University of Delaware | College of Agriculture & Natural Resources
SOIL TESTING PROGRAM

Nutrient Recommendations

Forage and Hay Crops:

Cool Season Annual Forages

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Annual or Italian Ryegrass Forage

Crop Highlights
• Target pH: 6.2 • Responds well to nitrogen (N) application • Do not apply N until the seedlings are 2 to 4 inches if seeded in mid- to late-spring. • Apply sulfur (S) with or without N to prevent S deficiency. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

There are two ryegrass subtypes available, one is a true annual and the other (Italian) behaves more like a very short-lived perennial. Seed will germinate in 3 to 7 days. Annual and Italian ryegrasses respond well to nitrogen (N) application. Harvest in late-boot stage for better quality or mid- to late heading for balance of yield and quality. Use a crimper and wide swathing to dry hay faster when biomass yields are heavy.

Yield Goal

A realistic yield goal for a annual or Italian ryegrass forage crop is 3.0 ton/ac in a good to average year. However, yield is dependent upon several factors, including grass species, seeding rate, seeding date, degree of stand establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop management practices, and grazing management practices.

Delaware growers should use field history to determine the yield goal for each field and use that information to adjust management decisions and fertility programs accordingly. Delaware nutrient management law requires the use of optimal rolling average for determining the yield goal for a specific field when field history is available. To calculate the optimal rolling average yield, see the UD Extension Fact Sheet ***Estimating Yield Goal for Crops***.

Target pH: 6.2

Soils that are high in organic matter (e.g., "black" soils; soil organic matter >6.0%) have a lower target pH (5.6) because organic matter moderates some of the negative effects of excessive soil acidity (e.g., aluminum toxicity).

The lime recommendation for a specific field is calculated from the soil pH and Adam-Evans buffer pH measurements using the steps outlined in the UD Extension Fact Sheet ***Calculating the Lime Requirement Using the Adams-Evans Soil Buffer***. Avoid over-liming to prevent deficiency of micronutrients such as manganese (Mn).

The recommended liming source is dependent upon Mehlich-3 (M3) soil test calcium (Ca) and magnesium (Mg) reported as a University of Delaware fertility index value (FIV) and can be determined using Table 1.

Table 1. Recommended type of lime as a function of Mehlich-3 soil test calcium (M3-Ca) and magnesium (M3-Mg) concentrations.

Soil Test Levels	Recommended Lime Type
M3-Mg is less than 50 FIV	Dolomitic
M3-Mg between 50 and 100 FIV AND M3-Mg is less than M3-Ca	Dolomitic
M3-Mg greater than 100 FIV	Calcitic
M3-Mg is greater than 50 FIV AND M3-Mg is greater than M3-Ca	Calcitic

Nitrogen

Nitrogen fertilization rates are based on regional research on crop response to N fertilizers and not on the results of a routine soil test.

1. For late summer, fall, or very early spring seedings, apply N at a rate of 40 to 60 lb/ac at or prior to planting if little weed competition is expected.
2. For mid- to late-spring seedings, do not apply N until the seedlings are 2 to 4 inches tall to avoid stimulating weed competition. Broadcast N at a rate of 20 lb/ac when forage growth reaches a height of 2 to 4 inches if weed pressure is not at a competitive level.
3. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.

Phosphorus

Phosphorus (P) fertilization is based on the results of a routine soil test (Table 2). Soil test results are reported as a fertility index value (FIV).

Table 2. Recommended broadcast phosphorus fertilizer application rates for annual or Italian ryegrass hay as a function of Mehlich-3 soil test phosphorus (M3-P) at 3.0 ton/ac yield goal.

	M3-P (UD FIV)										
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
lb P_2O_5/ac	120	110	100	85	75	65	50	40	25	10	0

1. If M3 soil test P (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), broadcast and plow down the recommended rate of phosphate (P_2O_5) fertilizer prior to seeding.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), broadcast and incorporate P_2O_5 fertilizer prior to seeding or surface broadcast at or shortly after planting.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of phosphorus in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 15 lb /ac for each additional ton of expected yield.

Potassium

The need for potassium (K) fertilization is determined by a routine soil test (Table 3). Soil test results are reported as a fertility index value (FIV).

Table 3. Recommended potassium fertilizer application rate for annual or Italian ryegrass hay as a function of Mehlich-3 soil test potassium (M3-K) at 3.0 ton/ac yield goal.

	M3-K (UD FIV)										
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
lb K_2O/ac	180	165	150	135	120	105	90	75	60	45	0

1. Broadcast and incorporate potash (K_2O) fertilizer at or prior to seeding.
2. Application rates of 120 lb/ac of K_2O or higher should be split into two applications. Apply ½ of the recommended rate after the first cutting and the remainder in late August or September.
3. Increase recommended K_2O application rate by 50 lb/ac for each additional ton of expected yield above 3.0 ton/ac.

Magnesium

The need for magnesium (Mg) fertilization is determined by a routine soil test (Table 4); Mg needs are often met by liming. Soil test results are reported as a fertility index value (FIV).

Table 4. Recommended application rates of soluble magnesium as a function of soil test magnesium (M3-Mg).

	M3-Mg (UD FIV)								
	0	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
lb soluble Mg/ac	80	70	60	50	40	30	20	10	0

1. Magnesium (Mg) is recommended when M3-Mg is less than 40 FIV.
1. Use dolomitic limestone if M3-Mg is less than 40 FIV and lime is recommended, use dolomitic limestone.
2. If M3-Mg is less than 40 FIV and lime is not needed, apply soluble Mg (Mg sulfate or Mg chloride) according to the rates in Table 4.

Sulfur

Sulfur (S) deficiency is occasionally observed in annual or Italian ryegrass grown on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Newly planted forage crops are susceptible to S deficiency because their shallow root systems do not allow the crop to tap into subsoil stores of S. Cutting hay also removes a significant amount of S from the soil and increases the risk of S deficiency. Legumes are more susceptible to S deficiency than grass species.

1. Apply S at a rate of 20 to 40 lb/ac to ensure that adequate sulfur is available to meet crop needs.
2. Broadcast S prior to seeding or use ammonium sulfate as an N source to supply needed S.
3. Sulfate-S is available for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for oxidation of the applied S to the sulfate form to occur.

Prediction of S deficiency is difficult. Currently available soil tests are not good predictors of S deficiency situations because only surface soil samples are analyzed. Many Delaware soils have a supply of plant available S in subsoil horizons that will not be detected in soil 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.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems. Also remember that sulfate-S is available for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for oxidation of the applied S to the sulfate form to occur.

Manganese

Manganese (Mn) needs are predicted by an availability index (MnAI) that includes M3 soil test Mn (M3-Mn) and soil pH. Interpretation of MnAI is crop specific (Table 5). Forage crops are moderately sensitive to Mn deficiency. Soil test Mn results are reported in lb/ac.

MnAI = 101.7 – (15.2 × soil pH) + (2.11 × M3-Mn)

Where:

MnAI = Mn availability index
Soil pH = Soil pH measured in water (1:1 V:V)
M3-Mn = Mehlich 3 soil test Mn in lb/ac

Table 5. Interpretation of manganese availability index for annual or Italian ryegrass.

Mn Availability Index	Interpretation
Less than 17	Mn deficiency is likely at this soil pH and soil test Mn concentration
17 to 25	Mn deficiency is possible at this soil pH and soil test Mn concentration. Monitor the crop for symptoms, especially if liming has been recommended.
Greater than 25	Mn deficiency is unlikely.

1. If Mn deficiency is predicted or was observed in the previous growing season, broadcast Mn at a rate of 20 to 40 lb/ac.
2. Broadcast applications of acid forming fertilizers may correct Mn deficiency without the actual application of Mn in some cases but may be less effective than applications of Mn. Long term application of acid forming fertilizers will require pH correction with lime.
3. If Mn deficiency symptoms appear during the growing season or after an application of lime, a foliar application of 1.0 to 2.0 lb/ac actual Mn as Mn sulfate, Mn oxide or chelated Mn can alleviate the symptoms and restore yield potential. Foliar applications can be applied before fall dormancy or after growth resumes in the spring. ***Apply only when adequate growth is present to aid absorption of foliar Mn.*** Foliar application can be repeated if symptoms reappear.

Zinc

Zinc (Zn) deficiency is predicted by an availability index that includes M3 soil test Zn, soil pH, and M3 soil test P. Zinc deficiency is most common on soils with a pH of 6.5 or higher and high soil test P concentrations but may also be induced by environmental conditions such as cold, wet soils that may limit root growth. See Table 6 to determine if Zn deficiency is predicted for this field.

Table 6. Interpretation of zinc availability index for annual or Italian ryegrass.

Soil Test Criteria	Interpretation
M3-Zn is less than 1.9 lb/ac	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is higher than 7.0	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is 6.6 or higher **AND** M3-P is 100 FIV or higher	Zn deficiency is predicted
M3-Zn is 3.2 lb/ac or higher	Zn deficiency is NOT predicted

If Zn deficiency is predicted by the availability index or was observed the previous year, one of the following treatments can be applied:

1. Broadcast Zn sulfate or Zn oxide at a rate of 10 to 12 lb/ac elemental Zn or Zn chelate (Zn-EDTA) at a rate of 2 to 3 lb/ac elemental Zn. Broadcast applications should correct Zn deficiency for several years.
1. Foliar application of Zn sulfate or Zn oxide at a rate of 1 lb/ac elemental Zn or Zn chelate at a rate of 0.5 lb/ac elemental Zn in 20 to 50 gallons of water. **Apply only when adequate growth is present to aid in the adsorption of foliar Zn.** Foliar Zn application should be repeated if symptoms re-appear.

Boron

Boron (B) deficiency is not common in annual forage crops. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.

Annual or Sweet Bromegrass Forage

Crop Highlights
• Target pH: 6.2 • Limited potential for hay production. • Do not apply N until the seedlings are 2 to 4 inches if seeded in mid- to late-spring. • Apply sulfur (S) with or without N to prevent S deficiency. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Annual and sweet bromegrasses produce hay with limited success. Limit acreage planted until you become experienced with the species. Annual and sweet bromegrass seed is light and fluffy; seeding at the recommended depth is important for successful establishment. Some sweet bromegrass varieties can survive like short-term perennial grasses.

Yield Goal

A realistic yield goal for a annual or sweet bromegrass forage crop is 2.0 ton/ac in a good to average year. However, yield is dependent upon several factors, including grass species, seeding rate, seeding date, degree of stand establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop management practices, and grazing management practices.

Delaware growers should use field history to determine the yield goal for each field and use that information to adjust management decisions and fertility programs accordingly. Delaware nutrient management law requires the use of optimal rolling average for determining the yield goal for a specific field when field history is available. To calculate the optimal rolling average yield, see the UD Extension Fact Sheet ***Estimating Yield Goal for Crops***.

Target pH: 6.2

Soils that are high in organic matter (e.g., "black" soils; soil organic matter >6.0%) have a lower target pH (5.6) because organic matter moderates some of the negative effects of excessive soil acidity (e.g., aluminum toxicity).

The lime recommendation for a specific field is calculated from the soil pH and Adam-Evans buffer pH measurements using the steps outlined in the UD Extension Fact Sheet ***Calculating the Lime Requirement Using the Adams-Evans Soil Buffer***. Avoid over-liming to prevent deficiency of micronutrients such as manganese (Mn).

The recommended liming source is dependent upon Mehlich-3 (M3) soil test calcium (Ca) and magnesium (Mg) reported as a University of Delaware fertility index value (FIV) and can be determined using Table 1.

Table 1. Recommended type of lime as a function of Mehlich-3 soil test calcium (M3-Ca) and magnesium (M3-Mg) concentrations.

Soil Test Levels	Recommended Lime Type
M3-Mg is less than 50 FIV	Dolomitic
M3-Mg between 50 and 100 FIV AND M3-Mg is less than M3-Ca	Dolomitic
M3-Mg greater than 100 FIV	Calcitic
M3-Mg is greater than 50 FIV AND M3-Mg is greater than M3-Ca	Calcitic

Nitrogen

Nitrogen fertilization rates are based on regional research on crop response to N fertilizers and not on the results of a routine soil test.

1. For late summer, fall, or very early spring seedings, apply N at a rate of 40 to 60 lb/ac at or prior to planting if little weed competition is expected.
2. For mid- to late-spring seedings, do not apply N until the seedlings are 2 to 4 inches tall to avoid stimulating weed competition. Broadcast N at a rate of 20 lb/ac when forage growth reaches a height of 2 to 4 inches if weed pressure is not at a competitive level.
3. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.

Phosphorus

Phosphorus (P) fertilization is based on the results of a routine soil test (Table 2). Soil test results are reported as a fertility index value (FIV).

