IPNI INSIGHTS
International Plant Nutrition Institute

September 2012

Capturing Residual Soil Nitrogen with Winter Cereal Cover Crops

The enduring and widespread drought this summer has resulted in reduced crop growth, poor yields, crop failures, and anticipated increases in residual nitrate-nitrogen (RSN) in the soil profile. When no nitrogen (N) is applied to productive Midwestern soils that have subsurface or tile-drains, nitrate-N losses commonly range from 8 to 20 lbs/A with nitrate-N concentrations in the drainage of 3 to 10 mg/L or ppm. Corresponding nitrate-N losses from recommended fertilization rates are often between 25 to 50 lbs N/A and 10 to 30 ppm (Sawyer and Randall, 2008). Many are asking if winter cereal cover crops (cereal rye, wheat, oats, or annual ryegrass) could help capture the RSN this fall and early winter, help prevent leaching and subsurface/tile drainage losses, and return some of that recovered N during the growing season of the crop planted next spring.

To help answer some of these cover crop N retention questions, we have referred to several important publications in preparing the information presented in this brief. Those review papers and book chapters (e.g. Kaspar et al., 2008; Dabney et al., 2010) and other cover crop management resources are shown in the reference list at the end of this brief. We will only use selected highlights, because the effects of cover crops on N in cropping system productivity and on environmental impacts have been reviewed by others.

We will consider two general approaches for managing RSN after a drought. The first is to use a cover crop and the second is to monitor RSN and adjust N addition.

To understand the potential to capture RSN following a drought in soils supporting either continuous corn, or corn-soybean systems, it is helpful to look back and consider observations from scientists who experienced the last major drought in 1988. The approach of using a cereal rye cover crop in the 1988 drought has been reported from Maryland by Brinsfield and Staver (1991), and the approach of monitoring and adjusting N additions has been reported from southwestern Minnesota by Randall et al. (1997).

Like much of the rest of the nation in the 1988 drought, Maryland's corn suffered, achieving only 50% of normal yields as a result of rainfall which was 48% below normal from the late-vegetative through early-grain fill period. Fortunately, an existing long-term study was underway in small watersheds in the Atlantic Coastal Plain (Brinsfield and Staver, 1991; Staver and Brinsfield, 1998), which provided data to compare the ability of a cereal rye cover crop versus no winter cover crop to capture RSN. The study used a continuous corn system receiving 140 lbs of fertilizer UAN-N/yr, with the cereal rye planted on October 1 of 1988, about two weeks before the average frost date. Soil samples were collected in 6-inch increments to a depth of five feet on November 1 and again on December 1, 1988, and analyzed for nitrate-N. Total above-ground rye samples were also collected and analyzed for total N. **Figure 1** summarizes these data and shows that the soil contained 191 lbs of RSN/A in the no cover crop treatment, while the soil under the rye cover crop contained 34 lbs/A less on November 1, 1988, which is consistent with the measured rye N uptake of 39 lbs of N/A on November 1. Most of this N came from the surface six inches of soil. A month later (December 1), the soil without a cereal rye cover crop had not lost any RSN (although the nitrate-N had moved deeper in the soil profile), but the rye cover crop had taken up 75 lbs of N/A, with most of that N absorbed from the surface two feet of the soil (**Figure 1**). These data clearly show the ability of a simple cereal rye cover crop to convert mobile soil nitrate-N into immobile plant protein and thereby sequester RSN within the soil N cycle.

The ability of a cereal rye cover crop to prevent nitrate-N leaching in a corn-soybean system was also shown in a study using large replicated plots on a subsurface-drained field (tile at 4 feet) in Iowa, which contained Canisteo and Nicol-

Dr. Clifford S. Snyder
Nitrogen Program Director
International Plant Nutrition Institute (IPNI)
P.O. Box 10509
Conway, AR 72034
Phone (501) 336-8110
E-mail: csnyder@ipni.net
Website: http://www.ipni.net

Dr. J.J. Meisinger
Soil Scientist
USDA ARS
Beltsville, MD
E-mail: john.meisinger@ars.usda.gov

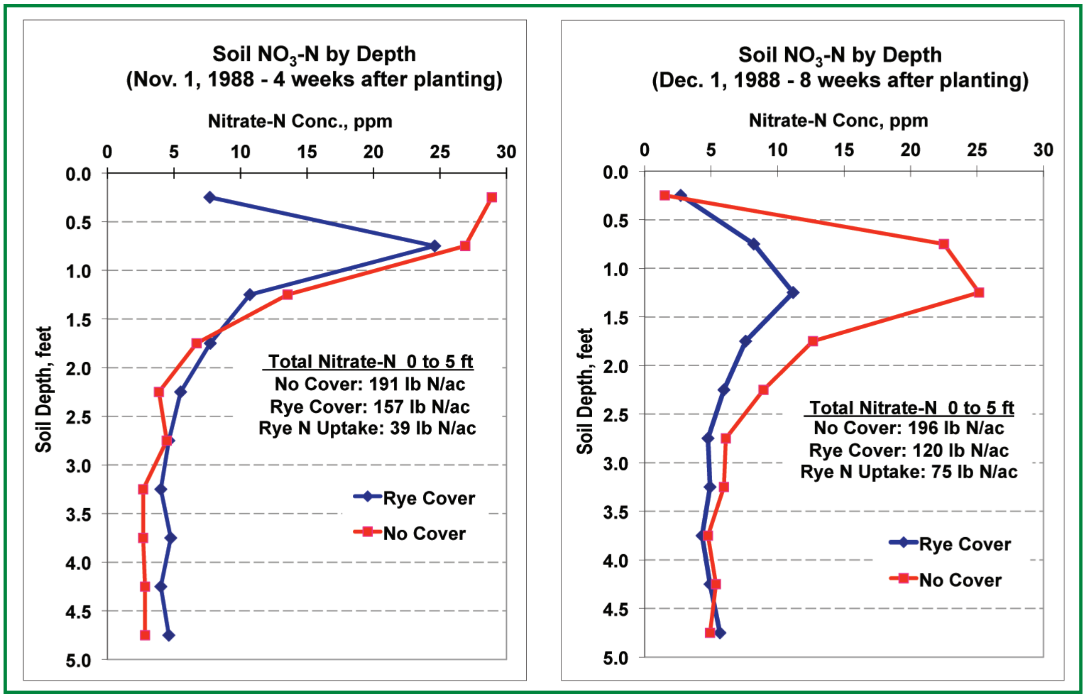


Figure 1. Fall soil profile nitrate-N at two dates following the growing season drought of 1988 in a continuous corn system, with and without a cereal rye cover crop in Maryland (adapted from Brinsfield and Staver, 1991; Staver and Brinsfield, 1998).

let soils (Kaspar et al., 2007). The goal was to evaluate the effects of a rye cover crop versus no cover crop on RSN, and on tile drainage nitrate-N concentration and load over four years. Rye was planted annually after the corn and the soybean harvest. Crop yields and rye N uptake were measured, tile drainage was continuously monitored and analyzed for nitrate-N, and soil samples were collected in early to mid-November each year to a depth of four feet and analyzed for nitrate-N. The data from this Iowa study are summarized in **Figure 2**. The rye cover crop was an effective scavenger of the RSN (**Figure 2a**), even though none of the years was a significant drought year. The low rye N uptake in 2003 was due to a poor aerially seeded stand that germinated in the midst of a warm-dry fall, causing seedling mortality. The rye cover crop took up considerable N, which resulted in lower nitrate-N concentrations (**Figure 2b**) and lower tile drainage nitrate-N loads compared to no cover crop (**Figure 2c**). The ability of a well-established rye cover crop to scavenge and take up N in amounts within the common range of RSN in this Iowa study (**Figure 2a**), illustrates the flexibility of this cover crop to conserve RSN and the potential to help protect water quality with grass cover crops.

Managing residual soil N after a drought by monitoring and adjusting fertilizer N

In a southwestern Minnesota study, Randall et al. (1997) measured: soil profile RSN (spring and fall), crop yields (see corn yields in **Figure 3a**), total above-ground N uptake, and nitrate-N losses to tile drainage in continuous corn and corn-soybean systems. Their measurements occurred between 1988 and 1993, and included drought years 1988 and 1989, which received 64 and 73% of long-term normal rainfall during the growing season, respectively. In 1990, the growing season rainfall was normal (approx. 21 inches), while subsequent years experienced above-normal rainfall during the growing season. The annual N application rates for corn followed the University of Minnesota Extension recommendations at the time, and were adjusted in consideration of: the nitrate-N content in soil samples taken from 0 to 48 inches in April, the previous crop (corn or soybean), moldboard plow primary tillage, and a yield goal of 140 bu/A (Randall et al., 1997). The fertilizer N source was urea, broadcast each spring and incorporated within 24 hours by tillage. Corn yields and total N uptake were significantly reduced by drought in 1988, with increased yields in the subsequent two years, and more typical yields and N uptake in 1991 and 1992 (**Figure 3a**). Significant RSN was observed in the soil profile beginning in the fall (measured in late October) of 1989, the spring of 1990, and continuing into the spring of 1991 (**Figure 3b**). This significant rise in RSN after drought is especially noteworthy, since only 50 lbs of N/A had been applied to corn plots in the study area from 1980 to 1987, in order to reduce the effects of residual nitrate-N and residual organic-N from prior studies before these studies began in the spring of 1988.

In this southwest Minnesota study (Randall et al., 1997), higher RSN levels in the upper 48 to 60 inches of the soil in the fall of 1989 and the spring and fall of 1990 (**Figure 3b**) were generally reflective of the lower total above-ground N uptake in the cropping systems in 1988 and 1989 (**Figure 3a**), but did not result in increased nitrate-N loss to tile drainage until 1991 (**Figure 3c**) because the drought stopped tile drainage. The magnitude of this RSN following 1988 is striking, but in agreement with the yield and N uptake data shown in **Figure 3a**. It is important to note again that spring RSN levels were used to downward adjust spring fertilizer N rates in this Minnesota study (**Figure 3c**), which illustrates the second approach that farmers and their crop advisers can use to reduce the risks of inefficient N utilization and N loss to water resources.

According to Randall and Mulla (2001), *"Noncontrollable factors such as climate and soil organic matter have a profound influence on nitrate-N concentrations and loadings in subsurface drainage water. The dynamics of N behavior in drained agricultural soils during these periodic climatic events and the management of both crops and nutrient inputs (controllable factors) must be considered carefully by agriculturalists as they manage the land. Furthermore, these factors must be understood by scientists and policymakers as they educate the public and develop environmental guidelines regarding nitrate loading to surface waters."*

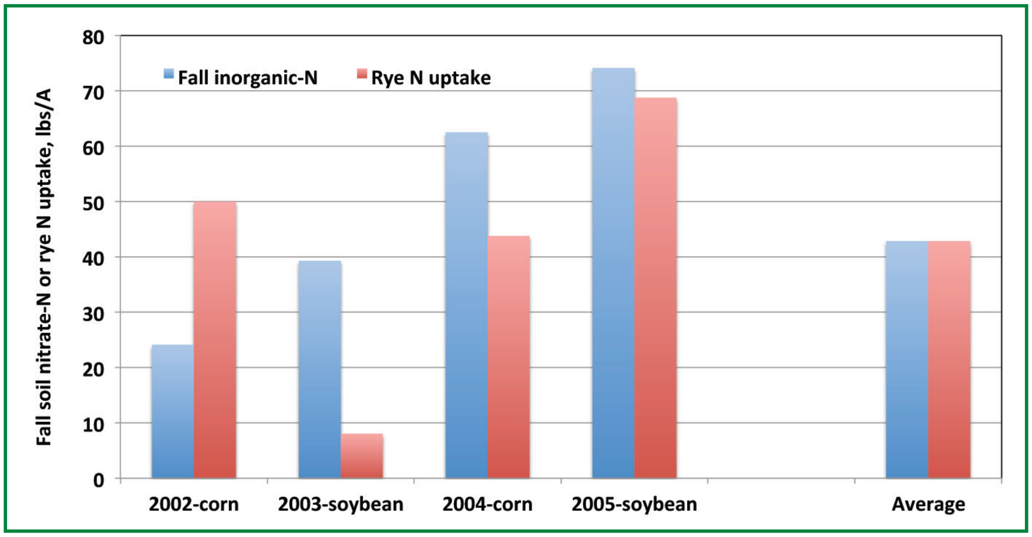


Figure 2a. Effects of a cereal rye cover crop on fall soil N and rye N uptake in corn-soybean production systems in Iowa (Kaspar et al, 2007).

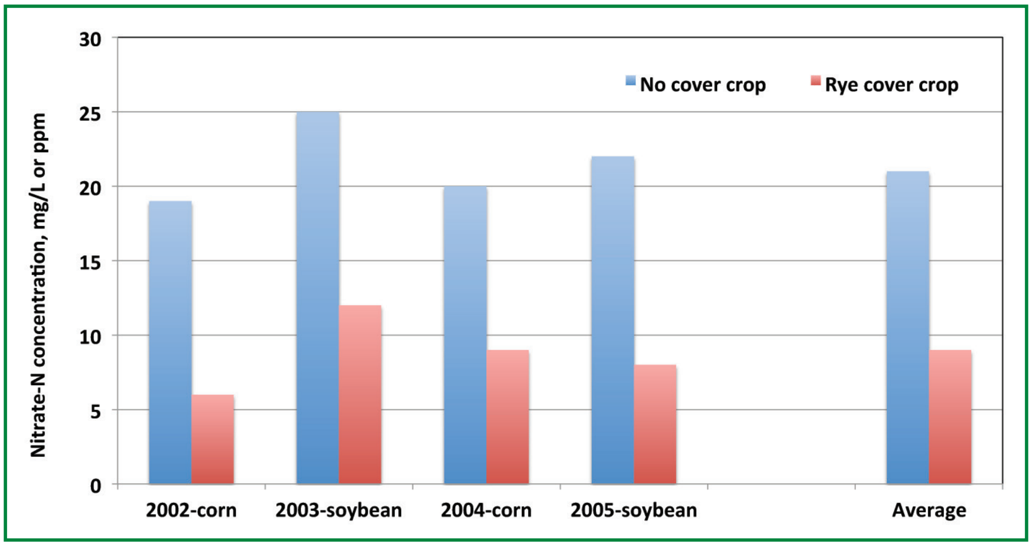


Figure 2b. Effects of a cereal rye cover crop on subsurface tile drainage nitrate-N concentrations in corn-soybean production systems in Iowa (Kaspar et al, 2007).

