BETTER CROPS

with plant food

FALL 1982

Target on
- **Agro-Economics**
- **Fall-Winter Fertilization**

Contents

Economics Favor Building Soil Fertility

By L. Fred Welch

PHOSPHORUS (P) and potassium (K) are classed as "immobile" nutrients because they move very little except in coarse-textured, sandy soils. Unlike P and K, nitrate nitrogen (N) is highly soluble and moves with the soil water. Nitrogen is classed as a "mobile" nutrient because it may leach below root depth during periods of high rainfall or may be lost from the soil after conversion to a gas.

The immobile nature of P and K allows them to be built-up in soils by addition of fertilizer. This article uses phosphorus as an example, showing why economics favor building fertility.

Reducing Uncertainty

Growers differ in the amount of risk they are willing to assume. The risk that P will limit crop yields can be reduced by increasing the supply of P in soils.

The gross cost of reducing risk depends on the cost of added P fertilizer. The initial cost of fertilizer is easy to determine. However, the reaction of growers to this cost would surely differ, depending on whether it is assigned solely to the immediate crop or to several crops. How many fields would have drainage tile installed if the total cost had to be recovered by the first crop after installation? It is readily understood that there are long term advantages to improved drainage. The same is true of improved fertility.

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"The supply of essential elements available for plant uptake can be controlled by growers. The risk of P and K limiting crop yields (profits) can be reduced to a low level. The risk of unrealized profits, due to inadequate P and K limiting yields, can be minimized by the use of fertilizer. The immobile nature of these two elements in soil makes them favorable for the insurance approach toward soil fertility. That is, they store well in soils until absorbed by plants."

Purpose of Fertilizing

In many areas, you should consider that fertilizer is being added for two reasons: 1. Some to build up the soil fertility level; 2. Other to maintain the fertility level by compensating for nutrients removed in the harvested portion of the crop.

We suggest the following for an Illinois soil that is in the medium-phosphorus-supplying geographical region:

Soil test P, lb/A	Add P fertilizer for:
less than 45	Buildup plus maintenance
45 to 65	Maintenance
more than 65	None

If the soil has a low P test, we suggest enough P for both buildup and maintenance. Maintenance is equal to that removed in the harvested portion of the current crop and should be charged to the current crop. Even if no P fertilizer is added shortly before the current crop, there should be a charge for P removed.

Assigning Buildup Cost

Buildup should be thought of as a capital investment rather than the cost being assigned totally to the year in which the P fertilizer was added. Once buildup has been attained it should persist for several years, provided fertilizer is added to equal that removed in harvested crops.

One would expect little disagreement about the high profitability of adding P fertilizer to soils very low in soil test phosphorus. There will certainly be differences of opinion as to how high phosphorus should be built up in soils. It is the area where the yield response curve has flattened considerably that is of major interest in this paper.

The following example addresses the cost of building up soil test P from 45 to 55 lb/A. The buildup will require 90 lb of P_2O_5. The initial cost is $24.30/A with P_2O_5 assigned a cost of 27¢/lb.

The annual payment necessary to amortize the buildup cost of P with various interest rates and amortization periods is given in **Table 1.** The differences in annual costs of buildup would surely influence the viewpoint of growers, landowners, and moneylenders.

Table 1. The annual payment necessary to amortize the $24.30/acre initial cost of buildup phosphorus with various interest rates and amortization periods.

Payoff Period, years	Interest rate		
	8%	12%	16%
	Annual payment for payoff		
1	$26.24	$27.22	$28.19
5	6.09	6.74	7.42
10	3.62	4.30	5.03
15	2.84	3.57	4.36
20	2.47	3.25	4.10

The increase in corn yields necessary to pay for the buildup cost of P is given in **Table 2.** The yield increase necessary to pay off buildup cost is modest when one considers the effect of buildup may persist for 20 or more years.

Table 2. The annual increase in corn yields required to pay off the $24.30/acre initial cost of buildup phosphorus with various amortization periods and corn prices. An interest rate of 12% was used.

Payoff Period, years	Corn price per bushel		
	$2.00	$3.00	$4.00
	Annual bu/A corn increase to payoff		
1	13.6	9.1	6.8
5	3.4	2.2	1.7
10	2.2	1.4	1.1
15	1.8	1.2	0.9
20	1.6	1.1	0.8

Phosphorus equal to only about 3 to 15% of that added for buildup will have been removed by the extra corn required for amortizing the cost of buildup, **Table 3.** This means that from 85 to 97% of the buildup phosphorus still remains in the soil after the pay off.

Table 3. The percent of buildup phosphorus that will be removed by the corn yield increase necessary to amortize the cost of buildup.

Payoff Period, years	Corn price per bushel		
	$2.00	$3.00	$4.00
	P removed, % of that added		
1	6.4	4.3	3.2
5	8.1	5.2	4.0
10	10.6	6.7	5.2
15	12.9	8.6	6.4
20	15.3	10.6	7.7

People Differ

Individuals may differ greatly in their psychological outlook toward taking risk, and in their financial ability to withstand any adverse consequences associated with risk. The cost of reducing risk may be great or small. Crop production has always entailed considerable risk because of factors such as floods, droughts, insects, and diseases. There will always be risk in crop production, but the grower can reduce some risks through management. ■

A New View of Potassium Chloride Fertilization of Potatoes

By T. L. Jackson, M. J. Johnson,
S. James, and D. Sullivan

CENTRAL OREGON has been an important potato seed producing area for many years. A combination of soil and environmental conditions has developed a complex, but interesting, set of production problems.

The growing season is short with frequent June and late August or early September frosts that reduce populations of aphid and insect vectors. The cool summer nights also reduce activity of insect vectors that spread virus diseases. But the short growing season is a disadvantage in reducing yield potential.

Soils

The soils are mostly developed from volcanic ash that covered central Oregon when Mt. Mazama (Crater Lake) erupted about 6,000 years ago. This pumice-volcanic ash parent materal has low potassium (K) supplying power. It was originally deficient in phosphorus (P) and sulfur (S) and has been acidified with many years' applications of ammonium fertilizers and sulfur. Elemental S was often applied to reduce scab when potato production began forty years ago in this area.

Responses to nitrogen (N), P and S were evident in the first fertilizer demonstrations established; response from application of K on potatoes soon followed.

The increased acidity developed on these poorly buffered soils, and the possibility of response from lime, has been a recent development. Previous experiments with lime and K have varied from no response to a lime-K interaction that resulted in 3 or 4 ton increases in yield when both lime and K were applied.

An experiment was initiated in 1978 to evaluate possible lime responses and determine if lime applications might accentuate K deficiencies. Treatments of zero, 2 and 4 tons of lime/A and 1.5 tons of S/A were established. After thorough mixing throughout the top 12 inches of soil and time to react during 1978 and 1979, the plots had soil pH values of 4.5, 5.3, 5.9 and 6.3.

Potatoes were grown in 1979 with a standard lb/A rate of 160 N, 160 P_2O_5, 160 K_2O, and 100 lb of S/A banded at planting. In 1979, added lime reduced yields. But plant analyses showed higher than normal manganese (Mn) levels on low pH (S

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Table 1. Lime and KCl effects on potato yields (total).

Soil pH	KCl Treatments — K lb/A				
	0	100	200	400	800
	Total Yield Tons/A				
4.5	14.5	16.3	17.6	19.8	18.8
5.3	11.3	14.5	14.5	16.9	18.3
5.9	9.5	13.7	14.9	16.4	17.3
6.4	10.1	11.9	13.6	14.7	15.3

Average K soil test value = 149 ppm   Central Oregon - 1980

treated) plots. Potassium deficiency was present on all treatments. We assumed that yields would be increased from lime after the K deficiency was corrected in 1980.

The 1980 experiment was planted with a complete lime x K factorial (0-100-200-400-800 lb K/A as KCl disced in the soil) on the four replications. Average exchangeable soil K values taken about four weeks after fertilization for increasing rates were 149, 190, 223, 262, and 363 ppm K, respectively.

Calcium (Ca) and magnesium (Mg) for the no lime treatments were 10.4 and 4.2 meq/100 g. At planting 1,000 lb of 16-20-0-14 S was banded to supply N, P, and S. The experiment was irrigated with a solid set sprinkler system. Routine weed control practices were followed. Petiole samples were taken July 18 and August 5 for analyses.

1980 Results

Yields in 1980 were a surprise. **Table 1 shows that increasing the soil pH reduced yields** even though petiole samples exceeded 600 ppm Mn on plots with soil pH of 4.5. Increasing increments of applied KCl progressively increased yields; the 800 lb K/A rate at pH 4.5 was the main exception.

Lime did not influence the K response; the lime x potassium interaction was not significant. The average yield responses to pH and to KCl are presented in **Figures 1 and 2,** respectively.

SOIL pH EFFECTS ON TUBER YIELDS
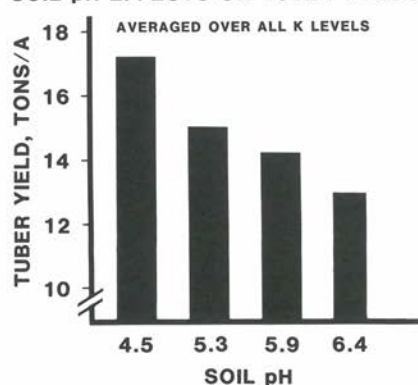
Figure 1

KCl EFFECTS ON TUBER YIELDS
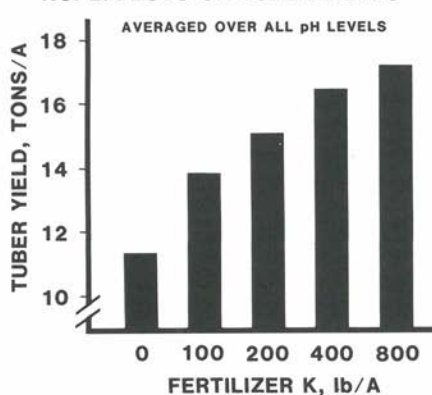
Figure 2

Table 2. KCl effects on nitrate — N, K, P, and Cl concentrations in potato petioles

	Treatments, K lb/A				
	0	100	200	400	800
	% in petiole				
NO_3-N	2.30%	2.10%	1.93%	1.78%	1.66%
Cl	1.4	2.6	3.3	4.3	5.5
P	.44	.44	.42	.44	.43
K	3.0	4.7	6.0	8.0	10.8

Concentrations averaged across lime rates. August 5, 1981. Central Oregon.

K Response

The increase in yield from K rates through 200, or possibly 400 lb at high lime, was expected. However, yields also increased from 800 lb of K/A on all except the S treatments with soil pH below 5.0.

The K check plot petiole samples started with 5% to 8% K July 18 and dropped to an average of 3% K August 5. See **Table 2.** However, the high K treatment had 11-13% K July 18 and had only dropped to 10-12% K by August 5.

We assumed this response from the highest KCl rates was not a response from K as a nutrient. We looked for other explanations.

