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

Nutrient Recommendations

Forage and Hay Crops:

Cool Season Perennial Forages – Established Hay

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Alfalfa Hay - Established Stand

Crop Highlights
• Target pH: 6.8 • Large quantities of nitrogen (N) can accumulate in soils after an alfalfa crop. • Monitor soil phosphorus (P), potassium (K), and sulfur (S) status, as cuttings can reduce soil stores of these nutrients. • Apply K in two equal increments, after the first harvest of the season and after the late summer (August to early Sept) harvest. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Yield Goal

A realistic yield goal for an alfalfa hay crop is 5.0 ton/ac in a good to average year. However, yield is dependent upon several factors, including grass species, seeding rate, seeding date, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop 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: 6.8

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. Evaluate stand composition at the beginning of each season. Nitrogen application is not usually recommended if the stand composition is 25% or more legumes. Applied N makes the grasses more competitive and can result in the loss of desireable legumes from the stand. If the stand contains less than 25% legumes, switch to the recommendation for an alfalfa and grass mix.

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 alfalfa hay as a function of Mehlich-3 soil test phosphorus (M3-P) at 5.0 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 phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 30 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 alfalfa hay as a function of Mehlich-3 soil test potassium (M3-K) at 5.0 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. Topdress potash (K_2O) fertilizer after the first cutting.
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 5.0 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 alfalfa on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay 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. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately 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.

Hay harvest removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

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 hay and pasture systems.

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 alfalfa hay.

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 alfalfa hay.

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 alfalfa hay crops but may occur if the stand contains more than 25% legumes. If the forage stand is less than 25% legumes, B application is not required. If B deficiency symptoms appear in a stand with more than 25% legumes:

1. Apply B at a rate of 2.0 to 4.0 lb/ac each year.
2. Boron can be applied in a blended, broadcast fertilizer, as a soil spray or applied in a foliar spray, generally in late May or June. ***Foliar applications should only be made when adequate growth is present to aid absorption of foliar B.***
3. **Caution:** Although B is required for maximum productivity of hay fields containing legumes, even slight over-application can be toxic to the crop. When applying B as a foliar spray, be certain to apply the correct rate.

Alfalfa/Grass Mixed Hay - Established Stand

Crop Highlights
• Target pH: 6.8 • Nitrogen (N) management can alter the proportions of legume to grass in the stand. • High soil pH, phosphorus (P), and postassium (K) can favor the legume component of the mix. • Monitor soil phosphorus (P), potassium (K), and sulfur (S) status, as cuttings can reduce soil stores of these nutrients. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

The combination of grass and broadleaf crop makes management difficult, especially weed control. In drought years, alfalfa will pull moisture from deep in soil restricting grass growth and possibly survival. Alfalfa/grass mixes require careful management to control weeds.

Yield Goal

A realistic yield goal for an alfalfa/grass hay crop is 5.0 ton/ac in a good to average year. However, yield is dependent upon several factors, including grass species, seeding rate, seeding date, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop 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: 6.8

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. Evaluate stand composition at the beginning of each season. Nitrogen application is not usually recommended if the stand composition is 25% or more legumes. Applied N makes the grasses more competitive and can result in the loss of desireable legumes from the stand. If the stand contains less than 25% legumes, follow the management practices outlined below.

1. After each cut, apply an additional 40 to 60 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 80 to 120 lb/ac of N if the expected yield of the next cut is 2 tons/ac.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.
3. To promote deeper rooting, enhance winter survival and enhance spring recovery, apply N at a rate of 40 to 50 lb/ac between mid-October and mid-November.
4. Early spring N rates should be reduced by the rate of N applied in late fall.
5. Early spring N rates can lead to excessive spring tonnage which will increase the time and difficulty encountered in drying hay to an acceptable level.

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 alfalfa/grass hay as a function of Mehlich-3 soil test phosphorus (M3-P) at 5.0 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 phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 30 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 alfalfa/grass hay as a function of Mehlich-3 soil test potassium (M3-K) at 5.0 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. Topdress potash (K_2O) fertilizer after the first cutting.
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 5.0 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 alfalfa/grass on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay 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. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately 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.

