Agricultural Fertilizer Applicator Certification
Training Manual

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Requirements for Certified Agricultural Fertilizer Applicators

Who Needs to be Certified Under the New Agricultural Nutrient Law Senate Bill 150?

Fertilizer certification is required by September 30, 2017 if you apply fertilizer to more than 50 acres of agricultural production grown primarily for sale. Under this law, fertilizers are materials that contain one or more recognized plant nutrients and have a guaranteed analysis. Limestone, manure and other residual farm products are excluded unless they are mixed with fertilizer materials. A certificate is not required if you only use starter fertilizer through the planter, or if a certified applicator makes the application for you.

Call the Ohio Department of Agriculture at 614-728-6987 if you are unsure whether your crop is grown primarily for sale, or primarily for livestock or other purposes. Both horticultural and agronomic crops are included in this law.

Direct Supervision

You may apply fertilizer to more than 50 acres without the certificate if making that application under the instruction and control of a certified applicator who is an immediate family member, or employed by the same business. Instructions must include where, when, and how to apply the fertilizer. The responsible certified applicator must be within 25 miles or 2 hours travel from the applicator during the application.

Certification Process

There is no distinction between commercial and private fertilizer applicators. There are procedural differences for certifying Ohio licensed pesticide applicators and non-licensed pesticide applicators.

If no pesticide license, fertilizer applicators are certified by:

1. Attending a three hour Ohio Department of Agriculture (ODA)-approved training provided by OSU and completing the forms at the end of the meeting
2. Submitting an application and
3. Paying a $30 fee to the ODA.

The ODA sends the application after the training is completed; once the fee and application are received, the ODA mails the fertilizer certificate.

For Licensed Pesticide Applicators. There is a different initial fertilizer certification procedure for pesticide applicators licensed in the State of Ohio, and no fee for the fertilizer certificate. Pesticide applicators may attend the two or three hour ODA-approved certification programs that are offered with OSU pesticide applicator recertification programs. At the end of the certification training, pesticide applicators will complete a form. They are not required to fill out a separate application or pay a fee; the ODA will mail the fertilizer certificate after the training as long as the form was filled out and returned at the end of the certification meeting.

Certified Crop Advisers and Certified Livestock Managers need a fertilizer certificate if applying to more than 50 acres, but are not required to attend training programs if they submit proof of their credentials to the ODA with the fertilizer certificate application.

Non-licensed pesticide applicators are able to sign up for three hour certification meetings at **nutrienteducation.osu.edu**

Pesticide applicators are able to sign up for two hour fertilizer certification meetings at: **pested.osu.edu**

Recertification

After the initial certification, fertilizer applicators will maintain certification by attending two hours of approved training and submitting the $30 fee to the ODA with a renewal application every three years.

There are differences for those with and without a pesticide license. The $30 renewal fee is waived for pesticide applicators. For non-licensed pesticide applicators, the fertilizer certification year begins June 1 and ends May 30, and recertification hours must be earned every three years prior to the May 30 deadline.

For pesticide applicators, the fertilizer recertification deadline will synchronize with the pesticide license deadline, regardless of when the fertilizer certificate was earned.

For example, if a licensed pesticide applicator renewed the pesticide license in 2016 and obtains a fertilizer certificate for the first time in 2017, both will expire on the pesticide license deadline in 2019.

For private pesticide applicators, the certification deadline for both fertilizer and pesticides will be March 31; for commercial pesticide applicators, September 30.

Fertilizer applicators will not be able to recertify in the first year of the three year cycle.

What is a Voluntary Nutrient Management Plan?

A voluntary nutrient management plan is one of the following:

1. A nutrient management plan in the form of the Ohio nutrient management workbook made available by the Ohio State University;
2. A comprehensive nutrient management plan developed by USDA - Natural Resources Conservation Service, a technical service provider certified by the conservation service, or a person authorized by the conservation service to develop a plan;
3. A document that is equivalent to a plan specified in the above bulleted points that is approved by the Director of the Ohio Department of Agriculture director and that contains the following information:
    - » Soil tests that have been conducted within the last three years to standards described in Ohio Revised Code;
    - » Documentation of the method and seasonal time of utilization and application of nutrients;
    - » Identification of all nutrients applied, including manure, fertilizer, sewage sludge, and biodigester residue;
    - » Field information regarding land subject to the plan, including the location, spreadable acreage, crops grown, and actual and project yields.

For more information about the law, go to: agri.ohio.gov/apps/odaprs/pestfert-PRS-index.aspx?ols=CommercialFertilizerCert.htm

Affirmative Defense for Private Civil Action

The law provides an affirmative defense for Private Civil Action if these three conditions are met:

1. The fertilizer applicator is certified, or applying fertilizer under the direct supervision of a certified applicator.
2. The required fertilizer application records were maintained.
3. The fertilizer has been applied according to and in substantial compliance with a Voluntary Nutrient Management Plan (VNMP). The VNMP may be developed using the Ohio Nutrient Management Workbook, or a comprehensive nutrient management plan developed by the NRCS, or a document equivalent to these that identifies all nutrients applied. VNMPs are submitted for approval every five years to the Soil and Water Conservation District or to the designee of the Director of the Ohio Department of Agriculture.

Manure from Concentrated Animal Feeding Facility (CAFF)

In Ohio, no person may apply manure from a concentrated animal feeding facility (CAFF) without a permit from ODA unless:

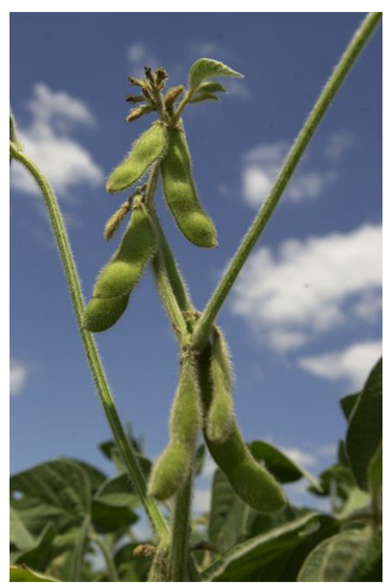
- The person is an Ohio Certified Livestock Manager (CLM)

  OR

- The person has been certified through the Agricultural Fertilizer Applicator Certification Training (FACT).

This became effective in July, 2015 with Senate Bill 1 (SB1).

For more information about the agricultural fertilizer applicator certification, visit nutrienteducation.osu.edu or call 614-292-4070.



Application Record Requirements for Certified Fertilizer Applicators

Record the following information within 24 hours of application:

- Name of certified fertilizer applicator (always required)
- Name of uncertified applicator working under direct supervision of certified applicator (if any)
- Date of application
- Location, field ID
- Fertilizer analysis of all fertilizers used (e.g., 11-52-0)
- Fertilizer application rate(s) (lbs./Acre)
- Total acres (not required but recommended)
- Fertilizer application method (e.g., surface-applied, incorporated, injected)
- Soil conditions at time of application (e.g., moisture)
- Temperature and precipitation conditions at time of application
- For surface applications only: ground frozen or snow-covered (yes/no)?
- Weather forecast through day following application

Fertilizer application records must be kept for three years. Certified applicators who make applications for others are responsible for keeping the record, but also must provide a copy to the farm operator within 30 days. The recordkeeping form on the next page is only a suggested format. There is no format requirement; however, the records must contain all required items.

Recordkeeping Tools

Ohio Nutrient Management Record Keeper is an app that contains all the required items for certified fertilizer applicators. The app is available at ONMRK.com and for use with Android or iOS.

This Excel spreadsheet is a digital copy of the sample recordkeeper form found on the next page: nutrienteducation.osu.edu/sites/nutriented/files/imce/Copy%20of%20SampleFertApplicationRecordForm.xlsx

Agricultural retailers may also have access to other application software that meets the requirements as well.

Frequently Asked Question about Agricultural Fertilizer Applicator Certification

Q. I am an Ohio licensed pesticide applicator. Can I be certified in fertilizer application by attending a 3 hour certification program?
A. The two-hour meetings held with pesticide applicator recertification were conceived for the convenience of pesticide applicators, but you can attend and be certified at the 3-hour meetings. Note, those without an Ohio pesticide license cannot be certified by attending a 2-hour meeting.

Q. How are immediate family members defined for direct supervision?
A. Immediate family member includes spouse, parents, children, grandparents, siblings, grandchildren, in-laws (brother-, sister-, son-, mother-, and father-in-law); step-children, step-siblings, step-parents, or a legal guardian.

Q. Does this law cover grain field crop production only?
A. No, nursery, greenhouse or any other type of agricultural production grown for sale are included if exceeding 50 acres of production.

Q. Does my acreage have to be all in one location or all one crop?
A. No, add the acreage in multiple crops or in multiple parcels of land that you fertilize to determine whether you meet the 50+ acre criteria.

Ohio Agricultural Fertilizer Applicator Recordkeeping Form

Maintain records for 3 years from date of application

Who: Name of certificate holder:

Name of Applicator (if different than above):

When: (mm/dd/yyyy)							
Application date							
Where:							
Location							
What:							
Fertilizer analysis							
Rate applied							
Type of application method							
Application conditions:							
Soil conditions							
Air temperature							
Precipitation							
Soil frozen or snow covered (Y/N)							
Weather forecast:							
24 hour forecast following application							

Notes:

Fertilizer and Manure Regulations for Northwestern Ohio Counties

New regulations for manure and fertilizer application started on July 3, 2015 when Senate Bill Number 1 came into effect. The legislation affects nitrogen and phosphorus application whether applied as manure or fertilizers. The regulations are targeted specifically to define watersheds that encompass the Western Lake Erie Basin (WLEB). This article summarizes important provisions but does not substitute for the legislative text which is found in Ohio Revised Code and Ohio Administrative Code. The regulations are administered through the Ohio Department of Agriculture.

Fertilizer Application Restrictions (in the Western Basin Only)

For applications of fertilizer in the western basin, a person may not apply fertilizer, defined as nitrogen or phosphorous, under these conditions:

1. On snow-covered or frozen soil, or
2. When the top two inches of soil are saturated from precipitation, or
3. In a granular form when the local weather forecast for the application area contains greater than a 50% chance of precipitation exceeding one inch in a twelve-hour period, unless the fertilizer is injected into the ground, incorporated within 24 hours of surface application or applied onto a growing crop.

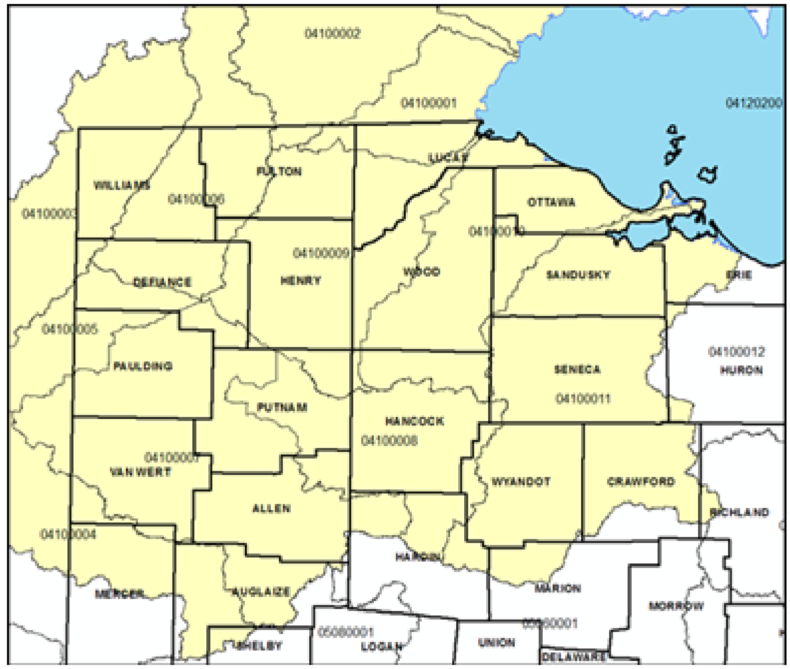


Figure 1. Watersheds and Associated Counties in the Lake Erie Western Basin Watershed.

Table 1. Watersheds and associated counties in WLEB.

Counties	Watersheds Names and Hydrologic Unit Code
Williams, Fulton, Lucas, Defiance, Henry, Paulding, Putnam, Hancock, Huron, Van Wert, Allen, Mercer, Auglaize, Hardin, Shelby, Wood	St. Mary's Lake (04100004) Auglaize River (04100007) Blanchard River (4100008) Lower Maumee River (04100009) Upper Maumee River (04100005) Tiffin River (04100006) St. Joseph River (04100003) Ottawa River (04100001) River Raisin (04100002)
Wood, Ottawa	Cedar-Portage River (04100010)
Wyandot, Crawford, Richland, Marion, Seneca, Sandusky, Erie	Sandusky River (04100011)

Manure Application Restrictions (in the Western Basin Only)

A person may not surface apply manure in the western basin under any of the following circumstances:

1. On snow-covered or frozen soil;
2. When the top two inches of soil are saturated from precipitation;
3. When the local weather forecast for the application area contains greater than a 50% chance of precipitation exceeding one-half inch in a 24 hour period unless the manure is injected into the ground, incorporated within 24 hours of surface application, applied onto a growing crop, or if in the event of an emergency, the chief of the division of soil and water resources or the chief's designee provides written consent and the manure application is made in accordance with procedures established in the United States department of agriculture natural resources conservation service practice standard code 590 prepared for this state.

Facilities currently permitted as Confined Animal Feeding Operations (CAFO) and Certified Livestock Managers (CLM) must continue to follow more restrictive criteria based on soil hydrologic classification noted in the facility permit.

How Will Application Terms be Defined?

The following information are working definitions provided by the Ohio Department of Agriculture.

Snow covered soil is defined as soil or residue lying on the soil, that cannot be seen because of snow cover, or soil covered by one-half inch of ice or more.

Frozen soil is ground that is impenetrable because of frozen soil moisture. The restriction is intended to prevent situations where fertilizer or manure is unable to freely infiltrate the soil and therefore would likely run off to surface water. Generally, frozen soil will:

1. Not be easily penetrated by a metal object (such as a knife, screwdriver, or shovel),
2. Not deform to show a visible imprint under downward pressure, and
3. Have a temperature below 32° F.

Saturated soil occurs when all the pore spaces in the soil are filled with water. A soil that has an available water capacity above field capacity will be considered saturated. According to the Natural Resource Conservation Service Standard 590 for Ohio, when the available water capacity of a soil is above field capacity, then free water will appear on the surface of the soil when the soil is bounced, kneaded, or squeezed. For a fertilizer or manure application to be considered a violation of the law, the top two inches of the soil would need to be saturated and the application would have been made without incorporation, injection or a growing crop.

Growing crops will vary by season. In the summer, a growing crop is any green plant that will be harvested or that was planted as a cover crop. In the winter, a growing crop is any plant that will be harvested or that was planted as a cover crop and that will not winter-kill. Plants in dormancy will be considered growing crops, as long as the plant species typically "greens up" and continues to grow in the spring. For practical purposes, a growing crop has emerged from the ground and provides reasonable ground cover.

Injection means placing the fertilizer or manure beneath the soil surface. The applied material is retained by the soil and does not concentrate or pool at or below the soil surface. If fertilizer or manure is injected, then the application is not a violation of the WLEB restrictions.

Incorporation is tillage that mixes the fertilizer or manure into the soil to an average minimum depth of four inches and mixes the fertilizer or manure with surface soil so that at least 80% of applied material is covered with soil. If surface applied fertilizer or manure is incorporated within 24 hours of application, then the application is not a violation of the WLEB restrictions.

This article summarizes important provisions but does not substitute for the legislative text which is found in Ohio revised code sections 6109.10, 903.40, 905.326, 905.327, 1511.10, 1511.11, 3745.50 and 6111.32 plus subsequent rule making by the state agencies. Full text of the civil penalty rules can be found at codes.ohio.gov/oac/901%3A5-4

Exemption Request Process for Small Operations

Small agricultural operations may apply for a temporary exemption from the law's restrictions on manure applications. This exemption will expire July 3, 2017. Size of operation is defined in Ohio Revised Code (ORC) and is summarized in Table 2. The chief of the division of soil and water resources may grant the exemption if the operation is working toward compliance.

An exempted operation may request technical assistance to reach compliance, and will not be subject to civil penalties for violations. The law defines small agricultural operations in the same way as the Livestock Environmental Permitting program, based on the number of livestock according to species.

Complaints and Penalties

The trigger for an investigation is a complaint by any person or information received by the state authority that a violation has occurred. Both the Fertilizer and Manure rules give the appropriate state authority the ability to assess civil penalties that shall not exceed $10,000 per violation. The right to a hearing and other administrative procedures are defined.

Table 2. Ohio Classification of Livestock Operation by Animal Numbers. *Source ORC 903.01*

Livestock	Major CAFO 10 times large	Large	Medium	Small
Mature Dairy	7,000	700	200-699	<200
Veal Calves	10,000	1,000	300-999	<300
Cattle-not mature dairy or veal	10,000	1,000	300-999	<300
Swine =>50lbs.	25,000	2,500	750-2,499	<750
Swine < 50 lbs.	100,000	10,000	3,000-9,999	<3,000
Horses	5,000	500	150-499	<150
Sheep or Lambs	100,000	10,000	3,000-9,999	<3,000
Turkey	550,000	55,000	16,500-54,999	<16,500
Layer or Broiler liquid manure	300,000	30,000	9,000-29,999	<9,000
Chicken other than laying, not liquid manure	1,250,000	125,000	37,500-124,999	<37,500
Laying Hen not liquid manure	820,000	82,000	25,000-81,999	<25,000
Ducks	50,000	5,000	1,500-4,999	<1,500

Obtaining Precipitation Information to Meet 12 and 24 Hour Forecast Criteria

New Ohio regulations in targeted watersheds in the Western Lake Erie Basin require considering ground conditions and predicted rainfall prior to granular fertilizer and manure applications started on July 3, 2015.

For granular fertilizer, applications should not occur when the local forecast contains greater than a 50% chance of precipitation exceeding one inch in a twelve-hour period. For manure, application should not occur when the local forecast contains greater than a 50% chance of precipitation exceeding one-half inch in a 24 hour period. It is recommended that forecast information be printed off prior to planned applications. This requires the applicator to show proof of reviewing the forecast if actual rainfall exceeds the predicted rainfall.

A good source of a printable local forecast can be obtained from National Oceanic and Atomospheric Administration (NOAA) through the website: weather.gov. A zip code location close to the application site can be entered on the website. A detailed hourly forecast graphic can be reviewed and printed off as seen in Figure 2.

Rainfall can be totaled from the graphic to obtain the needed 12 or 24 hour predicated rainfall. A short video presentation showing how to obtain the forecast can be found on the OSU Agronomic Crops Team You Tube Channel at: youtube.com/watch?v=Z7Ip8hsL4bA

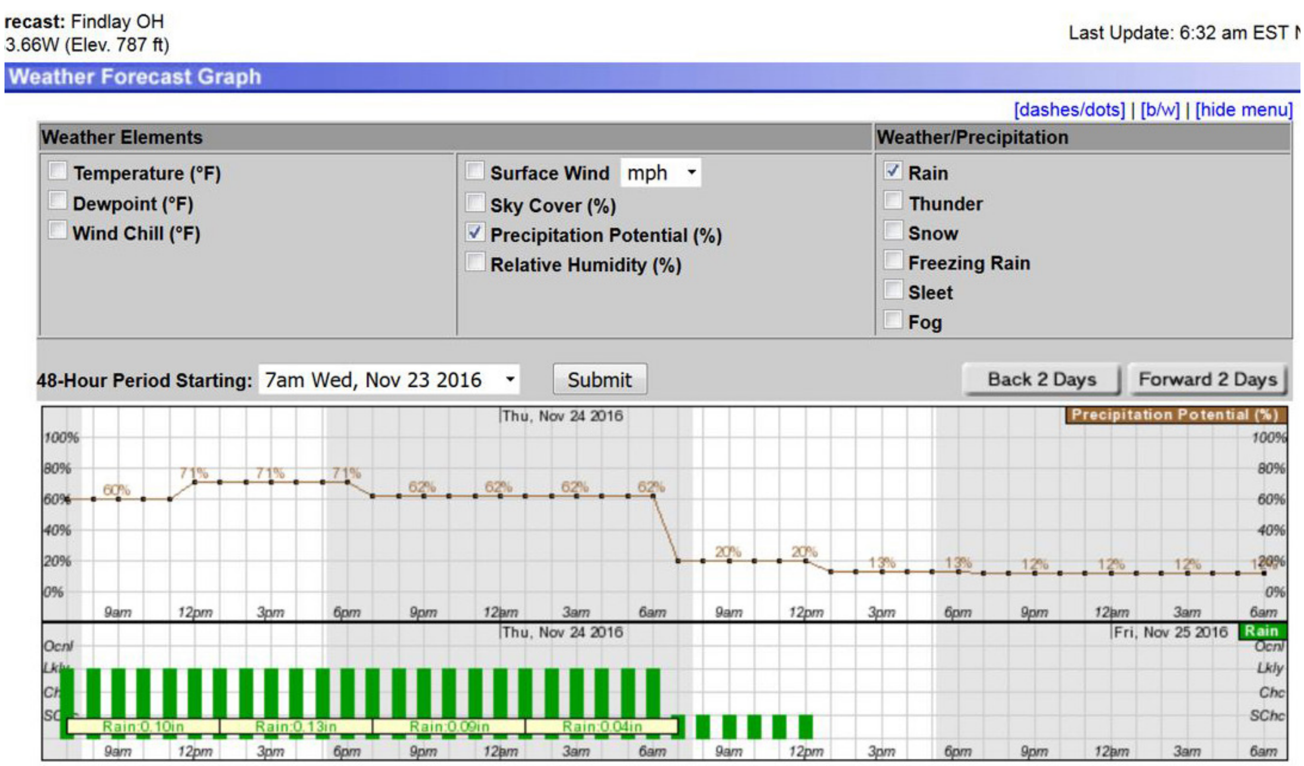


Figure 2. Detailed Hourly Forecast from NOAA that can be used meet granular fertilizer and manure application criteria.