The concentrations of K, Ca and Mg in plant samples were converted to chemically equivalent weights, shown in **Figure 3.**

The application of KCl decreased concentrations of Ca and Mg, as expected; however, the increase in K resulted in an increase in the sum of K + Ca + Mg found in the plant.

Lime — Nitrate N — Chloride

Nitrate N in the petiole was reduced at low pH and with added KCl. This was not surprising since either a pH of 4.5 or a high rate of Cl should reduce nitrification of NH_4-N applied. Also, the high level of Cl should reduce the NO_3-N found in the plant. All of these effects were evident.

The anion concentration in potato petioles as affected by KCl fertilization is presented in **Figure 4.**

KCl EFFECTS ON CATION CONCENTRATIONS OF POTATO PETIOLES
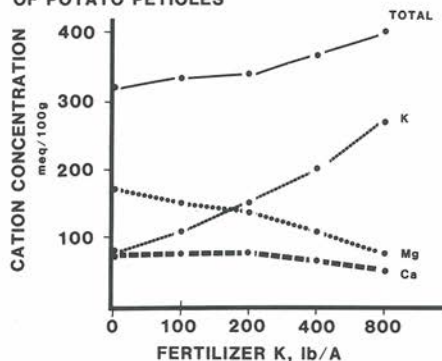
Figure 3

KCl EFFECTS ON ANION CONCENTRATIONS OF POTATO PETIOLES
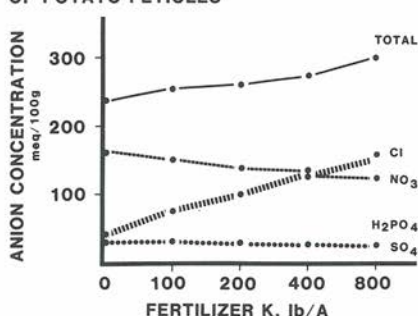
Figure 4

Frost Protection

Potassium deficiency symptoms were evident in late August when a frost occurred. By mid-September, vines were dead on the K check plots and on most 100 lb K treatments. **Vines remained green with luxuriant growth on high K plots.**

Reduced frost damage with high KCl applications had been observed in previous experiments. The increased level of total cations $(K + Ca + Mg)$ with the 5% to 7% Cl levels on the high KCl treatments would be expected to increase the osmotic concentration of cell sap. This could have reduced frost damage.

Note in **Figures 3 and 4** that total cation and anion concentration in the petioles increased with increasing rates of KCl fertilization.

Potassium deficiency was probably a dominating factor affecting vine death at low K levels. But K deficiency is not a good explanation for reduced damage when the 200, 400 and 800 lb K treatments are compared. The 400 and 800 lb K treatments maintained vigorous vine growth through September.

Plant disease relationships

This was the second consecutive potato crop. A concerted effort was made to pick up cull potatoes and pull volunteer plants to reduce virus infection. However, *Verticillium dahliae* can be identified in all "old" potato fields in central Oregon. Previous research by Huber and others has shown that reduced NO_3 nutrition and increased NH_4 nutrition reduces *Verticillium* infections; specific effects of soil pH on the "early dying" complex of diseases has not yet been established. Potassium chloride applications may have reduced infection; this has not been established.

Summary

This array of treatment effects suggests a complex set of plant nutrition-disease-frost damage interactions that can affect potato production.

Possible effects of KCl in reducing specific gravity of tubers needs to be considered; the use of potassium sulfate has resulted in higher specific gravity of tubers than application of potassium chloride in a number of experiments. However, the 800 lb K treatments were required in our 1980 experiment to reduce specific gravity with soil pH of 5.3 in the original lime check and 5.9 in the 2 ton lime rate plot.

A set of factors—maturity, tuber moisture content, level of N nutrition, disease, and starch-sugar translocation—affect specific gravity.

The marked reduction in NO_3-N concentrations measured in petiole samples as Cl increased must be recognized and "taken into account" by agronomists and other consultants who are using plant analyses to monitor fertilizer programs and recommend N applications.

One experiment is not enough to change recommendations for production practices. However, these results point strongly towards a reevaluation of plant nutrition-disease relationships. Changes in the NH_4/NO_3 nutrition balance with marked shifts in Cl and K ion concentrations in cell sap can have many effects on plant growth and metabolism.

Additional experiments have been established where ammonium nitrate, ammonium sulfate, and ammonium chloride are applied in combination with different rates of potassiuim chloride and potassium sulfate.

Detailed disease readings and chemical analyses of plant samples will be taken on all treatments. These experiments will provide a more complete evaluation of the questions raised in the 1980 research.

If this research supports the possibility of a plant nutrition-plant disease relationship affecting potatoes, a re-evaluation of many previous soil fertility experiments will be in order. ■

Placement Improves Fescue Responses to NPK

By Ray E. Lamond and J. L. Moyer

TALL FESCUE is widely used as a cool-season forage in eastern Kansas, western Missouri, eastern Oklahoma and other areas. Like most cool-season grasses, it responds well to fertilization. Maximum fescue yields demand adequate fertilization. And proper fertility management also maximizes fescue quality.

Placement Influences Response

Research at Kansas State University's Southeast Branch Experiment Station indicates that NPK placement can have significant effects on nutrient use efficiency, fescue forage yields and quality, shown in **Tables 1 and 2.**

The research reported here is an extension of earlier work at Kansas State comparing broadcast and "dribble" applications of 28% nitrogen solution (UAN) and ammonium polyphosphate (10-34-0). The broadcast applications involved use of fan nozzles which delivered relatively small droplets. The surface strip or "dribble" treatments were produced by removing the orifice plate from the nozzle body which delivered a coarse stream of solution on 18 inch centers. The solution wetted an area about 6 inches wide in each band.

Data from that work indicated an advantage for the dribble applications compared to broadcast treatments. The work now underway goes one step further and evaluates subsurface band or "knifed" applications.

Knifed Applications

This study was initiated in 1980 to evaluate two fertilizer application techiques on established tall fescue. Only liquid fertilizers were used, formulated from UAN (28% N), ammonium polyphosphate (10-34-0) and soluble potassium chloride. The solutions were applied either surface-broadcast through flat fan spray nozzles or injected 6-8 inches deep using shanks on 15-inch centers.

The 1980 work was conducted on a Parsons silt loam soil with a pH of 6.5, P_i level of 11 ppm and an exchangeable K level of only 60 ppm. The 1981 site was also a Parsons silt loam with a pH of 7.1, P_1 level of 10 ppm and a K level of 115 ppm. These P and K levels are in the low to low-medium range. Earlier work done in Kansas and ohter states has shown that cool season grasses respond well to P fertilization when the soil test levels are in this range.

The fertilizer treatments were applied on March 7 in 1980 and on February 19 in 1981. The forage was harvested near heading both years and samples were taken at harvest for analysis.

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Table 1. Fertilizer rate and placement effects on tall fescue forage yields.

Treatment, lb/A			Yield, lb/A (12.5% moisture)			
			1980		1981	
N	P_2O_5	K_2O	Broadcast	Knifed	Broadcast	Knifed
12	0	0	2352	2659	2630	3342
12	0	40	2204	2292	3200	3380
12	40	0	2267	3346	3090	3760
12	40	40	2628	3311	2854	4125
100	0	0	3347	3641	3770	4240
100	0	40	3317	3800	3276	4828
100	40	0	3749	4093	3747	4829
100	40	40	3835	4343	3438	5082
150	0	0	3696	4078	3356	5226
150	0	40	3545	3798	3389	5650
150	40	0	4172	4492	4443	5452
150	40	40	4591	4713	3692	5153

Southeast Kansas Branch Experiment Station

The effects of fertilizer placement on fescue are shown in **Table 1.** Knifed applications produced higher yields than broadcast treatments for all NPK combinations both years.

Visual response differences were evident early in the growing season. There was an excellent N response and yield levels were increased by application of 41 lb of P_2O_5 at every N level regardless of the method of application. **Figure 1** shows the results.

The overall K response was small, but when K was supplied in addition to N and P, yields increased especially on the low K site in 1980. Note in **Figure 2** that K increased yield more at the higher N rates. When the soil K level was higher (1981 data), applied K had less effect.

Nutrient rates and placement also had an effect on forage quality, especially
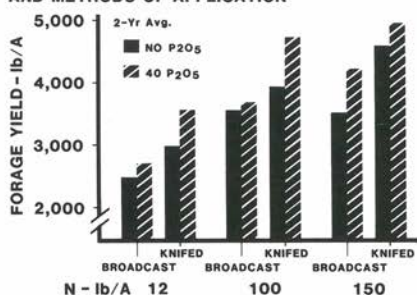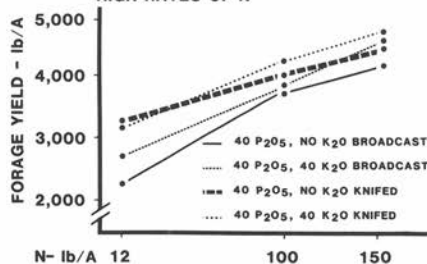
Figure 1

Figure 2

Table 2. Fertilizer rate and placement effects on protein production.

Treatment			Protein, lb/A			
			1980		1981	
N	P₂O₅	K₂O	Broadcast	Knifed	Broadcast	Knifed
12	0	0	202	237	239	271
12	0	40	190	209	262	281
12	40	0	190	271	272	301
12	40	40	226	292	240	338
100	0	0	341	415	419	416
100	0	40	341	464	374	502
100	40	0	390	618	405	512
100	40	40	376	534	347	564
150	0	0	403	567	433	580
150	0	40	394	524	403	559
150	40	0	438	696	515	650
150	40	40	519	651	425	598

Southeast Kansas Branch Experiment Station

total crude protein production, shown in **Table 2.** The knifed treatments at each N rate consistently produced more crude protein per acre than comparable broadcast applications. **Added phosphorus consistently increased crude protein production at each N level and significantly increased forage P levels.**

Placement Improves Nutrient Use Efficiency

In summary, this research indicates that knifing is a viable fertilizer application technique which can increase tall fescue responses. Knifed-in applications produced higher yields of better quality forage than did surface broadcast applications because knifed nutrients were generally used more efficiently.

These results are similar to earlier work which showed that dribble applications of solutions were generally more effective than broadcast applications.

Explanation of the differences between methods of solution application probably centers on efficiency of N and P utilization. Small droplets of solutions in broadcast applications may remain attached to plant residues and not reach the soil. Dribble applications saturate surface residue in a narrow band which probably allows more nutrients to reach the soil where they can be absorbed by plants.

The knifed technique places the nutrients directly in the soil. We can only speculate on the relationships of these methods of N application to ammonia volatilization but this is probably not the primary reason for the difference. There is some indication that immobilization may be a factor where a heavy residue or thatch layer is present. Studies are underway to try to explain the differences.

