BETTER CROPS
WITH PLANT FOOD

Fall 1991

BETTER CROPS With Plant Food

Editor: Donald L. Armstrong
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Circulation Mgr.: Lethia Griffin

Vol. LXXV (75), No. 4 Fall 1991

BETTER CROPS WITH PLANT FOOD (ISSN: 0006-0089) is published quarterly by Potash & Phosphate Institute (PPI), 2801 Buford Hwy., N.E., Suite 401, Atlanta, GA 30329. Phone (404) 634-4274. Subscriptions: Free on request to qualified individuals; others $8.00 per year or $2.00 per issue.

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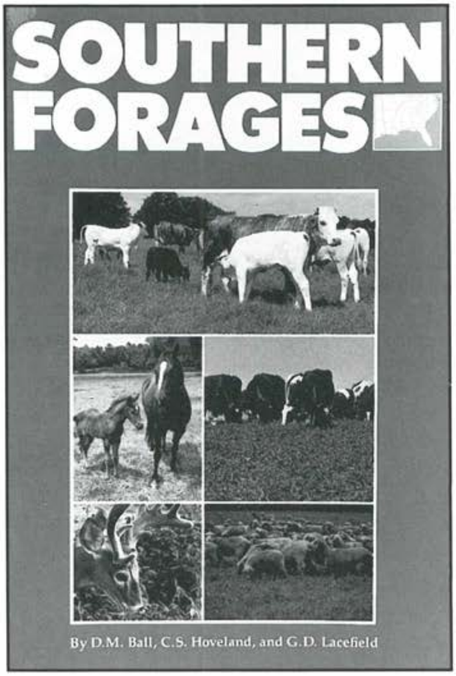
Our Cover: Research by Washington State University is investigating the effects of potassium nutrition on apple color and quality. Photo by Dr. Larry Murphy.

New Book Covers Southern Forages

A NEW BOOK titled *Southern Forages* is now available. Published jointly by the Potash & Phosphate Institute (PPI) and the Foundation for Agronomic Research (FAR), 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.



"We are pleased to introduce this new book by three scientists who are widely recognized for their work with forages. We believe the information will help forage producers in many areas, not just the South," noted Dr. David W. Dibb, PPI President.

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.

"*Southern Forages* represents a new effort for us in publishing a comprehensive document on a major area of agricultural production," said Dr. Bob C. Darst, FAR President. "It crosses subject matter disciplines and will be of broadbased utility to many people involved with forage production. We thank all those who contributed to the development of the publication."

Many of the forage species discussed in the book 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 new book is a 6-by-9 inch paperback totaling more than 250 pages with 32 chapters, appendices, and index.

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

See page 31 for more details. ■

Minnesota Research

Residual Effects of Potash in an Alfalfa-Corn Rotation

By M.A. Schmitt, M.P. Russelle, and C.C. Sheaffer

Observation and data from a recent study in Minnesota point out the tremendous potassium (K) needs of alfalfa. It also reinforces the concept of long-term fertility management that considers the needs of individual crops, but focuses on the entire cropping system using frequent soil testing to monitor soil fertility.

IN THE LATE SUMMER OF 1990, dramatic K deficiency symptoms were present in corn in a "bulk" field of the Rosemount research station in Minnesota. The stark contrast between the best and worst corn was remarkable (see photo at right and next page).

The field displayed a checkerboard pattern—with remnants of previous treatments creating various increments of corn height and overall health. The "good" corn was more than 7 feet tall and had full ear development, while the "worst" corn was no more than than 2 feet tall, including its tassel. The classic marginal necrosis of the corn leaves was present on all but the best looking "squares" of corn—no doubt a previous study had involved K fertilization!

The soil was a Waukegan silt loam with approximately 28 inches of loam over outwash sand and gravel. This hidden, almost forgotten, plot area had been part of an alfalfa study. That study, initiated in the spring of 1985, investigated the interacting effects of K fertilization, alfalfa cutting management schedules, and alfalfa varieties, differing in winterhardiness ratings. The K fertilization rates consisted of 0, 125, 250, and 500 lb of K_2O per acre. This fertilizer was added as a plowdown treatment in 1985 and applied in split, topdressed applications in 1986 and 1987.

CORN plants in the low-K plot areas showed classic deficiency symptoms . . . note marginal "firing" and necrosis of leaves.

The initial soil K test was 100 parts per million (ppm), rated as "low". The control plot plants exhibited K deficiency symptoms in the establishment year and produced little harvestable forage in 1987. Oats were grown in the plot area in 1989 and corn was then grown in 1990. The field has received no fertilizer since the alfalfa project ended in 1987.

After the discovery of this nutrient-deprived area, a previous plot plan was obtained to link past treatments with current blocks or "checkerboard squares." The alfalfa-fertilization study used a split-split plot design with K fertilizer rates being in the main plots. This is the only factor that provided a significant visible effect on the 1990 corn crop.

M.A. Schmitt is a soil scientist in the Department of Soil Science, M.P. Russelle is a soil scientist with USDA-Agricultural Research Service-U.S. Dairy Forage Research Center, and C.C. Sheaffer is an agronomist in the Department of Agronomy and Plant Genetics, all at the University of Minnesota, St. Paul, MN.

VISIBLE differences in corn growth were the effects of earlier K treatments, when alfalfa was grown in the plot area.

Results

Corn grain yields were measured after physiological maturity. The yield data, ranging from 6 to 180 bu/A, are shown in **Figure 1**. Yields were measured separately for the 3-cut and 4-cut management treatments, but they did not differ. The alfalfa variety subsub plots were harvested together.

Available K in the plow layer in 1990 ranged from 53 ppm K for the control plot to 87 ppm for the high K treatment, which had received 1,500 lb of K_2O just a few years earlier (**Figure 1**). Although these data show relative differences in soil test values due to fertilizaton programs, the range of the soil test values is quite narrow when compared to the wide range of yields produced by these plots.

This plot area has led to more questions than answers, and the number of questions grows each year. While the refinement of soil K tests and the resulting K recommendations can be a future goal from this project, a broader issue may be the development of fertilization plans for the entire rotations.

It is important to use a fertilizer management plan that meets current needs **and** that is adaptable for future needs as well. This particular study exhibited greater K treatment differences (excluding the controls) with the subsequent corn crops than it did during the alfalfa crops. ■

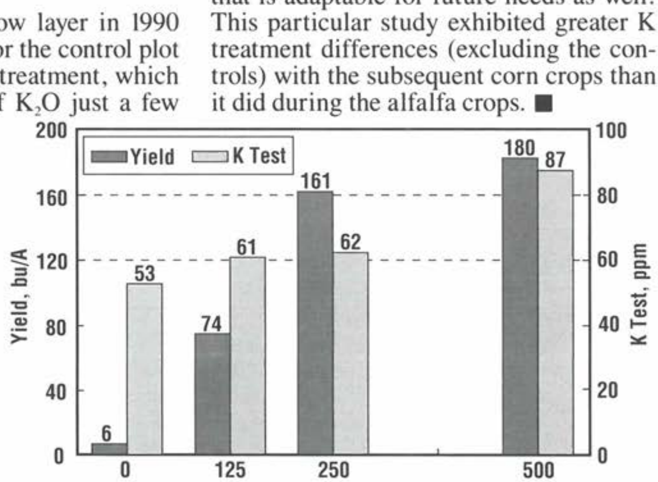


Figure 1. Corn yields ranged from 6 bu/A to 180 bu/A in the plot areas where alfalfa had been grown previously.

Cotton Accumulates Small Amounts of Copper, Iron, Manganese, and Zinc

By G.L. Mullins and C.H. Burmester

Micronutrients are elements required in small or "micro" amounts by all plants. Although a mature crop may accumulate less than an ounce of some micronutrients per acre, plants will not grow and yield properly without adequate levels of these nutrients. Cotton is no exception. However, there has never been an intensive study of the micronutrient uptake characteristics of the cotton plant in the U.S.

TO EVALUATE cotton's accumulation of copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn), a field study was conducted during 1986 and 1987. The two non-irrigated sites were a Decatur silt loam soil in north Alabama and a Norfolk sandy loam soil in central Alabama. Copper, Fe, Mn and Zn are not normally recommended for cotton on these soils and there were no supplemental applications of these nutrients during this two-year study.

Four genetically varied cotton varieties were compared: Deltapine 90, an Acala cotton; Coker 315, a Midsouth cotton resulting from Carolina breeding; Stoneville 825, a Midsouth cotton from Delta breeding; and Paymaster 145, which was developed for the High Plains area of Texas. Micronutrient uptake was evaluated by sampling whole plants at two-week intervals over the growing season beginning approximately 30 days after planting. Plants were separated into stems, leaves, and fruit for dry matter and micronutrient analysis. Bolls were divided into seed, burs, and lint. The bur fraction included squares and flowers.

Results

Even though the four cotton varieties resulted from genetically different breeding, all varieties were very similar in their ability to accumulate Cu, Fe, Mn and Zn. There were no consistent differences among the varieties in total uptake of the four elements or uptake by a given plant part. At the last sampling for each year, total Cu, Fe, Mn and Zn uptake averaged over soils and varieties were 0.40, 8.90, 5.49, and 1.47 oz/A, respectively (**Table 1**). Total Fe and Zn uptake was very similar for the two soils. However, total Cu and Mn uptake was lower on the Norfolk soil compared to the Decatur soil. The Norfolk soil had lower levels of dilute double-acid extractable Cu and Mn as compared to the Decatur soil. Micronutrient removal in seed cotton represented 30 percent of the total plant Cu, 13 percent of the Fe, 6 percent of the Mn, and 48 percent of the Zn (**Table 2**). Seed cotton yields for the study averaged 1,874 lb/A. Combining yield data with total micronutrient uptake data indicated an average uptake of 0.06 oz of Cu, 1.4 oz of Fe, 0.90 oz of Mn and 0.24 oz of Zn for every 100 lb of lint produced.

The maximum daily uptake rates for the micronutrients studied occurred at 58 to 98 days after planting (first to fourth week of bloom), very close to the period of maximum dry matter production. Except for Zn, none of these nutrients were

Table 1. Accumulation of Cu, Fe, Mn and Zn by mature cotton (average of four varieties) on two soils.