Hay harvest removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

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 hay and pasture systems.

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.

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

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 alfalfa/grass hay.

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 alfalfa/grass hay.

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 alfalfa/grass hay crops but may occur if the stand contains more than 25% legumes. If the forage stand is less than 25% legumes, B application is not required. If B deficiency symptoms appear in a stand with more than 25% legumes:

1. Apply B at a rate of 1.0 to 2.0 lb/ac each year.
2. Boron can be applied in a blended, broadcast fertilizer, as a soil spray or applied in a foliar spray, generally in late May or June. ***Foliar applications should only be made when adequate growth is present to aid absorption of foliar B.***
3. **Caution:** Although B is required for maximum productivity of hay fields containing legumes, even slight over-application can be toxic to the crop. When applying B as a foliar spray, be certain to apply the correct rate.

Annual or Italian Ryegrass Hay - Established Stand

Crop Highlights
• Target pH: 6.5 • Best used as an emergency forage. • Annual and Italian ryegrass species respond well to nitrogen (N) fertilization. • Monitor soil phosphorus (P), potassium (K), and sulfur (S) status, as cuttings can reduce soil stores of these nutrients. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

The best use of annual or Italian ryegrass is as emergency forage because the crop is short-lived. Annual and Italian ryegrass species respond well to nitrogen (N) fertilization. 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 an annual or Italian ryegrass hay 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, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop 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: 6.5

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. Evaluate stand composition at the beginning of each season. If the stand composition is 25% or more legumes, follow N recommendations for a grass/legume mix crop. If the stand contains less than 25% legumes, follow the N management practices outilined below.

1. After each cut, apply an additional 40 to 60 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 80 to 120 lb/ac of N if the expected yield of the next cut is 2 tons/ac.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.
3. To promote deeper rooting, enhance winter survival and enhance spring recovery, apply N at a rate of 40 to 50 lb/ac between mid-October and mid-November.
4. Early spring N rates should be reduced by the rate of N applied in late fall.
5. Early spring N rates can lead to excessive spring tonnage which will increase the time and difficulty encountered in drying hay to an acceptable level.

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 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 phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P 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 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. Topdress potash (K_2O) fertilizer after the first cutting.
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 Italian ryegrass on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay 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. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately 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.

Hay harvest removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

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 hay and pasture systems.

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.

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

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 annual or Italian ryegrass hay.

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 hay.

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 usually observed in annual or Italian ryegrass hay cops. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Brassica/Grass Hay - Established Stand

Crop Highlights
• Target pH: 6.2 • Inexpensive and useful as emergency forage or to extend grazing season. • Monitor soil phosphorus (P), potassium (K), and sulfur (S) status, as cuttings can reduce soil stores of these nutrients. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Yield Goal

A realistic yield goal for a brassica/grass hay 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, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop 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. Evaluate stand composition at the beginning of each season. If the stand composition is 25% or more legumes, follow N recommendations for a grass/legume mix crop. If the stand contains less than 25% legumes, follow the N management practices outilined below.

1. After each cut, apply an additional 40 to 60 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 80 to 120 lb/ac of N if the expected yield of the next cut is 2 tons/ac.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.
3. To promote deeper rooting, enhance winter survival and enhance spring recovery, apply N at a rate of 40 to 50 lb/ac between mid-October and mid-November.
4. Early spring N rates should be reduced by the rate of N applied in late fall.
5. Early spring N rates can lead to excessive spring tonnage which will increase the time and difficulty encountered in drying hay to an acceptable level.

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 brassica/grass 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 phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P 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 brassica/grass 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. Topdress potash (K_2O) fertilizer after the first cutting.
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.
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 brassica/grass on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay 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. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately 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.

Hay harvest removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

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 hay and pasture systems.

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.

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

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 brassica/grass hay.

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 brassica/grass hay.

