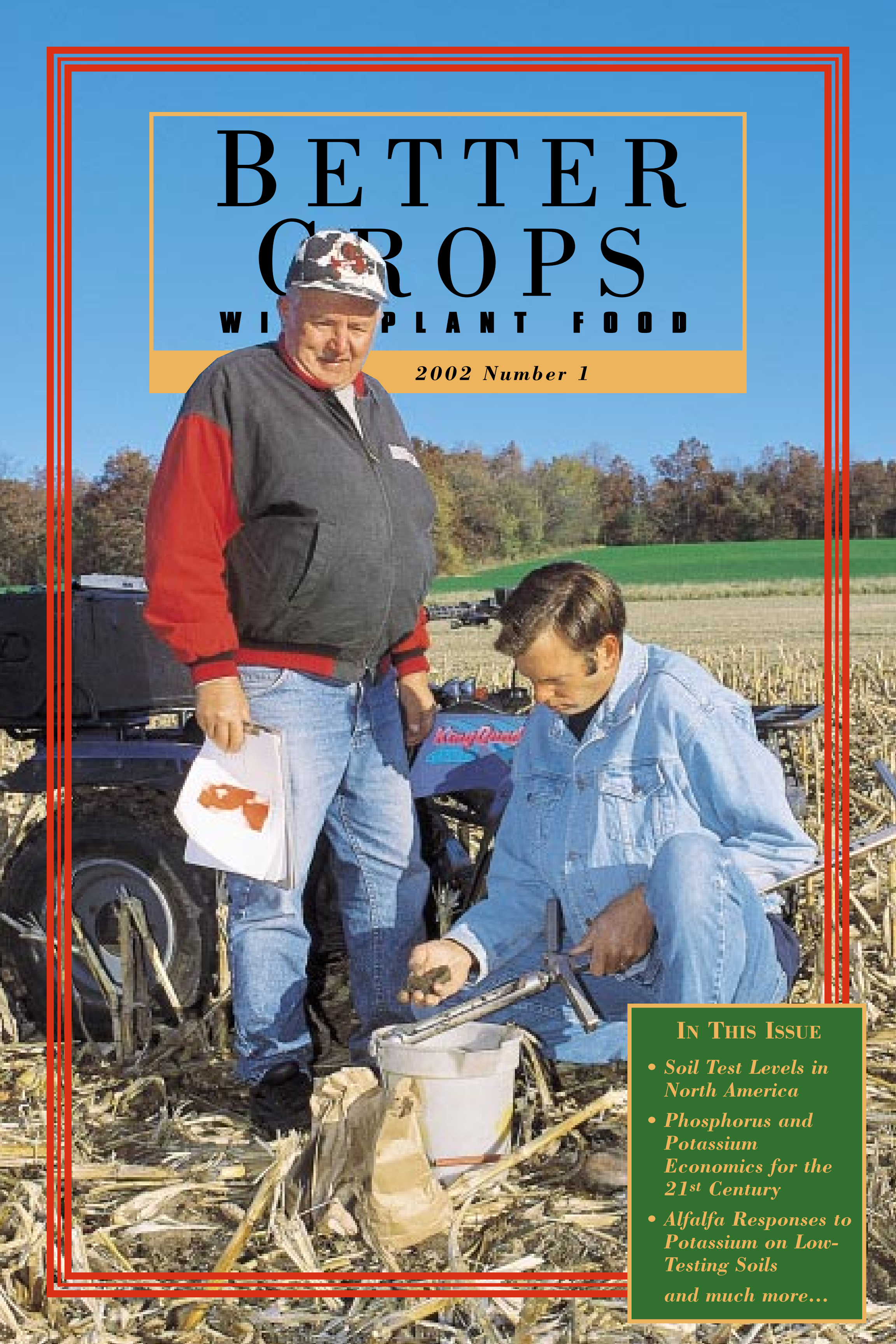

BETTER CROPS
WITH PLANT FOOD

2002 Number 1

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- *Soil Test Levels in North America*
- *Phosphorus and Potassium Economics for the 21st Century*
- *Alfalfa Responses to Potassium on Low-Testing Soils*

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BETTER CROPS WITH PLANT FOOD

Vol. LXXXVI (86) 2002, No. 1

Our Cover: Agronomist Tim Maloney (at right) works with Wisconsin farmer Earl Findlay in soil sampling.
Photo Credit: Bob Elbert

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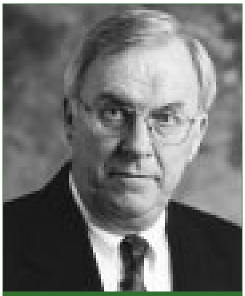
Henk Mathot Elected Chairman, S.A. Riemann Vice Chairman of PPI and FAR Boards of Directors

Henk Mathot, President of Worldwide Fertilizer Operations, Cargill, was elected Chairman of the Potash & Phosphate Institute (PPI) Board of Directors at a recent meeting. He will also serve as Chairman of the Foundation for Agronomic Research (FAR) Board. **Stanley A. Riemann**, Executive Vice President and President, Crop Production Group, Farmland Industries, Inc., was elected Vice Chairman of the PPI and FAR Boards.



Henk Mathot

"With their insight and wide range of experience in the industry, we welcome these men to important leadership positions for the Institute in the year ahead," said Dr. David W. Dibb, President of PPI. "We look forward to further progress in PPI programs with their direction."

S.A. Riemann

Mr. Mathot's responsibilities with Cargill include phosphate mining and fertilizer production facilities in Florida and the company's North American and international network of fertilizer trading, blending, and distribution facilities. He also serves on the board of Saskferco, Cargill's nitrogen-producing joint venture with the Province of Saskatchewan.

Mr. Mathot joined Cargill in 1974 as production manager at its protein-products plant in Amsterdam, The Netherlands. He was later appointed general manager of the corn milling plant in Tilbury, England, and then technical director for Cargill Europe. In 1986, he was appointed president of Cargill's Florida-based phosphate fertilizer operations, before becoming president in 1994 of Cargill Agricola S.A., the Brazilian subsidiary of Cargill.

Mr. Riemann, new Vice Chairman of the PPI and FAR Boards, has responsibility for the Crop Production Group of Farmland, which produces, markets, and distributes farm input products and services. He also supervises the Farmland Transportation Division. Farmland Industries, Inc., is the largest farmer-owned cooperative in North America, with 600,000 farmer-owners in the U.S., Canada, and Mexico. Farmland has major business lines in crop production and crop protection products, livestock feeds, petroleum, grain processing, and marketing,

In other action of the PPI Board, John M. Van Brunt, President and CEO, Agrium Inc., was elected Chairman of the Finance Committee.

During the FAR Board of Directors meeting, Denny Addis of The Andersons and Ken Moshenek of Royster-Clark were named members of the Board. Dr. Terry L. Roberts, Vice President, PPIC, Latin America Programs, continues as President of FAR. BC

You can reach PPI, PPIC and FAR on-line. To visit the PPI/PPIC website use **www.ppi-ppic.org**. *Use* **www.ppi-far.org** *to go to the FAR website.*

Phosphorus and Potassium Economics for the 21st Century

By Jess Lowenberg-DeBoer and Harold F. Reetz, Jr.

In the U.S., building soil phosphorus (P) and potassium (K) levels typically becomes an issue on farms that have had limited nutrient application and when doing site-specific management. Intensive soil sampling often reveals islands of low P and/or K in otherwise well-managed fields. Most soil fertility recommendations suggest a slow buildup of those low fertility areas. Financial analysis indicates that if it is profitable to build up soil P and K levels, it is most profitable to do it as quickly as possible. This article outlines the potential benefits of rapid buildup and the soil chemistry constraints to such a strategy.

> Farmers acquiring land with depleted nutrient levels or identifying low-fertility 'islands' within fields that need significant buildup under site-specific systems may find a rapid buildup program (one or two years) to be most appropriate under today's economic and risk management constraints. Rapid buildup reduces risk of lost profits.

Phosphorus and K fertilizers are an investment in long-term soil fertility. In general only a portion of this year's P and K application is used by this year's crop. A large part goes to increase overall soil fertility. In economic terms, the cost of building soil fertility is the potential gain on investments not made because funds were tied up in P and K in the soil. Depending on the farm, those alternative opportunities or investments might include paying off existing loans, replacing equipment, new livestock facilities, or a non-farm business. Sometimes this opportunity cost of not investing is referred to as the time value of money.