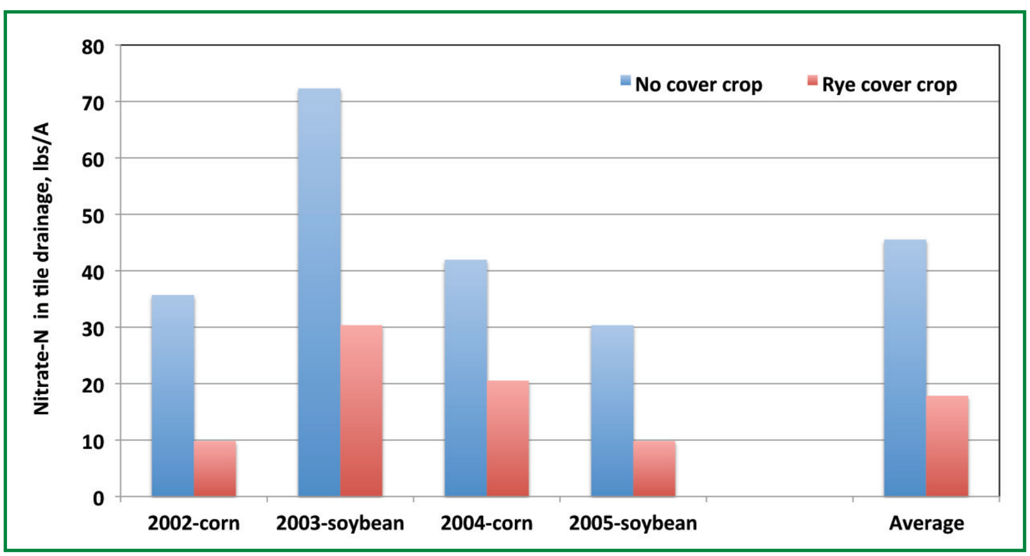


Figure 2c. Effects of a cereal rye cover crop on nitrate-N loads in corn-soybean production systems in Iowa (Kaspar et al, 2007).

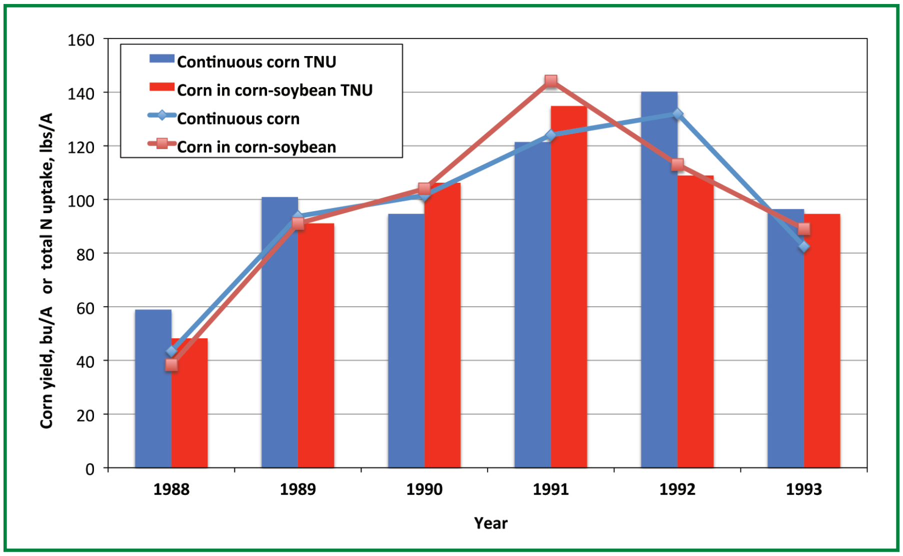


Figure 3a. Effects of the 1988 and 1989 drought years on corn yields and total N uptake (TNU) in southwestern Minnesota (Randall et al., 1997). Note: spring nitrate-N samples were collected in April at 0 to 60 inches and fall samples were collected in October at 0 to 48 inches.

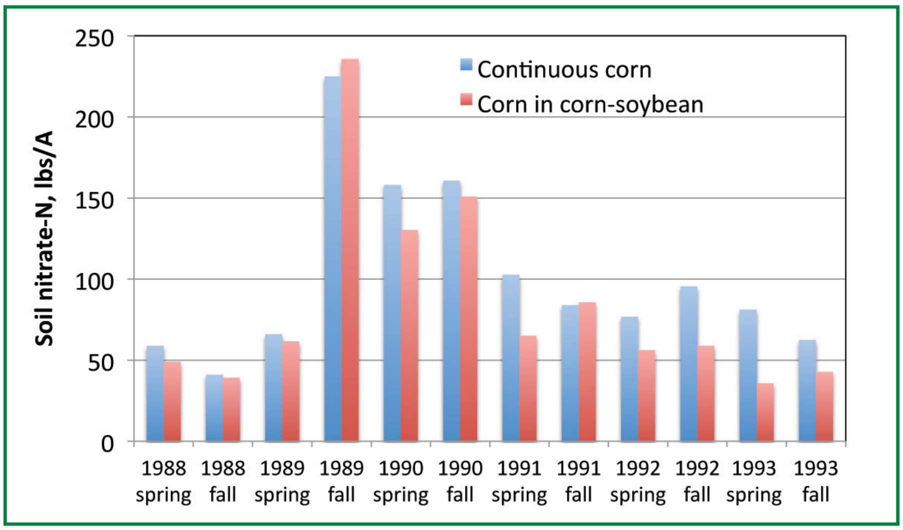


Figure 3b. Effects of the 1988 and 1989 drought years on fall and spring soil nitrate-N in the root zone in southwestern Minnesota (Randall et al., 1997). Note: spring nitrate-N samples were collected in April at 0 to 60 inches and fall samples were collected in October at 0 to 48 inches.

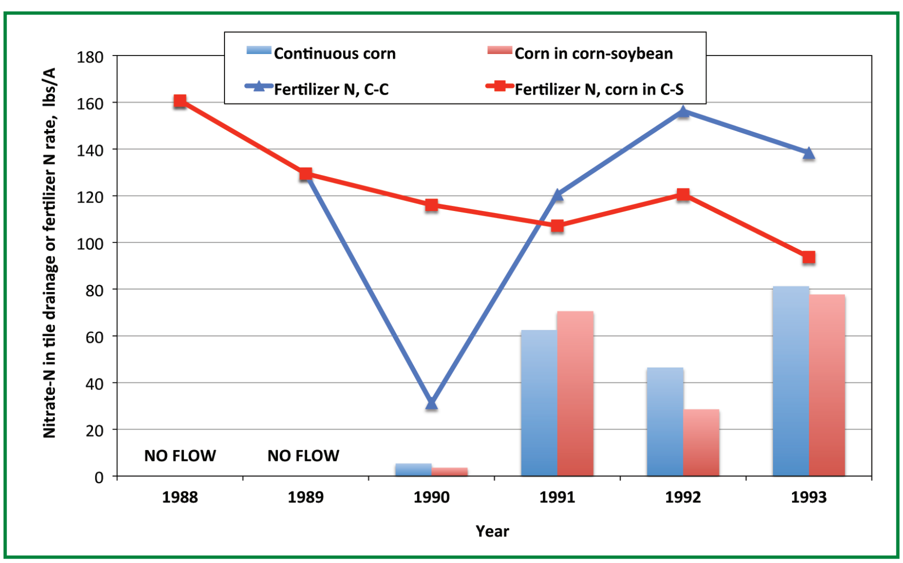


Figure 3c. Effects of the 1988 and 1989 drought years on tile drainage nitrate-N losses and adjustments to fertilizer N applied to continuous corn and corn in corn-soybean production systems in southwestern Minnesota (Randall et al., 1997).

Broad geographic potential to reduce soil N loss with winter grass cover crops

Cereal cover crops hold significant potential for reducing RSN leaching and drainage losses, with reductions often ranging above 60% (Kaspar et al., 2008), depending on the location, cropping system, amount of cover crop growth, and environmental conditions (**Table 1**). Additionally, winter cereal cover crops help reduce surface runoff loss of phosphorus (P), with reductions in loss ranging from 54 to 92% in several studies (Kaspar et al., 2008).

Table 1. Percent reduction in nitrate-N leaching losses with grass winter cover crops (adapted from Kaspar et al., 2008, including citations in Meisinger et al., 1991).

Location of cited study, (year published)	Cover crop	Reduction in nitrate-N leaching, %
California, U.S. (1996)	Rye	65 to 70
Connecticut, U.S. (1942)	Rye	66
Delaware, U.S. (1998)	Rye	30
Denmark (1985)	Ryegrass	62
France (1990)	Ryegrass	63
Indiana, U.S. (2004)	Winter wheat and less fertilizer	61
Iowa, U.S. (2007)	Rye	61
Kentucky, U.S. (1950)	Rye	74
Kentucky, U.S. (1994)	Rye	94
Maryland, U.S. (1990)	Rye	77
Minnesota, U.S. (2004)	Rye	13
Oregon, U.S. (1997)	Rye	32 to 42

Research has also shown that annual ryegrass is often superior to annual winter cereal grasses (oats, wheat, rye) in scavenging soil N. But any grass cover crop raises spring management challenges with termination of growth and risks of potential soil moisture deficits for the targeted cash crop. Conversely, in wet springs, grass cover crops may provide beneficial moisture draw-down and facilitate timely spring planting. Successful N scavenging from any winter cover crop heavily depends on timely fall planting, favorable weather, and the extent of root growth. Successfully established winter grass cover crops can take up more than 60 lbs of N/A in many central Midwest states, and more than 100 lbs of N/A in Atlantic Coast states, depending on the quantity of RSN. Isotopically-labeled N (^{15}N-RSN) studies in Maryland measured cover crop above-ground ^{15}N uptake and estimated root ^{15}N in the spring, and showed that a cereal rye cover crop recovered 50 to 60% of the labeled RSN, while annual ryegrass recovered 40 to 50%. The recovery of labeled RSN by these grass cover crops was substantially higher than the recoveries using hairy vetch, crimson clover, or native weeds; which amounted to less than 10% of the labeled RSN (Shipley et al., 1992).

N release from annual winter grass cover crops, plus other benefits of cover crops

Synchrony of N release from winter cereal cover crops is hard to predict and to manage, and release may not occur until well into the growing season of the spring-planted crop. The release of scavenged N from grass cover crops has been shown to be quite small (with negative releases often reported, i.e. somewhat higher N additions are needed for the next crop). This is because the vast majority of the scavenged N is returned to slowly decomposing components of the soil N cycle. However, the dynamics of cover crop decomposition and N mineralization will vary depending on the number of years the cover crop has been part of the cropping system, the cover crop residue carbon to nitrogen ratio (C:N), soil microbial activity, soil temperature and moisture, and also whether the cover crop has been soil-incorporated by tillage.

Other crops like the brassicas, such as turnips or radishes, have also been successfully used as N scavengers although they require earlier planting than the grasses and will likely winter kill in the Midwest. Hairy vetch and clovers have also been used successfully as winter cover crops primarily to supply N to the following summer crop. When these brassica and legume cover crops are used alone, or in combination with grass cover crops, some N release may occur both early in the targeted field crop growing season (i.e. late spring) from the lower C:N residues (< 20 to 30:1) of the non-grass cover crops, and again later in the growing season as soil microbes release N from the decomposing grass cover crop residues.

It is also important to note that the positive contributions of winter cover crops are not restricted just to RSN capture and to improved water quality. These additional benefits include sequestering N and carbon into building soil organic matter, improving water infiltration, and lowering soil erosion. Farmers should also think about these other soil, cropping system, and the environment benefits when considering the use of cover crops. Further descriptions and discussions of the benefits of cover crops can be found at the Midwest Cover Crop Council website (see link below) and the USDA website for the publication "Managing Cover Crops Profitably" (see link below).

Summary

This brief has illustrated two key opportunities for many farmers to more efficiently manage RSN (i.e. residual soil nitrate-N), which may be elevated after drought in corn and other crop production systems:

1. use of a winter cover crop, and
2. spring monitoring of soil nitrate-N with adjustment of fertilizer N rates for corn when spring nitrate-N is elevated.

The advantages of a winter cover crop are: a rapid capture of RSN and a reduction in the soil nitrate-N pool, which enables appropriate adjustment of spring fertilizer

N rates, as well as a reduced risk of nitrate-N leaching and drainage losses.

It has been estimated that cover crops could be used on 70 to 80% of the U.S. corn and soybean acreage to help reduce soil nitrate-N losses. Kaspar et al. (2008) aptly summarized: "Establishment on some acres would be limited because of lack of rainfall in some years, late planting because of harvest delays, and poor soil conditions at time of planting." They also concluded that, 1) reductions in nitrate loss and cover crop growth would be diminished in the northern parts of the U.S. "because of cold temperatures and frozen soil between main crops and because of less growth of the cover crops", 2) Benefits and cover crop growth would also be limited in the drier regions west of the Mississippi river (unless irrigated) because of water limitations for cover crop growth and nitrate leaching, and 3) "Crop acres with more diverse rotations than a typical corn-soybean rotation may have even better opportunities for cover crops."

There is still a great deal of uncertainty in the estimation of the potential nitrate-N losses and N availability to crops next spring (2013), largely because of our inability to accurately predict the weather between fall and spring, and our current lack of knowledge about the RSN levels across broad and varied geographies (F. Fernandez – U. of Illinois, J. Camberato – Purdue University, R. Mullen – Potashcorp; and T. S. Murell and P. Fixen – IPNI; personal communication August 18, 2012). It is clear, however, that farmers will experience increased cropping system management challenges and initial investment costs when including winter cover crops as a component of their annual cropping systems. The costs, benefits, and local management guidance on winter cover crops need to be evaluated on a field-by- field or farm-by farm basis, in consultation with an experienced agronomist.

The expertise of a Certified Crop Adviser, university extension specialist, USDA soil conservationist or other skilled agronomic professional should be sought in making your winter cover crop management decisions. A helpful starting place to consider is the website of the Midwest Cover Crops Council: http://www.mccc.msu.edu/ and several of the references posted at that website; especially the Kaspar et al. (2008) article listed in the references below. The USDA website for the informative 2007 publication "Managing Cover Crops Profitably" is: http://www.sare.org/publications/covercrops.htm . The August 20, 2012 webinar - Dealing With Drought: Securing Nitrogen With Cover Crops, which was hosted by CropLife (see http://www.croplife.com/webinars and specifically http://www.croplife.com/register-video?forward=video/c:56/webinars/1304/) may also be of special interest to those considering winter cover crops, particularly for the first time.

Acknowledgement

There are numerous scientists whose work could have been mentioned in this brief. We express appreciation for their work and apologize if their reports were not included in this brief because of space limitation, unintentional oversight, and the limited time available to summarize studies and disseminate this information.

