertilizers applied to mature, undisturbed turf are generally no threat to groundwater quality.

Highest percolate NO_3-N concentrations in late summer and early autumn are probably due to diminished root initiation and elongation and less plant uptake of N during this time of year. Seasonal variation in climate is likely to have more effect on nitrate leaching than fertilization treatments.

Although establishment method, fertilization program and N source treatment effects were significantly different, percolate NO_3-N concentrations from established turf were well below the current drinking water standard of 10 ppm NO_3-N. ■

Canola Production for Southeast Agriculture

By N.R. Usherwood

Canola presents some interesting opportunities as a new crop for the southeastern U.S. Reasons for interest in the crop and some critical aspects of canola management are presented.

FARMERS in North America produce food for themselves and more than 100 others. Such productivity provides a major dividend to every consumer. It allows U.S. and Canadian families to spend less than 12 percent of their take-home pay for food. It provides a dependable and abundant variety of safe and high quality food.

Yet, even with such productivity, many farmers are in a struggle for economic survival. There are several reasons. Crop yields rise or fall due to external influences such as climate. Farmers have limited control over the number of acres that can be planted to major crops and even less over the market value of their products. To cope with these challenges, farmers are searching for innovative and creative ways to: 1) improve productivity, 2) lower the unit cost of production, 3) become more skilled at marketing, and 4) evaluate and develop the potential of crops such as canola.

Canola Background

Canola is an internationally registered trademark of the Canola Council of Canada. Canola is a type of rapeseed which has been modified by plant breeders to lower the content of erucic acid in the oil and of glucosinolates in the meal. These modifications have resulted in a type of rapeseed having oil satisfactory for consumption by humans and meal acceptable for use as a feed protein source for poultry and livestock.

Canola is a member of the mustard family of plants which includes turnips, radishes and cabbage. All of these crops contain high concentrations of the amino acids which contain sulfur (S), creating a high crop demand for S, nitrogen (N) and potassium (K). Each of these nutrients is essential for plant protein synthesis.

The seed contains 40 to 45 percent oil on a dry weight basis. This cholesterol-free vegetable oil contains only 6 percent saturated fat and is in growing demand for human consumption. Other high quality cholesterol-free vegetable oils such as soybean, peanut, cottonseed, corn and olive contain from 11 to 27 percent saturated fat. Canola meal contains about 35 percent crude protein and is well-suited for use in livestock and poultry feed.

Canola, a cool season annual, fits well as a winter crop in the southeastern U.S. and other areas where doublecropping can be practiced. It serves as a companion crop with wheat, triticale and other small grains and fits well with soybeans, grain, millet, tropical corn or other summer crops in doublecrop systems.

Rapeseed is an established major crop in Asia and Europe. In North America, Canadian farmers are the major producers of canola with about 10 million acres grown each year. Less than 200,000 acres are harvested in the U.S. However, some anticipate rapid adoption of the crop. Predictions are that canola could develop into a multi-million acre crop within the next 10 years.

Interest in canola production in the U.S. began in earnest when low glucosinolate varieties containing less than 2 percent erucic acid were developed. Then, in 1985, the U.S. Food and Drug Administration (FDA) approved canola as a source of

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CANOLA plants are shown at bolting stage.

CANOLA varieties at flowering.

MATURING canola seed pods.

vegetable oil for human consumption. Scientists in industry, university and government have recently devoted more attention to establishing science-based best management practices (BMPs) for improving crop yield, quality and profitability.

Canola Responds to Good Management

Canola is a first class crop deserving first class production management. It is "equipment friendly" . . . requiring the same planting and harvesting equipment as wheat, but with some adjustments. It responds well to production inputs such as N, phosphorus (P), K, S and boron (B).

Expectations from canola during the first few years of production should be realistic. Yields will improve and production problems will decline as experience is gained with growing, harvesting, storing and marketing this new crop. With most alternative crops, a grower will initially know little about its production and marketing and can become discouraged if the crop is not highly profitable. This problem can be overcome, however, if the producer recognizes the critical nature of timeliness in certain BMPs.

BMPs for Canola

Variety Selection. Review canola variety performance results from regional field trials. Select and plant two or more of the best varieties based upon disease resistance, cold temperature requirement for flowering, seedling vigor, grain yield potential, seed oil percentage, seed shatter at harvest, and winter hardiness.

Field Selection. Select a well-drained, fertile soil which has not been planted to canola for the past three years. Avoid fields heavily infested with weeds such as wild mustard, garlic or radish. Make a major effort to control these weeds in the crop grown just prior to canola.

Soil and Seedbed Preparation. Soil test and then incorporate lime and build-up P and K into the root zone for optimum soil water and nutrient use efficiency. A firm, well-prepared seedbed is needed for canola. Remember, the seed is small . . . about the size of alfalfa. Avoid tillage that causes soil compaction which restricts seedling root growth.

Crop Establishment. Getting a good stand of canola is a top priority. It depends on several practices. Seed treatment with a fungicide is essential. The planting window is narrow and critical for success, so check with your local Extension agent. Recent research suggests these guidelines:

- Be prepared to plant on time . . . Seed at a rate of about 5 to 7 lb/A.
- Drill seed one-half inch deep and in 7 to 8-inch rows.
- Use starter fertilizer to stimulate seedling growth.
- Prevent aphid damage to seedlings.
- Use packer wheels to firm the seedbed for soils without crusting problems.

Preliminary results look promising where seed is broadcast and lightly incorporated into soil with good moisture and fertility levels.

Fertilization and Liming. Soil testing continues to be the best tool for determining lime requirements and the availability of nutrients in the soil reservoir. Build and maintain soil fertility levels for P and K in the medium to high range. Georgia research indicates canola soils should be limed to pH of about 6.2 for optimum production.