Because of compounding, the time value of money tends to favor investments that pay off quickly. While the mechanics of compound interest and net present value (NPV) can be complicated, the idea is simple. (Net present value is the sum of discounted profits, minus initial costs. The weights used in discounting future returns are a function of the opportunity cost of capital and the time since the initial investment.) If an investment is profitable quickly, it provides additional income which can be reinvested to generate even more profit. For crop producers this means that a mismanaged field or a low fertility island should be brought up to maximum economic yield (MEY) as quickly as possible given the constraints of financing and soil chemistry.

Slow Buildup Fits Small Farm Scenario

In the early 20th century, when farms were small and the agricultural credit system was in its infancy, cashflow was a key constraint to building up soil fertility. It was difficult for farmers to pay for P and K fertilizer that built soil fertility when the cashflow generated by that buildup stretched over the next three to five years. In that case, the best they could do was to build soil fertility slowly, applying only as much buildup P and K fertilizer as could be paid for out of current cashflow.

Risk and short-term farm rental also contributed to a preference for slow soil fertility buildup in the 20th century. While P and K in the soil may be a good investment, it is a highly illiquid asset with minimal use in risk management. Tenants on one-year leases with high turnover were reluctant to invest in building soil fertility.

Most Extension fertilizer recommendations seem to have been developed with this small farm scenario in mind. The current situation in the U.S. and Canada is much different. Most commercial farms can obtain credit for profitable investments. Risk is still important, but government farm programs, availability of crop insurance, contracting, hedging, and options provide producers with some tools to help manage that risk. Many farms are still on one-year leases, but many of these are repeatedly renewed, and landlords are increasingly aware of the importance of soil fertility as a way to make their investment profitable. This is particularly true on professionally managed farms. It is time to re-examine those slow P and K buildup recommendations that were designed to deal with the problems of an earlier period of agricultural history.

Agronomic Limitations

A larger part of the response to buildup fertilizer applications may come from the first increments added than from the latter amounts. The response will depend on how low the initial soil test was and on soil characteristics. If soil tests are low, more of the yield will likely come from the added fertilizer than from the background soil supply. Splitting the buildup over time into two or more applications will slow the buildup process, but may still achieve more rapid increase in yield than in soil test.

In most cases, rates required for rapid buildup plans need not be limited by agronomic concerns. However, there is potential for salt injury if required K applications are extremely high. If the recommendation exceeds 600 lb K_2O/A, it may be best to limit the first year application to 600 lb/A and complete the buildup process in the next fertilizer application. Since accuracy of soil tests may be less reliable at the lower end of the scale, this will also allow for another soil test to be taken to reaffirm the need for the higher rate. The majority of the crop response will be obtained with the first increment, so the yield loss from splitting the application will be minimal.

Rapid buildup strategies for P and K may be the most economical approach when soil tests are medium or low.

For surface-applied fertilizer, especially P under reduced tillage, splitting large applications may help reduce risk of environmental problems. In soils with a high sand content or other cases where leaching is a high risk, or on soils where there is a high rate of fixation of P in unavailable forms, heavy applications to build soil test are not advised. The best approach on these soils will be annual applications. For most farms, buildup is sound management, and rates should not be restricted for agronomic reasons. Rapid buildup will generate the quickest return and lead to a more profitable level of management in the shortest period of time.

The example below compares three different scenarios of buildup P and K, with an economic and agronomic evaluation that is more appropriate for 21st century farms.

Example

A partial budget example was developed using the P and K response functions and soil carryover relationships presented by Schnitkey, Hopkins and Tweeten of Ohio State University. These relationships are based on Ohio data, but results would be similar anywhere in the Midwest. The land is assumed to be in a corn/soybean rotation (starting with corn) and have a cation exchange capacity (CEC) of 20 meq/100 g. The baseline compares three buildup strategies:

- **Rapid Buildup** – Enough P and K is

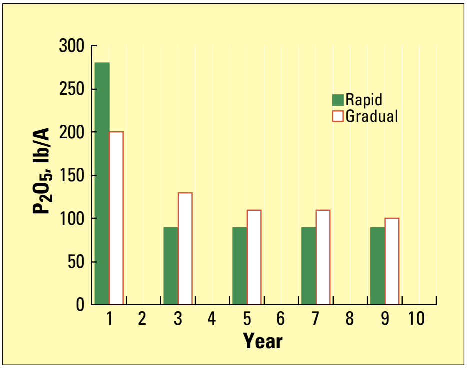


Figure 1. Phosphorus buildup alternatives (application every second year).

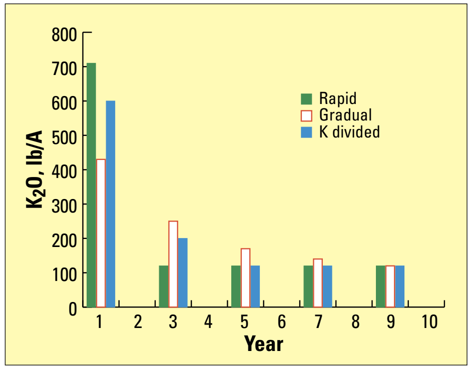


Figure 2. Potassium buildup alternatives (application every second year).

applied the first crop season to build soil tests to critical levels. The critical levels from the Tri-State university recommendations (Michigan, Ohio, Indiana) are used: P, 30 lb/A; K, 250 lb/A for a CEC = 20.

- **Gradual Buildup** – The equations in the Tri-State recommendations are followed, resulting in a buildup over about seven years.
- **Rapid Buildup with K in Two Applications** – Like the Rapid Buildup strategy, but when first year K_2O is limited to 600 lb/A (Hoeft and Peck, 2000).

When soil tests reach the critical levels, the Tri-State recommendations are followed, which specify maintenance applications based on crop removal. The example assumes that initial soil test levels are 10 lb P/A and 100 lb K/A.

Baseline price and cost assumptions are: corn, \$2/bu; soybeans, \$5/bu; P_2O_5, \$0.22/lb; K_2O, \$0.13/lb; nitrogen (N), \$0.20/lb; drying, \$0.10/bu; and hauling grain, \$0.20/bu. Fertilizer applications are assumed to be made only in the corn year. A 10-year planning period was used. Only costs of fertilizer and drying and hauling grain are deducted in the net return calculation; all other costs are assumed to be the same for all three strategies. A sensitivity test was conducted assuming: higher grain prices – \$3/bu for corn and \$7/bu for soybeans; lower P and K prices – P_2O_5, \$0.10/lb; K_2O, \$0.10/lb; and higher P and K prices – P_2O_5, \$0.30/lb; K_2O, \$0.20/lb.

Given initial soil test levels, the rapid buildup plan requires 280 lb P_2O_5/A and 910 lb K_2O, compared to 200 lb P_2O_5 and 530 lb K_2O/A under the Tri-State recommendations for gradual buildup. With the rapid buildup plan, subsequent applications are at a maintenance level (**Figures 1** and **2**). With the

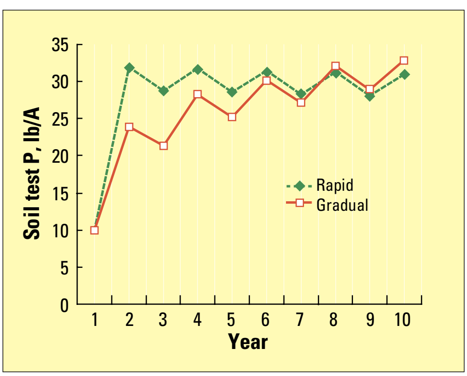


Figure 3. Phosphorus buildup plan soil tests (application every second year).

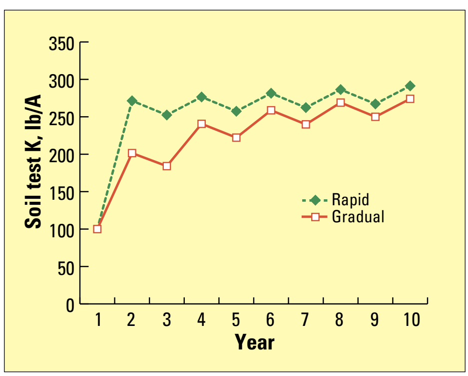


Figure 4. Potassium buildup plan soil tests (application every second year).