References Cited

Brinsfield, R.B. and K.W. Staver. 1991. Use of cereal grain cover crops for reducing ground water nitrate contamination in the Chesapeake Bay region. pp 79-82. In W.L. Hargrove (ed.). Cover crops for clean water. Proc. Intl. Conf., April 9-11 1991, Jackson, TN. Soil and Water Conserv. Soc. Am., Ankeny, IA.

Dabney, S. M. J. A. Delgado, J.J. Meisinger, H.H. Schomberg, M.A. Liebig, T. Kaspar, J. Mitchell, and W. Reeves. 2010. Using cover crops and cropping systems for nitrogen management. Ch. 9, pp. 230-281 In JA. Delgado and R.F. Follett (eds.), Advances in Nitrogen Management for Water Quality. Soil and Water Conservation Society of America. Ankeny, IA.

Kaspar, T.C. D.B. Jaynes, T.B. Parkin, and T.B. Moorman. 2007. Rye cover crop and Gamagrass strip effects on NO3 concentration and load in tile drainage. J. Environ. Qual. 36:1503–1511.

Kaspar, T.C., E.J. Kladivko, J.W. Singer, S. Morse, and D. R. Mutch. 2008. Potential and limitations of cover crops, living mulches, and perennials to reduce nutrient losses to water sources from agricultural fields in the Upper Mississippi River Basin. pp. 127-148 in UMRSHNC (Upper Mississippi River Sub-basin Hypoxia Nutrient Committee). Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop. St. Joseph, Michigan: ASABE. Copyright 2008 by the American Society of Agricultural and Biological Engineers.

Meisinger, J. J., W. L. Hargrove, R. L. Mikkelsen, J. R. Williams, and V. W. Benson. 1991. Effects of cover crops on groundwater quality. pp. 57-68, In W. L. Hargrove (ed.), Cover Crops for Clean Water: Proc. Intl. Conference. Soil and Water Conservation Society of America. Ankeny, IA.

Randall, G. W., D. R. Huggins, M. P. Russelle, D. J. Fuchs, W. W. Nelson, and J. L. Anderson. 1997. Nitrate Losses through Subsurface Tile Drainage in Conservation Reserve Program, Alfalfa, and Row Crop Systems. J. Environ. Qual. 26:1240-1247.

Randall, G.W. and D.J. Mulla. 2001. Nitrate nitrogen in surface waters as influenced by climatic conditions and agricultural practices. J. Environ. Qual. 30:337–344.

Sawyer, J. E. and G.W. Randall. 2008. Nitrogen rates. pp. 59-71 in UMRSHNC (Upper Mississippi River Sub-basin Hypoxia Nutrient Committee). Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop. St. Joseph, Michigan: ASABE. Copyright 2008 by the American Society of Agricultural and Biological Engineers.

Shipley, P.R., J.J. Meisinger, and A.M. Decker. 1992. Conserving residual corn fertilizer nitrogen with winter cover crops. Agron. J. 84:869-876.

Staver, K.W. and R. B. Brinsfield. 1998. Using cereal grain winter cover crops to reduce groundwater nitrate contamination in the mid-Atlantic coastal plain. J. Soil Water Conserv. 53(3): 230-240.

Additional Suggested References

Dabney, S.M., J. A. Delgado, and D. W. Reeves. 2001. Using winter cover crops to improve soil and water quality. Commun. Soil Sci. Plant Anal. 32:7,1221-1250.

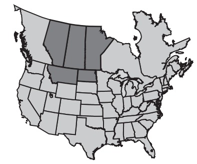
Dinnes, D.L., D.L. Karlen, D.B. Jaynes, T.C. Kaspar, J.L. Hatfield, T.S. Colvin, and C. A. Cambardella. 2002. Nitrogen management strategies to reduce nitrate leaching in tile-drained Midwestern soils. Agron. J. 94:153–171.

Strock, J.S., P. M. Porter, and M. P. Russelle. Cover cropping to reduce nitrate loss through subsurface drainage in the northern U.S. corn belt. J. Environ. Qual. 33:1010–1016.

Wagger, M.G., and D.B. Mengel. 1988. The role of nonleguminous cover crops in the efficient use of water and nitrogen. pp 115-127, In W.L. Hargrove (ed.) Cropping Strategies for Efficient Use of Water and Nitrogen. American Society of Agronomy. Madison, WI.

Ref # 12091

INSIGHTS
International Plant Nutrition Institute



September 2012

Drought and Nutrient Applications: A Northern Great Plains Perspective

In the Northern Great Plains (NGP) region of North America there is almost always an area that experiences drought in any one year. This is because the region is expansive—going from the southern borders of Montana and North Dakota, north through the agricultural land of Manitoba, Saskatchewan, and Alberta, and further north and west up into northeastern British Columbia. Much of the region is considered semi-arid and would probably be considered arid, even in normal rainfall years, if it wasn't for reduced evapotranspiration from lower temperatures experienced in the cold winters, and cool springs and falls. Total average annual precipitation ranges from a high of 20.2 in. from eastern North Dakota in the Red River Valley, to a low of 12.7 in. around the tri-corner area of northeast Montana, southwest Saskatchewan, and southeast Alberta. The whole region, especially the lower rainfall areas, have historically experienced drought periods that can last for up to 3 or even 5 years. One of the more memorable droughts over the past century occurred from 1933 to 1940 (7 years) in parts of the Great Plains.

In North America during the 2012 crop year, drought has been present in extensive areas of the southwest, Great Plains, and most of the Corn Belt up into northeastern Canada (**Figure 1**). For the NGP region there has been quite severe drought in Montana and parts of North Dakota, but as you go north the moisture conditions have been average, to above average through Manitoba, Saskatchewan, and Alberta, until the Peace River block of northwest Alberta and northeast British Columbia, where dry to droughty conditions have been present (**Figure 2**).

A farmer could decide on the most effective rate of fertilizer nutrients to apply to a spring planted crop, if the following information was known at the time of planting:

- Plant available moisture in the soil
- Levels of plant available nutrients [e.g. nitrogen (N), phosphorus (P), potassium (K), sulfur (S)]
- How much N will be mineralized and made available to the crop from soil organic matter and previous crop residues
- Growing season temperatures
- **Most importantly, how much and when will rainfall be received**

The amount and timing of rainfall is very difficult to predict, and rainfed crop yields are very dependent on growing season moisture. If however the upcoming rainfall amounts and timings were known, the potential yield could be accurately estimated, and the effective rates of fertilizer nutrients required to achieve potential crop yields could be determined. To a certain degree this is done by farmers who have access to irrigation, but even with irrigation sometimes hot dry and windy weather can result in evapotranspiration demands that exceed irrigation capacity for high crop yields.

Most farmers plan for average, to somewhat above average moisture conditions, and apply fertilizer nutrients accordingly. Minor adjustments are often made if spring soil moisture conditions are either somewhat lower or somewhat higher than average. If very dry or even droughty conditions persist from the previous growing season most farmers will apply lower rates of fertilizer nutrients than normal. However, the reduction of fertilizer rates can be excessive, especially if moisture conditions improve early in the rest of the growing season, and inadequate plant available nutrients are present to match the improved crop yield potential.

Adequate fertilizer can help even a moisture deficient crop to yield higher, often with reasonable economic returns. It is useful to observe what effect moderate rates of fertilizer can have on crop yields over a few decades at locations where long-term crop rotation studies have been conducted. One such study, named the ABC Rotation, is at the Agriculture and Agri-Food Canada Research Station near Lethbridge, Alberta. Part of this study has recorded spring wheat yields from 1912 until present.

Dr. Thomas L. Jensen
Northern Great Plains Director
International Plant Nutrition Institute (IPNI)
102-411 Downey Road
Saskatoon, SK S7N 4L8
Phone: 306-652-3535
Fax: 306-664-8941
E-mail: tjensen@ipni.net
Website: http:/nangp.ipni.net

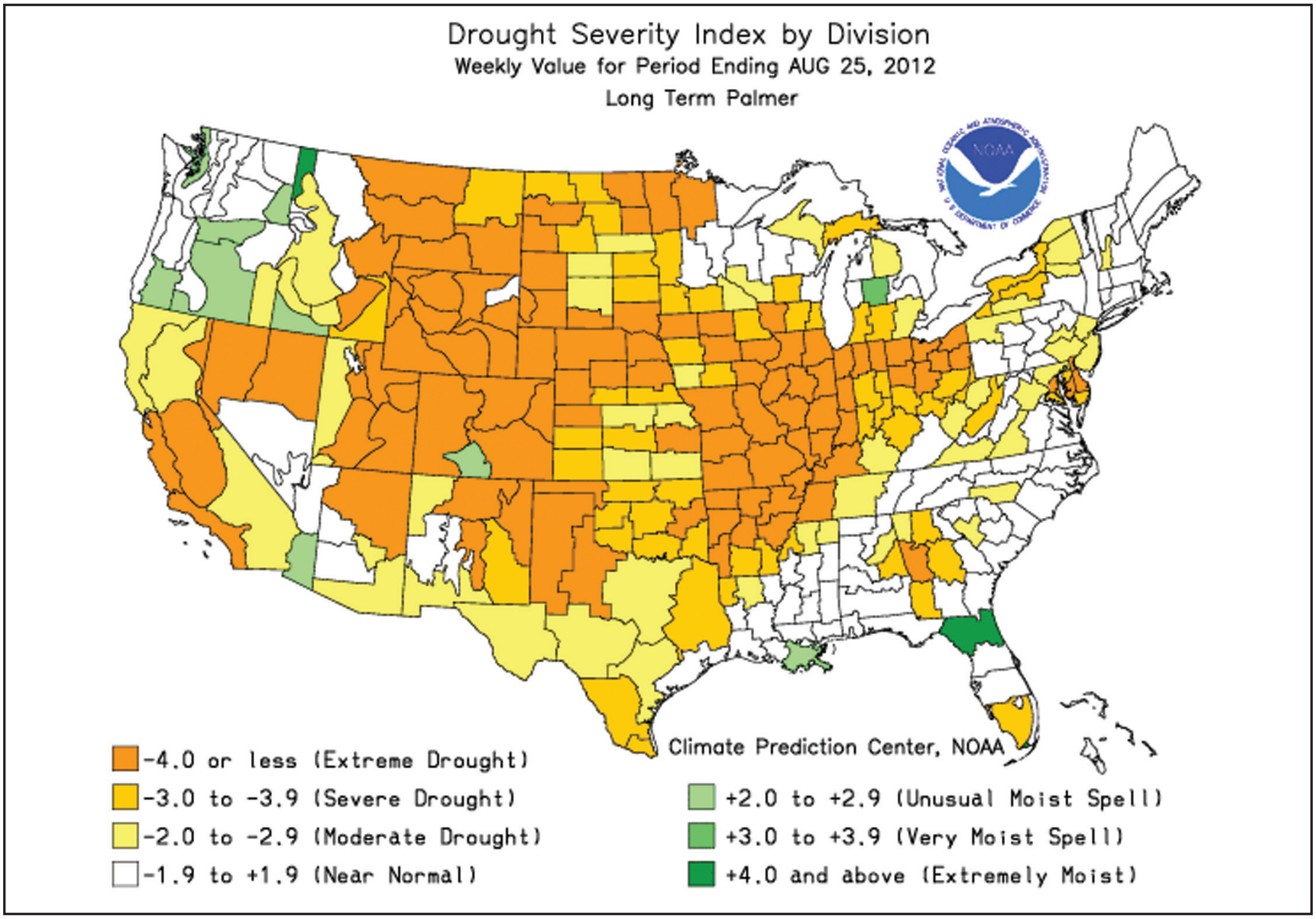


Figure 1. US Drought Severity by Division, Weekly Value for Period Ending Aug 25, 2012, Long Term Palmer Drought Index. http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/regional_monitoring/palmer.gif

This represents continuously planted spring wheat for one century. With the general use of fertilizer becoming common in the late 1960s, a portion of the original study was separated out and has received N and P fertilizer since 1972, at rates of 40 lb N/A, and 41 lb P_2O_5/A. It is possible to compare wheat yields from the long-term check portion that has received no fertilizer, to the fertilized portion having received N and P at the above noted rates, for 38 years ….1972 through 2010. The average growing season precipitation (April 1 through to August 31) over the 38-year time period has been 9.8 in.

The 38-year average yield of the check, or no fertilizer, treatment has been 20.5 bu/A, compared to fertilized treatment yielding 34.8 bu/A. In **Table 1** below there is comparison of the 38-year average values, to selected years, either wetter or drier than the average. The largest relative yield increase over the check of 111% occurred in the driest year (2000) and resulted in a greater yield response (15.2 bu/A) and a greater increase in net return than the 38-year average.

It is important to note that the fertilizer applications in the long-term study that began in 1972 were probably sub-

Table 1. Spring wheat yields (bu/A) from non-fertilized and fertilized areas, 38-year average, compared to very dry, very moist, a bit lower than average, and dry growing season precipitations.

Year	Growing season precipitation, in.	Check yield	Fertilized yield (40 lb N and 41 lb P_2O_5/A)	Yield increase with fertilizer	% increase over check	Increased net returns (fertilized minus check)*
2002 (very moist)	16.2	26.7	44.4	17.7	66	$104.71
38-year avg.	**9.8**	**20.5**	**34.8**	**14.3**	**70**	**$76.05**
2006 (lower than avg.)	8.5	19.1	39.0	19.9	104	$123.26
2007 (dry)	6.8	16.3	26.9	10.6	65	$44.86
2000 (very dry)	3.9	13.7	28.9	15.2	111	$83.64

*Net returns calculated using 46-0-0 at $567/ton, 11-52-0 at $640/ton, and wheat at $8.43/bu, 29-Aug-2012 western Canada prices.

optimal for N, as most wheat crops in the Lethbridge area under rainfed conditions will now receive applications between 70 and 80 lb N/A; and P_2O_5 applications in the original study are in excess of removals and more commonly are around 20 to 25 lb P_2O_5 in farmer fields. However, farmers will adjust fertilizer applications rates down if moisture conditions appear drier than normal at planting, and adjust fertilizer application rates up if moisture conditions seem greater than normal at planting. This is especially so for N fertilizer, but also P fertilizer to a lesser degree. However, the data in **Table 1** clearly show that fertilizer plays a critical role in dry years and needs to be managed properly following the principles of 4R Nutrient Stewardship (right source at the right rate, right time and right place) just as in more favorable production seasons.

Here are some strategies for farmers experiencing drought conditions for a couple of years in a row:

- It is useful to soil test in the spring prior to planting and if there is above average residual N in the soil, the fertilizer applications rate should be reduced proportionally. For example, under more normal moisture conditions soil-test N can be around 15 lb N/A, and a normal N application is 70 lb N/A, for a total of 85 lb N/A crop available N. However, because of dry to drought conditions the previous year the residual N is 35 lb N/A, and the drought conditions appear to be continuing, a farmer may decide to reduce the combined total pre-plant N to 60, and only apply 25 lb N/A as additional fertilizer.
- If moisture conditions improve early in the growing season after planting, say by the 4-leaf stage of spring wheat, there could be a contingency plan to top-dress with a surface application of urea or UAN. This makes use of moisture received and improves yield potential. For example, a typical top-dressing N application for the Lethbridge area under rainfed conditions could be between 25 and 30 lb N/A.