Table 2. Recommended broadcast phosphorus fertilizer application rates for annual or sweet bromegrass hay as a function of Mehlich-3 soil test phosphorus (M3-P) at 2.0 ton/ac yield goal.

	M3-P (UD FIV)										
	0	10	20	30	40	50	60	70	80	90	100
lb P_2O_5/ac	120	110	100	85	75	65	50	40	25	10	0

1. If M3 soil test P (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), broadcast and plow down the recommended rate of phosphate (P_2O_5) fertilizer prior to seeding.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), broadcast and incorporate P_2O_5 fertilizer prior to seeding or surface broadcast at or shortly after planting.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of phosphorus in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 15 lb /ac for each additional ton of expected yield.

Potassium

The need for potassium (K) fertilization is determined by a routine soil test (Table 3). Soil test results are reported as a fertility index value (FIV).

Table 3. Recommended potassium fertilizer application rate for annual or sweet bromegrass hay as a function of Mehlich-3 soil test potassium (M3-K) at 2.0 ton/ac yield goal.

	M3-K (UD FIV)										
	0	10	20	30	40	50	60	70	80	90	100
lb K_2O/ac	180	165	150	135	120	105	90	75	60	45	0

1. Broadcast and incorporate potash (K_2O) fertilizer at or prior to seeding.
2. Application rates of 120 lb/ac of K_2O or higher should be split into two applications. Apply ½ of the recommended rate after the first cutting and the remainder in late August or September.
3. Increase recommended K_2O application rate by 50 lb/ac for each additional ton of expected yield above 2.0 ton/ac.

Magnesium

The need for magnesium (Mg) fertilization is determined by a routine soil test (Table 4); Mg needs are often met by liming. Soil test results are reported as a fertility index value (FIV).

Table 4. Recommended application rates of soluble magnesium as a function of soil test magnesium (M3-Mg).

	M3-Mg (UD FIV)								
	0	5	10	15	20	25	30	35	40
lb soluble Mg/ac	80	70	60	50	40	30	20	10	0

1. Magnesium (Mg) is recommended when M3-Mg is less than 40 FIV.
2. Use dolomitic limestone if M3-Mg is less than 40 FIV and lime is recommended, use dolomitic limestone.
3. If M3-Mg is less than 40 FIV and lime is not needed, apply soluble Mg (Mg sulfate or Mg chloride) according to the rates in Table 4.

Sulfur

Sulfur (S) deficiency is occasionally observed in annual or sweet bromegrass grown on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Newly planted forage crops are susceptible to S deficiency because their shallow root systems do not allow the crop to tap into subsoil stores of S. Cutting hay also removes a significant amount of S from the soil and increases the risk of S deficiency. Legumes are more susceptible to S deficiency than grass species.

1. Apply S at a rate of 20 to 40 lb/ac to ensure that adequate sulfur is available to meet crop needs.
2. Broadcast S prior to seeding or use ammonium sulfate as an N source to supply needed S.
3. Sulfate-S is available for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for oxidation of the applied S to the sulfate form to occur.

Prediction of S deficiency is difficult. Currently available soil tests are not good predictors of S deficiency situations because only surface soil samples are analyzed. Many Delaware soils have a supply of plant available S in subsoil horizons that will not be detected in soil 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.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems. Also remember that sulfate-S is available for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for oxidation of the applied S to the sulfate form to occur.

Manganese

Manganese (Mn) needs are predicted by an availability index (MnAI) that includes M3 soil test Mn (M3-Mn) and soil pH. Interpretation of MnAI is crop specific (Table 5). Forage crops are moderately sensitive to Mn deficiency. Soil test Mn results are reported in lb/ac.

$$MnAI = 101.7 - (15.2 \times \text{soil pH}) + (2.11 \times \text{M3-Mn})$$

Where:

MnAI = Mn availability index
Soil pH = Soil pH measured in water (1:1 V:V)
M3-Mn = Mehlich 3 soil test Mn in lb/ac

Table 5. Interpretation of manganese availability index for annual or sweet bromegrass.

Mn Availability Index	Interpretation
Less than 17	Mn deficiency is likely at this soil pH and soil test Mn concentration
17 to 25	Mn deficiency is possible at this soil pH and soil test Mn concentration. Monitor the crop for symptoms, especially if liming has been recommended.
Greater than 25	Mn deficiency is unlikely.

1. If Mn deficiency is predicted or was observed in the previous growing season, broadcast Mn at a rate of 20 to 40 lb/ac.
2. Broadcast applications of acid forming fertilizers may correct Mn deficiency without the actual application of Mn in some cases but may be less effective than applications of Mn. Long term application of acid forming fertilizers will require pH correction with lime.
3. If Mn deficiency symptoms appear during the growing season or after an application of lime, a foliar application of 1.0 to 2.0 lb/ac actual Mn as Mn sulfate, Mn oxide or chelated Mn can alleviate the symptoms and restore yield potential. Foliar applications can be applied before fall dormancy or after growth resumes in the spring. ***Apply only when adequate growth is present to aid absorption of foliar Mn.*** Foliar application can be repeated if symptoms reappear.

Zinc

Zinc (Zn) deficiency is predicted by an availability index that includes M3 soil test Zn, soil pH, and M3 soil test P. Zinc deficiency is most common on soils with a pH of 6.5 or higher and high soil test P concentrations but may also be induced by environmental conditions such as cold, wet soils that may limit root growth. See Table 6 to determine if Zn deficiency is predicted for this field.

Table 6. Interpretation of zinc availability index for annual or sweet bromegrass.

Soil Test Criteria	Interpretation
M3-Zn is less than 1.9 lb/ac	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is higher than 7.0	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is 6.6 or higher **AND** M3-P is 100 FIV or higher	Zn deficiency is predicted
M3-Zn is 3.2 lb/ac or higher	Zn deficiency is NOT predicted

If Zn deficiency is predicted by the availability index or was observed the previous year, one of the following treatments can be applied:

1. Broadcast Zn sulfate or Zn oxide at a rate of 10 to 12 lb/ac elemental Zn or Zn chelate (Zn-EDTA) at a rate of 2 to 3 lb/ac elemental Zn. Broadcast applications should correct Zn deficiency for several years.
2. Foliar application of Zn sulfate or Zn oxide at a rate of 1 lb/ac elemental Zn or Zn chelate at a rate of 0.5 lb/ac elemental Zn in 20 to 50 gallons of water. **Apply only when adequate growth is present to aid in the adsorption of foliar Zn.** Foliar Zn application should be repeated if symptoms re-appear.

Boron

Boron (B) deficiency is not common in annual forage crops. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.

Barley Forage

Crop Highlights
• Target pH: 6.2 • Plant as soon after the Hessian fly free date to increase forage yield potential. • Split spring N applications can improve protein levels and yield potential. • Apply sulfur (S) with or without N to prevent S deficiency. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Cereal grain crops provide lush, high protein, low fiber animal feed. Early planting is recommended when barley is used for grazing, hay, or silage. However, Hessian fly can lead to lodging if the crop is planted before the Hessian fly-free date (3 Oct - New Castle; 8 Oct - Kent; 10 Oct - Sussex); plant as soon after the Hessian fly free date as possible. Barley can be seeded alone or in combination with a legume such as vetch or pea. Increase seeding rate to 3 bu/ac when grown for grazing, hay, or silage. Moderate grazing in fall is possible without significant hay or silage losses. Split spring N applications can improve protein levels and yield potential. Resume spring grazing at greenup when growth begins. If harvesting for silage, terminate grazing just prior to jointing. Cut barley for hay at early head emergence up to the milky stage. Cut barley for silage at the boot or soft dough stage to have more fermentable starch present. When cut at or before boot stage, rye must be wilted and conditioned due to high moisture content.

Yield Goal

A realistic yield goal for a forage barley forage crop is 2.0 ton/ac in a good to average year. However, yield is dependent upon several factors, including grass species, seeding rate, seeding date, degree of stand establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop management practices, and grazing management practices.

Delaware growers should use field history to determine the yield goal for each field and use that information to adjust management decisions and fertility programs accordingly. Delaware nutrient management law requires the use of optimal rolling average for determining the yield goal for a specific field when field history is available. To calculate the optimal rolling average yield, see the UD Extension Fact Sheet ***Estimating Yield Goal for Crops***.

Target pH: 6.2

Soils that are high in organic matter (e.g., "black" soils; soil organic matter >6.0%) have a lower target pH (5.6) because organic matter moderates some of the negative effects of excessive soil acidity (e.g., aluminum toxicity).

The lime recommendation for a specific field is calculated from the soil pH and Adam-Evans buffer pH measurements using the steps outlined in the UD Extension Fact Sheet ***Calculating the Lime***

Requirement Using the Adams-Evans Soil Buffer. Avoid over-liming to prevent deficiency of micronutrients such as manganese (Mn).

The recommended liming source is dependent upon Mehlich-3 (M3) soil test calcium (Ca) and magnesium (Mg) reported as a University of Delaware fertility index value (FIV) and can be determined using Table 1.

Table 1. Recommended type of lime as a function of Mehlich-3 soil test calcium (M3-Ca) and magnesium (M3-Mg) concentrations.

Soil Test Levels	Recommended Lime Type
M3-Mg is less than 50 FIV	Dolomitic
M3-Mg between 50 and 100 FIV AND M3-Mg is less than M3-Ca	Dolomitic
M3-Mg greater than 100 FIV	Calcitic
M3-Mg is greater than 50 FIV AND M3-Mg is greater than M3-Ca	Calcitic

Nitrogen

Nitrogen fertilization rates are based on regional research on crop response to N fertilizers and not on the results of a routine soil test.

1. For late summer, fall, or very early spring seedings, apply N at a rate of 40 to 60 lb/ac at or prior to planting if little weed competition is expected.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.

Phosphorus

Phosphorus (P) fertilization is based on the results of a routine soil test (Table 2). Soil test results are reported as a fertility index value (FIV).

Table 2. Recommended broadcast phosphorus fertilizer application rates for forage barley hay as a function of Mehlich-3 soil test phosphorus (M3-P) at 2.0 ton/ac yield goal.

	M3-P (UD FIV)										
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
lb P_2O_5/ac	120	110	100	85	75	65	50	40	25	10	0

1. If M3 soil test P (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), broadcast and plow down the recommended rate of phosphate (P_2O_5) fertilizer prior to seeding.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), broadcast and incorporate P_2O_5 fertilizer prior to seeding or surface broadcast at or shortly after planting.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of phosphorus in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 15 lb /ac for each additional ton of expected yield.

Potassium

The need for potassium (K) fertilization is determined by a routine soil test (Table 3). Soil test results are reported as a fertility index value (FIV).

Table 3. Recommended potassium fertilizer application rate for forage barley hay as a function of Mehlich-3 soil test potassium (M3-K) at 2.0 ton/ac yield goal.

	M3-K (UD FIV)										
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
lb K_2O/ac	180	165	150	135	120	105	90	75	60	45	0

1. Broadcast and incorporate potash (K_2O) fertilizer at or prior to seeding.
2. Application rates of 120 lb/ac of K_2O or higher should be split into two applications. Apply ½ of the recommended rate after the first cutting and the remainder in late August or September.
3. Increase recommended K_2O application rate by 50 lb/ac for each additional ton of expected yield above 2.0 ton/ac.

Magnesium

The need for magnesium (Mg) fertilization is determined by a routine soil test (Table 4); Mg needs are often met by liming. Soil test results are reported as a fertility index value (FIV).

Table 4. Recommended application rates of soluble magnesium as a function of soil test magnesium (M3-Mg).

	M3-Mg (UD FIV)								
	0	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
lb soluble Mg/ac	80	70	60	50	40	30	20	10	0

1. Magnesium (Mg) is recommended when M3-Mg is less than 40 FIV.
2. Use dolomitic limestone if M3-Mg is less than 40 FIV and lime is recommended, use dolomitic limestone.
3. If M3-Mg is less than 40 FIV and lime is not needed, apply soluble Mg (Mg sulfate or Mg chloride) according to the rates in Table 4.

Sulfur

Sulfur (S) deficiency is occasionally observed in forage barley grown on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Newly planted forage crops are susceptible to S deficiency because their shallow root systems do not allow the crop to tap into subsoil stores of S. Cutting hay also removes a significant amount of S from the soil and increases the risk of S deficiency. Legumes are more susceptible to S deficiency than grass species.

1. Apply S at a rate of 20 to 40 lb/ac to ensure that adequate sulfur is available to meet crop needs.
2. Broadcast S prior to seeding or use ammonium sulfate as an N source to supply needed S.
3. Sulfate-S is available for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for oxidation of the applied S to the sulfate form to occur.

Prediction of S deficiency is difficult. Currently available soil tests are not good predictors of S deficiency situations because only surface soil samples are analyzed. Many Delaware soils have a supply of plant available S in subsoil horizons that will not be detected in soil 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.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems. Also remember that sulfate-S is available for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for oxidation of the applied S to the sulfate form to occur.