Finally, this research has shown that P and K fertilization is a critical factor in maximizing tall fescue forage yields and quality on low testing soils. ■

Quotes
"Men do not stumble over mountains, but over molehills." — *Confucius*

"Baloney is the unvarnished lie laid on so thick you hate it. Blarney is flattery laid on so thin you love it." — *Fulton Sheen*

Liming Research for Dryland Agriculture in Western Canada

By P. B. Hoyt

RESEARCH ON LIMING for dryland agriculture in western Canada began at Beaverlodge, Alberta and Scott, Saskatchewan in the 1960's. Until then, it was thought that low pH soils on the Great Plains were few and presented no serious soil acidity problems even where they did occur. However, these early field experiments showed that soil acidity was indeed a problem and research on liming increased rapidly, particularly at Beaverlodge in the Peace River region of northern Alberta and British Columbia.

Extent of Soil Acidity

Acid soils, in terms of serious damage to agricultural crops, are defined here as those having pH of 6.0 or below. Manitoba has few acid soils, as shown in **Table 1.** A half-million acres of acid soils occur in Saskatchewan, mostly in the west-central part of the province.

Table 1. Estimated cultivated land on the Great Plains with different ranges of soil pH.

Province or region	Acres		
	ph 5.5 or less	pH 5.6-6.0	pH 6.1-6.5
Manitoba		25,000	
Saskatchewan	500,000	500,000	1,000,000
Alberta, excluding Peace River region	570,000	2,880,000	5,625,000
Peace River region of Alberta and British Columbia	240,000	1,100,000	1,490,000
Total	1,310,000	4,505,000	8,115,000

Acid soils are much more widespread in Alberta, where 16% of the cultivated soils were estimated to be acid in 1972. This amounts to about 3.5 million acres of acid soils excluding those in the Peace River region. There, 31% of the soils are acid, amounting to nearly 1.5 million more acres.

Further acidification has likely taken place since 1972 from fertilizer use and industrial emissions. It has been projected that fertilizers alone will cause an additional 2.5 million acres of acid soils in Alberta and northeastern British Columbia by 1985. By then, 25% of the soils in Alberta
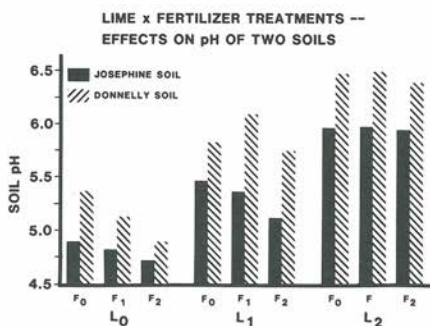
Dr. Hoyt is with the Research Branch, Agriculture Canada, Summerland, British Columbia.

LIME x FERTILIZER TREATMENTS --
EFFECTS ON pH OF TWO SOILS

Figure 1 shows how annual fertilizer applications (F_0, F_1, F_2) and 4 or 5-year-old lime applications (L_0, L_1, L_2) affected the pH of Donnelly and Josephine soils.

could be acid while 40% of the soils in the Peace River region could be acid.

Causes of Soil Acidity

Fertilizers are presently the major cause of soil acidification in western Canada. The acidity from fertilizers is mainly produced from nitrification of ammonium in fertilizers that either contain or produce ammonium. Leaching of anions, such as nitrate, from the fertilizers also causes acidification.

Annual applications of fertilizers, containing nitrogen (N) at 124 lb/A, to consecutive barley crops caused the pH of Donnelly soil (a medium textured Gray Luvisol) to decrease by 0.43 unit in 4 years, as shown in **Figure 1.** The fertilizers also caused the pH to fall by 0.18 unit in Josephine soil (a fine textured Gleysol) over a 5-year period.

Industrial activity also causes soil acidification in western Canada. In agricultural areas, acidification is mostly from sulphur dioxide gases that are emitted from natural gas processing plants. These emissions affect approximately 400,000 acres of soil with pH less than 6.5.

Crop Tolerance to Soil Acidity

Tolerance to soil acidity varies considerably among crops. Particularly, tolerance varies to aluminum and manganese toxicities, which are major causes of soil acidity damage. Oats and some of the grasses will produce well on very acid soils. The problem with growing such crops is that the soil becomes even more acid from the use of fertilizers and eventually it becomes difficult to produce even the tolerant crops.

Benefits of Correcting Soil Acidity

Liming is the long-term solution to soil acidity. Liming eliminates aluminum and manganese toxicities. Liming increases the activity of Rhizobia bacteria, which fix atmospheric N in association with the legumes. It also releases N from soil organic matter. This can amount to 30 to 100 lb of N/A during the first three years after liming.

Recent tests show that lime improves soil tilth and results in better emergence of rapeseed. This is particularly important for Gray Luvisolic soils which are noted for their poor surface structure.

Better fertilizer response is one of the great benefits from liming. When lime was applied to a soil of pH 4.9 in the Peace River region, NPKS fertilizers more than doubled the yield of five consecutive barley crops. Without lime, the fertilizers gave large yield increases to the first three crops, but then ceased to give any yield increases to the fourth and fifth

crops. Hence, fertilizers alone may not be able to sustain economic production on acid soils.

Liming increased phosphorus availability in an experiment conducted by H. Ukrainetz in Saskatchewan. Lime applied at 2 and 3 tons/A increased extractable P (by the sodium bicarbonate method) from 26 ppm to 33 and 45 ppm, respectively. These liming treatments increased the wheat yields where no P fertilizer was applied from 18.3 bu/A to 22.3 and 26.8 bu/A.

Table 2.   Effect of lime and fertilizer on yields of wheat on Scott loam, Saskatchewan.

Lime treatment, tons/A	Wheat yields, bu/A (7-year average)	
	No fertilizer	N - 5 lb/A P_2O_5 - 40 lb/A
0	18.3	24.7
2	22.3	26.5
3	26.8	30.2

These increases, shown in **Table 2,** were 22% and 46%, respectively. The increases were smaller where 5 lb/A of N and 40 lb/A of P_2O_5 were applied; the two liming rates gave increases of 7% and 22%. The greater responses to lime alone were probably due to release of soil P by the lime. Likewise, the lime probably increased the availability of fertilizer P.

Yield increases and profits from lime can be great and these are now being demonstrated in field-scale plots. In the past, high costs of lime due to high transportation costs from source to the farm have been a deterrent to liming. However, government assistance in Alberta is now being given to greatly defray transportation costs.

Long-term Benefits
The initial cost of liming may still be fairly high, but those costs should be met in two years or less. Profits will accrue because lime is long lasting in the soil.

Yield increases of wheat from liming are still being sustained in Saskatchewan 17 years after 2 tons of lime/A was applied. Despite these good economic benefits, farmers may tend to **tolerate** the soil acidity problem because there has been little option to correct it until recently. It is hoped that complacency will be properly challenged by the higher production and profits that liming can give in dryland farming. ■

Effect of N, P, and K on Cold Hardiness of Winter Wheat Crowns

By S. Freyman

THE MANY ADVANTAGES of growing fall-seeded rather than spring-seeded crops on the Canadian prairie have led to a constant expansion of winter wheat production to areas where winterkill may occur. This has given urgency to the breeding of ever-hardier cultivars and the development of cultural practices that will reduce the risk of winterkill.

Fertilizer Affects Cold Hardiness

It has generally been found that applied nitrogen (N) reduces cold hardiness while potassium (K) increases hardiness. The effect of phosphorus (P) has been variable.

Most of the winter wheat on the Canadian prairies is grown on dark brown soils in southwestern Alberta. These soils are, as a rule, rich in K but low in N and P.

No previous studies have been reported on the effect of fertilizers on winter survival of crops in Alberta.

This study was to determine, under controlled environment conditions, the effect of applied N, P, and K on the cold hardiness of winter wheat. Controlled environment was used because of the unpredictability of southern Alberta winters; field experiments would have to be conducted for many years at many sites to detect differential winterkill.

Experiments

In the two experiments conducted, the various fertilizer rates were mixed with the soil on a weight-to-weight basis using the assumption that 6-inch depth of soil on one acre weighs 998 tons. **See Tables 1 and 2.**

Table 1. Effect of applied N and P on cold hardiness of two winter wheat cultivars.

| N P K lb/A | Temperature at which 50% of plants failed to recover from freezing | | | |
| | Kharkov MC 22 | | Sundance | |
	°C	°F	°C	°F
0-0-0	−16.0	+3.2	−15.7	+3.7
80-0-0	−13.9	+7.0	−14.1	+6.6
160-0-0	−13.9	+7.0	−14.2	+6.4
0-36-0	−15.5	+4.1	−15.3	+4.5
0-72-0	−15.5	+4.1	−15.3	+4.5
80-36-0	−15.7	+3.7	−14.9	+5.9
160-36-0	−15.9	+3.4	−15.9	+3.4

Table 2. Effect of applied N, P, and K on cold hardiness of Norstar winter wheat.

N P K lb/A	Temperature at which 50% of plants failed to recover from freezing	
	°C	°F
0-0-0	−13.0	+8.6
89-0-0	−11.6	+11.1
0-40-0	−13.6	+7.5
0-0-89	−12.9	+8.8
89-40-0	−13.6	+7.5
89-0-89	−11.5	+11.3
0-40-89	−13.7	+7.3
89-40-89	−13.8	+7.2

Levels of available nutrients in the soil were: N, 10.7 ppm (NH_4^+ and NO_3^-); P, 7.3 ppm; and K, 513 ppm. The soil was placed in plastic trays and wheat was grown for 27 days in the greenhouse. The plants were then hardened for 14 days in a low temperature growth cabinet.

After hardening, the trays were moved to a freezer in which the temperature was dropped 1°C (1.8°F) after each hour.

To test the plants' level of cold hardiness, trays were removed from the freezer after one hour at −8, −10, −12, −14, and −16°C (+18, +14, +10, +6, and +2°F) and placed in a greenhouse for a two-week recovery period. The number of surviving plants was then counted in each tray to determine the temperature at which 50% of the plants failed to recover from freezing. This is called the LT_{50} value of cold hardiness.

Effects of Nutrients on Cold Hardiness

This study showed that applied N decreased cold hardiness in the absence of P. However, P in the absence of N had little effect, as **Table 1** shows.

When applied together, P counteracted the effect of N, resulting in plants as hardy or hardier than those that had received no N. In western Canada, phosphate fertilizer is usually applied by banding near the seed. As such, the level of available P for the developing crown could be much higher than that available in this study.

The soil was rich in K and application of additional amounts had no effect on cold hardiness. See **Table 2.** It has generally been accepted that K plays an important role in the development of cold hardiness. These results show that in soils deficient in P, K alone does not counteract the effect of N. Both P and, presumably, K are needed to attain a high degree of hardiness when winter wheat is grown on a soil rich in N.

Conclusions

Results of this study suggest that if N fertilizer is applied in the fall, the soil P content should also be high in order to maintain cold hardiness at a high level. ∎

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Economists-Agronomists Seek Maximum Economic Crop Yield Systems

AGRONOMISTS and agricultural economists are in search of better understanding to help farmers reach maximum economic crop yields.