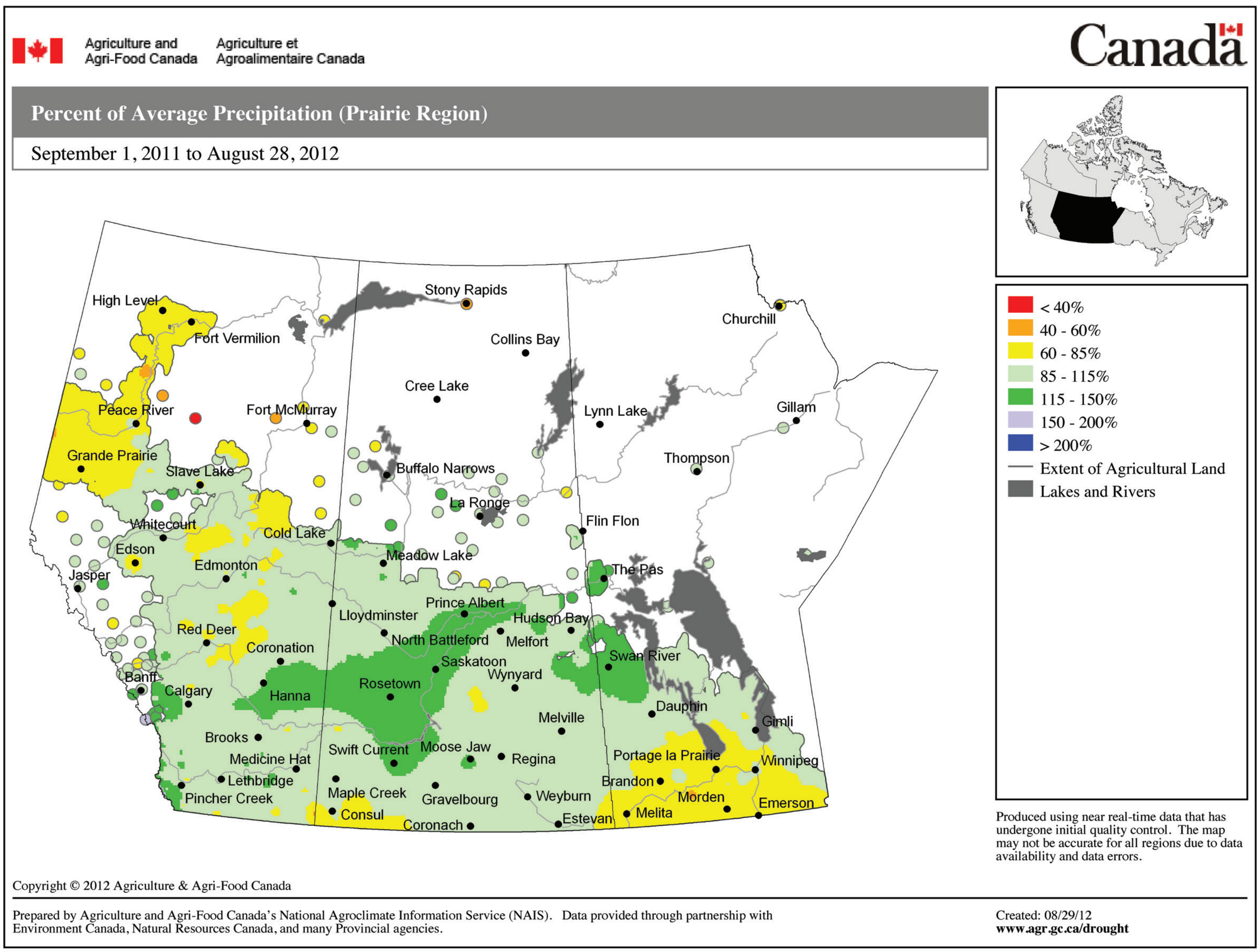


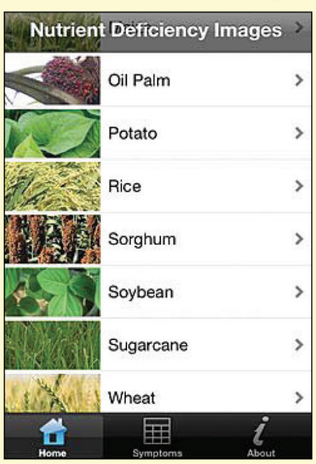
Figure 2. Moisture Conditions, Percent of Normal Amounts, for the Crop Year 2012, Sept. 1, 2011 through to August 27, 2012. http://www4.agr.gc.ca/DW-GS/current-actuelles.jspx?lang=eng&jsEnabled=true

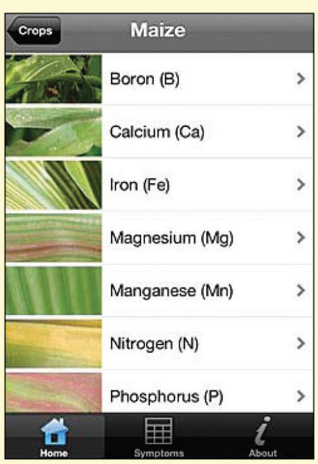
Summary

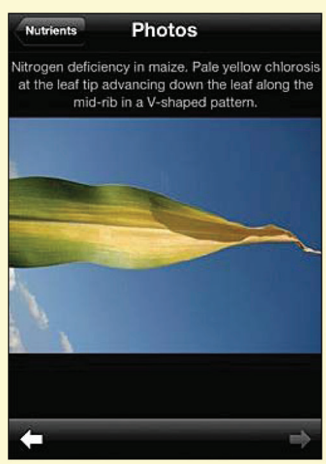
In summary, dry to drought conditions are common in the NGP. Farmers should consider soil testing and if there is above normal residual plant nutrient levels, primarily N, adjust N fertilizer applications to rates lower than normal based on the soil test results. Additional adjustments in fertilizer rates, either up or down, can be based on the weather in the early part of the growing season. However, cutting back fertilizer rates to zero is usually not wise as even in dry years there is usually a net economic benefit from optimum rates of fertilizer. If rainfall conditions improve early in the growing season, there can be benefits from topdressing additional N. In essence, 4R Nutrient Stewardship is no less important in dry years than in normal years and may in fact make the difference between profit and loss.

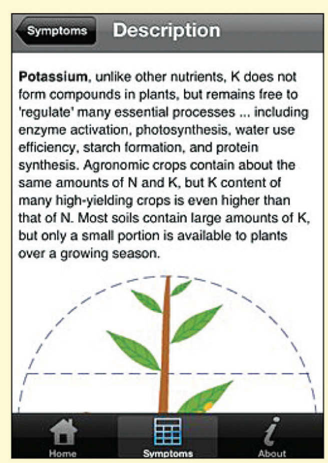
Nutrient Deficiency Photo Application for iPhone/iPad Released

IPNI has released a new Crop Nutrient Deficiency Photo Library app for your iPhone or iPad (see http://info.ipni.net/ndapp). The app contains key photos of classic nutrient deficiency documented from research plots and farm fields for 14 common crops. It also provides supporting text and illustrations of nutrient deficiencies. This mobile app will be a great tool for crop advisers, consultants, farmers, and anyone wanting help in identifying nutrient deficiency symptoms in common crops. BC

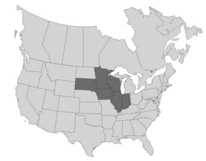








IPNI INSIGHTS
International Plant Nutrition Institute



September 2012

Crop Nutrition Following the 2012 Drought: Northcentral U.S.

The drought that affected many areas in the Midwest has created several questions about nutrient management, especially looking forward to next season. Here are a few of the most commonly asked questions and some thoughts about them.

How has the drought affected soil nitrate levels?

Where corn was grown, it is likely that nitrate (NO_3^-) levels in the soil are higher than normal (Randall et al., 2003). Higher levels arise from decreased downward movement of soil water and from reduced fertilizer nitrogen (N) uptake by the drought-stressed plant (Rimski-Korsakov et al., 2009). A 6-yr study in Minnesota, conducted on a Canisteo clay loam with 0 to 1% slope and 5.5% organic matter (Randall et al., 2003), measured generally higher soil nitrate levels when seasonal precipitation dropped below average.

Pulses of N can also occur any time dry soils are rewetted. As soils dry, the microbial decomposition of organic matter that releases N (mineralization) slows, approaching zero under very dry conditions (less than 10-15% moisture; Ford et al., 2007). In addition, some soil microbes are killed (Marumoto et al., 1982a; Murumoto et al., 1982b). When dry soils are rewetted, a sudden pulse of inorganic N may occur, termed a "flush" or a "hot moment" (Cabrera, 1993; McClain et al., 2003). This pulse can last for days to weeks. A significant portion of this flush is thought to come from the decomposition of the microbes recently killed during the dry spell (Marumoto et al., 1982a; Marumoto et al., 1982b). Another contributor to the flush is the release of organic compounds from the reactive sites at clay mineral surfaces (van Gestel et al., 1991).

Dr. T. Scott Murrell
Northcentral Director
International Plant Nutrition Institute (IPNI)
PO Box 2539
West Lafayette, IN 47996
Phone: 765-413-3343

E-mail: smurrell@ipni.net
Website: http://nanc.ipni.net

Whether or not residual nitrate will be available for next season's crop depends greatly upon the precipitation that occurs between cropping seasons. In the Midwest, nitrate losses can be substantial during the fall, winter, and early spring months (Dabney et al., 2010). For example, the same Minnesota study cited above (Randall et al, 2003) demonstrated higher losses of nitrate to tile drainage with precipitation occurring in spring to early summer months. Corn and soybean crops have less above- and below-ground biomass during those months, resulting in greater chances that N will move below the root system before being taken up.

Should I consider planting cover crops?

Regardless of whether corn or soybean is planted next year, consider planting a catch crop. A catch crop is a cover crop planted for the express purpose of taking up soil nitrate to keep it from leaching to tile drains or to deeper zones in the profile that are out of reach by crop roots (Dabney et al., 2010). A summary of studies conducted in the Midwest showed that catch crops can reduce nitrate losses to tile lines by 6 to 58 lb NO_3-N/A (Dabney et al., 2010). The following are a few general considerations for catch crops. For more information visit the Midwest Cover Crops Council's Cover Crop Decision Tool (http://www.mccc.msu.edu/selectorINTRO.html) and also consult local expertise for needed details and guidance.

Cover crop selection

Crops with deep roots that grow quickly are key. Small grains that have been more widely used in the Midwest are cereal rye, winter wheat, and oats. Annual ryegrass is a forage grass that has been widely used too. Popular brassicas are turnips and radishes. Of these cover crops, brassicas and oats do not survive the winter and need no chemical killing in the spring. Cover crop combinations are also possible. For instance, it is recommended that radishes be planted with another cover crop, such as cereal rye or oats, and many other combinations are possible (Meisinger et al., 2012).

Planting date

Crops should be planted as soon as possible in later summer or early fall to maximize root growth and N uptake. Different cover crops require different planting dates (Midwest Cover Crop Council, 2012). Planting dates also depend on what cash crop is being grown. For instance, for corn it is recommended that cereal rye or oats be aerially seeded just before black layer (R5) and before September 15 (Meisinger et al., 2012). For soybean, cereal rye or oats should be sown as the plants begin to dry down after maturity (Meisinger et al., 2012).

Planting method

Aerial seeding, tractor-driven broadcast spreading, and drilling are some of the planting possibilities (Meisinger et al., 2012). When planting into dry soils, a firm seedbed with good seed-soil contact is needed, so drilling is preferable. Drilling limits cultivar selection to those crops that can be established after harvesting corn or soybean. Aerial seeding and broadcast spreading provides more options for earlier sowing dates and cover crop selection.

Killing date

Proper times to kill cover crops that overwinter depend on whether corn or soybean is to be planted. Another consideration is soil moisture in the spring. For corn, cover crops should be killed at least two weeks prior to planting (Meisinger et. al., 2012; Dabney et al., 2010). If soils are dry, earlier killing may be needed, such as four weeks prior to planting. Soybean is less sensitive to the time when cover crops are killed. Up to three days ahead of planting is acceptable unless dry conditions exist, then earlier killing is needed (Meisinger et al., 2012).

Long-term catch crop management

Although catch crops are getting a lot of attention this year, they have been shown to be important for reducing N losses over the long term. Regularly growing catch crops after each crop of corn and soybean has been shown to reduce nitrate losses by an average of 20 lb N/A/yr, which represents a 53% reduction (Meisinger et al., 2012). Long term management also keeps N cycling through the system, building organic N reserves.

How do soil nitrate tests change how much N is recommended?

Soil nitrate tests are the best early-season diagnostic tool for assessing the quantity of residual soil N. There are basically two different types of soil nitrate tests. Both measure nitrate present at the time of sampling; however, they differ in the way the nitrate levels are interpreted.

The first type of test, often referred to as a **soil nitrate test,** uses an N budget interpretation. The amount of nitrate in the soil (or proportion thereof) is simply subtracted from the base N rate, resulting in less total recommended N. Tests in this category are: South Dakota and western Minnesota - the deep nitrate test (Gerwing and Gelderman, 2005; Rehm et al., 2006); and Wisconsin - pre-plant soil nitrate test (Bundy et al., 2001).

The second type of test, often termed a **soil N test,** uses an interpretation based on calibration with crop response to N (Khan et al., 2001; Magdoff, 1991; Magdoff et al, 1984). Consequently, the nitrate levels are used not only to measure soil N present at the time of sampling but also to account for the N supplying capacity of the soil during the season. Calibration data are used either to configure the base N recommendation or to figure an N credit that is subtracted from the base N recommendation. Tests in this category are: Indiana – pre-sidedress soil nitrate test (Brouder and Mengel, 2003); Iowa - the late spring nitrate test (Blackmer et al., 1997; Sawyer et al., 2003); Minnesota – soil N test (Schmitt et al., 1998); Illinois and Wisconsin – pre-sidedress soil nitrate test (Bundy, 1998; Fernandez et al., 2009).

A large, regional research effort was conducted in 1988-92 that examined the efficacy of using the soil N tests (Bundy et al., 1999). This evaluation did not consider the more recently developed Illinois Soil Nitrogen Test (Khan et al., 2001). The study was conducted in 307 site-years across North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, Wisconsin, Illinois, Michigan, and Ohio. Results showed that this test seldom failed to identify sites responsive to N. Consequently, there appears to be little chance that the use of this type of test will result in a missed application of required N. If anything, such tests may incorrectly recommend too much N.