Manganese

Manganese (Mn) needs are predicted by an availability index (MnAI) that includes M3 soil test Mn (M3-Mn) and soil pH. Interpretation of MnAI is crop specific (Table 5). Forage crops are moderately sensitive to Mn deficiency. Soil test Mn results are reported in lb/ac.

MnAI = 101.7 – (15.2 × soil pH) + (2.11 × M3-Mn)

Where:

MnAI = Mn availability index
Soil pH = Soil pH measured in water (1:1 V:V)
M3-Mn = Mehlich 3 soil test Mn in lb/ac

Table 5. Interpretation of manganese availability index for forage barley.

Mn Availability Index	Interpretation
Less than 17	Mn deficiency is likely at this soil pH and soil test Mn concentration
17 to 25	Mn deficiency is possible at this soil pH and soil test Mn concentration. Monitor the crop for symptoms, especially if liming has been recommended.
Greater than 25	Mn deficiency is unlikely.

1. If Mn deficiency is predicted or was observed in the previous growing season, broadcast Mn at a rate of 20 to 40 lb/ac.
2. Broadcast applications of acid forming fertilizers may correct Mn deficiency without the actual application of Mn in some cases but may be less effective than applications of Mn. Long term application of acid forming fertilizers will require pH correction with lime.
3. If Mn deficiency symptoms appear during the growing season or after an application of lime, a foliar application of 1.0 to 2.0 lb/ac actual Mn as Mn sulfate, Mn oxide or chelated Mn can alleviate the symptoms and restore yield potential. Foliar applications can be applied before fall dormancy or after growth resumes in the spring. ***Apply only when adequate growth is present to aid absorption of foliar Mn.*** Foliar application can be repeated if symptoms reappear.

Zinc

Zinc (Zn) deficiency is predicted by an availability index that includes M3 soil test Zn, soil pH, and M3 soil test P. Zinc deficiency is most common on soils with a pH of 6.5 or higher and high soil test P concentrations but may also be induced by environmental conditions such as cold, wet soils that may limit root growth. See Table 6 to determine if Zn deficiency is predicted for this field.

Table 6. Interpretation of zinc availability index for forage barley.

Soil Test Criteria	Interpretation
M3-Zn is less than 1.9 lb/ac	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is higher than 7.0	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is 6.6 or higher **AND** M3-P is 100 FIV or higher	Zn deficiency is predicted
M3-Zn is 3.2 lb/ac or higher	Zn deficiency is NOT predicted

If Zn deficiency is predicted by the availability index or was observed the previous year, one of the following treatments can be applied:

1. Broadcast Zn sulfate or Zn oxide at a rate of 10 to 12 lb/ac elemental Zn or Zn chelate (Zn-EDTA) at a rate of 2 to 3 lb/ac elemental Zn. Broadcast applications should correct Zn deficiency for several years.
2. Foliar application of Zn sulfate or Zn oxide at a rate of 1 lb/ac elemental Zn or Zn chelate at a rate of 0.5 lb/ac elemental Zn in 20 to 50 gallons of water. **Apply only when adequate growth is present to aid in the adsorption of foliar Zn.** Foliar Zn application should be repeated if symptoms re-appear.

Boron

Boron (B) deficiency is not common in annual forage crops. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.

Cereal Rye Forage

Crop Highlights
• Target pH: 6.2 • Early planting is recommended to increase forage yield, but crop is suceptible to Hessian fly. • Split spring N applications can improve protein levels and yield potential. • Apply sulfur (S) with or without N to prevent S deficiency. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Cereal grain crops provide lush, high protein, low fiber animal feed. Cereal rye is the most winter hardy cereal crop. Rye often heads earlier than barley or triticale and may have a slightly lower yield potential. Early planting is recommended when rye is used for grazing, hay, or silage. However, Hessian fly can lead to lodging if the crop is planted before the Hessian fly-free date (3 Oct - New Castle; 8 Oct - Kent; 10 Oct - Sussex); plant as soon after the Hessian fly free date as possible. Increase seeding rate to 3 bu/ac when grown for grazing, hay, or silage. Moderate grazing in fall is possible without significant hay or silage losses. Split spring N applications can improve protein levels and yield potential. Resume spring grazing at greenup when growth begins. If harvesting for silage, terminate grazing just prior to jointing. Cut rye for haylage or silage no later than early heading; cutting at flag-leaf or early boot stage is preferred as cutting later may lead to lower palatability. Silage cut at boot stage must be wilted and conditioned due to high moisture content. It is difficult to produce dry hay from rye when cut at the desired stage. Dry hay and higher tonnages are possible with later cuts, but hay may require grinding for good consumption.

Yield Goal

A realistic yield goal for a forage rye forage crop is 2.0 ton/ac in a good to average year. However, yield is dependent upon several factors, including grass species, seeding rate, seeding date, degree of stand establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop management practices, and grazing management practices.

Delaware growers should use field history to determine the yield goal for each field and use that information to adjust management decisions and fertility programs accordingly. Delaware nutrient management law requires the use of optimal rolling average for determining the yield goal for a specific field when field history is available. To calculate the optimal rolling average yield, see the UD Extension Fact Sheet ***Estimating Yield Goal for Crops***.

Target pH: 6.2

Soils that are high in organic matter (e.g., "black" soils; soil organic matter >6.0%) have a lower target pH (5.6) because organic matter moderates some of the negative effects of excessive soil acidity (e.g., aluminum toxicity).

The lime recommendation for a specific field is calculated from the soil pH and Adam-Evans buffer pH measurements using the steps outlined in the UD Extension Fact Sheet ***Calculating the Lime Requirement Using the Adams-Evans Soil Buffer***. Avoid over-liming to prevent deficiency of micronutrients such as manganese (Mn).

The recommended liming source is dependent upon Mehlich-3 (M3) soil test calcium (Ca) and magnesium (Mg) reported as a University of Delaware fertility index value (FIV) and can be determined using Table 1.

Table 1. Recommended type of lime as a function of Mehlich-3 soil test calcium (M3-Ca) and magnesium (M3-Mg) concentrations.

Soil Test Levels	Recommended Lime Type
M3-Mg is less than 50 FIV	Dolomitic
M3-Mg between 50 and 100 FIV AND M3-Mg is less than M3-Ca	Dolomitic
M3-Mg greater than 100 FIV	Calcitic
M3-Mg is greater than 50 FIV AND M3-Mg is greater than M3-Ca	Calcitic

Nitrogen

Nitrogen fertilization rates are based on regional research on crop response to N fertilizers and not on the results of a routine soil test.

1. For late summer, fall, or very early spring seedings, apply N at a rate of 40 to 60 lb/ac at or prior to planting if little weed competition is expected.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.

Phosphorus

Phosphorus (P) fertilization is based on the results of a routine soil test (Table 2). Soil test results are reported as a fertility index value (FIV).

Table 2. Recommended broadcast phosphorus fertilizer application rates for forage rye hay as a function of Mehlich-3 soil test phosphorus (M3-P) at 2.0 ton/ac yield goal.

	M3-P (UD FIV)										
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
lb P_2O_5/ac	120	110	100	85	75	65	50	40	25	10	0

1. If M3 soil test P (M3-P) is "Low" or "Medium" (i.e., 50 FIV or less), broadcast and plow down the recommended rate of phosphate (P_2O_5) fertilizer prior to seeding.
2. If M3-P is "Optimum" (i.e., 51 to 100 FIV), broadcast and incorporate P_2O_5 fertilizer prior to seeding or surface broadcast at or shortly after planting.
3. If M3-P is "Excessive" (i.e., greater than 100 FIV), the application of phosphorus in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 15 lb /ac for each additional ton of expected yield.

Potassium

The need for potassium (K) fertilization is determined by a routine soil test (Table 3). Soil test results are reported as a fertility index value (FIV).

Table 3. Recommended potassium fertilizer application rate for forage rye hay as a function of Mehlich-3 soil test potassium (M3-K) at 2.0 ton/ac yield goal.

	M3-K (UD FIV)										
	0	10	20	30	40	50	60	70	80	90	100
lb K_2O/ac	180	165	150	135	120	105	90	75	60	45	0

1. Broadcast and incorporate potash (K_2O) fertilizer at or prior to seeding.
2. Application rates of 120 lb/ac of K_2O or higher should be split into two applications. Apply ½ of the recommended rate after the first cutting and the remainder in late August or September.
3. Increase recommended K_2O application rate by 50 lb/ac for each additional ton of expected yield above 2.0 ton/ac.

Magnesium

The need for magnesium (Mg) fertilization is determined by a routine soil test (Table 4); Mg needs are often met by liming. Soil test results are reported as a fertility index value (FIV).

Table 4. Recommended application rates of soluble magnesium as a function of soil test magnesium (M3-Mg).

	M3-Mg (UD FIV)								
	0	5	10	15	20	25	30	35	40
lb soluble Mg/ac	80	70	60	50	40	30	20	10	0

1. Magnesium (Mg) is recommended when M3-Mg is less than 40 FIV.
2. Use dolomitic limestone if M3-Mg is less than 40 FIV and lime is recommended, use dolomitic limestone.
3. If M3-Mg is less than 40 FIV and lime is not needed, apply soluble Mg (Mg sulfate or Mg chloride) according to the rates in Table 4.

Sulfur

Sulfur (S) deficiency is occasionally observed in forage rye grown on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Newly planted forage crops are susceptible to S deficiency because their shallow root systems do not allow the crop to tap into subsoil stores of S. Cutting hay also removes a significant amount of S from the soil and increases the risk of S deficiency. Legumes are more susceptible to S deficiency than grass species.

1. Apply S at a rate of 20 to 40 lb/ac to ensure that adequate sulfur is available to meet crop needs.
2. Broadcast S prior to seeding or use ammonium sulfate as an N source to supply needed S.
3. Sulfate-S is available for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for oxidation of the applied S to the sulfate form to occur.

Prediction of S deficiency is difficult. Currently available soil tests are not good predictors of S deficiency situations because only surface soil samples are analyzed. Many Delaware soils have a supply of plant available S in subsoil horizons that will not be detected in soil 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.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems. Also remember that sulfate-S is available for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for oxidation of the applied S to the sulfate form to occur.

Manganese

Manganese (Mn) needs are predicted by an availability index (MnAI) that includes M3 soil test Mn (M3-Mn) and soil pH. Interpretation of MnAI is crop specific (Table 5). Forage crops are moderately sensitive to Mn deficiency. Soil test Mn results are reported in lb/ac.

$$MnAI = 101.7 – (15.2 \times \text{soil pH}) + (2.11 \times \text{M3-Mn})$$

Where:

MnAI = Mn availability index
Soil pH = Soil pH measured in water (1:1 V:V)
M3-Mn = Mehlich 3 soil test Mn in lb/ac

Table 5. Interpretation of manganese availability index for forage rye.

Mn Availability Index	Interpretation
Less than 17	Mn deficiency is likely at this soil pH and soil test Mn concentration
17 to 25	Mn deficiency is possible at this soil pH and soil test Mn concentration. Monitor the crop for symptoms, especially if liming has been recommended.
Greater than 25	Mn deficiency is unlikely.

1. If Mn deficiency is predicted or was observed in the previous growing season, broadcast Mn at a rate of 20 to 40 lb/ac.
2. Broadcast applications of acid forming fertilizers may correct Mn deficiency without the actual application of Mn in some cases but may be less effective than applications of Mn. Long term application of acid forming fertilizers will require pH correction with lime.
3. If Mn deficiency symptoms appear during the growing season or after an application of lime, a foliar application of 1.0 to 2.0 lb/ac actual Mn as Mn sulfate, Mn oxide or chelated Mn can alleviate the symptoms and restore yield potential. Foliar applications can be applied before fall dormancy or after growth resumes in the spring. ***Apply only when adequate growth is present to aid absorption of foliar Mn.*** Foliar application can be repeated if symptoms reappear.

Zinc

Zinc (Zn) deficiency is predicted by an availability index that includes M3 soil test Zn, soil pH, and M3 soil test P. Zinc deficiency is most common on soils with a pH of 6.5 or higher and high soil test P concentrations but may also be induced by environmental conditions such as cold, wet soils that may limit root growth. See Table 6 to determine if Zn deficiency is predicted for this field.

Table 6. Interpretation of zinc availability index for forage rye.