Fertilizer needs for high-yielding canola can vary considerably from one field to another. The reasons vary, but soil fertility levels, total crop requirements, timeliness of application, nutrient interactions with other production practices, and response to climatic influences are all involved.

Total nutrient uptake data for canola are presented in **Table 1**. These quantities must be absorbed by the crop from soil reserves and fertilizer.

Table 1. Total nutrient uptake for canola and for wheat.

Yield level, bu/A	N	P_2O_5	K_2O	S
	----------	lb/A	----------	
Canola				
40	260	80	240	60
Wheat				
80	135	55	160	20

Timing fertilizer applications with specific nutrient requirements by growth stage is difficult. Another challenge is to make in-season adjustments to the fertilization program due to unpredictable climatic conditions. For canola growing on sandy soils subject to intense rainfall, special attention is needed for N, K, S and B . . . each is subject to partial loss from the root zone by leaching.

University field study results provide guidelines for optimum yield and nutrient use efficiency. For example, the guidelines might suggest a preplant application of about 40 lb N/A and all the P, K, S and B (except for sandy soils subject to leaching). Then, the remaining 120 to 140 lb N would be split, with half applied as plant growth begins in the spring and the remainder as plants begin to bolt. For the very sandy soils, K and B might be applied half preplant and the remainder with first growth in early spring. Canola is highly responsive to both S and B. About 30 lb S/A and 1 to 2 lb B/A should be adequate in most years.

Starter fertilizer is often recommended to get the crop off to a fast start and ahead of the weed competition. It stimulates early row closing which gives soil protection against loss by erosion. Another benefit is that P also improves plant winter hardiness and stand survival.

Economics

The economic outlook for canola is promising for growers who are willing to carefully study the market, adjust production practices, plant the crop on highly productive soils, and recognize the importance of timely operations.

Georgia scientists compared canola with wheat at two of the three canola production centers. Top canola varieties and good management practices resulted in profitable canola at all locations. As shown in **Table 2**, top varieties of canola yielded 47 bu/A and wheat 44.6 bu/A under comparable levels of production management. The total cost of production was $159 (canola) and $154 (wheat) per acre. Due to a higher market price, canola profitability was superior, with $64 per acre profit for canola and a loss of $20 for wheat.

Pest Control

Few chemicals have been cleared for weed control in canola. Trifluralin can be applied preplant and incorporated to control most winter annual grasses as well as chickweed and henbit.

Table 2. Production economics of canola and wheat.

	Canola[1]	Wheat[1]
Grain yield, bu/A	47.0	44.6
Market price, $/bu	4.75	3.00
Total prod. cost $/A	159	154
Gross income, $/A	223	134
Unit prod. cost, $/bu	3.38	3.46
Net profit, $/A	64	(-20)

[1]Canola average from three production centers, wheat average from two production centers in Georgia, 1992/93 growing season.

The major insect pests are aphids and cabbage seedpod weevil. Nematodes such as root knot can sometimes contribute to early stand loss. Healthy, well-nourished plants have the highest tolerance to such stress and can recover more quickly from injury by insects.

The soilborne diseases such as *Rhizoctonia solani* can sometimes cause damping-off problems when canola is planted after peanuts. Powdery mildew, *Sclerotinia* and *Alternaria* can also be a problem. Use only certified seed which is treated for seedborne diseases.

Summary

Canola production is expected to increase dramatically in the Southeast. There are several reasons for this view. Profitability of canola continues to be favorable and can improve with marketing and production experience. Equipment needs for canola and wheat are similar. Both crops have good fit into existing cropping systems. Consumer demand for canola oil continues to increase and now represents oil production from about 1.5 million acres. U.S. farmers produce less than one out of each five acres of canola needed in this country. New food labeling laws favor canola as a low saturated fat vegetable cooking oil. These reasons illustrate that increased strength exists not only in production but also in marketing and utilization of canola to supply consumer needs.

As farmers search for alternative crops with realistic profit potential, canola deserves an evaluation for best fit into the crop production system. Persons interested in furthering their knowledge of canola production should contact their local Extension specialist. A copy of the Proceedings of the First International Canola Conference (1990) may be obtained by contacting PPI Circulation Department, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2821. Cost is $15.00. ■

Alabama

Cotton Root Growth as Affected by Phosphorus Fertilizer Placement

GROWTH chamber studies were conducted to determine how cotton root growth is affected by the proportion of soil volume treated by fertilizer phosphorus (P). Cotton was grown in pots, using two soils: Dewey silty clay loam (low P) and Marvyn loamy sand (high P). Phosphorus was added at a constant base rate, but mixed with decreasing proportions of soil volume: 1.0, 0.5, 0.25 and 0.125.

Results showed that P uptake and root growth of cotton seedlings are affected by P placement. When a constant rate of P was applied per pot, P uptake by cotton shoots reached a maximum when 0.25 and 0.50 of the soil volume was treated with P on the Marvyn and Dewey soils, respectively. Root growth was also stimulated by fertilizer P, the degree of stimulation being similar for both soils. ■

Source: Mullins, G.L. 1993. *Fertilizer Research* 34: 23-26

Potassium Response on High-Potassium Soils Leads to New Soil Test

By Earl O. Skogley

Montana research over several decades has indicated that crop response to potassium (K) fertilization can occur on western soils that test very high in extractable K. A new resin soil test may be able to diagnose these K-responsive soils and improve the accuracy of response prediction for other nutrients as well.