States vary considerably in their suggestions for use of soil N tests, so consulting local guidance is required.

Will higher nitrate levels impact next year's N program?

Here are some options for addressing the uncertainty in N rate for next year, caused by residual soil nitrate and unpredictable weather conditions:

- Take soil nitrate tests to assess levels, paying attention to within-field variability.
- Move from fall to spring and in-season applications. This provides better synchrony between N supply and N uptake by the crop.
- Use a chlorophyll meter, such as a SPAD meter, or active crop reflectance sensors, to determine rates of N to side-dress.

Will higher nitrate levels adversely affect next year's soybean crop?

If a soybean crop is planned for next year, it will simply scavenge the nitrate left. Higher nitrate levels do not adversely affect soybean yields (Schmidt et al., 2000). Under higher nitrate supplies, soybean derives less of its N from biological fixation, and total N uptake will likely be the same or somewhat higher (Herridge and Peoples, 1990).

Will the drought affect soybean N credits for next year's corn?

The soybean N credit is a reduction in the N recommended for corn following soybean compared to corn following corn. While the exact causes of this reduction are still under investigation, several contributing factors have been identified.

The most commonly cited factor in the N credit is biological N fixation. Under drought stress, there may be lower numbers of nodules on soybean roots, and N_2 fixation in the nodules themselves may be reduced (Serraj et al., 1999). This reduction may arise from decreased N demand by the drought-stressed soybean plant (Streeter, 2003) and decreased phloem flow (Serraj et al., 1999).

In a study comparing nodulated to non-nodulated soybean isolines, soil N supplies were higher after nodulated soybeans than after non-nodulated soybeans (Bergerou et al., 2004). However, both types of soybeans produced higher N supplies than when corn was grown. Consequently, factors other than biological N fixation are important for determining the N credit.

There is evidence that soybean increases readily mineralizable organic N supplies in soils while corn decreases them (Martens et al., 2006). The additional supplies provided by soybean appear to come from micro-roots as well as from organic compounds exuded by the roots themselves, such as amino acids, hormones, and enzymes (Mayer et al., 2003). It is expected that drought would reduce the quantity of these contributions to the organic N pool.

Rate of N mineralization from soybean residues is also important. Nitrogen mineralizes more rapidly from soybean residue than from corn residue (Gentry et al., 2001). The lower C:N ratio explains part of this difference, but not all. As discussed, there are many other factors at work.

Finally, the biological transformation of soil inorganic nitrogen into organic forms (immobilization) is faster for soybean residues than for those of corn. When corn and soybean are harvested, N is initially immobilized by their residues, making it unavailable for uptake by the next crop. After this initial phase, N is mineralized from the residues, creating N that is available (Green and Blackmer, 1995). Soybeans immobilize N more quickly than corn, allowing the N mineralization phase to start earlier, providing N to the succeeding crop more rapidly. Additionally, the lower quantity of soybean residue compared to corn means less overall N is immobilized. In dry conditions, immobilization is slowed, which can delay final N release.

Considering the impact that drought has upon all the various factors that contribute to the soybean N credit, it is hypothesized that some, but perhaps not all, of the credit should be taken if corn is to be grown after this year's soybean crop. A conservative approach would be to apply a basal amount of N that is reduced by the full credit and then monitor the corn crop and apply additional N if diagnostic tests (tissue tests, chlorophyll meter readings, or active crop reflectance sensors) indicate a deficiency.

How much phosphorus (P) and potassium (K) carryover can be expected?

On most soils in the Midwest, both P and K form chemical bonds with soil minerals that keep them from moving very far from the point of application. Unlike N, they are not subject to as many losses. Primary pathways for loss are erosion and runoff, and then, only the P and K near the soil surface. In mucks and sandy soils, K can be lost through leaching. So in most situations, P and K not taken up by the crop carry over for use in future years.

Lower yields caused by the drought mean less P and K will be removed with grain harvest. If, on the other hand, corn that was intended for grain harvest was instead cut for silage, P and K removal will be greater than planned.

Some average rates of removal by corn and soybean are given in the **Table 1.** Multiplying these rates by harvested yield estimates total removal.

Table 1. Average P and K nutrient removal by corn and soybean (Phillips and Majumdar, 2012).

Crop	Harvested portion	Unit	Nutrient removal	
			P_2O_5	K_2O
			-------(lb/unit)-------	
corn	grain	bu	0.35	0.25
	stover	ton	5.8	40
corn silage (67% water)	whole plant	ton	3.1	7.3
soybean	grain	bu	0.73	1.18
	stover	ton	8.8	37

Drought can cause changes in nutrient concentrations of various plant organs. The magnitude of these changes depends upon when the drought occurred and how long it lasted. Measuring nutrient concentrations in harvested crop portions can provide more accurate assessments than average rates.

Comparing the amount of P and K applied before this season to the amount actually removed by crops this year provides an estimate of the P and K carrying over.

How will the drought affect P and K soil test levels?

Drought can change soil tests in several ways.

- Reduced grain yield results in lower nutrient removal, damping reductions in soil test P and K;
- Corn planned for grain harvest but instead cut for forage increases nutrient removal, amplifying reductions in soil test P and K;
- Low moisture affects the reactions K has with soil minerals. These reactions impact the amount of K measured by soil tests and create swings in readings that cannot be explained solely by comparing K application rates with nutrient removals. In some cases, soil tests levels may be lower than expected and in some cases they may be higher.

Keeping good records of nutrient application rates and conducting tissue nutrient analyses create good nutrient budget estimates. If soil tests don't change as expected based on budgets, drought-induced changes in soil chemical reactions are likely a significant part of the explanation.

Summary

The drought this season impacts next season's nutrient management planning. Some key factors to consider are:

- soil nitrate levels can be higher than normal, but whether or not this additional N is available to crops next year depends a lot on the precipitation this winter and next spring;
- catch crops can capture a significant amount of this nitrate and convert it to organic forms that become available to subsequent crops;
- soil nitrate tests can be used to adjust N application rates to those that more closely match what the plant needs but the soil lacks;
- higher soil nitrate levels will not adversely affect a soybean crop;
- drought may reduce the N credit normally used following soybean, but the probability and magnitude of this effect is not well defined;
- P and K not taken up by the crop this year remain in the soil for uptake by future crops;
- the quantity of P and K carryover can be estimated by comparing nutrient application rates to the quantity removed by crop harvest;
- soil test changes normally follow nutrient budgets over time, but drought can cause unexpected swings in soil test K and the magnitude and direction of those swings depend in large part on soil mineralogy and soil chemical reactions.

References

Bergerou, J.A., L.E. Gentry, M.B. David, and F.E. Below. 2004. Role of N2 fixation in the soybean N credit in maize production. Plant Soil 262:383-394.

Blackmer, A.M., R.D. Voss, and A.P. Mallarino. 1997. Nitrogen fertilizer recommendations for corn in Iowa. Pm-1714. May 1997. Iowa State Univ. Coop. Ext. Serv., Ames. Available online at http://www.agron.iastate.edu/soiltesting/pm1714.pdf (verified 14 Aug. 2012).

Brouder, S.M. and D.B. Mengel. 2003. The presidedress soil nitrate test for improving N management in corn. AY-314-W. Purdue Univ. Coop. Ext. Serv., West Lafayette, IN. Available at http://www.agry.purdue.edu/ext/pubs/AY-314-W.pdf (verified 14 Aug. 2012).

Bundy, L.G. 1998. Corn fertilization. A3340. Univ. Wisconsin Coop. Ext. Serv., Madison. Available at http://www.soils.wisc.edu/extension/pubs/A3340.pdf (verified 14 Aug. 2012).

Bundy, L.G., S.J. Sturgul Sr., and R.W. Schmidt. 2001. Wisconsin's preplant soil nitrate test. A3512. Univ. Wisconsin Coop. Ext. Serv., Madison. Available at http://corn.agronomy.wisc.edu/Management/pdfs/A3512.pdf (verified 14 Aug. 2012).

Bundy, L.G., D.T. Walters, and A.E. Olness. 1999. Evaluation of soil nitrate tests for predicting corn nitrogen response in the North Central region. North central regional res. publ. no. 342. Univ. Wisconsin Agric. Exp. Sta., Madison.

Cabrera, M.L. 1993. Modeling the flush of nitrogen mineralization caused by drying and rewetting soils. Soil Sci. Soc. Am. J. 57:63-66.

Dabney, S.M., J.A. Delgado, J.J. Meisinger, H.H. Schomberg, M.A. Liebig, T. Kaspar, J. Mitchell, and W. Reeves. 2010. Using cover crops and cropping systems for nitrogen management. p. 230-281. In J.A. Delgado and R.F. Follett (eds.) Advances in nitrogen management for water quality. Soil and Water Conservation Society. Available at http://www.swcs.org/en/publications/advances_in_nitrogen_management_for_water_quality/ (verified 14 Aug. 2012).

Fernandez, F.G., E.E. Nafziger, S.A. Ebelhar, and R.G. Hoeft. 2009. Managing nitrogen. pp. 113-132. In Illinois agronomy handbook. Univ. Illinois Coop. Ext. Serv., Urbana-Champaign.

Ford, D.J., W.R. Cookston, M.A. Adams, and P.F. Grierson. 2007. Role of soil drying in nitrogen mineralization and microbial community function in semi-arid grasslands of north-west Australia. Soil Biol. Biochem. 39:1557-1569.

Gentry, L.E., F.E. Below, M.B. David, and J.A. Bergerou. 2001. Source of the soybean N credit in maize production. Plant Soil 236:175-184.

Gerwing, J. and R. Gelderman. 2005. South Dakota fertilizer recommendation guide. EC750. Sep. 2005. South Dakota State Univ. Coop. Ext. Serv., Brookings. Available at http://pubstorage.sdstate.edu/AgBio_Publications/articles/EC750.pdf (verified 14 Aug. 2012).

Green, C.J. and A.M. Blackmer. 1995. Residue decomposition effects on nitrogen availability to corn following corn or soybean. Soil. Sci. Soc. Am. J. 59:1065-1070.

Herridge, D.F. and M.B. Peoples. 1990. Ureide assay for measuring nitrogen fixation by nodulated soybean calibrated by 15N methods. Plant Physiol. 93:495-503.

Khan, S.A., R.L. Mulvaney, and R.G. Hoeft. 2001. A simple test for detecting sites that are nonresponsive to nitrogen fertilization. Soil Sci. Soc. Am. J. 65:1751-1760.

Magdoff, F.R. 1991. Understanding the Magdoff pre-sidedress nitrate test for corn. J. Prod. Agric. 4:297-305.

Magdoff, F.R., D. Ross and J. Amadon. 1984. A soil test for nitrogen availability to corn. Soil Sci. Soc. Am. J. 48:1301-1304.

Martens, D.A., D.B. Jaynes, T.S. Colvin, T.C. Kaspar, and D.L. Karlen. 2006. Soil organic nitrogen enrichment following soybean in an Iowa corn-soybean rotation. Soil Sci. Soc. Am. J. 70:382-392.

Marumoto, T., J.P.E. Anderson, and K.H. Domsch. 1982a. Decomposition of 14C- and 15N-labelled microbial cells in soil. Soil Biol. Biochem. 14:461-467.

Marumoto, T., J.P.E. Anderson, and K.H. Domsch. 1982b. Mineralization of nutrients from soil microbial biomass. Soil Biol. Biochem. 14:469-475.

Mayer, J., F. Buegger, E.S. Jensen, M. Schloter, and J. Hess. 2003. Estimating N rhizodeposition of grain legumes using a 15N in situ stem labeling method. Soil Biol. Biochem. 35:21-28.

McClain, M.E., E.W. Boyer, C.L. Dent, S.E. Gergel, N.B. Grimm, P.M. Groffman, S.C. Hart, J.W. Harvey, C.A. Johnston, E. Mayorga, W.H. McDowell, and G. Pinay. 2003. Biogeochemical hot spots and hot moments at the interface of terrestrial and aquatic ecosystems. Ecosys. 6:301-312.

Meisinger, J., T. Kaspar, and D. Robison. 2012. Dealing with drought: Securing nitrogen with cover crops. CropLife Media Group Webinars. 20 Aug. 2012. Listed at http://www.croplife.com/webinars (verified 21 Aug. 2012).

Midwest Cover Crop Council. 2012. Cover crop decision tool [online]. Available at http://www.mccc.msu.edu/selectorINTRO.html (verified 21 Aug. 2012).

Phillips, S. and K. Majumdar. 2012. Scientific principles supporting – right rate. p. 4-1 to 4-11. In Bruulsema, T., P.E. Fixen, and G.D. Sulewski (eds.) 4R plant nutrition: A manual for improving the management of plant nutrition. North American version. International Plant Nutrition Institute, Norcross, Georgia.

Randall, G.W., J.A. Vetsch, and J.R. Huffman. 2003. Nitrate losses in subsurface drainage from a corn-soybean rotation as affected by time of nitrogen application and use of nitrapyrin. J. Environ. Qual. 32:1764-1772.

Rehm, G., G. Randall, J. Lamb, and R. Eliason. 2006. Fertilizing corn in Minnesota. FO-0379O. Rev. 2006. Univ. Minnesota Coop. Ext. Serv., St. Paul. Available online at http://www.extension.umn.edu/distribution/cropsystems/dc3790.html (verified 14 Aug. 2012).

Rimski-Korsakov, H., G. Rubio, and R.S. Lavado. 2009. Effect of water stress in maize crop production and nitrogen fertilizer fate. J. Plant Nutr. 32:565-578.

Sawyer, J.E., A.P. Mallarino, and R. Killorn. 2003. Interpretation of soil test results. PM 1310. Iowa State Univ. Coop. Ext. Serv., Ames. Available at http://www.extension.iastate.edu/Publications/PM1310.pdf (verified 14 Aug. 2012).

Schmidt, J.P., M.A. Schmitt, G.W. Randall, J.A. Lamb, J.H. Orf, and H.T. Gollany. 2000. Swine manure application to nodulating and nonnodulating soybean. Agron. J. 92:987-992.

Schmitt, M.A., G.W. Randall, and G.W. Rehm. 1998. A soil nitrogen test option for N recommendations with corn. FO-06514-GO. Univ. Minnesota Coop. Ext. Serv., St. Paul. Available at http://www.extension.umn.edu/distribution/cropsystems/dc6514.html (verified 14 Aug. 2012).

Serraj, R., T.R. Sinclair, and L.C. Purcell. 1999. Symbiotic N2 fixation response to drought. J. Exp. Bot. 50:143-155.