TABLE 1. Estimated benefits of rapid P and K buildup under different price scenarios.		
Scenario	Rapid, ... $/A	Split K applications, ...
Baseline	3.34	2.74
Higher grain prices	4.94	3.97
Lower P and K prices	3.46	2.77
Higher P and K prices	2.86	2.47

gradual buildup, applications remain above the maintenance level for the whole 10-year period.

With rapid buildup, soil tests reach the critical level in year two (**Figures 3** and **4**). Because of the application only for corn, soil tests overshoot slightly in the corn year to allow enough soil fertility to carry through the soybean year, resulting in a zig-zag soil test time path. With the gradual buildup strategy, soil tests rise throughout the 10-year planning period. When the K_2O is limited to 600 lb/A the first year, the soil test reached the critical level in the third year.

Under baseline assumptions, the estimated benefit of rapid buildup is an increase of over $3/A in the average net return over the 10-year period (**Table 1**). The rapid buildup plan has a much lower expected net return in the first year because of the large fertilizer application, but more than makes up for it with higher returns in subsequent years (**Figure 5**). Three dollars per acre is not a large sum of money, but when fine tuning farm management every dollar counts.

When the K application is spread over two years, rapid buildup is still expected to be more profitable than with the gradual plan, but the difference is smaller. The reduction comes because K is below the critical level for two years, and the full effect of the P buildup is not felt during that time because K is still limiting.

When grain prices are higher, the rapid buildup plan becomes even more profitable. It shows an estimated advantage of almost $5/A in average net return in this example when K can be applied in the first season. The rapid buildup advantage grows slightly when P and K prices are lower and shrinks

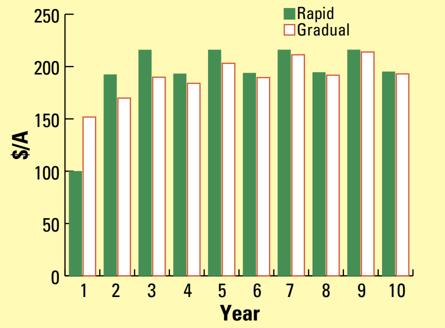


Figure 5. Buildup plan net returns (application every second year).

when prices are higher, but this is a relatively small change.

When the time value of money is taken into account, the benefits of the rapid buildup are clearly seen. Rapid buildup results in an increase in the estimated NPV of about $12/A under the baseline conditions and $24/A under the higher grain prices. The split K application plan shows an expected NPV advantage of $11/A for the baseline and $20/A for the higher grain price scenario.

Conclusions

In the past, P and K buildup was often spread over several years because of how farms were managed. Financial constraints, risk management problems, and rapid turnover in rental land motivated farmers to build soil P and K in small increments. Soil chemistry issues, such as salt buildup and unreliability of soil tests, also contributed to this decision, but were usually not the determining factor. With the development of agricultural credit, improvement in risk management tools, and changes in the rental market, those slow buildup strategies should be revisited.

There are several situations where a rapid buildup program (one or two years) is the most economical approach when initial soil test levels are low or medium.

1. Farmers who take over run-down farms and want to get them into full potential production as quickly as possible should consider a rapid buildup strategy.

2. A crop-share landlord who acquires a mismanaged farm and wants to get it into full production as quickly as possible should work with the tenant to adopt a rapid buildup program.
3. A cash-rent landlord who pays for the buildup P and K fertilizer and purchases land with low soil tests should build P and K levels quickly so that higher cash rents can be justified.
4. Producers who use intensive soil sampling and identify low fertility islands in otherwise higher fertility fields should consider a rapid buildup. If the islands are a small part of the farm area, the cashflow effects of the extra fertilizer application will be correspondingly small. BC

Dr. Lowenberg-DeBoer is Director, Site-Specific Management Center, Department of Agricultural Economics, Purdue University, West Lafayette, Indiana. E-mail: lowenberg-deboer@agecon.purdue.edu. Dr. Reetz is Midwest Director, Potash & Phosphate Institute (PPI), located at Monticello, Illinois. E-mail: hreetz@ppi-far.org.

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Precision Farming Profitability Book Discusses Site-Specific Management Topics

A recently-released book written by Purdue University specialists offers information on site-specific tools and strategies to improve crop management. Titled *Precision Farming Profitability*, the 132-page publication contains 14 chapters on subjects such as: estimating precision farming benefits, variety-performance testing with global positioning systems (GPS), drainage, soil fertility, yield monitoring and mapping, soil sampling, variable-rate technologies, Geographic Information Systems (GIS), and on-farm research. It also includes a glossary and reference information.

"This book won't make people experts in the new technology, but it will help them identify questions to ask in adapting to individual farm situations," explains Dr. Jess Lowenberg-DeBoer. He is Director of the Purdue Site-Specific Management Center and Coordinating Editor of the new publication. It was prepared in cooperation with CNH Global N.V., which manufactures Case IH and New Holland equipment.

Fifteen Purdue specialists wrote chapters or assisted with content of the book. They represent the School of Agriculture, Departments of Agricultural Economics, Agronomy, Agricultural and Biological Engineering, Botany and Plant Pathology, and the Purdue Agricultural Centers. In North America, about 30,000 producers currently use yield monitors and an increasing number use GPS.

Precision Farming Profitability can be purchased for $25.00 by calling the Purdue Media Distribution Center toll-free at (888) 398-4636 or by e-mail at Media-Order@ces.purdue.edu. A printable order form is available on the Purdue site-specific management website at http://www.purdue.edu/ssmc. BC

UTAH

Alfalfa Responses to Potassium on Low-Testing Soils

By R.T. Koenig, J.V. Barnhill, and J.A. Gale

A potassium (K) study conducted over two years produced increased alfalfa yield responses of 1.0 to 3.2 tons/A at application rates as high as 600 lb K_2O/A. A single application of 600 lb K_2O/A reduced yield at two of three sites, while split applications of 600 K_2O/A did not reduce yield. Results show that alfalfa may respond to high rates of K fertilizer on low K-testing soils and that very high rates of K are necessary to increase available soil K to adequate levels on low K-testing soils. Rates of potassium chloride fertilizer (KCl, 0-0-60) exceeding 400 lb K_2O/A should be split-applied to prevent yield reductions.

Alfalfa is an important forage and cash crop for producers in Utah and other western states. In the mid-1950s, Utah State University fertilizer guides declared no crop K deficiencies existed due to the high native levels of K in Utah soils and high K concentrations in many irrigation waters. Alfalfa yields at that time averaged less than 2 tons/A. Today, many growers are achieving irrigated alfalfa yields in excess of 8 tons/A. Since 1960, the incidences of low K-testing soils and alfalfa K deficiency symptoms have increased. Also, K fertilizer recommendations have failed to maintain adequate soil test K levels in many areas, likely due to the high K demand of productive alfalfa.

The main objective of this research was to determine alfalfa yield and soil test responses to high rates of K and, ultimately, to develop better K management recommendations for low K-testing soils.

Field Studies

Experiments were conducted at one location in 1999 and three locations in 2000 (**Table 1**). At the Cache county location in 1999, K fertilizer (KCl) was applied at rates of 0, 200, 400, and 600 lb K_2O/A in early April to established alfalfa. An additional treatment of 200 lb K_2O/A in April followed by 200 lb K_2O/A applied after the first and second cuttings (total of 600 lb K_2O/A) was also included.

At the Cache, Weber, and Sevier county locations in 2000, K was applied at rates of 0, 100, 200, 400, and 600 lb K_2O/A in early April to established stands. A split application treatment of 300 lb K_2O/A applied in early April followed by 300 lb K_2O/A applied after the first cutting was also included at each of these sites. Each experiment was a randomized complete block design with three to four replications. Yield and soil test K were measured at each location.

Results

Among sites and years, K responses ranged from 1.0 to 3.2 tons/A above the unfertilized treatments (**Figure 1**). Some yield depression was experienced at the 600 lb K_2O/A single application rate at the Cache and Weber locations. The split application resulted in significantly higher yields at both locations than the single application (**Figure 1**). Considering the current price of K fertilizer ($0.14/lb K_2O) and value of alfalfa hay ($80 to 100/ton), an application of at least 400 lb K_2O/A would be economical.