DURING the early 1970s we studied the K response situation for Montana soils and crops. We did not expect many K responses on small grains and forages grown in this area. These crops have only moderate K requirements and nearly all Montana soils tested "high" in extractable K. We were amazed to discover that various crops responded from 25 to over 70 percent of the time when K was included in a balanced fertilizer program with nitrogen (N) and phosphorus (P). These responses were truly K responses, and not chloride (Cl) responses that have also been reported for some soils in this region.

Potassium Availability

Studies to develop an improved soil test for K revealed that no chemical extractant would provide values that related well to crop response in the field for our kinds of soils and climatic conditions. A search of the literature provided good clues to explain this lack of correlation. Two processes are responsible for most of the K that becomes plant-available . . . that is, K ions present at a plant root surface.

Water taken up by the plant contains dissolved K ions that are transported with the water, a process termed mass flow. With Montana conditions, generally no more than 50 percent of plant K is accounted for by this process. More K required by the plant must reach the plant root by diffusion movement of K ions in soil solution from areas of higher to areas of lower concentration. Because the plant root removes K from its immediate surroundings, K diffuses toward the root. Root extension into new soil volumes is also highly important, but mainly as it allows these other processes to be effective. Soil test results from chemical extraction relate mainly to exchangeable K . . . that K **may** become available . . . but they tell little about the processes that regulate K availability.

Improved Soil Test Correlations

We discovered that the best relationships between soil test values and crop response were provided by ion-exchange resin extraction of soil samples. A resin capsule method was developed to simplify this approach. Use of resin capsules allows diffusion-regulating characteristics of soils to be reflected in soil test values. Results also reflect K concentration in soil solution. This relates strongly to mass-flow of K to plant roots. Thus, this approach pro-

Dr. Skogley is Professor of Soil Science at Montana State University and President of UNIBEST, Inc., manufacturer and distributor of resin capsules for soil and environmental testing.

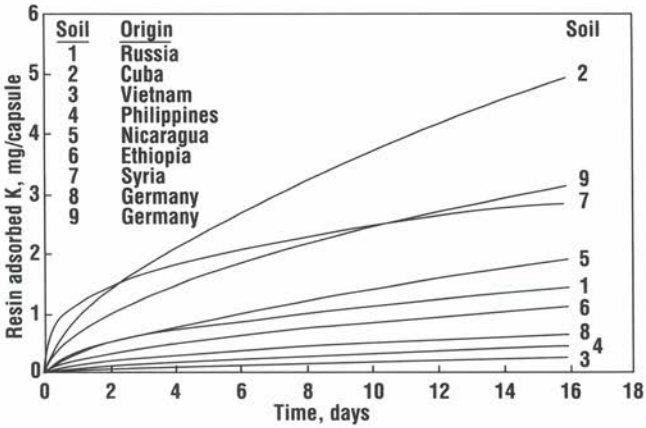

Figure 1. Resin adsorption of K from soils of worldwide origin.

vides a methodology that allows separation of soils based on their abilities to deliver K to growing plant roots.

Recent results from resin capsule extraction of soil samples from throughout the world indicate that this method works well on an extremely broad array of soils, ranging from coarse to fine textures and from calcareous to strongly acid soils (**Figure 1**). The K supplying capacity of these soils varies greatly, even though many have similar amounts of chemically extractable K.

While studying K, it quickly became obvious that the resin capsule approach could be developed to solve most of the problems inherent in chemical-extraction soil testing for other nutrients as well. The method is sensitive to processes that control availability at the plant root surface, so it provides more accurate values. By using mixed-bed (both cation and anion adsorbing) ion-exchange resins, a "universal" extractant is provided. The method works on soils of all natures, so it is possible to "standardize" soil testing, worldwide. Finally, field-fresh soil samples are used, with only pure water being added to the sample. Numerous error-prone steps in soil testing are eliminated by this simple methodology.

We have studied the methodology for K, P, N (both nitrate and ammonium are measured), sulfur (S), calcium (Ca), magnesium (Mg), sodium (Na), iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), boron (B), chloride (Cl), and some of the heavy-metal soil contaminants. Simultaneous, independent adsorption of these elements has been shown.

Data shown in **Figure 2** illustrate the sensitivity of the methodology to fertilizer management. In this experiment with rice, annual fertilizer applications were made, as indicated, for more than 20 years. Where no fertilizer was added on this low-P soil, available P remains low, but not as low as when N, or N plus K were added. Somewhat increased plant growth with these nutrients depletes the soil's already low supply of

(continued on page 23)

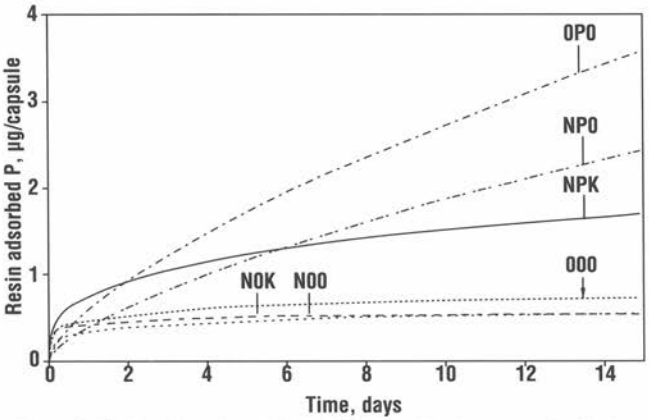

Figure 2. Resin adsorption of P as influenced by long-term fertilization.

Data for figures provided by Dr. A. Dobermann, International Rice Research Institute, Philippines.