A recent workshop in St. Louis, Missouri, sponsored by the Potash & Phosphate Institute (PPI) and the Foundation for Agronomic Research (FAR), brought together more than 170 university economists and agronomists, industry agronomists, consultants, and farm lenders. PPI and FAR are non-profit organizations promoting research and education on attaining higher, more profitable crop yields.

"In view of the current cost/price relationship and narrow profit margin situation, we felt that the workshop was meaningful and the timing was fortuitous," noted Dr. R. E. Wagner, President of PPI. "Maximum economic yield systems are the farmer's best strategy in good times and probably even more so in these difficult times."

The theme for the two-day workshop was: **Higher crop yields mean less unit cost and more profit.**

Dr. Werner Nelson, senior vice president of PPI, and Dr. John Marten, a well-known economist, coordinated the program. "PPI planned the workshop as a positive step toward encouraging more interaction among agronomists and economists," Dr. Nelson emphasized.

The workshop featured a series of presentations by soil and crop researchers, economists, bankers, and other specialists. Program participants discussed the concepts of maximum yield research and maximum economic yields for farmers, budgeting for higher crop yields, and applying economics to agronomic responses.

Here are some capsule comments from the program:
The economic necessity for the farmer as well as expanding world food needs sum up the urgency for higher yields, said Dr. David Dibb of PPI. And as researchers identify maximum yield management inputs, economic analysis will be essential to implement new information into production systems, added Dr. W. K. Griffith, also a PPI agronomist.

In industry and at some universities, agronomists and economists are already involved in cooperative programs. For example, Dr. J. E. Baylor, Pennsylvania State University extension agronomist, and Prof. W. K. Waters, area farm management specialist, reported on successful programs designed to obtain definitive on-farm data for high yield corn and alfalfa production.

University of Illinois economists Dr. Royce Hinton and Dr. Al Harms prepared budgets for high yield corn

and soybeans; Purdue University economist Dr. David Petritz presented budgets for high yield alfalfa; and Kansas State University economist Dr. Don Pretzer outlined budgets for high yield wheat.

Some management practices that lead to higher crop yields actually cost little or nothing, explained Dr. Joe T. Touchton, Auburn University agronomist. "Timeliness, proper equipment adjustment, and crop rotation are no-cost inputs. Reduced tillage, narrow row spacing, and improved weed control with proper herbicide practices usually add little cost or might even reduce cost while increasing yields," he pointed out.

Researchers who have achieved extremely high crop yields reported on their techniques and experiences with farmer-cooperators.

The agronomic research data was presented by Dr. Roy L. Flannery, Rutgers University; Dr. David L. Wright, University of Florida; Dr. Jay W. Johnson, Ohio State University; Dr. Maurice L. Vitosh, Michigan State University; Dr. Sterling R. Olsen, Colorado State University; Dr. R. L. Cooper, Ohio Agricultural Research and Development Center; Dr. Tom L. Jackson, Oregon State University; and Dr. M. L. Tesar, Michigan State University.

Economists then analyzed the agronomic response data applying economics to management factors in maximum yield research. Dr. Don Shurley, University of Kentucky, discussed corn; Dr. R. W. Jolly of Iowa State University highlighted soybeans; Dr. K. D. Olson, University of California, discussed wheat; and Dr. R. A. Schoney, University of Saskatchewan, evaluated alfalfa research.

Dr. Fred Welch, University of Illinois agronomist, and Dr. H. Doug Jose, University of Nebraska farm management specialist, discussed the economics of building soil fertility. Dr. Welch said that phosphorus and potassium fertility buildup should be considered a capital investment, rather than cost being assigned totally to the year fertilizer is added. He suggested that buildup cost be amortized over several years.

Earl Kingman of Growmark, Inc., Bloomington, Illinois, described how the organization's crops service department considers economics in crop production recommendations. "Yield level, selling price, and cost of production are the three factors that most affect profitability," he said.

Edgar M. Urevig, a farm manager from Lewisville, Minnesota, explained how increased crop yields and improved efficiency have contributed to profits for the farms he manages.

Marty Thornton, vice president and senior farm manager, Peoples Bank of Bloomington, Illinois, stressed the need for accurate budgeting in setting yield goals and planning fertility levels. "In our budget estimates for corn and soybeans, the higher yield goals typically show much higher net income. Even if growers have to secure credit to pay for the inputs, return on investment can be very good with higher yields from improved fertility. Relatively small yield increases can service sizable amounts of farmer debt," he concluded. ■

"It is more important to be **effective** than to be **efficient**. There's nothing more useless than doing **efficiently** what never should have been done at all." — *J. Fielding Reed, President (Retired), Potash & Phosphate Institute.*

Maximizing Profit or Reducing Expenses

By Marty Thornton

BEFORE we discuss how a banker looks at maximizing profit, let's look at what happened to the cost of farm inputs from 1976-1980. Increases in expenses to farmers were:

Interest	230%
Fuel & Energy	190%
Chemicals	158%
Seed	156%
Fertilizer & Lime	142%
Farm Machinery	130%
Feed	103%

With these dramatic cost increases, coupled with recent commodity price declines, how does a farmer stay solvent? Should he spend more dollars on extra inputs? Until recent times a farmer's EQUITY position was the major concern for securing credit and satisfying his banker. Today EQUITY is not enough. CASH FLOW and RETURN ON INVESTMENT are foremost in the minds of agricultural lenders and progressive farmers. Should he use more credit even though interest expense was the leader in percent of increase? **Prioritizing** the selection of inputs if he's in a tight cash flow situation may be one approach to the problem.

Debt service is an automatic number one priority. **If he doesn't meet his commitments, his creditors will surely dictate the decisions he makes. Seed cost** offers little flexibility for change if high yields are to be maintained. **Petroleum** costs are flexible only to the extent that fewer trips across the field can still maintain or increase the present yield levels. **Grain drying** charges could be reduced by field drying — with additional risk. **Fertilizer** reduction is the first area farmers may perceive as an alternative. They may **or** may not consider the effects on yield level! **Chemicals, repairs, insurance,** and **equipment** are more often thought of as ways to cut costs without significantly reducing income.

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This stereotyped response has to be challenged! Both your and my jobs and livelihood depends on an **open minded** approach to **maximum utilization of all products and systems** which may increase the cash generated from a farming operation.

Why are we looking at a ranking of inputs and their **short term importance?** The reason is to better understand the logic that is used by farmers as they plan and then produce crops. **Three** types of farmers exist. There are those who **make** things happen, those who **watch** things happen and those who **wonder** what happened. Each type responds differently to today's economic squeeze, but all are going through a "change" process.

To bring farmers to change the kinds and amounts of products and services they use in their farming operations requires that they be "led" through five steps in the adoption process: 1. Awareness; 2. Interest; 3. Evaluation; 4. Trial; and, 5. Adoption.

This change process may be both more complex and reliable than a flip of the coin.

In our work with farm clientele we continually try to build from several basic components of high yields. We suggest expenditures in the order of drainage first, pH correction second, fertility third and other inputs fourth. We feel it's imperative that **all** inputs be given adequate consideration.

As we work with farmers we try to maximize their situations **without** additional capital requirements **first,** or with only small expenditures if the returns look impressive.

Some examples of the "freebies" that can be interjected into the cropping program are increasing corn planting populations for higher yield.

Another increase can be obtained by optimizing the planting date. Showing a farmer how these two interact and affect his yield can have an effect on his demand for credit as well as the income available for purchase of other farm inputs. He may be able to increase his borrowing but maintain the same Debt/Income relationship and increase his RETURN ON INVESTMENT.

If you use an Illinois annual corn yield increase of 1.65 bu/A per year, due to **improved technology and management techniques,** and price that at $2.75/bu, the result is a $4.53/A income increase. For farmers relying heavily on credit, that $4.53 would service $28.36 of debt at 16% interest.

We feel that "the most effective way to cope with change is to help create it."

As you and I work with farmers, when we help them increase their return on expenditures by adopting the "freebies" (enhancing their management skills) we have gained **trust and credibility**. That gives us the right to suggest that additional capital expenditures for **more product and services** can be **profitable** even in today's depressed farm economy.

Changing row spacing of both corn and soybeans is often justified even after paying for added chemicals and equipment costs.

Planning the fertility program is another **crucial** part of a high profit farming operation, yet it often is handled in five minutes or less. We approach the determination of fertility by analyzing four factors: 1. Soil test level; 2. Prior crop removal; 3. **Soil test goal;** and, 4. **Crop production goal.** We

emphasize **combining the goals** for determination of the material to be applied.

Goals must be realistic, but always **above** the previous high if continual progress is to be made. We feel that a 5-10% annual goal increase is realistic.

Although some bring up fertility **costs** and the "poor economy", we stress the need for accurate budgeting as you set yield goals and plan the cropping program. Examples of our budgets for low and high yielding corn and soybean production would be as follows:

BUDGET ESTIMATES

	Beans		Corn	
Yield	40	53	125	160
$/Bu	$6.00	$6.00	$2.50	$2.50
Net $/A	$40.00	$118.00	$42.50	$130.00
		$78.00		$87.50

When you make an additional $78.00 net on beans and $87.50 more on corn by managing for the higher yield levels, can you afford not to strive for those goals even if you have to secure credit to pay for the inputs?

The real question to answer continues to be: What **Rate of return** do I receive on the investment I make? **Table 1** shows examples for low, medium, and high soybean yield goals, along with the accompanying fertility investment and the additional cost of credit.

Table 1.   Rate of return on fertilizer investment for soybeans.

Yield bu/A	$N-P_2O_5-K_2O$ lb/A	Fertilizer Cost	Interest Cost	Added Cost	Gross $	Added Net	ROI***
35	0-30-45 M* 0-0-0 B.U.**						
	Total 0-30-45	$14.88	—	—	$210.00	—	—
45	0-38-60 M 0-69-80 B.U.						
	Total 0-107-140	$50.10	$2.82	$52.92	$270.00	$ 7.08	26.7%
55	0-47-71 M 0-69-80 B.U.						
	Total 0-116-151	$54.18	$3.15	$57.33	$330.00	$62.67	218.6%

Input items
I = 16% x .5 yr.
$6/bu = soybean price
0-46-0 = $250/ton
0-0-60 = $180/ton

*M = Maintenance
**B.U. = Buildup
***ROI = Return on Investment

Note that increasing the fertility cost by $35.22/A would add an interest cost of $2.82/A. Those combined expenditures could well realize an additional return of $7.08 or 26.7% return on the original investment. That's an almost unheard of rate of return compared to other investments. Going from 45 bu to 55 bu/A yields could give a rate of return eight times that large or 218.6%. It's almost unbelievable!

Debt Service

From a debt service standpoint, let's look back at the high yield versus low yield budget which had a $78.00 difference in soybean net income and an $87.50 difference in the corn net revenue. At 16% interest a farmer can service $487.50 of debt from the $78.00 per acre or $546.87 of debt from the $87.50. What easier way is there to carry the heavy interest load of today's agriculture?

Table 2 shows the amount of debt that can be serviced at various interest rates and increased net per acre income figures.