Apparently, the single application of

Incidences of K deficiency in alfalfa and low K-testing soils have increased in some areas. Alfalfa has a high requirement for K, which is removed in harvest.

KCl at 1,000 lb/A required to achieve the 600 lb K_2O/A rate caused a negative salt effect. Rates of KCl exceeding 400 lb K_2O/A should be split-applied to prevent yield reductions. Alternatively, applying high rates of a K fertilizer with a lower salt index such as potassium sulfate [K_2SO_4, 0-0-50-18 sulfur (S)] will likely prevent yield reductions.

The response to K was linear at the Sevier location, with little indication of a salt effect. The linear response to K at Sevier and the response to the split application at the Weber location indicate that the alfalfa at these two locations may have responded to additional K above the high 600 lb K_2O/A rate.

The application of 600 lb K_2O/A brought the soil test K levels up to an average of only 120 parts per million (ppm) at two of these sites, well below the critical level of 150 ppm used in current Utah State University fertilizer recommendations (**Figure 2**). Soil test K increased 1 ppm for each 5 lb K_2O/A applied at the Cache location and 1 ppm for each 12.5 lb K_2O/A applied at the Sevier and Weber locations. At this rate of change and considering the initial soil test K values (**Table 1**), 775 to 950 lb K_2O/A would be needed to bring the Weber and Sevier soils up to 150 ppm soil test K.

Research in Utah at these and previously studied sites shows a clear relationship between soil test K and relative yield (**Figure 3**).

Optimum soil test K levels were at or near the 105 ppm currently used in alfalfa fertilizer recommendations.

Summary

Alfalfa hay removes large quantities of K. In areas with a long history of high yielding alfalfa production, soil test K can be depleted to the point where relatively high

TABLE 1. Selected soil properties for the surface 12-in. soil layer at research locations.

	Cache county	Weber county	Sevier county
Texture class	Silt loam	Silty clay loam	Clay loam
% clay	25	28	29
% CCE[1]	37	0	54
pH	7.8	6.7	8.1
Soil test K[2], ppm	72	88	73

[1]Calcium carbonate equivalent
[2]Sodium bicarbonate extractable

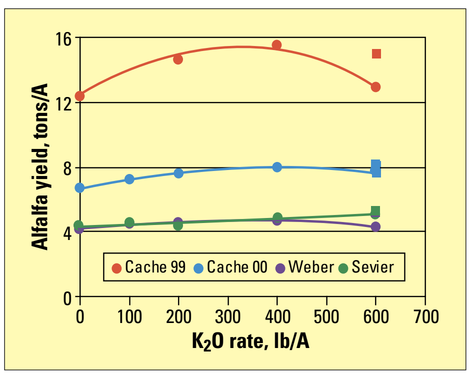

Figure 1. Effect of K fertilization on alfalfa yield at the Cache, Sevier, and Weber county locations.
(Circle symbols represent single application treatments, square symbols represent split application treatment).

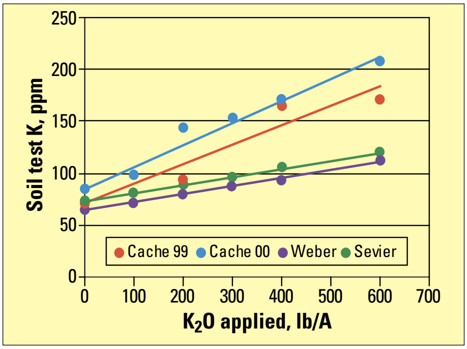

Figure 2. Effect of K fertilization on soil test K level at the Cache, Sevier, and Weber county locations.

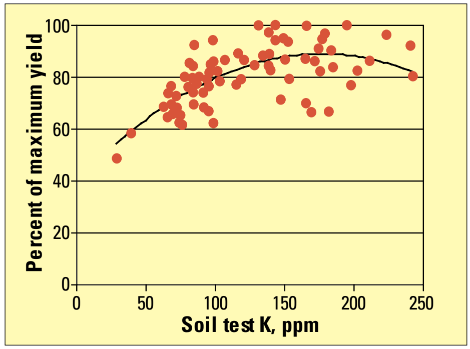

Figure 3. Relationship between soil test K (sodium bicarbonate extractable) and relative alfalfa yield.

rates of K are needed to rebuild soil tests.

Based on the results, the critical soil test K for alfalfa was not changed; however, K recommendations for very low and low soil test classes were increased by 50 to 100 lb K_2O/A. Increased emphasis is also being placed on annual soil testing for K and the importance of rebuilding and maintaining soil test levels in deficient areas. An electronic copy of the Utah State University fertilizer guide for alfalfa (AG-FG-01) can be found on the Internet at: http://extension.usu.edu/coop/ag/pub/index.htm. BC

Dr. Koenig is Associate Professor and Extension Soil Specialist, Utah State University (e-mail: richk@ext.usu.edu). Mr. Barnhill and Mr. Gale are Utah State University Extension County Agents.

Annual Statement of Ownership

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Donald L. Armstrong, Editor

SUMMARY UPDATE

Soil Test Levels in North America

By P.E. Fixen

The 2001 summary includes results of tests performed by 34 public and 31 private laboratories on approximately 2.5 million soil samples collected in the fall of 2000 and spring of 2001. Sample density was 166 acres per sample, but varied from a high of 22 for Georgia, New Hampshire and North Carolina to a low of nearly 3,000 for Wyoming. Soil test data are reported in two forms.

- Percent of samples analyzed that tested medium or below in P or K or had pH values less than or equal to 6.0. These are soil test categories where most agronomists would predict a significant yield response in the year of application to P, K or lime.
- Cumulative relative frequency across nine soil test ranges. This is the first time multiple ranges were requested from laboratories. As such, not all were able to provide data following this more intensive protocol.

> With the cooperation of numerous public and private soil testing laboratories, PPI periodically summarizes soil test levels for phosphorus (P), potassium (K), and pH in North America. This 2001 summary is the eighth completed by the Institute, with the first summary dating back to the late 1960s.

Great appreciation is extended to all the laboratories cooperating in the summary. They were asked to do considerably more work than in the past, resulting in what is likely the most comprehensive evaluation of the status of soil fertility in North America ever conducted.

Several weaknesses exist in the summary process:

- Quantity of samples was low in several states and provinces.
- It is possible that some samples originated out of the state or province

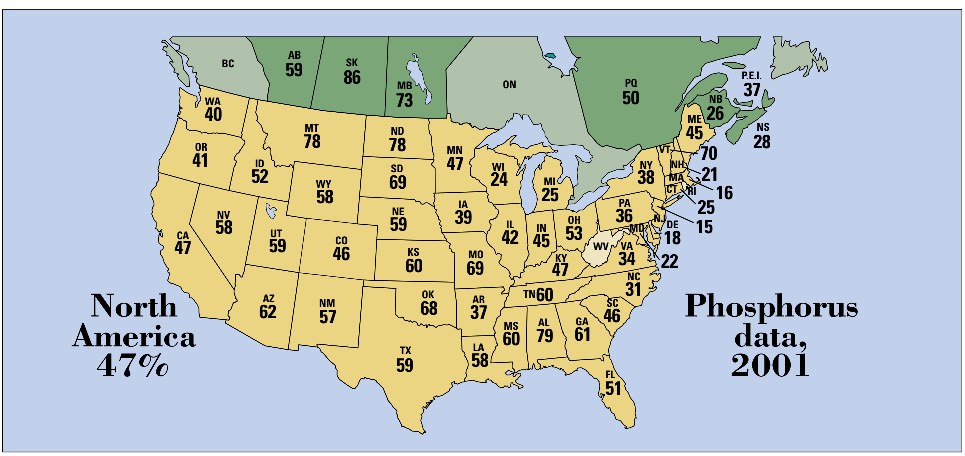

Figure 1. Percent of soils testing medium or lower in P.

indicated.