Ohio Water Quality Issues Related to Agricultural Production

Anyone living and working in a watershed has the potential to impact water quality in the watershed including municipal waste water treatment, lawn and landscaping activities, construction sites, industrial plants and all the other activities that happen in the daily course of living.

From an agricultural standpoint, there are three main influences that are identified impairments to water quality:

- Sedimentation
- Phosphorus
- Nitrogen

These three factors are hard to separate since sediment will contain soil bound nutrient P and N, in addition to the soluble P and N that is found in the water solution. Individual spikes in any of the three can cause issuance of warning or lead to adverse water conditions.

Water quality issues from sediment, nitrogen and phosphorus can be generally described in three areas. The deposition of sediment will cause issues as it is deposited downstream requiring the need for dredging to maintain shipping channels. Excess nitrogen and phosphorus leads to aquatic plant growth. In some cases, the presence of nutrients, primarily nitrogen, at a high enough concentration can cause the issuance of warnings.

Excessive Aquatic Plant Growth

The presence of nutrients in water effectively serves the same purpose as nutrients present in soil, they support plant growth. For aquatic plants, when nitrogen (N) and phosphorus (P) are limited, aquatic plants are suppressed. When water containing N and/or P are at higher concentrations, then aquatic plants grow at a greater rate.

Generally, for fresh water systems like Lake Erie, the presence of P triggers plant growth. For salt water systems like the Gulf of Mexico, the N content triggers the plant growth. Even though one nutrient may trigger growth, in many cases reduction in both N and P are discussed for reducing aquatic plant growth regardless of fresh or salt water systems.

There are two primary consequence of excessive plant growth. The formation of cyanobacteria (Harmful Algal Blooms) and Hypoxia are the concerns related to excess phosphorus and nitrogen.

What are Harmful Algae Blooms?

Harmful algal blooms (HABs) are so named because they can produce toxins (or poisons) that can cause illness or irritation—sometimes even death—in pets, livestock and humans.

The term algae is somewhat misleading since HABs are actually cyanobacteria, which are commonly referred to as “blue-green algae,” and are not true algae.

These organisms act like many other plants and use photosynthesis to capture sunlight, but unlike most plants and algae, some can fix their own nitrogen from the atmosphere. Most blooms in Lake Erie and Grand Lake St. Marys are types of cyanobacteria that cannot fix nitrogen. Occasionally, we do see nitrogen-fixing blooms.

Factors that can contribute to HABs include:

- Excess nutrients (phosphorus and nitrogen)
- Sunlight
- Low-water or low-flow conditions
- Calm water (low-wind conditions)
- Warmer temperatures
- Low salinity
- Selective grazing (avoiding cyanobacteria) by zooplankton or zebra/quagga mussels

Source: ohioseagrant.osu.edu/_documents/publications/FS/FS-091-2011%20Harmful%20Algal%20Blooms%20In%20Ohio%20Waters.pdf

Ohio EPA has established thresholds and monitors when suspected cyanobacteria are visually present in Ohio’s public waters, based on the toxin content of the water sampled. The warning criterion is noted in the table on page 15.

While much attention has been focused on Grand Lake St. Mary and Lake Erie, warning and advisories based on the criteria in the table have been posted on 26 different Ohio Lakes in the period 2010-2013. The public can track monitoring at the OEPA site: epa.ohio.gov/habalgae.aspx

Potable (drinking) water systems have needed to adapt to treatment for the toxins in surface waters. Fifty-five percent of Ohio’s population is served by public water systems that use surface water sources. When measured in gallons delivered, 66% of the water from public systems originates from surface water sources.

In areas where HAB potential exist, municipal water treatment plants have had to add treatment methods to lower finished drinking water toxin content to below EPA standards. Increased costs have ranged from $1,000,000 annually for Toledo's population of 450,000; Celina had a capital cost of $7.2 million and yearly operating cost of $500,000 for a population of 11,700 and in 2013-2014, Columbus spent $723,000 treating water from Hoover Reservoir.

In addition to treatment of drinking water, the timing of HAB blooms and their proliferation in the recreational waters, like in 2011, affected boating and fishing. The charter boat industry on Lake Erie accounts for $10 billion of tourism.

The issue of HAB toxins from cyanobacteria is different than the concerns about hypoxia that is often discussed related to algal blooms. HAB toxins were documented to have caused 48 human illnesses and 5 animal deaths in 2010. Thus the heightened human health concerns associated with HAB presence in Ohio Watersheds have made the demands to solve the problem more urgent.

What is Hypoxia?

Nutrient enrichment from nitrogen and phosphorus results in a variety of floating and rooted plants to grow in water. As these plants die, they fall into deeper water and organisms begin to break down the plant material using up oxygen. The decomposing plant matter results in a low oxygen concentration in water or "anoxic" conditions.

Water that has dissolved oxygen concentration of less than 3 ppm is considered anoxic and will not support fish or other higher forms of aquatic life. Hypoxia is a problem in the Gulf of Mexico with a five year average above 14,000 square kilometers (5,405 square miles).

The state of Ohio is 44,825 square miles, so the hypoxic area of the gulf is the equivalent of 12% of the area of Ohio, or about 10 counties in size. Closer to home, the central basin of Lake Erie experiences an annual hypoxic zone as well

Concentration Advisories for Nutrients

Concentration of nutrients present in water can trigger warnings that can affect the general population or specific segments of the population. Nitrogen in Nitrate form can cause warning and ammonium concentration in water can lead to fish kill.

Nitrate Warnings

Drinking water advisories are issued when nitrate levels are detected at concentrations greater than 10 mg/L. The advisory is targeted to infant populations who receive their primary nutrition from formula mixed with tap water.

Short-term exposure to drinking water with a nitrate level at or just above the health standard of 10 mg/L nitrate-N is a potential health problem primarily for infants. Babies consume large quantities of water relative to their body weight, especially if water is used to mix powdered or concentrated formulas or juices.

The immature digestive systems of infants are more likely than adult digestive tracts to allow the reduction of nitrate to nitrite. In particular, the presence of nitrite in the digestive tract of newborns can lead to a disease called methemoglobinemia or "Blue Baby Syndrome". *From PSEP Cornell University psep.cce.cornell.edu/facts-slides-self/facts/nit-heef-grw85.aspx*

Methemoglobinemia is a condition in which hemoglobin in the blood stream picks up the nitrate which reduces oxygen in the blood stream.

Table 3. Advisory criterion used by EPA in public waters.

Advisory Criterion used by Ohio EPA in Public Waters

Public Drinking water thresholds for microcystin and cylindrospermopsin, based on a 10-day exposure				
	All threshold values are reported in µg/L			
Type of Advisory	Microcystines	Anatoxina	Cylindro-spermopsin	Saxitoxin*
Recreational Public Health Advisory	6	80	5	0.8
Recreational No Contact Advisory**	20	300	20	3
Drinking Water: Do Not Drink Advisory (for bottle-fed infants and children younger than school age)	0.3	20	0.7	0.2
Drinking Water: Do Not Drink Advisory (for all)	1.6	20	3	0.2
Drinking Water: Do Not Use Advisory	20	300	20	3
* Microcystin and Saxitoxin thresholds are intended to be applied to total concentrations of all reported cogeners of those toxins.				
** A No Contact Advisory is issued when toxin levels exceed the recommended threshold and there are one or more probable cases of human illness or pet deaths attributable to HABS				
Notes: µg/L - micrograms per liter; ppb - part per billion; the units are identical with respect to the cyanotoxin threshold levels.				

Ammonia

Even trace amounts of ammonia (NH_3) are very toxic to fish, and kills result. Generally, accidents with fertilizer transport equipment or manure spills result in high ammonia concentrations in water for short duration.

River Water Quality Monitoring

Monitoring of the Maumee River provides an example of sediment, nitrogen and phosphorus concentration and loading in an Ohio watershed. Continuous monitoring at the detail that is available on the Maumee is difficult to find in other watersheds. Therefore, this monitoring provides some idea of what other watersheds might be experiencing when matched with other summary data.

Figure 3 on page 16 shows the results of Maumee River monitoring with charts for:

1. Suspended solids (which represent sediment)
2. Particulate phosphorus
3. Dissolved reactive or soluble P
4. Nitrates

The line on the chart represents the average of the current year plus the four previous years that smooths out year to year variations and provides an observation of the trend.

Source: Data is provided by Heidelberg University National Center for Water Quality Research.

Maumee River Water Quality Monitoring.

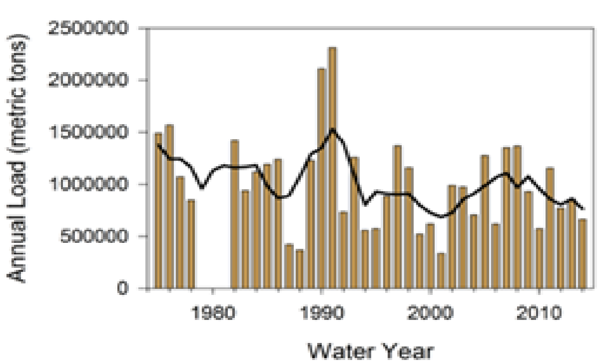
Total Loading

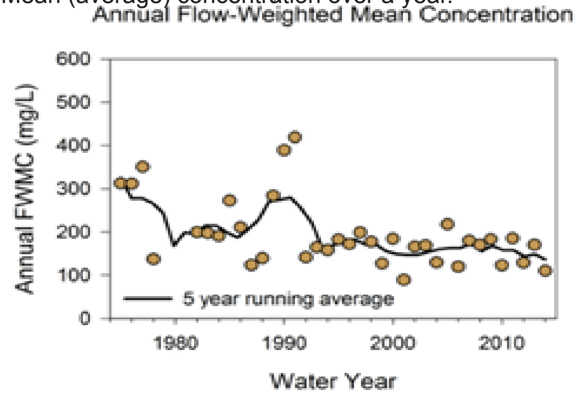
Total volume of water multiplied by the average concentration of the measured item (metric ton × 1.102 = U.S. ton)

Flow Weight Mean Concentration

Mean (average) concentration over a year.

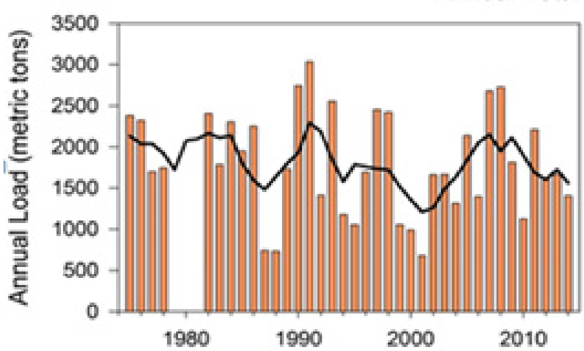
Sediment

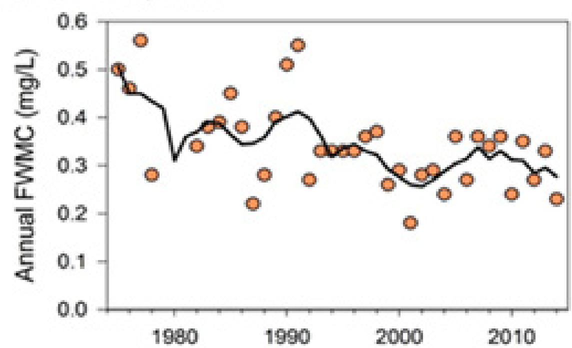




Particulate Phosphorus

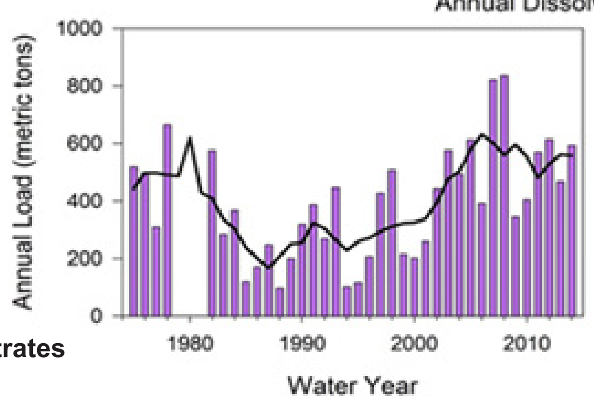
Annual Total Particulate Phosphorus

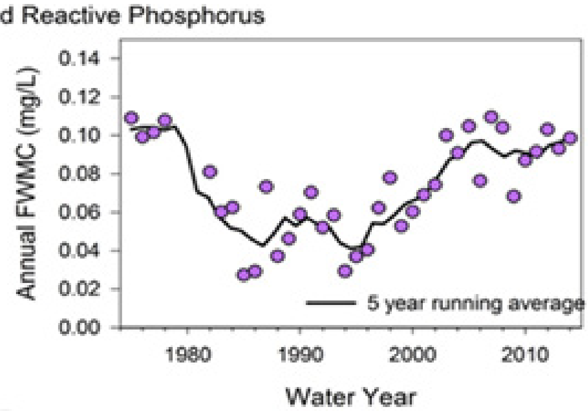




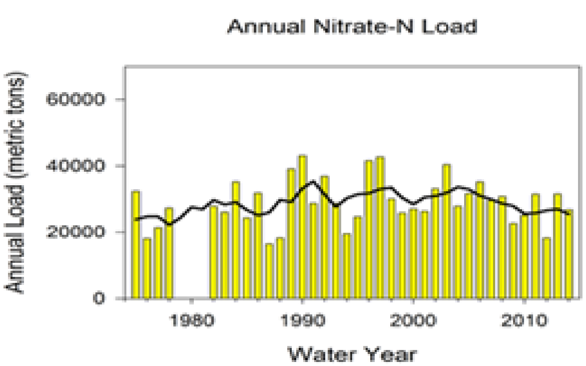
Dissolved Reactive or soluble P

Annual Dissolved Reactive Phosphorus





Nitrates



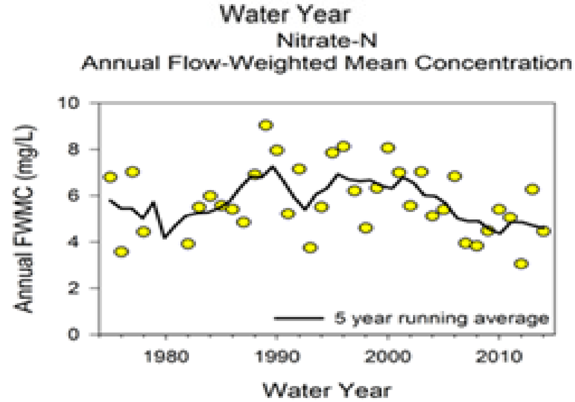


Figure 3. Maumee River Water Quality Monitoring.

Source: Heidelburg University National Center for Water Quality Research

Reduction Targets for Phosphorus in Lake Erie

Targets have been set by the International Joint Commission (IJC) and Ohio Phosphorus Task Force with the goal to "reduce the frequency and severity of harmful algae blooms in the western Lake Erie Basin."

Similar loading reductions are mentioned in both reports and the state of Ohio is developing reduction strategies to implement these goals. The actual reduction targets for both spring/summer and annual are listed in Table 4.

Table 4. Phosphorous reduction goals for target watersheds and calendar year periods to reduce Harmful Algal Blooms. Percent reductions are based on the average of the 2007-2012 loading values compared to target. *Source: IJC, 2014*

	Maumee River				All Western Lake Erie			
Phosphorus form	March to June Target loads in Metric Tonnes (MT)	% reduction	Annual in Metric Tonnes (MT)	% Reduction	Spring in Metric Tonnes (MT)	% reduction	Annual in Metric Tonnes (MT)	% reduction
Total P	800	37	1600	39	1600	*	3200	*
DRP	150	41			300	*		
* Percentage reduction not noted in report but appears to be approximately 40%								

Reduction Targets for the Gulf of Mexico

The 2015 "Dead Zone", or hypoxic area measured 16,760 square kilometers (6,474 square miles). The average size for the last five years measured 14,024 sq km (5,543 square miles). It is three times larger than the Hypoxia Task Force Goal of 5,000 square kilometers. *Source:* *epa.gov/ms-htf/northern-gulf-mexico-hypoxic-zone*

The Hypoxia Task Force (HTF) is a partnership of 12 states, five federal agencies and a representative for tribes that works collaboratively to reduce nutrient pollution in the Mississippi/ Atchafalaya River Basin (MARB) and the extent of the hypoxic zone in the Gulf of Mexico at the mouth of the Mississippi River. The Hypoxia Task Force in their January 2015 meeting, set new goals. The press release at the time of the meeting stated that a 45-percent reduction is needed in the nitrogen and phosphorus entering the Gulf of Mexico. The current goal is a 20-percent reduction in nutrient loads by 2025.

Edge of Field Water Quality Monitoring

In an edge of field study, field sites in Ohio have been monitored as water leaves the field through surface and subsurface drainage allowing researchers to document the impact of farmer management and inherent field characteristics on agricultural contribution to non-point source water quality.

These sites give a real life picture of the effects that different practices have on water quality and help identify effective Best Management Practices to address concerns.

The sites in Ohio utilize a before/after control impact design. At each of 20 sites, two fields under the same farmer management are monitored. Thus a total of 40 fields make up the study sample size. The sites are monitored for management implemented, inherent site characteristics, and total water leaving the site. The water monitoring includes measures of phosphorus, nitrogen and sediment.

The sites are initially monitored under the same management for one crop rotation which is typically a corn-soybean or corn-soybean-wheat rotation. This is used to gather information on the relative sameness of the two comparison sites so differences can be accounted for in future comparisons. Once the calibration rotation is completed then different management practices will be compared. Practices such as 4R nutrient stewardship, cover crops, soil amendments, tillage and other practices will be evaluated for their effect on water quality.