Table 2.   Debt per acre serviced at various interest rates by increasing net per acre income.*

| Increased | Interest rates | | | |
net $/A	9%	12%	15%	18%
$ 5	$ 55.56	41.67	33.33	27.78
$ 20	222.22	166.67	133.33	111.11
$ 50	555.56	416.67	333.33	277.78
$125	1,388.89	1,041.67	833.33	694.44

*Interest payment only.

While some persons may shout "doom and gloom" and preach that we must not spend for inputs, I think the choice we have to make is clearly between two strategies. One is **shortsighted** and only considers **reducing expenses**. The other removes the emotion, concentrates on **good business** principles and **maximizes the profit.**

Really, there is no choice. We must use more effective products and be willing to encounter more costs as long as they generate MORE PROFIT FOR ALL.

I believe . . . "To be a success in business you must be daring, be first, and be different." ■

Wide Beds Improve Wheat Yields and Nitrogen Efficiency on Poorly Drained Soils

By J. T. Batchelor and F. C. Collins

MUCH OF THE WHEAT acreage in Arkansas' Mississippi Delta has poor internal drainage because of clay surfaces and/or claypans. With slow internal drainage, fields not provided with adequate surface drainage will become saturated or waterlogged during winter months.

This condition frequently extends into March, causing loss of fertilizer nitrogen (N) after wheat has been topdressed in the spring. Gaseous losses

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of N through denitrification cause reduced wheat yields if additional N is not applied to compensate for denitrification losses prior to critical growth stages.

In 1978, we initiated research to evaluate a wide bed system for a Sharkey clay to improve N management through better drainage. Our two year study compared bedded and nonbedded wheat that was topdressed in early March with a range of N rates. The N was applied as urea and $NaNO_3$ (sodium nitrate) in 1978 and $Ca(NO_3)_2$ (calcium nitrate) in 1979. Beds of soil 76 inches wide were formed by positioning doublewinged lister plows behind tractor tires and pulling at a 4 to 6-inch depth. A small disc was then set to pull the furrowed soil to the center to complete the bed. **Figure 1** shows a schematic of a wide bed. The nonbedded area was disced and planted flat.
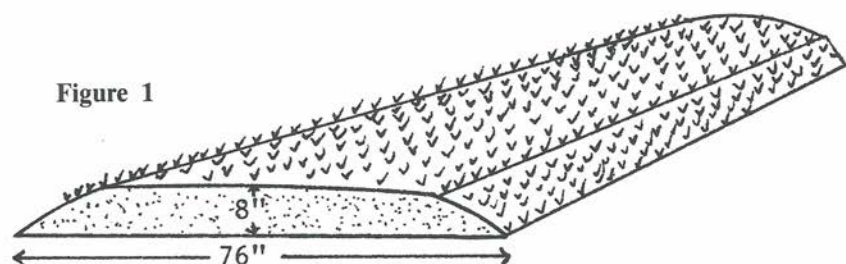
Figure 1

THIS sketch shows a cross section of the wide beds formed by tillage to improve soil drainage.

Figure 2 shows that landforming, N source and N rate affected grain yields in 1978. The values in **Figures 2 and 3** are predicted yields based on observed yields and were used to contrast treatment differences. Bedded wheat had higher yields than nonbedded wheat with greatest differences at approximately 85 to 120 lb/A of N for $NaNO_3$ and urea, respectively.

As the N rate was increased, there was generally a larger yield differential between bedded and nonbedded wheat. Apparently, more soil and fertilizer

WHEAT YIELDS AS AFFECTED BY BEDDING, N SOURCE AND N RATE
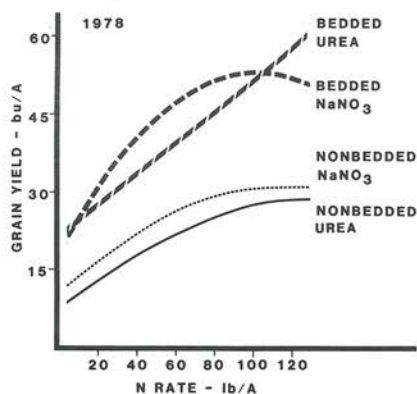
Figure 2

WHEAT YIELDS AS AFFECTED BY N SOURCE AND N RATE
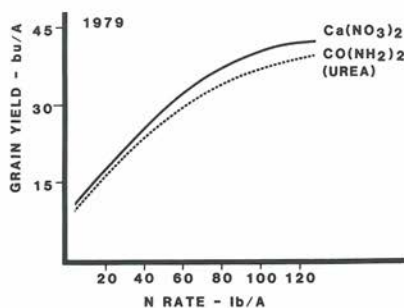
Figure 3

N along with dry matter was accumulated in bedded wheat than in nonbedded wheat when fertilized with increasingly greater N rates. See **Table 1.**

Table 1.   Total dry matter and total N accumulation as affected by land-forming practice.

Year		Total dry matter	Total N
		------------- lb/A -------------	
1978	Bedded	7,499	90
	Nonbedded	5,669	67
1979	Bedded	6,954	64
	Nonbedded	5,631	50

The yield data in 1978 indicated a synergistic relationship between bedding and N rate where the effect of bedding was enhanced by increasing the N rate. Wheat fertilized with $NaNO_3$ generally produced more grain than that fertilized with urea; however, the bedded wheat declined in yields when fertilized with $NaNO_3$ at higher N rates but did not when fertilized with urea.

The linear yield response to urea indicated that yield on the beds may have been further increased with additional urea. Nonbedded wheat fertilized with $NaNO_3$ yielded more than the nonbedded wheat fertilized with urea at all N rates. There was no significant advantage of either source on dry matter or N accumulation in wheat grown on either beds or flat surfaces even though more dry matter and N tended to accumulate in wheat fertilized with $NaNO_3$.

In 1979 landforming did not affect yield significantly, possibly because beds were formed early and had weathered prior to planting. Drainage was not as effective as in 1978.

Table 1, however, shows that total dry matter and total N that accumulated in bedded wheat in 1979 was significantly greater than that of nonbedded wheat. **Figure 3** shows that wheat fertilized with $Ca(NO_3)_2$ in 1979 produced significantly more grain than wheat fertilized with urea.

This was similar to the response found on nonbedded wheat in 1978 using $NaNO_3$ compared to urea as a N source. Again, although the effect of sources was significant on yields, neither source had an advantage in the amount of dry matter and N accumulated in 1979 (data not shown).

Regardless of clarity in explaining this response, the nitrate fertilizer source was generally better than urea for increasing yields in four different environments. The appropriate N source in practice, however, would depend on price, application costs and other factors.

Wide beds improved surface drainage in 1978 and possibly reduced N losses through denitrification which resulted in increased N efficiency and grain yield. Since bedded check plots produced more grain and accumulated more N than the nonbedded check plots (1978), the inorganic N mineralized from the soil's organic fraction in the beds most likely was more available to the wheat on beds. This availability was caused from either a more suitable soil environment for N mineralization and/or reduced losses of soil inorganic N through denitrification.

Advantages associated with bedded wheat in a well-drained wide bed system were: 1) reduction in risk of stand establishment for late planted wheat; 2) increased uptake of soil inorganic N; 3) more efficient uptake of fertilizer N; 4) increased dry matter accumulation; and, 5) increased yields. ■

Potassium in Ruminant Nutrition

By R.L. Preston

THE IMPORTANCE of potassium (K) for animal nutrition has been known since the early 1800's.

Potassium is the third most abundant mineral element in the animal's body, after calcium and phosphorus. Potassium is present in twice the concentration of sodium. Muscle and nerve cells contain 20 times more potassium than the interstitial fluid that bathe these cells. A dressed carcass will contain 75% of the body's potassium.

Potassium is absolutely essential for life. **Table 1** lists several critical functions in the body.

Table 1.   Important functions of potassium in the animal body.

1. Osmotic balance between cells and body fluids.
2. Acid-base regulation of the body.
3. Ionic balance controlling cellular excitability and activity.
4. Water balance of the body.
5. Activator of several enzyme systems in the body.
6. Oxygen and carbon dioxide transport in the blood.
7. Major mineral constitutent of muscle and milk.

Because of these functions, a deficiency of potassium in the diet of animals has serious consequences on the animal's well-being and productivity. The dietary potassium requirement of many animals is between 0.2-0.4% of the diet dry matter.

"The increased use of high concentrate, low forage rations for ruminants has increased the possibility of borderline or potassium deficient rations in ruminants. Potassium is the major intracellular cation of the body and has a principal role in the animal's metabolism. The fact that this cation is not stored to any great extent within the animal body, along with evidence indicating certain obligatory excretion rates, dictates that a consistent quantity must be fed to prevent depletion of the element." This summary by B.L. Workman sets the stage for a review of existing research on potassium in ruminant nutrition.

We shall explore research that has been conducted and look especially at the needs of cattle and sheep for meat production.
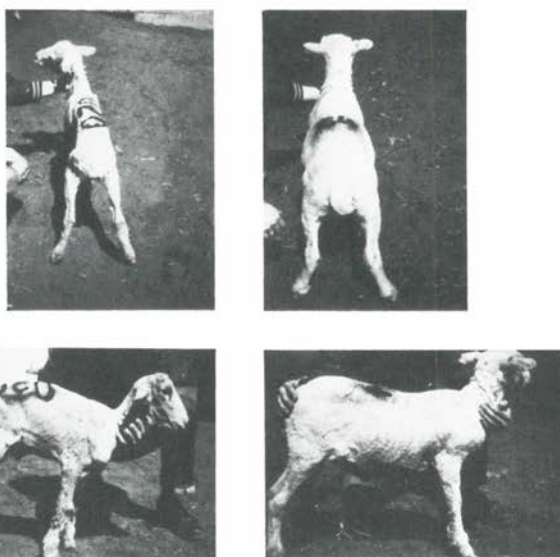
Potassium Requirements of Growing-Finishing Lambs

The earliest research on the role of potassium in lamb nutrition was

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Figure 1

Potassium deficient lamb (0.1% K in ration)   **Potassium adequate lamb (0.7% K in ration)**

conducted at the University of Missouri, by Brink. Adding KCl to a semi-purified diet containing 0.17% K, a growth response was observed when the potassium level was increased to 0.5%. However, the lambs consumed only 770 gm (1.7 lb) daily of this ration and gained only 130 gm (.28 lb) per day.

Further work at Missouri by Telle, Preston, Kintner and Pfander using more common feedstuffs demonstrated that growing-finishing lambs require 0.7% K in the ration for maximum growth rate and feed efficiency. For lambs to thrive, the ration must contain at least 0.3% K **(Table 2)**.

When rations contained less than this amount, severe deficiency symptoms appeared **(Figure 1)**.

These symptoms included a marked decrease in feed intake, loss of weight, listlessness, impaired response to sudden disturbances, progressive stiffness from the hind legs to the forelegs, neck and back, and eventual death. Some lambs fed the ration containing 0.3% K also showed some stiffness and emaciation early (21 days), but recovered completely by the end of the experiment. Microscopic examination of tissues from the deficient lambs showed abnormal lesions in the kidneys, liver and muscle.

