Alfalfa/Grass Mixed Pasture - Established Stand

Crop Highlights
• Target pH: 6.8 • Use a grazing, rhizomatous alfalfa cultivar for pasture. • Nitrogen (N) management can alter proportions of legume and grass in the stand. • Soil pH is critical for alfalfa success, as are good soil phosphorus (P) and potassium (K) fertility. • Apply sulfur (S) when seeding forage crops to prevent S deficiency in early growth. • Forage crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Best to use a grazing, rhizomatous alfalfa cultivar for pasture. 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.

Yield Goal

A specific yield goal is not utilized for pastures. The goal of these recommendations is to ensure good pasture performance to meet the needs of livestock being grazed.

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. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 40 to 60 lb/ac to encourage recovery and regrowth. Repeat application when needed. Do not apply more than 300 lb/ac of N per year.
2. Adjust the N application rate as productivity changes from one grazing cycle to the next 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. **With mid-fall N application:** A greenup N application should not be necessary. If growth is slow in the spring, an N application of 40 to 50 lb/ac in late April or early May will help push pasture growth.
5. **Without mid-fall N application:** Apply N at a rate of 40 to 60 lb/ac at the initiation of greenup to push early pasture growth.

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 phosphorus fertilizer rate to promote adequate pasture performance and productivity.

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

1. If M3 soil test phosphorus (M3-P) is “Low” (i.e., 25 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 “Medium” or “Optimum” (i.e., 26 to 100 FIV), topdress P_2O_5 fertilizer after the first grazing cycle.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.

Potassium

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

Table 3. Recommended potassium fertilizer rate to promote adequate pasture performance and productivity.

	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 grazing cycle.
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.

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 pastures grown 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. Grazing 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 forage 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 forage 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 the applied S to oxidize to the sulfate form.

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

Subsoil sampling to a depth of 24 inches is highly recommended as a means of identifying soils with subsoil reserves of S.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems.

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for alfalfa/grass pastures.

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.
1. 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.
2. 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 pastures.

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 pastures 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 on a cool season grass in season, contact your county agent for assistance with diagnosis and corrective recommendations. If B deficiency symptoms appear in season on a cool season grass/legume mix stand with more than 25% legumes, follow the guidelines below.

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.

Alfalfa Pasture - Established Stand

Crop Highlights
• Target pH: 6.8 • Use a grazing, rhizomatous alfalfa cultivar for pasture. • Large quantities of nitrogen (N) can accumulate in soils after an alfalfa crop. • Soil pH is critical for alfalfa success, as are good soil phosphorus (P) and potassium (K) fertility. • Apply sulfur (S) when seeding forage crops to prevent S deficiency in early growth. • Forage crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Alfalfa is the forage crop with the best monthly forage distribution due to its deep tap rooted nature. Select grazing or rhizomatous alfalfa cultivars if the crop will be grazed. Rotational grazing works best with alfalfa.

Yield Goal

A specific yield goal is not utilized for pastures. The goal of these recommendations is to ensure good pasture performance to meet the needs of livestock being grazed.

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. Applied N makes the grasses more competitive and can result in the loss of desireable legumes from. 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 phosphorus fertilizer rate to promote adequate pasture performance and productivity.

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

1. If M3 soil test phosphorus (M3-P) is “Low” (i.e., 25 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 “Medium” or “Optimum” (i.e., 26 to 100 FIV), topdress P_2O_5 fertilizer after the first grazing cycle.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.

Potassium

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

Table 3. Recommended potassium fertilizer rate to promote adequate pasture performance and productivity.

	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 grazing cycle.
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.

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 pastures grown 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. Grazing 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 forage 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 forage 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 the applied S to oxidize to the sulfate form.

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

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems.

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for alfalfa pastures.

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 pastures.

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 pastures 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 on a cool season grass in season, contact your county agent for assistance with diagnosis and corrective recommendations. If B deficiency symptoms appear in season on a cool season grass/legume mix stand with more than 25% legumes, follow the guidelines below.

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.

Brassica/Grass Mixed Pasture - Establish Stand

Crop Highlights
• Target pH: 6.2 • Inexpensive and useful as emergency forage or to extend grazing season. • Apply sulfur (S) when seeding forage crops to prevent S deficiency in early growth. • Forage crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Pearl millet and brassicas make excellent summer forage. High protein content is associated with brassicas so be sure to include a grass for its fiber content. Brassica/grass mixes can be grazed in as little as 35 to 40 days after planting. Brassicas are high in moisture often resulting in loose dung.