Soil Test Criteria	Interpretation
M3-Zn is less than 1.9 lb/ac	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is higher than 7.0	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is 6.6 or higher **AND** M3-P is 100 FIV or higher	Zn deficiency is predicted
M3-Zn is 3.2 lb/ac or higher	Zn deficiency is NOT predicted

If Zn deficiency is predicted by the availability index or was observed the previous year, one of the following treatments can be applied:

1. Broadcast Zn sulfate or Zn oxide at a rate of 10 to 12 lb/ac elemental Zn or Zn chelate (Zn-EDTA) at a rate of 2 to 3 lb/ac elemental Zn. Broadcast applications should correct Zn deficiency for several years.
2. Foliar application of Zn sulfate or Zn oxide at a rate of 1 lb/ac elemental Zn or Zn chelate at a rate of 0.5 lb/ac elemental Zn in 20 to 50 gallons of water. **Apply only when adequate growth is present to aid in the adsorption of foliar Zn.** Foliar Zn application should be repeated if symptoms re-appear.

Boron

Boron (B) deficiency is not common in annual forage crops. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.

Corn Silage

Crop Highlights
• Target pH: 6.0 • Split nitrogen (N) applications to increase N use efficiency in corn. Apply a small amount of N (20 to 25%) at planting and the bulk of the N requirement (75 to 80%) when the plants are 12 to 15 inches tall. • Use the pre-sidedress soil nitrate test (PSNT) for manured ground to calculate crop N needs in season. • For irrigated corn where fertigation is possible, split N applications to increase N use efficiency. Apply a small amount (15 to 20%) at planting and split the remainder into equal increments to be applied with irrigation water from the 5 to 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 corn stalk nitrate test (CSNT) at the end of the season to monitor the success of the N management program. • Monitor crop for manganese (Mn) deficiency, especially when Mehlich-3 soil test Mn is less than 3.4 lb/ac.

Yield Goal

Corn silage yields are influenced by many factors, including the variety selected, planting date, weather, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, and crop management practices. **Typical yield goals for corn grown for silage on Delaware soils are shown in Table 1.** Ranges reflect the variation in soil type, water availability, and tillage management.

Delaware growers should use field history to determine the yield goal for each field and use that information to adjust management decisions and fertility programs accordingly. Delaware nutrient management law requires the use of optimal rolling average for determining the yield goal for a specific field when field history is available. To calculate the optimal rolling average yield, see the UD Extension Fact Sheet ***Estimating Yield Goal for Crops***.

Table 1. Corn silage yield as a function of irrigation use and management level.

Production System	Silage Yield (ton/ac)
Dryland – Traditional Management	15 – 30
Irrigated - High Management	25 – 35
Irrigated - Intensive Management	30 – 40

Soil pH and Liming

Target pH: 6.0 for most soils

Soils that are high in organic matter (e.g., "black" soils; soil organic matter >6.0%) have a lower target pH (5.6) because organic matter moderates some of the negative effects of excessive soil acidity (e.g., aluminum toxicity).

The lime recommendation for a specific field is calculated from the soil pH and Adam-Evans buffer pH measurements using the steps outlined in the UD Extension Fact Sheet ***Calculating the Lime Requirement Using the Adams-Evans Soil Buffer***. Avoid over-liming to prevent deficiency of micronutrients such as manganese (Mn).

The recommended liming source is dependent upon Mehlich-3 (M3) soil test calcium (Ca) and magnesium (Mg) reported as a University of Delaware fertility index value (FIV) and can be determined using Table 1.

Table 2. Recommended type of lime as a function of Mehlich-3 soil test calcium and magnesium concentrations.

Soil Test Levels	Recommended Lime Type
M3-Mg is less than 50 FIV	Dolomitic
M3-Mg between 50 and 100 FIV AND M3-Mg is less than M3-Ca	Dolomitic
M3-Mg greater than 100 FIV	Calcitic
M3-Mg is greater than 50 FIV AND M3-Mg is greater than M3-Ca	Calcitic

Nitrogen

Nitrogen fertilization rates are based on regional research on crop response to N fertilizers and not on the results of a routine soil test. **The University of Delaware nitrogen (N) recommendations for corn silage production are based on a realistic yield goal (Table 3)**.

Table 3. Recommended nitrogen (N) rates for corn silage as a function of yield goal.

Yield Goal (ton/ac)	N Rate (lb/ac)
15	100 – 120
20	120 – 150
25	150 – 180
30	180 – 210
35	210 – 240
40	240 – 270

Split N applications can increase N use efficiency, thus requiring less total N to achieve the same silage yield. For most efficient N use, total N should be split into two or more applications during the growing season. Apply no more than 25% of total N at or just prior to planting. The remainder of the total N should be sidedressed when corn plants are 12 to 15 inches tall and the period of maximum N uptake is beginning.

For irrigated fields where fertigation is possible, the remainder of the N can be split into equal increments and applied with irrigation water beginning at the 5 or 6 leaf stage and continuing through silking.

For fields with a history of manure use, use the pre-sidedress soil nitrate test (PSNT) to determine the elemental sidedress N rate for the field. Information about sampling for and interpreting a PSNT is available in the UD Extension Fact Sheet ***Nitrogen Management for Corn in Delaware: The Pre-sidedress Nitrate Test.***

For in-season monitoring of crop N status, growers may wish to use the leaf chlorophyll meter. Use of a chlorophyll requires establishment of an N-rich strip for calibration of the meter.

Phosphorus

Phosphorus (P) fertilization is based on the results of a routine soil test (Tables 4 to 6). Soil test results are reported as a fertility index value (FIV). Phosphorus recommendations for corn are dependent upon the nutrient requirement of the crop as a function yield goal and crop management practices including tillage and nutrient application methods (e.g., banding, broadcast application or a combination of the two methods). Three management scenarios with the recommended application rates are presented.

Table 4. Recommended phosphorus rate for corn silage as a function of expected yield and Mehlich-3 soil test phosphorus (M3-P) when all phosphorus will be applied as a band application.

Yield	M3-P (UD FIV)										
	0	10	20	30	40	50	60	70	80	90	100
	-- lb P_2O_5/ac ---										
15	60	50	40	35	25	20	15	10	10	0	0
20	75	60	50	40	30	25	20	15	15	10	10
25	80	70	60	50	35	30	25	20	20	15	15
30	95	80	80	70	60	45	45	30	30	25	25
35	105	90	90	85	80	55	55	50	50	35	35
40	115	100	100	95	90	65	65	60	60	45	45

Table 5. Recommended phosphorus rate for corn silage as a function of expected yield and Mehlich-3 soil test phosphorus (M3-P) when all phosphorus will be applied as a broadcast application.

Yield	M3-P (UD FIV)										
	0	10	20	30	40	50	60	70	80	90	100
	-- lb P_2O_5/ac ---										
15	120	100	80	70	50	40	30	20	20	10	10
20	150	120	100	80	60	50	40	30	30	20	20
25	160	140	110	90	70	60	50	50	40	40	40
30	190	170	140	120	100	75	65	65	55	55	55
35	220	200	170	150	130	90	80	80	70	70	65
40	250	230	200	180	160	105	95	95	85	85	75

Table 6. Recommended phosphorus rate for corn silage as a function of expected yield and Mehlich-3 soil test phosphorus (M3-P) when applied as a broadcast + starter application.

Yield	M3-P (UD FIV)										
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
	--- lb P_2O_5/ac --										
	Starter Band										
All yields	40	40	35	35	30	30	25	25	20	20	20
	Broadcast Rate										
15	20	10	0	0	0	0	0	0	0	0	0
20	50	30	10	0	0	0	0	0	0	0	0
25	80	60	40	20	10	10	10	0	0	0	0
30	110	90	70	50	40	15	15	15	15	15	15
35	140	120	100	80	70	30	30	30	30	30	30
40	170	150	130	110	100	45	45	45	45	45	45

1. Select Table 4 when phosphate will be banded only. **This is the recommended practice for no-till systems and is suitable for all tillage schemes.**
2. Select Table 5 when phosphate will be applied as a broadcast application at or prior to planting. **Broadcast applications are NOT recommended for no-till fields.**
3. Select Table 6 when starter P will be applied, and the remainder of the P will be applied as a broadcast application.
4. If M3 soil test P is "Excessive" (e.g., M3-P >100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.

Potassium

The need for potassium (K) fertilization is determined by a routine soil test (Table 5). Soil test results are reported as a fertility index value (FIV).

Table 7. Recommended potassium rate for corn silage as a function of expected yield and Mehlich-3 soil test potassium (M3-K).

Yield	M3-K (UD FIV)										
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
	--- lb K_2O/ac ---										
15	200	170	150	125	100	75	70	65	60	55	50
20	220	190	170	140	115	85	80	70	65	60	55
25	240	210	190	165	130	95	90	85	80	75	70
30	260	230	210	180	155	105	100	90	85	80	75
35	280	250	230	195	170	115	110	95	90	85	80
40	300	270	250	210	185	125	120	100	95	80	85

1. Potassium (K) can be broadcast in the fall or spring or banded at planting.
2. For banded applications, reduce the rates in Table 7 by one-half.
3. To avoid salt injury to seedlings, do not band more than 75 lb/ac of K_2O at planting. When N and K_2O are banded together, the sum of the N rate and the K_2O rate should not exceed 75 lb/ac.

Magnesium

The need for magnesium (Mg) fertilization is determined by a routine soil test (Table 8); Mg needs are often met by liming. Soil test results are reported as a fertility index value (FIV).

Table 8. Recommended application rates of soluble magnesium for corn silage as a function of Mehlich-3 soil test magnesium (M3-Mg).

Soluble Mg	M3-Mg (UD FIV)								
	0	5	10	15	20	25	30	35	40
lb soluble Mg/ac	80	70	60	50	40	30	20	10	0

1. Magnesium (Mg) is recommended when M3-Mg is less than 40 FIV
2. If M3-Mg is less than 40 FIV and lime is recommended, use dolomitic limestone.
3. If M3-Mg is less than 40 FIV and lime is not needed, apply soluble Mg (Mg sulfate or Mg chloride) according to the rates in Table 4.

Sulfur

Sulfur (S) deficiency is frequently 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 soil tests are not good predictors of S deficiency situations because only surface soil samples are analyzed. Many Delaware soils have a supply of plant available S in subsoil horizons that will not be detected in soil 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 ear leaf samples collected at early silking. Tissue samples collected earlier in the season are not as good of an indicator 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. If the ear leaf S concentration is less than the critical value of 0.12% or the N:S ratio is greater than 15:1, S deficiency is occurring.

1. Apply 30 to 40 lb/ac of S as ammonium sulfate to correct the deficiency.

To prevent S deficiency in subsequent years, apply one of the following treatments:

2. Broadcast 30 to 40 lb/ac of S as ammonium sulfate (24% S) or gypsum (19% S) at planting.
3. Band 20 to 30 lb/ac of S as ammonium sulfate at planting.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in no-till systems. Also remember that sulfate-S is available for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for oxidation of the applied S to the sulfate form to occur.

Manganese

Manganese (Mn) needs are predicted by an availability index that includes M3 soil test Mn (M3-Mn) and soil pH. Interpretation of MnAI is crop specific. Corn is a moderately Mn sensitive crop. Soil test Mn results are reported in lb/ac.

$$MnAI = 101.7 - (15.2 \times \text{soil pH}) + (2.11 \times \text{M3-Mn})$$

Where:

MnAI = Mn availability index
Soil pH = Soil pH measured in water (1:1 V:V)
M3-Mn = Mehlich 3 soil test Mn in lb/ac

Table 9. Interpretation of manganese availability index for corn silage.

Mn Availability Index	Interpretation
Less than 17	Mn deficiency is likely at this soil pH and soil test Mn concentration
17 to 25	Mn deficiency is possible at this soil pH and soil test Mn concentration. Monitor the crop for symptoms, especially if liming has been recommended.
Greater than 25	Mn deficiency is unlikely.

1. Manganese deficiency is more likely for soils with a MnAI between 17 and 25 if soils were recently limed and the M3-Mn concentration is < 3.4 lb/ac.
2. If Mn deficiency is predicted or was observed in the previous growing season, broadcast 20 to 30 lb/ac elemental Mn.
3. In some cases, broadcast applications of acid forming fertilizers may correct Mn deficiency without the application of Mn; however, acid-forming fertilizers may be less effective than Mn fertilizers.
4. If Mn deficiency symptoms appear during the growing season or after an application of lime, a foliar application of Mn sulfate or Mn oxide at a rate of 1.0 to 2.0 lb/ac elemental Mn or chelated Mn (Mn-EDTA) at a rate of 0.5 to 1.0 lb/ac elemental Mn can alleviate the symptoms and restore yield potential. **Apply only when adequate growth is present to aid absorption of foliar Mn.**

NOTE: When using foliar application to correct Mn deficiency, growers may combine the treatment with a post emergence herbicide application to reduce the number of trips across the field. Sulfate containing forms of Mn (e.g., manganese sulfate [Techmangam] and manganese-lignin-sulfate) may be antagonistic to weed control with Roundup™. To overcome this antagonism, growers should add ammonium sulfate at a rate of 17 lb per 100 gallons of solution. Chelated-Mn (Mn-EDTA) has shown a slight degree of antagonism but little to no reduction in weed control was noted in the field studies.