Plant part	Cu	Fe	Mn	Zn
	------------ oz/A ------------			
Stems	0.12	1.82	1.08	0.26
Leaves	0.10	3.74	3.24	0.34
Burs	0.06	2.19	0.86	0.17
Seed	0.12	1.15	0.31	0.70
Total Uptake	0.40	8.90	5.49	1.47

G.L. Mullins is Associate Professor and C.H. Burmester is Extension Agronomist in the Department of Agronomy and Soils and Alabama Agricultural Experiment Station, Auburn University, AL 36849-5412. Alabama Agric. Exp. Stn. Journal Series No. 3-913054.

Table 2. Distribution of Cu, Fe, Mn and Zn in mature cotton plants (average of four varieties).

Plant part	Cu	Fe	Mn	Zn
	------ % of total uptake ------			
Stems	30	20	20	18
Leaves	25	43	56	23
Burs	15	24	18	11
Seed	30	13	6	48

redistributed within the cotton plant during the growing season (**Figures 1, 2, 3, and 4**). Zinc in the bur fraction was apparently redistributed into the seed.

Summary

Four varieties of cotton were very similar in their ability to accumulate and partition Cu, Fe, Mn and Zn. Seasonal accumulation of Cu, Fe, Mn and Zn averaged 0.40, 8.90, 5.49 and 1.47 oz/A, respectively. During the two-week interval corresponding to the maximum uptake rate for each element, an average of 42 percent of the total Cu, 51 percent of the total Fe, 42 percent of the total Mn, and 34 percent of the total Zn was accumulated. Maximum micronutrient uptake occurred during the first to fourth week of bloom. An average of 30 percent of the total Cu, 13 percent of the total Fe, 6 percent of the total Mn and 48 percent of the total Zn was removed in seed cotton. Cotton grown accumulated an average of 0.06 oz of Cu, 1.4 oz of Fe, 0.90 oz of Mn, and 0.24 oz of Zn for every 100 lb of lint produced. ■

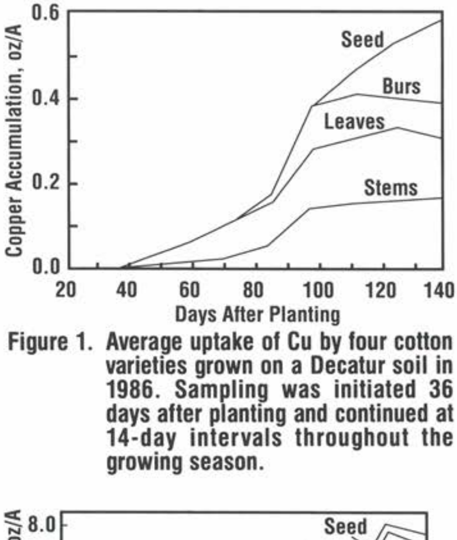


Figure 1. Average uptake of Cu by four cotton varieties grown on a Decatur soil in 1986. Sampling was initiated 36 days after planting and continued at 14-day intervals throughout the growing season.

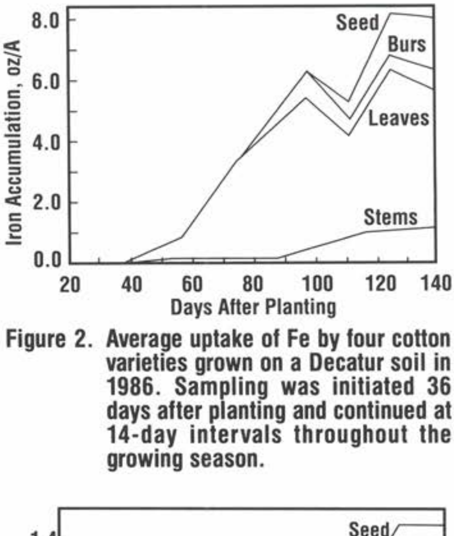


Figure 2. Average uptake of Fe by four cotton varieties grown on a Decatur soil in 1986. Sampling was initiated 36 days after planting and continued at 14-day intervals throughout the growing season.

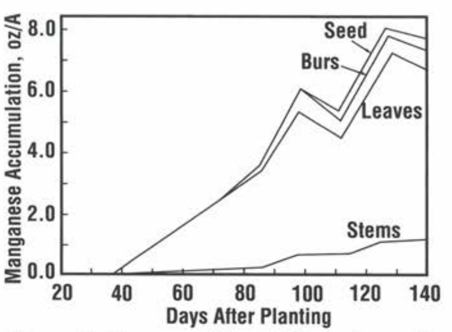


Figure 3. Average uptake of Mn by four cotton varieties grown on a Decatur soil in 1986. Sampling was initiated 36 days after planting and continued at 14-day intervals throughout the growing season.

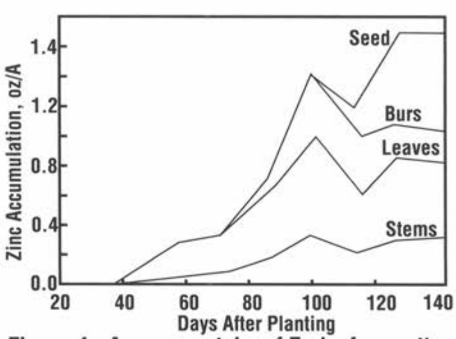


Figure 4. Average uptake of Zn by four cotton varieties grown on a Decatur soil in 1986. Sampling was initiated 36 days after planting and continued at 14-day intervals throughout the growing season.

Boron and Molybdenum—Critical Plant Levels in Forage Legumes

By Umesh C. Gupta

Boron (B) and molybdenum (Mo) are important micronutrients for forage legumes in the northeastern region of Canada and the U.S. Soils of the region are subject to intensive leaching, leading to frequent crop deficiencies of these nutrients.

BORON AND Mo are probably more important than any other micronutrient for the production of forage legumes in the northeastern region of Canada and areas of the northeastern U.S. Available forms of these nutrients exist in the soil as anions. Because precipitation in the region is normally high, both nutrients are subject to intensive leaching. Crops are frequently deficient, particularly on sandy soils.

Boron Deficiency and Toxicity Symptoms and Levels

Boron deficiency symptoms generally appear on younger plant parts since B is relatively immobile in the plant. In alfalfa and clover, B deficiency symptoms appear in a variety of colors. **Figure 1** shows symptoms of yellowish-red colored young leaves in alfalfa. In Persian clover, the symptoms appear as bright pinkish-red colored leaves.

Boron toxicity symptoms are confined to the older leaves and appear as burning and/or browning of the edges of the leaves, as shown for alfalfa in **Figure 2**. When normal application rates of 1 to 2 lb B/A are used, there is no danger of B toxicity.

Boron deficiency and toxicity levels in forage legumes are generally associated with less than 20 and more than 60 parts per million (ppm) B, respectively, in the vegetative tops at 10 percent bloom (**Table 1**). Plant B concentrations of 20 to 50 ppm are considered to be optimum for the growth of forage legumes.

Molybdenum Deficiency Symptoms and Levels in Plants

Molybdenum deficiency in forage legumes appears as a general yellowing of the whole plant and is associated with

Figure 1. Yellowish-red colored young leaves indicate B deficiency in alfalfa.

Figure 2. Boron toxicity symptoms in alfalfa appear on older leaves.

Dr. Gupta is a research scientist at the Agriculture Canada Research Station, Charlottetown, PEI.

Table 1. Deficient, sufficient and toxic plant B concentrations in forage legumes.

Crop	B concentration, ppm		
	Deficient	Sufficient	Toxic
Alfalfa	20	20-50	100
Red Clover	20	20-50	60
Birdsfoot Trefoil	15	30-40	70

Table 2. Deficient, sufficient and toxic plant Mo concentrations in forage legumes.

Crop	Mo concentration, ppm		
	Deficient	Sufficient	Toxic
Alfalfa	0.2	0.2-2	5-10[1]
Red Clover	0.2	0.2-2	5-10[1]

[1]Toxic to livestock but not to the plant itself.

reduced yields. Deficiency of Mo prevents utilization of nitrogen (N) by plants . . . the conversion of nitrates to ammonium, amides and proteins. For this reason, Mo deficiency symptoms resemble those of N deficiency. Molybdenum deficiency also interferes with the activity of the N-fixing Rhizobium bacteria by reducing the number of nodules formed and the amount of N fixed in them. **Figure 3** compares forage growth in a Mo deficient clover field (left side) to a healthy clover crop (right side) which received Mo fertilization.

Plant requirements for Mo are lower than those of the other essential micronutrients. Plant Mo deficiency generally occurs when forage legume plants contain less than 0.2 ppm, while sufficiency levels often range from 0.2 to 2.0 ppm Mo (**Table 2**).

Forage concentrations of Mo can increase to levels which are toxic to livestock without the plants exhibiting toxicity symptoms. Forage producers should be aware of this, particularly when fertilizing forage legumes with Mo.

The relationship of liming to plant available Mo is critical. Soil pH greatly influences the availability of Mo to crops. Unlike the other micronutrients which become less available as soil pH rises, Mo becomes more available when soil pH increases. Liming the soil to pH 6.5 can alleviate the Mo deficiency on most soils. However, sandy soils with low total soil Mo may require some Mo fertilization of crops such as clovers and Brassicas (such as kale, fodder rape, and canola) in addition to liming. **Figure 4** shows Mo deficiency in Brussels sprouts.

Summary

To overcome B deficiency in established stands of forage legumes, soil application of 2 lb B/A in alternate years is recommended. For foliar sprays, the recommended rate is 0.5 to 1 lb B/A. Annual application rates of 2 to 4 ounces Mo per acre are recommended as a foliar spray to provide sufficient Mo for forage legume production, particularly for soils below pH 6.0. ■

Figure 3. Clover growth at left was limited by Mo deficiency; healthy clover at right received Mo fertilization.

Figure 4. Molybdenum deficiency symptoms are shown in Brussels sprouts.

How Much Boron Do Flowers Need?

By Eric Hanson

Meeting the boron (B) requirements of crops has been a continuing challenge for farmers and scientists. Some tree crops appear to require more B than previously thought.

BORON, long known as an essential plant nutrient, is recognized for its critical role in the flowering process and seed set. Yet, answers pertaining to its specific influence on flowering and subsequent fruit and nut set or how much tree crops need for optimum production are not clear.