Yield Goal

A specific yield goal is not utilized for pastures. The goal of these recommendations is to ensure good pasture performance to meet the needs of livestock being grazed.

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. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 40 to 60 lb/ac to encourage recovery and regrowth. Repeat application when needed. Do not apply more than 300 lb/ac of N per year.
2. Adjust the N application rate as productivity changes from one grazing cycle to the next 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. **With mid-fall N application:** A greenup N application should not be necessary. If growth is slow in the spring, an N application of 40 to 50 lb/ac in late April or early May will help push pasture growth.
5. **Without mid-fall N application:** Apply N at a rate of 40 to 60 lb/ac at the initiation of greenup to push early pasture growth.

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 phosphorus fertilizer rate to promote adequate pasture performance and productivity.

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

1. If M3 soil test phosphorus (M3-P) is “Low” (i.e., 25 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 “Medium” or “Optimum” (i.e., 26 to 100 FIV), topdress P_2O_5 fertilizer after the first grazing cycle.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.

Potassium

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

Table 3. Recommended potassium fertilizer rate to promote adequate pasture performance and productivity.

	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 grazing cycle.
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.

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 pastures grown 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. Grazing 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 forage 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 forage 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 the applied S to oxidize to the sulfate form.

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

Subsoil sampling to a depth of 24 inches is highly recommended as a means of identifying soils with subsoil reserves of S.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems.

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for brassica/grass pastures.

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 pastures.

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 pastures. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Chicory/Grass Mixed Pasture - Established Stand

Crop Highlights
• Target pH: 5.8 • High-yielding alternative forage. • Prevent spring bolting grazing to a 1.5-inch stubble; follow with 25 day rest period. • Chicory responds well to nitrogen (N), but stem growth increases at high N rates. • Apply sulfur (S) when seeding forage crops to prevent S deficiency in early growth. • Forage crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Chicory provides spring and summer forage. Production is optimized under rotational grazing with an expected stand life of 5 to 7 years. Keep chicory from bolting in spring by grazing to a 1.5-inch stubble height and with rest periods of about 25 days.

Yield Goal

A specific yield goal is not utilized for pastures. The goal of these recommendations is to ensure good pasture performance to meet the needs of livestock being grazed.

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. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 40 to 60 lb/ac to encourage recovery and regrowth. Repeat application when needed. Do not apply more than 300 lb/ac of N per year.
2. Adjust the N application rate as productivity changes from one grazing cycle to the next 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. **With mid-fall N application:** A greenup N application should not be necessary. If growth is slow in the spring, an N application of 40 to 50 lb/ac in late April or early May will help push pasture growth.
5. **Without mid-fall N application:** Apply N at a rate of 40 to 60 lb/ac at the initiation of greenup to push early pasture growth.

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 phosphorus fertilizer rate to promote adequate pasture performance and productivity.

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

1. If M3 soil test phosphorus (M3-P) is “Low” (i.e., 25 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 “Medium” or “Optimum” (i.e., 26 to 100 FIV), topdress P_2O_5 fertilizer after the first grazing cycle.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.

Potassium

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

Table 3. Recommended potassium fertilizer rate to promote adequate pasture performance and productivity.

	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 grazing cycle.
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.

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 pastures grown 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. Grazing 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 forage 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 forage 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 the applied S to oxidize to the sulfate form.

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

Subsoil sampling to a depth of 24 inches is highly recommended as a means of identifying soils with subsoil reserves of S.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems.

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for chicory/grass pastures.

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 pastures.

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 pastures. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Tall Fescue Pasture - 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. • Apply sulfur (S) when seeding forage crops to prevent S deficiency in early growth. • Forage 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. Application of nitrogen (N) at rates above 50 lb/ton of expected yield under drought conditions can results in high nitrate levels; test forages prior to grazing to prevent livestock poisoning.

Yield Goal

A specific yield goal is not utilized for pastures. The goal of these recommendations is to ensure good pasture performance to meet the needs of livestock being grazed.

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. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 40 to 60 lb/ac to encourage recovery and regrowth. Repeat application when needed. Do not apply more than 300 lb/ac of N per year.
2. Adjust the N application rate as productivity changes from one grazing cycle to the next 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. **With mid-fall N application:** A greenup N application should not be necessary. If growth is slow in the spring, an N application of 40 to 50 lb/ac in late April or early May will help push pasture growth.
5. **Without mid-fall N application:** Apply N at a rate of 40 to 60 lb/ac at the initiation of greenup to push early pasture growth.

