Grain Corn

Management Highlights

- Target pH: **6.0**
- Split N applications to increase N-use efficiency in corn. Apply a small amount (20-25%) at planting and the bulk of the N requirement (75-80%) when the plants are 12-15" tall.
- Use the **Pre-sidedress Soil Nitrate Test** for manured ground or soils with high organic matter levels to calculate crop N needs in season
- In **irrigated corn** where fertigation is possible, split N applications to increase N-use efficiency. Apply a small amount (15-20%) at planting and split the remainder into equal increments to be applied with irrigation water from the 5-6 leaf stage through silking. Use the **Leaf Chlorophyll Meter** to monitor crop N needs in season and make small adjustments as needed.
- Use the **Stalk Nitrate Test** at the end of the season to monitor the success of the N management program.
- Monitor crop for Mn deficiency, especially when soil test Mn is less than 3.4 lbs/ac.

Yield Goals

Corn grain yields are influenced by many factors, including the hybrid selected, planting date, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure and crop management practices. Table 1 shows typical yield goals for grain corn on Delaware soils. As indicated, irrigation use can increase corn yields significantly. Likewise, since no-tillage production systems favor water conservation and an early planting date, corn grown under no-tillage management frequently produces higher yields than does corn in conventional-tillage systems on the same soil type. Use of conservation-tillage practices can be expected to produce yields between the management extremes of conventional-tillage and no-tillage systems.

When field history supports the use of a different yield goal, growers should use that information to adjust management decisions and fertility programs accordingly.

Table 1. Grain corn yield goals as a function of soil type, tillage system and irrigation use.

Dryland Corn Production		
Soil Type	**CT***	**NT****
	-------- bu / ac -------	
Sands, loamy sands	80	90
Sandy loams	125	140
Black soils	140	160
Silt loams	150	160

Irrigated Corn Production	
Level of Management	
	-------- bu / ac -------
High management	175 - 200
Intensive crop management	240 - 250

*CT= Conventional-tillage
**NT= No-tillage

Soil pH and Liming

The target pH for corn grown on most Delaware soils is **6.0.** Soils with higher organic matter contents ("black" soils) have a lower target pH (5.6) because organic matter moderates some of the negative effects of excessive soil acidity (e.g., aluminum toxicity). Lime recommendations for corn can be calculated from soil pH and buffer pH measurements using the steps outlined in ***Calculating the Lime Requirement – Chapter 3, Section 3.4.***

In most cases, the lime requirement can be met by either calcitic or dolomitic limestone.

Dolomitic limestone is recommended if:
- soil test Mg is less than 50 FIVs, or
- soil test Mg is between 50 and 100 FIVs ***and less than soil test Ca.***

Calcitic limestone is recommended if:
- soil test Mg is greater than 100 FIVs, or
- soil test Mg is between 50 and 100 FIVs ***and greater than soil test Ca.***

Nitrogen Management

University of Delaware nitrogen (N) recommendations for grain corn production are based on a N rate of ***1 lb N per bushel of expected yield*** (i.e., a realistic yield goal of 150 bu/ac should receive a maximum of 150 lbs N/ac).

Nitrogen applications should be split for greater N-use efficiency. One-quarter or less of the total N rate should be applied at or just prior to planting. The remainder should be applied as a sidedress application when plants are 12-15 inches tall and the period of maximum N uptake by the crop is beginning. In irrigated corn production where fertigation is possible, the remainder should be split into equal increments and applied with irrigation water from the **5-6th** leaf stage through silking.

For fields which have received manure and/or which have have levels of soil organic matter, use the Pre-sidedress Soil Nitrate Test (PSNT) to determine the actual sidedress N rate for the field.

Use of the Pre-sidedress Soil Nitrate Test

Until recently, soil tests for N could not reliably identify the amount of N available to corn from soil organic matter, manures, crop residues, or previous applications of N fertilizers. The **PSNT**, developed in the late 1980's in Vermont and now used commercially in many eastern and midwestern states, is based on the concept that the soil nitrate level early in the growing season is proportional to the amount of N that will become available during the rest of the growing season from soil organic matter and organic N sources recently added to the soil (e.g., manures, legume residues). By using the PSNT to estimate the N contribution of soil organic matter and organic sources of nutrients, growers can more accurately estimate the additional N needed to meet crop requirements and can apply that additional N more efficiently as a sidedress application or through fertigation at the time when crop uptake is greatest.