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 usually observed in brassica/grass hay crops. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Chicory/Grass Hay - Established Stand

Crop Highlights
• Target pH: 5.8 • High-yielding alternative forage. • Chicory responds well to nitrogen (N), but stem growth increases at high N rates. • Monitor soil phosphorus (P), potassium (K), and sulfur (S) status, as cuttings can reduce soil stores of these nutrients. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Yield Goal

A realistic yield goal for a chicory/grass hay 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, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop 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: 5.8

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. Evaluate stand composition at the beginning of each season. If the stand composition is 25% or more legumes, follow N recommendations for a grass/legume mix crop. If the stand contains less than 25% legumes, follow the N management practices outilined below.

1. After each cut, apply an additional 40 to 60 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 80 to 120 lb/ac of N if the expected yield of the next cut is 2 tons/ac.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.
3. To promote deeper rooting, enhance winter survival and enhance spring recovery, apply N at a rate of 40 to 50 lb/ac between mid-October and mid-November.
4. Early spring N rates should be reduced by the rate of N applied in late fall.
5. Early spring N rates can lead to excessive spring tonnage which will increase the time and difficulty encountered in drying hay to an acceptable level.

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 chicory/grass 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 phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P 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 chicory/grass 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. Topdress potash (K_2O) fertilizer after the first cutting.
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.
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 chicory/grass on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay 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. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately 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.

Hay harvest removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

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 hay and pasture systems.

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 chicory/grass hay.

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 chicory/grass hay.

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 usually observed in chicory/grass hay crops. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Grass/Clover Hay - Established Stand

Crop Highlights
• Target pH: 6.5 • Nitrogen (N) management can alter proportions of legume and grass in the stand. • Monitor soil phosphorus (P), potassium (K), and sulfur (S) status, as cuttings can reduce soil stores of these nutrients. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

The combination of grass and broadleaf crop makes management difficult, especially weed control. Manage nitrogen (N), phosphorus (P), and potassium (K) levels carefully, as well as stage of growth at harvest to maintain balance of grass to clover. Crimping and wide swathing can help with drying mixed hay.

Yield Goal

A realistic yield goal for a mixed grass/clover hay 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, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop 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: 6.5

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. Evaluate stand composition at the beginning of each season. Nitrogen application is not usually recommended if the stand composition is 25% or more legumes. Applied N makes the grasses more competitive and can result in the loss of desireable legumes from the stand. If the stand contains less than 25% legumes, follow the management practices outlined below.

1. After each cut, apply an additional 40 to 60 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 80 to 120 lb/ac of N if the expected yield of the next cut is 2 tons/ac.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.
3. To promote deeper rooting, enhance winter survival and enhance spring recovery, apply N at a rate of 40 to 50 lb/ac between mid-October and mid-November.
4. Early spring N rates should be reduced by the rate of N applied in late fall.
5. Early spring N rates can lead to excessive spring tonnage which will increase the time and difficulty encountered in drying hay to an acceptable level.

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 mixed grass/clover 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 phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P 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 mixed grass/clover 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. Topdress potash (K_2O) fertilizer after the first cutting.
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.
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 mixed grass/clover on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay 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. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately 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.

Hay harvest removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

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 hay and pasture systems.

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 mixed grass/clover hay.

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 mixed grass/clover hay.

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 mixed grass/clover hay crops but may occur if the stand contains more than 25% legumes. If the forage stand is less than 25% legumes, B application is not required. If B deficiency symptoms appear in a stand with more than 25% legumes:

1. Apply B at a rate of 0.5 to 1.0 lb/ac each year.
2. Boron can be applied in a blended, broadcast fertilizer, as a soil spray or applied in a foliar spray, generally in late May or June. ***Foliar applications should only be made when adequate growth is present to aid absorption of foliar B.***
3. **Caution:** Although B is required for maximum productivity of hay fields containing legumes, even slight over-application can be toxic to the crop. When applying B as a foliar spray, be certain to apply the correct rate.

Kentucky Bluegrass Hay - Established Stand

Crop Highlights
• Target pH: 6.5 • Low yields during summer months. • Crop prefers slightly higher soil pH than other forages. • Apply a small amount of nitrogen (N) in the early spring before greenup to stimulate growth and additional N in late spring to early fall. • Monitor soil phosphorus (P), potassium (K), and sulfur (S) status, as cuttings can reduce soil stores of these nutrients.