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 phosphorus fertilizer rate to promote adequate pasture performance and productivity.

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

1. If M3 soil test phosphorus (M3-P) is “Low” (i.e., 25 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 “Medium” or “Optimum” (i.e., 26 to 100 FIV), topdress P_2O_5 fertilizer after the first grazing cycle.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.

Potassium

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

Table 3. Recommended potassium fertilizer rate to promote adequate pasture performance and productivity.

	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 grazing cycle.
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.

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 pastures grown 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. Grazing 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 forage 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 forage 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 the applied S to oxidize to the sulfate form.

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

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems.

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for tall fescue pastures.

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 pastures.

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 pastures. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Mixed Grass/Legume Pasture - Established Stand

Crop Highlights
• Target pH: 6.5 • Nitrogen (N) management can alter proportions of legume and grass in the stand. • Apply sulfur (S) when seeding forage crops to prevent S deficiency in early growth. • Forage crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

The combination of grass and broadleaf crop makes management difficult, especially weed control. Manage mixture balance using rotational grazing, nitrogen (N) fertilizer, grazing height, and grazing frequency.

Yield Goal

A specific yield goal is not utilized for pastures. The goal of these recommendations is to ensure good pasture performance to meet the needs of livestock being grazed.

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. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 40 to 60 lb/ac to encourage recovery and regrowth. Repeat application when needed. Do not apply more than 300 lb/ac of N per year.
2. Adjust the N application rate as productivity changes from one grazing cycle to the next 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. **With mid-fall N application:** A greenup N application should not be necessary. If growth is slow in the spring, an N application of 40 to 50 lb/ac in late April or early May will help push pasture growth.
5. **Without mid-fall N application:** Apply N at a rate of 40 to 60 lb/ac at the initiation of greenup to push early pasture growth.

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 phosphorus fertilizer rate to promote adequate pasture performance and productivity.

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

1. If M3 soil test phosphorus (M3-P) is “Low” (i.e., 25 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 “Medium” or “Optimum” (i.e., 26 to 100 FIV), topdress P_2O_5 fertilizer after the first grazing cycle.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.

Potassium

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

Table 3. Recommended potassium fertilizer rate to promote adequate pasture performance and productivity.

	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 grazing cycle.
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.

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/legume pastures grown 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. Grazing 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 forage 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 forage 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 the applied S to oxidize to the sulfate form.

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

Subsoil sampling to a depth of 24 inches is highly recommended as a means of identifying soils with subsoil reserves of S.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems.

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for mixed grass/legume pastures.

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/legume pastures.

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/legume pastures 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 on a cool season grass in season, contact your county agent for assistance with diagnosis and corrective recommendations. If B deficiency symptoms appear in season on a cool season grass/legume mix stand with more than 25% legumes, follow the guidelines below.

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.

Annual or Italian Ryegrass Pasture - Established Stand

Crop Highlights
• Target pH: 6.5 • Best used as an emergency forage. • Adequate nitrogen (N) and water will promote productivity. • Apply sulfur (S) when seeding forage crops to prevent S deficiency in early growth. • Forage crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

The best use of annual or Italian rygrass is as emergency forage because the crop is short-lived. Highest crop productivity occurs with adequate nitrogen (N) and rainfall or irrigation. The interval between one grazing cycle and next can be as short as 21 days.

Yield Goal

A specific yield goal is not utilized for pastures. The goal of these recommendations is to ensure good pasture performance to meet the needs of livestock being grazed.

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. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 40 to 60 lb/ac to encourage recovery and regrowth. Repeat application when needed. Do not apply more than 300 lb/ac of N per year.
2. Adjust the N application rate as productivity changes from one grazing cycle to the next 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. **With mid-fall N application:** A greenup N application should not be necessary. If growth is slow in the spring, an N application of 40 to 50 lb/ac in late April or early May will help push pasture growth.
5. **Without mid-fall N application:** Apply N at a rate of 40 to 60 lb/ac at the initiation of greenup to push early pasture growth.

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 phosphorus fertilizer rate to promote adequate pasture performance and productivity.

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

1. If M3 soil test phosphorus (M3-P) is “Low” (i.e., 25 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 “Medium” or “Optimum” (i.e., 26 to 100 FIV), topdress P_2O_5 fertilizer after the first grazing cycle.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.