Streeter, J.G. 2003. Effects of drought on nitrogen fixation in soybean root nodules. Plant Cell Environ. 26:1199-1204.

Van Gestel, M., J.N. Ladd, and M. Amato. 1991. Carbon and nitrogen mineralization from two soils of contrasting texture and microaggregate stability: Influence of sequential fumigation, drying and storage. Soil Biol. Biochem. 23:313-322.

Ref # 12080

INSIGHTS
International Plant Nutrition Institute

September 2012

Crop Nutrition Following the 2012 Drought: Northeast

The 2012 drought will affect the nutrition of the 2013 crop. While its impacts may not have been as severe in Northeastern USA and Eastern Canada as in other parts of North America, crop nutrient cycling on many farms changed in unforeseen ways. To ensure the right management adjustments are made for 2013 cropping system performance, issues to be considered include carryover nutrient potential, crop nutrient removal, legume N credits, and the opportunity for cover crops.

Carryover nutrient potential

Since a drought-affected crop takes up less nutrients, more than usual may be left over. Nitrogen (N) behaves differently than phosphorus (P) or potassium (K). When dry soils are rewetted, a sudden flush of inorganic N release often occurs. This flush, arising from the decomposition of the microbes killed during the dry spell and release of organic compounds from clay mineral surfaces, can last for days to weeks. Fall-planted crops, such as winter wheat, may take advantage of high levels of mineral N in soil.

However, since most of this region receives enough rain in the winter to either cause leaching or saturate the soil, all this mineral N can easily be lost for crops in the following year. For corn, a spring nitrate test (at planting, or ideally at side-dressing time) can be useful to determine whether a useful residual remains. In Pennsylvania, the pre-sidedress soil nitrate test (PSNT) was first introduced in 1989, following the 1988 drought. Owing to a wet spring in 1989, the expected carryover N was lost, and the PSNT results showed that clearly. However, the possibility exists, if the coming winter is drier than usual, that some residual N may be available. So it may very well be worthwhile to plan on using the PSNT or some other assessment of mineral N next spring.

In contrast, P and K applied but not taken up will largely remain in the soil, regardless of winter precipitation. Soil tests in either fall or spring will usually detect the surplus P and K, but the effect of the residual nutrients on the soil test is not likely to be large. Leftover nutrients from a typical nutrient application for corn might increase soil test levels by 3 to 5 parts per million for P and K, assuming the worst-case scenario with zero yield and no nutrient removal from the field. If the drought cuts nutrient removal by only a portion, the increase caused by residual nutrients is likely to be smaller.

Dry soil conditions can also influence the availability of P and K in soils. But it can be hard to predict whether their availability will increase or decrease. Soil K tests will be particularly prone to some large variability from previous years' tests. Generally, soil test K increases with drying for soils with low to optimum K levels, and decreases with drying for soils with very high K levels. However, in recent years in Ontario and other parts of the corn-belt, many are seeing dramatic decreases in soil test K. Many laboratories air-dry all their soil samples before testing, but some use a field-moist sample for K analysis. Under normal conditions, the field-moist sample reduces variability in results from one year to the next, but it may also show a more dramatic change in response to severe drought conditions.

Crop nutrient removal

If the crop produced grain, but with lower yield than normal, nutrient removal will be less than usual. Keep in mind that under drought stress, most cereals like corn and wheat have higher protein, so the reduction in removal of N may be less than the reduction in yield. On the other hand, the lower stover production in drought-stunted corn will likely reduce N immobilization and response to N for the following crop. If crops planted for grain were harvested instead as forage, nutrient removal may be higher than that for a normal crop of grain—especially for K. Only about 20% of the K taken up by the corn plant is normally found in the grain.

Plant analysis can be useful in calculating crop nutrient budgets and balances. Crops harvested as forage may likely have been sampled for nitrate testing. Testing for protein, P and K would provide solid information with which to calculate the true crop removal of nutrients. Measuring nutrient contents in harvested crop portions takes the guesswork out of how the drought affected nutrient removal.

The early and warm growing season also opened more opportunity than usual for double-crop soybeans following wheat. If good weather prevails in the fall, the nutrient removal from the two crops could be quite substantial and should be taken into account in the crop nutrient balance.

Drought-stricken corn *in Maryland 2012. What nutrients will remain for next year?*

Legume N credits

What N credit does a failed soybean crop provide to a subsequent crop of corn? The soybean N credit is a reduction in the N recommended for corn following soybean compared to corn following corn. While the exact causes of this reduction are still under investigation, several contributing factors have been identified. The most commonly cited factor in the N credit is biological N fixation. In an Illinois study comparing nodulated to non-nodulated soybean isolines, soil N supplies were higher after nodulated soybeans than after non-nodulated soybeans (Bergerou et al., 2004). However, both types of soybeans produced higher N supplies than where corn was grown. Consequently, additional factors beyond just biological N fixation are important for determining the N credit.

Soybean also appears to produce a pool of readily mineralizable N in the soil. This pool is thought to come from the soybean roots and the organic compounds they release. Decomposing soybean residue therefore releases N quicker than corn residue - soon enough to be used by the succeeding corn crop, which reduces the amount of fertilizer N needed. During a drought, N mineralization slows, and biological N fixation in soybean nodules lessens. Drought can reduce both the number of nodules on soybean roots as well as the quantity of N fixation in the nodules themselves. All of these changes can result in a decrease in soil N supply for the following corn crop. It is not clear just how much the N credit is affected. Sparse data indicate that the credit may range between half to the full rate normally used.

What N credit does a drought-stressed alfalfa stand provide to a subsequent crop of corn? In the case of forages, the accumulation of readily mineralizable organic N occurs over a longer time period. Much accumulation may have taken place already before the drought. Thus, less reduction in the N credit would be expected.

Cover crops

The early and warm growing season of 2012 opens up more opportunity than usual for cover crops. Some may be planted early owing to early grain harvest, or very much earlier following harvest as forage of crops intended for grain, or following crop abandonment. Planted earlier, cover crops are likely to take up more nutrients before their growth ceases in the fall.

How much of the N captured by a cover crop is made available to next year's crops? Research has not generally been able to show a reliable N credit for cover crops other than legumes, with one exception: both grass and legume cover crops, managed as green manure, can increase the fertilizer equivalence of the N from manure applied in late fall. But in addition, cover crops provide significant benefits to soil organic matter, soil structure, and soil trafficability. The P and K they contain is recycled back to the soil, maintaining the soil test levels of those nutrients. In addition, the N they capture is N loss prevented, and thus reduces impact on the environment through nitrate loss to water or nitrous oxide emitted to the air. So the opportunity for cover crops should not be neglected.

Since forages may be in demand in many areas, some of these cover crops may be harvested as emergency forage. Such harvests can generate substantial nutrient removals that need to be included in the crop nutrient balance.

Summary

The best social, economic and environmental outcomes arise from applying the right nutrient at the right rate, time and place. Drought in many parts of the Northeast in 2012 created a lot of unforeseen changes in nutrient cycles, and this means we need to re-evaluate what "right" means for 2013. Reassessments are critical. Measure the nutrients in the crops removed this year, whether it was grain or forage. Compare that removal to what was planned and reexamine nutrient budgets. Measure what's left in the soil to make informed adjustments to future applications of nutrients. ■

Reference

Bergerou, J.A. et al. 2004. Plant Soil 262:383-394.

Dr. Tom W. Bruulsema
Northeast Director
International Plant Nutrition Institute (IPNI)
18 Maplewood Drive
Guelph, Ontario, Canada N1G 1L8
Phone: (519) 835-2498

E-mail: tom.bruulsema@ipni.net
Website: http://nane.ipni.net

Dr. Douglas B. Beegle
Distinguished Professor of Agronomy, Penn State University

E-mail: dbb@psu.edu

Dr. T. Scott Murrell
Northcentral Director
International Plant Nutrition Institute (IPNI)
PO Box 2539
West Lafayette, IN 47996
Phone: 765-413-3343

E-mail: smurrell@ipni.net
Website: http://nanc.ipni.net

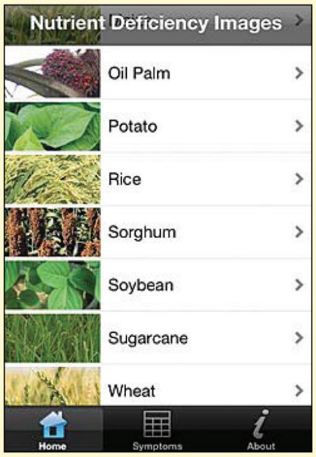
Dr. Gregory Roth
Professor of Agronomy, Penn State University

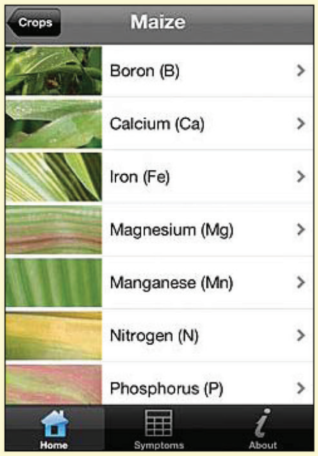
E-mail: gwr@psu.edu

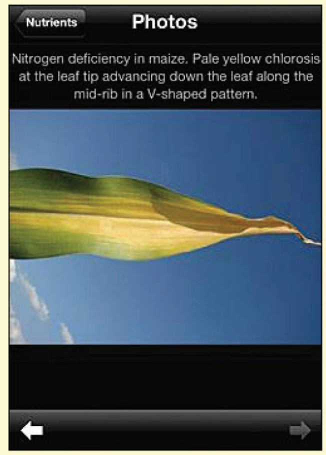
Ref # 12082

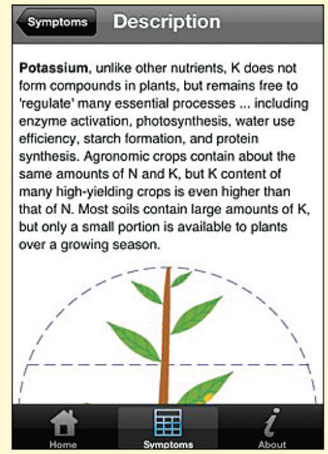
Nutrient Deficiency Photo Application for iPhone/iPad Released

IPNI has released a new Crop Nutrient Deficiency Photo Library app for your iPhone or iPad (see http://info.ipni.net/ndapp). The app contains key photos of classic nutrient deficiency documented from research plots and farm fields for 14 common crops. It also provides supporting text and illustrations of nutrient deficiencies. This mobile app will be a great tool for crop advisers, consultants, farmers, and anyone wanting help in identifying nutrient deficiency symptoms in common crops. BC





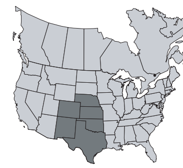




INSIGHTS
IPNI
International Plant Nutrition Institute

September 2012

Crop Nutrition Following the 2012 Drought: South and Central Great Plains



The summer of 2011 brought a record-breaking drought to much of the Southern and Central Great Plains Region. Thus we released newsletters and other information last summer on the topic of fertilizing after a drought. Unfortunately, this is a relevant topic again in 2012. Last year the Sept. 22 US Drought Monitor Map showed severe to exceptional drought covering the entire states of Texas and Oklahoma, most of New Mexico, eastern Colorado, and southern Kansas, while Nebraska was unaffected. The conditions this year have shifted somewhat (see map) as a low pressure system brought needed rain in July to areas in the southern part of the region, but for the most part conditions are still tough, with the majority of the six state region still affected by some degree of drought. The state of Kansas has been especially hard-hit this year, and as a result KSU Extension faculty have been earnestly addressing drought issues. This newsletter will again focus on basic soil fertility and drought.

Where crops fail or are damaged by drought, questions arise on the best ways to handle nutrient management programs going forward. In most cases, the majority of the fertilizer that was applied to unharvested, failed crops should still be there for the next crop—either in the soil or in the crop residue. Farmers will need to do some soil testing to know with best certainty the nutrient status of fields with failed corn and other crops. Farmers will also want to have some idea of the amount of nutrients present in the residue remaining, and how quickly those nutrients will become available to crops. Scientists at KSU have studied drought-affected fields across Kansas to help producers answer questions about residue (*KSU Agronomy E-updates, July 27 and July 20, 2012, see http://www.agronomy.ksu.edu/extension/p.aspx?tabid=58#July_12*)

There are a number of potential sources of nutrients other than applied fertilizers that could contribute to a 2013 crop. These include:

1. Nitrate (NO_3^--N), sulfate (SO_4^{-2}-S), and chloride (Cl^-) in the soil profile
2. Phosphorus (P), potassium (K), and zinc (Zn) in the surface soil
3. Nutrients in crop residues

The first category consists of mobile nutrient forms, and the second category consists of immobile nutrients. The difference is important. Mobile nutrient forms are found in the soil solution and can move through the soil in water, while immobile nutrients generally stay where applied. Of the 14 essential mineral elements, the common **mobile nutrients** in soils we apply as fertilizer are N, S, and Cl^-, and the common **immobile nutrients** we apply as fertilizer are P, K, and Zn.

Mobile nutrients in the soil

A very large portion of those mobile nutrients that were not taken up by the 2012 corn and/or wheat crops are likely to remain in the top foot or two of soil. With the low rainfall in most of the southern and central Great Plains, very little of the NO_3^--N will have been lost. The K-State Soil Testing Lab is seeing higher-than-normal soil test levels for NO_3^--N, reflecting its accumulation in the soil. Any unused SO_4^{-2}-S or Cl^- would also be present in that top foot or two of the soil profile. Most is still in the top few inches and will remain there until we receive some soaking rains.

So the first tool a farmer should think about when planning a 2013 fertilizer program is a deep profile soil test for NO_3^--N, SO_4^{-2}-S, and Cl^-.

Immobile nutrients in the soil

What about P, K, or Zn? Where these nutrients were applied to the 2012 crop, will they still be available for crops in 2013? When immobile nutrients such as P, K, and Zn are applied to the soil, they interact with different portions of the soil and are retained. Note the word *"retained,"* not *"fixed."*

W.M. (Mike) Stewart, IPNI
Southern and Central Great Plains Director
International Plant Nutrition Institute (IPNI)
2423 Rogers Key
San Antonio, TX 78258
Phone: 210-764-1588
Fax: 210-764-1593
E-mail: mstewart@ipni.net
Website: http://nascgp.ipni.net

Dave Mengel
Professor of Agronomy
Kansas State University
3703 Throckmorton Hall
Manhattan, KS 66502
E-mail: dmengel@ksu.edu

Dorivar Ruiz Diaz
Assistant Professor, Soil Fertility and Nutrient Management
Kansas State University
2711 Throckmorton Hall
Manhattan KS, 66506
E-mail: ruizdiaz@ksu.edu

Phosphorus reacts with the clay surfaces, and the iron and aluminum coatings found on the soil particles, and is **sorbed** to those surfaces. Sorption reactions occur in stages, and the initial stages are highly reversible. Sorbed P can be desorbed and go into soil solution, replacing the P taken up by plants. This is a buffering system that maintains a constant small quantity of P in the soil solution and supplies the P needed for good crop growth. This is how we store P in the soil and build soil test values, with little worry about that P being lost. Sorbed P is the primary P fraction in soils measured by a soil test. But the soil test only reflects a fraction of the total P present in the soil. For example, most Kansas soils have an 18:1 buffer factor. If we add 18 lbs of P_2O_5 and it reacts with the soil, becoming sorbed to the clays and other minerals present, the soil test will increase 1 ppm.