Fruit and nut tree growers typically judge the nutritional health of their tree crops based on the nutrient levels in leaves. Recent investigations have shown that some tree crops respond to applied B even though tissue analysis and tree appearance indicated adequate B nutrition. In these cases, foliar B sprays improved yields by increasing the percentage of flowers which set fruit.

Photo credit: Dave Burkhart

MOST temperate tree crops show B deficiency symptoms as shoot dieback and leaf distortion when leaf tissue B levels fall below 15 or 20 parts per million (ppm). Corrective applications are usually made when leaf B is low or deficiency symptoms are evident.

The B nutrition–fruit set relationship was first observed in apple and pear orchard trials. A detailed study of B nutrition of 'Italian' plum, grown in the Pacific Northwest for prune production, showed that foliar B sprays often increased fruit set, even when growth was normal and leaf tissue B level of 30 to 40 parts per million (ppm) was considered adequate. Similar work in the 1980s on filberts or hazelnuts was even more surprising. Trees having up to 80 ppm B in the leaf tissue usually increased the percentage of flowers which set and matured nuts when supplied with additional B. Deficient levels in filbert leaves were previously thought to be less than 11 ppm. More intensive production systems require that the B needs of tree crops be re-evaluated.

Research found that sour cherry trees respond well to B nutrition. Low fruit set percentages frequently limit yields under Michigan conditions. Foliar B sprays,

Table 1. Boron sprays affect fruit set and production of sour cherries.

B in control leaves, ppm	Response (% increase)		
	Fruit set	Yield/ tree	Yield/unit trunk cross sectional area
19	+110	ns	+100
20	ns	ns	+34
22	+30	ns	+14
23	ns	ns	+13
25	ns	ns	ns
27	ns	+13	ns
28	ns	—	—
32	+34	ns	ns
32	ns	ns	ns

(ns) no significant effect. (—) data not available.

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applied in the autumn while leaves are still functional and before leaves begin to abscise, are an effective method and time for supplying B to flowers and increasing fruit set the following spring. Absorbed B moves out of leaves and into adjacent spurs and twigs during a 2 to 4 week period in the autumn, remains in the wood during the winter, and becomes available to the developing flowers in spring. Fall sprays usually increase B concentrations in the flowers by 50 to 100 percent.

Foliar B sprays enhanced fruit set and increased fruit production (**Table 1**). The greatest responses, where B doubled fruit set and production, were observed in those orchards having relatively low leaf tissue B levels. Additional trials have clearly illustrated that orchards with low leaf B levels respond the most to B treatments. Trees containing 30 ppm B or higher were less likely to show a benefit. Spray concentrations were 500 ppm B, applied at rates of 0.5 to 1.0 lb B/A. In these trials, no apparent deficiency symptoms existed and leaf B levels were 19 to 32 ppm, well above the previously considered deficiency levels of 15 ppm.

Fruit set is a complex process, involving a series of steps including pollination, pollen germination, pollen tube growth, fertilization, etc. Deficiency or stress at any point can limit fruit set and yield. Although the mechanism by which B operates to improve fruit set is unclear, studies show that when fruit tree pollen grains are cultured in low B sugar solutions, pollen germination and the growth of pollen tubes are reduced.

Boron benefits the flowering process most when weather during the bloom period is wet and cold, conditions which lower fruit set and yield potentials. Under adverse conditions, slow pollen tube growth limits fruit set because flowers deteriorate before fertilization is completed. Boron may enhance fruit set by accelerating this process.

Complicating our understanding of B nutrition is the fact that fruit set and yields are not always increased by B sprays. Numerous questions remain unanswered. We need to better understand how B influences fruit set in order to predict accurately when sprays are likely to be beneficial. Further, several tree crops and cultivars have not been adequately tested. For example, little work has been done on sweet cherries. Undoubtedly, more research is needed to determine the role of B in flowering and fruit set. ■

BORON recommendations for the sour cherry or pie-cherry industry in North America should be relatively easy to improve since only one cultivar, "Montmorency", is used.

Comparative Effects of Nitrogen Sources on Soil Chemical and Physical Characteristics

By David Whitney, Loyd Stone, Keith Janssen, and Jim Long

Few long-term studies have compared nitrogen (N) source effects on soil physical and chemical properties. Kansas researchers recently summarized 20 years of data comparing the effects of anhydrous ammonia, urea, ammonium nitrate and urea-ammonium nitrate solution (UAN).

OVER A 20-YEAR PERIOD (1969-1988), four N sources . . . anhydrous ammonia, ammonium nitrate, urea, and UAN . . . were applied annually to plots at three Kansas locations. The soil types were Smolan silty clay loam at Manhattan, Woodson silt loam at Ottawa, and Grundy silty clay loam at Powhattan.

Crops grown during the study were corn and grain sorghum at Powhattan; grain sorghum, winter wheat, and soybeans at Manhattan; and grain sorghum at Ottawa. The four N sources were spring-applied, beginning with a rate of 200 lb N/A in the first year. Nitrogen rates were adjusted downward as the study progressed, with recommended applications of phosphorus (P) and potassium (K). Each site also included a zero-N control plot which received recommended amounts of P and K. Soil properties were examined in two soil layers (2.5 to 5.5-inch and 8.5 to 11.5-inch) after 10 and 20 years; only the 20-year data will be reported in this article.

Soil Chemical Properties

Chemical analyses for the two sampled soil layers are shown in **Table 1**. Neither of the soil layers showed significant differences in chemical properties among the four N sources. Nitrogen applications, however, did produce significant differences in several chemical properties when compared to the check treatment. In the upper soil layer (2.5 to 5.5 inch depth), N fertilization had reduced pH, available P and exchangeable calcium (Ca) and magnesium (Mg). Exchangeable K was unaffected by N application. Plots receiving N had significantly higher DTPA extractable iron (Fe), copper (Cu), and manganese (Mn) levels than the check plot. Soil nitrate (NO_3-N) and ammonium (NH_4-N) levels were increased by N fertilization in the upper soil layer, reflecting the high initial rate of application. In the lower soil layer, N fertilized plots compared with the zero-N check showed only reduced pH and higher NO_3^--N levels.

All N sources reduced soil pH compared with the no-N check. There were no significant differences in pH effects among the four N sources. The identical effects of N sources on soil pH confirm the results of studies by Kissel and Betzen. They showed that the theoretical requirement of 3.6 lb pure calcium carbonate to offset the acidity produced by nitrification of each pound of N was the same for ammonia, urea, and ammonium nitrate. The requirement was 7.2 lb of calcium carbonate per pound of N from ammonium sulphate. The reduction in soil pH led to the increased extractability of the micronutrients Fe, Cu, and Mn in the 2.5 to 5.5 layer.

Soil Physical Properties

Results of the analyses of soil physical properties at all locations are summarized in **Table 2**. There were no significant differences among the effects of the four N sources on the physical properties of either

The authors are with Kansas State University. Dr. Whitney and Dr. Stone are in the Department of Agronomy at Manhattan, KS. Dr. Janssen is at the East Central Kansas Experiment Field at Ottawa, KS; Dr. Long is at the Southeast Kansas Experiment Station at Parsons, KS.

Table 1. Chemical properties of two soil layers for all field locations as influenced by 20 years of applications of four N sources.

Nitrogen source	pH	Organic matter	CEC	Avail. P	Exchangeable K	Exchangeable Ca	Exchangeable Mg	DTPA-extractable Zn	DTPA-extractable Fe	DTPA-extractable Cu	DTPA-extractable Mn	NO_3-N	NH_4-N
		%	meq/100g	parts per million (ppm)									
2.5- to 5.5-inch soil layer													
Check (no N)	6.2	2.04	23.3	38	220	2,949	548	1.23	52.8	1.63	14.8	4.0	5.0
Anhydrous ammonia	5.2	1.84	22.7	27	217	2,601	459	1.20	75.9	1.99	39.8	26.6	8.7
Ammonium nitrate	5.2	2.27	21.7	26	220	2,443	432	1.11	70.4	2.14	44.3	20.9	11.2
Urea	5.1	2.28	22.7	24	210	2,566	478	1.07	75.7	2.12	51.2	30.8	11.5
UAN solution	5.2	2.04	22.2	28	204	2,494	425	1.02	77.8	1.89	38.0	20.2	8.4
8.5- to 11.5-inch soil layer													
Check (no N)	6.4	1.52	32.6	8	210	3,893	822	0.48	44.7	1.94	8.9	1.4	4.7
Anhydrous ammonia	6.0	1.28	31.6	6	199	3,823	733	0.36	49.4	1.90	10.4	13.0	4.8
Ammonium nitrate	6.2	1.49	34.0	6	208	4,060	815	0.42	43.1	1.93	7.4	9.3	5.1
Urea	6.0	1.54	32.6	6	212	3,666	719	0.38	45.4	1.99	15.6	10.1	5.9
UAN solution	6.2	1.41	31.0	5	209	3,949	808	0.33	39.0	1.80	7.1	9.0	4.8

soil layer. The only significant physical difference between the no-N check and the N-fertilized plots was an increase with N application in the geometric mean diameter (GMD) of soil aggregates in the upper soil layer and a decrease of GMD in the lower layer. The larger the GMD, the greater the proportion of large, water-stable aggregates.

Bulk density and clod density analyses did not indicate that N sources had any influencing effect on soil compaction. If chemical dispersion of clay and clay

(continued on page 15)

Table 2. Physical properties of two soil layers for all field locations as influenced by 20 years of applications of four N sources.