Influence of Copper on Coastal Bermudagrass Forage Yield and Quality

By W.B. Gass, J.N. Pratt, D.B. Herd, H.D. Pennington and J.L. Sanders

Copper (Cu) is essential to the growth of plants, with the normal range of concentrations in plant tissue being 5 to 20 parts per million (ppm). Copper concentrations in plants normally do not increase appreciably before becoming toxic to normal plant growth. Even under conditions of Cu toxicity, most of the excess Cu accumulates in the roots, and very little is translocated to the aerial portion of the plant.

COPPER has been identified for many years as an essential nutrient for cattle. Nutritional requirements for beef cattle (NRC-1980) suggest dietary Cu levels of 8 ppm and a maximum tolerable level at 115 ppm. Copper deficiencies in animals are characterized by:

- Depressed growth . . . calves on pastures show poor response in weight gain and may appear wormy.
- Bone disorders – bone fractures can occur in rapidly growing young animals.
- De-pigmentation of hair . . . all hair may be affected, but usually hair around eyes and ears shows loss of color first. Angus may show a reddish-brown color, whereas Herefords may show a yellowish coloring.
- Diarrhea or scours.
- Greater disease susceptibility.

Many other symptoms may occur as Cu deficiency intensifies.

Research on Cu fertilization of Coastal bermudagrass in Texas has been conducted in an effort to meet dietary needs for Cu in grazing beef cattle. The following table shows the effects of Cu rates on Coastal bermudagrass yields at two different cuttings. Copper rates up to 4 lb/A (liquid banded on surface) did not have a significant effect on forage yield levels during this initial work on Cu fertilization (**Table 1**).

Editor's Note: **Dr. Willis B. Gass**, senior author of this article, died in an automobile accident near Bryan, TX, on October 8, 1993. The staff of the Potash & Phosphate Institute express our condolences to Dr. Gass' family and colleagues. His contributions to agricultural research and education in Texas and surrounding states will be sorely missed.

Table 1. Influence of Cu fertilization on Coastal bermuda yield.

Copper rate, lb/A	Yield per cutting, lb/A Cutting 1	Cutting 2	Total yield, lb/A
0	3,674	7,112	10,786
1	3,603	7,150	10,753
2	3,342	7,321	10,663
4	3,612	7,116	10,728

Lee County, C. Marek Farm (1992)
Liquid Cu banded on surface

Dr. Gass (deceased) was Extension Soil Fertility Specialist, Dr. Pratt is Extension Forage Specialist Emeritus, Dr. Herd is Extension Beef Cattle Specialist-Nutrition, and Dr. Pennington is Extension Soil Chemist, Texas Agricultural Extension Service, College Station, TX. Dr. Sanders is Great Plains/Southwest Director, Potash & Phosphate Institute, Stanley, KS.

Table 2. Influence of Cu fertilization on Cu levels in Coastal bermuda forage.

Copper rate, lb/A	Forage Cu concentrations, ppm Cutting 1	Cutting 2
0	6.1	5.7
1	17.3	23.9
2	23.6	8.4
4	47.1	15.2

Lee County, C. Marek Farm (1992)

Although the Cu levels reported in **Table 2** do not exceed the maximum tolerable Cu level suggested for beef cattle, the banded liquid Cu resulted in levels much higher than the normal ranges considered adequate in ruminant diets. There is a fine line between Cu deficiency and toxicity in both plants and animals. The 1 lb/A Cu rate increased Cu levels in the plant at the first and second cutting, and levels appear to be sufficient (but not toxic) for both Coastal bermudagrass and cattle under most conditions.

Summary

Copper is an important nutrient for both livestock and forage production. Although forage production may not be noticeably affected at a certain Cu level, the same level may be deficient for cattle production. Utilization of Cu in forages by the animal can also be negatively influenced by high levels of molybdenum (Mo), sulfur (S) and Iron (Fe). Further research is needed in order to investigate these interactions and their effects on forage and cattle production. ■

COPPER deficiency in cattle may include several symptoms, such as scouring and dull, dry hair. Black animals may show a reddish-brown color.

New Soil Test . . . from page 21

P. Where P was added over many years, but plant growth was limited by deficiencies of N or K, soil levels of P were very high. When a balanced N-P-K fertilizer program was used, the amount of P is moderate, reflecting a build-up of plant-available P, but not an excess, due to high plant yields and P removal by the crop. All of these effects are clearly shown by resin capsule data. This type of sensitivity to fertilizer management has been demonstrated for other elements as well.

Summary

Laboratory soil testing of K (and several other nutrients) will likely never be extremely well correlated to crop response in the field. Variables that influence diffusion (especially soil water content and temperature) are not accounted for in results obtained in the laboratory, regardless of the method. However, it is clear that the resin capsule methodology provides a new, improved approach to soil testing. ■

Potassium Chloride . . .

Alternative Regenerant for Softening Water

By Kim Polizotto and Charles Harms

A recent development in the water treatment industry is the use of potassium chloride (KCl) as a regenerant for water softeners.

POTASSIUM CHLORIDE is an excellent substitute for sodium chloride (NaCl) for both residential and commercial water softening processes. Using KCl will reduce the levels of sodium (Na) in tap water, eliminate the discharge of Na into the environment, and help provide additional potassium (K) in people's diets.

How KCl Softens Water

Softening of water involves removal of the hardness ions . . . calcium (Ca^{++}) and magnesium (Mg^{++}) . . . from the incoming water. Ordinary water softeners are cation exchangers which contain synthetic ion exchange resins. Resin beads contain many negative charge sites which are occupied by positively charged cations. The resin beads have a preference for attraction of different cations with the order generally being $Ca^{++} > Mg^{++} > K^{+} > Na^{+}$. Since the resins prefer Ca^{++} and Mg^{++}, these ions can easily be exchanged with K^{+} or Na^{+}. In the process, the K which was on the resin is released into the softened water. Softening water with KCl can be characterized by equation 1:

Equation 1.

$$\text{Resin-K}_2 + Ca^{++} + Mg^{++} \rightarrow 2\,K^{+} + \text{(Ca-Mg)-Resin}$$

The K in soft water is present as bicarbonate and carbonate rather than chloride (Cl). Chloride is removed with the waste generation stream (equation 2).