Management Notes

Kentucky bluegrass produces a highly palatable feed source for horse, sheep, and cattle. This crop produces the most forage during cool of spring and some in fall, however, yields tend to be on the lower side. Kentucky bluegrass can also be seeded with tall grasses, such as orchardgrass, timothy, smooth bromegrass, or tall fescue, especially if used for hay.

Yield Goal

A realistic yield goal for a Kentucky bluegrass hay 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, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop 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: 6.5

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. Evaluate stand composition at the beginning of each season. If the stand composition is 25% or more legumes, follow N recommendations for a grass/legume mix crop. If the stand contains less than 25% legumes, follow the N management practices outilined below.

1. After each cut, apply an additional 40 to 60 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 80 to 120 lb/ac of N if the expected yield of the next cut is 2 tons/ac.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.
3. To promote deeper rooting, enhance winter survival and enhance spring recovery, apply N at a rate of 40 to 50 lb/ac between mid-October and mid-November.
4. Early spring N rates should be reduced by the rate of N applied in late fall.
5. Early spring N rates can lead to excessive spring tonnage which will increase the time and difficulty encountered in drying hay to an acceptable level.

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 Kentucky bluegrass 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 phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P 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 Kentucky bluegrass 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. Topdress potash (K_2O) fertilizer after the first cutting.
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 Kentucky bluegrass on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay 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. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately 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.

Hay harvest removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

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 hay and pasture systems.

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 Kentucky bluegrass hay.

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 Kentucky bluegrass hay.

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 usually observed in Kentucky bluegrass hay crops. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Mushroom Hay - Established Stand

Crop Highlights
• Target pH: 6.2 • Low rates of nitrogen (N) can increase yield but may make drying the tonnage more difficult. • Monitor soil phosphorus (P), potassium (K), and sulfur (S) status, as cuttings can reduce soil stores of these nutrients. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Most mushroom hay consists of a range of grass and weed species. Mushroom hay is normally harvested at full maturity (full flower or later). Applying low rates of nitrogen (N) can increase yield but may make drying the tonnage more difficult.

Yield Goal

A realistic yield goal for a mushroom hay 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, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop 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. Evaluate stand composition at the beginning of each season. If the stand composition is 25% or more legumes, follow N recommendations for a grass/legume mix crop. If the stand contains less than 25% legumes, follow the N management practices outilined below.

1. After each cut, apply an additional 20 to 40 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 40 to 80 lb/ac of N if the expected yield of the next cut is 2 tons/ac.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.
3. To promote deeper rooting, enhance winter survival and enhance spring recovery, apply N at a rate of 40 to 50 lb/ac between mid-October and mid-November.
4. Early spring N rates should be reduced by the rate of N applied in late fall.
5. Early spring N rates can lead to excessive spring tonnage which will increase the time and difficulty encountered in drying hay to an acceptable level.

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 mushroom 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 phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P 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 mushroom 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. Topdress potash (K_2O) fertilizer after the first cutting.
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 mushroom on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay 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. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately 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.

Hay harvest removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

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 hay and pasture systems.

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 mushroom hay.

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 mushroom hay.

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 usually observed in mushroom hay crops. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Orchardgrass Hay - Established Stand

Crop Highlights
• Target pH: 6.5 • Orchardgrass decline syndrome can shorten stand life. • Matching nitrogen (N) and potassium (K) fertilization is vital to crop success. • Monitor soil phosphorus (P), potassium (K), and sulfur (S) status, as cuttings can reduce soil stores of these nutrients. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Orchardgrass decline syndrome is present in this region and shortens stand life. It is essential to keep nitrogen (N) and potassium (K) fertilization matched; do not fertilize with N unless K is supplied. Avoid cutting orchardgrass below 4-inch residue.

Yield Goal

A realistic yield goal for a orchardgrass hay 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, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop 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: 6.5

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. Evaluate stand composition at the beginning of each season. If the stand composition is 25% or more legumes, follow N recommendations for a grass/legume mix crop. If the stand contains less than 25% legumes, follow the N management practices outilined below.