Nitrogen source	Compactability analysis: Maximum bulk density	Compactability analysis: Optimum water content for compaction	Clod density	Water content at permanent wilting point	Particle-size distribution: Sand (0.05-2 mm)	Particle-size distribution: Coarse silt (0.02-0.55 mm)	Particle-size distribution: File silt (0.002-0.02 mm)	Particle-size distribution: Clay <0.002 mm)	Geometric mean diameter
	g/cc	kg/kg	g/cc	%	%				mm
2.5- to 5.5-inch soil layer									
Check (no N)	1.60	0.190	1.50	12.5	11.3	26.0	33.8	29.0	0.95
Anhydrous ammonia	1.59	0.193	1.45	12.6	9.5	21.3	39.8	29.5	1.48
Ammonium nitrate	1.59	0.189	1.46	12.7	8.5	25.3	36.8	29.5	1.50
Urea	1.58	0.196	1.46	12.5	10.3	21.5	39.5	28.8	1.75
UAN solution	1.60	0.190	1.49	12.7	10.8	25.5	34.3	29.5	1.57
8.5- to 11.5-inch soil layer									
Check (no N)	1.49	0.220	1.67	18.8	7.5	18.0	33.0	41.5	1.35
Anhydrous ammonia	1.51	0.216	1.66	18.9	7.0	18.3	33.0	41.8	0.90
Ammonium nitrate	1.52	0.217	1.65	19.1	5.8	21.5	30.8	42.0	0.98
Urea	1.50	0.219	1.68	19.2	6.0	17.5	33.8	42.8	0.94
UAN solution	1.49	0.232	1.67	18.7	8.0	17.3	32.8	42.0	1.02

Boron-Lime Interactions on Clovers

By V.A. Haby, R.H. Loeppert, and R. Villavicencio

Liming to provide the proper pH for availability of major nutrients and activity of legume nodulating bacteria can increase plant needs for micronutrients, including boron (B).

BORON, an essential nutrient for plants, is needed in only small quantities. Clovers are among the more sensitive crops to B deficiency. The accumulation of carbohydrates, ammonium compounds, and other soluble nitrogenous compounds in B-deficient plants suggests a breakdown of protein synthesis.

Boron is involved in processes of cell division and transport of sugars. A buildup of sugars in plant leaves due to B deficiency can result in bright colors that may range from yellows to reds (**Figure 1**). Also, evidence links B to calcium (Ca) and potassium (K) metabolism of the plant.

Boron deficiency in clovers usually appears on the youngest leaves. These leaves will develop a red to reddish-yellow color, depending on the K level in the plant. If the deficiency is sufficiently severe, the growing point will die. Clover can grow out of a B deficiency but may suffer a significant yield loss.

Boron deficiencies are common in sensitive plants in higher rainfall areas. Boron is adsorbed by clay minerals and metal oxides more strongly than chloride (Cl) or nitrate (NO_3). Still, B is relatively mobile in the soil and can leach with heavy rainfall. Much of the available B in soil is associated with organic matter accumulated in the surface soil layer. Because of this, uptake by the plant may be reduced by surface soil moisture stress.

Figure 1. Rose clover sample at left shows B deficiency on early growth where 1 ton/A of 100 ECCE lime was applied with no B. Sample in center received 1 lb/A rate of B, and at right 2 lb/A. Although the plants appeared to overcome the early B deficiency, yield loss due to the deficiency was about 1,000 lb of forage per acre.

In **Figure 1**, the B deficiency symptoms appear on the lower leaves. The initial reddening of these leaves occurred when they were new growth during cool temperatures. As temperatures increased, B availability increased, probably because of organic matter mineralization and plant root extension. This allowed the clover plants to grow out of the deficiency.

Boron availability is affected by high soil pH. As soil pH increases, B availability decreases. Liming can lower B

Dr. Haby is Professor, Texas Agricultural Experiment Station at Overton; Dr. Loeppert is Professor, Texas A&M University and Texas Agricultural Experiment Station at College Station; Mr. Villavicencio is a former graduate research assistant now working in Guatemala City, Guatemala.

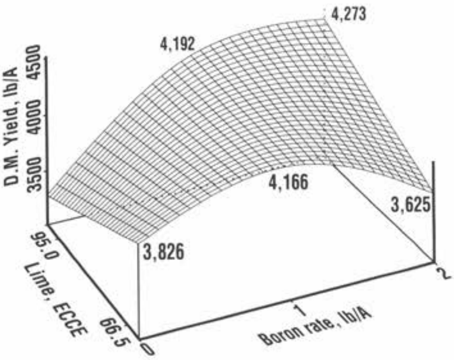

Figure 2. Rose clover response to lime ECCE and rate of B.

availability and increase the need for B fertilization. Research in Texas has shown that use of 100 percent effective calcium carbonate equivalent (ECCE) lime decreased B availability to clover and allowed the plants to tolerate 2 lb B/A (**Figure 2**). The less efficient 62 percent ECCE limestone was not as effective in increasing soil pH and lowering B availability. With the less effective liming material, the 2 lb/A rate appeared to be toxic to the clover, decreasing yield to levels below the zero B treatment.

In summary, liming soil to provide the proper pH for macronutrient availability and activity of legume nodulating bacteria can increase plant needs for micronutrients, including B. For optimum clover production, don't overlook this significant nutrient interaction on highly leached, limed soils. Soil tests for B availability and lime requirement are suggested. ■

Nitrogen sources . . . from page 13

migration result from N source application, then N source should influence soil physical properties such as water content at the permanent wilting point. There were no significant differences in either soil layer in water content (at the permanent wilting point) among the four N sources or between the N treated and the no-N check.

Summary

Grain yields at Ottawa and Powhattan during the period 1985 through 1988 indicated that plots receiving N yielded significantly more grain (overall average of 78 bu/A) than no-N check (average of 37 bu/A). There were no significant differences in grain yield among the four N sources.

The primary influence of 20 years of N fertilization has been on soil acidification and associated changes in nutrient availability. Lower nutrient availability probably reflected greater nutrient removal in the higher yields of N-fertilized areas.

Thus, N source selection should be based on:

- cost of N
- adaptability of the N source to the producer's crop-tillage system
- availability of N supply.

Pound for pound, all N sources in this study were shown to be agronomically equal when properly applied. ■

Kansas

Evaluation of Starter Fertilizers for Grain Sorghum Production

THREE YEARS OF FIELD WORK have provided good evidence of the responsiveness of grain sorghum to high phosphorus (P) starter fertilizers on low P soils. Yields were increased an average 21 to 27 bu/A (1,176 to 1,512 lb/A). The magnitude of response is comparable to that of wheat and corn under similar conditions. Results of the studies indicated no differences in effectiveness between a 9-18-9 (N-P_2O_5-K_2O) orthophosphate liquid starter and a polyphosphate containing 7-21-7. Researchers concluded that selection of a starter fertilizer source for grain sorghum should be made on the basis of economics and availability rather than formulation ingredients. ■

Source: R.E. Lamond and D.A. Whitney. Published in Journ. Fertilizer Issues, 8(1): 20-24 (1991).

The U.S. Nutrient Budget Is in the Red

By G.W. Wallingford

A nutrient budget is a balance sheet showing nutrient exports (removals) and imports (additions) for a farm. Nutrients are exported when plant material or animal products are sold off the farm. Nutrients can be imported in animal feeds, off-farm waste products and commercial fertilizers or added to the soil by legume fixation of nitrogen (N).

FOR A FARM TO BE SUSTAINABLE, its nutrient budget must balance. If there is a net loss of nutrients, the farm's soils will eventually be depleted of nutrients. Productivity will decline. If there is a net gain of nutrients, which most often occurs on farms with relatively large numbers of livestock, environmental problems can occur due to the combined effects of nutrient accumulation in the soil and soil erosion.

The two nutrients most susceptible to depletion through crop removal are phosphorus (P) and potassium (K). Unlike N, which can be partially replenished by rotation with legume crops, there is no biological method of replacing P and K. Once soil supplies are depleted through crop removal, the only method of replacement is through the importation of outside sources.

Nutrient removal is perhaps the most critical factor when evaluating the sustainability of a farming system. Simply put, if the nutrients removed are not replaced the system is not sustainable.

The U.S. Nutrient Budget

Nutrient budget calculations can also be applied to a region or a nation. There are examples all over the world of farming systems which have failed because nutrients removed in harvested crops were not replaced. The result is a decline in soil productivity and loss of the nation's ability to feed its people.

Figure 1 shows the nutrient budget for the major U.S. crops since 1965. The N budget for the U.S. is slightly positive and has been fairly stable since 1980. The P budget is now negative after being positive for most of the 1960s and 1970s. The K budget continues to be strongly negative. In 1989, U.S. crops removed 2.6 million more tons of K_2O than were applied in commercial fertilizer.

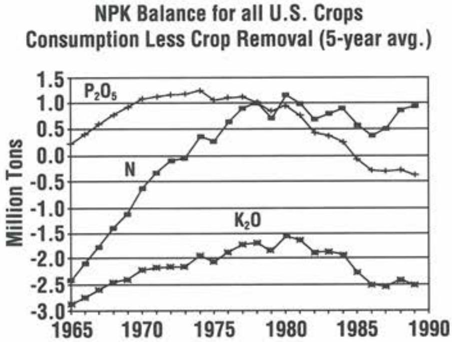

Figure 1. The nutrient budget for 20 major U.S. crops, 1965-1989. The amounts of N, P_2O_5 and K_2O removed in the harvested portion of 20 major U.S. crops were subtracted from the amounts applied to all crops in commercial fertilizer. The data shown are five-year running averages. (Data from USDA analyzed by the author.)

Strengths and Limitations of the Nutrient Budget Approach

The technique used to calculate the nutrient budgets shown in **Figure 1** is useful when evaluating the overall sustainability of U.S. agriculture. The application of commercial fertilizers has come under criticism in recent years partly

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because of the belief that overuse has built up nutrient levels in soils beyond crop needs. The data clearly show, however, that the nation as a whole is experiencing a nutrient deficit for P and K.

A limitation of this approach is the masking of differences among crops and regions of the country. The high native soil levels of K, for example, in the western states will forestall problems resulting from K deficits for many years. On the other hand, forage crops such as alfalfa normally remove more nutrients from the soil than are returned through commercial fertilizer.

Impact of Soil Erosion and Animal Manures

The nutrient budgets shown in **Figure 1** do not take into account losses of nutrients by soil erosion or the addition of nutrients in animal manures and other waste products. The quantity of nutrients lost to soil erosion annually has been estimated at 3 million tons of N, 5 million tons of P_2O_5, and 45 million tons of K_2O[1]. If these numbers were subtracted from the values in **Figure 1**, the nutrient budget for the U.S. would look much worse.

These large losses of N, P, and K are not all available forms of the nutrients. Most are unavailable or slowly available forms found in the mineral and organic portions of the soil. Many clays and silt particles, for example, have a high content of K.