Regeneration or Recharge Cycle

After a given volume of "hard" water is passed through the exchange resin, a majority of the negative charge sites will have Ca and Mg attached (adsorbed) to them. Once this occurs, the resin's ability to remove additional Ca and Mg from incoming water is essentially zero. At this point, the resin must be regenerated or recharged. During this cycle a concentrated KCl brine is passed through the resin bed. The very high concentration of K ions forces the Ca and Mg ions off of the negatively charged resin and the K ions take their place. After a brief rinse to remove the excess KCl brine, the resin is again ready to remove Ca and Mg from the incoming water. The regeneration or recharge cycle can be explained by equation 2:

Equation 2.

$$\text{(Ca-Mg)-Resin} + 2\,KCl \rightarrow \text{Resin-K}_2 + MgCl_2 \text{ and } CaCl_2$$

Why Make the Switch?

Probably the most important issue is that use of KCl can reduce or eliminate Na in drinking and/or cooking water. If NaCl is used in the softener, each Ca or Mg ion removed from the incoming hard water results in two Na ions being released into the softened water. The harder the water, the higher the Na content after softening (**Table 1**). If KCl is used instead, two K ions are released for each Ca or Mg ion adsorbed onto the resin.

Table 1. Potassium or Na added to water softened with KCl and NaCl.

Water hardness, grains/gallon	KCl softened K added, mg/l	NaCl softened Na added, mg/l
10	133	78
20	266	157
30	400	236
40	533	314

Dr. Polizotto is Head of Agronomy for PCS Sales, Inc., located in Greenfield, IN. Dr. Harms is Manager, Market Research and Development, Vigoro Industries, West Lafayette, IN.

If the incoming hard water contains Na, softening with KCl initially removes the Na from the water. However, as the resin is expended, the Na that was initially captured in the cycle releases back into the softened water (**Figure 1**). The levels of Na in softened water are always lower when using KCl than when using NaCl, however.

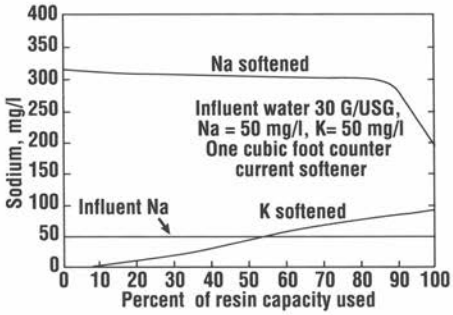

Figure 1. Sodium content of water softened with NaCl and KCl.

Brine Disposal

Another issue of water softening is disposal of the brine solution after regeneration. Several cities in California, Florida and Michigan are taking aim at the water softening industry for discharging high levels of Na and Cl into municipal sewage treatment facilities. Some cities are finding it difficult to meet discharge standards set for "no degradation" of groundwater.

Other cities want to develop secondary markets for their wastewater such as selling it to agricultural producers for irrigation purposes. Since some crops are sensitive to Na and/or Cl, the discharge from wastewater treatment facilities may not be suitable for resale if NaCl is the predominant salt used for water conditioning in the community.

For both groundwater standards or reuse of wastewater, reduced Na and Cl levels are desirable. Not only will the switch to KCl reduce Na in the system but Cl concentrations will also be decreased. Potassium chloride has a lower molecular percentage of Cl compared to NaCl. In most softening systems, this would equate to a 10 to 20 percent reduction in the amount of Cl discharged during each cycle.

Potassium chloride (KCl) is currently available as a water softening product, under the trade names of Softouch, Envirosoft, K-Life and Soft Care. The price may be up to twice that of sodium chloride (NaCl). Thus, consumers who pay $100 per year for NaCl salt would pay $150 to $200 per year for KCl. However, several consumer group studies indicate that health and environmental benefits of KCl overcome the price issue for many potential users.

Dietary Potassium

Another major benefit in the use of KCl is that additional K is available in people's diets. Potassium is vital for human health. A good diet consists of enough fruit, vegetables and dairy products to supply adequate K on a daily basis (**Table 2**). Potassium is not stored in the human body so a continual supply is needed. Modern fast food diets and rushed life-styles do not lend themselves to adequate dietary K. Potassium chloride water softening could help supply the additional needed K.

Table 2. Some leading food sources of K.

Food/serving	K content
8 oz. whole milk	370 mg.
1 medium banana	451 mg.
1 cup fresh orange juice	496 mg.
3 oz. broiled sirloin steak	299 mg.
1 medium baked potato	844 mg.

Plant Nutrient Potassium

Potassium is an essential plant nutrient utilized in high concentrations for a large variety of chemical reactions and water relations in plants. Sodium is also taken up by plants, but has no essential role. Many plants expend energy to isolate Na so it doesn't interfere with normal growth and development. Potassium in water softener brine can be readily utilized by all plants. Disposal of the waste generation stream from KCl brines on agricultural lands is

Intensive Wheat Management Conference Set for March 10-11, 1994

PLANS for the 1994 Intensive Wheat Management Conference have been announced by the Potash & Phosphate Institute (PPI) and the Foundation for Agronomic Research (FAR). This Conference is one of a continuing series of educational programs focusing on the need for intensified crop management to improve producer profitability and the production of quality wheat.