The PSNT is one of the most promising advances in soil N testing in many years. Proper use of this test can result in economic savings and reduce the likelihood of groundwater contamination by nitrate-N.

To estimate sidedress N requirements from the PSNT, a soil sample is collected from the field immediately before the period of maximum N uptake by corn when plants are about 10-12" high (***see Figure 1-11 in Chapter 1***). The sample is air-dried as quickly as possible and analyzed for nitrate-N content (also known as the PSNT value) either by a soil testing laboratory or with one of several "quick test" kits now available. A N recommendation is then made based on the sample PSNT value and other factors such as yield goal, plant stand, insect or weed pressure and irrigation use.

Detailed examples illustrating the development of a N recommendation for corn with and without the PSNT are included in the worksheets on the following pages. Additional information on the PSNT is provided in Fact Sheet ST-01 and Soil Test Note 14 (*see Appendices APP-7 and APP-8 at the end of this handbook).*

PSNT Analysis of Samples

Growers wishing to use the PSNT have several ways for having their samples analyzed.

- Growers may analyze their own samples using one of the testing kits available commercially. A list of vendors is available at the end of the recommendation under "***Additional Information***".

- The University of Delaware Soil Testing Laboratory in Newark offers the PSNT for $6.00 per sample. Kits can be obtained at any Cooperative Extension office or can be ordered directly from the lab. Samples from Kent and Sussex should be sent directly to the lab by overnight delivery to ensure that results are received as quickly as possible.

- Crop consultants and the Conservation Districts in Kent and Sussex counties may offer PSNT testing. Clients should call for further information.

Worksheet 1: Calculation of the Sidedress N Rate in the Absence of a PSNT Test:

1. Determine ***total crop N requirement*** **(TCNR)**. Total crop nitrogen requirement is equal to yield goal. If the realistic yield goal for the field is 125 bu/ac, the **TCNR** is 125 lbs N/ac.
2. Determine ***N adjustments*** **(NADJ)**. Adjustments include any N already applied such as preplant applications, starters, N in herbicide carriers, and manures. Contributions from previous legume crops should be included as well.
3. The ***sidedress N rate*** **(SDNR)** is equal to the difference between **TCNR** and **NADJ**.

	Example	Your Field	
Realistic Yield Goal	**150**	_____	**bu/ac**
Total Crop N Requirement (TCNR)	**150**	_____	**lbs N/ac**
N Adjustments (NADJ)	**- 90**	-	**lbs N/ac**
Sidedress N Rate (SDNR)	**60**		**lbs N/ac**

Adjustments =	**Preplant**	+	**Starter**	+	**Herbicides**	+	**Manure N**	=	**Total**	**(NADJ)**
Example	**0**	+	**30**	+	**60**	+	**0**	=	**90**	**lbs N/ac**
Your Field	_____	+	_____	+	_____	+	_____	=	_____	**lbs N/ac**

Worksheet 2: Calculation of the Sidedress N Using the PSNT

1. Collect a representative soil sample from the field when plants are 10-12" tall and have it analyzed by the PSNT. The result is referred to as the **PSNT Value.**
2. Select the ***basic N rate*** **(BNR)** from Table 2 for that PSNT Value and a realistic yield goal for the field.

Table 2. Basic N Recommendation (lb N/ac).

	Realistic Yield Goal (bu/ac)							
PSNT Value	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**
0 - 10	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**
11 - 15	**55**	**75**	**95**	**115**	**135**	**150**	**170**	**190**
16 - 20	**0**	**55**	**70**	**85**	**100**	**115**	**140**	**160**
21 - 25	**0**	**0**	**0**	**60**	**75**	**85**	**100**	**115**
> 25	**0**	**0**	**0**	**0**	**0**	**0-50**	**50**	**50**

3. Determine if starter N was used. If yes, **SNAP=** ***starter N application rate*** (lbs N/ac). If no starter was used, **SNAP**=0.
4. Determine if a ***manure credit*** **(MC)** is needed. If less than 3 tons/ac of manure was applied, no credit is needed and **MC**=0. If 3 or more tons/ac was applied, use the PSNT value to select the appropriate adjustment from Table 3A or 3B. **MC = adjustment X manure application rate.**
5. Calculate the ***sidedress N rate*** **(SDNR)** using the equation:
   SDNR (lbs N/ac) = BNR - SNAP - MC

Table 3. Credits for Manure Applications -- 3 tons/ac or more only.

