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

Nutrient Recommendations

Forage and Hay Crops:

Warm Season Perennial Forages – Established Pasture

Amy Shober
Professor and Extension Specialist – Nutrient Management and Environmental Quality

Karen Gartley
Soil Testing Program Director

Jarrod Miller
Assistant Professor and Extension Specialist – Agronomy

Richard Taylor
Extension Specialist – Agronomy (Retired)

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Bermudagrass Pasture - Established Stand

Crop Highlights
• Target pH: 6.5 • Growth starts in late spring, continues in summer, and slows in fall. • Summer nitrogen (N) applications may be needed to promote maximum production. • Monitor hay crops for S deficiency or use ammonium sulfate as the N source to provide S. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Growth starts late in the spring, but this grass grows well during the heat of summer. Growth slows in fall (Sept to Oct) as night temperatures decline. Bermudagrass responds well to nitrogen (N) fertilizer and is tolerant of heat and drought. Shade from weeds is often the greatest danger, so graze close. Bermudagrass can be grazed under intensive. Overseed with annual or Italian ryegrass in September to allow for winter grazing.

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.

1. An initial N application of 40 to 60 lb/ac should be applied when growth begins in mid- to late-spring, followed by additional N in early June as needed.
2. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 50 to 70 lb/ac to encourage recovery and regrowth. Repeat application when needed.
3. Adjust the N application rate as productivity changes from one grazing cycle to the next and with expected weather conditions.

Phosphorus

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

Table 2. Recommended 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 bermudagrass 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 bermudagrass.

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 bermudagrass 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 bermudagrass pastures. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.

Big Bluestem Pasture - Established Stand

Crop Highlights
• Target pH: 6.2 • Rotational grazing is mandatory to maintain stand life. • Apply nitrogen (N) in mid- to late-spring when growth begins. • Monitor hay crops for S deficiency or use ammonium sulfate as the N source to provide S. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Big bluestem is a native warm-season grass with good to excellent palatability. This grass is intermediate in maturity (heads in mid-summer). Big blue stem stores its residual or regrowth carbohydrates in the lower stem base. Rotational grazing is mandatory to maintain stand life.

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.

1. An initial N application of 40 to 60 lb/ac should be applied when growth begins in mid- to late-spring, followed by additional N in early June as needed.
2. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 20 to 40 lb/ac to encourage recovery and regrowth. Repeat application when needed.
3. Adjust the N application rate as productivity changes from one grazing cycle to the next and with expected weather conditions.

Phosphorus

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

Table 2. Recommended 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 big bluestem 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 big bluestem.

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 big bluestem 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 big bluestem pastures. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.

Eastern Gamagrass Pasture - Established Stand

Crop Highlights
• Target pH: 6.5 • Performs best if first harvest is taken as hay (large round bales) and regrowth is grazed. • Summer nitrogen (N) applications may be needed to promote maximum production. • Monitor hay crops for S deficiency or use ammonium sulfate as the N source to provide S. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Eastern gamagrass has excellent palatability. Eastern gamagrass heads out earlier than other warm-season grasses. This crop performs best if first harvest is taken as hay (large round bales) and regrowth is grazed. The optimum rest period between grazing cycles is approximately 45 days. Halt grazing at a considerably higher height to maintain a minimum stubble height of 6 to 8 inches. Keep grazing periods relatively short or animals will graze new regrowth. Herbage is often coarse, but palatability is excellent. Allow a minimum of 45 days rest before the first killing 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.

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

Nitrogen

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

1. An initial N application of 40 to 60 lb/ac should be applied when growth begins in mid- to late-spring, followed by additional N in early June as needed.
2. 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.
3. Adjust the N application rate as productivity changes from one grazing cycle to the next and with expected weather conditions.

Phosphorus

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

Table 2. Recommended 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).

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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.
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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).

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	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 eastern gamagrass 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.
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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.

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

Where:

MnAI = Mn availability index
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M3-Mn = Mehlich 3 soil test Mn in lb/ac

Table 5. Interpretation of manganese availability index for eastern gamagrass.

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 eastern gamagrass 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 eastern gamagrass pastures. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.

Indiangrass Pasture - Established Stand

Crop Highlights
• Target pH: 6.2 • Limit the number of grazing cycles to maintain stand quality. • Apply nitrogen (N) in mid- to late-spring when growth begins. • Monitor hay crops for S deficiency or use ammonium sulfate as the N source to provide S. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Indiangrass, a native warm season grass that heads late in the summer. New stands can take two years to establish before they can be grazed. Once established, limit the number of grazing cycles to maintain stand quality. Rotational grazing is mandatory to maintain stand life. This grass requires high stubble (at least a minimum 6 to 8 inches) and adequate recovery time before frost. There is potential for prussic acid (cyanide) poisoning with indiangrass.

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.

1. An initial N application of 40 to 60 lb/ac should be applied when growth begins in mid- to late-spring, followed by additional N in early June as needed.
2. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 20 to 40 lb/ac to encourage recovery and regrowth. Repeat application when needed.
3. Adjust the N application rate as productivity changes from one grazing cycle to the next and with expected weather conditions.

Phosphorus

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

Table 2. Recommended 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 indiangrass 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 indiangrass.

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 indiangrass 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 indiangrass pastures. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.

Little Bluestem Pasture - Established Stand

Crop Highlights
• Target pH: 6.2 • Rotational grazing is mandatory to maintain stand life. • Apply nitrogen (N) in mid- to late-spring when growth begins. • Monitor hay crops for S deficiency or use ammonium sulfate as the N source to provide S. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Little bluestem is much shorter in stature than other warm-season grasses and, therefore, is lower yielding. New stands may take two years to establish sufficiently before they can be grazed. When grazing, leave 6 to 8 inches of stubble to improve regrowth potential. Rotational grazing is mandatory to maintain stand life.

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.

1. An initial N application of 40 to 60 lb/ac should be applied when growth begins in mid- to late-spring, followed by additional N in early June as needed.
2. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 20 to 40 lb/ac to encourage recovery and regrowth. Repeat application when needed.
3. Adjust the N application rate as productivity changes from one grazing cycle to the next and with expected weather conditions.

Phosphorus

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

Table 2. Recommended 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 little bluestem 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 little bluestem.

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 little bluestem 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 little bluestem pastures. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.

Switchgrass Pasture - Established Stand

Crop Highlights
• Target pH: 6.2 • Rotational grazing is mandatory to maintain stand life. • Apply nitrogen (N) in mid- to late-spring when growth begins. • Monitor hay crops for S deficiency or use ammonium sulfate as the N source to provide S. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Switchgrass is a native warm season grass that heads earlier than bluestems or Indiangrass. New stands may take two years to establish sufficiently before they can be grazed. When grazing, leave 6 to 8 inches of stubble to improve regrowth potential. Rotational grazing is mandatory to maintain stand life. Switchgrass hay can cause liver lesions if used as the sole feed source for ruminants.

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.

1. An initial N application of 40 to 60 lb/ac should be applied when growth begins in mid- to late-spring, followed by additional N in early June as needed.
2. If forage growth is slow or inadequate for livestock needs, apply N at a rate of 20 to 40 lb/ac to encourage recovery and regrowth. Repeat application when needed.
3. Adjust the N application rate as productivity changes from one grazing cycle to the next and with expected weather conditions.

Phosphorus

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

Table 2. Recommended 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 switchgrass 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 switchgrass.

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 switchgrass 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 switchgrass pastures. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.