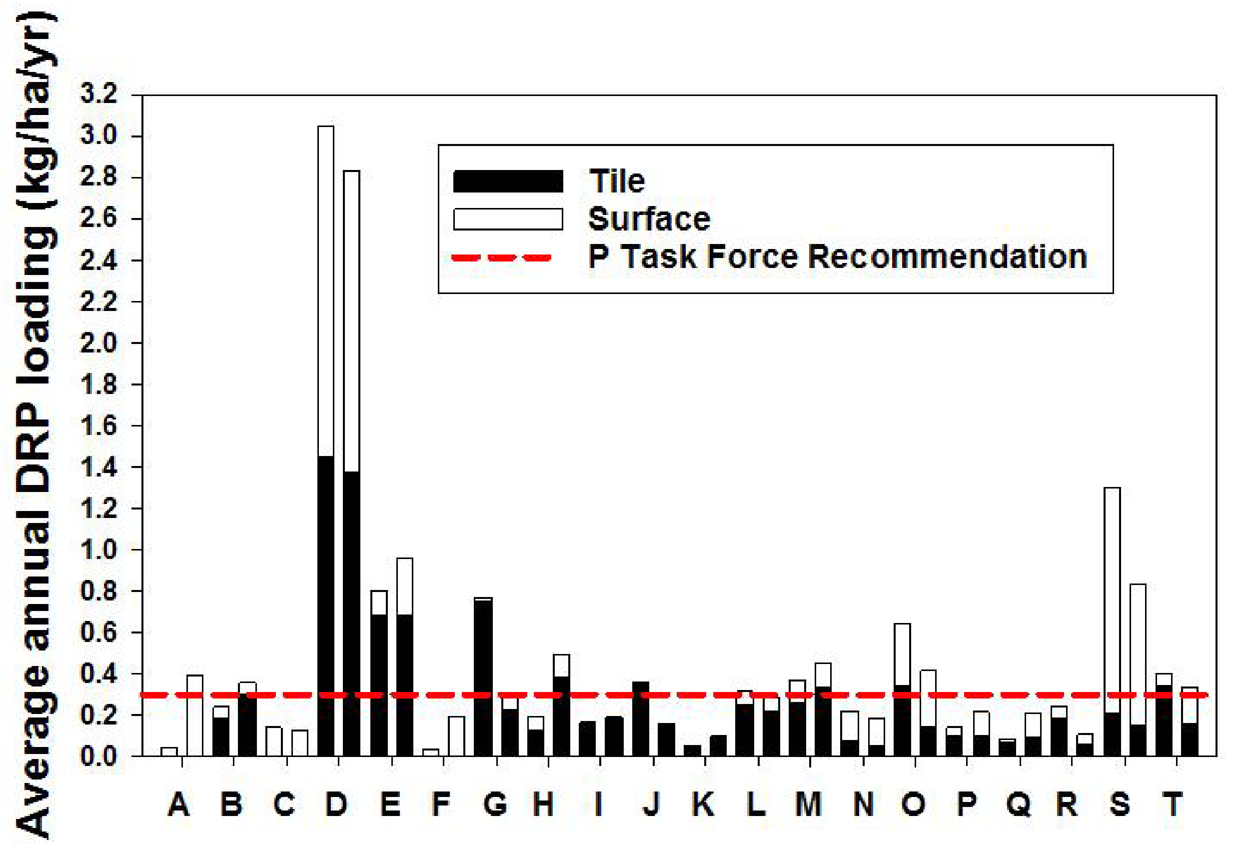


Figure 4. Average annual DRP loading from Edge of Field study sites (2011-2015). *Source: USDA-ARS*

Phosphorus Observed Results

Figure 4 shows the dissolved reactive phosphorus (DRP) loads measured in kg/ha/yr of DRP loss from sites in the Edge of Field study (Note to convert from kg/ha/yr to pounds/acre/year use a factor of 0.89). The sites do not all have a full five years of data but are summed and average from when the sites came on line and ending in 2015. Bars on either side of a letter on the X axis represent the two fields at a single site. The dashed horizontal line represents the balance of P that remains (0.3 kg/ha/yr) if we subtract off the 40% reduction in DRP suggested by the International Joint Commission and Ohio P Task Force recommendations, divided by the acres in the Western Lake Erie Basin.

All fields do not have equal amounts of DRP leaving the study sites. Soil test P levels and other management factors have a great influence on the ultimate contribution. When compared to the “target” value 21 of the 40 fields (53%) are less than the “target”. Another 11 (27%) of the sites are slightly above the target line. Only eight fields (20%) are substantially higher (two to ten times higher) than the target value. Factors that seem important to those higher contributing fields are soil test values that exceed the agronomic need range by 3 to 8 times and surface applied fertilizer applications with a runoff rainfall event.

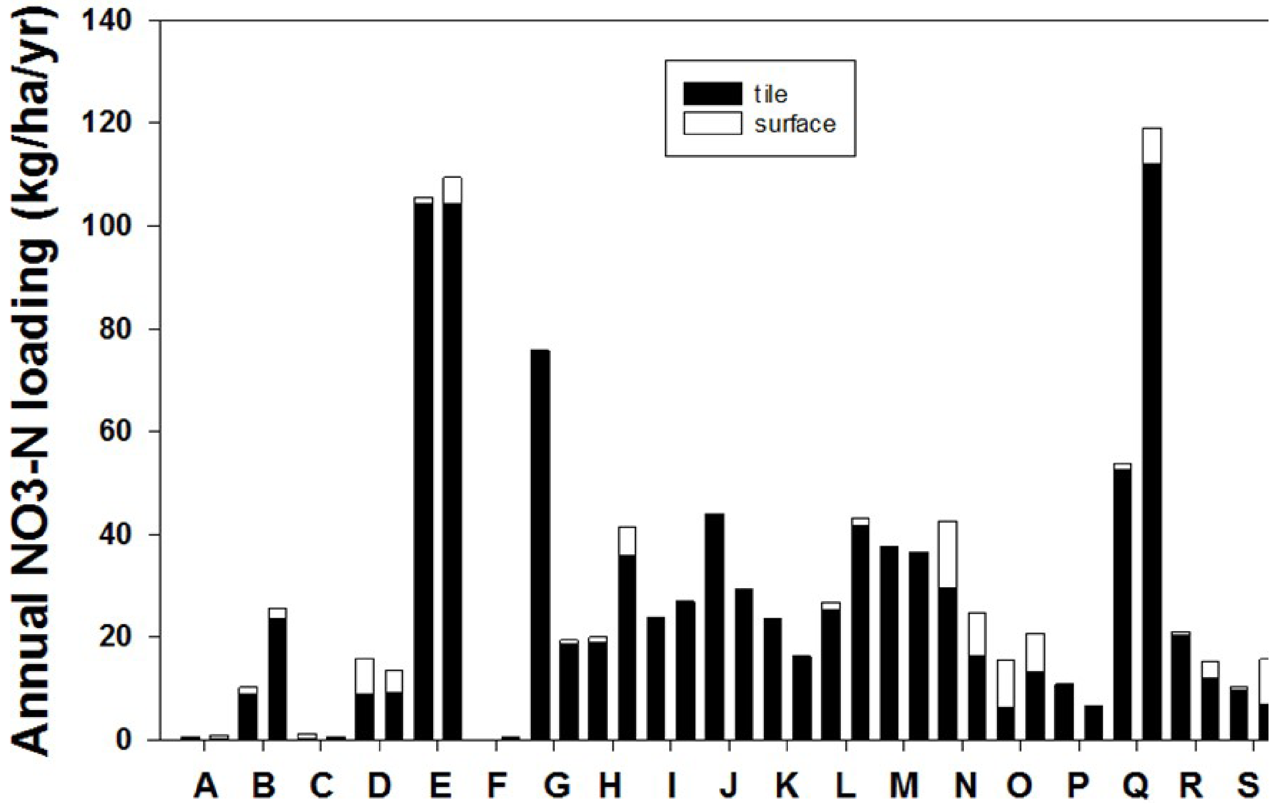


Figure 5. Losses of nitrates from Edge of Field sites (2011-2015). *Source: USDA-ARS*

Nitrogen Observed Results

Figure 5 shows the annual nitrate loads measured in kg/ha/yr of DRP loss from sites in the edge of field study. Note to convert from kg/ha/yr to pounds/acre/year, use a factor of 0.89. The sites do not all have a full five years of data but are summed and averaged from when the sites came on line and ending in 2015

Most nitrates are lost from a field site via the tile system. The data confirms this is true for the EOF sites in Ohio. Average annual losses are in the 20-30 kg/ha/yr area. Eleven fields are higher than 40 kg/ha/yr with 6 of those fields at 80 to 110 kg/ha/yr. The management data has not been fully compared to the nitrate loss results. Factors that could explain these losses are not accounting for nitrogen in the soil from manure applications when determining N fertilizer rates, weather conditions resulting in reduced yield or placement of nitrogen during application.

Quality Control in Soil Sampling

The foundation of a soil fertility program for crop production should be a soil test we have confidence in. Confidence comes from seeing repeatability in the soil test results over time. The process used on the farm to collect soil samples should provide sample results that over time can track trends in the soil effects of the soil fertility recommendation to build, maintain or drawdown soil test as desired.

A long-term nutrient balance can be calculated by looking at fertilizer or manure inputs, yield responses and soil test results over time. This could provide a field-by-field or practice-by-practice response of the soil to the management used. This can lead to an adaptive management program that individualizes a fertility program to the management practices used on the farm or even to an individual field.

To obtain a repeatable soil test there needs to be quality checks in the sampling procedure focused on three areas.

1. Dividing up the landscape within the field borders to obtain representative samples
2. Collecting cores
3. Selecting a laboratory

The discussion here is provided to set a base line in soil sampling decisions. The factsheet *Recommendations for Soil Sampling in the Landscape* provides more details on sampling recommendations to produce a quality soil sample.

The factsheet is available at:
ohioline.osu.edu/factsheet/AGF-513

Dividing up the Landscape Within the Field Borders

With GPS technology there are multiple ways to determine how to group representative areas of a field. There are pros and cons to each. The following minimums should be observed.

- Sampling area should be no larger than 25 acres for whole fields
- Use a zig-zag pattern to collect samples
- Avoid soil sampling after manure application (wait at least 6 months) or fertilizer application (2 months)
- Use GPS to mark sample points for follow-up sampling in future years

Collecting cores

- 10-15 cores per sample area
- Increase cores in fields with history of banded fertilizer (20-25)
- Scrape soil surface of debris/residue
- Consistent sample depth
    - Variation in depth can skew soil test data dramatically
    - 4” sample does not provide same nutrient analysis as 8” sample
    - Tri-State Fertilizer Recommendations are based on 8 inch sample
    - With established forages, no-till and minimum tillage, an additional sample should be taken at a shallower depth (0 to 4 inches) to assess acidification of the soil surface and make appropriate lime recommendations.

Selecting a Laboratory

- Soil sample procedures are defined for the North Central Regions and are published by the Land Grant Universities in Recommended Chemical Soil Test Procedures for the North Central Region NCR-13 available at: extension.missouri.edu/explorepdf/specialb/sb1001.pdf
- Soil testing labs generally do a good job of analysis. Much of the variation is in sample collection.
    - Clients submitting samples can discuss with labs the internal and external testing programs they participate in to get a better report. Often labs publish their results from external programs on their website.
    - Also ask the lab what phosphorus test is used. Tri-State Fertilizer Recommendations are based on Bray P1.
    - Other criteria to consider can be found in Choosing a Soil Test Laboratory at: ohioline.osu.edu/factsheet/HYG-1133
    - A listing of laboratories can be found at: ohioline.osu.edu/factsheet/hyg-1132

Developing a Strategy for Precision Soil Sampling

There are many different tools and approaches available that, if used correctly, can help to improve your nutrient management (variable rate application, precision placement, crop sensing via Normalized Difference Vegetation Index (NDVI), late-season application, nutrient BMPs, etc). However, selecting the correct tools and using them to your advantage is not always an easy process, since the best tool and the best approach can vary by farmer and field. The key to a successful soil fertility program is to identify your goals and develop a plan to meet those goals each season. Identifying both short and long term goals make it possible to develop a strategy to use precision technologies to systematically improve your soil fertility program. Some goals you may consider are:

1. Improve mapping of field variation that affects soil fertility
2. Maximize the economic return of fertilizer applications
3. Reduce off-site movement of nutrients

Selecting A Soil Sampling Approach

One of the most important decisions that you will make as part of your fertility program is how to divide (the area within a field boundary) a field into representative areas and what the area represents, yield,soil type, etc. Currently, there are two widely used methods: grid and zone sampling. Deciding between the two is not as simple as it may seem, since these methods require different sampling techniques, different analysis, and different applications. It is important to keep your fertility program goals in mind when making this decision.

Grid Sampling

Grid sampling involves taking samples at regular intervals across the landscape of a field. Grid size is selected to provide the desired data resolution. A 2.5-acre grid size is commonly used (360 by 360 feet); however, choosing a grid size that matches up to spreader equipment widths is recommended. Smaller grids may be necessary to accurately capture differences in fields with a high degree of variation and it may be possible to increase grid size if a field is fairly uniform. Cost increases as the number of samples increase; however, research has shown that smaller grids provide higher resolution, and often more useful, data.

When to Use

Grid sampling should be used when there is little information available about the variation in nutrient levels across a field. Grid sampling may be useful in fields where variability is expected but the field history is not well known, topography is uniform but differences in soil type occur, varied management patterns have been used in the past or manure applications have occurred. Proper grid sampling makes it possible to identify variation within a field and is an important data layer when determining future management zones for fertilizer applications.

How to Sample

The goal when grid sampling is to determine the best estimate of each soil test value near the center of the gridded area. The changes that occur in unsampled areas of the field are then modeled using interpolation to determine a likely pattern of variation. Several different geostatistical models can be used; for example, point kriging, inverse distance, and splines. Studies have concluded that the initial selection of sample number is more important in successfully reflecting actual fertility levels across the landscape than the statistical model used. The interpolation method may vary depending on the software used to generate the prescription; therefore, it is important to check with your consultant before sampling.

Figure 6. shows a recommended method for collecting soil cores when grid sampling. Samples at each sample point are collected in a 10-foot circle with a two cores pulled from each quadrant or a total of eight cores.

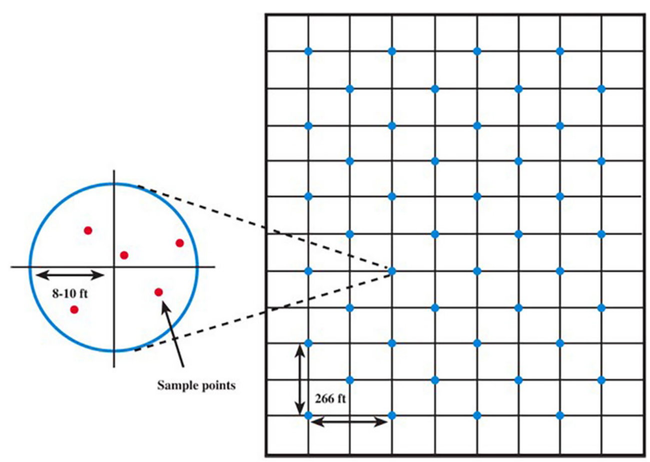


Figure 6. Shows a recommended pattern of taking soil cores for grid sampling. *Source University Nebraska-Lincoln, Extension.*

Zone Sampling

Zone sampling involves dividing the field into zones that are uniform enough to be managed as a whole and then sampling to determine the average soil test values for those zones. The success of the zone sampling relies on the amount and quality of the data used to determine the zones. Layers such as soils maps, aerial photos, yield maps, topographic maps, management history and personal field experience can provide valuable information about the variation in a field. This information can be used to define sample zones or management zones in a field. As the number of management zones in a field increase, the number of samples needed increase. If only a few zones exist, samples can be combined to reduce the cost of analytical expenses.

When to Use

Management zones are a better choice than grids when the operator has a long history of working with the field, topography varies and can be used to define zones, where yield map data over time has defined high and low yielding areas, the soil type map represents yield zones or other remote sensing data is available to overlay with operator experience to define yield patterns in a field.

It is important to note that differences in yield may not be always be caused by differences in soil test values. Identifying other yield limiting factors will help fine tune your soil fertility program for each field.

How to Sample

The goal when sampling by management zone is to determine the best estimate of the entire zone. If the data used to determine the zones is accurate, the soil test values should be relatively consistent. In this case, taking multiple soil cores is necessary to reduce the chance of pulling one from a “bad spot.”

Figure 7. shows the recommended pattern for pulling soil cores when zone sampling. Sample points should be taken randomly (recommended to walk in a zigzag pattern) with 10-15 cores per sample area up to 25 acres. Georeferenced sample points may give a better opportunity to compare sample trends over time by returning to near the same point in future years. This can be beneficial to tracking soil fertility recommendation program effects on soil test levels over time.

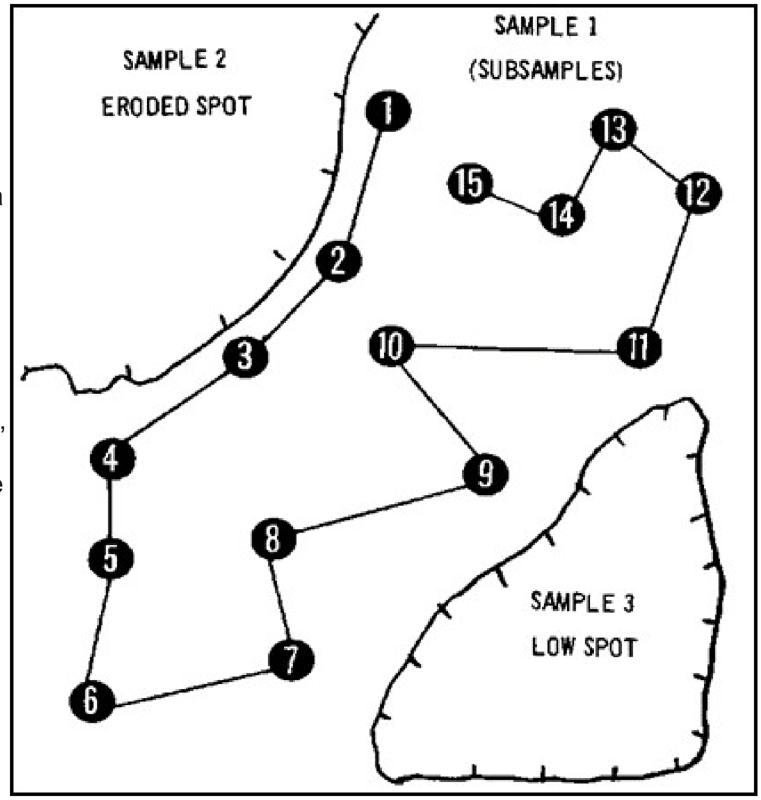


Figure 7. A recommended pattern for collecting soil cores for zone sampling.

Since the soil test values will represent the average for the entire zone, interpolation should not be used. A blanket fertilizer application rate within each zone is most appropriate when zone sampling is used.

Understanding the Tri-State Fertilizer Recommendations for Corn, Soybean, Wheat and Alfalfa

In the mid-1990s, soil fertility specialists from The Ohio State University, Purdue University and Michigan State University developed soil fertility recommendations for the Tri state area. The recommendations for phosphorus and potassium are still in use today. The value of these recommendations is in the correlation studies that were conducted to evaluate crop response to the soil test values, a prediction of the need for added fertilizer.

The approach used for these recommendation is one of the more common approaches used, a build-maintenance approach in which the recommendation is designed to provide adequate nutrient for the crop and maintain a soil capable providing sufficient nutrients without fertilizer addition for one or more years. This approach is often called the “Feed the soil” concept.

All phosphorus soil tests discussed here are based on the Bray P1 expressed as parts per million or ppm. Figure 8 below is a slightly revised version of the scheme in the original publication. The approach defines a "Critical Level" or CL.

- **Below the CL** …"the soil is not able to provide P and K requirements of the crop." And additional fertilizer is needed or there is a risk of yield reduction due to inadequate nutrients.

- **Above the CL**…"the soil is capable of supplying the nutrient required by the crop and no response to fertilizer would be expected." For fields where a corn and soybeans rotation is grown, the critical level is 15 ppm soil test value; in fields with a rotation that includes alfalfa or wheat in the rotation, the critical level is 25 ppm.

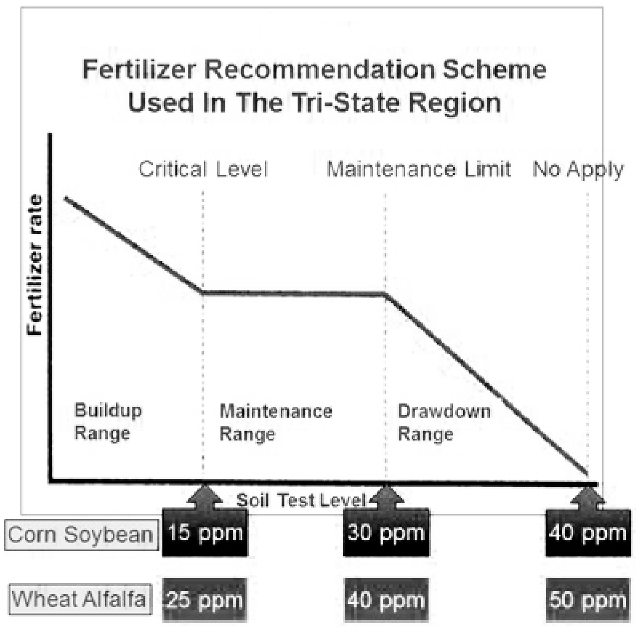


Figure 8. Fertilizer recommendation Scheme.

The **"Maintenance Range"** provides a soil test target range where a maintenance level of fertilizer is applied to maintain the soil test level. The target range starts with the critical level and ends at the "maintenance limit". The target range for corn and soybeans is between 15 ppm to 30 ppm. The target range when alfalfa or wheat are grown is 25 ppm to 40 ppm.

Above the maintenance range nutrient recommendations are quickly reduced. For fields in this range we expect "…no response to fertilizer in the year of application expected." and "No response to placement technique …"

Above 40 ppm in a corn-soybean rotation or 50 ppm in the wheat-alfalfa rotation there is no expectation of additional yield from fertilizer addition thus the recommendation becomes zero.