Zinc

Zinc (Zn) deficiency is predicted by an availability index (ZnAI) that includes M3 soil test Zn, soil pH, and M3 soil test P. Soil test Zn results are reported in lb/ac. Zinc deficiency is most common on soils with a pH of 6.5 or higher and high soil test P concentrations but may also be induced by environmental conditions such as cold, wet soils that may limit root growth. Zinc deficiency symptoms often appear early in the season and disappear as root growth increases or environmental conditions improve. See Table 9 to determine if Zn deficiency is predicted for this field.

Table 10. Interpretation of Zn availability index for corn silage.

Soil Test Criteria	Interpretation
M3-Zn is less than 1.9 lb/ac	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is higher than 7.0	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is 6.6 or higher **AND** M3-P is 100 FIV or higher	Zn deficiency is predicted
M3-Zn is 3.2 lb/ac or higher	Zn deficiency is unlikely

If zinc deficiency is predicted by the availability index or was observed the previous year, one of the following treatments can be applied:

1. Broadcast Zn sulfate or Zn oxide at a rate of 10 to 12 lb/ac elemental Zn or Zn chelate (Zn-EDTA) at a rate of 2 to 3 lb/ac elemental Zn. Broadcast applications should correct Zn deficiency for several years.
2. If a banded application is preferred, apply 6 to 8 lb/ac elemental Zn as Zn sulfate or Zn oxide or 1 to 2 lb/ac elemental Zn as Zn chelate (Zn-EDTA) in the fertilizer band. Banded applications are only effective in the growing season in which they are applied.
3. Foliar application of Zn sulfate or Zn oxide at a rate of 1 lb/ac elemental Zn or Zn chelate (Zn-EDTA) at a rate of 0.5 lb/ac elemental Zn in 20 to 50 gallons of water. **Apply only when adequate growth is present to aid in the adsorption of foliar Zn.** Foliar Zn application should be repeated if symptoms re-appear.

Boron

Boron (B) deficiency is rarely observed in corn silage production. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Small Grain/Legume Forage

Crop Highlights
• Target pH: 6.2 • Early planting is recommended to increase small grain forage yield, but crop is suceptible to Hessian fly. • Skip spring nitrogen (N) application to support legume establishment. • Apply sulfur (S) with or without N to prevent S deficiency. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Small grain and legume mixes can be grown as a forage crop; however, nitrogen (N) management is more difficult due to legume component. Match legume and small grain maturities for best forage quality and yield. Small grains will grow in fall and resume growth in spring. Legume growth occurs primarily late spring after planting. Skip spring N applications to support legume establishment. Cut for hay or silage when the small grain at the late boot to heading growth stage and the legume is at bud or very early bloom for the best quality and yield balance.

Yield Goal

A realistic yield goal for a small grain/legume mix forage crop is 2.0 ton/ac in a good to average year. However, yield is dependent upon several factors, including grass species, seeding rate, seeding date, degree of stand establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop management practices, and grazing management practices.

Delaware growers should use field history to determine the yield goal for each field and use that information to adjust management decisions and fertility programs accordingly. Delaware nutrient management law requires the use of optimal rolling average for determining the yield goal for a specific field when field history is available. To calculate the optimal rolling average yield, see the UD Extension Fact Sheet ***Estimating Yield Goal for Crops***.

Target pH: 6.2

Soils that are high in organic matter (e.g., "black" soils; soil organic matter >6.0%) have a lower target pH (5.6) because organic matter moderates some of the negative effects of excessive soil acidity (e.g., aluminum toxicity).

The lime recommendation for a specific field is calculated from the soil pH and Adam-Evans buffer pH measurements using the steps outlined in the UD Extension Fact Sheet ***Calculating the Lime Requirement Using the Adams-Evans Soil Buffer***. Avoid over-liming to prevent deficiency of micronutrients such as manganese (Mn).

The recommended liming source is dependent upon Mehlich-3 (M3) soil test calcium (Ca) and magnesium (Mg) reported as a University of Delaware fertility index value (FIV) and can be determined using Table 1.

Table 1. Recommended type of lime as a function of Mehlich-3 soil test calcium (M3-Ca) and magnesium (M3-Mg) concentrations.

Soil Test Levels	Recommended Lime Type
M3-Mg is less than 50 FIV	Dolomitic
M3-Mg between 50 and 100 FIV AND M3-Mg is less than M3-Ca	Dolomitic
M3-Mg greater than 100 FIV	Calcitic
M3-Mg is greater than 50 FIV AND M3-Mg is greater than M3-Ca	Calcitic

Nitrogen

Nitrogen fertilization rates are based on regional research on crop response to N fertilizers and not on the results of a routine soil test.

1. For late summer, fall, or very early spring seedings, apply N at a rate of 40 to 60 lb/ac at or prior to planting if little weed competition is expected.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.

Phosphorus

Phosphorus (P) fertilization is based on the results of a routine soil test (Table 2). Soil test results are reported as a fertility index value (FIV).

Table 2. Recommended broadcast phosphorus fertilizer application rates for small grain/legume mix hay as a function of Mehlich-3 soil test phosphorus (M3-P) at 2.0 ton/ac yield goal.

	M3-P (UD FIV)										
	0	10	20	30	40	50	60	70	80	90	100
lb P_2O_5/ac	120	110	100	85	75	65	50	40	25	10	0

1. If M3 soil test P (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), broadcast and plow down the recommended rate of phosphate (P_2O_5) fertilizer prior to seeding.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), broadcast and incorporate P_2O_5 fertilizer prior to seeding or surface broadcast at or shortly after planting.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of phosphorus in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 15 lb /ac for each additional ton of expected yield.

Potassium

The need for potassium (K) fertilization is determined by a routine soil test (Table 3). Soil test results are reported as a fertility index value (FIV).

Table 3. Recommended potassium fertilizer application rate for small grain/legume mix hay as a function of Mehlich-3 soil test potassium (M3-K) at 2.0 ton/ac yield goal.

	M3-K (UD FIV)										
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
lb K_2O/ac	180	165	150	135	120	105	90	75	60	45	0

1. Broadcast and incorporate potash (K_2O) fertilizer at or prior to seeding.
2. Application rates of 120 lb/ac of K_2O or higher should be split into two applications. Apply ½ of the recommended rate after the first cutting and the remainder in late August or September.
3. Increase recommended K_2O application rate by 50 lb/ac for each additional ton of expected yield above 2.0 ton/ac.

Magnesium

The need for magnesium (Mg) fertilization is determined by a routine soil test (Table 4); Mg needs are often met by liming. Soil test results are reported as a fertility index value (FIV).

Table 4. Recommended application rates of soluble magnesium as a function of soil test magnesium (M3-Mg).

	M3-Mg (UD FIV)								
	0	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
lb soluble Mg/ac	80	70	60	50	40	30	20	10	0

1. Magnesium (Mg) is recommended when M3-Mg is less than 40 FIV.
2. Use dolomitic limestone if M3-Mg is less than 40 FIV and lime is recommended, use dolomitic limestone.
3. If M3-Mg is less than 40 FIV and lime is not needed, apply soluble Mg (Mg sulfate or Mg chloride) according to the rates in Table 4.

Sulfur

Sulfur (S) deficiency is occasionally observed in small grain/legume mix grown on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Newly planted forage crops are susceptible to S deficiency because their shallow root systems do not allow the crop to tap into subsoil stores of S. Cutting hay also removes a significant amount of S from the soil and increases the risk of S deficiency. Legumes are more susceptible to S deficiency than grass species.

1. Apply S at a rate of 20 to 40 lb/ac to ensure that adequate sulfur is available to meet crop needs.
2. Broadcast S prior to seeding or use ammonium sulfate as an N source to supply needed S.
3. Sulfate-S is available for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for oxidation of the applied S to the sulfate form to occur.

Prediction of S deficiency is difficult. Currently available soil tests are not good predictors of S deficiency situations because only surface soil samples are analyzed. Many Delaware soils have a supply of plant available S in subsoil horizons that will not be detected in soil 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.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems. Also remember that sulfate-S is available for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for oxidation of the applied S to the sulfate form to occur.

Manganese

Manganese (Mn) needs are predicted by an availability index (MnAI) that includes M3 soil test Mn (M3-Mn) and soil pH. Interpretation of MnAI is crop specific (Table 5). Forage crops are moderately sensitive to Mn deficiency. Soil test Mn results are reported in lb/ac.

$$MnAI = 101.7 - (15.2 \times \text{soil pH}) + (2.11 \times \text{M3-Mn})$$

Where:

MnAI = Mn availability index
Soil pH = Soil pH measured in water (1:1 V:V)
M3-Mn = Mehlich 3 soil test Mn in lb/ac

Table 5. Interpretation of manganese availability index for small grain/legume mix.

Mn Availability Index	Interpretation
Less than 17	Mn deficiency is likely at this soil pH and soil test Mn concentration
17 to 25	Mn deficiency is possible at this soil pH and soil test Mn concentration. Monitor the crop for symptoms, especially if liming has been recommended.
Greater than 25	Mn deficiency is unlikely.

1. If Mn deficiency is predicted or was observed in the previous growing season, broadcast Mn at a rate of 20 to 40 lb/ac.
2. Broadcast applications of acid forming fertilizers may correct Mn deficiency without the actual application of Mn in some cases but may be less effective than applications of Mn. Long term application of acid forming fertilizers will require pH correction with lime.
3. If Mn deficiency symptoms appear during the growing season or after an application of lime, a foliar application of 1.0 to 2.0 lb/ac actual Mn as Mn sulfate, Mn oxide or chelated Mn can alleviate the symptoms and restore yield potential. Foliar applications can be applied before fall dormancy or after growth resumes in the spring. ***Apply only when adequate growth is present to aid absorption of foliar Mn.*** Foliar application can be repeated if symptoms reappear.

Zinc

Zinc (Zn) deficiency is predicted by an availability index that includes M3 soil test Zn, soil pH, and M3 soil test P. Zinc deficiency is most common on soils with a pH of 6.5 or higher and high soil test P concentrations but may also be induced by environmental conditions such as cold, wet soils that may limit root growth. See Table 6 to determine if Zn deficiency is predicted for this field.

Table 6. Interpretation of zinc availability index for small grain/legume mix.

Soil Test Criteria	Interpretation
M3-Zn is less than 1.9 lb/ac	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is higher than 7.0	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is 6.6 or higher **AND** M3-P is 100 FIV or higher	Zn deficiency is predicted
M3-Zn is 3.2 lb/ac or higher	Zn deficiency is NOT predicted

If Zn deficiency is predicted by the availability index or was observed the previous year, one of the following treatments can be applied:

1. Broadcast Zn sulfate or Zn oxide at a rate of 10 to 12 lb/ac elemental Zn or Zn chelate (Zn-EDTA) at a rate of 2 to 3 lb/ac elemental Zn. Broadcast applications should correct Zn deficiency for several years.
2. Foliar application of Zn sulfate or Zn oxide at a rate of 1 lb/ac elemental Zn or Zn chelate at a rate of 0.5 lb/ac elemental Zn in 20 to 50 gallons of water. **Apply only when adequate growth is present to aid in the adsorption of foliar Zn.** Foliar Zn application should be repeated if symptoms re-appear.

Boron

Boron (B) deficiency is not common in annual forage crops. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.

Sorghum Silage

Crop Highlights
• Target pH: 6.0 • Base nitrogen (N) application rates on the crop rotation in use. Sorghum has shown only minimal response to N when following an average soybean crop (e.g., 30 to 40 bu/ac yield) or another legume. Increase N rates when sorghum follows a corn or sorghum crop.

Yield Goal

Silage yield of sorghum is influenced by many factors, including the cultivars selected, planting date, winter weather, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, and crop management practices. **On Delaware soils, 10 to 15 ton/ac is a realistic yield goal for sorghum silage production in a good to average year.**

Delaware growers should use field history to determine the yield goal for each field and use that information to adjust management decisions and fertility programs accordingly. Delaware nutrient management law requires the use of optimal rolling average for determining the yield goal for a specific field when field history is available. To calculate the optimal rolling average yield, see the UD Extension Fact Sheet ***Estimating Yield Goal for Crops***.

Soil pH and Liming

Target pH: 6.0 for most soils

Soils that are high in organic matter (e.g., "black" soils; soil organic matter >6.0%) have a lower target pH (5.6) because organic matter moderates some of the negative effects of excessive soil acidity (e.g., aluminum toxicity).

The lime recommendation for a specific field is calculated from the soil pH and Adam-Evans buffer pH measurements using the steps outlined in the UD Extension Fact Sheet ***Calculating the Lime Requirement Using the Adams-Evans Soil Buffer***. Avoid over-liming to prevent deficiency of micronutrients such as manganese (Mn).