- Some areas of each state or province are likely under or over-represented.
- It is likely that the better managers soil test and that their soil tests are higher than the average.
- Home and garden samples sometimes could not be separated from agricultural samples. Since these average considerably higher in fertility than agricultural samples, they contribute to an upward bias.
- Although an attempt was made to define agronomic equivalency for each of the nine categories among the various soil test procedures, it is likely that error was introduced in this process.
- In many states and provinces, soil test K levels interpreted as medium will vary markedly depending on soil texture, soil mineralogy, physiographic region, and the crops to be grown.

These weaknesses need to be considered in interpreting and using the results of the summary.

There are many benefits of high P and K soil test levels. They are important in providing plants with needed nutrients to take advantage of optimum growing conditions and reduce the negative effects of stressful conditions. They provide protection against deficiencies induced by nutrient stratification in reduced tillage systems, plus offer more options in fertilizer placement, time of application, nutrient application rates, and frequency of soil sampling. High and very high field average soil test levels offer insurance against profit robbing deficiencies occurring in low testing parts of variable fields. Considering the very high frequency of extreme within field variability revealed by intensive sampling, this factor alone in many cases justifies building soil test levels to at least the high category.

Because of the factors discussed above, the categories of medium or below generally represent soils where current P and K use is barely adequate or inadequate...where increasing use above current levels will very likely increase long-term profitability by building soil fertility to optimum levels. At the same time, it is important to recognize that these nutrients should be protected from loss to avoid environmental degradation. This can be accomplished through proper management. It should not be assumed that because a soil area or field is high in fertility that it represents a threat to water quality or because it is low in fertility that it offers no threat to water quality. Management relative to watershed characteristics makes the difference.

Of the entire 2.5 million soil samples in this summary, 47 percent tested medium or below in P and 43 percent tested medium or below in K. As expected, considerable variation existed among states and provinces (**Figures 1** and **2**). The northern Great

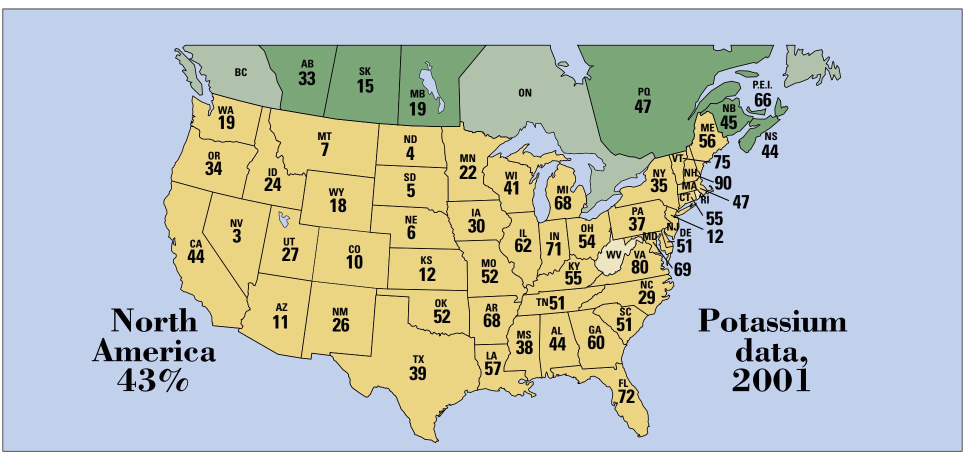

Figure 2. Percent of soils testing medium or lower in K.

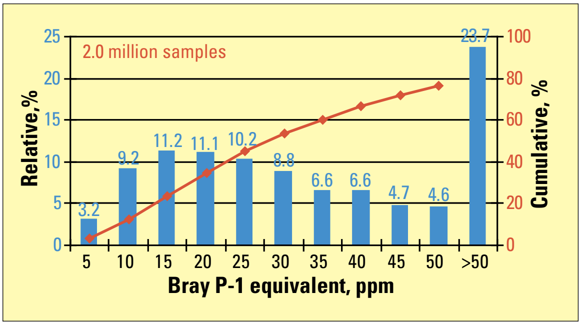

Figure 3. Soil test P frequency distribution for North America in 2001.

response.

Percent of soil samples testing 6.0 or below in pH for each state and province is shown in **Figure 5**. A pH of 6.0 was selected as a breaking point because soil pH above 6.0 is desirable for most cropping systems. Historically, soil pH values have tended to be more acid where rainfall is higher and where large amounts of vegetation have helped to acidify the soil. Those conditions have been associated with areas east of the Mississippi River in the U.S. and in the eastern Canadian provinces. But, continued research has revealed that soil acidity problems are not limited to those areas. The highest frequency of soil acidification continues to be found in the Southeast where in some states over 60 percent of the soils test below pH 6.0.

Plains had the highest frequency of medium or below P tests with values in the 60 to 90 percent range, while a few states in the Northeast dropped below 20 percent. Western states and provinces generally had fewer soils in the medium or below K categories than those in the East. The higher K levels of the West reflect the less weathered status of western soils. However, in states such as California where 44 percent of soils test medium or below in K, crop removal over several decades with limited nutrient addition has significantly reduced soil K levels.

Relative frequencies and cumulative relative frequencies for soil test P in North America are shown in **Figure 3**. Soil test P shows a skewed frequency distribution with a broad peak running from 5 to 30 parts per million (ppm) Bray P-1 equivalent and accounting for over 50 percent of the samples. Another 24 percent of the samples test greater than 50 ppm.

Relative frequencies and cumulative relative frequencies for soil test K in North America are shown in **Figure 4**. Over 50 percent of the soils in North America test below 160 ppm K, and over a third test between 120 and 200 ppm. This distribution is compelling evidence of the need for proper and regular soil testing to carefully monitor soil K status. Many soils test near or below what most calibration research indicates is a critical level for crop

Conclusions

Approximately 45 percent of soil samples are currently testing medium or below in P or K. Historical trends apparent from the eight soil test summaries now completed suggest that in many key agricultural states this percentage is increasing. For example, P soil fertility appears to be decreasing in the heart of the Corn Belt, and K levels appear to be in decline in the eastern states of the Corn Belt. These data are supported by nutrient budget estimates for the Corn Belt that show crop removal exceeding P and K application.

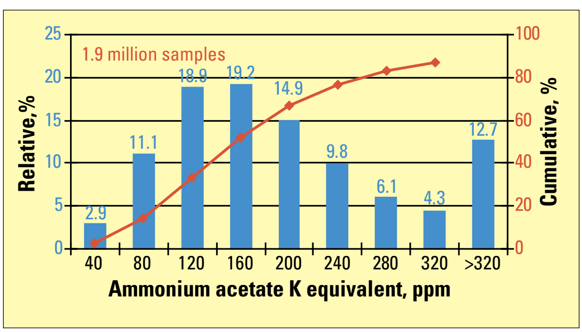

Figure 4. Soil test K frequency distribution for North America in 2001.

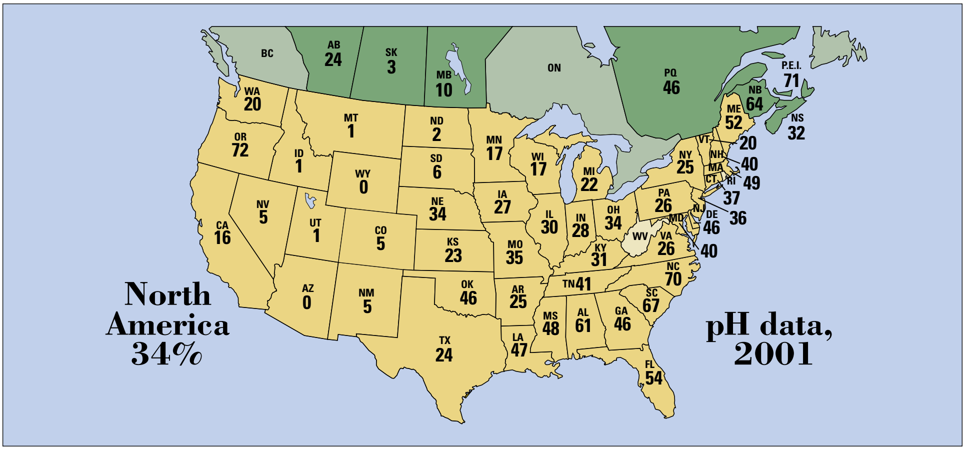

Figure 5. Percent of soils testing 6.0 pH or less.