Potassium

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

Table 3. Recommended potassium fertilizer rate to promote adequate pasture performance and productivity.

	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 grazing cycle.
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.

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 pastures grown 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. Grazing 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 forage 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 forage 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 the applied S to oxidize to the sulfate form.

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

Subsoil sampling to a depth of 24 inches is highly recommended as a means of identifying soils with subsoil reserves of S.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems.

Manganese

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

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

Where:

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

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

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 pastures.

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 pastures. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Kentucky Bluegrass Pasture - Established Stand

Crop Highlights
• Target pH: 6.5 • Low yields during summer months. • Crop prefers slightly higher soil pH than other forages. • Wait until the grass is 2 to 3 inches tall before applying nitrogen (N) fertilizer. • Apply sulfur (S) when seeding forage crops to prevent S deficiency in early growth. • Forage crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

The majority of Kentucky bluegrass forage is produced in early spring, with another small peak in the fall. This crop can be grazed relatively closely due to extensive rhizome (underground stem) system. White clover often invades open areas if the crop is over-grazed.

Yield Goal

A specific yield goal is not utilized for pastures. The goal of these recommendations is to ensure good pasture performance to meet the needs of livestock being grazed.

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. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 40 to 60 lb/ac to encourage recovery and regrowth. Repeat application when needed. Do not apply more than 300 lb/ac of N per year.
2. Adjust the N application rate as productivity changes from one grazing cycle to the next 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. **With mid-fall N application:** A greenup N application should not be necessary. If growth is slow in the spring, an N application of 40 to 50 lb/ac in late April or early May will help push pasture growth.
5. **Without mid-fall N application:** Apply N at a rate of 40 to 60 lb/ac at the initiation of greenup to push early pasture growth.

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 phosphorus fertilizer rate to promote adequate pasture performance and productivity.

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

1. If M3 soil test phosphorus (M3-P) is “Low” (i.e., 25 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 “Medium” or “Optimum” (i.e., 26 to 100 FIV), topdress P_2O_5 fertilizer after the first grazing cycle.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.

Potassium

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

Table 3. Recommended potassium fertilizer rate to promote adequate pasture performance and productivity.

	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 grazing cycle.
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.

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 pastures grown 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. Grazing 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 forage 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 forage 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 the applied S to oxidize to the sulfate form.

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

Subsoil sampling to a depth of 24 inches is highly recommended as a means of identifying soils with subsoil reserves of S.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems.

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for Kentucky bluegrass pastures.

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 pastures.

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 pastures. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Orchardgrass Pasture - 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. • Apply sulfur (S) when seeding forage crops to prevent S deficiency in early growth. • Forage crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Orchardgrass performs best on well-drained, highly fertile soil with good organic matter content. 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 over-fertilize with N unless K is supplied. Avoid grazing orchardgrass below 4 inches. Susceptible to leaf spot diseases in hot humid weather. Orchardgrass is not useful as a fall-accumulated winter grazing crop as quality declines rapidly after frost.

Yield Goal

A specific yield goal is not utilized for pastures. The goal of these recommendations is to ensure good pasture performance to meet the needs of livestock being grazed.

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. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 40 to 60 lb/ac to encourage recovery and regrowth. Repeat application when needed. Do not apply more than 300 lb/ac of N per year.
2. Adjust the N application rate as productivity changes from one grazing cycle to the next 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. **With mid-fall N application:** A greenup N application should not be necessary. If growth is slow in the spring, an N application of 40 to 50 lb/ac in late April or early May will help push pasture growth.
5. **Without mid-fall N application:** Apply N at a rate of 40 to 60 lb/ac at the initiation of greenup to push early pasture growth.

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 phosphorus fertilizer rate to promote adequate pasture performance and productivity.

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

1. If M3 soil test phosphorus (M3-P) is “Low” (i.e., 25 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 “Medium” or “Optimum” (i.e., 26 to 100 FIV), topdress P_2O_5 fertilizer after the first grazing cycle.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.

Potassium

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

Table 3. Recommended potassium fertilizer rate to promote adequate pasture performance and productivity.

	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 grazing cycle.
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.

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 pastures grown 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. Grazing 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 forage 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 forage 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 the applied S to oxidize to the sulfate form.

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

Subsoil sampling to a depth of 24 inches is highly recommended as a means of identifying soils with subsoil reserves of S.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems.