U.S. farmers are using improved tillage and residue management techniques to reduce these large losses of nutrients by soil erosion. As an example, surveys by the Conservation Technology Information Center found that in 1990 more than 26 percent of the planted crop acreage was in conservation tillage systems which leave over 30 percent of the soil surface covered by crop residue. Corn acreage was 32 percent conservation tilled, while winter wheat and soybeans were each 27 percent conservation tilled.

The quantities of nutrients in animal manures available for application to soils have been estimated to be 1.9 million tons of N, 0.5 million tons of P_2O_5 and 1.2 million tons of K_2O[2]. These estimates reflect handling losses but do not allow for losses which may occur after field application. These values are significant but much less so than the estimated losses to erosion.

Sustainability Versus Fertilizer Use Efficiency

In order to maintain soil productivity and the sustainability of food production, nutrients removed from the soil must be replaced. Research and practical experience have shown that in order to maintain soil test levels in soils not susceptible to significant erosion losses, nutrient replacement of P and K through commercial fertilizer must roughly equal 110 percent to 120 percent of crop removal. An ideal nutrient efficiency of 100 percent is difficult to achieve because of such factors as soil chemical fixation and losses to water and wind erosion which occur even on well managed soils.

Achieving a steady-state nutrient balance in the 110 to 120 percent range assumes that soil tests have already been raised to sufficient levels for optimum yields. This is not the case for millions of acres in the U.S. which still test in the low and medium categories. These soils need nutrient applications greater than crop removal in order to attain their full production potential.

Figure 2 shows that, as a percentage of crop removal, fertilizer use is now less than 100 percent for both P and K. In other words, U.S. farmers are now, on the average, mining their soils of P and K. Rather than nutrient buildup, nutrient depletion is occurring.

Attempts at further improvements in fertilizer use efficiency run the risk of accelerating the rate of nutrient depletion. Many programs aimed at improving efficiency depend primarily on lowering fertilizer application rates. While this may achieve short-term economic benefits on

[1]Frye, W.W., O.L. Bennett and G.J. Buntley. 1985. In *Soil Erosion and Crop Productivity*, R.F. Follett and B.A. Stewart, eds. American Society of Agronomy, Madison, WI. p. 341.
[2]Van Dyne, D.L., and C.B. Gilbertson. 1974. Estimating U.S. Livestock and Poultry Manure and Nutrient Production. USDA Economics, Statistics, and Cooperative Services. ESCS-12. (Estimates for 1974 livestock numbers updated to 1987 by the author).

Nutrient Budget . . . from page 17

NPK Application/Removal Ratios
Fertilizer Use as Percent of Crop Removal

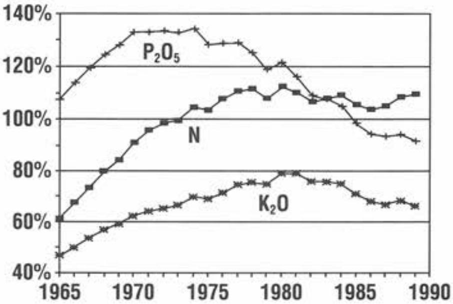

Figure 2. Fertilizer use as a percentage of crop removal for 20 major U.S. crops, 1965-1989. The percentages or ratios were obtained by dividing nutrient consumption by crop removal. The data shown are 5-year running averages.

soils testing high in P or K, a red flag should be raised anytime the application rate is less than crop removal. The danger is that the long-term sustainability of agriculture may be jeopardized by attempts to achieve short-term economic gains.

Selection of Nutrient Sources

From the standpoint of plant nutrition, the source used to replace nutrients makes no difference long-term. The challenge is to select the most efficient and environmentally sound technology to replace nutrients in order to maintain soil fertility and productivity. A corn plant responds equally well to K, for example, whether it is applied to the soil in the form of manure or commercial fertilizer.

Systems which encourage nutrient recycling help to lessen the need to import off-farm sources. Nutrient sources produced on the farm should receive first attention in recycling efforts. Returning nutrients contained in animal manures, livestock bedding, and plant residues to the soil, for example, is economically wise and environmentally responsible. With regards to sewage sludge and manufacturing by-products, high transportation costs and limited availability in agricultural regions have discouraged their widespread use as off-farm nutrient sources.

In the long-run, it is not the source but the quantity of nutrients applied that determines if soil fertility and productivity can be sustained. Most farmers find commercial fertilizer to be the most desirable nutrient source because of its relatively low cost, wide availability, high analysis, ease of handling and application, and predictable nutrient availability. ■

Nebraska

Nitrogen and Irrigation Management Practices to Minimize Nitrate Leaching from Irrigated Corn

PRACTICES related to management of fertilizer nitrogen (N) and irrigation water for corn were evaluated in a series of studies conducted at 79 sites in Nebraska from 1984 through 1988. Practices evaluated included N credit from nitrate (NO_3^-) in soil, N credit from NO_3^- in irrigation water, realistic yield goal selection, and irrigation scheduling according to crop water use. The procedure for determining the recommended fertilizer N rate provided adequate N without reducing yields. Averaged over the 79 sites, yield goal was 170 bu/A; recommended fertilizer N rate was 130 lb/A. Average yield was 173 bu/A, and fertilizer N reduction due to accounting for various N sources was 45 lb/A. This study emphasizes the importance of crediting other N sources in order to maximize crop production efficiency and minimize NO_3^- losses. ■

Source: R.B. Ferguson, C.A. Shapiro, G.W. Hergert, W.L. Kranz, N.L. Klocke, and D.H. Crull, Institute of Agricultural and Natural Resources, University of Nebraska. Published in J. Prod. Agric. 4:186-192 (1991).

Kansas Research

Sulphur Can Increase Yields, Quality, and Profits from Cool Season Grasses

By R.E. Lamond and D.A. Whitney

Yields and quality of cool season forage grasses may be limited by unrecognized sulphur (S) deficiencies. Kansas researchers report that S responses, recognized for almost 20 years, are becoming more consistent.

THE ROLE OF S in plant nutrition is well recognized, but the need for supplemental S in forage fertilization has not received as much attention in eastern Kansas and western Missouri. Data from earlier investigations have demonstrated that providing adequate S can improve nitrogen (N) use efficiency, increase plant crude protein concentrations, and enhance forage quality of grasses such as brome and fescue.

Early Investigations

Studies conducted by Kansas State University agronomists in the early 1970s indicated the probable need for supplemental S on cool season forage grasses in the eastern part of the state. Comparisons of performances among various N sources included urea and urea-ammonium sulphate (40 percent N, 4 percent S). Urea-ammonium sulphate (UAS) frequently was superior to urea in these studies, both in terms of forage yield (**Table 1**) and forage crude protein content (**Table 2**). Effects were consistent for both fall and spring applications. Since UAS was frequently superior to ammonium nitrate as well, the effect was arguably due to the addition of sulphate-S, not a change in performance of urea in the more acid environment of the UAS prill. All soils in these studies were acid, with pHs of 5.3 to 6.6, silt loam to silty clay loam in texture. The soils had organic matter contents ranging from about 1.8 to 2.3 percent.

Responses to S in UAS varied with year in these early investigations, possibly related to soil temperature and release of S from organic matter.

The effects of S on crude protein content of the forage (**Table 2**) were much more pronounced early in the growing season when cattle would have been on pasture. Even when S applications had less effect on total yield (1974), protein was higher when S was applied. The higher crude protein levels reflect this improved N use efficiency. Nitrogen recovery increased about 23 lb/A because of S application, improving efficiency of applied N recovered from 61 to 80 percent.

Table 1. Sulphur effects on cool season grasses are not new. (Kansas, 1973).

N	S	Source	Riley Co. Brome	Jackson Co. Brome	Franklin Co. Brome	Labette Co. Fescue
lb/A			Yield, lb/A			
120	0	Urea	7,118	4,476	6,846	5,632
120	12	UAS	8,511	7,062	7,979	5,760

N spring applied. Yield at 12.5% moisture. Lamond, Kansas State Univ.
UAS = Urea-ammonium sulphate, 40% N, 4% S.

Dr. Lamond is state Extension soil fertility specialist and Dr. Whitney is state Extension agronomy leader, Department of Agronomy, Kansas State University.

Table 2. Sulphur application can affect bromegrass protein. (Kansas, 1973).

N	S	Source	April 24	May 8	May 21	June 1
lb/A			---------- % crude protein ----------			
120	0	Urea	18.6	13.6	9.7	7.4
120	12	UAS	21.2	14.5	10.4	8.1

Data average of three N rates. Riley County.
Lamond, Kansas State Univ.

Response Continues

Little use was made of the early information indicating S responses in cool season grasses. However, increasing incidence of S responses in wheat in Kansas and low S concentrations in tissue analyses of both grain sorghum and grasses prompted the resumption of studies of S application effects on cool season grass yields and quality.

These studies included evaluation of the effectiveness of ammonium sulphate and ammonium thiosulphate at rates of 15 and 30 lb S/A. Sulphur rates in the earlier studies had ranged from 6 to 18 lb S/A. Nitrogen was held constant at 120 lb N/A. Both N and S were spring-applied, broadcast. Soils were silt loam to silty clay loam in texture, mildly acidic.

Data in **Table 3** indicate S responses from 1987 through 1991. Magnitude of response varied with year, temperature and moisture stress, but the effects were consistently positive. An additional site-year in 1991 at a third location in Brown county produced a net increase in yield from S of 822 lb/A. Both ammonium sulphate and ammonium thiosulphate were effective sources of S with no significant differences between the performance of the two materials.

Crude protein in forage taken at harvest, usually mid- to late-May . . . early bloom, did not show large effects of S application. However, N recovery did increase about 10 to 15 percent. Late April plant sampling in Riley county in 1990 showed the same positive effects of S on crude protein noted in the 1970s. Sulphur application increased crude protein to an average value of 22.5 percent compared to 19.9 percent in the controls. Sulphur concentration in the immature grass was also increased significantly by S application . . . from a low 0.08 percent in the controls to 0.21 percent for areas receiving S. Sulphur levels at the hay-stage were not affected as much by S application . . . often the result of dilution of nutrient content by greater dry matter production.