Organic materials could be added above this level but excessive soil test values can increase potential environmental impacts of nutrient loss and should be avoided. Even with organics, soil test values that exceed 150 ppm should not receive additional phosphorous inputs by any source.

Phosphorus is fairly highly buffered in the soil. The Tri-State Fertilizer Recommendations for phosphorus based on it taking 20 pounds of P_2O_5 added or removed to move soil test 1 ppm Bray P1 with crop production. Table 5 shows anticipated change in soil test value in ppm without additional nutrient added based on statewide crop yields in 2015 which range from 1.8 to 3.3 ppm.

Even a corn silage crop at 20 ton per acre yields would only change soil values 3.3 ppm. Thus a soil test at the high end of the corn-soybean rotation maintenance range at 30 ppm would only move to 27 ppm, still in the upper end of the target range provided.

Table 5. Phosphorus Removed per unit Yield in harvested crops based on 2015 yield and soil test value change (without added nutrient (20 lb = 1 ppm)

Crop	Yield Unit	P_2O_5 Removed per unit yld	2015 Ohio State Avg. yield	Lbs P_2O_5 Removal Based on 2015 yield	Expected change in ppm Bray P1 Soil Test
Corn Grain	bushel	0.37	153	57	2.8
Corn Silage	ton	3.30	20	66	3.3
Soybeans	bushel	0.80	50	40	2.0
Wheat Grain	bushel	0.63	67	42	2.1
Wheat Straw	bushel	0.09	67	6	0.3
Alfalfa	ton	13.0	2.9	37	1.8

Background data used to generate Tri-State Fertilizer Recommendations for P.

At Ohio State University, Dr. Jay Johnson was the Soil Fertility Specialist who conducted field trials and helped develop fertilizer recommendations. From 1976 – 1999, Dr. Johnson reported the results of his field trials from that field season in an annual report. We went through these reports and pulled out every field trial that looked at phosphorus and potassium fertilization. We found 85 P trials conducted over 8 sites: 47 in corn, 33 in soybeans and 5 in wheat.

For each trial, we calculated the percentage of relative grain yield by dividing the yield of the unfertilized plots by the yield of the fertilized plots and multiplying the result by 100. Since yields can vary greatly over sites and years, we use the relative yield to shows us how much fertilization increased or decreased grain yields. For each trial, we then took the relative yield and graphed it against the soil test P level. Figure 9 shows this relationship with P. Each dot represents a single field trial from one year. The solid black horizontal line at 100% represents no change between unfertilized and fertilized plots. The dotted black line at 90% shows a 10% reduction in yield. The dashed vertical line shows the Tri-State critical levels of 15 ppm Bray P1 (Figure 9). These are the data from Ohio that helped establish the critical soil test P found in the Tri-State Fertilizer Recommendations! A field with soil test levels to the left of the dashed line has a reasonable chance of a yield response to fertilization and so fertilizer is recommended, while fields with soil test levels higher than the dashed line have a very low chance of a yield response to fertilizer, and so little to no fertilizer is recommended.

We can consider this information 'historic' or 'old' and efforts are now underway to produce 'current' information to see if the fertilizer recommendations need to be revised. A collective effort will be required to generate robust information across the state. We are looking for farmer cooperators to conduct on-farm strip trials to help us generate this information. More information can be found here: go.osu.edu/fert-trials. This work is supported by the Ohio Soybean Council and the Corn and Small Grains Marketing Program.

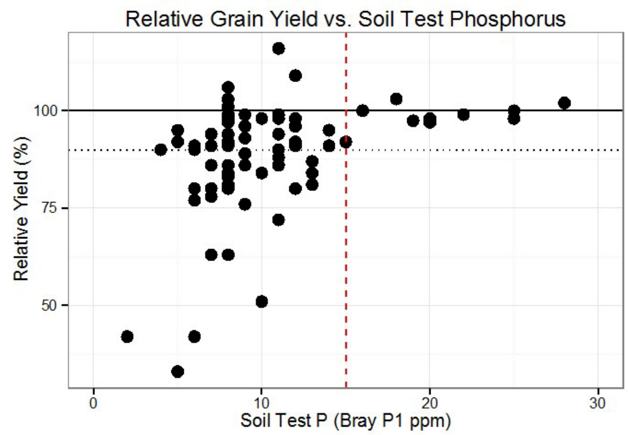


Figure 9. Relative Grain Yield vs. Soil Test Phosphorus.

Equation and tables which can be used to generate Tri-State Fertilizer Recommendations are found later in this manual.

Source: Steve Culman, Muhammad Tariq Saeed, Anthony Fulford

Fertilizer Math

One of the challenges in making nutrient and fertilizer recommendations is paying close attention to units used in results coming from testing laboratories for analysis services. There is no single reporting standard. For example, soil tests may be reported as parts per million or pounds per acre. Manure tests may have phosphorus reported as P (elemental P) versus P_2O_5 (phosphate).

Only fertilizer "guaranteed analysis" standards are defined in Ohio Revised Code to one reporting unit. The reporting form for fertilizer is Total N (percent)-available phosphate expressed as P_2O_5 (percent)-soluble potash expressed as K_2O (percent) and listed in that order for the material. For example, a bag of fertilizer may have the analysis reported as 11-52-0, indicating N-P_2O_5-K_2O at 11%, 52% & 0 % respectively.

As you review reports, take a few minutes to look closely at the units reported with each measure. If a report form has units you do not recognize, check with the originating lab for an explanation of the units plus conversion equations, so test results and a nutrient recommendation can be converted into matching units. Some common conversions and other fertilizer math are below.

Converting Parts per Million to Pounds Per Acre

The conversion between PPM (Parts Per Million) and Pounds per acre is often needed for soil test interpretation. For example, a soil test report is in pounds per acre but a recommendation table is in PPM soil test units.

Equation	*Example*
PPM × 2 = pounds per acre	40 PPM × 2 = 80 pounds per acre
Pounds per acre ÷ 2 = PPM	80 pounds per acre ÷ 2 = 40 PPM

Converting Elemental Phosphorus to Phosphate

Conversion between elemental phosphorus (P) and phosphate (P_2O_5). Manure analysis can have the phosphorus content listed as elemental P but fertilizer recommendations are always reported as the phosphate form. Be sure to convert to phosphate or you will be over applying phosphorous.

Equation	*Example*
Pounds P × 2.29 = pounds of P_2O_5	26 pounds P × 2.29 = 60 pounds of P_2O_5
Pounds of P_2O_5 × 0.44 = pounds of P	60 Pounds P_2O_5 × 0.44 = 26 pounds of P

Converting Elemental Potassium to Potassium Oxide

Conversion between elemental potassium (K) and potassium oxide (K_2O). Manure analysis can have the phosphorus content listed as elemental K but fertilizer recommendations are always report as the Potassium Oxide form.

Equation	*Example*
Pounds K × 1.21 = pounds of K_2O	54 pounds K × 1.21 = 65 pounds of K_2O
Pounds of K_2O × 0.83 = pounds of K	65 pounds K_2O × 0.83 = 54 pounds of K

Using Dry Fertilizer

Sometimes for starter or other applications, we apply a set amount of material per acre and need to know the nutrient we are actually applying so it can be credited to (or subtracted from) the overall recommendation for the crop. The equation below is for dry fertilizer materials and the next equation is for liquid materials.

Equation	*Example*: 100 pounds of material with an analysis of 9-23-30
Pounds of material × (% N ÷ 100) = pounds N	100 × 0.09 = 9 pounds N
Pounds of material × (% P_2O_5 ÷ 100) = pounds P_2O_5	100 × 0.23 = 23 pounds P_2O_5
Pounds of material × (% K_2O ÷ 100)= pounds of K_2O	100 × 0.30 = 30 pounds K_2O

Using Liquid Fertilizer

Determining pounds of nutrient in a liquid fertilizer source.

Equation	*Example*: 3 gallons of 11.65 pound per gallon material with analysis of 10-34-0
Gallons of material × material weight per gallon × (% N÷100) = pounds of N	3 × 11.65× 0.10 = 3.495 pounds N
Gallons of material × material weight per gallon × (% P_2O_5÷100) = pounds of P2O5	3 × 11.65 × 0.34 = 11.883 pounds P_2O_5
Gallons of material × material weight per gallon× (% K_2O÷100) = pounds of K_2O	3 × 11.65 × 0.0 = 0.0 pounds K_2O

Measuring

When we get a nutrient recommendation and are going to meet that need in a single application, the following formula gets us the needed amount of fertilizer material (11-52-0) to meet the nutrient need of 50 pounds P_2O_5. Note we are applying 10 pound of N (96 pounds ×.11) in the application as well.

Equation	*Example*: How many pounds of 11-52-0 are needed for 50 pounds of P_2O_5 recommendation?
Nutrient need in pounds ÷ (% nutrient in analysis÷100)= pounds of material	50 ÷ 0.52 = 96 pounds of 11-52-0

Value of Nutrient

The following equation calculates per unit nutrient

Equation	*Example:* Cost per unit of N in 28-0-0 at $280 per ton?
Cost per ton ÷ (2000×(% nutrient in analysis×0.01))= pounds of material.	280 ÷ (2000 × 28) = 0.50 cents per unit of N

Best Management Practices to Keep Phosphorus on the Field

Looking at current Ohio field research and the literature available on the topic of minimizing losses of phosphorus at the edge of the field, the following recommendations are a starting point to maximizing productivity while minimizing environmental impacts on water quality.

Farm and Field Features

Minimize Erosion

Appropriate conservation practices should be implemented to minimize erosion. Maintain 30% cover as crop residue/cover crop. Filter strips, grassed waterways, water retention, wetlands and water diversion structures are appropriate tools.

Know Your Field's Risk

Soil test P, field proximity to water and soil hydrologic class impacts edge of field losses of phosphorus. The NRCS Ohio P Risk index provides a risk of loss index and should be used as part of the development of a Nutrient Management Plan to assess the individual field risk.

Slow the Movement of Water

Surface water flows from fields directed to tile via standpipes should be converted to blind inlets. As risk loss potential increases for a field, consideration should be given for edge of field treatments which control water movement or treat water as it is leaving the site. Drainage water management control structures in ditch treatments such as two stage ditches and other stream practices can reduce loading.

Strive to Build Soil Quality

Soil condition is a mitigating factor. Increasing the water infiltration by reducing compaction and improving soil structure increase water retention, nutrient cycling, crop rooting capacity and crop yield. Drainage and soil pH provide a foundation for other practices such as cover crops, drainage, residue management, controlled traffic and soil amendments.

Phosphorous Rate, Application and Timing

Avoid overloading soils

Utilize current soil test (less than 3 years old) and follow tri-state fertilizer recommendation. Where soil test levels are above 40 ppm Bray P1 or 58 ppm Mehlich III-ICP, do not apply additional phosphorus in the corn-soybean rotation. These levels require no additional fertilizer, according to the Tri-State Fertilizer Recommendations. Fertilizing soils testing above these levels increases risk of P in surface runoff and tile drainage.

Avoid Winter Application

Eliminate surface application of manure or fertilizer to frozen or snow-covered fields. Frozen ground is ground that is frozen to the degree that tillage is not possible. Surface applied manure or fertilizer is subject to runoff events that may occur before the ground thaws and allows nutrients to bind to soil.

Avoid Surface Application of Fertilizer/manure

Surface applications of phosphorus are subject to higher loss if runoff producing rainfall events happen close to application. Placement of nutrient below the surface of the soil reduces loss. If tillage is planned in the crop rotation, P applications should be applied prior to the tillage and incorporated before a rain event. Full width tillage has the potential to increase soil erosion and total phosphorus losses.

New placement tools or strategies need to be implemented that place P below the surface with minimal soil disturbance. Until these tools become available, use banded application or the minimal amount of tillage to mix nutrient in the soil.

Ohio State University Extension Fact Sheets on P, K and Liming

Fertility

Fertility fact sheets and useful information are found at the website: agcrops.osu.edu along with general agronomy information.

Timely Updates – C.O.R.N. newsletter

For timely updates regarding agronomic crops in Ohio, subscribe to the free digital C.O.R.N. newsletter. The newsletter is available at:

corn.osu.edu

Interpreting a Soil Test Report

This fact sheet discusses key numbers on a soil test report and what they mean:

ohioline.osu.edu/agf-fact/pdf/Interpreting_a_Soil_Test_Report_AGF-514-12.pdf

Developing Nutrient Recommendations from Soil Test for Phosphorus and Potassium

This fact sheet shows step-by-step development of a nutrient recommendation and how much fertilizer is needed to meet that need.

ohioline.osu.edu/agf-fact/pdf/Developing_Phosphorus_and_Potassium_Recommendations_for_Field_Crops_AGF-515-12.pdf

pH and Liming

This fact sheet shows how to use buffer pH to determine liming need and the term *Effective Neutralizing* power of lime sources to develop a lime material recommendation:

agcrops.osu.edu/sites/agcrops/files/imce/fertility/AGF505.pdf

Nitrogen recommendations

Nitrogen recommendations for corn in the Tri-State Fertilizer Recommendations are now out of date. Current recommendations use an economic based model and can be found in the multi-state Corn Nitrogen Rate Calculator: cnrc.agron.iastate.edu

Nitrogen recommendations for wheat in the Tri-State continue to be recognized as appropriate. This fact sheet outlines BMPs for nitrogen in wheat: agcrops.osu.edu/sites/agcrops/files/imce/fertility/0148.pdf

Rates are also included in the Supplemental Recommendations table on page 56 in the manual.

Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa E-2567

agcrops.osu.edu/publications/tri-state-fertility-guide-corn-soybean-wheat-and-alfalfa

Supplemental tables were created using Tri State Fertilizer equations for higher yield goals and provide guidance on Phosphorus where Mehlich III extractants are reported:

agcrops.osu.edu/sites/agcrops/files/imce/fertility/PPM-TriState%20Supplemental%20Tables%20BrayP1-M3.docx

Supplemental tables were also created for Potassium using Tri-State Fertilizer Recommendation equations for higher yield goals:

ohioline.osu.edu/factsheet/AGF-515

This spreadsheet can be used to develop recommendations for P, K and Lime:

agcrops.osu.edu/sites/agcrops/files/imce/fertility/TriStateFertCalcV2013-4.xlsm

Managing manure nutrients

The Ohio Manure Management Guide (Bulletin 604) agcrops.osu.edu/sites/agcrops/files/imce/fertility/bulletin_604.pdf

Manure Nutrient Rate and Value Calculator Version 2 (Excel Spreadsheet): agcrops.osu.edu/sites/agcrops/files/imce/fertility/OSU_manure_balance_calculator_locked.xls

Originally designed for managing nutrients from manure, the Nutrient Management Workbook is a tool to create your nutrient management plan. The Nutrient Management Workbook is available:

As a pdf: agcrops.osu.edu/NMW

And as the eNutrient workbook:

agcrops.osu.edu/sites/agcrops/files/imce/fertility/NutrientManagementWorkbookRelease3.5.1.xlsm

Videos for a review of the Fertilizer Applicator Training

agcrops.osu.edu/video/fact-videos

Nitrogen Best Management Practices-
Adapted for Ohio Conditions

Adapted from fact sheet by Peter C. Scharf, John B. Lory, Plant Sciences Extension, University of Missouri. *plantsci.missouri.edu/nutrientmanagement/nitrogen/practices.htm*

Successful nitrogen management delivers enough nitrogen to the crop to optimize yield and profitability while minimizing losses to water and air. With nitrogen, economic success and environmental success overlap almost completely. Everyone wants the nitrogen to end up in the crop. Thus, the best management practices (BMPs) presented here are identified as sound practices from economic, production and environmental viewpoints.

The BMP for timing of nitrogen (N) fertilizer applications is to apply fertilizer as close as possible to the period of rapid crop uptake.

- Nitrogen fertilizer can be lost from agricultural fields especially in regions with moderate to high rainfall. In most years, some region of Ohio gets enough rainfall to cause N loss.
- The period with the greatest risk of N loss is spring, when soils tend to be wet and before rapid crop growth begins to pump water out of the soil. Early spring application of N for summer crops like corn can result in loss of N and reduction in yield.
- If N is to be applied more than two weeks before planting, use of anhydrous ammonia is recommended to reduce this risk of loss.
- A second period of high risk for N loss can occur in late May and June. Even though rapid crop growth may have started, if heavy rains create saturated or near-saturated soil conditions for several days or longer, the combination of warm and wet soil conditions can lead to rapid N loss through denitrification.
    - This risk is greatest on poorly drained soils. Sidedress application of N or use of a nitrogen stabilizer such as N-Serve with preplant applications will reduce this risk.
- In all crops, rapid uptake of N occurs during the maximum growing period.
- There is reducded risk of N loss when fertilizer is applied a the beginning of the period of rapid growth.

Best management practices for nitrogen fertilizer application rate are poorly developed, but some promising new practices are on the horizon.

Nitrogen fertilizer rate is one of the most important N management variables, both economically and environmentally.

- The amount of N fertilizer needed to optimize crop yield often differs significantly from one field to another, from one part of a field to another part, and from year to year.
    - Unfortunately, the tools available to predict how much N is needed are not yet very satisfactory for most crops under Ohio conditions.
- Although corn color is the best predictor of how much N fertilizer is needed, it does not fit with the preplant N management system favored by many Ohio corn producers.
    - As nitrogen prices and environmental pressures increase, the usefulness of color-based N sidedressing for corn may increase.
    - Sensors can be mounted either on tractor-based or high-clearance sidedressing equipment and can control application rates of sidedress N.

Nitrogen fertilizer materials lend themselves to a range of application methods, including broadcast application, surface banding, knife or coulter injection and application with the planter. Choice of method and placement is related to the source of N.

Broadcast applications can be used with urea, ammonium nitrate and UAN solution. However, broadcast applications of urea can result in substantial loss of fertilizer N to the air.

Treatment of urea with Agrotain before broadcasting, or incorporating the urea into the soil with tillage within three or four days, will reduce or prevent N loss.

- Broadcasting UAN solution (28 percent to 32 percent N) is not recommended when residue levels are high because of the potential for the N in the droplets to become tied up on the residue.
- Dribbling the solution in a surface band will reduce tie-up on residue, and knife or coulter injection will eliminate it.
    - Broadcast UAN solution is also susceptible to volatile loss of N to the air in the same way as urea, but only half as much will be lost (half of the N in UAN solution is in the urea form).
- The same treatments that reduce volatile loss from urea will also work with UAN solutions (Agrotain, tillage, irrigation or injection) but are not as necessary.

Promoting efficient uptake

Sound general crop management practices are essential to produce crops that are capable of efficient uptake of N fertilizer. The following best management practices fall within this category:

- Avoid practices that result in soil compaction. Soil compaction reduces root growth, which is critical for efficient uptake of N and for general crop health.
- Minimize traffic on very moist or wet soils, limit axle loads, ensure enough tire contact area on soil to support loads, and consider using controlled traffic.
- Choose good hybrids or varieties.
- Fertilize for normal yields. Even in years with excellent yield potential, increasing N rates above rates associated with normal yields is rarely needed.
- Conditions that are good for corn growth are also good for microbial activity that releases N from soil, and the soil tends to supply more N to the crop in these years.
- Manage soil P, K and pH to ensure optimum levels for crop production. Soil sample each field at least every four years to guide P, K and lime applications.
- Carefully set planters and drills and check their performance (seed depth, spacing, soil contact and slot closure).
- Prevent weeds from getting too large. Large weeds can drain substantial amounts of N away from the crop, even if they are successfully controlled later.

Soil Nutrient Exercises

Exercise 1. Reading and Understanding a Soil Test Report for Phosphorus

Due to changes over time in soil testing processes and reporting, there are a number of ways that soil test level phosphorus is expressed on reports. While a bit confusing, a quick look for three key items can make the soil test understandable and a recommendation can confidently be determined.

The three items to identify are:

1) Is P reported as **elemental P** or some other form?

Fortunately, the majority of soil tests (99%) will be reported as “P” or “Phosphorus” which indicates the elemental form.

If you see a reported value as “P_2O_5” do not use this value with recommendation charts. Stop and call the lab for a corrected copy expressed as Elemental P.

2) What **Units** are used with the P value?

Common report units with a soil test are:

a. Pound per acre expressed as “lb/A”, “lbs/A”, “pounds/A” or other expression.
b. Parts per million expressed as “ppm”, “PPM” or “mg/kg”

To convert pounds per acre to parts per million:

60 pounds per acre ÷ 2 = 30 parts per million

To convert parts per million to pounds per acre:

30 parts per million X 2 = 60 pounds per acre

3) What **Extractant** is being used to express the P value?