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for orchardgrass pastures.

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 pastures.

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 pastures. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Perennial Ryegrass Pasture - Established Stand

Crop Highlights
• Target pH: 6.5 • Short-lived perennial best suited for northern Delaware. • Crop is a heavy nitrogen (N) user. • Apply sulfur (S) when seeding forage crops to prevent S deficiency in early growth. • Forage crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

In Delaware, perennial ryegrass does best in the northern areas with adequate moisture. Tetraploid cultivars yield more and stands last longer than diploid cultivars. Perennial ryegrass performs best when a legume is included. This crop is excellent as no-till interseeded crop to extend the stand life of legume crops like alfalfa. Perennial ryegrass is not useful as a fall-accumulated winter grazing crop, as quality declines rapidly after frost.

Yield Goal

A specific yield goal is not utilized for pastures. The goal of these recommendations is to ensure good pasture performance to meet the needs of livestock being grazed.

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. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 40 to 60 lb/ac to encourage recovery and regrowth. Repeat application when needed. Do not apply more than 300 lb/ac of N per year.
2. Adjust the N application rate as productivity changes from one grazing cycle to the next 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. **With mid-fall N application:** A greenup N application should not be necessary. If growth is slow in the spring, an N application of 40 to 50 lb/ac in late April or early May will help push pasture growth.
5. **Without mid-fall N application:** Apply N at a rate of 40 to 60 lb/ac at the initiation of greenup to push early pasture growth.

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 phosphorus fertilizer rate to promote adequate pasture performance and productivity.

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

1. If M3 soil test phosphorus (M3-P) is “Low” (i.e., 25 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 “Medium” or “Optimum” (i.e., 26 to 100 FIV), topdress P_2O_5 fertilizer after the first grazing cycle.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.

Potassium

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

Table 3. Recommended potassium fertilizer rate to promote adequate pasture performance and productivity.

	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 grazing cycle.
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.

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 pastures grown 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. Grazing 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 forage 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 forage 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 the applied S to oxidize to the sulfate form.

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

Subsoil sampling to a depth of 24 inches is highly recommended as a means of identifying soils with subsoil reserves of S.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems.

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for perennial ryegrass pastures.

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 pastures.

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 pastures. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Red Clover Pasture - 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. • Apply sulfur (S) when seeding forage crops to prevent S deficiency in early growth. • Forage crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

The best yield and grazing gains come if red clover is seeded with an accompanying forage grass. Older cultivars survive only 1.5 to 2 years as stands thin. Rotate red clover in fields as disease pressure builds with time. Red clover is best used with a companion forage grass.

Yield Goal

A specific yield goal is not utilized for pastures. The goal of these recommendations is to ensure good pasture performance to meet the needs of livestock being grazed.

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. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 40 to 60 lb/ac to encourage recovery and regrowth. Repeat application when needed. Do not apply more than 300 lb/ac of N per year.
2. Adjust the N application rate as productivity changes from one grazing cycle to the next 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. **With mid-fall N application:** A greenup N application should not be necessary. If growth is slow in the spring, an N application of 40 to 50 lb/ac in late April or early May will help push pasture growth.
5. **Without mid-fall N application:** Apply N at a rate of 40 to 60 lb/ac at the initiation of greenup to push early pasture growth.

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 phosphorus fertilizer rate to promote adequate pasture performance and productivity.

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

1. If M3 soil test phosphorus (M3-P) is “Low” (i.e., 25 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 “Medium” or “Optimum” (i.e., 26 to 100 FIV), topdress P_2O_5 fertilizer after the first grazing cycle.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.

Potassium

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

Table 3. Recommended potassium fertilizer rate to promote adequate pasture performance and productivity.

	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 grazing cycle.
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.

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 pastures grown 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. Grazing 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 forage 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 forage 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 the applied S to oxidize to the sulfate form.

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

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems.

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for red clover pastures.

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 pastures.

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 pastures 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 on a cool season grass in season, contact your county agent for assistance with diagnosis and corrective recommendations. If B deficiency symptoms appear in season on a cool season grass/legume mix stand with more than 25% legumes, follow the guidelines below.

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 Pasture - Established Stand

Crop Highlights
• Target pH: 6.5 • Grows well with Ladino-type white clover. • Apply sulfur (S) when seeding forage crops to prevent S deficiency in early growth. • Forage crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Low alkaloid cultivars are best for cattle and sheep, but goats have done well with common (high alkaloid) reed canarygrass. This crop requires careful management and a longer recovery period between grazings; suited only for rotational grazing practices. Reed canarygrass grows well with Ladino-type white clover.