The recommended liming source is dependent upon Mehlich-3 (M3) soil test calcium (Ca) and magnesium (Mg) reported as a University of Delaware fertility index value (FIV) and can be determined using Table 1.

Table 1. Recommended type of lime as a function of Mehlich-3 soil test calcium and magnesium concentrations.

Soil Test Levels	Recommended Lime Type
M3-Mg is less than 50 FIV	Dolomitic
M3-Mg between 50 and 100 FIV AND M3-Mg is less than M3-Ca	Dolomitic
M3-Mg greater than 100 FIV	Calcitic
M3-Mg is greater than 50 FIV AND M3-Mg is greater than M3-Ca	Calcitic

Nitrogen

Nitrogen fertilization rates are based on regional research on crop response to N fertilizers and not on the results of a routine soil test.

The University of Delaware nitrogen (N) recommendations for sorghum are based upon the crop rotation in use. **A total nitrogen (N) application rate of 160 to 180 lb/ac per growing season is recommended for a sorghum silage crop following corn or sorghum.** When the sorghum crop is following an average soybean crop (e.g., 30 to 40 bu/ac yield) or another legume in the rotation, the N application rate should be reduced to 80 to 90 lb/ac per growing season.

Nitrogen use will be most efficient when applied in a split application. A small amount of N (approximately 25%) should be applied at or prior to planting. The remainder of the N should be applied at the 5th leaf stage. If a single N application is desired, then N should be applied as close to planting as possible to reduce the potential loss of N by leaching prior to crop uptake. When planting into fields where manure has been applied, determine the plant available N (PAN) for the manure application and reduce fertilizer N rates as appropriate.

Phosphorus

Phosphorus (P) fertilization is based on the results of a routine soil test (Table 2). Soil test results are reported as a fertility index value (FIV).

Table 2. Broadcast phosphorus application rates for sorghum silage.

	M3-P (UD FIV)										
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
lb P_2O_5/ac	100	80	60	50	40	40	30	30	30	20	20

1. If M3 soil test P (M3-P) is “Low” or “Medium” (e.g., 50 FIV or less), broadcast and plow down the recommended rate of phosphate prior to seeding.
2. If M3-P is “Optimum” (e.g., 51 to 100 FIV), broadcast and incorporate phosphate prior to seeding or surface broadcast at or shortly after planting.
3. If M3-P is “Excessive” (e.g., greater than 100 FIV), the application of phosphorus in fertilizers or manures is NOT RECOMMENDED.
4. If P fertilizers are banded, reduce the rates in Table 2 by one-half.

Potassium

The need for potassium (K) fertilization is determined by a routine soil test (Table 3). Soil test results are reported as a fertility index value (FIV).

Table 3. Recommended potassium application rates for sorghum silage.

	M3-K (UD FIV)										
	0	10	20	30	40	50	60	70	80	90	100
lb K_2O/ac	150	120	90	70	50	30	30	20	20	20	0

1. Broadcast and incorporate or band potash prior to planting.
2. For banded applications, reduce the rates in Table 3 by one-half.
3. To avoid salt injury to seedlings, do not band more than 75 lb/ac K_2O at planting. When N and K_2O are banded together, the sum of the N rate and the K_2O rate should not exceed 75 lb/ac.

Magnesium

The need for magnesium (Mg) fertilization is determined by a routine soil test (Table 4); Mg needs are often met by liming. Soil test results are reported as a fertility index value (FIV).

Table 4. Recommended application rates of soluble magnesium as a function of Mehlich 3 soil test magnesium.

Soluble Mg	M3-Mg (UD FIV)								
	0	5	10	15	20	25	30	35	40
lb soluble Mg/ac	80	70	60	50	40	30	20	10	0

1. Magnesium (Mg) is recommended when M3 soil test Mg is less than 40 FIV.
2. If M3-Mg is less than 40 FIV and lime is recommended, use dolomitic limestone.
3. If M3-Mg is less than 40 FIV and lime is not needed, apply soluble Mg according to the rates in Table 4.

Sulfur

Sulfur (S) deficiency is occasionally observed in early in the season on sorghum grown on sandy Delaware soils. The use of ammonium sulfate as the N source or the addition of a small amount of ammonium sulfate to liquid UAN can prevent S deficiency from occurring.

Prediction of S deficiency is difficult. Currently available soil tests are not good predictors of S deficiency situations because only surface soil samples are analyzed. Many Delaware soils have a supply of plant available S in subsoil horizons that will not be detected in soil 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.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in no-till systems. Also remember that sulfate-S is available for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for oxidation of the applied S to the sulfate form to occur.

Manganese

Manganese (Mn) needs are predicted by an availability index that includes M3 soil test Mn (M3-Mn) and soil pH. Interpretation of MnAI is crop specific. Sorghum is a moderately Mn sensitive crop. Soil test Mn results are reported in lb/ac.

$$\text{MnAI} = 101.7 - (15.2 \times \text{soil pH}) + (2.11 \times \text{M3-Mn})$$

Where:

MnAI = Mn availability index
Soil pH = Soil pH measured in water (1:1 V:V)
M3-Mn = Mehlich 3 soil test Mn in lb/ac

Table 5. Interpretation of manganese availability index for sorghum silage.

Mn Availability Index	Interpretation
Less than 17	Mn deficiency is likely at this soil pH and soil test Mn concentration
17 to 25	Mn deficiency is possible at this soil pH and soil test Mn concentration. Monitor the crop for symptoms, especially if liming has been recommended.
Greater than 25	Mn deficiency is unlikely.

1. Manganese deficiency is more likely for soils with a MnAI between 17 and 25 if soils were recently limed and the M3-Mn concentration is <3.4 lb/ac.
2. If Mn deficiency is predicted or was observed in the previous growing season, broadcast 20 to 30 lb/ac elemental Mn.
3. In some cases, broadcast applications of acid forming fertilizers may correct Mn deficiency without the application of Mn; however, acid-forming fertilizers may be less effective than Mn fertilizers.
4. If Mn deficiency symptoms appear during the growing season or after an application of lime, a foliar application of Mn sulfate or Mn oxide at a rate of 1.0 to 2.0 lb/ac elemental Mn or chelated Mn (Mn-EDTA) at a rate of 0.5 to 1.0 lb/ac elemental Mn can alleviate the symptoms and restore yield potential. **Apply only when adequate growth is present to aid absorption of foliar Mn.**

NOTE: When using foliar application to correct Mn deficiency, growers may combine the treatment with a post emergence herbicide application to reduce the number of trips across the field. Sulfate containing forms of Mn (e.g., manganese sulfate [Techmangam] and manganese-lignin-sulfate) may be antagonistic to weed control with Roundup™. To overcome this antagonism, growers should add ammonium sulfate at a rate of 17 lb per 100 gallons of solution. Chelated-Mn (Mn-EDTA) has shown a slight degree of antagonism but little to no reduction in weed control was noted in the field studies.

NOTE: Manganese toxicity has also been observed in sorghum silage grown on Delaware soils with low soil pH. Symptoms of Mn toxicity include generally stunted growth, yellowed or chlorotic leaves, or (in severe cases) a series of reddish-purple bands that run parallel to the leaf veins about ½ to ⅓ of the way back from the leaf tip. Suspected Mn toxicity can be confirmed by a tissue or soil pH test. When detected early, the problem may be corrected by broadcasting agricultural-grade lime at a rate of 1 ton/ac. Little can be done to correct Mn toxicity when identified later in the season. Take note of the area where Mn toxicity occurs in the field so that lime can be applied in that location following harvest to raise the pH for future crops.

Zinc

Zinc (Zn) deficiency is predicted by an availability index that includes M3 soil test Zn, soil pH, and M3 soil test P. It is most common on soils with a pH of 6.5 or higher and high soil test P concentrations but may also be induced by environmental conditions such as cold, wet soils that may limit root growth. Zinc deficiency symptoms often appear early in the season and disappear as root growth increases or environmental conditions improve. See Table 6 to determine if Zn deficiency is predicted for this field.

Table 6. Interpretation of zinc availability index for sorghum silage.

Soil Test Criteria	Interpretation
M3-Zn is less than 1.9 lb/ac	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is higher than 7.0	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is 6.6 or higher **AND** M3-P is 100 FIV or higher	Zn deficiency is predicted
M3-Zn is 3.2 lb/ac or higher	Zn deficiency is unlikely

If zinc deficiency is predicted by the availability index or was observed the previous year, one of the following treatments can be applied:

1. Broadcast Zn sulfate or Zn oxide at a rate of 10 to 12 lb/ac elemental Zn or Zn chelate (Zn-EDTA) at a rate of 2 to 3 lb/ac elemental Zn. Broadcast applications should correct Zn deficiency for several years.
2. Foliar application of Zn sulfate or Zn oxide at a rate of 1 lb/ac elemental Zn or Zn chelate (Zn-EDTA) at a rate of 0.5 lb/ac elemental Zn in 20 to 50 gallons of water. **Apply only when adequate growth is present to aid in the adsorption of foliar Zn.** Foliar Zn application should be repeated if symptoms reappear.

Boron

Boron (B) deficiency is not usually observed in sorghum silage. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Triticale Forage

Crop Highlights
• Target pH: 6.2 • Early planting is recommended to increase forage yield, but crop is suceptible to Hessian fly. • Split spring N applications can improve protein levels and yield potential. • Apply sulfur (S) with or without N to prevent S deficiency. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Triticale is a cross of wheat (usually durum wheat) and rye that produces high protein animal feed with good digestibility. Triticale is self-pollinated, while other small grains like rye are cross pollinated. Winter triticale is the traditional type used in this region. Early planting is recommended when triticale is used for grazing, hay, or silage. However, Hessian fly can lead to lodging if the crop is planted before the Hessian fly-free date (3 Oct - New Castle; 8 Oct - Kent; 10 Oct - Sussex); plant as soon after the Hessian fly free date as possible. Moderate grazing in fall is possible without significant hay or silage losses. Split spring N applications can improve protein levels and yield potential. Resume spring grazing at greenup when growth begins. If harvesting for silage, terminate grazing just prior to jointing. Cut for silage at boot stage for best forage quality. Cutting for silage can be delayed until soft dough for higher yields. Hay quality is highest if cut prior to boot stage, but a better yield to quality balance occurs if harvested in mid- to late-heading. When cut at or before boot stage, triticale must be wilted and conditioned due to high moisture content.

Yield Goal

A realistic yield goal for a triticale forage crop is 2.0 ton/ac in a good to average year. However, yield is dependent upon several factors, including grass species, seeding rate, seeding date, degree of stand establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop management practices, and grazing management practices.

Delaware growers should use field history to determine the yield goal for each field and use that information to adjust management decisions and fertility programs accordingly. Delaware nutrient management law requires the use of optimal rolling average for determining the yield goal for a specific field when field history is available. To calculate the optimal rolling average yield, see the UD Extension Fact Sheet ***Estimating Yield Goal for Crops***.

Target pH: 6.2

Soils that are high in organic matter (e.g., "black" soils; soil organic matter >6.0%) have a lower target pH (5.6) because organic matter moderates some of the negative effects of excessive soil acidity (e.g., aluminum toxicity).

The lime recommendation for a specific field is calculated from the soil pH and Adam-Evans buffer pH measurements using the steps outlined in the UD Extension Fact Sheet ***Calculating the Lime***

Requirement Using the Adams-Evans Soil Buffer. Avoid over-liming to prevent deficiency of micronutrients such as manganese (Mn).

The recommended liming source is dependent upon Mehlich-3 (M3) soil test calcium (Ca) and magnesium (Mg) reported as a University of Delaware fertility index value (FIV) and can be determined using Table 1.

Table 1. Recommended type of lime as a function of Mehlich-3 soil test calcium (M3-Ca) and magnesium (M3-Mg) concentrations.

Soil Test Levels	Recommended Lime Type
M3-Mg is less than 50 FIV	Dolomitic
M3-Mg between 50 and 100 FIV AND M3-Mg is less than M3-Ca	Dolomitic
M3-Mg greater than 100 FIV	Calcitic
M3-Mg is greater than 50 FIV AND M3-Mg is greater than M3-Ca	Calcitic

Nitrogen

Nitrogen fertilization rates are based on regional research on crop response to N fertilizers and not on the results of a routine soil test.

1. For late summer, fall, or very early spring seedings, apply N at a rate of 40 to 60 lb/ac at or prior to planting if little weed competition is expected.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.

Phosphorus

Phosphorus (P) fertilization is based on the results of a routine soil test (Table 2). Soil test results are reported as a fertility index value (FIV).

Table 2. Recommended broadcast phosphorus fertilizer application rates for triticale hay as a function of Mehlich-3 soil test phosphorus (M3-P) at 2.0 ton/ac yield goal.