Higher Yields and Higher Quality Mean More Profits

Sulphur in the nutrition of cool season grasses means higher yields . . . higher quality . . . and higher profits for the hay producer and cattleman. **Here's an example of how that works, based on the Kansas data.**

Hay value = \$50 per ton
Protein value = \$0.25 per lb
Sulphur cost = \$0.16 per lb S

Average yield increase from S, 9 site-years (1987-91) = 572 lb hay/A

Value of extra hay produced = 572 lb/A × \$50/ton = \$14.30/A

Cost of S, average rate of 22.5 lb/A × \$0.16/lb = \$3.60/A

Net from application of S = \$10.70/A or about \$4 for each dollar invested in S.

But data indicate that yield alone is not the only increased value from better forage nutrient management. Sulphur

Table 3. Current studies continue to show the need for S in bromegrass production.

S	Greenwood Co. 1988	Greenwood Co. 1989	Greenwood Co. 1990	Riley Co. 1987	Riley Co. 1988	Riley Co. 1989	Riley Co. 1990	Riley Co. 1991
lb/A				Yield, lb/A				
0	5,411	3,910	5,930	6,231	4,089	2,990	8,280	5,200
15	5,907	4,070	7,155	6,641	4,317	3,525	8,905	5,745
30	5,691	4,260	6,930	7,065	4,090	3,245	9,260	5,935
Avg S. response	+388	+255	+1,112	+622	+114	+395	+802	+640

Yield at 12.5% moisture.
Averaged for ammonium sulphate and ammonium thiosulphate.

application produced a slight increase in protein in hay . . . about 0.2 percent. That increase was as much as 0.7 percent in some cases. Extra protein in the hay can add profit by replacing protein supplement in animals' rations.

Average yield with S = 6,037 lb hay/A

Crude protein increase from S = 0.2 percent

6,037 lb hay/A × 0.2 percent more protein with S × \$0.25/lb protein = \$3.02/A

Increased value of hay/A = \$14.30

Value of extra protein/A = \$3.02

Increased net from S = \$17.32/A or a return of about \$4.80 per dollar invested in S.

An increase of 0.7 percent protein for 6,037 lb of hay would have added over \$10 per acre in additional protein value.

SULPHUR fertilization increases bromegrass yield and protein content. Note the effects of S (right) on growth and leaf color.

Summary

Research has shown that S fertilization is an important part of improved management of cool season grasses. Kansas data have shown S responses in bromegrass and tall fescue hay can range from zero to over a ton per acre. Over the past 5 years, S responses have been recorded each year. Nitrogen use efficiency has been improved by eliminating S deficiencies and forage quality has been improved. In the final analysis, forage profitability has been substantially improved by the use of S. Sulphur soil tests may be of some value in determining areas needing S, but forage producers and cattlemen should also consider using plant analysis in April to help in the diagnostic process. ■

North Carolina

Cotton Response to Starter Fertilizer Placement and Planting Dates

FIELD STUDIES were conducted in four North Carolina environments to determine the effect of planting date on cotton response to side-banded starter fertilizer on soil testing high in phosphorus (P). Three planting dates, early-, mid- and late May, and two methods of starter fertilizer placement, broadcast and side-banded, were evaluated. Ammonium polyphosphate starter was applied at a rate of 15 lb N and 51 lb P_2O_5 per acre.

Fertilizer placement had only minor effect on population. Mid- and late May planting decreased average lint yields across the four environments by 31 and 50 percent, respectively. Lint yield was increased by 9 percent by side-banded fertilizer placement, even though 24 lb N and 45 lb P_2O_5 had been broadcast prior to seeding at 3 of 4 locations. No significant planting date by fertilizer placement interactions were observed for plant population, flower production or lint yield.

The researcher concluded that applying side-banded starter fertilizer can benefit cotton producers, irrespective of planting date. ■

Source: D.S. Guthrie, Department of Crop Science, North Carolina State University, Raleigh, NC 27695. Published in Agron. J. 83:836-839 (1991).

Sulphur Fertilization Improves Bahiagrass Pastures

By Jack E. Rechcigl

Recent field studies have shown that addition of sulphur (S) can increase yields and quality of bahiagrass grown in Florida.

SULPHUR DEFICIENCIES for plant growth have been reported in over 35 states, including Florida. Though it is usually termed a secondary plant nutrient, S should be considered one of the major nutrients essential for crop growth along with nitrogen (N), phosphorus (P), and potassium (K).

Sulphur is required by plants for the synthesis of essential amino acids required for protein production. Thus, if S is limiting, forage quality as well as quantity will be reduced. In fact, S deficiencies are often confused with N deficiencies because of the similiarity of symptoms.

Symptoms of S deficiency consist of stunted plant growth and a yellowing of plant tissue, which are similar to N deficiency. In less severe cases of S deficiency, visual symptoms may not always show up, but crop yield and quality will still be affected.

Until recently, little attention has been focused on the need for S fertilization in Florida. In the past, low analysis fertilizers contained S. Therefore, growers did not need to be concerned with S fertilization. Modern, high analysis fertilizers such as triple superphosphate and diammonium phosphate contain very little S. Further, emission controls have decreased S deposition from the atmosphere. As a result, S deficiencies are becoming more pronounced and widespread. Coarse textured soils commonly found in Florida often exhibit S deficiencies because of low organic matter levels and leaching.

Sulphur fertilization will likely affect crop yield and quality only when S is deficient. Sulphur status of a crop is best determined by having plant tissue analyzed by a reputable laboratory. Tissue analysis is more reliable than a soil test for determining deficiencies. Sulphur levels in grasses should range from 0.2 to 0.5 percent. If the

BAHIAGRASS in plots at left and right both received 134 lb/A rate of N as ammonium nitrate. Note response in plot at right which also received S at a rate of 77 lb/A.

Dr. Rechcigl is Associate Professor, University of Florida, I.F.A.S., Agricultural Education and Research Center, Ona, FL 33865.

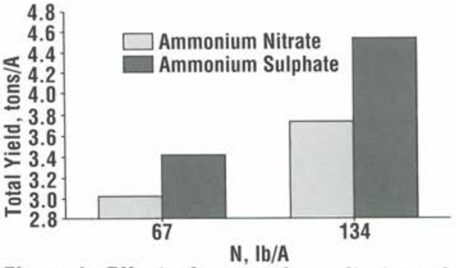

Figure 1. Effect of ammonium nitrate and ammonium sulphate rates on bahiagrass yields.

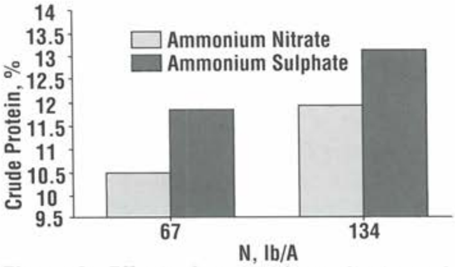

Figure 2. Effect of ammonium nitrate and ammonium sulphate on percent crude protein content of bahiagrass.

level of S is less than 0.2 percent, the grass should respond to S fertilization.

Florida Studies

A 3-year study was conducted at Arcadia, Florida, to evaluate the influence of S and N on bahiagrass yield and quality. Treatments consisted of two forms of N (ammonium nitrate and ammonium sulphate), and three rates of S (0, 77, and 155 lb S/A/yr from potassium sulphate), applied to an established Pensacola bahiagrass field. In addition, all plots received an annual application of 50 lb/A P_2O_5 and 100 lb/A K_2O. Fertilizer was applied in split applications, half in March and the remainder in September.

Yields. Bahiagrass yields increased with increasing rates of N. Highest yields were obtained with ammonium sulphate compared to ammonium nitrate (**Figure 1**). The higher yields were likely the result of the ammonium sulphate providing needed S. The addition of S (77 lb S/A) increased bahiagrass yields by 25 percent. Plant numbers were also higher on areas fertilized with ammonium sulphate as compared to ammonium nitrate.

Forage Quality. This research demonstrated that the addition of 77 lb S/A increased crude protein 1.2 percent (**Figure 2**) and digestibility 3 to 4 percent 30 days after S was applied (**Figure 3**). The quality effects reflected the essential role of S in protein production. Improved digestibility with S applications reflects the more rapid, lush growth of the forage.

Plant tissue S was greater in bahiagrass treated with ammonium sulphate compared to ammonium nitrate (**Figure 4**). Sulphur application increased S concentration of plant tissue from around 0.10 percent up to 0.23 and 0.30 percent for S applications of 77 and 155 lb S/A, respectively. It is important to note that the

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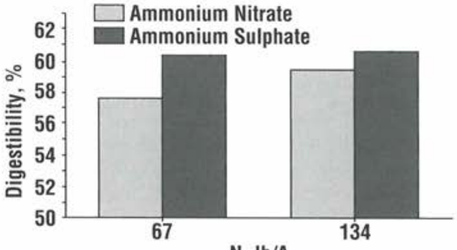


Figure 3. Effect of ammonium nitrate and ammonium sulphate on bahiagrass digestibility.

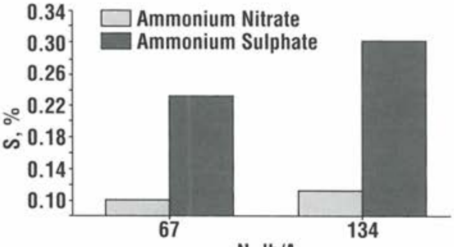


Figure 4. Effect of ammonium nitrate and ammonium sulphate on S concentrations in bahiagrass.

Institute Announces New Book: *Sugarcane Nutrition*

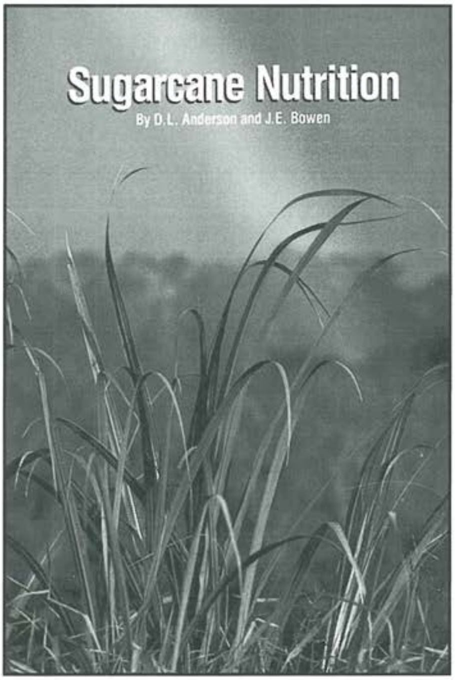
A NEW BOOK titled *Sugarcane Nutrition* is now available from the Potash & Phosphate Institute (PPI). The publication features more than 40 pages of information with 44 color photographs illustrating specific malnutrition conditions in sugarcane.