There are two common extractants which are solutions mixed with the soil to determine the phosphorus content. While both are good tests, they do not result in equal soil test values.

a. Bray P1 expressed as “P1”, “P-P1” or “Bray P1”.
b. Mehlich III expressed as “P-M3”, “M III”, “Mehlich 3” or “Mehlich III”.
c. If other terms are used that are not Bray P1 or Mehlich III call the lab.

For Ohio, the conversion from Mehlich-3-ICP to Bray P1 is:

-8.08 + 0.832(Mehlich-3-ICP value)=Bray P1-colormetric value

Example from Soil Sample 1(page 33): -8.08 + 0.832 (22) = 10

As you review your soil test reports, if you cannot identify the information in 1-3 above, call the lab for clarification.

Use the four example soil test reports below to identify the phosphorus units and extractants reported to complete the table on the next page with the results.

Sample Soil Test Report 1

Soil Test Labs Inc.
4555 Buckeye Dr.
Buckeye, OH 55555
Phone: 555-555-3400

Report Number: 1002
Account Number: ABC-102

To: Buckeye Farmer
Corn-Soybean Rd
High Yield, OH 99999

Date Received: 5/28/2015 Date: Reported 06/02/2015

Soil Test Report

Sample Number	1
Lab Number	68816
Organic matter %	2.7
Phosphorus, P-M3, ppm	22
Phosphorus, P2, ppm	
Potassium, K-M3, ppm	126
Magnesium, Mg-M3, ppm	265
Calcium, Ca-M3, ppm	1787
Sodium, Na-M3, ppm	
Soil pH	6.6
Buffer pH	6.9
CEC meq/100g	12.7
% K	2.6
% Mg	17.4
% Ca	70.5
% H	9.5

Sample Soil Test Report 2

Quality Soil Test Labs Inc.

Soil Analysis Report

USA Street
Brutus, OH 55567
Phone: 555-555-2110

Date Reported: 5/27/2015
Customer: FAOE22990123

Lab Number: 12-7861
Sample Id: 1

Buckeye Farmer
Corn-Soybean Rd
High Yield, OH 99999

Item		Units	Test Result
pH			6.6
Lime Test Index			69
Organic Matter		%	2.7
Phosphorus	M3	lb/a	44
Potassium	K	lb/a	252
Magnesium	Mg	lb/a	530
Calcium	Ca	lb/a	3574
Sodium	Na	lb/a	
Soluble Salts		mmho/cm	
Cation Exchange Capacity	CEC	meq/100g	12.7
Base Saturation		%	
Potassium		%	2.6
Magnesium		%	17.4
Calcium		%	70.5
Sodium		%	
Hydrogen		%	9.5

Sample Soil Test Report 3

State Lab Services

Industrial Parkway
Main Town, OH 55589
555-555-5520

Soil Test Report for:
Buckeye Farmer
Corn-Soybean Rd
High Yield, OH 99999

Date	Lab#	County	Field Id	Acres
5/26/2015	S12-42265		1	

Soil Nutrient Levels

[1] Soil pH	6.6
[2] Phosphorus P ppm	10
[3] Potassium K ppm	126
[3] Magnesium ppm	265
[3] Calcium ppm	1787
CEC meq/100g	12.7
% Saturation of CEC	
K	2.6
Mg	17.4
Ca	70.5
Organic Matter %	2.7
Test Methods: [1] 1:1 soil:water, [2] Bray P1, [3] Mehlich 3 (ICP)	

Sample Soil Test Report 4

Report Number 228.040

Soil Testing Labs LLC

Send to:
Buckeye Farmer
Corn-Soybean Rd
High Yield, OH 99999

Lab Number	13919
Sample Id	1

Organic matter %	2.7
Phosphorus, Bray P1, lbs/A	20
Phosphorus, P2, lbs/A	
Potassium, K, lbs/A	252
Magnesium, Mg, lbs/A	530
Calcium, Ca, lbs/A	3574
Soil pH	6.6
Buffer pH	6.9
CEC meq/100g	12.7
% K	2.6
% Mg	17.4
% Ca	70.5
% H	9.5

Complete the table below:

- Use the four example soil test reports on the previous page to identify the phosphorus units and extractants reported to complete the table below.
- Put an X next to the extractant and units used then fill in the soil test number value.

Exercise 1 Summary Table:

Measure	Report 1	Report 2	Report 3	Report 4
Bray P1				
Mehlich III				
Parts per million				
Pounds per acre				
Soil test number				
Conversions to Bray P1 PPM				
Convert lbs/A to PPM				
Convert M III to Bray P1				

Exercise 1 Summary Table: <u>Answer Key and Explanation</u>

Measure	Report 1	Report 2	Report 3	Report 4
Bray P1			X	X
Mehlich III	X	X		
Parts per million	X		X	
Pounds per acre		X		X
Soil test number	22	44	10	20
Conversions to Bray P1 PPM				
Convert lbs/A to PPM	22	44/2=22	10	20/2=10
Convert M III to Bray P1	-8.08 + 0.832 (22)=10		10	
Once converted to Bray P1 PPM standard the soil test for all is 10 PPM				

Soil Nutrient Exercises:

Exercise 2. Determining a Phosphorus Nutrient Recommendation and Fertilizer Rate

Use the Field 2 and Field 5 in the soil test reports below to determine a 2-year phosphorus fertilizer rate for a corn and soybean rotation based on the Tri-State Fertilizer Recommendations Tables 13 and 15 on page 37.

Use the worksheet on the next page for Field 2 and 5 to record your results. Answers are on page 39.

Example Reports- For Exercise 2

Soil Test Labs Inc.
4555 Buckeye Dr.
Buckeye, OH 55555
Phone: 555-555-3400

Report Number: 1200
Account Number: OSUE240

To: Example Farms
Corn-Soybean Rd
High Yield, OH 99999

Date Received: 5/28/2015 Date: Reported 06/02/2015

Soil Test Report

Sample Number	1	2	3	4	5
Lab Number	68816	68817	68824	68822	68823
Organic matter %	2.7	1.7	2.2	4.3	4.2
Phosphorus, Bray P1, ppm	10	9	29	58	24
Phosphorus, P2, ppm					
Potassium, K-M3, ppm	126	89	102	229	149
Magnesium, Mg-M3, ppm	265	309	261	391	741
Calcium, Ca-M3, ppm	1787	1393	1261	3100	3309
Sodium, Na-M3, ppm					
Soil pH	6.6	6.5	5.9	6.1	7.0
Buffer pH	6.9	6.9	6.9	6.7	
CEC meq/100g	12.7	11.0	9.9	22.9	23.1
% K	2.6	2.1	2.6	2.6	1.7
% Mg	17.4	23.5	21.9	14.2	26.7
% Ca	70.5	63.5	63.4	67.6	71.6
% H	9.5	10.9	12.1	15.7	

Yield Goals for Fields 1-5 bu/A

Year	Crop	1	2	3	4	5
2016	Corn	170	170	170	200	200
2017	Soybeans	45	45	45	50	50

Exercise 2: Recommendation and Fertilizer Worksheet

The formulas for calculating the recommendations for this table are on page 38.

Field ID Field 2					
Nutrient Recommendation-Phosphorus					
2016 Crop Corn		Yield 170 bu/A			
2017 Crop Soybeans		Yield 45 bu/A			
			Recommendation		
Nutrient	Reported as PPM Maintenance Range	My Soil Test Value	2016	2017	Total
P	**15-30**	9			

Fertilizer Need				
Nutrient	Needed Nutrient Recommendation in lbs/A	% P_2O_5 in Fertilizer Source	Amount of Fertilizer applied in lbs/A	Extra Nutrients
P		11-52-0		

Field ID Field 5					
Nutrient Recommendation-Phosphorus					
2016 Crop Corn		Yield 200 bu/A			
2017 Crop Soybeans		Yield 50 bu/A			
			Recommendation		
Nutrient	Reported as PPM Maintenance Range	My Soil Test Value	2016	2017	Total
P	**15-30**	24			

Fertilizer Need				
Nutrient	Needed Nutrient Recommendation in lbs/A	% P_2O_5 in Fertilizer Source	Amount of Fertilizer applied in lbs/A	Extra Nutrients
P		11-52-0		

Exercise 2: Tables for completing Recommendation and Fertilizer Worksheet (Tables are numbered as they appear in the Tri-State Fertilizer Recommendation for Corn, Soybeans, Wheat and Alfalfa)

Table 13. Fertilizer (P_2O_5) Recommendations for Corn (adapted from Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa)

Soil Test Level (expressed as P) and Method		Realistic Yield Goal (bu/acre)					
Bray P1 Colorometric	Mehlich III-ICP	120	145	170	200	225	250
PPM	PPM	lbs P_2O_5/acre recommended					
5	16	95	105	115	125	135	145
10	22	70	80	90	100	110	120
15-30	28-46	45	55	65	75	85	95
35	52	20	25	30	40	40	45
40	58	0	0	0	0	0	0

Table 15. Fertilizer (P_2O_5) Recommendations for Soybean. (adapted from Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa)

Soil Test Level (expressed as P) and Method		Realistic Yield Goal (bu/acre)					
Bray P1 Colorometric	Mehlich III-ICP	30	40	50	60	70	80
PPM	PPM	lbs P_2O_5/acre recommended					
5	16	75	80	90	100	105	115
10	22	50	55	65	75	80	90
15-30	28-46	25	30	40	50	55	65
35	52	10	15	20	25	30	35
40	58	0	0	0	0	0	0

Exercise 2: Calculations for completing Recommendation and Fertilizer Worksheet

Determining fertilizer amount needed to meet nutrient recommendation.

Fertilizer Phosphorus Source

Name	N Content*	P_2O_5 Content*	Common*	Water Solubility**	pH*
Rock Phosphate	0	3-8	0-3-0	0	
Triple Super Phosphate	0	44-48	0-46-0	>90%	1-3
Mono-ammonium Phosphate	10-12	48-61	11-52-0	100	4-4.5
Di-ammonium phosphate	18	46	18-46-0	100	7.5-8
Polyphosphate	10	34	10-34-0		5.9

Source: *4R Plant Nutrition IPNI

**Soil Fertility and Fertilizers

Granular Fertilizer Calculation

A granular fertilizer rate to meet a nutrient recommendation is determined in the following way:

We are selecting Mono-Ammonium Phosphate (MAP) or 11-52-0 as the nutrient source to meet 125 pound P_2O_5 need.

Nutrient Need P_2O_5	Divided by	% P_2O_5 content of the fertilizer source	Equals	Pounds of 11-52-0 per acre to meet nutrient need
125	÷	0.52	=	240

How much nitrogen is applied?

Pounds of 11-52-0 per acre to meet nutrient need	Multiplied by	% N content of the fertilizer source	Equals	Pounds of nitrogen per acre in the fertilizer application
240	×	0.11	=	26

Liquid Fertilizer Calculation

A liquid fertilizer rate to meet a nutrient recommendation is determined in the following way:

We are selecting Polyphosphate or 10-34-0 which weighs 11.65 lbs per gallon as the nutrient source to meet the 125 pound P2O5 need.

Nutrient Need P_2O_5	Divided by	% P_2O_5 content of the fertilizer source	Equals	Pounds of 10-34-0 per acre to meet nutrient need	Divided by	Liquid weight in pounds per gallon	Gallons of 10-34-0 applied per acre to meet nutrient need
125	÷	0.34	=	368	÷	11.65	31.5

How much nitrogen is applied?

Pounds of 10-34-0 per acre to meet nutrient need	Multiplied by	% N content of the fertilizer source	Equals	Pounds of nitrogen per acre in the fertilizer application
368	×	0.10	=	36.8

Exercise 2: Recommendation and Fertilizer Worksheet Table: (completed answers)

Field ID *Field 2*					
Nutrient Recommendation-Phosphorus					
2016 Crop *Corn* Yield *170 bu/A*					
2017 Crop *Soybeans* Yield *45 bu/A*					
			Recommendation-P_2O		
Nutrient	Reported as PPM Maintenance Range	My Soil Test Value	2016	2017	Total
P	15-30 Bray P1	*9*	(From Table 13) *90*	(From Table 15) *60*	*150*
Fertilizer Need					
Nutrient	Needed Nutrient Recommendation in lbs/A	% P_2O_5 in Fertilizer Source	Amount of Fertilizer applied in lbs/A	Extra Nutrients	
P	*150*	*11-52-0*	*(150 ÷ 0.52)* *288 lbs 11-52-0*	*(288 × 0.11)* *32 lbs of N*	

Field ID *Field 5*					
Nutrient Recommendation-Phosphorus					
2016 Crop *Corn* Yield *200 bu/A*					
2017 Crop *Soybeans* Yield *50 bu/A*					
			Recommendation-P_2O		
Nutrient	Reported as PPM Maintenance Range	My Soil Test Value	2016	2017	Total
P	15-30 Bray P1	*24*	(From Table 13) *75*	(From Table 15) *40*	*115*
Fertilizer Need					
Nutrient	Needed Nutrient Recommendation in lbs/A	% P_2O_5 in Fertilizer Source	Amount of Fertilizer applied in lbs/A	Extra Nutrients	
P	*115*	*11-52-0*	*(115 ÷ 0.52)* *221 lbs 11-52-0*	*(221 × 0.11)* *24 lbs of N*	

Sample Forms

Field ID					
Nutrient Recommendation-Phosphorus					
Crop	Yield				
Crop	Yield				
			Recommendation		
Nutrient	Reported as PPM Maintenance Range	My Soil Test Value	2016	2017	Total

Fertilizer Need				
Nutrient	Needed Nutrient Recommendation in lbs/A	% P_2O_5 in Fertilizer Source	Amount of Fertilizer applied in lbs/A	Extra Nutrients

Field ID					
Nutrient Recommendation-Phosphorus					
Crop	Yield				
Crop	Yield				
			Recommendation		
Nutrient	Reported as PPM Maintenance Range	My Soil Test Value	2016	2017	Total

Fertilizer Need				
Nutrient	Needed Nutrient Recommendation in lbs/A	% P_2O_5 in Fertilizer Source	Amount of Fertilizer applied in lbs/A	Extra Nutrients

Nitrogen for Corn Production

Nitrogen Cycle & Crop Uptake

Nitrogen (N) in crop production is a dynamic element. While approximately 80% of the atmosphere is nitrogen gas, only ammonium and nitrate forms can be used by crops.

Legumes and other bacteria can produce nitrogen for plant growth, but in modern agriculture much of our nitrogen fertilizers comes from combining natural gas with atmospheric nitrogen under pressure and in the presence of a catalyst.

Animal waste also contains nitrogen fertilizer. Lightning can also be a source of nitrates. Before 1910 nitrogen fertilizers for crops came from manures and legumes.

As shown in Figure 10, nitrogen is affected by many processes. Our concern for water quality is mostly about nitrate loss in groundwater, but ammonia in water can also cause health concerns.

The greatest removal of nitrogen is likely to be in the grain removed at harvest – about 0.6 lb/bu for corn or about 3.5 lbs N/bu for soybeans – for approximately 100 lbs N/A for corn or 200 lbs N/A for soybeans.

We apply nitrogen to our corn crop and let our Rhizobia supply the N for soybean. When does our crop need that nitrogen? In Figure 11 on the following page, we see that the corn crop really needs little nitrogen until the V8 to V10 growth stage.

The 30 to 50 pounds of N we may apply at planting can get us one third of the way through the growing season. Applying in-crop nitrogen can supply the remainder, and reduce potential loss to the environment.

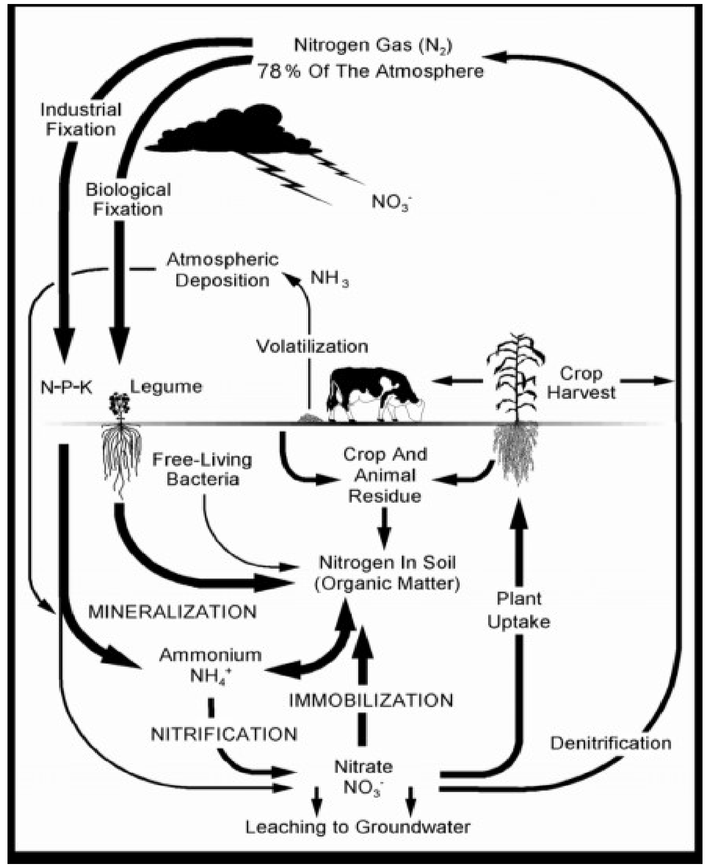


Figure 10. The nitrogen cycle – sources and losses of nitrogen. *Source: ENVIRONMENTAL IMPACTS OF NITROGEN USE IN AGRICULTURE, by K. McKague, K. Reid and H. Simpson. Ontario Ministry of Agriculture, Food & Rural Affairs Factsheet. Order Number 05-073, November 2005, Agdex 720/500.*

Weather variability, N uptake and Crop Yield

From nitrogen rate trials conducted at OSU's Western Agricultural Research Station over several years it becomes obvious that it is difficult to find the right N rate for corn. Variability from year-to-year at just this one location shows we can grow 157 bu/A of corn with 0 N applied or with 250 N applied. Or some years we can grow from 235 to 255 bu/A with just 50 to 100 pounds of N. Figure 12 on page 42 shows the variability in crop yield across various N rates.

Remarks by Jim Camberato & Bob Nielsen, Agronomists at Purdue University.

- The bottom line on N use in corn is dealing with a biological system that interacts with everything under the sun, including the sun.
- We cannot accurately predict the weather.
- We cannot accurately predict soil N supply throughout the year.
- Yet, we cannot afford (financially or environmentally) to simply apply "more than enough" N.
- We can minimize risk of fertilizer N loss by understanding processes and matching N source with placement and timing. And we can develop average N rate recommendations that work in "average" years.

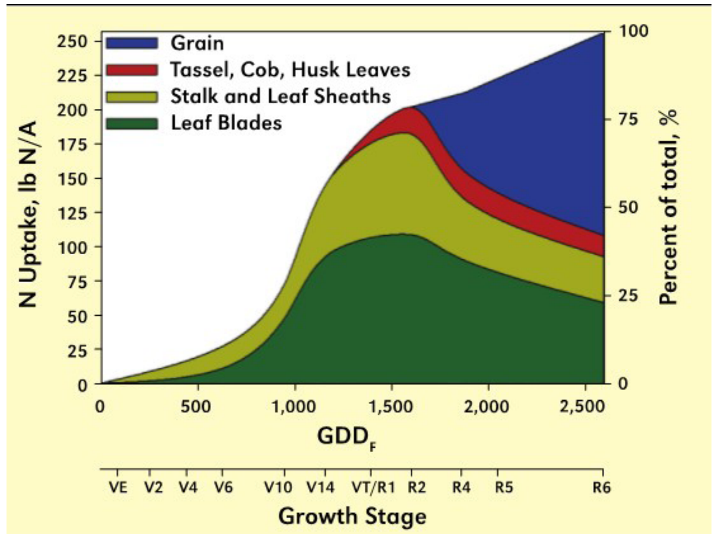


Figure 11. Total maize N uptake and partitioning across four plant fractions: leaf, stalk, reproductive, and grain tissues. Each value is a mean of six hybrids across two site-years at Urbana, IL (2010) and DeKalb, IL (2010). GDDF = growing degree days (˚F).