A. Poultry Manure

PSNT Value	Length of Time Since Application	
	1 month or less	More than 1 month
0 - 10	30 lbs N/ac/ton applied	20 lbs N/ac/ton applied
11 - 15	20 lbs N/ac/ton applied	10 lbs N/ac/ton applied
16 - 25	10 lbs N/ac/ton applied	5 lbs N/ac/ton applied
> 25	0 lbs N/ac/ton applied	0 lbs N/ac/ton applied

B. Dairy, Swine or Horse Manure

PSNT Value	1 month or less	More than 1 month
0 - 10	3 lbs N/ac/ton applied	2 lbs N/ac/ton applied
11 - 15	2 lbs N/ac/ton applied	1 lbs N/ac/ton applied
16 - 25	1 lbs N/ac/ton applied	0.5 lbs N/ac/ton applied
> 25	0 lbs N/ac/ton applied	0 lbs N/ac/ton applied

	Example	Your Field	
Realistic Yield Goal	150	_____	bu/ac
PSNT Value	14	_____	ppm soil nitrate-N
Basic N Rate (BNR - Table 2)	115	_____	lbs N/ac
Starter N Application (SNAP)	- 30	- _____	lbs N/ac
Manure Credit (MC - see below)	- 30	- _____	lbs N/ac
Sidedress N Rate (SDNR)	= 55	= _____	lbs N/ac
Manure Credit Calculation:			
PSNT Value:	14	_____	ppm soil nitrate-N
Manure Application Rate:	3	_____	tons/ac
Manure Type:	Poultry	_____	
Time Since Application:	2	_____	months
Manure Adjustment (Table 3):	10	_____	lbs N/ac/ton applied

	Adjustment	X	Appl. Rate	=	Manure Credit (MC)	
Example	10	X	3	=	30	lbs N/ac
Your Field	_____	X	_____	=	_____	lbs N/ac

In-Season Nitrogen Management – The Leaf Chlorophyll Meter

Growers with fertigation capability may further increase their N use efficiency by using the **Leaf Chlorophyll Meter** (LCM) to monitor their crop. The LCM can be used to rapidly measure the "Greenness" of the leaf which has been shown in research to be a good indicator of leaf N status. By monitoring N status through the season, growers can adjust future fertigation applications to meet crop needs. For more information on the use of LCM, see **Fact Sheet ST-02: *"Use of the Leaf Chlorophyll Meter for Nitrogen Management of Corn"*** in Appendix 8 or contact your Cooperative Extension agent.

Post-Season Nitrogen Management – Corn Stalk Nitrate Test

The Corn Stalk Nitrate Test is a simple, inexpensive test that growers can use to evaluate the success of their N management program at the end of the growing season. The test is based on the fact that corn plants will accumulate N in or release N from the lower stalk of the plant based on soil N availability. Studies from many parts of the US including Delaware and covering a wide range of growing conditions have found similar relationships between the concentration of N in the lower stalk at the end of the growing season and the likelihood that the crop was over- or under-fertilized. By using the stalk nitrate test and interpretations that are based on Delaware research, growers can use results obtained from the stalk nitrate test to fine-tune N management programs in subsequent years.

For more information on the Corn Stalk Nitrate Test, see **Fact Sheet NM-03: *"End-of Season Corn Stalk Nitrate Testing to Optimize Nitrogen Management"*** in Appendix 8 or contact your Cooperative Extension agent.

Phosphorus Management

Yield-limiting phosphorus (P) deficiency is rarely a concern on Delaware soils. Long-term applications of fertilizers and manures have resulted in P accumulations in many soils that are capable of supplying crop needs for several years with no further additions.

To determine whether P fertilization is necessary for a specific field, conduct a routine soil test. University of Delaware P recommendations for corn are dependent upon yield goal and soil test P value. A summary of P recommendations for corn are given in Table 4 below.