The impact of manure production on regional soil test levels is apparent in this summary as it was in the 1997 summary. Generally, in regions where manure production is high relative to crop nutrient removal, a lower percentage of soils currently test medium or below in P, and percentages are trending even lower.

Results indicate the importance of regular soil testing because a large number of samples test in or near critical soil test ranges where nutrient recommendations vary greatly. These data also amplify the need for representative soil sampling.

Nutrient management should occur on a site-specific basis where the needs of individual fields, and in many cases areas within fields, are recognized. Therefore, a general soil test summary like this one has no value in on-farm nutrient management. Its value lies in calling attention to broad nutrient needs, in motivating educational and action programs, and in reminding farmers and their advisers of the importance of a soil testing program to monitor soil nutrient status.

More detailed information is included in Technical Bulletin 2001-1 and accompanying CD, available for purchase from PPI. Check the website at www.ppi-ppic.org or contact the Circulation Department, phone (770) 825-8082, fax (770) 448-0439. BC

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Correction to Data in Better Crops No. 4, 2001

A calculation error occurred in **Table 3** of the article "Spring Wheat Cultivar Response to Potassium Chloride Fertilization", which appeared on page 23 in *Better Crops with Plant Food*, No. 4, 2001. In the column listing mean yield response to chloride fertilizer for three years on fine sandy loam soil, the value for yield mean response should be 2.7 bu/A for the cultivar CDC Teal. The value is incorrectly shown as 8.0 bu/A. BC

K A N S A S

Nutrient Management for Cool Season Grasses

By Ray Lamond

Several million acres of introduced cool season grasses, primarily smooth bromegrass and tall fescue, are used for haying and grazing in Kansas and neighboring states. While these cool season grasses have great potential to produce large quantities of high quality forage, many stands are not managed to their full potential. In order to achieve optimum production from these grass pastures, fairly intensive management is required. A nutrient management program including application of nitrogen (N), phosphorus (P), potassium (K), and sulfur (S) should be considered for optimum production.

Cool season grasses can provide high quality forage from the fall into the spring months. Fertility can dramatically affect both forage yield and quality. Thirty-one site years of research in producer fields in Kansas has demonstrated the importance of adequate and balanced fertility on bromegrass yield and quality.

Soil test results from established cool season grass pastures in Kansas often show very low P and sometimes K levels, indicating that many producers employ an N-only management plan. Since these grasses remove 10 to 12 lb P_2O_5/A per ton of production, low soil test P levels are not unexpected where P has not been included in the nutrient management plan. In addition, since these grasses complete growth and development in the spring and fall when soil temperatures are cool, the need for S fertilization may be enhanced due to cooler soil temperatures and reduced mineralization release of S from organic matter. This research was conducted to evaluate N, P, and S fertilization of established smooth bromegrass in eastern Kansas.

All research sites were on producer-cooperator land that had been in bromegrass at least 15 years. Soil samples were taken at all sites at the time studies were established. All sites had organic matter levels in excess of 3 percent. Soil test P levels ranged from as low as 4 parts per million (ppm) Bray P-1 (very low), to as high as 15 ppm (medium). Fertilizer was applied surface broadcast in February. Either ammonium nitrate

TABLE 1. Forage yield and quality in bromegrass, 31 site-year average, 1994-2001.

Nutrient treatment $N-P_2O_5-S$,	Forage yield,	Yield increase due to fertilizer,	Forage[1] Protein	Forage[1] P	Forage[1] S
lb/A			%		
0-0-0	2,530	—	7.2	0.17	0.15
40-0-0	4,720	87	7.9	0.15	0.13
80-0-0	5,360	112	8.9	0.14	0.14
120-0-0	6,100	141	10.0	0.14	0.14
40-30-0	5,320	110	7.6	0.18	0.13
80-30-0	6,310	149	8.5	0.18	0.13
120-30-0	6,930	174	9.7	0.17	0.14
80-30-20	6,710	165	8.8	0.17	0.17

[1]Forage protein values are 15 site-year averages; P and S values are 11 site-year averages.

or urea was used as the N source, P was supplied as triple superphosphate, and S was supplied as ammonium sulfate. The studies were harvested in late May to early June.

Thirty-one site years of forage yield data are summarized in **Table 1** and **Figure 1**. The work was conducted from 1994 through 2001. Yields varied considerably from year to year and among sites due to environmental conditions. However, significant responses to N, P, and S fertilization were noted regardless of yield level.

This research clearly shows the importance of N fertilization in producing high yields of high quality forage. Nitrogen fertilization alone resulted in as much as a 141 percent increase in yield. It also resulted in an average 22 percent increase in forage protein. The data also illustrate the importance of including P in the overall nutrient management program for cool season grasses. Within each N treatment, P fertilizer increased yield. Increases due to P ranged from 13 to 18 percent. This demonstrates the importance of balanced fertilization in producing yield and maximizing N use efficiency.

The inclusion of 30 lb P_2O_5/A increased forage yields by 800 lb/A, or 15 percent, when averaged across 31 site years and all N rates. Assuming a P fertilizer price of $0.26 per pound of P_2O_5 and $70/ton hay price, the forage yield increase would generate an additional $28/A for a $7.80 investment. The addition of P also reduced competition from undesirable species (bromesedge, redtop, bluegrass) in the cool season grass stands.

Another interesting facet of this work was the response to S fertilizer. The addition of 20 lb S/A increased forage yields by 400

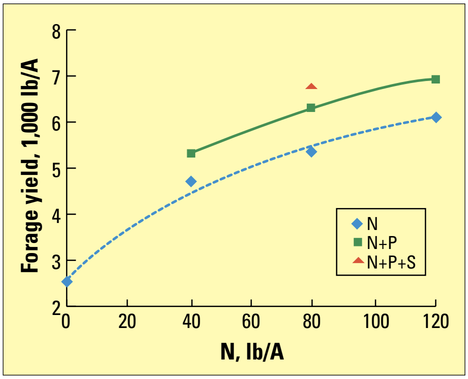

Figure 1. Effect of N, P, and S on bromegrass forage yield, 31 site-year average. Phosphorus applied at 30 lb P_2O_5/A and S at 20 lb/A.

lb/A, verifying earlier work in Kansas showing cool season grasses consistently respond to S fertilization. Our current recommendation is to apply 10 to 15 lb S/A on brome that is managed for optimum production, in spite of the fact that established stands often have organic matter levels in excess of 3 percent.

In summary, cool season grasses require intensive management for optimum production of high quality forage. This long-term research shows that adequate P and S should be included with N in the nutrient management program. BC

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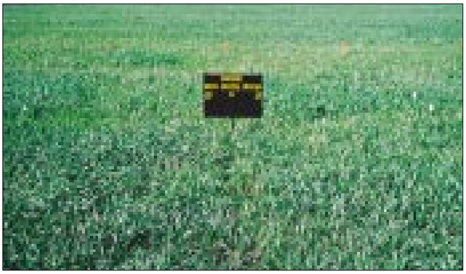
Bromegrass makes high quality pasture for beef cattle.



Bromegrass response to S is shown at left in this photo. The plot at right side received no S.

CALIFORNIA

Phosphorus and Potassium Nutrition of Pistachio Trees as Affected by Alternate-Bearing

By R.C. Rosecrance, S.A. Weinbaum, and P.H. Brown

The large amount of woody biomass of mature trees (branches, trunk, roots) makes it difficult to assess the magnitude and dynamics of nutrient uptake and over-winter storage. The situation is further complicated by alternate fruit bearing, because differential crop load influences the pattern of nutrient uptake and usage.

Pistachio trees are highly alternate bearing, with an on-year followed by an off-year. Heavy fruiting has been shown to depress root growth in many tree crops, but little is known about the relationship between root growth and nutrient uptake in mature trees. Many researchers have assumed that nutrient uptake and root growth are concurrent processes, with increased root growth resulting in greater nutrient uptake. This hypothesis, however, has not been adequately tested. An understanding of the effects of alternate nut bearing on nutrient uptake and root growth is a prerequisite to developing best management practices for pistachio fertilization.

Pistachio trees are highly alternate bearing, with a heavy cropping year (on-year) followed by a light cropping year (off-year). Uptake and partitioning of phosphorus (P) and potassium (K) among tree parts were determined during nut fill (late May to early September). Although root growth was reduced during nut fill in on-year trees compared with off-year trees, there was no relationship between root growth and the uptake of P or K from the soil. This indicates that sink (nut) demand rather than root growth regulates the uptake of P and K.