Yield Goal

A specific yield goal is not utilized for pastures. The goal of these recommendations is to ensure good pasture performance to meet the needs of livestock being grazed.

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. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 40 to 60 lb/ac to encourage recovery and regrowth. Repeat application when needed. Do not apply more than 300 lb/ac of N per year.
2. Adjust the N application rate as productivity changes from one grazing cycle to the next 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. **With mid-fall N application:** A greenup N application should not be necessary. If growth is slow in the spring, an N application of 40 to 50 lb/ac in late April or early May will help push pasture growth.
5. **Without mid-fall N application:** Apply N at a rate of 40 to 60 lb/ac at the initiation of greenup to push early pasture growth.

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 phosphorus fertilizer rate to promote adequate pasture performance and productivity.

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

1. If M3 soil test phosphorus (M3-P) is “Low” (i.e., 25 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 “Medium” or “Optimum” (i.e., 26 to 100 FIV), topdress P_2O_5 fertilizer after the first grazing cycle.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.

Potassium

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

Table 3. Recommended potassium fertilizer rate to promote adequate pasture performance and productivity.

	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 grazing cycle.
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.

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 pastures grown 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. Grazing 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 forage 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 forage 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 the applied S to oxidize to the sulfate form.

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

Subsoil sampling to a depth of 24 inches is highly recommended as a means of identifying soils with subsoil reserves of S.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems.

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for reed canarygrass pastures.

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 pastures.

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 pastures. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Smooth Bromegrass Pasture - 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. • Forage 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 N fertilization.

Yield Goal

A specific yield goal is not utilized for pastures. The goal of these recommendations is to ensure good pasture performance to meet the needs of livestock being grazed.

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. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 40 to 60 lb/ac to encourage recovery and regrowth. Repeat application when needed. Do not apply more than 300 lb/ac of N per year.
2. Adjust the N application rate as productivity changes from one grazing cycle to the next 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. **With mid-fall N application:** A greenup N application should not be necessary. If growth is slow in the spring, an N application of 40 to 50 lb/ac in late April or early May will help push pasture growth.
5. **Without mid-fall N application:** Apply N at a rate of 40 to 60 lb/ac at the initiation of greenup to push early pasture growth.

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 phosphorus fertilizer rate to promote adequate pasture performance and productivity.

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

1. If M3 soil test phosphorus (M3-P) is “Low” (i.e., 25 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 “Medium” or “Optimum” (i.e., 26 to 100 FIV), topdress P_2O_5 fertilizer after the first grazing cycle.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.

Potassium

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

Table 3. Recommended potassium fertilizer rate to promote adequate pasture performance and productivity.

	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 grazing cycle.
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.

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 pastures grown 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. Grazing 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 forage 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 forage 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 the applied S to oxidize to the sulfate form.

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

Subsoil sampling to a depth of 24 inches is highly recommended as a means of identifying soils with subsoil reserves of S.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems.

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for smooth bromegrass pastures.

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 pastures.

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 pastures. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Sericea Lespedeza Pasture - 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. • Apply sulfur (S) when seeding forage crops to prevent S deficiency in early growth. • Apply sulfur (S) when seeding forage crops to prevent S deficiency in early growth. • Forage 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 specific yield goal is not utilized for pastures. The goal of these recommendations is to ensure good pasture performance to meet the needs of livestock being grazed.

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. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 40 to 60 lb/ac to encourage recovery and regrowth. Repeat application when needed. Do not apply more than 300 lb/ac of N per year.
2. Adjust the N application rate as productivity changes from one grazing cycle to the next 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. **With mid-fall N application:** A greenup N application should not be necessary. If growth is slow in the spring, an N application of 40 to 50 lb/ac in late April or early May will help push pasture growth.
5. **Without mid-fall N application:** Apply N at a rate of 40 to 60 lb/ac at the initiation of greenup to push early pasture growth.

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 phosphorus fertilizer rate to promote adequate pasture performance and productivity.

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

1. If M3 soil test phosphorus (M3-P) is “Low” (i.e., 25 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 “Medium” or “Optimum” (i.e., 26 to 100 FIV), topdress P_2O_5 fertilizer after the first grazing cycle.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.

Potassium

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

Table 3. Recommended potassium fertilizer rate to promote adequate pasture performance and productivity.