1. After each cut, apply an additional 40 to 60 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 80 to 120 lb/ac of N if the expected yield of the next cut is 2 tons/ac.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.
3. To promote deeper rooting, enhance winter survival and enhance spring recovery, apply N at a rate of 40 to 50 lb/ac between mid-October and mid-November.
4. Early spring N rates should be reduced by the rate of N applied in late fall.
5. Early spring N rates can lead to excessive spring tonnage which will increase the time and difficulty encountered in drying hay to an acceptable level.

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 orchardgrass 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 phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P 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 orchardgrass 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. Topdress potash (K_2O) fertilizer after the first cutting.
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.
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 orchardgrass on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay 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. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately 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.

Hay harvest removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

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 hay and pasture systems.

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.

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

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 orchardgrass hay.

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 orchardgrass hay.

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 usually observed in orchardgrass hay crops. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Perennial Ryegrass Hay - Established Stand

Crop Highlights
• Target pH: 6.5 • Short-lived perennial best suited for northern Delaware. • Crop is a heavy nitrogen (N) user. • Monitor soil phosphorus (P), potassium (K), and sulfur (S) status, as cuttings can reduce soil stores of these nutrients. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

In Delaware, perennial ryegrass does best in the northern areas with adequate moisture. Perennial ryegrass is a heavy user of nitrogen (N) fertilizer.

Yield Goal

A realistic yield goal for a perennial ryegrass hay 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, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop 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: 6.5

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. Evaluate stand composition at the beginning of each season. If the stand composition is 25% or more legumes, follow N recommendations for a grass/legume mix crop. If the stand contains less than 25% legumes, follow the N management practices outilined below.

1. After each cut, apply an additional 40 to 60 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 80 to 120 lb/ac of N if the expected yield of the next cut is 2 tons/ac.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.
3. To promote deeper rooting, enhance winter survival and enhance spring recovery, apply N at a rate of 40 to 50 lb/ac between mid-October and mid-November.
4. Early spring N rates should be reduced by the rate of N applied in late fall.
5. Early spring N rates can lead to excessive spring tonnage which will increase the time and difficulty encountered in drying hay to an acceptable level.

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 perennial 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 phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P 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 perennial 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. Topdress potash (K_2O) fertilizer after the first cutting.
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.
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 perennial ryegrass on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay 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. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately 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.

Hay harvest removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

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 hay and pasture systems.

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 perennial ryegrass hay.

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 perennial ryegrass hay.

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 usually observed in perennial ryegrass hay crops. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Red Clover Hay - Established Stand

Crop Highlights
• Target pH: 6.5 • Best suited for cattle and sheep; not for horses (slobbers). • Legume crop will fix atmospheric nitrogen (N). • Nitrogen (N) management can alter proportions of legume and grass in the stand. • Monitor soil phosphorus (P), potassium (K), and sulfur (S) status, as cuttings can reduce soil stores of these nutrients.

Management Notes

Red clover is best suited for cattle and sheep hay; do not hay for horses due to slobbers. Older cultivars of red clover survive only 1.5 to 2 years as stands thin. Rotate red clover in fields as disease pressure builds with time. Hairs on red clover create a 'dusty' hay crop. Crimping stems will allow for faster drying.

Yield Goal

A realistic yield goal for a red clover hay 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, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop 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: 6.5

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. Evaluate stand composition at the beginning of each season. Nitrogen application is not usually recommended if the stand composition is 25% or more legumes. Applied N makes the grasses more competitive and can result in the loss of desireable legumes from the stand. If the stand contains less than 25% legumes, follow the management practices outlined below.

1. After each cut, apply an additional 40 to 60 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 80 to 120 lb/ac of N if the expected yield of the next cut is 2 tons/ac.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.
3. To promote deeper rooting, enhance winter survival and enhance spring recovery, apply N at a rate of 40 to 50 lb/ac between mid-October and mid-November.
4. Early spring N rates should be reduced by the rate of N applied in late fall.
5. Early spring N rates can lead to excessive spring tonnage which will increase the time and difficulty encountered in drying hay to an acceptable level.

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 red clover 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 phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P 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 red clover 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. Topdress potash (K_2O) fertilizer after the first cutting.
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.
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 red clover on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay 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. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately 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.