An experiment was conducted to evaluate the effects of alternate bearing on root growth and P and K nutrition of pistachios in the San Joaquin Valley of California. On-year trees yielded approximately 2,400 lb/A, while off-year yields were 800 lb/A.

Root Growth

Roots from 12 trees were counted every two weeks between fruit set and leaf senescence (April 15 to November 15). Root growth was determined by counting white (actively growing) roots growing up against root observation boxes installed in the herbicide strip in the microjet spray zone.

Root growth varied seasonally and was influenced by alternate bearing (**Figure 1**). On-year trees initiated root growth earlier in the spring than off-year trees and produced three times more roots during spring flush than off-year trees, measured three weeks following anthesis (April 22). On-year trees, however, produced significantly fewer white roots during nut growth (June 16) compared with off-year trees. During nut growth and development, root growth rates and elongation were significantly depressed in on-year vs. off-year trees (data not shown). This research supports previous studies with other fruit tree species that heavy fruiting reduces root growth.

Nutrient Uptake

To assess the effects of alternate bearing on P and K uptake in pistachio trees, six trees (three on-year and three off-year) were excavated following spring growth flush

(May 24), and another six were excavated following nut fill (September 8). The trees were separated into various fractions (leaves, fruit, trunk, branches, and roots) and were weighed and analyzed for P and K. Total annual P and K uptake was determined by the difference in the total tree P and K contents between the September and May tree excavations dates.

Root observation boxes among pistachio trees allowed counting of actively growing roots from April to November. However, researchers found no relationship between root growth and uptake of P and K from the soil.

Heavy cropping increased nutrient uptake, particularly in the case of K (**Figure 2**) compared to the alternate light crop. Pistachio trees took up over 200 lb K_2O/A during the on-year as compared to only 70 lb during the off-year...about three times more. Fourteen percent more P was taken up in on-year vs. off-year trees. The large increase in K uptake may reflect the role it plays in sugar transport which includes: 1) binding to carboxylates and transport (mainly as K_2-malate) in the phloem to fruits and roots and 2) acting as an osmoticum to develop pressure gradients in the phloem for the transport and storage of sugars.

The increase in P and K uptake occurred despite the fact that root growth was significantly reduced in on-year vs. off-year trees. On-year trees had four times fewer white roots growing against the root boxes during the nut fill period than off-year trees, yet K uptake was triple in the on-year trees. For the decoupling between root growth and nutrient uptake to occur, the rate of nutrient uptake per unit of root length in fruiting trees must be higher than that of non-fruiting trees. Simulation models have shown that doubling root uptake kinetics (activity) is as effective as doubling root growth in increasing nutrient uptake. Thus, increases in the rate of nutrient uptake by roots can compensate for a lack of root growth.

(continued on page 22)

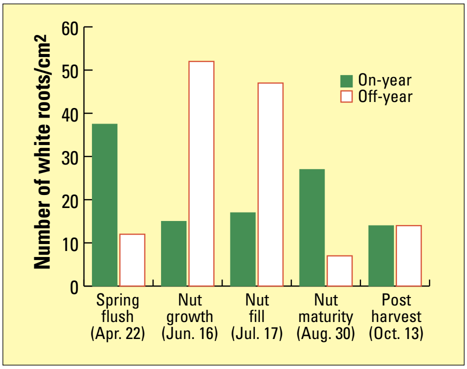


Figure 1. Effects of alternate-bearing on the number of observed white roots during the various growth phases.

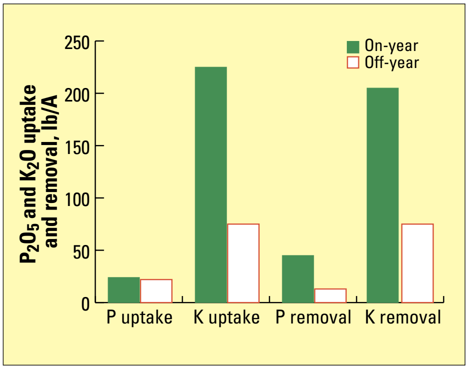


Figure 2. Uptake of P and K during the nut fill period (May 24 to September 8) and removal of P and K in nuts and abscised leaves in on-year and off-year trees.

A L B E R T A

Weeds Dine Out on Nitrogen and Phosphorus

By Robert E. Blackshaw, Randall N. Brandt, and H. Henry Janzen

Cultural weed control methods are becoming more important where efficacious herbicides are limited or herbicide resistance has become prevalent. Manipulating crop fertilization may be one method of reducing weed interference in crops. Nitrogen (N) fertilizer can break seed dormancy of certain weed species and thus may directly affect weed infestation densities. Added N can markedly alter crop-weed competitive interactions. Depending on the species and density, N fertilizer can increase the competitive ability of weeds more than that of the crop.

> Weeds, like crops, respond positively to increased soil fertility. In fact, a number of common weed species show a greater response to fertilization than spring wheat or canola.

Research indicates that fertilizer placement can alter weed competition with crops. Nitrogen fertilizer placement in narrow in-soil bands has been found to reduce the competitive ability of downy brome (*Bromus tectorum*), foxtail barley (*Hordeum jubatum*), and wild oat (*Avena fatua*) more than surface broadcast. However results vary, and other studies report that N placement had little effect on the competitive ability of downy brome or green foxtail (*Setaria viridis*). Despite extensive knowledge of how crops respond to soil fertility, little information is available on how weeds respond to fertility levels. Since N and phosphorus (P) are the major nutrients applied to crops in western Canada, we conducted a study to determine the growth response of common weed species to increasing amounts of N and P.

Weed and crop species were grown in a nutrient deficient sandy loam soil (less than 15 lb/A of available N and P) under controlled conditions in a greenhouse. Twenty-three weed species were evaluated, but only data on green foxtail, wild oat, Russian thistle (*Salsola iberica*), stork's-bill (*Erodium cicutarium*), cleavers (*Galium aparine*), redroot pigweed (*Amaranthus retroflexus*), wild mustard (*Sinapis arvensis*), kochia (*Kochia scoparia*), round-leaved mallow (*Malva pusilla*), and wild buckwheat (*Polygonum convovulus*) are presented. The crops grown were spring wheat (*Triticum aestivum*) and canola (*Brassica napus*). Five plants of each

Response of hairy nightshade to increasing soil P levels is shown in this greenhouse photo. Rates are equivalent to parts per million (ppm).

species were grown in 6-in. diameter pots. Nutrients were applied at rates approximating field rates. Nitrogen was applied as ammonium nitrate (NH_4NO_3) and P as potassium phosphate (K_2HPO_4). All treatments were replicated four times. Other nutrients were maintained at levels adequate for healthy plant growth, using potassium sulfate (K_2SO_4). Shoot dry weights of each species were determined after six weeks of growth. Separate experiments were conducted for each nutrient, and the study was repeated.

TABLE 1. Shoot biomass response to increasing amounts of N taken six weeks after emergence.

Species	Nitrogen, ppm				
	40	80	120	180	240
	% of biomass at 0 N rate				
Wheat	243	332	330	339	370
Canola	214	320	378	440	474
Russian thistle	141	182	165	149	158
Stork's-bill	232	314	336	347	350
Cleavers	265	368	390	368	371
Wild oats	349	456	413	466	456
Redroot pigweed	290	407	610	662	692
Wild mustard	317	517	644	733	800

TABLE 2. Shoot biomass response to increasing amounts of P taken six weeks after emergence.

Species	Phosphorus, ppm				
	5	10	20	40	60
	% of biomass at 0 P rate				
Wheat	169	234	261	293	308
Canola	177	240	285	311	348
Kochia	185	218	232	229	273
Wild oats	310	480	608	536	550
Green foxtail	433	570	717	977	820
Round-leaved mallow	279	472	580	674	624
Wild buckwheat	383	561	651	782	796
Stork's-bill	452	690	784	949	950

In this nutrient deficient soil, wheat and canola shoot biomass increased markedly (300 to 400 percent) to added N and P (**Tables 1** and **2**). Weed biomass also increased with added N and P, although the magnitude of the biomass increases varied considerably among the weed species.