When lambs fed either the 0.1 or 0.2% K rations were placed on rations containing either 0.7 or 0.9% K midway through the experiment, the

Table 2. Potassium requirements of growing-finishing lambs.

Dietary K level	Avg. daily gain		Feed/gain
0.1%	− 222 gm	(− .48 lb)	—
0.2	− 68	(− .15)	—
0.3	+ 172	(.38)	6.6
0.4	+ 172	(.38)	7.1
0.5	+ 190	(.41)	6.2
0.7	+ 200	(.44)	6.2

recovery was dramatic including considerable compensatory gain.

Similar results with lambs were reported by the Canadian workers Campbell and Roberts.

Potassium Requirements of Growing-Finishing Cattle

In view of the research results with lambs, the Canadian workers Delvin, Roberts and St. Omer, continued their studies with growing-finishing cattle. Their results parallel quite closely the results obtained with lambs. When rations contained less than 0.4% K, performance was markedly reduced. Furthermore, deficiency symptoms observed were similar to those described in lambs. These include partial to complete inanition, pica (hair licking and chewing wood), rough hair coats, weakness, incoordination and wobbling of the hindquarters. These workers concluded that the potassium requirement for growing-finishing steers is higher than 0.6% K but not higher than 0.8% K.

Further evidence of the need for potassium by feedlot cattle has come from Ohio. In studies by Preston, Workman and Byers, supplemental protein has been withdrawn from the ration after cattle have been on concentrate feed for at least 28 days and weigh at least 750 lb.

Most plant sources of supplemental protein (e.g. soybean meal and cottonseed meal) are excellent sources of potassium. Therefore, if supplemental protein from these sources is removed from the ration, there is a possibility of potassium becoming deficient. Indeed, when plant sources of supplemental protein were withdrawn from the ration of feedlot cattle, or when urea was used as the source of supplemental protein, the importance of adding supplemental K to meet the animals' requirement was easily demonstrated. An example of these results is shown in **Table 3.**

Table 3. Role of K during supplemental protein withdrawal in feedlot cattle.

Protein supplement	K	Avg. daily gain		Feed/gain
Soybean meal-continuous	adequate	1.71 kg	(3.77 lb)	5.7
Urea-continuous	adequate	1.60	(3.53)	6.0
Supplemental	adequate	1.70	(3.75)	5.9
protein withdrawal	inadequate	1.50	(3.31)	6.0

Thus, the research presented here demonstrates that growing-finishing cattle and lambs have a K requirement that is at least two times higher than monogastric animals. The optimum level of K required in the ration of growing-finishing ruminants for maximum performance is near 0.7% of the ration dry matter. **Table 4.**

Table 4. Minimum and optimum requirements for potassium.*

Animal	Minimum	Optimum
Monogastric	0.3%	0.4%
Growing-finishing lambs	0.5%	0.7%
Growing-finishing cattle	0.6%	0.7%

*Percent of the ration dry matter.

Table 5. Potassium levels* in typical feeds for cattle and sheep.

Feed	% Potassium
Alfalfa hay, mid-bloom	1.8%
Barley grain	0.5
Corn silage, mature, well eared	1.0
Corn grain	0.4
Cottonseed hulls	1.0
Cottonseed meal	1.4
Milo grain	0.4
Molasses, beet	6.1
Molasses, cane	4.0
Orchard grass hay	2.8
Sorghum silage	1.5
Soybean meal	2.1
Urea	none
Wheat grain	0.4

*Dry matter basis.

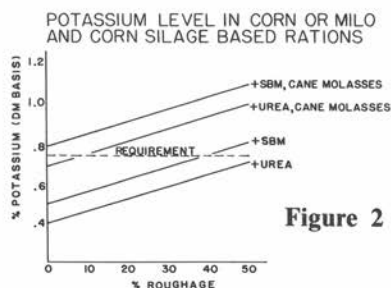## Potassium Levels in Typical Rations for Cattle and Lambs

Most roughages, molasses and many plant protein sources are good sources of K. Grains, however, are not. Typical levels of potassium in feedstuffs have been reported and a few examples are shown in **Table 5.**

Typical values are shown; however, the K content of feeds can vary. Recently we found the K content of barley grain to range from 0.37 to 0.58%. Thus, potassium analysis of feedstuffs used in feeding programs will give the actual K content of the rations. If typical potassium values are used, rations should be formulated to contain at least 0.75% K.

Figures 2 and 3 show the range in potassium content of various rations fed to growing-finishing cattle and lambs in comparison to the ration requirement of 0.75%. In corn or milo plus corn silage based ration, note that all rations where urea is the source of supplemental protein also require the supplementation of K. This would also be true of these rations if supplemental protein was withdrawn. For rations containing less than 40% corn silage, where soybean meal supplies the supplemental protein, K supplementation is required.

Rations containing 8% cane molasses require much less supplemental K. Only rations containing urea, cane molasses and less than 10% corn silage require supplemental K. With barley grain and alfalfa hay based rations, those containing 8% cane molasses will contain sufficient potassium; however, rations that do not contain cane molasses will require supplemental K when the alfalfa hay drops below 20% of the ration.

These are only examples of ration situations where potassium may be

POTASSIUM LEVEL IN CORN OR MILO AND CORN SILAGE BASED RATIONS

Figure 2

POTASSIUM LEVEL IN BARLEY AND ALFALFA BASED RATIONS
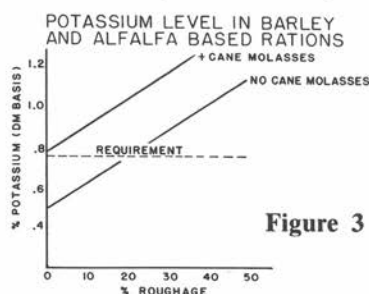
Figure 3

deficient. They illustrate, however, that as the level of roughage decreases, K deficiency becomes an increasing possibility. Also, since molasses is a good source of K, rations containing molasses are less likely to be deficient in K.

Plant protein feeds are also good sources; therefore, when these are withdrawn from the ration or when urea is used as the source of supplemental protein, the chance of K deficiency increases.

Range forage at times can be deficient in K. This is especially true of winter range and range that has undergone considerable weathering. Potassium levels in this type of forage may drop below 0.7% in the dry matter. Research at Nebraska and Wyoming has shown improved weight gains when K is supplemented to weanling calves and bred cows grazing this type of forage.

Shipping Stress and Potassium Needs

"Cattle subjected to the stresses of shipping encounter many metabolic changes, one of which is weight loss primarily due to losses of body and digestive tract water. In the case of water losses due to stress, when K moves out of cells and only sodium salts are available to replace electrolyte balance, cellular deficiency of K may occur." This statement by Hutcheson, Cole and McLaren indicates that K may be especially important when cattle are shipped.

In human medicine, Krehl states that "Studies have demonstrated that the mortality rate from all causes is much higher in potassium depleted patients."

To test the theory that shipping stress may result in a conditioned K deficiency, Texas and Tennessee workers have studied the response of cattle to added K after they are received at the feedlot.

Rations containing either 1.0 or 1.5% K were fed for the first two weeks after which the ration K level was dropped to 0.8%. During the first 14 days after the steers were received in the feedlot, those receiving a high energy ration containing 1.5% K gained 16% more than those receiving the ration with 1.0% K. A major factor in the improved performance is the relatively low feed intake by cattle after they are received by the feedlot. This low consumption does not permit an adequate K intake unless the ration contains a higher level of K. It is recommended that feedlot receiving rations contain at least 1.3% K.

Potassium in Relation to Hypomagnesemic Tetany

Often when cattle are grazing lush pasture forage or wheat pasture, some animals succumb to an acute "grass tetany" or hypomagnesemic tetany. Forage in these pastures is generally quite high in K and animals that succumb to this disorder have low serum magnesium levels.

One is not the cause of the other, however, since all lush pasture material is high in K and not all cattle with low serum magnesium show symptoms of grass tetany.

Pastures have been classified as "tetany prone" if the equivalent ratio of K:Ca + Mg is 1.8 or higher. Potassium fertilization will increase the K content of pastures, especially when K is deficient in the soil. In controlled work where cattle and sheep have either been dosed with high levels of K or chronically fed high levels of K, the effect of serum Mg levels has been marginal and tetany has not resulted.

In lush pastures, most of the plant magnesium may be in the form of chlorophyll. This form of magnesium may have low availability to the animal. At this time, K fertilization of pastures does not appear to be

the cause of hypomagnesmia. Supplemental magnesium either fed directly to the animal or applied to pasture forage seems to be the only sure way to prevent grass tetany.

Summary
Ruminants require at least twice as much K in their ration compared to monogastric animals. A level of 0.7% K in the ration dry matter appears to give maximum performance in feedlot cattle and lambs. Since the K level in feedstuffs can vary from typical values shown in tables of feed consumption, formulating feedlot rations to contain at least 0.75% K will provide a safety margin, unless analytical values on feeds being used have been determined.

Recent work indicates that somewhat higher levels of K may allow cattle to regain weight losses faster following shipment and perhaps reduce some of the death loss in newly received feeder cattle. ∎

Potash Fertilization Revives Stands, Boosts Yields and Nutritive Value of Coastal Bermudagrass

By Marcus M. Eichhorn, Jr.

HIGH PRODUCTIVITY and persistence of Coastal bermudagrass have been responsible for its widespread acceptance for hay production. The grass is especially well adapted to a wide range of soils in the Coastal Plain regions of the southern United States.

In recent years, many producers have harvested reduced yields from fields that had been highly productive in the past. Declining yields of as much as 40% have been attributed to mineral imbalances in the soil, insects, nematodes, diseases, herbicides, poor management, and other factors. The condition has become progressively worse each year and has been referred to as stand loss, winterkill, spring dead spot, rapid dieback, thin stand, and leaf spot disease.

A recent survey, made in the fall, of affected fields in north Louisiana revealed that soils were low in exchangeable potassium (K) and that forage was infected with a toxin-producing variant of the fungus, *Helminthosporium cynodontis.*

A study of K fertilization was initiated in 1980 on Shubuta very fine sandy loam recently limed with dolomite limestone to adjust soil reaction to pH 6.5-7.0. The site had been in continuous hay production for 11 years and was exhibiting severe stand loss.

Objectives of the 5-year study were to determine effects of K fertilizer rates and application frequencies on Coastal bermudagrass yield and stand

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regeneration. Rates up to 600 lb/A of K_2O were applied annually and in two and four split applications. In addition to K_2O, the grass was fertilized annually with 100 lb/A of nitrogen per cutting, 150 lb/A of phosphate, and 90 lb/A of sulfur(S). Forage was managed for four cuttings annually.

Results up to 1982, the third year of the study, indicate that K plays a vital role in regenerating reduced stands of Coastal bermudagrass on soil cropped previously to a low K level, **Table 1**.

Table 1.   Effects of K fertilization on stand recovery.