Hay harvest removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

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 hay and pasture systems.

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 red clover hay.

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 red clover hay.

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 red clover hay crops but may occur if the stand contains more than 25% legumes. If the forage stand is less than 25% legumes, B application is not required. If B deficiency symptoms appear in a stand with more than 25% legumes:

1. Apply B at a rate of 1.0 to 2.0 lb/ac each year.
2. Boron can be applied in a blended, broadcast fertilizer, as a soil spray or applied in a foliar spray, generally in late May or June. ***Foliar applications should only be made when adequate growth is present to aid absorption of foliar B.***
3. **Caution:** Although B is required for maximum productivity of hay fields containing legumes, even slight over-application can be toxic to the crop. When applying B as a foliar spray, be certain to apply the correct rate.

Reed Canarygrass Hay - Established Stand

Crop Highlights
• Target pH: 6.5 • Grows well with Ladino-type white clover. • Monitor soil phosphorus (P), potassium (K), and sulfur (S) status, as cuttings can reduce soil stores of these nutrients. • Forage and hay crops are moderately sensitive to manganese (Mn).

Management Notes

This crop grows well with Ladino-type white clover.

Yield Goal

A realistic yield goal for a reed canarygrass hay 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, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop 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: 6.5

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. Evaluate stand composition at the beginning of each season. If the stand composition is 25% or more legumes, follow N recommendations for a grass/legume mix crop. If the stand contains less than 25% legumes, follow the N management practices outilined below.

1. After each cut, apply an additional 40 to 60 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 80 to 120 lb/ac of N if the expected yield of the next cut is 2 tons/ac.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.
3. To promote deeper rooting, enhance winter survival and enhance spring recovery, apply N at a rate of 40 to 50 lb/ac between mid-October and mid-November.
4. Early spring N rates should be reduced by the rate of N applied in late fall.
5. Early spring N rates can lead to excessive spring tonnage which will increase the time and difficulty encountered in drying hay to an acceptable level.

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 reed canarygrass 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 phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P 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 reed canarygrass 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. Topdress potash (K_2O) fertilizer after the first cutting.
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.
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 reed canarygrass on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay 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. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately 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.

Hay harvest removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

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 hay and pasture systems.

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.

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

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 reed canarygrass hay.

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 reed canarygrass hay.

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 usually observed in reed canarygrass hay crops. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Sericea Lespedeza Hay - Established Stand

Crop Highlights
• Target pH: 6.2 • Crop is more tolerant of low soil pH and droughty or infertile soils than clovers. • Little nitrogen (N) is shared between this legume crop and companion grasses. • Monitor soil phosphorus (P), potassium (K), and sulfur (S) status, as cuttings can reduce soil stores of these nutrients. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Sericea lespedeza is more tolerant of acid (low pH) and infertile or droughty soils than clover. Although sericea lespedeza is a legume, little nitrogen (N) is shared between this crop and companion grasses. This species contains moderate levels of condensed tannins, which can reduce parasite loads in small ruminants. If not cut or grazed, the stand often persists due to late summer and fall seed production.

Yield Goal

A realistic yield goal for a sericea lespedeza hay 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, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop 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. Evaluate stand composition at the beginning of each season. Nitrogen application is not usually recommended if the stand composition is 25% or more legumes. Applied N makes the grasses more competitive and can result in the loss of desireable legumes from the stand. If the stand contains less than 25% legumes, follow the management practices outlined below.

1. After each cut, apply an additional 40 to 60 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 80 to 120 lb/ac of N if the expected yield of the next cut is 2 tons/ac.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.
3. To promote deeper rooting, enhance winter survival and enhance spring recovery, apply N at a rate of 40 to 50 lb/ac between mid-October and mid-November.
4. Early spring N rates should be reduced by the rate of N applied in late fall.
5. Early spring N rates can lead to excessive spring tonnage which will increase the time and difficulty encountered in drying hay to an acceptable level.

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 sericea lespedeza 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 phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P 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 sericea lespedeza 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. Topdress potash (K_2O) fertilizer after the first cutting.
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 sericea lespedeza on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay 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. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately 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.

Hay harvest removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

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 hay and pasture systems.