Table 4. Band application rates of P for grain corn.

	P Index Value							
Yield	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**
bu/ac	---------- lbs P_2O_5 / ac ----------							
75	50	40	35	25	15	10	0	0
100	50	40	35	25	15	10	0	0
125	70	60	50	35	25	10	0	0
150	90	75	60	45	30	15	0	0
175	100	85	70	55	40	25	15	0
200	110	95	80	65	50	35	20	0-10
225	120	105	90	70	60	40	25	0-10
250	130	115	100	85	70	55	30	0-10

Note: These rates are for a banded application. If P is to be applied in a broadcast application, rates should be doubled.

Occasionally, symptoms of P deficiency may occur early in the growing season, even when the soil test indicates that soil P is sufficient. These symptoms are most often environmentally induced (e.g., by cold, wet weather) and usually disappear as the stress-inducing condition is alleviated. Growers who suspect possible deficiency should contact their county Extension agent for assistance with diagnosis.

Potassium Management

The need for potassium (K) fertilization of corn is best determined by the use of a routine soil test. As with P, K recommendations are based on expected yield and soil test K value. A summary of University of Delaware K recommendations for corn is given in Table 5. Potassium can be broadcast in the fall or spring or banded at planting.

If both N and K are to be banded, the sum of the N and K_2O rates should not exceed 75 lbs/ac or salt injury to seedlings may occur.

Table 5. Potassium recommendations for grain corn.

	K Index Value							
Yield	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**
bu/ac	---------- lbs K_2O / ac ----------							
75	90	75	60	45	30	15	0	0
100	90	75	60	45	30	15	0	0
125	110	95	80	60	40	25	0	0
150	140	120	100	80	60	40	20	0
175	170	145	120	95	70	50	25	0
200	190	165	140	110	80	60	30	0
225	210	190	160	140	115	95	60	0-50
250	230	205	180	155	130	105	70	30-60

Magnesium Management

Mg application to corn is recommended if the soil test Mg value is less than 38 FIVs. If liming is also recommended, use dolomitic limestone to raise soil pH and increase soil Mg. If, however, liming is not necessary but Mg fertilization is still indicated, apply Mg as Mg sulfate or Mg chloride to increase soil Mg. Application rates are summarized below in Table 6.

Table 6. Application rates for soluble Mg as a function of Mg fertility index value.

Mg Index Value								
0	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
---------- lbs soluble Mg / ac ----------								
80	70	60	50	40	30	20	10	0

Sulfur Management

Sulfur (S) deficiency is occasionally observed in corn grown on Delaware's sandy, highly leached, low-organic-matter soils. Deficiency is most likely to occur under irrigated production practices where intensive management is employed to obtain maximum yields. Deficiency is less common on high-organic-matter soils or those with a history of manure application as both materials provide moderate amounts of plant-available S.

Prediction of S deficiency is difficult. Currently available topsoil tests are not good predictors of S deficiency situations because many Delaware soils have a considerable supply of plant available-S in subsoil horizons that will not be detected in samples taken from shallower depths. Subsoil sampling to a depth of 24 inches is highly recommended as a means of identifying soils with subsoil reserves of S.

Suspected S deficiency can be confirmed through tissue analysis of earleaf samples collected at early silking. Tissue samples collected earlier in the season are not good indicators of yield-limiting S deficiency because roots, may not have penetrated subsoil reserves at that time. In-season correction of S deficiency may be difficult. Growers with early season deficiency of S should contact their county Extension agent for assistance in diagnosis and corrective action. In subsequent years, deficiency can be prevented by either of the following treatments:

- A broadcast application at planting of 40 lbs actual S/ac as ammonium sulfate (24% S) or gypsum (19%S).
- A band application of 20-30 lbs actual S/ac as ammonium sulfate.

Manganese Management

Manganese deficiency may occur in corn grown on Delaware soils, most often as a result of over-liming soils that are naturally low in Mn. The University of Delaware Soil Testing Program uses an availability index based on the soil test Mn value and soil pH to predict the likelihood of Mn deficiency. That availability index is calculated using the equation:
where:

$$MnAI = 101.7 - (15.2 \times pH) + (2.11 \times ST\text{-}Mn)$$

where:

MnAI = Mn availability index
pH = water pH of the soil
ST-Mn = Mehlich 3 soil test Mn in lbs/ac.