Annual			Spring stand density estimates			
K_2O	Appl. freq.	Initial Soil K	Initial 1980	1981	1982	1980-1982
(lb/A)		(ppm)		%		
0	0	47	57	46	39	− 18
100	1	31	24	55	50	+ 26
200	1	37	35	60	72	+ 37
400	1	40	42	67	83	+ 41
600	1	30	36	60	81	+ 45
50	2	40	36	69	75	+ 39
100	2	31	49	69	82	+ 33
200	2	38	45	66	85	+ 40
300	2	38	46	70	87	+ 41
25	4	28	47	55	69	+ 22
50	4	33	45	74	87	+ 42
100	4	31	41	79	89	+ 48
150	4	39	58	80	88	+ 30

Samples collected November 1979.   Stand estimates made April 20 each year.

Stand density increased considerably following one and two years of K fertilization and cropping, except on plots receiving 100 lb/A of K_2O applied in one increment. In absence of K_2O fertilizer, stands diminished an additional 18% below the initial level of 57%.

Coastal bermudagrass yield and composition responded favorably to applied K fertilizer rates after cropping for two years, **Table 2**. Application frequency did not have a significant effect on responses. Optimum yield,

Table 2.   Effects of K fertilization on mean annual forage yield and mean K uptake, K content, and *in vitro* dry matter digestibility (IVDMD) for all cuttings of Coastal bermudagrass, 1980-81.

K_2O	Dry forage	K content	K uptake	IVDMD
lb/A	lb/A	%	lb/A	%
0	11,783	1.00	123.4	52.7
100	13,204	1.29	169.1	53.6
200	14,111	1.47	209.4	53.7
400	14,653	1.84	274.0	53.9
600	15,161	2.05	319.6	54.0

K content, K uptake, and nutritive value of Coastal bermudagrass was obtained from application of 600 lb/A of K_2O. Compared to the zero lb/A check, yield and K uptake were increased 3,378 and 196 lb/A, respectively. Potassium content and *in vitro* dry matter digestibility (IVDMD) were increased 1.05% and 1.3%.

The increase in IVDMD attributable to K fertilization has special significance to livestock producers. Animal feeding trials conducted on bermudagrass in Georgia showed that average daily gains increased 5% to 9% for each 1% increase in IVDMD.

Applied potash rates and application frequencies affected soil exchangeable K levels following Coastal bermudagrass cropping for two years, **Table 3.**

Table 3. Effects of K fertilization on soil exchangeable K level following Coastal bermudagrass cropping.

Annual		Exchangeable soil K				
K_2O	Appl. freq.	Initial 1979	1980	1981	1979-1980	1980-1981
(lb/A)		------------------------------- ppm -------------------------------				
0	0	47	18	14	− 29	− 4
100	1	31	21	12	− 10	− 9
200	1	37	21	10	− 16	− 11
400	1	40	30	18	− 10	− 12
600	1	30	45	23	15	− 22
0	0	47	18	14	− 29	− 4
50	2	40	29	15	− 11	− 13
100	2	31	42	19	11	− 23
200	2	38	69	35	31	− 35
300	2	38	71	44	33	− 27
0	0	47	18	14	− 29	− 4
25	4	28	28	15	0	− 13
50	4	33	44	19	11	− 25
100	4	31	88	43	57	− 46
150	4	39	95	68	56	− 27

In 1980, an exceedingly dry year, yields were relatively low for all rates and frequencies of applied K_2O. Soil K levels were higher than the initial level, however, only where 600 lb/A of K_2O was applied in one increment and where rates of 200 lb/A and higher were applied in two and four increments.

In 1981, conditions were highly favorable for hay production, but soil K levels decreased for all K_2O treatments below the 1980 level. Furthermore, after two years of cropping, soil K was above initial levels only where 400 lb/A of K_2O was applied in four increments and where 600 lb/A of K_2O was applied in either two or four increments.

Summary

Results after two years indicate that potash fertilization is essential for regenerating diminished stands of Coastal bermudagrass on hay fields cropped for many years. Potash fertilization increased both yield and nutritive value of forage. Applied K_2O rates of 100 lb/A for each cutting or 300 lb/A prior to the first and third cutting were required to maintain soil K levels. The study will continue for another three cropping seasons. ■

Higher Alfalfa Yields: Costs, Returns, Considerations

By David C. Petritz

GROWING ALFALFA is not a low cost enterprise. For example, the estimated non-land costs for producing eight-ton annual yields are more than $400 per acre. But even though production costs per acre increase with higher yields, the cost per ton declines because seeding, machinery ownership and other costs are fixed.

Tables 1 and 2 present estimates of costs and net returns associated with production of 2, 5, 6 and 8 tons of alfalfa per acre.

Net returns per acre increase with higher yield and price. However, a selling price of more than $60 per ton **and** a yield of six-tons per acre are required for a positive return to land. As prices increase, the breakeven yield declines.

Whatever the combination, high yields of excellent quality alfalfa, "marketed" at top prices, are required for alfalfa to be a feasible alternative crop.

Alfalfa Value

Estimating the costs of production is relatively simple: specific yields require certain quantities of seed, fertilizer, chemicals and machinery. It is many times more difficult to assign a market price. Prices from a local hay market can be used, or hay prices can be based on the price of substitute feeds which do have market prices, such as corn or soybean meal. Both methods have flaws.

First, the hay market is very "thin," because so little hay is actually bought and sold. As such, the prices being reported may not be an accurate representation of the value of hay. Also, the hay sold at auctions is usually in pick-up load lots (20-30 bales) and the quality is typically excellent. Thus, the producer with a barn full of hay, some of which has been rained on, has a difficult time relating auction prices to his marketing decisions because of these quantity and quality differences.

Since the general lifetime of an alfalfa seeding (in the Midwest) is three to five years, producers would like to have a price forecast for this planning horizon. But, hay prices fluctuate widely; they are nearly impossible to predict.

Case in point: alfalfa hay prices in Indiana have varied from $60 to $300 per ton in a 12 month period. For these reasons, it is nearly impossible to predict accurately the revenue side of the alfalfa budget.

Basing alfalfa's value on corn and soybean meal has serious flaws. This process ignores the marketability of alfalfa hay vs. these concentrates. The density, flowability, transportation costs and alternative uses are different.

The process also tends to "double count" the feed value of the alfalfa.

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Table 1. Costs of producing alfalfa for specified yields.

Cost Item	Yield per acre				Your cost
	3 tons	5 tons	6 tons	8 tons	
	(costs per acre)				
Establishment and maintenance					
Fertilizer[1]	$ 28.14	$ 50.15	$ 60.18	$ 85.44	_____
Lime[2]	10.00	10.00	10.00	10.00	_____
Seed[3]	7.80	7.80	7.80	7.80	_____
Pesticides[4]	--	26.15	26.15	26.15	_____
Custom seeding[5]	1.50	1.50	1.50	1.50	_____
Interest and misc.[6]	8.54	20.95	22.75	27.30	_____
Subtotal/Acre	$ 55.98	116.55	128.38	158.19	_____
Harvest					
Machine operation[7]	$ 24.00	$ 40.00	$ 48.00	$ 64.00	_____
Interest and misc.[6]	4.32	7.20	8.64	11.52	_____
Machinery investment[8]	64.32	64.32	64.32	64.32	_____
Storage[9]	23.52	39.20	47.04	62.72	_____
Labor[10]	20.70	34.50	41.40	55.20	_____
Subtotal/Acre	$136.86	185.22	209.40	257.76	_____
Total non-land and cost/Acre	$192.84	301.77	337.78	415.95	_____
/Ton	64.28	60.35	56.30	52.00	_____
Land cost	$ 80.00	100.00	100.00	135.00	_____
Total all costs/Acre	$272.84	401.77	437.78	550.95	_____
/Ton	90.95	80.35	72.96	68.87	_____

1. Fertilizer costs are based on removal; K_2O cost 13¢/lb, P_2O_5 cost 24¢/lb.
2. One ton of lime annually, including spreading cost.
3. Seeding rate of 12 lb/A. Assumes four year stand.
4. Includes weed control and insecticides for potato leaf hopper and alfalfa weevil.
5. It is more economical to hire the seeding done than to purchase the required equipment to seed, unless equipment is already on the farm.
6. Interest on operating capital at 14%, plus one percent allowance for miscellaneous costs.
7. Includes fuel and oil, repairs and twine.
8. Assumed minimum of 60 acres and same depreciation schedule for all equipment for all yields.
9. Based on 14 square feet per ton, investment cost of $3.50 per square foot for clear-span building, and annual ownership costs equal to 16% of new costs.
10. Based on wage rate of $5.00 per hour.

All of the alfalfa is used for energy evaluation; then all is used for protein evaluation. It is likely that the two parts add to something greater than the whole! The process may also put a value on the protein portion when it really has no value.

For instance, non-lactating beef cows require little protein. Thus, the protein in a ration of alfalfa hay would be partially wasted — so why put a dollar value on it?

There is another flaw in the procedure of using the nutrient value of corn to establish the value of alfalfa; a unit of digestible energy in corn is

Table 2. Impact of alfalfa yields and prices on net returns to land.

Alfalfa Price[1]	Yield per acre			
	3 tons	5 tons	6 tons[2]	8 tons[2]
	Net Returns to Land			
$40.00	-$72.84	-$101.77	-$97.78	-$95.95
$50.00	- 42.84	- 51.77	- 37.78	- 15.95
$60.00	- 12.84	- 1.77	22.22	64.05
$70.00	17.16	48.23	82.22	144.05
$80.00	47.16	98.23	142.22	224.05
$100.00	107.16	198.23	262.22	384.05
$120.00	167.16	298.23	382.22	544.05

1. Net farm price. Does not include transportation costs to point of sale.
2. High management requirements needed as these yields equal to 140 and 200 bu/A of corn respectively.

not equal to a unit of digestible energy found in forage.[1]

Due to the difference in the heat increment of digestion, there is not a one-to-one relationship. Moreover, the energy utilization of forage is tied to the intended use by the consuming livestock; maintenance and milk production result in more efficient utilization of the energy found in forages. So, using the energy value of corn to establish the value of alfalfa would result in an over-statement of the dollar value of the alfalfa.

Livestock

On a livestock farm, the "value" of the alfalfa fed is tied to the efficiency and profitability of the livestock enterprise, unless the producer uses a very strict set of enterprise budgets. With the exception of dairy, the cattle business has generally not been very profitable in the last few years. As a result, many producers have believed their alfalfa has not been economically worthwhile either.

On a livestock farm, the productivity or efficiency of the livestock enterprise plays in integral role in determining the value of the alfalfa hay being fed. Any one who produces 18,000 lb of milk per cow or weans ninety-five 500 lb calves from 100 cows knows what I mean.

Quite simply, the alfalfa is just part of the forage-livestock system on each individual farm. Some producers have mastered their forage-livestock as one system. They are able to generate more net returns to the farm.

Finally, weather is a critical factor in determining the quantity and quality of alfalfa hay harvested during the growing season. A week of showers and high humidity will cause almost total deterioration in a raked field of hay. Yields of later cuttings are reduced by the windrows of hay blocking out sunlight and by the damage due to the extra traffic required for re-raking of the hay. Even if the hay is standing, the quality of the crop and the quantity of future crops will decline in a domino effect due to the delayed harvest of the immediate crop. Controlling weather and/or speeding up the hay harvest process will be critical to achieving high yields of superior quality hay.