Sugarcane Nutrition was authored by Dr. David L. Anderson, Sugarcane Nutritionist at University of Florida, Everglades Research and Education Center, and by Dr. John E. Bowen, Plant Physiologist, University of Hawaii, Honolulu. The book was published jointly by PPI, the Potash & Phosphate Institute of Canada (PPIC), and the Foundation for Agronomic Research (FAR).

"*Sugarcane Nutrition* is international in scope and should appeal to sugarcane growers, research scientists, Extension specialists, consultants and others interested in nutritional deficiencies and toxicities affecting sugarcane plants," said Dr. David W. Dibb, PPI President.

The text includes descriptions of the metabolic functions of important nutrients, leaf nutrient concentrations, listing of fertilizer sources, and comments on management considerations.

Printed on special synthetic paper resistant to moisture, the book is durable and easy to use.



Sugarcane Nutrition is priced at $15.00 per copy (plus shipping). Discounts are available on quantities.

See page 31 for more details. ■

Bahiagrass . . . from page 23

bahiagrass fertilized with ammonium nitrate contained about 0.1 percent S, which indicates S deficiency. Ideally, bahiagrass should contain between 0.2 to 0.5 percent S.

Soil pH. Application of both ammonium sulphate and ammonium nitrate resulted in a decrease in soil pH 3 years after application. Predictably, ammonium sulphate resulted in a greater decrease in soil pH than ammonium nitrate (pH 4.8 versus 5.2 at the highest N rate). However, the results of a 3-year liming study on bahiagrass show no significant differences in dry matter production with soil pH values within the pH range observed in this study (4.8 to 5.7).

Summary

Based on the results of this 3-year study and other research conducted in Florida, S application increases both yield and quality of bahiagrass pasture. Bahiagrass tissue should be tested for S to determine fertilization needs, with a level below 0.20 percent of the tissue dry matter indicating a S deficiency. Where S is limiting, forage yield and quality may be improved by using S-containing fertilizers. ■

Fertilization of Warm Season Turfgrass

By Noble R. Usherwood

Nutrient management for turfgrass is important to achieve the quality and appearance expected for today's standards.

FOR EVERY 10 PEOPLE in the U.S., there is about one acre (43,560 square feet) of turfgrass. These 25 million acres are expected to increase further with new home subdivisions, with expanding turf-farm acreage, and with a growing interest in the beautification of office and industrial park surroundings.

Turfgrass has captured the interest and involvement of a greater percentage of the U.S. population than any other major crop. There are several reasons for this. A well-groomed lawn can build home value and contribute to the overall beauty of the community. For some, turfgrass is a business with economic incentives. Many gain hobby-type benefits from home lawn care. Others are involved through recreation and expect quality turf on the thousands of golf courses throughout the nation.

Like a forest of trees or a field of corn, a beautiful lawn is no more than a collection of individual plants growing very close together. These plants must compete wth each other for sunlight, water and available nutrients. Only the strong will survive. Well-nourished plants will best resist stress caused by disease, insects, occasional moisture shortage, high summer and/or low winter temperatures . . . and management-induced stress such as frequent mowing, high traffic and compaction.

Nutrient Management

Turfgrass responds to intensive management. This is especially true for the warm season grasses. A vital part of the management system is a finely tuned plant nutrition program. Such a program must be designed to supply each plant with nutrients in the right amounts and at the right time to minimize plant stress. Understanding a few basic facts concerning nutritional requirements of turf grasses can help to remove plant nutrition as a limiting factor in turf management.

Soil pH. Adjust soil acidity (pH) to the requirement of each particular species of grass. In general, nutrient availability improves as soil acidity is corrected. The desired pH range for warm season lawn grasses includes two distinct groups. See **Table 1**.

Table 1. Desirable pH ranges for warm season lawngrasses.

Moderately Acidic Soils (pH 5.0 to 5.9)	Slightly Acidic Soils (pH 6.0 to 6.9)
Bahia	Bermuda
Carpet	St. Augustine
Centipede	Zoysia

Source: Dr. J.B. Sartain, University of Florida.

Finely ground dolomitic or calcitic limestone can be used to adjust soil pH. Dolomitic limestone will also serve as a source of magnesium (Mg). For best results, mix the limestone into the topsoil during soil preparation for establishing new seedings. For established turf, top-dress 50 lb of good quality limestone per 1,000 square feet every six months until the recommended quantity of limestone has been applied.

Each nutrient contributes to quality turf in its own specific way.

(continued on next page)

Dr. Usherwood is Vice President and Southeast Director, Potash & Phosphate Institute (PPI), 2801 Buford Hwy., NE, Suite 401, Atlanta, GA 30329.

Turfgrass . . . from page 25

Nitrogen (N) stimulates rapid growth and provides a desired dark green color. Too little produces a weak plant and a poor return from other inputs. Too much N can be uneconomical and can reduce plant tolerance to diseases, nematodes, and other causes of plant stress.

Phosphorus (P) stimulates a healthy and vigorous root system and is essential for energy transfer critical to rapid plant development.

Potassium (K) is being "rediscovered" in the turf industry. It improves overall plant use of N since both are vital to key plant functions such as photosynthesis, protein formation, and actions of many enzyme systems. Potassium also helps improve turfgrass tolerance to heat and moisture stress and to compaction.

Sulphur (S), like K, teams with N for protein formation and is essential for chlorophyll synthesis . . . the basis for the dark green color of quality turf. Sulphur also improves plant tolerance to high traffic, winter injury and intensive cutting stress.

Magnesium is the central element in the chlorophyll molecule. A severe shortage restricts photosynthesis and the efficiency of plants to utilize other inputs. Magnesium needs often increase when soil pH is adjusted with calcitic limestone and when plant available K is high in an intensive management system.

Micronutrients, such as iron (Fe), zinc (Zn), manganese (Mn), and boron (B), sometime limit plant growth. Availability of these essential elements declines when soils are limed. Micronutrients are especially important for those grass species growing in the soil pH range of 6.0 to 6.9. Research shows, for example, that Fe can improve color of centipede turfgrass when soil pH is too high. Manganese might also limit plant growth when soil pH approaches or exceeds neutrality.

Time, Rate and Method of Fertilizer Application

Soil test results, special nutrient needs for turf quality, climatic conditions, and many other management factors go into the development of a sound fertilization program. University, USDA and private industry scientists have evaluated nutrient requirements for most turfgrass species under a variety of growing conditions.

In Georgia, turf scientists studied the N-P-K needs for centipede grass under natural shade. Results of that three-year study illustrate how a balanced, properly timed fertilization program can improve both turf quality and density.

Fertilizer Is a Team Player

Fertilizer interactions with other management practices are especially important for managers of warm season turfgrasses. The following points help illustrate some of the ways fertilizer contributes to the total turfgrass management program.

- Dr. Bob Dunn, University of Florida Extension Nematologist, reminds us that nematicides and insecticides can control pest problems, but adequate plant nutrition is essential for rapid regrowth of new roots to heal the injury. He notes, "Nutrient deficiencies, especially soil potassium and phosphorus, and compacted soils can make turf more sen-

Table 2. Influence of nitrogen, phosphorus and potassium on centipede grass under natural shade.

Time of Application		Turf Quality[1]			Turf Quality[2]		
April	Sept.	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
N-P_2O_5-K_2O lb/1,000 sq. ft.		---------- turfgrass ratings ----------					
1.0-0.4-0.8	1.0-0.4-0.8	5.5	5.4	3.9	8.1	8.0	5.6
2.0-0.8-1.6	2.0-1.8-1.6	5.0	4.9	4.0	8.0	7.2	6.5
2.0-0.8-1.6	0-0-4.0	5.8	6.4	6.0	8.8	8.2	7.5

[1]Quality: 1 = brown or no turf, 10 = dark green, dense, uniform turf.
[2]Density: 1 = no turf, 10 = complete, dense turf.
Source: Drs. B.J. Johnson, R.E. Burns, and R.N. Carrow, University of Georgia.

sitive to the root damage caused by nematodes."

- Dr. J.B. Sartain, University of Florida Turf Nutrition Specialist, points out that time, rate and method of fertilizer application depend upon the type of turfgrass, turfgrass quality needs, and the level of maintenance desired. He adds, "Although water and pest infestations influence turfgrass growth, more lawns suffer from nutritional deficiencies than from the former problems."
- University of Georgia scientists have documented that nutrient balance is essential. Potassium, for example, is vital for best plant N use efficiency. The proper amounts of N and K can improve plant tolerance to disease, plant color, turf density, turf quality, and plant response to other inputs such as water and certain plant protection chemicals.

DR. J.B. SARTAIN examines turf plots in Florida.

Summary

Research by turfgrass scientists emphasizes the importance of good plant nutrition and supports this conclusion: A fertile soil does not always produce a quality turfgrass, but the soil under quality turfgrass must be fertile. ■

Nebraska

Management Practices for Subirrigated Meadows

RESEARCH conducted at the University of Nebraska Gudmundsen Sandhills Laboratory over the past nine years to evaluate methods of increasing subirrigated meadow hay yield and/or forage quality indicates that nitrogen (N), phosphorus (P) and sulphur (S) are limiting factors in hay yield and protein production. The application of N, P and S increased dry matter yields over the control by a range of values from 937 to 3,315 lb/A, yields increasing with higher N rates and the additive effects of P and S. All fertilizer was spring applied. Effects on Garrison creeping foxtail and native meadow vegetation were similar. Economic analysis of the study indicated that in N, P and S applications were highly cost effective. ■

Source: J.T. Nichols, West Central Research and Extension Center, University of Nebraska. Published in Proc. Third Intermountain Meadow Symposium, Colorado Agricultural Experiment Station, Technical Bulletin. LTB91-2, pages 27-38 (1991).

American Society of Agronomy Recognizes Potash & Phosphate Institute Support

THE Potash & Phosphate Institute (PPI) was recognized as a charter member and 40-year Sustaining Member of the American Society of Agronomy (ASA) at the Society's recent annual meetings in Denver.