	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 grazing cycle.
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.

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 pastures grown 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. Grazing 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 forage 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 forage 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 the applied S to oxidize to the sulfate form.

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

Subsoil sampling to a depth of 24 inches is highly recommended as a means of identifying soils with subsoil reserves of S.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems.

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for sericea lespedeza pastures.

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 pastures.

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 pastures. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

Timothy Pasture - Established Stand

Crop Highlights
• Target pH: 6.5 • Performance is site-specific. • Cereal rust mite damage can mimic severe nitrogen (N) deficiency. • Apply sulfur (S) when seeding forage crops to prevent S deficiency in early growth. • Forage crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Performance of a timothy stand is often very site specific. Cereal rust mite damage can appear as drought or severe N deficiency early in the spring. Timothy has haplocorms at the base of the plant that form in the fall and can be damaged by grazing animals.

Yield Goal

A specific yield goal is not utilized for pastures. The goal of these recommendations is to ensure good pasture performance to meet the needs of livestock being grazed.

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. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 40 to 60 lb/ac to encourage recovery and regrowth. Repeat application when needed. Do not apply more than 300 lb/ac of N per year.
2. Adjust the N application rate as productivity changes from one grazing cycle to the next 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. **With mid-fall N application:** A greenup N application should not be necessary. If growth is slow in the spring, an N application of 40 to 50 lb/ac in late April or early May will help push pasture growth.
5. **Without mid-fall N application:** Apply N at a rate of 40 to 60 lb/ac at the initiation of greenup to push early pasture growth.

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 phosphorus fertilizer rate to promote adequate pasture performance and productivity.

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

1. If M3 soil test phosphorus (M3-P) is “Low” (i.e., 25 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 “Medium” or “Optimum” (i.e., 26 to 100 FIV), topdress P_2O_5 fertilizer after the first grazing cycle.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.

Potassium

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

Table 3. Recommended potassium fertilizer rate to promote adequate pasture performance and productivity.

	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 grazing cycle.
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.

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 pastures grown 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. Grazing 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 forage 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 forage 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 the applied S to oxidize to the sulfate form.

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

Subsoil sampling to a depth of 24 inches is highly recommended as a means of identifying soils with subsoil reserves of S.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems.

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for timothy hay pastures.

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 pastures.

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 pastures. If B deficiency symptoms appear, contact your county agent for assistance with diagnosis and corrective recommendations.

White Clover Pasture - 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. • Apply sulfur (S) when seeding forage crops to prevent S deficiency in early growth. • Forage crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

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

Yield Goal

A specific yield goal is not utilized for pastures. The goal of these recommendations is to ensure good pasture performance to meet the needs of livestock being grazed.

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. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 40 to 60 lb/ac to encourage recovery and regrowth. Repeat application when needed. Do not apply more than 300 lb/ac of N per year.
2. Adjust the N application rate as productivity changes from one grazing cycle to the next 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. **With mid-fall N application:** A greenup N application should not be necessary. If growth is slow in the spring, an N application of 40 to 50 lb/ac in late April or early May will help push pasture growth.
5. **Without mid-fall N application:** Apply N at a rate of 40 to 60 lb/ac at the initiation of greenup to push early pasture growth.

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 phosphorus fertilizer rate to promote adequate pasture performance and productivity.

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

1. If M3 soil test phosphorus (M3-P) is “Low” (i.e., 25 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 “Medium” or “Optimum” (i.e., 26 to 100 FIV), topdress P_2O_5 fertilizer after the first grazing cycle.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.

Potassium

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

Table 3. Recommended potassium fertilizer rate to promote adequate pasture performance and productivity.

	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 grazing cycle.
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.

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 pastures grown 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. Grazing 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 forage 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 forage 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 the applied S to oxidize to the sulfate form.

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

Subsoil sampling to a depth of 24 inches is highly recommended as a means of identifying soils with subsoil reserves of S.

Long-term applications of ammonium sulfate or other acid-forming fertilizers may lower pH of the soil surface and require correction with lime. Monitor surface pH with a 0- to 2-inch soil sample, especially in pasture systems.

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for white clover pastures.

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 pastures.

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 pastures 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 on a cool season grass in season, contact your county agent for assistance with diagnosis and corrective recommendations. If B deficiency symptoms appear in season on a cool season grass/legume mix stand with more than 25% legumes, follow the guidelines below.

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.