	M3-P (UD FIV)										
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
lb P_2O_5/ac	120	110	100	85	75	65	50	40	25	10	0

1. If M3 soil test P (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), broadcast and plow down the recommended rate of phosphate (P_2O_5) fertilizer prior to seeding.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), broadcast and incorporate P_2O_5 fertilizer prior to seeding or surface broadcast at or shortly after planting.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of phosphorus in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 15 lb /ac for each additional ton of expected yield.

Potassium

The need for potassium (K) fertilization is determined by a routine soil test (Table 3). Soil test results are reported as a fertility index value (FIV).

Table 3. Recommended potassium fertilizer application rate for triticale hay as a function of Mehlich-3 soil test potassium (M3-K) at 2.0 ton/ac yield goal.

	M3-K (UD FIV)										
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
lb K_2O/ac	180	165	150	135	120	105	90	75	60	45	0

1. Broadcast and incorporate potash (K_2O) fertilizer at or prior to seeding.
2. Application rates of 120 lb/ac of K_2O or higher should be split into two applications. Apply ½ of the recommended rate after the first cutting and the remainder in late August or September.
3. Increase recommended K_2O application rate by 50 lb/ac for each additional ton of expected yield above 2.0 ton/ac.

Magnesium

The need for magnesium (Mg) fertilization is determined by a routine soil test (Table 4); Mg needs are often met by liming. Soil test results are reported as a fertility index value (FIV).

Table 4. Recommended application rates of soluble magnesium as a function of soil test magnesium (M3-Mg).

	M3-Mg (UD FIV)								
	0	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
lb soluble Mg/ac	80	70	60	50	40	30	20	10	0

1. Magnesium (Mg) is recommended when M3-Mg is less than 40 FIV.
2. Use dolomitic limestone if M3-Mg is less than 40 FIV and lime is recommended, use dolomitic limestone.
3. If M3-Mg is less than 40 FIV and lime is not needed, apply soluble Mg (Mg sulfate or Mg chloride) according to the rates in Table 4.

Sulfur

Sulfur (S) deficiency is occasionally observed in triticale grown on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Newly planted forage crops are susceptible to S deficiency because their shallow root systems do not allow the crop to tap into subsoil stores of S. Cutting hay also removes a significant amount of S from the soil and increases the risk of S deficiency. Legumes are more susceptible to S deficiency than grass species.

1. Apply S at a rate of 20 to 40 lb/ac to ensure that adequate sulfur is available to meet crop needs.
2. Broadcast S prior to seeding or use ammonium sulfate as an N source to supply needed S.
3. Sulfate-S is available for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for oxidation of the applied S to the sulfate form to occur.

Prediction of S deficiency is difficult. Currently available soil tests are not good predictors of S deficiency situations because only surface soil samples are analyzed. Many Delaware soils have a supply of plant available S in subsoil horizons that will not be detected in soil 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.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems. Also remember that sulfate-S is available for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for oxidation of the applied S to the sulfate form to occur.

Manganese

Manganese (Mn) needs are predicted by an availability index (MnAI) that includes M3 soil test Mn (M3-Mn) and soil pH. Interpretation of MnAI is crop specific (Table 5). Forage crops are moderately sensitive to Mn deficiency. Soil test Mn results are reported in lb/ac.

MnAI = 101.7 – (15.2 × soil pH) + (2.11 × M3-Mn)

Where:

MnAI = Mn availability index
Soil pH = Soil pH measured in water (1:1 V:V)
M3-Mn = Mehlich 3 soil test Mn in lb/ac

Table 5. Interpretation of manganese availability index for triticale.

Mn Availability Index	Interpretation
Less than 17	Mn deficiency is likely at this soil pH and soil test Mn concentration
17 to 25	Mn deficiency is possible at this soil pH and soil test Mn concentration. Monitor the crop for symptoms, especially if liming has been recommended.
Greater than 25	Mn deficiency is unlikely.

1. If Mn deficiency is predicted or was observed in the previous growing season, broadcast Mn at a rate of 20 to 40 lb/ac.
2. Broadcast applications of acid forming fertilizers may correct Mn deficiency without the actual application of Mn in some cases but may be less effective than applications of Mn. Long term application of acid forming fertilizers will require pH correction with lime.
3. If Mn deficiency symptoms appear during the growing season or after an application of lime, a foliar application of 1.0 to 2.0 lb/ac actual Mn as Mn sulfate, Mn oxide or chelated Mn can alleviate the symptoms and restore yield potential. Foliar applications can be applied before fall dormancy or after growth resumes in the spring. ***Apply only when adequate growth is present to aid absorption of foliar Mn.*** Foliar application can be repeated if symptoms reappear.

Zinc

Zinc (Zn) deficiency is predicted by an availability index that includes M3 soil test Zn, soil pH, and M3 soil test P. Zinc deficiency is most common on soils with a pH of 6.5 or higher and high soil test P concentrations but may also be induced by environmental conditions such as cold, wet soils that may limit root growth. See Table 6 to determine if Zn deficiency is predicted for this field.

Table 6. Interpretation of zinc availability index for triticale.

Soil Test Criteria	Interpretation
M3-Zn is less than 1.9 lb/ac	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is higher than 7.0	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is 6.6 or higher **AND** M3-P is 100 FIV or higher	Zn deficiency is predicted
M3-Zn is 3.2 lb/ac or higher	Zn deficiency is NOT predicted

If Zn deficiency is predicted by the availability index or was observed the previous year, one of the following treatments can be applied:

1. Broadcast Zn sulfate or Zn oxide at a rate of 10 to 12 lb/ac elemental Zn or Zn chelate (Zn-EDTA) at a rate of 2 to 3 lb/ac elemental Zn. Broadcast applications should correct Zn deficiency for several years.
2. Foliar application of Zn sulfate or Zn oxide at a rate of 1 lb/ac elemental Zn or Zn chelate at a rate of 0.5 lb/ac elemental Zn in 20 to 50 gallons of water. **Apply only when adequate growth is present to aid in the adsorption of foliar Zn.** Foliar Zn application should be repeated if symptoms re-appear.

Boron

Boron (B) deficiency is not common in annual forage crops. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.

Winter Oat Forage

Crop Highlights
• Target pH: 6.2 • Early planting is recommended to increase forage yield; crop is not suceptible to Hessian fly. • Split spring N applications can improve protein levels and yield potential. • Apply sulfur (S) with or without N to prevent S deficiency. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Cereal grain crops provide lush, high protein, low fiber animal feed. Early planting is recommended when rye is used for grazing, hay, or silage. However, wheat is the most susceptible small grain to Hessian fly, which can lead to lodging if the crop is planted before the Hessian fly-free date (3 Oct - New Castle; 8 Oct - Kent; 10 Oct - Sussex); plant after, but as close to, the Hessian fly free date. Increase seeding rate to 3 bu/ac when grown for grazing, hay, or silage. Moderate grazing in fall is possible without significant hay or silage losses. Split spring N applications can improve protein levels and yield potential. Resume spring grazing at greenup when growth begins. If harvesting for silage, terminate grazing just prior to jointing. Cut for silage at boot stage for best forage quality. Cutting for silage can be delayed until soft dough for higher yields. Hay quality is highest if cut prior to boot stage, but a better yield to quality balance occurs if harvested in mid- to late-heading. When cut at or before boot stage, wheat must be wilted and conditioned due to high moisture content.

Yield Goal

A realistic yield goal for a winter oats forage crop is 2.0 ton/ac in a good to average year. However, yield is dependent upon several factors, including grass species, seeding rate, seeding date, degree of stand establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop management practices, and grazing management practices.

Delaware growers should use field history to determine the yield goal for each field and use that information to adjust management decisions and fertility programs accordingly. Delaware nutrient management law requires the use of optimal rolling average for determining the yield goal for a specific field when field history is available. To calculate the optimal rolling average yield, see the UD Extension Fact Sheet ***Estimating Yield Goal for Crops***.

Target pH: 6.2

Soils that are high in organic matter (e.g., "black" soils; soil organic matter >6.0%) have a lower target pH (5.6) because organic matter moderates some of the negative effects of excessive soil acidity (e.g., aluminum toxicity).

The lime recommendation for a specific field is calculated from the soil pH and Adam-Evans buffer pH measurements using the steps outlined in the UD Extension Fact Sheet ***Calculating the Lime***

Requirement Using the Adams-Evans Soil Buffer. Avoid over-liming to prevent deficiency of micronutrients such as manganese (Mn).

The recommended liming source is dependent upon Mehlich-3 (M3) soil test calcium (Ca) and magnesium (Mg) reported as a University of Delaware fertility index value (FIV) and can be determined using Table 1.

Table 1. Recommended type of lime as a function of Mehlich-3 soil test calcium (M3-Ca) and magnesium (M3-Mg) concentrations.

Soil Test Levels	Recommended Lime Type
M3-Mg is less than 50 FIV	Dolomitic
M3-Mg between 50 and 100 FIV AND M3-Mg is less than M3-Ca	Dolomitic
M3-Mg greater than 100 FIV	Calcitic
M3-Mg is greater than 50 FIV AND M3-Mg is greater than M3-Ca	Calcitic

Nitrogen

Nitrogen fertilization rates are based on regional research on crop response to N fertilizers and not on the results of a routine soil test.

1. For late summer, fall, or very early spring seedings, apply N at a rate of 40 to 60 lb/ac at or prior to planting if little weed competition is expected.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.

Phosphorus

Phosphorus (P) fertilization is based on the results of a routine soil test (Table 2). Soil test results are reported as a fertility index value (FIV).

Table 2. Recommended broadcast phosphorus fertilizer application rates for winter oats hay as a function of Mehlich-3 soil test phosphorus (M3-P) at 2.0 ton/ac yield goal.

	M3-P (UD FIV)										
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
lb P_2O_5/ac	120	110	100	85	75	65	50	40	25	10	0

1. If M3 soil test P (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), broadcast and plow down the recommended rate of phosphate (P_2O_5) fertilizer prior to seeding.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), broadcast and incorporate P_2O_5 fertilizer prior to seeding or surface broadcast at or shortly after planting.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of phosphorus in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 15 lb /ac for each additional ton of expected yield.

Potassium

The need for potassium (K) fertilization is determined by a routine soil test (Table 3). Soil test results are reported as a fertility index value (FIV).

Table 3. Recommended potassium fertilizer application rate for winter oats hay as a function of Mehlich-3 soil test potassium (M3-K) at 2.0 ton/ac yield goal.

	M3-K (UD FIV)										
	0	10	20	30	40	50	60	70	80	90	100
lb K_2O/ac	180	165	150	135	120	105	90	75	60	45	0

1. Broadcast and incorporate potash (K_2O) fertilizer at or prior to seeding.
2. Application rates of 120 lb/ac of K_2O or higher should be split into two applications. Apply ½ of the recommended rate after the first cutting and the remainder in late August or September.
3. Increase recommended K_2O application rate by 50 lb/ac for each additional ton of expected yield above 2.0 ton/ac.

Magnesium

The need for magnesium (Mg) fertilization is determined by a routine soil test (Table 4); Mg needs are often met by liming. Soil test results are reported as a fertility index value (FIV).

Table 4. Recommended application rates of soluble magnesium as a function of soil test magnesium (M3-Mg).

	M3-Mg (UD FIV)								
	0	5	10	15	20	25	30	35	40
lb soluble Mg/ac	80	70	60	50	40	30	20	10	0

1. Magnesium (Mg) is recommended when M3-Mg is less than 40 FIV.
2. Use dolomitic limestone if M3-Mg is less than 40 FIV and lime is recommended, use dolomitic limestone.
3. If M3-Mg is less than 40 FIV and lime is not needed, apply soluble Mg (Mg sulfate or Mg chloride) according to the rates in Table 4.

Sulfur

Sulfur (S) deficiency is occasionally observed in winter oats grown on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Newly planted forage crops are susceptible to S deficiency because their shallow root systems do not allow the crop to tap into subsoil stores of S. Cutting hay also removes a significant amount of S from the soil and increases the risk of S deficiency. Legumes are more susceptible to S deficiency than grass species.

1. Apply S at a rate of 20 to 40 lb/ac to ensure that adequate sulfur is available to meet crop needs.
2. Broadcast S prior to seeding or use ammonium sulfate as an N source to supply needed S.
3. Sulfate-S is available for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for oxidation of the applied S to the sulfate form to occur.

Prediction of S deficiency is difficult. Currently available soil tests are not good predictors of S deficiency situations because only surface soil samples are analyzed. Many Delaware soils have a supply of plant available S in subsoil horizons that will not be detected in soil 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.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems. Also remember that sulfate-S is available for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for oxidation of the applied S to the sulfate form to occur.

Manganese

Manganese (Mn) needs are predicted by an availability index (MnAI) that includes M3 soil test Mn (M3-Mn) and soil pH. Interpretation of MnAI is crop specific (Table 5). Forage crops are moderately sensitive to Mn deficiency. Soil test Mn results are reported in lb/ac.