Source: Better Crops/Vol. 97 (2013, No. 1), International Plant Nutrition Institute: ipni.net/publication/bettercropsnsf/0/926946F50406A54085257B18005BB7AA/$FILE/page%207.pdfnsf/0/926946F50406A54085257B18005BB7AA/$FILE/page%207.pdf

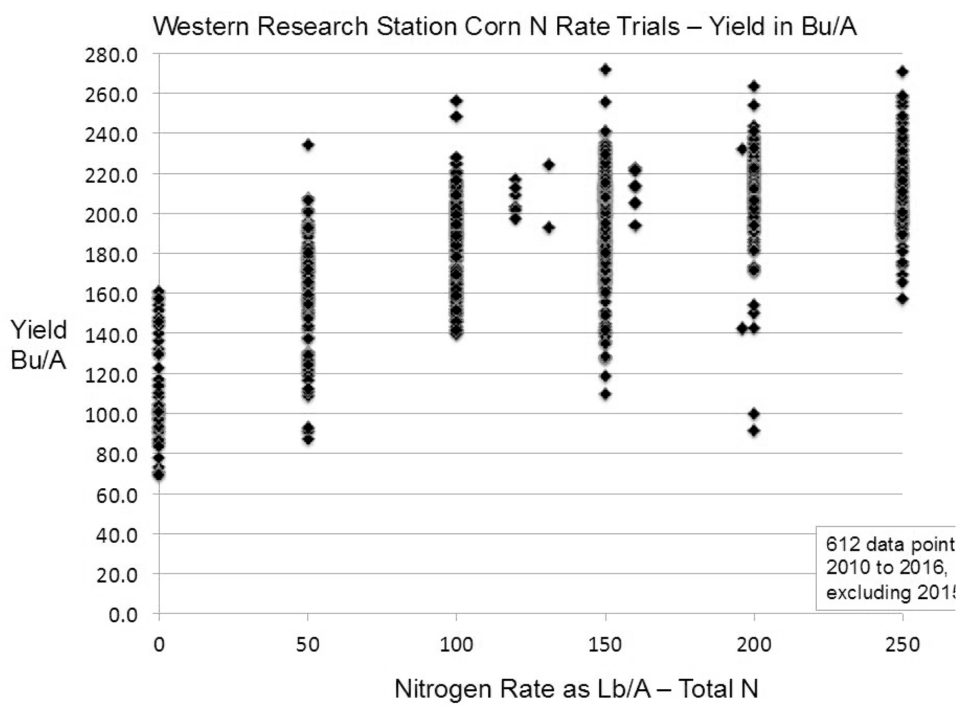


Figure 12. Western Research Station Corn N Rate Trials.

Determining N Rates for Corn in Ohio

Formerly we used crop yield goal to predict N recommendations for corn. It was determined that this method often over-supplied or under-supplied nitrogen – leading to potential environmental loss and economic impact.

Today we use economic models to predict N use for corn. University soil fertility specialists from the Corn Belt states began discussions in 2004 regarding nitrogen (N) rate for corn production. The reasons for the discussions centered on apparent differences in methods for determining suggested N rates across states, misperceptions regarding N rate guidelines, and concerns about application rates as corn yields have climbed to historic levels. An outcome of those discussions was an effort with the primary goal of developing an approach to N rate guidelines that could be utilized on a regional basis. A secondary goal was examining the most profitable fertilizer N rates for corn production across the Corn Belt.

This Corn Nitrogen Rate Calculator (CNRC) site: cnrc.agron.iastate.edu, provides a method to calculate the N rate and to find the maximum return to N (MRTN) at selected prices of N and corn. The MRTN approach is the regional approach suggested for developing corn N rate guidelines in individual states. Nitrogen rate trial data is provided in this web site for six states (Illinois, Iowa, Michigan, Minnesota, Ohio, and Wisconsin) where an adequate number of research trials (sites) were available for corn following soybean and corn following corn. These trials were conducted with spring, sidedress, or split preplant/sidedress applied N, and sites were not irrigated (except for those as indicated for irrigated sands in Wisconsin).

Prior to 2011, Ohio provided 80 sites to aid in the economic calculator model for our nitrogen rate. We anticipate adding significantly to the number of sites over the next few months with trial data from more recent farm-based yield trials. Please continue to check the CNRC website as we add more data.

The table below shows a model run for corn in Ohio in a corn/soybean rotation with nitrogen priced at $0.40/lb and corn sold for $3.50/bu.

Figure 13. Example from the CNRC.

Example from the Corn Nitrogen Rate Calculator **Run date: October 30, 2016**

State: Ohio
Number of sites: 80
Rotation: Corn following soybean
Non-responsive sites included

Nitrogen price ($/lb): 0.40
Corn price ($/bu): $3.50
Price ratio: 0.11

MRTN Rate (lb N/acre)	168
Profitable N Rate Range (lb N/acre)	153 - 184*
Net Return to N at MRTN Rate ($/acre):	$168.31
Percent of Maximum Yield at MRTN Rate:	98%
UAN (28% N) at MRTN Rate (lb product/acre):	599
UAN (28% N) Cost at MRTN Rate ($/acre):	$67.20

** There is only a $1 difference in the MRTN with the range in this example.*

From the Corn Nitrogen Rate Calculator we see that the optimum economic rate for nitrogen for corn in Ohio is 168 lb N/A. We would expect that 98% of the time this rate would provide the greatest return – that's not the highest yield but the best return on your nitrogen dollars. Any rate in the range of 153 N to 184 N would provide a similar return.

Please visit the website to run scenarios for your own operation and pricing: cnrc.agron.iastate.edu. For a better understanding of the background and the philosophy on the MRTN model, read: extension.iastate.edu/Publications/PM2015.pdf

Nitrogen Recommendations for Wheat

Work conducted since the Tri-State Fertilizer Recommendations were published suggests that N rates contained in that document are still appropriate for wheat. The nitrogen recommendations for wheat are found on page 56.

Tools to Improve Corn N Management

While the Corn Nitrogen Rate Calculator is the recommended tool for determining nitrogen rates for corn in Ohio, there are limitations to the model. It provides the average N rate recommendation for the state of Ohio – all of our corn crop. It doesn't take into account the variation in weather from year to year, or county to county. And what about soil differences? So while we currently provide the Corn Nitrogen Rate Calculator as the tool for Ohio corn N recommendations, we think we need to improve on those recommendations.

The following are some methods to help us learn how to better manage nitrogen. We don't believe that any of these tools are completely mature yet, but they are improving with more data. We will continue to explore better methods to manage corn N in Ohio - with the plan to reduce costs, reduce environmental impact, and maintain profitability.

Use of the Pre-Sidedress Nitrate Test (PSNT) in Ohio

A number of trials have historically been conducted in Ohio using the PSNT. The test can work in Ohio to predict nitrate availability for corn at early corn growth stages. The test works best where manures are applied or when corn follows a legume. In those situations the critical level would be 25-30 ppm nitrate-N. Meaning that above this level you would apply no additional nitrogen.

If you are not in a manure application or growing corn following a legume situation, then the PSNT would have no value, and there would be no reason to pull and test soil samples to determine nitrate levels. See remarks on the work done in Ohio at: agry.purdue.edu/cca/2008/proceedings/mullen.pdf

Purdue has also conducted trials to evaluate the PSNT: agry.purdue.edu/ext/pubs/ay-314-w.pdf. Their work refines the N application recommendation by nitrate level somewhat, but still recommends the use of the test in manure situations only. They also recommend waiting until corn is at the 4 to 6 leaf stage, and then pull soil samples from a 1-foot depth. The Purdue work can be found here: agry.purdue.edu/ext/pubs/ay-314-w.pdf

End of season corn stalk nitrate test (CSNT) use

Another evaluation tool can determine residual N at the end of the growing season. This would be a post mortem evaluation of your nitrogen application, telling you how much you had over- or under-applied.

Work at Purdue shows that if stalk nitrate levels are below 250 ppm nitrate-N you are probably under applying N, if above 2000 ppm then you are likely over applying N for corn. They suggest three years of evaluation before changing your nitrogen program. See the link for sampling procedures and a more complete interpretation on the use of this tool.

agry.purdue.edu/ext/soilfertility/news/cornstalknitrate.pdf

Crop Sensors (NDVI)

Predicting nitrogen recommendations for corn can be a difficult proposition. Remote sensing allows us an opportunity to postpone our decision until the corn crop has begun using soil available nitrogen – whether applied or from organic matter. The decision can be site-specific – that's something lacking with web-based or economic models. We can integrate a part of the growing season into our decision and by delaying an application we reduce the risk of N loss.

Crop sensors have been developed to measure plant reflectance to determine the "greenness" of a plant. The Normalized Difference Vegetation Index (NDVI) is a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum, and is adopted to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not. fsnau.org/downloads/Understanding_the_Normalized_Vegetation_Index_NDVI.pdf

Sensors exist to rapidly and accurately collect canopy reflectance information. From work coordinated by University of Missouri, Peter Scharf says, "Crop color was most accurate in 66 regional experiments in diagnosing which fields needed more N and which needed less".

View the whole work at: plantsci.missouri.edu/nutrientmanagement/nitrogen/pdf/sensor_manual.pdf

Nearby, Ontario has also done work on in-field crop sensors: gocorn.net/v2006/Nitrogen/articles/Seeking%20Green%2010%20Steps%20to%20Greenseeker.html

Work in Ohio from 2006 through 2009 by Robert Mullen, an Ohio soil fertility specialist, showed potential advantages for in-crop N sensors. Table 6 compares the sensor-based recommendation to a fixed 200 lbs N/A application with nearly equal results in income with an average of 75 pounds less N per acre.

There is good potential to better predict corn nitrogen needs if we delay the decision to apply until a month or more into the growing season – OSU work suggests waiting until V8 to sense the crop color. By applying N closer to the time of greatest crop need, we reduce the likelihood of N loss to the environment.

The Greenseeker used in Extension trials is a relatively inexpensive tool (suggested price $500). Other crop sensors are available in both hand-held and application equipment mounted to apply on the go. For information on the N rate calculator and an algorithm for use of the Trimble Greenseeker in Ohio, see the website: soiltesting.okstate.edu/sensor-based-n-rate-calculator

Yield levels across the sites and years are similar with less N applied. While not perfect, there is potential. Trials conducted in 2015 by Extension and industry agronomists also showed the impact on timing of application (as delayed by rainfall) can have on crop yield. One conclusion drawn from our 2015 experiments was the value of at-plant applications of 40 to 50 lbs N/A in assisting with recovery through and after waterlogged periods.

Table 6. Corn Yield at Sensor Recommendation Rate vs. 200 N/Acre in Ohio: Across 10 site-years

Location in Ohio/ Year	N rate based on sensor reading in lb/acre of N (*trt included 40 N at plant)	Yield in bu/acre for sensor reading treatment	Yield in bu/acre for 200 N preplant check
Clark County 2006	105	227	227
Wayne County 2006	36	96	105
Wood County 2007	70	164	172
Clark County 2007	42	195	181
Wayne County 2007	200	185	200
Clark County 2008	159	180	200
Wayne County 2008	147	174	177
Wood County 2009	36	161	181
Clark County 2009	63	204	215
Wayne County 2009	50	209	227
Average	*86 sensor avg + 40 planter = 126 N*	180 bu/A	*189 bu/A*
Net income[1]		*$576*	*$580*
[1]Net income here is bushels times $3.50, minus N rate times 40 cents per pound			
*Sensor plots received 40 lb N as a starter with the planter, included in the 126 N total			

A trial conducted in Darke County also showed the value of not applying nitrogen when it is not needed. In 2016 the prospect for the crop in western Ohio was excellent in June. All indicators would tell you we were well on the way to matching the 2015 yields. But, parts of the state went through a state of no rain from June 16 to August 12.

The results? In the Darke County nitrogen response study, shown in Table 7 on page 46, with treatments of 100, 150, 200 and 250 lb/A, there was no difference in NDVI sensor reading just prior to tassel or into July 12 indicating that no additional N was needed.

Without sufficient rainfall, additional nitrogen has no impact. It takes rain to make grain and to move the nitrogen up the stalk to fill the ear. End of season stalk nitrate levels also suggest that yes, we had excess nitrogen. We probably need 100 units of Nitrogen up to V6. Then depending on rainfall additional units of nitrogen should be added accordingly.

Table 8 on page 46, shows another sensor trial conducted in 2014 and 2016 in western Ohio at the OSU Western Ag Research Station near South Charleston, we compared sensor recommended rates to various set levels.

Table 7. 2016 Darke County N Rate Trial Yield in bu/A.

Trial N rate	Yield bu/A	End of Season stalk nitrate (NO_3-N)
100	110.2	558 ppm
150	120.7	1050 ppm
200	108.1	2048 ppm
250	110.4	2606 ppm

Table 8. OSU Western Ag Research Station Sensor Trials, 2014 & 2016.

Total N rate lbs/A	Yield bu/A
0	134.2
50	178.4
100	199.6
Sensor – 146 typically including 50 N at plant	206.3
150	204.4
200	209.3
250	214.1

With the average sensor rate (a GreenSeeker from Trimble) of 146 lbs N/A we matched the yield plateau from the fixed rate trial. What you don't see from the average is that we applied sensor recommended rates at side dress timing of from 60 to 146 lbs N/A, for a total N of 120 to 196 N. By using the NDVI sensor we were able to gauge the crop, the season, the year and the uptake to V8 of applied and soil available nitrogen.

Our observations on working with an NDVI sensor:

- You need a nitrogen rich strip in the field and across your various soil types to get a comparison to make to the recommendation, it is best if this N-rich strip is applied at or before planting.
- Wait until at least V8 before doing your sensor readings, too early and you get a reading off the soil. You want to capture information on the growing season to date for the seasonal weather impact.
- It may be best to have a base rate of 100lbs N/A. In 2015 we had difficulty in getting into some of our fields to make a side dress application, with 100 N we could have hung on until tassel. In a dry year, and maybe a normal year, the 100 N may be enough to make your crop. Perhaps apply 100 N as anhydrous ammonia in the
- spring, check your crop at V8 to V12 and apply as needed – in some years that addition will be nothing.

Other calculators

Are there other ways to determine your corn crop nitrogen needs? Yes, there are services that can help predict in-season crop needs:

- Cornell University has a web app to predict corn N needs more precisely based on field-specific conditions to recommend adjusting N applications based on local weather.
    - Called adapt-N: adapt-n.com
- Encirca from Pioneer is another service with a local advisor who works with you to include nitrogen management:
    - encirca.services.pioneer.com
- Climate Corp, a Monsanto company: climate.com
    - Their tool Climate Fieldview Pro includes a Nitrogen Advisor that uses satellite and web-based information to predict N losses and need.
- And there are many others… work with your local advisor to get their take on this

Do they work? That's up for debate, some say yes, some say no. But we need to work with these tools to see how you can integrate more information on your farm to get a better handle on N use for corn. Losses can be large – that's an economic impact as well as an environmental concern.

Supplemental Phosphorous Fertility Recommendation Tables

for Soil Testing Reported in parts per million (PPM) or mg/kg

Fertilizer Rate Recommendations Based on Tri-State Fertilizer Recommendations

The purpose for a soil sample should be to generate a fertilizer recommendation. The Tri-State Fertilizer Recommendations were generated using calibration studies with a Bray P1 soil test result. The tables can be used for levels reported from both a Bray P1 or Mehlich III-IPC equivalent result.

Farmers need to look on the soil test report to check the laboratory method reported in association with the Phosphorus soil test level. If the method used to report is unclear then a call to the laboratory can clear up any confusion. Reporting in PPM or kg/mg are equivalent unit measures. For a complete discussion of the comparison of phosphorus testing see agcrops.osu.edu/sites/agcrops/files/imce/fertility/Soil_Tests_Plant_Avail.pdf

Fertilizer recommendation tables on Tables 13 through 17 of the original publication have been updated. The tables shown below can be substituted in the original publication. The tables are updated to reflect the higher productivity of today's production systems utilizing the equations (page 11) from the Tri-State Fertilizer Recommendations publication can be found at: agcrops.osu.edu/sites/agcrops/files/publication-files/Tri-State.pdf

The philosophy of these recommendations can be found in the original publication on pages 10-12 of the Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa.

Table 13. Fertilizer (P_2O_5) Recommendations for Corn. (adapted from Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa).

Soil Test Level (expressed as P) and Method		Realistic Yield Goal (bu/acre)					
Bray P1 Colorometric	Mehlich III-ICP	120	145	170	200	225	250
PPM	PPM	lbs P_2O_5/acre recommended					
5	16	95	105	115	125	135	145
10	22	70	80	90	100	110	120
15-30	28-46	45	55	65	75	85	95
35	52	20	25	30	40	40	45
40	58	0	0	0	0	0	0

*adapted from Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa

Table 14. Fertilizer (P_2O_5) Recommendations for Corn Silage*.

Soil Test Level (expressed as P) and Method		**Realistic Yield Goal (Ton/acre)**					
Bray P1 Colorometric	**Mehlich III-ICP**	20	22	24	26	28	30
PPM	**PPM**	**lbs P_2O_5/acre recommended**					
5	16	115	125	130	135	140	150
10	22	90	100	105	110	115	125
15-30	28-46	65	75	80	85	90	100
35	52	35	40	40	45	45	50
40	58	0	0	0	0	0	0

*adapted from Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa

Table 15. Fertilizer (P_2O_5) Recommendations for Soybeans*.

Soil Test Level (expressed as P) and Method		**Realistic Yield Goal (bu/acre)**					
Bray P1 Colorometric	**Mehlich III-ICP**	30	40	50	60	70	80
PPM	**PPM**	**lbs P_2O_5/acre recommended**					
5	16	75	80	90	100	105	115
10	22	50	55	65	75	80	90
15-30	28-46	25	30	40	50	55	65
35	52	10	15	20	25	30	35
40	58	0	0	0	0	0	0

*adapted from Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa

Table 16. Fertilizer (P_2O_5) Recommendations for Wheat (Grain only).*

Soil Test Level (expressed as P) and Method		Realistic Yield Goal (bu/acre)					
Bray P1 Colorometric	**Mehlich III-ICP**	50	65	80	95	110	125
PPM	**PPM**	**lbs P_2O_5/acre recommended**					
15	28	80	90	100	110	120	130
20	34	55	65	75	85	95	105
25-40	40-58	30	40	50	60	70	80
45	64	15	20	25	30	35	40
50	79	0	0	0	0	0	0

*adapted from Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa

Table 17. Fertilizer (P_2O_5) Recommendations for Alfalfa*.

Soil Test Level (expressed as P) and Method		Realistic Yield Goal (Ton/acre)					
Bray P1 Colorometric	**Mehlich III-ICP**	5	6	7	8	9	10
PPM	**PPM**	**lbs P_2O_5/acre recommended**					
15	28	115	130	140	155	165	180
20	34	90	105	115	130	140	155
25-40	40-58	65	80	90	105	115	130
45	64	35	40	45	50	60	65
50	79	0	0	0	0	0	0

*adapted from Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa

Supplemental Potash Fertility Recommendation Tables

Fertilizer Rate Recommendations Based on Tri-State Fertilizer Recommendations

The purpose for a soil sample should be to generate a fertilizer recommendation. The Tri-State Fertilizer Recommendations provide that correlation data for Ohio. Tables 18-21 for Potassium recommendations were updated to a broader range of yield goals based on equations in the original publication. The equations are included at the end of this publication. The original publication, Tri State Fertilizer Recommendations can be found at: agcrops.osu.edu/sites/agcrops/files/publication-files/Tri-State.pdf The approach for these recommendations can be found in the original publication on pages 10-12. Table numbers reflect those in the Tri-State Fertilizer Recommendations.

Table 18. Fertilizer Potash (K_2O) Recommendations for Corn*.