Russian thistle biomass responded less than wheat or canola to added N (**Table 1**). The growth responses of stork's-bill, cleavers, and wild oats were of similar magnitude to those of the two crops. However, redroot pigweed and wild mustard biomass responded more to added N than either crop.

Kochia was one of the few species that responded less than wheat or canola to added P (**Table 2**). Wild buckwheat, green foxtail, and stork's-bill growth increased up to three-fold more than either canola or wheat, indicating the importance of P nutrition to the growth and competitive ability of many weed species.

It has often been reported that weeds thrive on soils with low fertility. Our study indicates that this is likely not the case. In fact many of the common agricultural weeds found in western Canada benefit from efforts to improve soil fertility. The biomass of many weed species increased considerably more than wheat or canola to added N or P.

This study also revealed that weed species varied tremendously in their response to added nutrients. Some species exhibited a strong growth response to either N or P, while others responded strongly to both nutrients. Surprisingly, biomass of many weeds increased more with added P than with added N.

One of the questions we wanted to answer with this study was if certain weed species were in fact luxury consumers of either N or P. At the highest N rate, Russian thistle biomass increased only one and a half-fold, but its shoot N concentration increased three-fold (data not shown). Growing in the field, Russian thistle would reduce N available to the crop by more than might be predicted from its growth response alone.

Fertilizer is a major cost to crop production. Efficient utilization of fertilizer nutrients requires reducing losses to the environment and to weeds. Weeds, like crops, respond positively to increased soil fertility. In a worst-case scenario, crop yields may actually decrease as fertilizer rates increase if weeds have access to the added fertility.

Further research will be conducted to develop agronomic practices that simultaneously reduce weed populations and result in optimal crop yields. A greater understanding of how N and P placement affects crop-weed competition should lead to a clearer interpretation of why differences occurred among previous studies. In addition, it could lead to the development of fertilization strategies, such as timing and placement of nutrients, that reduce weed interference with crops. BC

Dr. Blackshaw (e-mail: blackshaw@em.agr.ca) is a Weed Scientist, Mr. Brandt a Research Technician, and Dr. Janzen a Soil Scientist at the Agriculture and Agri-Food Canada Research Centre in Lethbridge, Alberta, Canada.

*P and K Nutrition of Pistachio Trees...**(continued from page 19)*

Nutrient Removal

Almost all of the K taken up by the on-year trees was subsequently removed in fruit and abscised leaves during late summer and fall (**Figure 2**). This indicates that little K was stored over winter and that substantial quantities of K must be present in the soil during heavy cropping years to avoid K deficiency. In contrast, P removal was double that of P uptake during the on-year, indicating that much of the P demand was met by redistribution from storage. Phosphorus, therefore, can be stored in perennial tree parts and used the following year, but little K appears to be stored and used in the subsequent year.

The pronounced effect of alternate fruit bearing on tree P and K demand and capacity for uptake has important implications for fertilizer management. The greatest amount of soil P and K uptake occurred during the nut fill period in on-year trees. Thus, P and K must be available in the soil at this time. How much P and K to apply, however, depends on management considerations such as method of application, soil test values, and tree density, as well as tree physiological considerations such as nutrient status and potential crop yield.

Summary

We examined interrelationships among crop load, P and K uptake, and root growth in mature pistachio trees that characteristically bear heavy (on-year) nut crops in alternate years. Uptake and partitioning of P and K among tree parts were determined during nut fill (late May to early September). Although root growth was reduced during nut fill in on-year trees compared with off-year trees, there was no relationship between root growth and the uptake of P or K from the soil. Our data support the hypothesis that sink demand rather than root growth regulates the uptake of P and K in pistachio trees. BC

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Terry L. Roberts Honored with ASA Fellow Award

Dr. Terry L. Roberts, PPIC Vice President, Latin America Programs, and President, Foundation for Agronomic Research (FAR), was recognized as a Fellow of the American Society of Agronomy (ASA) at the recent annual meeting of the organization. The Society has been electing outstanding members to the position of Fellow since 1924.

Dr. Roberts joined the staff of PPI in 1989 as Western Canada Director and was located in Coaldale, Alberta and Saskatoon, Saskatchewan, before moving to PPI headquarters in 1999. A native of southern Alberta, Dr. Roberts grew up in a family owned and operated retail fertilizer business. He earned his B.S.A. (crop science) at the University of Saskatchewan, then went on to complete his Ph.D. (soil fertility) degree there in 1985. Before joining PPI, Dr. Roberts worked as a contract scientist and project leader with Agriculture and Agri-Food Canada in Alberta and previously with Alberta Environment/Soil Protection Branch.

A.E. Ludwick Receives Soil Science Professional Service Award

Dr. Albert E. Ludwick, PPI Western Director, received the Soil Science Professional Service Award at the recent annual meeting of the Soil Science Society of America (SSSA). The award recognizes productive, competent individuals known for original and significant research and for an outstanding ability to inspire the qualities of sound thinking, objectivity, integrity, and cooperativeness in students and others with whom they associate.

Before joining the staff of PPI in 1980, Dr. Ludwick was Professor in the Agronomy Department at Colorado State University and served in Brazil with the USAID-sponsored University of Wisconsin Agricultural Development Team. He earned his B.S. degree at California Polytechnic State University and his M.S. and Ph.D. degrees from the University of Wisconsin. Dr. Ludwick served as President of the California Chapter of the American Society of Agronomy (ASA) and chaired the State Board of the Certified Crop Adviser program. He is Fellow in ASA.

B.C. Darst Recognized with Agronomic Service Award

Dr. B.C. Darst, Executive Vice President of PPI, was named the recipient of the Agronomic Service Award of ASA recently. The award recognizes productive, capable individuals for original and significant research and for an outstanding ability to inspire in others the qualities of sound thinking, objectivity, integrity, and cooperativeness.

After earning his B.S. degree at Oklahoma State University, Dr. Darst completed his M.S. and Ph.D. degrees at Auburn University. He designed, built and managed the world's first automated, computerized high volume soil testing laboratory while employed with Custom Farm Service, Inc. In 1978, Dr. Darst wrote the PPI *Soil Fertility Manual*, which has been revised and reprinted numerous times and translated to several foreign languages. He joined the PPI staff in 1973 as Southwest Director and was elected Executive Vice president in 1992. He is Fellow in both ASA and SSSA.

SOIL TESTING

When soil testing was introduced during the first half of last century, it brought with it considerable controversy. Certain university administrators looked upon it with a jaundiced eye. A few even referred to it as black magic and wouldn't allow it to damage the reputation of the local Cooperative Extension Service by banning it from campus, so to speak. There have been and probably always will be detractors.

Serious rifts between public and private soil testers have surfaced from time to time. Most disagreements grew out of conflicting philosophies which influenced the way results were interpreted (or manipulated). I suspect a few differences of opinion still exist. People seldom look at the same information and come up with like answers. Some have misused soil testing. Others never appreciated its true value. The concept caught on, however, and continues to be a valuable tool in nutrient management.

Back in 1967, the soil testing laboratory I helped to design, build and then manage was going full force. It was automated and computerized, with the capability to accurately analyze up to 4,000 samples per day. New-age printers spat out recommendations for fertilizer, lime, pesticides, and corn hybrids. Big Blue offered one or more of nearly 70 additional observations and bits of advice pertinent to the information submitted with each soil sample. It was all cutting-edge stuff. Current technology is eons ahead of those days.

The problem back in the 1960s was that we didn't always get good samples. Even though I am no longer actively involved in soil testing, people tell me that sampling is still the weak link, whether an acre grid or a sample per 40-acre field is used to interpret laboratory results. I can't refute that claim, but believe, and always have, that the real weaknesses in soil testing are improper use of test results and apathy.

The Institute has just completed a survey of about 2.5 million soil samples taken for the 2001 growing season in North America. Nearly half of them tested medium or lower in phosphorus (P) and potassium (K). That means that a majority of the farmers involved in the survey could be losing yields and profits from too little fertilizer and/or inadequate soil fertility. At the same time, I'm sure some are over fertilizing, either because they don't bother to test their soils or fail to correctly adjust recommendations when they do. Too little or too much fertilizer can be a negative for the environment and cut nutrient use efficiency.

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