Table 3-13 in ***Chapter 3, Section 3.5.5.2 (Manganese Management)*** gives a summary of MNAI values for various soil pH-soil test Mn combinations. Interpretations of the index for grain corn are given below in Table 7.

Table 7. Interpretation of Mn availability index for grain corn.

MnAI Value	Interpretation
Less than 17	Mn deficiency is possible at this soil pH and soil Mn concentration.
17 or greater	Mn deficiency is unlikely at this soil pH and soil Mn concentration.
Exception: MnAI >17 **but** ST-Mn is less than 3.4 lbs/ac, pH is less than 6.0 and liming has been recommended.	Soil Mn concentration is adequate at this soil pH but may become deficient following liming. Monitor crop for symptoms.

Suspected Mn deficiency can be confirmed by tissue analysis. Confirmed deficiency situations can be corrected in season by foliar applications of Mn of 1-2 lbs/ac of actual Mn as Mn sulfate, Mn oxide or Mn chelate. If deficiency is predicted by the availability index or was observed during the previous growing season, it can be prevented by an application of 8-10 lbs/ac of actual Mn in the fertilizer band. Band applications of acid-forming fertilizer, which lower soil pH in the area of plant roots, may correct Mn deficiency without the addition of Mn fertilizers.

Zinc Management

Zinc (Zn) deficiency is occasionally observed in corn grown on Delaware soils. It is most commonly associated with soil pH values in excess of **6.5** and high soil test P values. Zinc deficiency may also be induced by environmental stress such as cold, wet soils which can restrict root growth and uptake of nutrients. Zinc deficiency symptoms often appear early in the growing season and later disappear as root growth occurs and environmental conditions improve. The University of Delaware Soil Testing Program uses an availability index based on soil pH, soil test P and soil test Zn to identify Zn deficient soils. Deficiency is predicted if:

1. Soil test Zn is less than 1.9 lb/ac; **or**
2. Soil test Zn is less than 3.1 lbs/ac and soil pH is greater than 7.0; **or**
3. Soil test Zn is less than 3.1 lbs/ac and soil pH is 6.6 or greater and soil test P is 100 FIVs or greater.

Suspected Zn deficiency can be confirmed with a plant tissue test. In-season correction of deficiency can be accomplished by foliar applications of Zn at a rate of 1 lb/ac actual Zn as Zn sulfate or Zn oxide or at a rate of 0.5 lb/ac actual Zn as Zn chelate (see Appendix Table 12-4 for representative rates of micronutrient fertilizer sources).

If deficiency is predicted by the availability index, broadcast applications at a rate of 10-12 lbs/ac actual Zn asr Zn sulfate or Zn oxide or at a rate of 2-3 lbs/ac actual Zn as Zn chelate should correct the problem for several years. If a banded application is more suitable, apply 6-8 lbs/ac actual Zn as Zn sulfate or Zn oxide or 1-2 lbs/ac actual Zn as Zn chelate in the fertilizer band. Banded applications are only effective for the growing season in which they are applied.

Other Nutrients

Boron (B) deficiency is occasionally observed in intensively managed, irrigated corn production. Boron applications are not, however, a general recommendation at this time. If deficiency is suspected, contact your county Extension agent for assistance in diagnosis and correction.

Additional Information

See Soil Test Notes 1, 2, 4, 5 and 14 (Appendix APP-7) and Fact Sheet ST-01 (Appendix APP-8) for additional information on nutrient management of grain corn.

Vendors for soil nitrate quick test kits for use by the grower:

- **Hawk Creek Laboratory, Inc.**
  RD1 Box 686
  Simpson Rd.
  Glen Rock, PA 17327
  Phone: 1-800-637-2436

- **Spectrum Technologies, Inc.**
  23839 W. Andrew Road
  Plainfield, IL 60544
  Phone: 1-800-248-8873
  Fax: 1-815-436-4460
  www.specmeters.com

- **Hach Company**
  P.O. Box 389
  Loveland, CO 80539
  Phone: 1-800-227-4224
  www.hach.com

NOTE: Vendors are included purely for informational purposes with the understanding that discrimination is not intended and no endorsement by the University of Delaware is implied.