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 sericea lespedeza hay.

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 sericea lespedeza hay.

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 usually observed in sericea lespedeza hay crops. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

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

Smooth Bromegrass Hay - Established Stand

Crop Highlights
• Target pH: 6.5 • Suited only for high-quality soils in northern Delaware locations. • May become sod-bound without adequate nitrogen (N) fertilization. • Monitor soil phosphorus (P), potassium (K), and sulfur (S) status, as cuttings can reduce soil stores of these nutrients. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Smooth bromegrass is suited only high-quality soils in northern Delaware locations. Smooth bromegrass can become sod bound without adequate nitrogen (N) fertilization.

Yield Goal

A realistic yield goal for a smooth bromegrass hay 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, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop 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: 6.5

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. Evaluate stand composition at the beginning of each season. If the stand composition is 25% or more legumes, follow N recommendations for a grass/legume mix crop. If the stand contains less than 25% legumes, follow the N management practices outilined below.

1. After each cut, apply an additional 40 to 60 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 80 to 120 lb/ac of N if the expected yield of the next cut is 2 tons/ac.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.
3. To promote deeper rooting, enhance winter survival and enhance spring recovery, apply N at a rate of 40 to 50 lb/ac between mid-October and mid-November.
4. Early spring N rates should be reduced by the rate of N applied in late fall.
5. Early spring N rates can lead to excessive spring tonnage which will increase the time and difficulty encountered in drying hay to an acceptable level.

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 smooth bromegrass 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 phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P 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 smooth bromegrass 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. Topdress potash (K_2O) fertilizer after the first cutting.
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.
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 smooth bromegrass on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay 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. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately 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.

Hay harvest removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

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 hay and pasture systems.

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.

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

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 smooth bromegrass hay.

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 smooth bromegrass hay.

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 usually observed in smooth bromegrass hay crops. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Tall Fescue Hay - Established Stand

Crop Highlights
• Target pH: 6.5 • Use the novel or friendly endophyte cultivars for best stand life and improved performance. • Under drought conditions, high nitrogen (N) can result in high nitrate levels in hay that can affect animal health. • Monitor soil phosphorus (P), potassium (K), and sulfur (S) status, as cuttings can reduce soil stores of these nutrients. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Use the novel or friendly endophyte cultivars for best stand life and improved performance. Old endophyte infected tall fescue cultivars contain toxic alkaloids, which can cause low weight gains, fescue foot, and other animal problems. Endophyte-free cultivars can be useful when a shorter-term crop is desired. Crimping stems of headed tall fescue can help drying process. Application of nitrogen (N) at rates above 50 lb/ton of expected yield under drought conditions can results in high nitrate levels in hay; test any suspect cuttings to prevent livestock poisoning.

Yield Goal

A realistic yield goal for a tall fescue hay 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, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop 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: 6.5

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. Evaluate stand composition at the beginning of each season. If the stand composition is 25% or more legumes, follow N recommendations for a grass/legume mix crop. If the stand contains less than 25% legumes, follow the N management practices outilined below.

1. After each cut, apply an additional 40 to 60 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 80 to 120 lb/ac of N if the expected yield of the next cut is 2 tons/ac.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.
3. To promote deeper rooting, enhance winter survival and enhance spring recovery, apply N at a rate of 40 to 50 lb/ac between mid-October and mid-November.
4. Early spring N rates should be reduced by the rate of N applied in late fall.
5. Early spring N rates can lead to excessive spring tonnage which will increase the time and difficulty encountered in drying hay to an acceptable level.

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 tall fescue 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 phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P 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 tall fescue 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. Topdress potash (K_2O) fertilizer after the first cutting.
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.
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 tall fescue on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay 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. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately 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.

Hay harvest removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

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 hay and pasture systems.

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.

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

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 tall fescue hay.

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 tall fescue hay.