MnAI = 101.7 – (15.2 × soil pH) + (2.11 × M3-Mn)

Where:

MnAI = Mn availability index
Soil pH = Soil pH measured in water (1:1 V:V)
M3-Mn = Mehlich 3 soil test Mn in lb/ac

Table 5. Interpretation of manganese availability index for winter oats.

Mn Availability Index	Interpretation
Less than 17	Mn deficiency is likely at this soil pH and soil test Mn concentration
17 to 25	Mn deficiency is possible at this soil pH and soil test Mn concentration. Monitor the crop for symptoms, especially if liming has been recommended.
Greater than 25	Mn deficiency is unlikely.

1. If Mn deficiency is predicted or was observed in the previous growing season, broadcast Mn at a rate of 20 to 40 lb/ac.
2. Broadcast applications of acid forming fertilizers may correct Mn deficiency without the actual application of Mn in some cases but may be less effective than applications of Mn. Long term application of acid forming fertilizers will require pH correction with lime.
3. If Mn deficiency symptoms appear during the growing season or after an application of lime, a foliar application of 1.0 to 2.0 lb/ac actual Mn as Mn sulfate, Mn oxide or chelated Mn can alleviate the symptoms and restore yield potential. Foliar applications can be applied before fall dormancy or after growth resumes in the spring. ***Apply only when adequate growth is present to aid absorption of foliar Mn.*** Foliar application can be repeated if symptoms reappear.

Zinc

Zinc (Zn) deficiency is predicted by an availability index that includes M3 soil test Zn, soil pH, and M3 soil test P. Zinc deficiency is most common on soils with a pH of 6.5 or higher and high soil test P concentrations but may also be induced by environmental conditions such as cold, wet soils that may limit root growth. See Table 6 to determine if Zn deficiency is predicted for this field.

Table 6. Interpretation of zinc availability index for winter oats.

Soil Test Criteria	Interpretation
M3-Zn is less than 1.9 lb/ac	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is higher than 7.0	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is 6.6 or higher **AND** M3-P is 100 FIV or higher	Zn deficiency is predicted
M3-Zn is 3.2 lb/ac or higher	Zn deficiency is NOT predicted

If Zn deficiency is predicted by the availability index or was observed the previous year, one of the following treatments can be applied:

1. Broadcast Zn sulfate or Zn oxide at a rate of 10 to 12 lb/ac elemental Zn or Zn chelate (Zn-EDTA) at a rate of 2 to 3 lb/ac elemental Zn. Broadcast applications should correct Zn deficiency for several years.
2. Foliar application of Zn sulfate or Zn oxide at a rate of 1 lb/ac elemental Zn or Zn chelate at a rate of 0.5 lb/ac elemental Zn in 20 to 50 gallons of water. **Apply only when adequate growth is present to aid in the adsorption of foliar Zn.** Foliar Zn application should be repeated if symptoms re-appear.

Boron

Boron (B) deficiency is not common in annual forage crops. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.

Winter Wheat Forage

Crop Highlights

- Target pH: 6.2
- Early planting is recommended to increase forage yield, but crop is suceptible to Hessian fly.
- Split spring N applications can improve protein levels and yield potential.
- Apply sulfur (S) with or without N to prevent S deficiency.
- Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Cereal grain crops provide lush, high protein, low fiber animal feed. Early planting is recommended when rye is used for grazing, hay, or silage. However, wheat is the most susceptible small grain to Hessian fly, which can lead to lodging if the crop is planted before the Hessian fly-free date (3 Oct - New Castle; 8 Oct - Kent; 10 Oct - Sussex); plant after, but as close to, the Hessian fly free date. Increase seeding rate to 3 bu/ac when grown for grazing, hay, or silage. Moderate grazing in fall is possible without significant hay or silage losses. Split spring N applications can improve protein levels and yield potential. Resume spring grazing at greenup when growth begins. If harvesting for silage, terminate grazing just prior to jointing. Cut for silage at boot stage for best forage quality. Cutting for silage can be delayed until soft dough for higher yields. Hay quality is highest if cut prior to boot stage, but a better yield to quality balance occurs if harvested in mid- to late-heading. When cut at or before boot stage, wheat must be wilted and conditioned due to high moisture content.

Yield Goal

A realistic yield goal for a forage winter wheat forage crop is 2.0 ton/ac in a good to average year. However, yield is dependent upon several factors, including grass species, seeding rate, seeding date, degree of stand establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop management practices, and grazing management practices.

Delaware growers should use field history to determine the yield goal for each field and use that information to adjust management decisions and fertility programs accordingly. Delaware nutrient management law requires the use of optimal rolling average for determining the yield goal for a specific field when field history is available. To calculate the optimal rolling average yield, see the UD Extension Fact Sheet ***Estimating Yield Goal for Crops***.

Target pH: 6.2

Soils that are high in organic matter (e.g., "black" soils; soil organic matter >6.0%) have a lower target pH (5.6) because organic matter moderates some of the negative effects of excessive soil acidity (e.g., aluminum toxicity).

The lime recommendation for a specific field is calculated from the soil pH and Adam-Evans buffer pH measurements using the steps outlined in the UD Extension Fact Sheet ***Calculating the Lime***

Requirement Using the Adams-Evans Soil Buffer. Avoid over-liming to prevent deficiency of micronutrients such as manganese (Mn).

The recommended liming source is dependent upon Mehlich-3 (M3) soil test calcium (Ca) and magnesium (Mg) reported as a University of Delaware fertility index value (FIV) and can be determined using Table 1.

Table 1. Recommended type of lime as a function of Mehlich-3 soil test calcium (M3-Ca) and magnesium (M3-Mg) concentrations.

Soil Test Levels	Recommended Lime Type
M3-Mg is less than 50 FIV	Dolomitic
M3-Mg between 50 and 100 FIV AND M3-Mg is less than M3-Ca	Dolomitic
M3-Mg greater than 100 FIV	Calcitic
M3-Mg is greater than 50 FIV AND M3-Mg is greater than M3-Ca	Calcitic

Nitrogen

Nitrogen fertilization rates are based on regional research on crop response to N fertilizers and not on the results of a routine soil test.

1. For late summer, fall, or very early spring seedings, apply N at a rate of 40 to 60 lb/ac at or prior to planting if little weed competition is expected.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.

Phosphorus

Phosphorus (P) fertilization is based on the results of a routine soil test (Table 2). Soil test results are reported as a fertility index value (FIV).

Table 2. Recommended broadcast phosphorus fertilizer application rates for forage winter wheat hay as a function of Mehlich-3 soil test phosphorus (M3-P) at 2.0 ton/ac yield goal.

	M3-P (UD FIV)										
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
lb P_2O_5/ac	120	110	100	85	75	65	50	40	25	10	0

1. If M3 soil test P (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), broadcast and plow down the recommended rate of phosphate (P_2O_5) fertilizer prior to seeding.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), broadcast and incorporate P_2O_5 fertilizer prior to seeding or surface broadcast at or shortly after planting.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of phosphorus in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 15 lb /ac for each additional ton of expected yield.

Potassium

The need for potassium (K) fertilization is determined by a routine soil test (Table 3). Soil test results are reported as a fertility index value (FIV).

Table 3. Recommended potassium fertilizer application rate for forage winter wheat hay as a function of Mehlich-3 soil test potassium (M3-K) at 2.0 ton/ac yield goal.

	M3-K (UD FIV)										
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
lb K_2O/ac	180	165	150	135	120	105	90	75	60	45	0

1. Broadcast and incorporate potash (K_2O) fertilizer at or prior to seeding.
2. Application rates of 120 lb/ac of K_2O or higher should be split into two applications. Apply ½ of the recommended rate after the first cutting and the remainder in late August or September.
3. Increase recommended K_2O application rate by 50 lb/ac for each additional ton of expected yield above 2.0 ton/ac.

Magnesium

The need for magnesium (Mg) fertilization is determined by a routine soil test (Table 4); Mg needs are often met by liming. Soil test results are reported as a fertility index value (FIV).

Table 4. Recommended application rates of soluble magnesium as a function of soil test magnesium (M3-Mg).

	M3-Mg (UD FIV)								
	0	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
lb soluble Mg/ac	80	70	60	50	40	30	20	10	0

1. Magnesium (Mg) is recommended when M3-Mg is less than 40 FIV.
2. Use dolomitic limestone if M3-Mg is less than 40 FIV and lime is recommended, use dolomitic limestone.
3. If M3-Mg is less than 40 FIV and lime is not needed, apply soluble Mg (Mg sulfate or Mg chloride) according to the rates in Table 4.

Sulfur

Sulfur (S) deficiency is occasionally observed in forage winter wheat grown on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Newly planted forage crops are susceptible to S deficiency because their shallow root systems do not allow the crop to tap into subsoil stores of S. Cutting hay also removes a significant amount of S from the soil and increases the risk of S deficiency. Legumes are more susceptible to S deficiency than grass species.

1. Apply S at a rate of 20 to 40 lb/ac to ensure that adequate sulfur is available to meet crop needs.
2. Broadcast S prior to seeding or use ammonium sulfate as an N source to supply needed S.
3. Sulfate-S is available for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for oxidation of the applied S to the sulfate form to occur.

Prediction of S deficiency is difficult. Currently available soil tests are not good predictors of S deficiency situations because only surface soil samples are analyzed. Many Delaware soils have a supply of plant available S in subsoil horizons that will not be detected in soil 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.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems. Also remember that sulfate-S is available for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for oxidation of the applied S to the sulfate form to occur.

Manganese

Manganese (Mn) needs are predicted by an availability index (MnAI) that includes M3 soil test Mn (M3-Mn) and soil pH. Interpretation of MnAI is crop specific (Table 5). Forage crops are moderately sensitive to Mn deficiency. Soil test Mn results are reported in lb/ac.

MnAI = 101.7 – (15.2 × soil pH) + (2.11 × M3-Mn)

Where:

MnAI = Mn availability index
Soil pH = Soil pH measured in water (1:1 V:V)
M3-Mn = Mehlich 3 soil test Mn in lb/ac

Table 5. Interpretation of manganese availability index for forage winter wheat.

Mn Availability Index	Interpretation
Less than 17	Mn deficiency is likely at this soil pH and soil test Mn concentration
17 to 25	Mn deficiency is possible at this soil pH and soil test Mn concentration. Monitor the crop for symptoms, especially if liming has been recommended.
Greater than 25	Mn deficiency is unlikely.

1. If Mn deficiency is predicted or was observed in the previous growing season, broadcast Mn at a rate of 20 to 40 lb/ac.
2. Broadcast applications of acid forming fertilizers may correct Mn deficiency without the actual application of Mn in some cases but may be less effective than applications of Mn. Long term application of acid forming fertilizers will require pH correction with lime.
3. If Mn deficiency symptoms appear during the growing season or after an application of lime, a foliar application of 1.0 to 2.0 lb/ac actual Mn as Mn sulfate, Mn oxide or chelated Mn can alleviate the symptoms and restore yield potential. Foliar applications can be applied before fall dormancy or after growth resumes in the spring. ***Apply only when adequate growth is present to aid absorption of foliar Mn.*** Foliar application can be repeated if symptoms reappear.

Zinc

Zinc (Zn) deficiency is predicted by an availability index that includes M3 soil test Zn, soil pH, and M3 soil test P. Zinc deficiency is most common on soils with a pH of 6.5 or higher and high soil test P concentrations but may also be induced by environmental conditions such as cold, wet soils that may limit root growth. See Table 6 to determine if Zn deficiency is predicted for this field.

Table 6. Interpretation of zinc availability index for forage winter wheat.

Soil Test Criteria	Interpretation
M3-Zn is less than 1.9 lb/ac	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is higher than 7.0	Zn deficiency is predicted
M3-Zn is less than 3.1 lb/ac **AND** soil pH is 6.6 or higher **AND** M3-P is 100 FIV or higher	Zn deficiency is predicted
M3-Zn is 3.2 lb/ac or higher	Zn deficiency is NOT predicted

If Zn deficiency is predicted by the availability index or was observed the previous year, one of the following treatments can be applied:

1. Broadcast Zn sulfate or Zn oxide at a rate of 10 to 12 lb/ac elemental Zn or Zn chelate (Zn-EDTA) at a rate of 2 to 3 lb/ac elemental Zn. Broadcast applications should correct Zn deficiency for several years.
2. Foliar application of Zn sulfate or Zn oxide at a rate of 1 lb/ac elemental Zn or Zn chelate at a rate of 0.5 lb/ac elemental Zn in 20 to 50 gallons of water. **Apply only when adequate growth is present to aid in the adsorption of foliar Zn.** Foliar Zn application should be repeated if symptoms re-appear.

Boron

Boron (B) deficiency is not common in annual forage crops. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.