So how does this relate to planning for 2013? Any P applied in 2012 for this year's crop that was not taken up was sorbed onto clays and other minerals. This creates a new equilibrium in the soil, and will to some degree increase the soil test values for P. How much P in the soil increases depends on how much P fertilizer was applied and how much, if any, P was taken up by the 2012 crop. Higher soil test values will result in a somewhat lower P fertilizer recommendation.

Potassium is a charged cation, K^+, which is attracted to, and retained on, the soil's cation exchange capacity (CEC). Like sorbed P, exchangeable K maintains a constant supply of K in the soil solution to support plant growth. Also like P, this exchangeable K can be measured by a soil test, and it is a highly buffered system. With K, every 4 to 8 lbs of K_2O added will increase the soil test by 1 ppm. The buffer factor is a function of CEC and soil minerals present. On low-CEC sandy soils this factor is closer to 4, while on high-CEC silty clay loams the value will be closer to 8. Any K applied and not taken up by the 2012 crop would have been retained on the CEC in the surface soil and remains available for 2013. And, the higher K soil test values will result in lower K fertilizer recommendations for 2013.

With Zn, a third mechanism, chelation, helps to retain applied forms of Zn fertilizer. Soil organic matter is a strong natural chelating agent, much like some of the synthetic compounds we buy as fertilizer sources. Zinc sulfate added to soil slowly dissolves. A portion reacts with the organic matter and is retained in soluble, natural organic matter chelates. The vast majority of the Zn that moves to plant roots for uptake is present as a natural soil organic matter chelate. Again, this can be measured by a soil test, and there is a common buffer factor of about 10:1 with the DTPA soil test. If we add 1 lb of Zn, the DTPA soil test value will increase by about 0.1 ppm.

Testing for soil nutrients

The bottom line for soil nutrients is that any N, P, K, S, Zn, and Cl^- added as fertilizer and not taken up by crops is still likely there, and can be measured by soil tests. The mobile nutrient forms (NO_3^--N, SO_4^{-2}-S, and Cl^-) will need to be measured using a deep profile test, while the immobile nutrients (P, K, and Zn) can be measured using a surface sample.

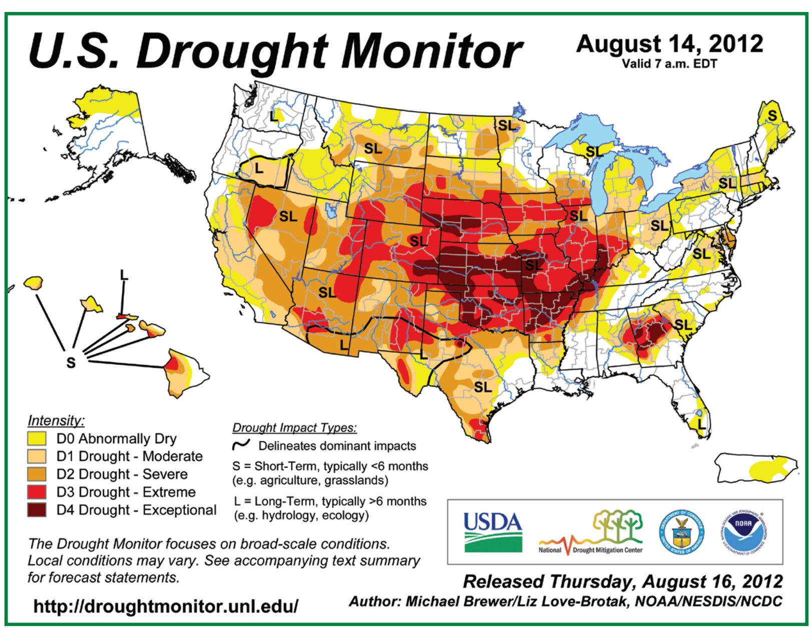
For those planting wheat this fall in these failed crop fields, a profile soil test for NO_3^--N, SO_4^{-2}-S, and Cl^- is a must. Phosphorus and K applications should also be made based on a surface soil sample. For those planting corn or sorghum next spring, it would be best to wait until late winter or early spring to take the profile sample to get a better feel for the amount of the residual N which will be remaining in the soil. Mobile N can be moved below the root zone, especially in sandy soils if we get a wet winter.

Another potentially valuable tool to consider is the use of a crop sensor to help estimate the amount of the N being mineralized from the 2012 crop residues. Kansas has good recommendation systems for both wheat and sorghum to help interpret sensor data. The rate of mineralization will depend greatly on soil moisture and soil temperatures during March through June. A sensor-based N management system can help take some of the risk out trying to take credit for mineralized N.

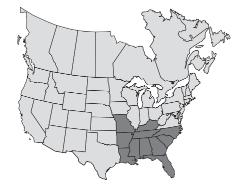
Summary

A significant amount of residual nutrients will be present in many fields where this year's crops failed or were otherwise affected by drought. In severe situations, only a fraction of the nutrients applied were actually taken up by this year's crop. Many of the nutrients remain in the soil and can be measured using soil tests. This is especially true for the mobile nutrient forms such as NO_3^--N, SO_4^{-2}-S, and Cl^- But to get a good estimate of the amounts present, a profile soil test to a depth of 24 in. will be required.

In some cases plant biomass accumulation was significant, but no grain was produced. Where this occurred many of the nutrients taken up by the crop will also be available, especially the K and Cl^-, which are not incorporated into organic compounds in the residue. However the N, P, and S must be mineralized as the vegetation decays. This process will likely be faster than normal, and will increase the availability of these nutrients. But the exact rate of mineralization will depend on the weather, and is difficult to estimate. Crop sensors can help take some of the risk out of crediting these mineralized nutrients. ■



IPNI INSIGHTS
INTERNATIONAL PLANT NUTRITION INSTITUTE



September 2012

Crop Nutrition Following the 2012 Drought: Southeast

The drought during the spring and summer of 2012 was one of the most damaging and widespread that growers across the US had experienced in decades. A drought of this magnitude can definitely affect nutrient uptake, retention, and behavior in soils and the way nutrients may need to be managed for post-drought crops. Unfortunately for farmers in the Southeast US, dealing with a drought is business as usual. When asked about management changes in response to this year's drought, the typical response among southern growers has been along the lines of "nothing different; this happens every year". While "this happens every year" is an obvious exaggeration, an analysis of historical US Drought Monitor data revealed that dealing with at least moderate drought is, in fact, common in the Southeast region.

Drought Frequency and Severity in the Southeast

Looking at the past ten years during the period between March and September, only twice did the IPNI Southeast region average below abnormally dry on the Drought Monitor. In three years the region was abnormally dry and five times over the past ten, the data show that the majority of the region was under moderate to severe drought conditions for most of the spring/summer growing season. All states in the region have experienced extreme to exceptional drought conditions at least three out of the past ten years, while AL, FL, GA, and SC endured the worst categorized drought at least five times since 2006. This fact is not surprising as these states make up the Southern Coastal Plain, which is characterized by coarse-textured, low cation exchange capacity (CEC) soils that can get dry in a hurry. Conversely, the states least prone to drought stress are the northern-most states in the region, KY, MO, and TN, where the soils have a much greater water holding capacity.

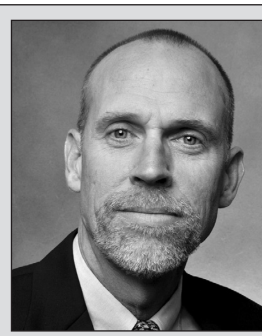
Another contributor to the frequent drought stress in the Southeast is inconsistent rainfall. In many years, total volume of precipitation will be normal, but the erratic distribution leads to drought conditions. While extreme to exceptional drought happens most often in July and August, severe drought conditions occur just as frequently in the spring as in mid-summer.

So while living with drought is a reality in most years for growers in the Southeast, 2012 was significant in terms of reduced yields in rain-fed crops, crop failure or abandonment, and harvesting crops for other than the intended purpose (hay rather than grain). These factors result in nutrient management implications that need to be considered going into 2013.

Nutrient Removal

With the exception of some hay and pasture, most crops in the region received nutrient forms application rates appropriate for typical yield levels. The reduced yields, especially in dryland corn, will certainly leave residual nutrients in the field. Excess levels of mobile nutrient forms like nitrate (NO_3^-) and sulfate (SO_4^{-2}) are susceptible to leaching; but even in the sandy Coastal Plain soils, NO_3^- will not move through the soil profile without water. Many states in the Great Plains and Midwest will use inorganic soil N tests to measure the residual N contribution for 2013 crops; however, in the Southeast, this practice is of little value. Normal winter precipitation in the region is more than adequate to leach any remaining NO_3^- out of the soil profile and no contribution to next year's crops should be counted on, even following the extreme drought conditions of 2012. **Figures 1** and **2** illustrate the average rainfall and NO_3^- leaching potential for a Southern Coastal Plain soil. **Figure 2** demonstrates that under normal winter precipitation, NO_3^- can migrate two to three feet during the time between fall harvest and spring planting of a cotton crop in Central Alabama.

Dr. Steve Phillips
Southeast Region Director
International Plant Nutrition Institute (IPNI)
3118 Rocky Meadows Road
Owens Cross Roads, AL 35763
Phone: 256-529-9932
E-mail: sphillips@ipni.net
Website: http://nase.ipni.net



Dr. Nathan Slaton
Professor & Director of Soil Testing
University of Arkansas Division of Agriculture Crop, Soil, and Environmental Sciences Department
1366 West Altheimer Drive
Fayetteville, AR 72704
E-mail: nslaton@uark.edu

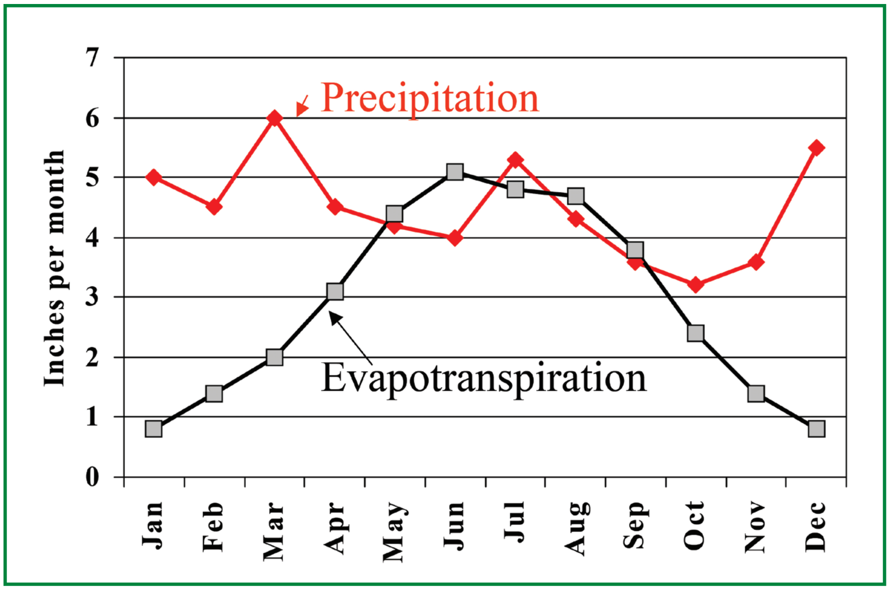


Figure 1. Average monthly precipitation and evapotranspiration (plant use and evaporation) for Central Alabama. (Ward et al., 1959 as presented in Mitchell, 2001).

Soil Testing

When collecting soil samples following an extreme drought, it is advisable to wait until a few weeks after a rain. If this is not possible and the ground is not too hard to sample, there are some issues that growers and advisers need to be aware of. First, the seasonal variability in soil test K is well known and substantial and can be even more pronounced under drought conditions. The amount of variation depends on the amount and type of clay present, the severity of the drought when the sample is collected, and the available K levels under normal soil moisture conditions. All of this potential variation in measuring soil test K makes collecting the samples from a consistent depth even more important. In a drought year, K and other nutrients will be concentrated near the surface. When sampling in a field with hard, dry soil, it is easy to pull the sample from too shallow of a depth. A soil sample collected from the wrong depth can result in an incorrect fertilizer recommendation.

Depending on the timing and volume of fall moisture, some growers may consider planting a cover crop to sequester some of the unused N. Most cover crops in the South are used as a moisture and soil conservation practice and little data exist on using them as catch-crops. More details on this practice are covered in other papers in this *INSIGHTS* collection.

Residual amounts of immobile nutrients like phosphorus (P) and potassium (K) will also be higher following reduced yields or crop failure and should result in lower fertilizer need in the following year. In the sandier soils in the region found throughout south GA and FL, excess K can leach with winter rains and become unavailable to the next spring's crop. The best way to determine the nutrient levels available for the crop following a drought is a soil test.

Another situation that can affect nutrient removal in a drought year is when the crop is harvested for hay rather than grain. Baling drought-stressed corn is a common practice in the more severely affected areas of the region. This practice salvages some value from the drought-stricken crop, but results in a higher nutrient removal than if the crop were only harvested for grain and the stover remained in the field. The quantity of nutrient removed in the hay is difficult to estimate because the crop is usually harvested at a different stage than if it were initially intended to be a forage crop. Also, the nutrient content of the plants will vary according to how badly the crop was stressed. In addition to baling the failed crops, many growers in the region are planning on baling the straw from irrigated rice, corn, soybean, and peanut crops to offset the hay shortages. This practice will also result in greater nutrient removal that will need to be accounted for. Just like in the failed crop situation, the number one tool to ensure the nutrient needs for the following crop will be met under these circumstances is a soil test.