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 usually observed in tall fescue hay crops. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Timothy Hay - Established Stand

Crop Highlights
• Target pH: 6.5 • Performance is site-specific. • Cereal rust mite damage can mimic severe nitrogen (N) deficiency. • Monitor soil phosphorus (P), potassium (K), and sulfur (S) status, as cuttings can reduce soil stores of these nutrients. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Timothy is often a one-cut wonder with most of the yield occurring in the first harvest. Newer, heat-tolerant cultivars may offer multiple hay harvests especially with irrigation. Late-summer, early-fall plantings increase first hay harvest tonnage. Performance of a timothy stand is often very site specific. Cereal rust mite damage can appear as drought or severe nitrogen (N) deficiency early in the spring.

Yield Goal

A realistic yield goal for a timothy hay 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, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop 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: 6.5

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. Evaluate stand composition at the beginning of each season. If the stand composition is 25% or more legumes, follow N recommendations for a grass/legume mix crop. If the stand contains less than 25% legumes, follow the N management practices outilined below.

1. After each cut, apply an additional 40 to 60 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 80 to 120 lb/ac of N if the expected yield of the next cut is 2 tons/ac.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.
3. To promote deeper rooting, enhance winter survival and enhance spring recovery, apply N at a rate of 40 to 50 lb/ac between mid-October and mid-November.
4. Early spring N rates should be reduced by the rate of N applied in late fall.
5. Early spring N rates can lead to excessive spring tonnage which will increase the time and difficulty encountered in drying hay to an acceptable level.

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 timothy hay 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 phosphorus (M3-P) is "Low" or "Medium" (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is "Optimum" (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is "Excessive" (i.e., greater than 100 FIV), the application of P 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 timothy hay 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. Topdress potash (K_2O) fertilizer after the first cutting.
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.
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 timothy hay on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay 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. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately 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.

Hay harvest removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

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 hay and pasture systems.

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.

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

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 timothy hay hay.

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 timothy hay hay.

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 usually observed in timothy hay crops. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

White Clover Hay - Established Stand

Crop Highlights

- Target pH: 6.5
- Best yields and animal performance occur if with white clover is seeded with an accompanying forage grass.
- Legume crop will share nitrogen (N) with companion grasses.
- Nitrogen (N) management can alter proportions of legume and grass in the stand.
- Monitor soil phosphorus (P), potassium (K), and sulfur (S) status, as cuttings can reduce soil stores of these nutrients.

Management Notes

Ladino-type cultivars are the only useful white clovers for hay. Unless planted with a companion crop, yield will be low consisting of leaves and flowers. White clover stands will share nitrogen (N) with companion grasses.

Yield Goal

A realistic yield goal for a white clover hay 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, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop 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: 6.5

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. Evaluate stand composition at the beginning of each season. Nitrogen application is not usually recommended if the stand composition is 25% or more legumes. Applied N makes the grasses more competitive and can result in the loss of desireable legumes from the stand. If the stand contains less than 25% legumes, follow the management practices outlined below.

1. After each cut, apply an additional 40 to 60 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 80 to 120 lb/ac of N if the expected yield of the next cut is 2 tons/ac.
2. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.
3. To promote deeper rooting, enhance winter survival and enhance spring recovery, apply N at a rate of 40 to 50 lb/ac between mid-October and mid-November.
4. Early spring N rates should be reduced by the rate of N applied in late fall.
5. Early spring N rates can lead to excessive spring tonnage which will increase the time and difficulty encountered in drying hay to an acceptable level.

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 white clover 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 phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P 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 white clover 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. Topdress potash (K_2O) fertilizer after the first cutting.
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 white clover on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay 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. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately 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.

Hay harvest removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

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 hay and hay and pasture systems.

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 white clover hay.

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 white clover hay.

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 white clover hay crops but may occur if the stand contains more than 25% legumes. If the forage stand is less than 25% legumes, B application is not required. If B deficiency symptoms appear in a stand with more than 25% legumes:

1. Apply B at a rate of 0.5 to 1.0 lb/ac each year.
2. Boron can be applied in a blended, broadcast fertilizer, as a soil spray or applied in a foliar spray, generally in late May or June. ***Foliar applications should only be made when adequate growth is present to aid absorption of foliar B.***
3. **Caution:** Although B is required for maximum productivity of hay fields containing legumes, even slight over-application can be toxic to the crop. When applying B as a foliar spray, be certain to apply the correct rate.