In conclusion, increasing alfalfa yields per acre will be only one component in making alfalfa profitable in the future. An effective marketing program and an efficient livestock enterprise will be equally or more important for the producer who wants to achieve maximum economic yields per acre for his entire farm. ∎

[1]Bula, R. J., Lechtenberg, V. L., and Holt, D. A., "Potential of Temperate Zone Cultivated Forages," Winrock Report, *Potential of the World's Forages for Ruminant Animal Production,* September 1977.
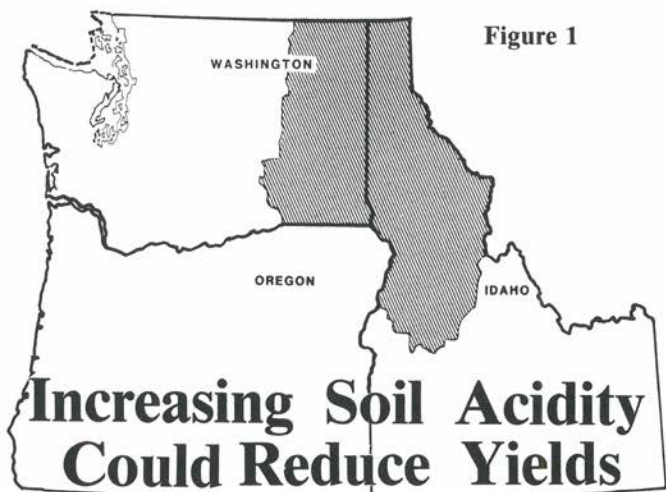
Figure 1

Increasing Soil Acidity Could Reduce Yields
in the Inland Pacific Northwest

By R. L. Mahler

IN THE PAST SEVERAL YEARS many scientists, county agents, growers and consultants throughout eastern Washington state and northern Idaho have noted that the pH of agricultural soils has been falling at an alarming rate.

This agricultural region shown on the map in **Figure 1,** is semi-arid. Annual rainfall ranges from 14 to 25 inches and large quantities of soft white winter wheat, peas, lentils, barley and hay are produced. This article presents information on the cause, magnitude and speed of pH decline in the region.

What is soil acidity and where does it occur?

Soil acidity has long been recognized as a primary factor reducing crop yields throughout the world. Yield reductions due to acidity are commonly observed in the Midwest, Southern and Eastern regions of the United States. Soils west of the Cascades in Washington and Oregon are also acid.

An acid soil can be defined as one with a pH below 7.0, but for most practical purposes a soil with a pH below 6.6. The term "acid" is usually applied to the soil surface and does not imply anything about the pH of the subsoil.

Soil acidity occurs when the levels of exchangeable aluminum (Al^{+++}) and hydrogen (H^+) on clay particles in the soil are high relative to levels of calcium (Ca^{++}), magnesium (Mg^{++}) and potassium (K^+). Excessive levels of H^+ and Al^{+++} on soil colloids have been shown to reduce wheat yields by over 80%. The primary method of correcting soil acidity is by lime application.

Causes of soil acidity

Soils naturally become acid via several factors, including high rainfall, acid rainfall, crop removal of basic plant nutrients, and application of

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ammonium based fertilizers to the soil. **The addition of ammonium based fertilizers is by far the most important factor causing soils in the Inland Pacific Northwest to rapidly become acid.**

Each ion of ammonium fertilizer added to the soil will produce 2 ions of H^+ when conversion to nitrate occurs.

$$2 NH_4^+ + 3 O_2 \rightarrow 2 NO_2^- + 4 H^+ + 2 HOH$$

$$\underbrace{\hspace{3cm}}_{\text{Generates}} \uparrow$$
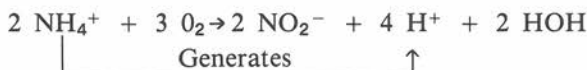
For every pound of nitrogen (N) added to the soil as ammonium, 1.9 to 3.6 lb of calcium carbonate is required to neutralize the acidity generated. **Table 1** shows the acidity of nitrogen fertilizers commonly used in the Inland Northwest on the basis of potential soil acidity generation from greatest to least. On a pound for pound basis of total material, the ranking would be: 1. ammonia; 2. ammonium sulfate; 3. urea; 4. ammonium nitrate.

Table 1. Acidity of commonly used nitrogen fertilizers.

Material	CaCO₃ Equivalent per ton*	CaCO₃ Equivalent per 100 lb of N
Anhydrous Ammonia	2,960	181
Ammonium Sulfate	2,200	523
Urea	1,680	181
Ammonium Nitrate	1,180	89

*Amount of lime needed per ton of material to neutralize the acidity generated.

Growers in eastern Washington and northern Idaho have been adding acidity in the form of ammonium fertilizers in large quantities to their soils for over thirty years. Conversely, most growers have not added as much as one pound of a liming material such as calcium carbonate or dolomite to their soil to neutralize the generated acidity.

TYPICAL N RATES USED ON WHEAT IN THE IDAHO-WASHINGTON BORDER AREA
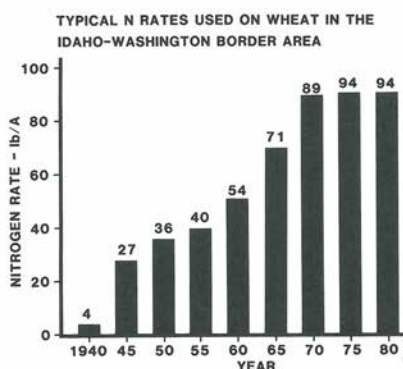
GROWERS in northern Idaho and eastern Washington have been adding acidity in the form of ammonium-based fertilizers to their soils for over 30 years.

Figure 2

Soil acidity in eastern Washington and northern Idaho

Most agricultural soils in eastern Washington and northern Idaho were slightly acid (pH 6.6) to slightly alkaline (pH 7.2) in their virgin state. Farmers used N fertilizers sparingly on their soils until after World War II, when higher yielding wheat varieties became available.

Nitrogen fertilizer use rapidly increased in the early 1950's (about 36 lb N/A) and has continued to increase as improved wheat varieties became available. **Figure 2** shows typical N rates since 1940.

Nitrogen fertilizer rates began to stabilize at 90 to 110 lb N/A per wheat crop in the early 1970's. Since the virgin prairie was first plowed, approximately 1100 lb N/A has been added to typical Palouse farmland on the Idaho-Washington border. See **Figure 3**.

THE BAR GRAPH depicts the total fertilizer N added to a typical soil in the Palouse area on the Idaho-Washington border. In general, N is added only to the grain crop in a grain-legume rotation. Thus N is added to the soil every other year.

Figure 3

TOTAL AMOUNT OF NITROGEN ADDED OVER TIME
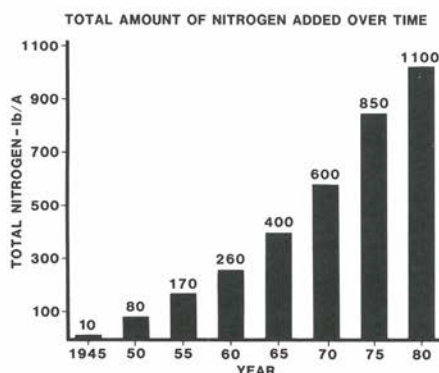
In 1960, less than 15% of the soils in the region had pH less than 6.0. However, by 1980, many of the main wheat producing counties in the region reported that well over 65% of their soils were less than pH 6.0.

How quickly will soil acidity develop?

Buffering curves have been conducted on northern Idaho soils to try and simulate this rapid pH decline. If a Palouse soil at an initial pH of 7.2 is amended with 110 lb N/A on an annual basis the pH of the soil will drop to 5.4 in just 10 years.

The values shown in **Figure 4** are unrealistic because for crop rotation 110 lb N/A would not be added to soil each year. However, the values do explain why soils in the region are rapidly becoming acid. The decline in pH would take less time if the N source was ammonium sulfate, more time if ammonium nitrate is the N source, and approximately the same amount of time if urea.

As long as large quantities of N are required for high crop yields, soil pH in both states will continue to decline. The decline of soil pH in eastern Washington and northern Idaho is a development present in only the upper 12 inches of the soil profile. Once plant roots get through the upper 12 inches of the soil into the higher pH zone below there should be few problems with plant growth.

However, it is the time period in which the roots are in the upper 12

LABORATORY simulation of the soil pH reduction caused by continuous high rates of anhydrous ammonia application to Palouse area soils.

Figure 4

ANHYDROUS AMMONIA REDUCES SOIL pH
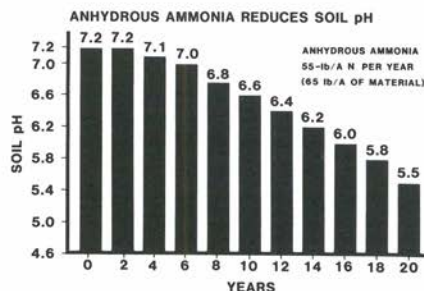
inches of the soil that crop yields may be affected. **The major concerns should be with seed germination, seedling establishment and young plant vigor.**

How urgent is the need for lime?

In northern Idaho and eastern Washington the question is not: "Will we need to add lime in the future?" Rather, the question is: "When will lime be required to prevent soil acidity from reducing wheat, barley, pea and hay yields significantly?"

Another factor which magnifies the probable need for lime in the near future is that the varieties of wheat grown in northern Idaho and eastern Washington are extremely intolerant to acidity when compared to wheat varieties grown in acid soils of the Midwest and Southeastern United States.

As a rule, legumes such as peas, lentils and alfalfa are less tolerant of acid conditions than cereals. The acidic conditions prevent nitrogen fixation at optimum levels.

To complicate matters even more, soil acidity may create problems with weeds, diseases and the nutritional needs of the plant. As conditions become acid, weeds which were not a problem in the past may become more competitive at lower pH. Conditions might also allow diseases to become major pests. With lower pH, the soil environment becomes more favorable for pathogenic fungi. This may promote more plant diseases.

Along with weed, disease and variety problems, acid soils could create nutritional problems for plant growth. Under acid conditions, exchangeable aluminum (Al) in the soil tends to precipitate phosphorus (P) and calcium (Ca) before it can enter the plant. Low soil pH would also decrease molybdenum (Mo) availability.

Where soil acidity is a problem, the full benefits from investments in fixed and variable costs will not be realized. Thus, in these days of high production costs and low crop prices, it is essential not to jeopardize satisfactory returns on other necessary inputs including applications of N, P, K and S.

Lime may already be needed for satisfactory production of wheat, peas and alfalfa in isolated areas of the region. It will be necessary over a widespread area in the very near future. An estimated 80% of crop acreage in northern Idaho and over 60% of the acreage in eastern Washington may someday require lime. And someday may be much sooner than most people think! ■