Soil pH can also be misleading under drought conditions. The lack of water movement and restricted nutrient uptake results in a concentration of soluble salts in the soil surface that lowers soil water pH. This is a temporary decrease and pH will come up 0.2 to 0.6 units once soil moisture returns to normal. This is why it is good to wait until after it rains to begin collecting soil samples for the next crop. Some soil test laboratories measure soil pH in a salt solution (called salt pH rather than water pH), which minimizes or eliminates the soluble salt effect. Therefore, it is important to check soil test reports or with the laboratory to determine which method was used to measure pH. In most public and private soil testing laboratories in the South, a buffer pH (BpH) is measured and used to estimate liming requirement. The buffer is a salt solution and is not affected by the increased soluble salts

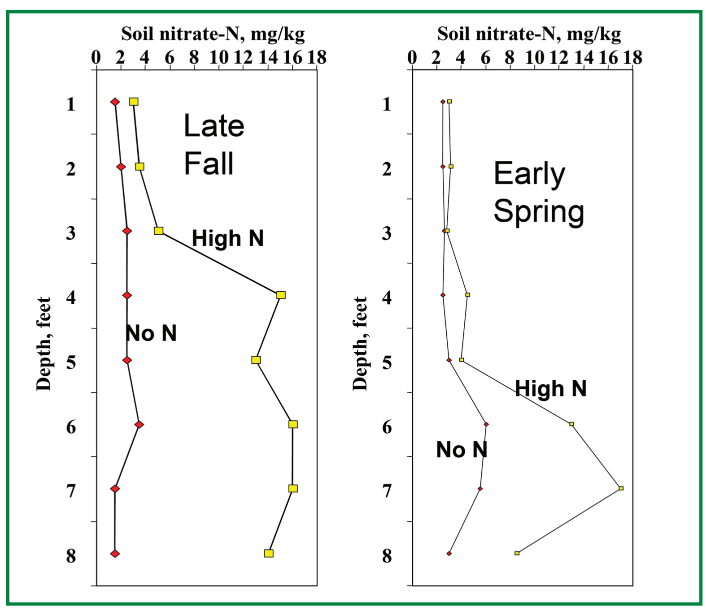


Figure 2. Soil nitrate movement in a Benndale sandy loam in Central Alabama. (Jackson,1998 as presented in Mitchell, 2001).

in the sample, so even though a water-pH will provide an erroneous low reading, unnecessary lime will not be recommended. Another consideration regarding pH and liming is that during extended drought periods like happened in 2012, lime applied in the spring may not have had sufficient moisture to react with the soil. In these cases, recommended lime may not be necessary.

Since drought conditions can lead to somewhat unpredictable changes in soil test results, growers should compare their soil test results (from this coming fall) against the results from previous years. That said, growers should be aware that rapid changes in soil nutrient availability indices may occur on low CEC soils subjected to greater than normal amounts of nutrient removal (e.g., grain and stubble removal), but on soils with moderate to high CEC, soil test nutrient values may not change appreciably from one year to the next, especially when annual fluctuations from temporal and spatial variability are considered. Knowledge of each field's history of nutrient deficiency problems (if any), applied fertilizer sources and rates, and soil test history are all important considerations in making nutrient management decisions for 2013.

Summary

4R Nutrient Stewardship is applying the right nutrient source at the right rate, at the right time, and in the right place. Considering the economic toll taken this year, all of the uncertainty surrounding nutrient removal in drought-stricken crops, and the variability in soil test results collected under drought conditions, determining what is "right" in 2013 will be more challenging than ever. Even in the Southeast where "this happens every year". ■

References

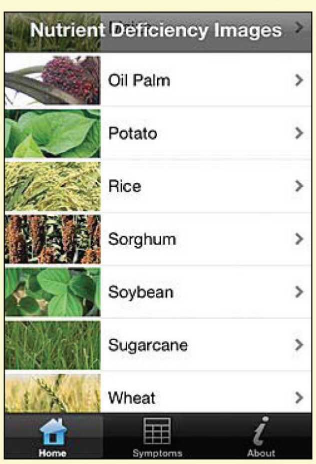
Jackson, S.E. 1998. Nitrogen movement under long-term fertilization and cropping in two Alabama soils. M.S. Thesis. 84 pp. Auburn University, AL.

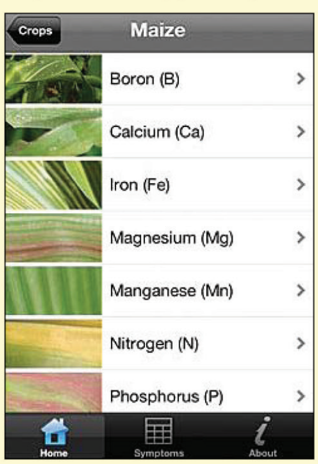
Mitchell, C. 2001. Late fall and winter application of nutrients to cool-season forages in Alabama. Ala. Coop. Ext. Serv. No. S-01-01. Auburn, AL.

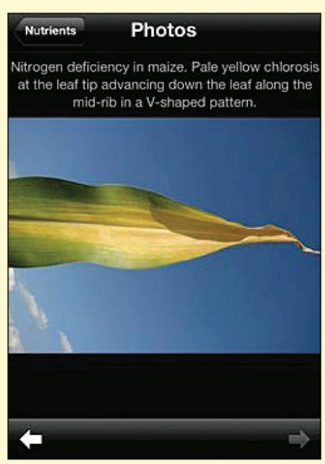
Ward, H.S., C.H.M. van Bavel, J.T. Cope, Jr., L.M. Ware, and H. Bouwer. 1959. Agricultural drought in Alabama. Ala. Agric. Exp. Stn. Bul. 316. Auburn, AL

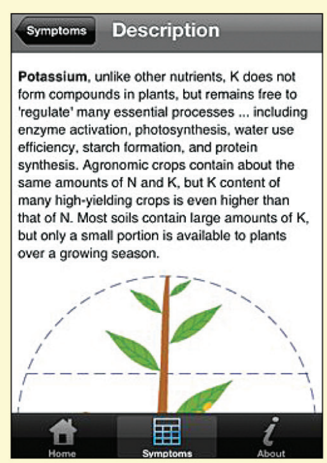
Nutrient Deficiency Photo Application for iPhone/iPad Released

IPNI has released a new Crop Nutrient Deficiency Photo Library app for your iPhone or iPad (see http://info.ipni.net/ndapp). The app contains key photos of classic nutrient deficiency documented from research plots and farm fields for 14 common crops. It also provides supporting text and illustrations of nutrient deficiencies. This mobile app will be a great tool for crop advisers, consultants, farmers, and anyone wanting help in identifying nutrient deficiency symptoms in common crops. BC









IPNI INSIGHTS
International Plant Nutrition Institute

September 2012

What About the Water?

Agriculture is the largest user of fresh water in the world and as demand grows for more food production, conflicts regarding water use are inevitable. In some areas, additional investment in irrigation and water supplies may provide room for further expansion of irrigated cropland. However in most areas of western North America, water is no longer in abundant supply and ferocious arguments erupt over water allocation. Since new supplies of irrigation water appear unlikely, there is significant incentive to improve water use efficiency. The pressure on the agricultural industry to carefully conserve water resources will certainly intensify.

Water uptake and plant nutrient absorption are closely related. When plant roots take up water, dissolved nutrients are carried to the root surface. When water uptake is restricted, the delivery of nutrients to the root also slows down. As the soil dries and the films of water between the particles shrink, the processes of mass flow and diffusion that bathe the roots with nutrients eventually come to a halt **(Figure 1)**.

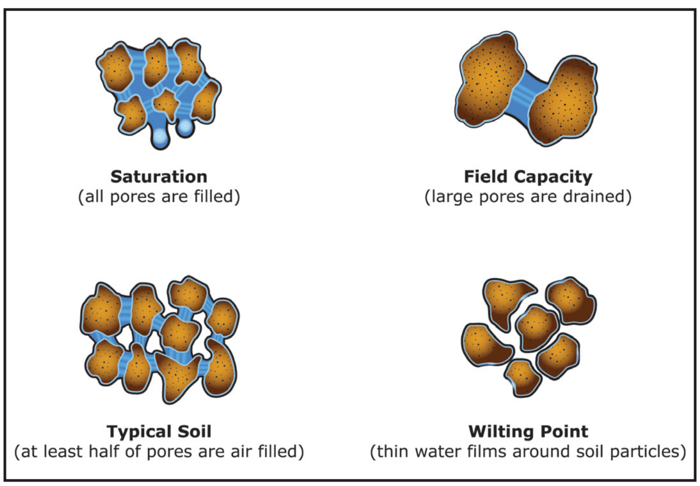
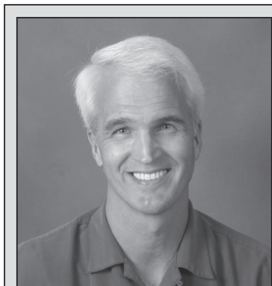


Figure 1. As soil dries, water films become thin and nutrient movement and uptake are reduced.



Dr. Robert Mikkelsen
Western North America Director
International Plant Nutrition Institute (IPNI)
4125 Sattui Court
Merced, CA 95348
Phone: 209-725-0382
E-mail: rmikkelsen@ipni.net
Website: www.ipni.net

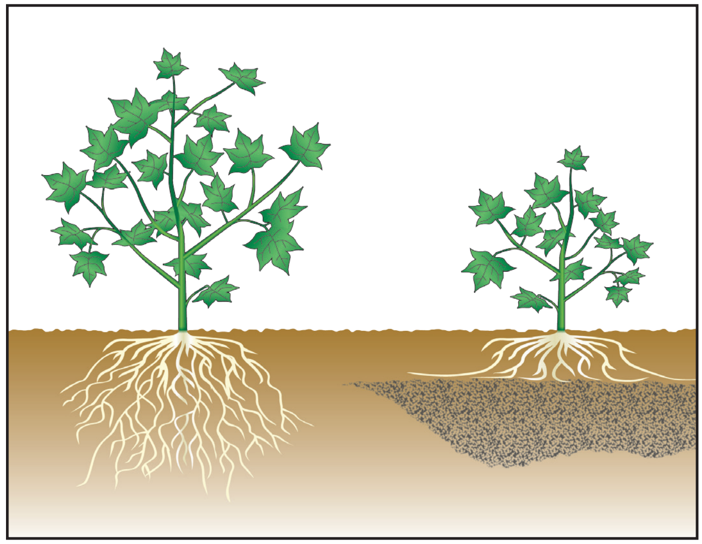


Figure 2. Soil factors that limit root growth will reduce water and nutrient uptake. These limitations become particularly severe during period of stress. These root restrictions may include hard pans, compacted soil, or acid subsoil.

Water use efficiency has several definitions. The most common usage is the ratio of the amount of water required to grow a crop compared with the amount of water actually applied by farmers (or supplied in rainfall). Sometimes it refers to economic efficiency (related to the economic benefits and costs of water use). The economic considerations include the cost of water delivery, the opportunity costs of irrigation and drainage, and any third party benefits or costs.

Healthy roots and water use

An important step towards improving water use efficiency is to encourage healthy plant roots. Maintaining proper soil conditions will enhance the volume of soil that roots explore. For example, a soil that has a compacted zone or a hard pan will present a barrier to plant roots and restrict their use of moisture deeper in the soil profile. Similarly, when subsoil acidity is not addressed, plant growth is stunted and roots cannot grow deep into the soil to utilize water and nutrients **(Figure 2)**.

Notes and Abbreviations: K = potassium; Ca = calcium; Mg = magnesium; Na = sodium; H = hydrogen; Al = aluminum; Cu = copper; Fe = iron; Mn = manganese; Ni = nickel; Zn = zinc; NH_4^+ = ammonium

How much water?

Plant species differ widely in their water requirements. One measure that is sometimes used is the "transpiration ratio", or the amount of water used to produce one pound of harvested product. While this number will vary depending on local conditions, some approximate figures are given in **Table 1**.

Table 1. Approximate amount of water required by various crops to grow one pound of harvested product (transpiration ratio).

Crop	Gallons of water/lb of dry matter
Alfalfa	100
Soybean	80
Oat, Potato	70
Wheat	66
Sugar beet	45
Corn	42
Sorghum	36

From Chrispeels, M.J. and D.E. Sadava (eds). 2002. Plants, Genes, and Crop Biotechnology. 2nd Ed. Jones and Bartlett, Sudbury, MA.

Plants grown with adequate nutrition typically have larger tops and root systems compared with crops grown with an inadequate nutrient supply. These well-fertilized plants are generally larger and may have greater water loss (transpiration), but a lower transpiration ratio. In other words, the healthy plant may use more water, but will generally produce larger yields. This translates into more yield per gallon of water extracted from the soil. Another way to say this is that greater water use efficiency results from proper plant nutrition.

How much water is in our food?

It seems like there is rarely enough water in western North America to meet everybody's needs. Especially after several years of prolonged drought in many areas, farmers are stressed to learn that there may be insufficient water to grow their crops.

A common cry from the urban areas is that agriculture uses more than its "fair share" of water. Some estimates have been made that more than 80% of developed water is going to agriculture in many areas. Attention is drawn to the fact that agriculture loses too much water through cracks, seepage, and evaporation from the miles of canals and pipelines. These losses should be addressed when financing is available.

Most consumers do not appreciate the large amount of water required to grow plants. A poorly understood concept is that a huge amount of water is indirectly delivered to cities in the form of food. A report by the Water Education Foundation documented the amount of water required to produce various foods in the western U.S. Their basic approach was to divide average water use (evapotranspiration) by average yields to determine the gallons of water per pound of food produced. Since some of the water delivered to a farm is unavoidably lost as deep percolation, runoff, or soil moisture storage, the irrigation efficiency was assumed to be 70%.

Using a typical 2,300-calorie menu proposed by the U.S. Department of Agriculture, the following meal was constructed and the gallons of water required to produce that particular food item are shown.

Breakfast	**Gallons of water per day**
One medium orange	14
Two eggs	126
Two slices of toast	22
Two pats of butter	92
One cup of milk	48
One quarter cantaloupe	40
	342 gallons
Lunch	
Taco salad (tomato, lettuce, hamburger, chips, and cheese)	806
One-quarter cantaloupe	40
	846 gallons
Snack	
One-quarter cup of almonds	160
One cup of yogurt	88
One cup of orange juice	49
	297 gallons
Dinner	
Chicken broccoli stir-fry	180
One cup of rice	50
Two slices of bread	22
Two pats of butter	92
Fruit cup	35
One cup of milk	48
	427 gallons
Total	**1,912 gallons**

Do farmers use a lot of water?

Yes… and we all benefit tremendously from their productivity. The water may not only come from our faucets, but it also comes to us in every bite we take.

Proper plant nutrition is a vital key to achieving efficient use of water. Nitrogen deficiencies have an impact on the ability of a crop to convert available water into yield. **Phosphorus** is important in stimulating seedling root development. This helps the plant explore more soil, increasing the recovery of nutrients and water. **Potassium** is often referred to as the regulator nutrient, influencing the water dynamics in plants. **Nutrients play an essential role in allowing plants to convert water and sunshine into food.**