	Realistic Yield Goal (bu/acre)						
Soil Test Level	120	145	170	200	225	250	275
PPM (lb/acre)	**lbs K_2O/acre recommended**						
	---------------------5 meq/100g------------------						
25 (50)	130	140	145	155	160	165	170
50 (100)	95	110	115	120	130	135	140
75 (150)	65	75	85	90	95	105	110
88-118 (175-235)	45	60	65	75	80	90	95
130 (260)	20	25	25	30	30	35	40
140 (280)	0	0	0	0	0	0	0
	---------------------10 meq/100g------------------						
25 (50)	160	170	180	190	195	200	205
50 (100)	120	135	140	150	155	165	170
75 (150)	85	100	105	110	120	125	130
100-130 (200-260)	45	60	65	75	80	90	95
140 (280)	25	30	35	40	40	45	50
150 (300)	0	0	0	0	0	0	0
	---------------------20 meq/100g------------------						
50 (100)	195	210	215	225	230	240	245
75 (150)	145	160	165	175	180	190	195
100 (200)	95	110	115	125	130	140	145
125-155 (250-310)	45	60	65	75	80	90	95
165 (330)	25	30	35	40	40	45	45
175 (350)	0	0	0	0	0	0	0
	---------------------30 meq/100g------------------						
75 (150)	240	250	255	260	270	275	280
100 (200)	175	185	190	200	205	215	220
125 (250)	115	120	130	140	145	150	160
150-180 (300-360)	50	60	65	75	80	90	95
190 (380)	25	30	35	40	40	45	45
200 (400)	0	0	0	0	0	0	0

*adapted from Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa

Table 19. Fertilizer Potash (K_2O) Recommendations for Soybeans.*

	Realistic Yield Goal (bu/acre)						
Soil Test Level	30	40	50	60	70	80	90
PPM (lb/acre)	**lbs K_2O/acre recommended**						
	---------------------5 meq/100g------------------						
25 (50)	140	155	170	180	195	210	225
50 (100)	110	125	135	150	165	180	195
75 (150)	80	90	105	120	135	150	160
88-118 (175-235)	60	75	90	105	120	130	145
130 (260)	25	30	35	40	45	55	60
140 (280)	0	0	0	0	0	0	0
	---------------------10 meq/100g------------------						
25 (50)	175	190	205	215	230	245	260
50 (100)	135	150	165	180	195	205	220
75 (150)	100	115	130	140	155	170	185
100-130 (200-260)	60	75	90	105	120	130	145
140 (280)	30	40	45	50	60	65	75
150 (300)	0	0	0	0	0	0	0
	---------------------20 meq/100g------------------						
50 (100)	210	225	240	255	270	280	295
75 (150)	160	175	190	205	220	230	245
100 (200)	110	125	140	155	170	180	195
125-155 (250-310)	60	75	90	105	120	130	145
165 (330)	30	40	45	50	60	65	75
175 (350)	0	0	0	0	0	0	0
	---------------------30 meq/100g------------------						
75 (150)	250	265	280	290	300	320	335
100 (200)	185	200	215	230	245	260	270
125 (250)	125	140	155	165	180	195	210
150-180 (300-360)	60	75	90	105	120	130	145
190 (380)	30	40	45	50	60	65	75
200 (400)	0	0	0	0	0	0	0

*adapted from Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa

Table 20. Fertilizer Potash (K_2O) Recommendations for Wheat (Grain only).*

	Realistic Yield Goal (bu/acre)					
Soil Test Level	50	65	80	95	110	125
PPM (lb/acre)	**lbs K_2O/acre recommended**					
	---------------------5 meq/100g----------------					
25 (50)	115	120	130	135	140	145
50 (100)	85	90	95	105	110	115
75 (150)	55	60	65	70	75	85
88-118 (175-235)	40	45	50	55	60	65
130 (260)	15	20	20	20	25	25
140 (280)	0	0	0	0	0	0
	--------------------10 meq/100g---------------					
25 (50)	150	160	160	170	175	180
50 (100)	115	120	125	130	135	140
75 (150)	75	80	85	95	100	105
100-130 (200-260)	40	45	50	55	60	65
140 (280)	20	20	25	30	30	35
150 (300)	0	0	0	0	0	0
	--------------------20 meq/100g----------------					
50 (100)	190	195	200	205	210	215
75 (150)	140	145	150	155	160	165
100 (200)	90	95	100	105	110	115
125-155 (250-310)	40	45	50	55	60	65
165 (330)	20	20	25	30	30	35
175 (350)	0	0	0	0	0	0
	--------------------30 meq/100g----------------					
75 (150)	225	230	235	245	250	255
100 (200)	165	170	175	180	185	190
125 (250)	100	105	110	120	125	130
150-180 (300-360)	40	45	50	55	60	65
190 (380)	20	20	25	30	30	35
200 (400)	0	0	0	0	0	0

*adapted from Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa

Table 21. Fertilizer Potash (K_2O) Recommendations for Corn Silage.*

	Realistic Yield Goal (tons/acre)						
Soil Test Level	20	22	24	26	28	30	32
PPM (lb/acre)	**lbs K_2O/acre recommended**						
	---------------------5 meq/100g-------------------						
25 (50)	260	275	290	300	300	300	300
50 (100)	225	245	260	275	290	300	300
75 (150)	195	210	230	245	260	275	290
88 (175)	180	195	210	230	245	260	275
110 (220)	100	110	115	125	135	145	155
130 (260)	25	30	30	35	35	40	40
140 (280)	0	0	0	0	0	0	0
	---------------------10 meq/100g-------------------						
25 (50)	295	300	300	300	300	300	300
50 (100)	255	270	270	300	300	300	300
75 (150)	220	235	235	265	280	280	295
100 (200)	180	195	195	230	245	260	275
120 (240)	110	120	120	135	145	155	165
140 (280)	35	40	40	45	50	50	55
150 (300)	0	0	0	0	0	0	0
	---------------------20 meq/100g-------------------						
50 (100)	300	300	300	300	300	300	300
75 (150)	280	295	295	300	300	300	300
100 (200)	230	245	245	280	295	300	300
125 (250)	180	195	195	230	245	260	275
145 (290)	110	120	120	135	145	155	165
165 (330)	35	40	40	45	50	50	55
175 (350)	0	0	0	0	0	0	0
	---------------------30 meq/100g-------------------						
75 (150)	300	300	300	300	300	300	300
100 (200)	300	300	300	300	300	300	300
125 (250)	245	260	260	290	300	300	300
150 (300)	180	195	195	230	245	260	275
170 (360)	110	120	120	135	145	155	165
190 (380)	35	40	40	45	50	50	55
200 (400)	0	0	0	0	0	0	0

*adapted from Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa

Table 22. Fertilizer Potash (K_2O) Recommendations for Alfalfa.*

	Realistic Yield Goal (tons/acre)					
Soil Test Level	5	6	7	8	9	10
PPM (lb/acre)	**lbs K_2O/acre recommended**					
	----------------5 meq/100g-----------------					
25 (50)	300	300	300	300	300	300
50 (100)	300	300	300	300	300	300
75 (150)	285	300	300	300	300	300
88 (175)	270	300	300	300	300	300
110 (220)	150	175	205	230	260	290
130 (260)	40	50	55	65	70	75
140 (280)	0	0	0	0	0	0
	--------------------10 meq/100g--------------					
25 (50)	300	300	300	300	300	300
50 (100)	300	300	300	300	300	300
75 (150)	300	300	300	300	300	300
100 (200)	270	300	300	300	300	300
120 (240)	160	190	220	250	280	300
140 (280)	55	65	75	85	95	105
150 (300)	0	0	0	0	0	0
	--------------------20 meq/100g--------------					
50 (100)	300	300	300	300	300	300
75 (150)	300	300	300	300	300	300
100 (200)	300	300	300	300	300	300
125 (250)	270	300	300	300	300	300
145 (290)	160	190	220	250	280	300
165 (330)	55	65	75	85	95	105
175 (350)	0	0	0	0	0	0
	--------------------30 meq/100g--------------					
75 (150)	300	300	300	300	300	300
100 (200)	300	300	300	300	300	300
125 (250)	300	300	300	300	300	300
150 (300)	270	300	300	300	300	300
170 (360)	160	190	220	250	280	300
190 (380)	55	65	75	85	95	105
200 (400)	0	0	0	0	0	0

*adapted from Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa

For computer generated recommendations the following equations were used to generate the fertilizer recommendations in the tables.

BUILDUP EQUATION

for P: lb P_2O_5/A to apply = [(CL - STL) x 5] + (YP x CR)

for K: lb K_2O/A to apply = [(CL - STL) x (1 + (0.05 x CEC))] + (YP x CR) + 20

MAINTENANCE EQUATION

for P: lb P_2O_5/A to apply = YP x CR

for K: lb K_2O/A to apply = (YP x CR) + 20 (for non-forage crops)

DRAWDOWN EQUATION

for P: lb P_2O_5/A to apply = (YP x CR) - [(YP x CR) x (STL - (CL + 15))/10]

for K: lb K_2O/A to apply = (YP x CR) + 20 - [((YP x CR) + 20) x (STL - (CL + 30))÷20](for non-forage crops)

Note: The K maintenance and drawdown equation for forages. including corn silage, is:

lb K_2O/A to apply [(YP x CR)+ 20] - [((YP x CR) + 20] x (STL-CL)÷50]

where:

CL = critical soil test level (ppm)

STL = existing soil test level (ppm)

YP = crop yield potential (bu per acre for grains, tons per acre for forages)

CR = nutrient removed per unit yield (lb/unit)

CEC = soil cation exchange capacity (meq/100g)

Document updated 10/2013.

Greg LaBarge, Field Specialist, Agronomic Systems, Ohio State University Extension labarge.1@osu.edu or
Dr. Steve Culman, State Soil Fertility Specialist, Ohio State University Extension culman.2@osu.edu

Nitrogen Recommendations For Wheat

The following N recommendations for wheat (Table 10 on page 10 of the Tri-State Fertilizer Recommendations) assume that the crop is planted during the optimum planting period on mineral soils with 1 to 5 percent organic matter and either good natural or improved drainage, and that proper cultural practices are utilized.

Table 10. Nitrogen Recommendations for wheat based on yield.

Yield potential Bu/A	Pounds N to apply Lb N/A
50	40
70	75
90+	110

Additional Comments

1. Recommended N rate is based on the relationship: N (lb/acre) = 40 + [1.75 x (yield potential - 50)]

2. No credits are given for the previous crop. Consult individual state recommendations concerning credits for organic waste materials such as manure.

3. Apply 15 to 30 lb N/acre at planting and the remainder near green-up in spring; or, apply all N at planting as anhydrous ammonia plus a nitrification inhibitor, injected on 15-inch or narrower row spacing.

4. To prevent serious lodging on high organic matter soils (greater than 20 percent organic matter), reduce the N rate by 30 to 50 lb N/acre.

On-Farm Studies

Ohio State University Extension Agronomic Crops Team supports a variety of on-farm trials. The following trials related to fertility studies will be used to provide more environments for other research branch work. The studies can be adapted to different systems and objectives. A listing of project results can be found at: agcrops.osu.edu/on-farm-research. Contact your local educator or any of Field Specialist Agronomic Systems, Elizabeth Hawkins, **hawkins.301@osu.edu**, Greg LaBarge, **labarge.1@osu.edu** or Harold Watters, **watters.35@osu.edu** if you are interested in cooperative on-farm trials with Ohio State University Extension.

One tool that can cna make setting up the trial on your farm easier is the smart phone app for Android or iOS: search for "Ohio State PLOTS".

On-Farm Trials Study 1. Updating P and K Recommendations in Soybeans and Corn

Specialists: Steve Culman, Laura Lindsey, Anne Dorrance, Andy Michael, Greg LaBarge
Questions on plot layout/controller files can be directed to Greg LaBarge.

Objective: Update tri-state recommendations for P and K in soybeans and corn.

Justification: The tri-state recommendations for P and K in soybeans and corn.

Treatments:

1. No fertilizer applied
2. 32 lbs P_2O_5/acre
3. 56 lbs K_2O/acre
4. 32 lbs P_2O_5/acre + 56 lbs K_2O/ acre

Experimental Design: Randomized complete block with minimum of three replications. Plot width will depend on cooperator's equipment; planting, and harvesting. Plot size should match the width of the combine header to maximize harvest efficiency. Plot length should be a minimum of 500 feet. Combines should be calibrated in season where yield monitor data will be used for crop yield. Harvest passes from the center of plots will be extracted for treatment comparisons. GIS software can be used to tease out additional comparisons by soil type where soil types run perpendicular to treatments. Consideration to tile needs to be given and run opposite to the treatments

Data Collection: Soil samples for a standard soil test should be collected from each plot prior to planting or immediately after planting. Plant tissue samples from each plot at R1 (first flowering). Soybean grain yield at harvest.

Sample Plot Layout:

	Replication 1				Replication 2				Replication 3				
Border	2	4	3	1	4	1	3	2	3	1	4	2	Border

On-Farm Trials Study 2. Nitrogen Response in Corn

Specialists: Steve Culman, Peter Thomison
Questions on plot layout/controller files can be directed to Greg LaBarge.

Objective: Develop nitrogen response curves.

Justification: Nitrogen fertilizer remains one of the most expensive inputs to corn growers. Judicious use of nitrogen ensures optimal economic return on investment to growers and minimized losses of nitrogen to the environment. The starting point is to develop yield response curves across the different environments.

Treatments:

1. 0 (This area can be discussed and adjusted to minimize yield losses over a large area but greatly strength results and understanding of soil supplied N)
2. 50 pounds of N
3. 100
4. 150
5. 200
6. 250

Experimental Design: Randomized complete block with minimum of three replications. Plot width will depend on cooperator's equipment; planting, and harvesting. Plot size should match the width of the combine header to maximize harvest efficiency. Plot length should be a minimum of 500 feet. Combines should be calibrated in season where yield monitor data will be used for crop yield. Harvest passes from the center of plots will be extracted for treatment comparisons. GIS software can be used to tease out additional comparisons by soil type where soil types run perpendicular to treatments. Consideration to tile needs to be given and run opposite to the treatments.

Data Collection: Soil samples for a standard soil test should be collected within each replication. The presidedress nitrate test (PSNT- soil test taken when corn is V4-V6 or 6-12 inches tall intensity of sample density will differ based on previous management), in season spad meter, Green Seeker, tissue test or NDVI and Stalk N Test (plant analysis of nitrate in stalk taken 1-3 weeks after black layer) can be valuable additional information. If soil types are to be separate out observations in each soil type should be made. Corn grain yield at harvest.

Sample Plot Layout:

	Replication 1						Replication 2						Replication 3						
Border	3	5	2	1	4	6	5	1	4	2	6	3	2	6	1	5	3	4	Border

Resources for Fertilization of Horticultural Crops

Specialty Vegetable and Fruit Crop Nutrient Management

Vegetable Production Systems Laboratory Ohio State - u.osu.edu/vegprolab

Vegnet Website (OSU) - vegnet.osu.edu

Midwest Vegetable Production Guide for Commerical Growers 2017
ag.purdue.edu/btny/midwest-vegetable-guide/Documents/2017/01_MWVegGuide_2017.pdf

Nutrient Cycling and Maintaining soil fertility in fruit and vegetable crop systems: extension.umn.edu/garden/fruit-vegetable/nutrient-cycling-and-fertility/

Michigan State University interactive nutrient recommendation program for field crops, vegetable crops, and fruit crops.
maec.msu.edu/fertrec/

Nutrient Recommendations for Vegetable Crops in Michigan. MSU Extension Bulletin E2934.
shop.msu.edu/category_s/454.htm

Fertility Management of Small Fruits

Midwest Blueberry Production Guide
southcenters.osu.edu/news/midwest-blueberry-production-guide

Midwest Grape Production Guide
for purchase: estore.osu-extension.org/

Raspberry and Blackberry Production Guide for the Northeast, Midwest, and Eastern Canada: host31.spidergraphics.com/nra/doc/Fair%20Use%20Web%20PDFs/NRAES-35_Web.pdf

Wine Grape Production Guide for Eastern North America. NRAES-145
for purchase: palspublishing.cals.cornell.edu/nra_order.taf?_function=detail&pr_id=178&_UserReference=0E03A

Highbush Blueberry Nutrition. Michigan State University Bulletin E2011.
shop.msu.edu/category_s/454.htm

Fertilizers for Fruit Crops. Michigan State University Bulletin E852. shop.msu.edu/category_s/454.htm

Resource People for Fertilizer Management in Fruits and Vegetables

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Fruits & Vegetable Fertilizer Management
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Soil Applied Nutrient Management in Tree Fruits

Fruit Trees Internally Conserve Nutrients

Fruit Tree crops conserve nutrients in an annual cyclic fashion.

- Mobile nutrients withdrawn from leaves prior to leaf drop in fall and stored within the tree
- Nutrient loss from tree due to fruit harvest (and leaf drop)
- Nutrient dilution in tree due to tree growth

Perennial Fruit and Nut Crops protect against soil erosion and conserve soil nutrients; Important throughout Ohio but especially important in non-glaciated Appalachian foothills of southeast Ohio which are so subject to erosion with row cropping.

Chestnut Orchard – requires replanting once every 40 years or so; species is adapted to naturally acidic soils; low rate of nitrogen fertilizer applied in tree rows annually in spring time for adequate tree vigor, but vigor inhibits fruiting.

Nutrients Most Commonly Soil- Applied by Tree Fruit Growers in Ohio:

1. **Site preparation before planting – SOIL TEST for your site**

- **Lime** (calcium-containing) - for pH adjustment allowing natural availability of nutrients present in soil;
- **Potash** (potassium) - not a tree structural component but required in large amounts for plant metabolic processes, pest resistance and fruit quality.

2. **At Planting**

- **Potash** (potassium)
- **Phosphorus** (as di-ammonium phosphate) - important for tree energetics of growth, and fruit quality.

3. **In Young Orchards – use a leaf tissue test to determine nutrient requirements**

- **Peaches - Calcium Nitrate** - balancing act for tree growth and fruit firmness; split application preferred in March (spring) and after fruit set (May); applied in tree drip line for optimum root uptake;
- **Apples may benefit** – from calcium nitrate, but apply early spring in one application at half peach rate.

4. **Mature Orchards – Use soil and leaf tissue tests every 3-4 years to determine requirements**

- **Apples – may need potash**
- **May need micronutrients (boron)** – mixed with potash and spread in tree row – rely on tissue testing for guidance.
- **Peaches – Calcium nitrate** – done annually in split application (total ¼ lb. product/tree/yr. of tree age).

Fruit orchard replanting is often done in relatively small blocks surrounded by intact areas; this minimizes soil and nutrient erosion.

Area of fruit tree removal: will be limed, plowed, grown in cover crops for 2 years and then replanted to fruit trees.

Pre-Plant Site Preparation

Lime *(calcium-containing):*
Lime addition adjusts pH to a range that promotes optimal nutrient availability from the soil; typically soil applied as pelletized lime - dolomitic (12% magnesium, 20% calcium) or hi-cal (3% magnesium, 33% calcium); often at 2-3 tons/acre and incorporated to distribute in the soil profile as lime only moves downward roughly 1"/year. FOLLOW YOUR SOIL TEST RECOMMENDATIONS FOR ACTUAL RATES.

A second application can be soil applied and disked in prior to tree planting. If more serious pH adjustment is needed (as in eastern OH), a higher rate can be used with additional applications.

Potash *(potassium)*
Not a tree structural component but required in large amounts for plant metabolic processes, pest resistance and fruit quality;

Added as muriate of potash (60% K); spread across field as dry product; FOLLOW YOUR SOIL TEST RECOMMENDATIONS FOR ACTUAL RATES.

Ohio soils typically need lime and potash additions.

Plant trees into the tree row; sod between rows. Disk in Potash and di-ammonium phosphate applications to benefit the trees and avoid run-off to streams.

At Planting -

Potash *(potassium)*
As described in site preparation slide; can be broadcast or applied in tree row.

Phosphorus *(as di-ammonium phosphate)*
Typically applied either before trees are planted or at time of planting; formulation is 18-46-0; often spread in band centered in planting line. FOLLOW YOUR SOIL TEST RECOMMENDATIONS FOR ACTUAL AMOUNTS.

NOTE: In order to avoid nitrogen and phosphorus run-off into water, have grass aisles already in place. Pay attention to when and how you are doing this and avoid application before gully-washing rain storms.

Keep the areas in the row of young apple trees weed-free to avoid competition for nutrients. It is unlikely that any nutrient will be added to young and maturing trees; if added, nutrient will be spread in tree row, not broadcast over entire field.

In a mature block of fruiting apple trees within a herbicide strip, it is unlikely that any soil applied fertilizer will be added for the duration of the life of planting.

Mature Peach Trees: A split application of calcium nitrate is recommended yearly – in tree rows. First application in early spring (BEFORE the dandelions bloom); 2nd application after fruit set. This gets optimum availability of nitrogen to trees – at root growth and an extra shot when shoots are taking off; calcium helps fruit firmness; recommendation is ¼ lb. of product per tree/year of age

Adapted from materials by Dr. Diane Miller, Department of Horticulture and Crop Science, The Ohio State University

Fertilizing Nursery Soils

Best management practices (BMP) for nutrient and water quality management in nurseries can be complex, especially given the variety of plant material produced as well as options for growing in the field (balled and burlapped [B & B], bareroot) or in containers. Field soils are more stable due to volume and mineral content. Additionally, artificial mixes vary from business to business. Even with this variety, it is still necessary and possible to develop nutrient BMPs for the nursery.

As with most plant production, nitrogen, phosphorous and potassium are the three major nutrients growers are concerned with. Ideally in nursery production we are trying to match plant need with material applied. Absorption rates for various nutrients vary from season to season: nitrogen uptake is in fall and spring; phosphorous uptake in summer; potassium late summer into fall. However, work schedules, weather, and other variables don't always allow for attention to this level of detail and most growers apply all three elements at one time with some attention to micronutrients.

There are options for nutrient application in nursery production to help prevent waste and contamination. Best management practices for nutrient management listed below are divided into management of fertilizer products (nutrients) and irrigation management. Considering each BMP below on a crop-by-crop basis or for the entire nursery will not only help with nutrient waste issues but also with overall crop health.