The Conference is slated for March 10-11, 1994 at the Stouffer Concourse Hotel in Denver, CO. Wheat production practices across the U.S. and Canada will be addressed in a series of presentations by growers, researchers, Extension personnel, and representatives of agriculture supply industries. The orientation of the Conference presentations will be on why and how intensified crop management can improve production and grower profitability.

Specific program topics will include the importance of variety choice, stand establishment, seed size, seed treatments, and plant population in intensive management; the relation of plant growth stages to crop management decisions; use and practicality of tramlines; individualized phosphorus and potassium management decisions; yield variability and optimum fertilization; using chloride to suppress diseases and boost yields; pest management for intensive cropping systems; the impacts of intensive cropping systems on water use efficiency, pest management, input needs, economics and environment; economic impacts of better crop management for individuals and communities; and risk management in wheat production.

A proceedings of the Conference papers will be available to all registrants. Extra copies will be available by mail.

For more information, contact the PPI office in Manhattan, KS; phone (913) 776-0273, FAX (913) 776-8347. ■

Softening Water . . . from page 25

an option that can be considered. The waste contains calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$) and any KCl not consumed by the ion exchange resin. The K in softened water is also usable as a plant nutrient. When using K-softened water on house plants, large volumes should be utilized to prevent accumulation of soluble salts in the plant container.

In many farm operations, water softening/treatment is an important management component. All livestock producers monitor nitrate levels in their wells, veal producers watch iron levels closely, and many dairy operators treat their water to make milk house clean-up easier. Using KCl for water treatment is an option in each of these situations. In many operations, barn water and regenerate wastewater are routed into the manure pit, enriching the manure with K which is returned to cropland. This bypasses the septic system for wastewater treatment and decreases the amount of salts in water that enters the drain field.

Also of note, white KCl which is used as fertilizer cannot be substituted for the KCl used in the water softening market. The anti-caking and anti-dusting agents used to facilitate bulk handling of KCl for fertilizer could damage the exchange resins in water treatment systems. Potassium chloride water softening salt is a very clean industrial grade material which is very highly compacted into pellets at least 3/8-inch in size and packaged in 40 lb bags.

Summary

In conclusion, Na really has no redeeming value in the environment outside of saltwater or brackish water ecosystems. If alternatives to NaCl for water treatment can be developed, they should be used. Potassium chloride is a logical choice to reduce Na discharge from water softening systems, to provide additional K in human diets and to serve as a nutrient source for plants. ■

Wheat Response to Time of Phosphorus Application

By M.D. Correll, B.R. Wells, R.K. Bacon and J.T. Kelly

Arkansas research shows that wheat can respond to topdressed applications of phosphorus (P), particularly on soils with poor internal drainage. This information broadens the window for P application for wheat growers under some conditions and demonstrates that surface P applications can be positionally available.

PHOSPHORUS is the second most limiting plant nutrient for winter wheat production on many soils. In Arkansas, P can limit wheat yields on silt loam soils where rice is in the crop rotation. Extended periods of flooding for rice production shift soil P to forms that are less available to upland crops. Wheat growth during the colder part of the year also limits P availability by limiting both P diffusion in the soil and release of P from organic forms. Due to the low solubility of P compounds in soil, P mobility is very low. Most research suggests that only incorporated P applications at or before seeding are effective.

Arkansas silt loam soils used for rice production have very poor internal drainage. That fact combined with excessive winter rainfall results in a saturated soil profile for much of the period between wheat seeding in late November and reproductive growth in mid-to-late March. Under those conditions, the wheat plant develops a lateral root system near the soil surface where a limited amount of oxygen is available for root respiration. Thus, topdressed P applications may be positionally available for uptake by the wheat plants.

Wheat production on these soils usually occurs in a system where either rice or soybeans is the preceding crop. When rice is the preceding crop, seedbed preparation and surface drainage are major problems. When soybeans are the preceding crop, the date of seeding can be a problem. In both cases, rainfall immediately after seeding can result in poor stands.

Growers may wish to delay inputs until an adequate stand is assured. If both nitrogen (N) and P could be topdressed after stand establishment, there might be a greater assurance of a return on the fertilizer investment. Research has shown that most or all of the N should be applied in late February. If more flexibility can be established for time of P application it would allow growers more options in managing wheat for optimum profitability.

Time and Method of P Application

We studied time and method of P application for wheat on two soils, a Crowley silt loam at the Rice Research and Extension Center (RREC) at Stuttgart, AR, and a Calhoun silt loam at the Pine Tree Experiment Station (PTS) at Colt, AR. Soil test P levels (Mehlich III) were 5 and 27 lb/A, respectively, for the two locations. The Crowley soil had been in a rice rotation for many years, but the Calhoun soil had never been cropped to rice.

Fall N application treatments were 0 and 30 lb N/A as urea applied after wheat emergence. The P treatments were: 1) no P applied, 2) broadcast preplant P incorpo-

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This study was funded in part by the Arkansas Fertilizer Tonnage Fee.

rated, 3) P banded with the seed, 4) P topdressed immediately after seeding, 5) P topdressed in early December, 6) P topdressed in early February, 7) P topdressed in early March, and 8) P topdressed in early April, all as triple superphosphate (0-46-0) at a rate of 60 lb P_2O_5/A. Nitrogen was topdressed at 110 lb N/A as urea in late February.

Study and Results

Phosphorus application had a significant effect on wheat plant growth, P concentration, P uptake and grain yield on the Crowley silt loam (low soil test P), but not on the Calhoun soil (low to medium soil test P). Only the results for the Crowley soil (RREC) will be discussed further.