The Sustaining Member program was initiated in 1951 as a means for companies and other organizations to participate in furthering the agronomic profession and support the activities of the Society. ■

Dr. B.C. Darst Honored as Fellow of American Society of Agronomy

Dr. B.C. Darst

DR. BOB C. DARST, Vice President of the Potash & Phosphate Institute (PPI) and President of the Foundation for Agronomic Research (FAR), has been selected as a Fellow of the American Society of Agronomy (ASA). The announcement came at the 1991 ASA annual meetings in Denver.

Dr. Darst directs the communications program at PPI, furthering development of agronomic information for many audiences. He also heads the agronomic research and education efforts of FAR.

Dr. Darst is a graduate of Oklahoma State University and earned his Ph.D. from Auburn University in 1966. He has served as President of the American Forage and Grassland Council, as Chair of an ASA task force, and in numerous other responsibilities related to agronomic work. ■

Dr. A.E. Ludwick Honored as Fellow of American Society of Agronomy

Dr. A.E. Ludwick

DR. ALBERT E. LUDWICK, Western Director of the Potash & Phosphate Institute (PPI), has been selected as a Fellow of the American Society of Agronomy (ASA). The announcement came at the 1991 ASA annual meetings in Denver.

Dr. Ludwick directs agronomic research and education programs for the Institute in seven western states of the U.S. and in Mexico. His primary area of interest is soil fertility and fertilizer management as related to production efficiency. He has served as Associate Editor of *Agronomy Journal*, as Chair of ASA Division A-4, and in numerous other responsibilities to further agronomic understanding.

He graduated from California Polytechnic State University in 1962, then earned his M.S. and Ph.D. at the University of Wisconsin.

Friends and colleagues within the Society nominate worthy members, who are then ranked by a committee. Election to Fellow is made by the ASA Executive Committee, based on professional achievements and meritorious service. Only a small percentage of ASA members may be elected Fellows. ■

Dr. William K. Griffith Receives ASA Industrial Agronomist Award

Dr. W.K. Griffith

DR. WILLIAM K. GRIFFITH, Eastern Director of the Potash & Phosphate Institute (PPI), received the Industrial Agronomist Award at the 1991 annual meetings of the American Society of Agronomy.

The award is given to a productive, capable individual known for original and significant research and for an outstanding ability to inspire sound thinking, objectivity, integrity, and cooperation in associates.

Dr. Griffith has focused his career on working with industry and university personnel in the development and implementation of sound crop production systems through research and educational programs. He has served on numerous committees and in responsibilities with ASA, Soil Science Society of America (SSSA), and the American Forage and Grassland Council. Dr. Griffith is a graduate of Western Illinois University. He earned his M.S. at the University of Illinois and his Ph.D. from Purdue University in 1960. ■

Dr. Dale R. Hicks Receives 1991 Robert E. Wagner Award for Efficient Agriculture

DR. DALE R. HICKS, Professor and Extension Agronomist at the University of Minnesota, was named recipient of the Robert E. Wagner Award for Efficient Agriculture, presented at the 1991 American Society of Agronomy (ASA) annual meetings in Denver.

The award, supported by the Potash & Phosphate Institute (PPI) and administered by ASA, recognizes the importance of an efficient and competitive agriculture. It is named for the retired president of PPI, Dr. Robert E. Wagner.

Dr. Hicks is responsible for research and Extension educational programs on corn and soybeans in Minnesota. His programs relate to current crop production issues, emphasize the economic optimum for production inputs, and focus on the interdisciplinary approach to problem solving. His work has substantially increased profitability and production efficiency for corn and soybean producers.

Dr. Hicks earned his Ph.D. from the University of Illinois in 1968. ■

In Memory of Dr. Niven D. Morgan, Sr.

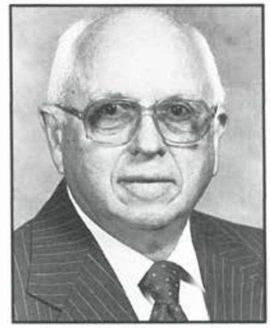
DR. NIVEN D. MORGAN, SR., passed away July 15, 1991, in Shreveport, LA, following a brief illness at the age of 83. Dr. Morgan is survived by his wife, Jeanette Pearce Morgan, and three sons: Niven Morgan, Jr., Shreveport; Edgar Morgan, Shreveport; and Douglas P. Morgan, Pineville, LA. He is also survived by seven grandchildren and seven great-grandchildren.

Dr. Morgan was an agronomist with the American Potash Institute (forerunner of the Potash & Phosphate Institute) for over 30 years. Born in Shongaloo, LA, he graduated from the University of Arkansas and received his M.S. and Ph.D. degrees from Iowa State University.

Nationally recognized for his work in agronomy, Dr. Morgan was a past president of the Louisiana Plant Food Education Society and the Texas Plant Food Society. He served as chairman, president, and director of numerous other boards and committees. He authored many articles and papers during his career.

Dr. Morgan was honored with several awards during his lifetime of work in agriculture, including the Distinguished Grasslander Award of the American Forage and Grassland Council, Certificate of Appreciation from Louisiana State University, and Outstanding Service to Arkansas Agriculture Award.

After retiring from the Institute in 1972, Dr. Morgan continued to operate a large forage-beef cattle farm in Louisiana and was untiring in his efforts to encourage improved management of forages and other crops. ■



Dr. N.D. Morgan, Sr.

IN 1973, I assumed the responsibilities of Southwest Director for the Institute. Niven Morgan had worked the territory since 1940, the year of my birth. During my 13-plus years in the Southwest, I never did "fill" Niven's shoes, but learned to follow his tracks because they usually led to where the action was in agriculture. Niven was an innovator in crop fertilization and management . . . ahead of his time in most cases. His legacy will long endure. Jeanette, Niven Doyle, Eddie, Doug . . . the entire Morgan family . . . will miss him. So will I.

—B.C. Darst
Vice President, PPI

THE FOODWATCH PLEDGE

We believe :

People have a right to healthful, abundant food. ❦ Food that is nutritious. ❦ Food that is produced and handled safely. ❦ Food that is grown with a deep respect for the environment. ❦ Food that is affordable. ❦ Food that will ensure our future and our children's future.❦

Because of these beliefs we pledge :

To use products properly. ❦ To read and follow all label directions. ❦ To produce, process and market food responsibly. ❦ To take every precaution and safety measure within our power and encourage others to do the same.❦

Consumers are agriculture's most important customers.
America's farmers and ranchers take seriously their responsibility to bring consumers high quality, reasonably priced food, while maintaining a sound environment.
Through FoodWatch, we are working to ensure America's food and agriculture system keeps growing better every day.

To find out how you can help, call or write FoodWatch:
202/682-9203, P.O. Box 27723, Washington, D.C. 20077-1614

FOODWATCH is a public education and awareness program designed to build confidence in the food and fiber system in the U.S. The effort emphasizes agriculture's commitment to ensuring safe food and a clean environment.

The Potash & Phosphate Institute (PPI) and the Foundation for Agronomic Research (FAR) continue to support the goals of explaining the benefits of the agricultural industry and furthering understanding of food safety and environmental issues.

Information Materials from PPI

Listed here are several recent releases from the Potash & Phosphate Institute (PPI).

	Quantity	Cost
SOUTHERN FORAGES New 250-page paperback book. See description on page 3. **Cost: $20.00 each**, plus shipping/handling (10% of subtotal, $3.00 minimum)	______	$______
Quantity Discounts: 5% for 10 to 49 copies; 10% for 50 to 99 copies; 15% for 100 to 199 copies; 20% discount for 200 or more copies.	Shipping/ Handling	$______
Sugarcane Nutrition New 40-page book. See description on page 24. **Cost: $15.00 each**, plus shipping/handling (10% of subtotal, $2.00 minimum)	______	$______
Quantity Discounts: 5% for 10 to 50 copies, 10% for more than 50 copies.	Shipping/ Handling	$______

Plant Problem Insights

Five new photo-cards are available, discussing specific field problems. A complete listing of topics is available on request.

		Quantity	Cost
#27 Potassium Deficiency in Potatoes	**Cost: 20¢ (MC* 10¢)**	______	______
#28 Phosphorus Deficiency in Potatoes	**Cost: 20¢ (MC* 10¢)**	______	______
#29 Potassium Deficiency in Apples	**Cost: 20¢ (MC* 10¢)**	______	______
#30 Phosphorus Deficiency in Alfalfa	**Cost: 20¢ (MC* 10¢)**	______	______
#31 Nutrient Deficiencies in Corn	**Cost: 20¢ (MC* 10¢)**	______	______

PRODUCTION AGRICULTURE: Feeding People, Protecting the Environment

Video in VHS format, runs 15:26 minutes.

Cost: $10.00 (MC* $5.00) ______ $______

Sustainable Innovations from Conventional Agriculture

Set of 47 color 35mm slides with printed script.

Cost: $30.00 (MC* $15.00) ______ $______

***The MC symbol indicates Member Cost: For members of PPI and contributors to Foundation for Agronomic Research (FAR), and for educational institutions.**

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Who's Going to Tell It?

The fewer the facts, the stronger the opinion.

Each year the public knows less and less about farming. When "Agriculture" is the category on TV's "Jeopardy" show, it is the last topic chosen by these knowledgeable contestants. Even though they know little about "The Bible," that category is chosen before "Agriculture."

In the early years of this century, much of the population, and especially the leadership, had a rural background. They had firsthand experience with farming. They understood and appreciated the problems and the dedication. Not so today. The public knows little of the everyday life of farming.

The most authoritative opinions are often expressed on subjects one knows least about. Today's public is very vocal about government farm programs, animal welfare, clean water, safe food, air pollution, and environmental protection–all agriculturally related topics.

The partially informed believe the farmer is responsible for increased erosion, depletion of mineral resources, poisoning of food and water, and air pollution through livestock. The fact that this is not true is a message that is not reaching the general public. Why?

There are too few educational programs to counter this concept. Agriculture is no longer a popular subject in high schools and colleges. And while millions of dollars are contributed to organizations whose goal is protecting the environment, these very sincere groups are often misinformed.

The future of the world may well depend on properly informing them about agriculture's contribution to the environment while feeding the world. It is a story of miracles and wonders–of remarkable scientists and educators.

To tell this true story won't be easy. It will be costly. But failure to tell it will be far more costly.

J. Fielding Reed

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