Checklist for BMPs

Nutrients

Storage—Keep liquid formulations separate from solids/granular. Keep fertilizers separate from pesticides. Many fertilizer products are hydrophilic, they like water so much they will even pull it out of humid air. Protecting them from exposure to moisture and wide temperature swings will maintain the quality of the fertilizer product. Generally, fertilizers damaged by moisture can still be used but their application will be difficult due to the loss of quality of the product.

Load and transfer fertilizers only where it can be confined. This makes spill cleanup simple. Apply spilled product over an appropriate area and crop.

Types

The majority of nutrients used are nitrogen (N), phosphorous (P) and potassium (K). Micronutrients are needed in some situations. Products can be divided into four basic categories according to the manner in which nutrients are released: osmotic, microbial action, water soluble, and mechanical.

Osmotically released products use a polymer coating that allows for measured release of nutrients when exposed to water. There are a wide variety of materials available with a variety of nutrient concentrations and duration of release (how many months they will last). Fertilizers released by microbial action require microbes to act on them in order for the nutrients to be released--no microbe activity, no release; limited microbe activity, limited release. Water-soluble fertilizers are dissolved and released when they come into contact with water. They tend to release a large percentage of their nutrients in a short period of time as long as sufficient water is available--products that dissolve more slowly will have a longer release curve. Mechanically released products require the physical breakdown of the product, or coating on the fertilizer, to make the nutrients available.

Quantities

The amount of fertilizer needed in the nursery will vary by crop, media, size of plant, irrigation schedule, media temperature, release rate of the fertilizer, and application method. With the wide variety of material produced, it is impractical to recommend a single rate of nutrient application for all crops. Beginning with a general recommendation and following up with a good monitoring program may present the best method for reducing overapplication of nutrients and catching nutrient deficiencies early.

For example, recommendations for field nursery production nitrogen applications used to be over 200 pound N per A per year. More recently, recommendations are to not exceed 150 pounds N per acre per year. And, work with controlled release products (Mathers, Case, Zondag, Daniel) is showing positive results with rates as low as 100 pounds per acre in a split application.

It is important to remember that plant growth and development will not exceed the most limiting factor. In other words even though other nutrients may be applied in excess, it is the nutrient that is missing that will limit that plant's growth. This "law of the minimum" can be found in nursery production when some nutrients may be applied in excess when growth is less than ideal, not realizing that the plant is actually unable to develop fully due to shortage of some other nutrient (such as applying excess N when the plant is actually short a particular micronutrient).

Application

Application methods are divided into methods for liquid feed and dry fertilizers.

Dry fertilizers

Dry products can be applied through incorporation, top dressing, and dibbling. Each method has benefits and drawbacks.

Dibbling places the material directly below root system. It poses the highest potential for burn and is labor intensive. *Incorporation* requires the largest amount of fertilizer, but is cheapest to apply. Up to 30% of the fertilizer can be lost before the roots that populate the media reach the fertilizer. *Topdressing* is the most labor intensive. It has a high potential for loss (if the pot falls over and spills product), but is the best method for getting fertilizer to the media for root utilization when needed.

For dry fertilizer application, controlled-release fertilizers (CRF) are the best delivery system for providing nutrients as the plant needs it.

CRF analysis can vary greatly, but depending on their release curves, CRFs can slow down nutrient release for both field and container operations resulting in less runoff potential. CRF includes organic, mechanical and microbial release products. IBDU, UF [urea formaldehyde], MU [methylene urea] are examples.

The grower can refer to individual product release curves when planning on using CRF products. CRFs have the added benefit of releasing fertilizer over a longer period of time, thereby providing nutrients to plants when they need them rather than in one large dose.

Farm grade fertilizers (such as 19-19-19) are more soluble and rapidly released than CRF types. They are available in a wide array of analysis, are relatively inexpensive and readily available.

Liquid fertilizers

Liquid feed provides the fastest means of getting fertilizer into the media but has the highest potential for runoff and pollution. Nutrients are dissolved in water and delivered to plants via overhead application, hose and drip irrigation.

Overhead is faster and easy to apply. It requires injection equipment and has the greatest potential for waste—70% can end up back on the ground. Hose application is similar to overhead, but has better control especially in smaller spaces. Labor to manage hose watering is costly.

Drip irrigation through trickle tapes, emitters or spray tubes applies solutions directly to the pot. Drip irrigation uses lower volumes of water and fertilizer and has lower risk of runoff. Initial cost in equipment and subsequent maintenance is higher.

Monitoring

A soil test still provides the best resource for monitoring nutrition of crops. Use random sampling for an entire block. Take samples prior to any lime or fertilizer applications and repeat the soil test every three years.

Samples should be taken as a core six to eight inches deep, peeling off the top two inches of turf, if present. Twelve to fifteen samples mixed to make a composite sample is usually sufficient. Each new batch of container mix should be tested to account for variability of ingredients.

Soil tests are pictures in time. Taken during the same relative time each season, a series of soil tests will provide a track record of the nutrient needs of any particular block. For convenience, keep track of fertilizer and lime applications on the back of the soil test sheet. This consolidates records for easy reference.

Other tests to supplement information from a soil test would include foliar analysis, media flow-through, and water testing. Keep any of these test results with the soil test(s) during the same time period.

Foliar analysis only helps if there is an accompanying soil test. Samples need to be taken after leaf expansion but before the leaves harden off (usually mid-June). Sample the leaves below the tip, near the midpoint of the seasonal growth.

Media flow through for containers involves catching the leachate from an individual container during a simulated irrigation cycle. After a normal irrigation cycle, the pot is held over a clean container, then watered until about 50 ml of leachate is collected.

Where possible, use distilled water; using pond or city water will impact conductivity and pH readings. Flow-throughs should be done every other week or monthly during the season. Regular conductivity (EC) and pH readings will help determine the impact of fertilizer application to that crop.

Irrigation *water testing* provides additional data to track water quality and nutrient application programs. Water quality constantly changes with temperature, microbial action, and time of day.

Therefore, readings can be radically different from test to test. Samples can be sent out to a local lab but handheld EC and pH meters may be the best equipment to use when testing water supply on a regular basis.

Table 10. Using saturated media extract (SME) Nutrient concentrations measured in ppm (Excerpted from: Biernbaum, 1994)

Acceptable Water Quality Chart

	Target	Acceptable
pH	5.5 – 7.0	4.0 – 10.0
Alkalinity	40 – 160	0 – 400
EC (mS)	0.2 – 0.8	0.0 – 1.5
Na	0 – 20	<50

Acceptable Soil Nutrient Chart

	Target	Acceptable
pH	5.8 – 6.2	5.5 – 6.5
EC (mS)	1.0 – 2.0	0.75 – 3.0
NO3	75 – 150	50 - 250
K	75 – 150	50 - 200
P	10 – 20	5 – 50
Ca	125 – 175	75 - 300
Mg	40 – 60 2	5 - 100
Na	<25	<75

Irrigation

Supplemental water is needed to replace that lost to evapotranspiration. Both natural precipitation and irrigation affect nutrient availability. Excessive irrigation/rainfall or significant rain events can leach

nutrients, requiring application of additional nutrients, especially soluble N and K. Dry seasons (drought)

or lack of irrigation will not release nutrients from some fertilizer products; fewer nutrients are available but less plant growth during dry weather will require fewer nutrients.

Type

Supplemental irrigation is commonly provided by either overhead or drip irrigation.

Overhead irrigation covers large areas with relatively little equipment. However, there is an inherent lack of uniformity across the area irrigated. Growers must be aware of volumes and pressures needed to cover an area without leaving dry zones. Most blocks are rectangular, most irrigation patterns are circular and space between pots can be substantial. This can lead to losses of up to 70% of the irrigation water not actually contacting the containers. A properly designed pattern for overhead irrigation will have overlaps ranging from 30 to 100% as determined by sprinkler head selection, pressure, etc .

As mentioned earlier, drip irrigation through trickle tapes, emitters or spray tubes applies water directly to the pot, reducing waste. Drip equipment is rated to deliver specific volumes of water per unit time (usually gallons per hour) at specific pressures. This makes it possible to calculate actual water applied if the system is in good working order. Initial cost in equipment and subsequent maintenance is higher than overhead irrigation.

Rates

Applying water too fast or in too great a volume leaches fertilizers from containers and field soils. Runoff from the field is water not making it to the crop and therefore wasted.

Percolation rates for soils vary from 0.8 acre-inch water per hour for sandy soil, 0.2 acre-inch per hour for clay soil. Applying irrigation at rates greater than the soil can accept will result in puddling and runoff. Artificial media will take in water at a higher rate than field soil with the actual rate varying from mix to mix. Less water is stored in artificial mixes so more frequent irrigation is often needed.

Providing all of the required water in one cycle will result in the greatest waste of water. Most of this waste is realized in the early part of the irrigation cycle during which the media is in a more dry condition and much of the water runs through. Pulse irrigation divides irrigation into multiple cycles. Time between cycles allows for expansion of media resulting in better absorption during the following irrigation cycle. Most pulse irrigation cycles are divided into three applications—each successive cycle usually shorter than the previous one. Field applications follow the same system but with a shorter cycle.

Though this is not an exhaustive list of best management practices for nutrient management in the nursery, it provides a starting point from which a good nutrient BMP can be created. Management plans for water quality can be more extensive as well, but here are considered primarily as related to nutrient management.

Nursery Fertilizer and Irrigation BMPs

This checklist provides a short list of items to consider when planning a nutrient management program for the nursery. Make copies and utilize the right column for notes.

- ◻ Osmotic, timed release
- ◻ Microbial, temperature dependent, slow release
- ◻ Water soluble, quick release
- ◻ Mechanical, timed release

Keep Fertilizer Products

- ◻ Locked and protected
- ◻ Well lighted well ventilated
- ◻ Separate from pesticides
- ◻ Liquid formulations separate from solids/ granular
- ◻ Dry and safe from wide temperature swings

Dry Fertilizer Application

- ◻ Dibbling
- ◻ Incorporation
- ◻ Topdressing

Program Monitoring

- ◻ Soil test at least every three years
- ◻ Flow-through test every month for container stock
- ◻ Foliar test as needed, usually mid-June
- ◻ Water test as needed, at least for pH and EC

Optimizing Irrigation

- ◻ Overhead or drip irrigation
- ◻ Proper overlap for overhead irrigation
- ◻ Calculate irrigation rate for drip irrigation systems
- ◻ Calculate infiltration rates for field soil types

People Resources for Fertilizer & Nutrient Management

Ohio State University Extension
Nutrient State and Field Specialist:

Greg LaBarge, Field Specialist, Agronomic Systems,
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Contact the Agriculture and Natural Resources Extension Educator at your local, Ohio State University Extension Office for information about fertilizer and nutrient management. Here's a list of the county OSU Extension offices:

Adams: 937-544-2339   adams.osu.edu

Allen: 419-879-9108....allen.osu.edu

Ashland: 419-281-8242....ashland.osu.edu

Ashtabula: 440-576-9008....ashtabula.osu.edu

Athens: 740-593-8555....athens.osu.edu

Auglaize: 419-739-6580....auglaize.osu.edu

Belmont: 740-695-1455....belmont.osu.edu

Brown: 937-3778-6716....brown.osu.edu

Butler: 513-887-3722....butler.osu.edu

Carroll: 330-627-4310....carroll.osu.edu

Champaign: 937-484-1526....champaign.osu.edu

Clark: 937-521-3860....clark.osu.edu

Clermont: 513-732-7070....clermont.osu.edu

Clinton: 937-382-0901....clinton.osu.edu

Columbiana: 330-424-7291....columbiana.osu.edu

Coshocton: 740-622-2265....coshocton.osu.edu

Crawford: 419-562-8731....crawford.osu.edu

Cuyahoga: 216-429-8200....cuyahoga.osu.edu

Darke: 937-548-5215....darke.osu.edu

Defiance: 419-782-4771....defiance.osu.edu

Delaware: 740-833-2030 ....delaware.osu.edu

Erie: 419-627-7631....erie.osu.edu

Fairfield: 740-653-5419....fairfield.osu.edu

Fayette: 740-335-1150....fayette.osu.edu

Franklin: 614-866-6900....franklin.osu.edu

Fulton: 419-337-9210....fulton.osu.edu

Gallia: 740-449-7007....gallia.osu.edu

Geauga: 440-834-4656....geauga.osu.edu

List of the county OSU Extension offices continued from the previous page:

Greene: 937-372-9971....greene.osu.edu

Guernsey: 740-489-5300....guernsey.osu.edu

Hamilton: 513-946-8989....hamilton.osu.edu

Hancock: 419-422-3851....hancock.osu.edu

Hardin: 419-674-2297....hardin.osu.edu

Harrison: 740-942-8823....harrison.osu.edu

Henry: 419-592-0806....henry.osu.edu

Highland: 937-393-1918....highland.osu.edu

Hocking: 740-385-3222....hocking.osu.edu

Holmes: 330-674-3015....holmes.osu.edu

Huron: 419-668-8219....huron.osu.edu

Jackson: 740-286-5044....jackson.osu.edu

Jefferson: 740-264-2212....jefferson.osu.edu

Knox: 740-397-0401....knox.osu.edu

Lake: 440-350-2582....lake.osu.edu

Lawrence: 740-533-4322....lawrence.osu.edu

Licking: 740-670-5315....licking.osu.edu

Logan: 937-599-4227....logan.osu.edu

Lorain: 440-326-5851....lorain.osu.edu

Lucas: 419-213-4254....lucas.osu.edu

Madison: 740-852-0975....madison.osu.edu

Mahoning: 330-533-5538....mahoning.osu.edu

Marion: 740-223-4040....marion.osu.edu

Medina: 330-725-4911....medina.osu.edu

Meigs: 740-992-6696....meigs.osu.edu

Mercer: 419-586-2179....mercer.osu.edu

Miami: 937-440-3945....miami.osu.edu

Monroe: 740-472-0810....monroe.osu.edu

Montgomery: 937-224-9654....montgomery.osu.edu

Morgan: 740-962-4854....morgan.osu.edu

Morrow: 419-947-1070....morrow.osu.edu

Muskingum: 740-454-0144....muskingum.osu.edu

Noble: 740-732-5681....noble.osu.edu

Ottawa: 419-898-3631....ottawa.osu.edu

Paulding: 419-399-8225....paulding.osu.edu

Perry: 740-743-1602....perry.osu.edu

Pickaway: 740-747-7534....pickaway.osu.edu

Pike: 740-289-4837....pike.osu.edu

Portage: 330-296-6432....portage.osu.edu

Preble: 937-456-8174....preble.osu.edu

Putnam: 419-523-6294....putnam.osu.edu

Richland: 419-747-8755....richland.osu.edu

Ross: 740-702-3200....ross.osu.edu

Sandusky: 419-334-6340....sandusky.osu.edu

Scioto: 740-354-7879....scioto.osu.edu

Seneca: 419-447-9722....seneca.osu.edu

Shelby: 937-498-7239....shelby.osu.edu

Stark: 330-830-7700....stark.osu.edu

Summit: 330-928-4769....summit.osu.edu

Trumbull: 330-638-6783....trumbull.osu.edu

Tuscarawas: 330-339-2337....tuscarawas.osu.edu

Union: 937-644-8117....union.osu.edu

Van Wert: 419-238-1214....vanwert.osu.edu

Vinton: 740-596-5212....vinton.osu.edu

Warren: 513-695-1311....warren.osu.edu

Washington: 740-376-7431....washington.osu.edu

Wayne: 330-264-8722....wayne.osu.edu

Williams: 419-636-5608....williams.osu.edu

Wood: 419-354-9050....wood.osu.edu

Wyandot: 419-294-4931....wyandot.osu.edu

Notes:

Notes:

Agricultural Fertilizer Applicator Certification Evaluation

Please read before completing evaluation on next page

- You are being asked to take no more than 4-5 minutes to complete a survey about your fertilization and soil management practices.
- Responses will be used in a research study that will help us understand current farm practices and will guide future work on nutrient management.
- No identifying information is requested.
- All responses will be combined so that no individual can be identified, and data will be kept at least 5 years.
- Completing this survey is voluntary; there is no compensation for participating.
- If at any time you are uncomfortable with the survey, there is no obligation to return it.

For questions about your rights as a participant in this study, or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact **Ms. Sandra Meadows in the Office of Responsible Research Practices at 1-800-678-6251**

Contact Mary Ann Rose at 614-247-7489 or rose.155@osu.edu for more information about this research study.

Thank you for participating in this important survey.

OHIO STATE UNIVERSITY EXTENSION

AGRICULTURAL FERTILZER APPLICATOR CERTIFICATION EVALUATION

Completion is voluntary. All survey responses are anonymous and cannot be linked to respondents. Only summary data will be reported.

1. County of Residence: ______________________________ Date:______________________

2. A. How many acres do you farm?

   1. Under 49 Acres
   2. 50-499 Acres
   3. 500-999 Acres
   4. 1000-1999 Acres
   5. Greater than 2000 Acres
   6. Not applicable

   B. If an **Ag Business** or **Crop Adviser**:

   How many acres do you personally make nutrient recommendations on? ______________

3. Age : (1) 18-30 (2) 31-40 (3) 41-50 (4) 51-60 (5) 60+

4. Education (highest): (1) HIGH SCHOOL (2) ASSOC. DEGREE (3) BACHELORS (4) MASTERS+

5. Have you attended OSU Extension programs in the past? **(circle one)**: YES NO

Please rate your agreement with the following statements:						
	Strongly **Disagree**	Disagree	Neutral / Not sure	Agree	Strongly **Agree**	Not Applicable
6. Farm field phosphorus (P) loss is a significant problem to our water resources.	1	2	3	4	5	NA
7. Phosphorus application rates on my farm do not exceed Tri-State fertility recommendations.	1	2	3	4	5	NA
Based on **today's meeting**, please rate your agreement with the following statements:						
8. I have improved my knowledge about nutrient management.	1	2	3	4	5	NA
9. The manual provided today is a useful reference.	1	2	3	4	5	NA
10. I will change my nutrient management practices as a result of this meeting.	1	2	3	4	5	NA
11. I plan to review my soil test and phosphorus recommendations as a result of this meeting.	1	2	3	4	5	NA

12. What is the **No-apply Soil Test Level for phosphorus** in **corn** and **soybeans**? (Circle one)

Bray P1 ppm (lbs/A)	or	**Mehlich 3 ICP ppm (lbs/A)**
1. 15 ppm (30 lbs/A)		≈ 28 ppm (56 lbs/A)
2. 30 ppm (60 lbs/A)		≈ 46 ppm (92 lbs/A)
3. 40 ppm (80 lbs/A)		≈ 58 ppm (116 lbs/A)
4. 150 ppm (300 lbs/A)		≈ 190 ppm (380 lbs/A)

13. What is the **Critical Soil Test Level** for **phosphorus** in **corn** and **soybeans**? (Circle one)

Bray P1 ppm (lbs/A)	or	Mehlich 3 ICP ppm (lbs/A)
1. 15 ppm (30 lbs/A)		≈ 28 ppm (56 lbs/A)
2. 30 ppm (60 lbs/A)		≈ 46 ppm (92 lbs/A)
3. 40 ppm (80 lbs/A)		≈ 58 ppm (116 lbs/A)
4. 50 ppm (100 lbs/A)		≈ 70 ppm (140 lbs/A)

14. What time of year do you apply **most of you**r **phosphorus fertilizer?** (Circle One)

1. September–November
2. December–February
3. March–May
4. June–August

15. What percentage of total phosphorus fertilizer do you apply through the **planter**?
Crop advisors – choose response applicable to most customers

__________% (fill in)

16. If broadcast-spreading phosphorus fertilizer, how do you treat the field after application? (Circle one)
Crop advisors – choose response applicable to most customers

» Not broadcasting any phosphorus (e.g., all through planter, deep-banded or strip-tilled)
» Broadcast into a standing crop/cover crop
» Do not incorporate
» Till to incorporate within 2 days of application
» Till to incorporate more than 2 days after application

17. How **frequently** do you take a **soil test**? (Circle One)

1. Every year 2. Every 2-3 years 3. Every 4-5 years 4. Less often or not at all

18. Which best describes your **soil testing & sampling practices,** if applicable? (Circle One)

1. More than 25 acres per soil sample
2. Less than 25 acres per soil sample
3. Grid soil samples (e.g., 2.5 acres per sample)
4. Zone sampling determined by soil type or yield monitor

19. How do you determine your **nitrogen rate for corn**? (Circle one)

1. Crop advisor or retailer's recommendation
2. Economic model based on corn and Nitrogen costs
3. Crop sensor (e.g., GreenSeeker, SPAD meter)
4. Soil Nitrate Test
5. Based on crop yield goal
6. Based on past experience
7. Based on field management zone

Please make any comments you may have about this meeting, or future programming needs below. Thank you!