Phosphorus application significantly increased plant growth at all three sampling dates on the Crowley silt loam (**Table 1**). Plant growth was increased two to threefold by P applied preplant, banded with the seed or topdressed. By March 1, topdressed P applied in early December resulted in plant growth equal to the earlier applications. When the P topdressing was delayed until February 1, plant growth had increased significantly by March 1, but had not reached the levels of growth obtained from P applied at planting or on December 1.

Table 1. Phosphorus applications increased wheat plant growth at all sampling dates on a low P, Crowley soil.

Time of application, 60 lb P_2O_5/A	Sampling date		
	Dec. 1	Feb. 1	Mar. 1
	Above-ground plant material, g/m²		
Control	18	65	180
Preplant incorporated	31	147	289
Banded with seed	45	171	370
Topdressed after seeding	33	174	359
Topdressed Dec. 1	—	83	378
Topdressed Feb. 1	—	—	267
LSD (0.05)	7	30	66

Variety: Cardinal

Phosphorus application increased plant P concentrations at the initial sampling in December (**Table 2**). By the March 1 sampling date, only plots where P was applied in December or February still showed elevated P concentrations. Initially, the P banded with the seed produced the highest plant P concentrations, but by March 1 this difference had disappeared. Higher plant P concentrations from the banded P were positively influenced by the application of fall N at both the December 1 and February 1 sampling dates. By March 1 the interaction with fall N was no longer evident (data not shown). The effects of time of P application on plant P concentrations raise serious questions as to the validity of tissue testing for P during the spring growing season.

Phosphorus uptake followed similar patterns to plant growth (**Table 3**). Phosphorus uptake by March 1, however, was strongly influenced by both plant growth and P concentration for the December and February topdress treatments. Phosphorus uptake was increased two to threefold by P applications, regardless of time of application.

Fall N application had no effect on grain yield with or without added P. Both sites had been summer fallowed in 1991 and nitrate N levels in the surface soils were approximately 100 lb/A.

Table 2. Time and method of P application affect wheat plant P concentrations.

Time of application, 60 lb P_2O_5/A	Sampling date		
	Dec. 1	Feb. 1	Mar. 1
	P concentration in plant tissue, %		
Control	0.15	0.21	0.23
Preplant incorporated	0.27	0.20	0.20
Banded with seed	0.40	0.24	0.23
Topdressed after seeding	0.20	0.19	0.22
Topdressed Dec. 1	—	0.35	0.31
Topdressed Feb. 1	—	—	0.36
LSD (0.05)	.08	0.03	0.03

Variety: Cardinal

Application of P preplant incorporated, banded with the seed, or topdressed anytime between seeding and early March increased grain yields by approximately 20 bu/A on the P-deficient Crowley silt loam soil (**Table 4**). Even early April P application significantly increased grain yield compared to the controls. However, there was a trend for less

TOPDRESSED P has been effective for wheat following rice in Arkansas studies. Delaying P application and topdressing with N can allow determination of stand adequacy before expenditures for fertilizer input. Better growth in some plots shown here is due to P application.

Table 3. Wheat plant P uptake was strongly influenced by plant growth, plant P concentrations and time of P application.

Time of application, 60 lb P_2O_5/A	Sampling date		
	Dec. 1	Feb. 1	Mar. 1
	Plant P uptake, g/m²		
Control	3	13	40
Preplant incorporated	8	29	57
Banded with seed	17	40	84
Topdressed after seeding	10	33	79
Topdressed Dec. 1	—	29	116
Topdressed Feb. 1	—	—	97
LSD (0.05)	2	9	19

Variety: Cardinal

Table 4. Phosphorus application method and application date influence wheat yields.

Time of P application, 60 lb P_2O_5/A	Wheat yield, bu/A	
	Rice Research and Extension Center	Pine Tree Station
Control	75	87
Preplant incorporated	92	86
Banded with seed	94	84
Topdressed after seeding	93	86
Topdressed early Dec.	94	87
Topdressed early Feb.	94	84
Topdressed early March	90	86
Topdressed early April	85	88
LSD (0.05)	8	NS
Soil test P (lb/A)	5	27

response from P applied after February.

Visual growth responses to P applications were noted two to four weeks after each P application at Stuttgart RREC. Neither visual growth responses nor increased grain yields occurred at the Pine Tree site despite a soil test P value below the critical level. Phosphorus availability was apparently not limiting at this location. Since the Pine Tree site had never been cropped to rice, soil P had not been subjected to conversion of the less soluble ferric and occluded forms that are only sparingly available to upland crops.

Summary

Topdress applications of P are positionally available for uptake by wheat on P-deficient Crowley soils with poor internal drainage. Growers may be able to wait until after the determination of adequate stands before applying needed P. Data indicate that the value of using only P tissue concentration as the criteria for need for P fertilization may be questionable due to the interactive effects of P application time and subsequent plant growth. ■

Environotes from TVA

By John E. Culp

THE REDIRECTION process at the Tennessee Valley Authority (TVA) has been completed. The new vision for TVA's National Environmental Research Center (NERC) at Muscle Shoals, AL, is to achieve world-class status as a Center that produces state-of-the-art technologies and practices.

"TVA will help lead the nation's utilities in environmental performance," said NERC Vice President and Senior Scientist Ronald L. Ritschard. "Our focus will be on environmental business and that includes agriculture."

NERC will conduct research, development, and technology transfer in five areas: Atmospheric Sciences, Agricultural Research and Practices, Waste Management and Remediation, Biotechnology and Environmental Site Remediation.

Several major activities will be emphasized under each area. Highlights include the following:

- **Atmospheric Sciences.** Solutions to air quality problems will be a key objective. Staff will work with state and local issues and enter into partnerships with public and private organizations.
- **Agricultural Research and Practices.** Pollution prevention strategies in nutrients, pesticides, and animal wastes will be key areas. The Center will explore alternative agricultural practices that protect the environment and develop technology for using wastes and byproducts.
- **Waste Management and Remediation.** Wastewater cleanup technologies will be developed and introduced. The Center will also develop waste management and remediation technologies and new chemical/radiochemical measurement methods.
- **Biotechnology.** Bioremediation and biotreatment technologies for waste treatment will be developed. Bioconversion technologies and biochemical solution to waste problems will also be investigated.
- **Environmental Site Remediation.** Cleanup of the NERC plant site will be a priority. The Center will also provide hazardous waste management services and environmental and chemical process expertise to public and private organizations.

In addition to announcing the new directions at TVA's NERC, Ritschard also has put a new management team in place. They include:

Department	Manager
Atmospheric Sciences	Jim Meagher
Agricultural Research and Practices	Ron Williams
Waste Management and Remediation	Tim Jones
Biotechnology	Harold Speidel
Environmental Site Remediation	Ron Kirkland
Technology Transfer	Linda Cournoyer
Support Services	John Blackwell

"The technologies and practices that our staff develops at the Center can help TVA, the region, and the nation achieve sustained agricultural and economic development in an environmentally acceptable way," said Ritschard. "In striving to meet this objective, we'll seek other public and private partners to assure a cost-effective return on the public investment in TVA." ■

Mr. Culp is with the National Environmental Research Center, Tennessee Valley Authority, Muscle Shoals, AL 35660.

Southern Forages Book Available

SOUTHERN FORAGES was published jointly by the Potash & Phosphate Institute (PPI) and the Foundation for Agronomic Research (FAR) in 1991. The book offers a comprehensive discussion of forage crops grown in the Southern U.S.

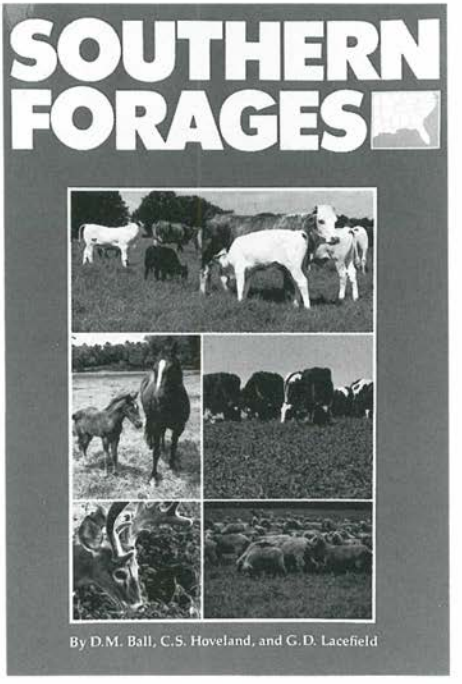
Southern Forages is intended for a wide range of readers, including: livestock and hay producers; Extension agents; seed, fertilizer, chemical, and equipment dealers; Soil Conservation Service personnel; vocational agriculture teachers; consultants; students; and others interested in forages.

Authors of the book are: Dr. Donald M. Ball, Extension Agronomist/Professor, Auburn University; Dr. Carl S. Hoveland, Terrell Distinguished Professor of Agronomy, University of Georgia; and Dr. Garry D. Lacefield, Extension Agronomist/Professor, University of Kentucky. All are former presidents of the American Forage and Grassland Council (AFGC) and have many years of experience in working with forage/livestock production.

The book is presented in an easy-to-read, understandable format. It is primarily intended as a practical management guide for forage production, although it may also be appropriate as a textbook for classroom instruction as well.

Many of the forage species discussed can be grown in the lower Midwest and the Northeast as well as in the South. Management principles emphasized in the book also fit other areas of the world where similar soils and climatic characteristics exist.

The text begins with a chapter on the history of Southern forage crops and ends with a chapter on forages and the environment. Four chapters feature concise discussions on the adaptation,



management, and utilization of Southern grasses and legumes. Other chapters address forage physiology, forage quality, plant and animal management, hay, silage, fencing, grazing management, poisonous plants and plants for wildlife.

Southern Forages has more than 150 color photographs, including over 60 closeups of Southern forage crops. The 256-page book is a 6-by-9 inch paperback with 32 chapters, appendices and index.

The price is $20 per copy, plus $3 shipping and handling. Discounts are available for quantity orders.

For additional information or to place an order, contact: Circulation Department, PPI, 655 Engineering Drive, Suite 110, Norcross, GA 30092; phone (404) 447-0335, fax (404) 448-0439. ■

RISK

"Life without risks would be mighty dull."

The sign outside the church listed the sermon topic: "The sin of gambling–(farmers excepted)." Regular attendants at the races take fewer risks than do farmers. Since the beginning of time, farmers learned to expect and to accept risk.

Today there is an increasing tendency to avoid risk, to insure against risk, and even to legislate concerning risk. The government is becoming an integral part of the risk factor. Senator Daniel P. Moynihan of New York has proposed a risk assessment bill. It would create special committees that would rank environmental risks and estimate benefits versus costs of environmental regulation.

How far can we go in making risks illegal? Most businesses recognize risk and try to balance risk with return. The question is: In so doing do they take risks that could be harmful?

Capitalism is based on risk. Communism tries to eliminate it. Farmers will never feed and clothe the world without taking some risks. Contrary to popular belief, proper use of agrichemicals adds little or nothing to environmental risk. In fact, inadequate use increases risk while proper use decreases risk.

There is a great danger that environmental policy could be based more on misleading statistics or emotional perception of risk than on solid scientific evidence. ■

J. Fielding Reed