Bermudagrass Hay - Established Stand

Crop Highlights
• Target pH: 6.5 • Can produce high tonnage, high protein hay. • 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

High protein, high tonnage hay is possible with established bermudagrass fields. 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. Bermudagrass can be cut very frequently. Growers may need to tightly pack bales to prevent excessive field losses.

Yield Goal

A realistic yield goal for a bermudagrass hay crop is 5 ton/ac in a good to average year. However, yield is dependent upon several factors, including grass species, seeding rate, seeding date, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop and grazing management practices.

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

Target pH: 6.5

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

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

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

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

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

Nitrogen

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

1. Apply an initial N application of 40 to 60 lb/ac when growth begins in mid- to late-spring, followed by additional N in early June as needed.
2. Additional applications of N may be needed in the summer to promote maximum production.
3. After each cut, apply an additional 50 to 70 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 100 to 140 lb/ac of N if the expected yield of the next cut is 2 ton/ac.
4. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.

Phosphorus

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

Table 2. Recommended broadcast phosphorus fertilizer application rates for bermudagrass hay as a function of Mehlich-3 soil test phosphorus (M3-P) at 5 ton/ac yield goal.

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

1. If M3 soil test phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 20 lb/ac for each additional ton of expected yield above 5 ton/ac.

Potassium

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

Table 3. Recommended potassium fertilizer application rate for bermudagrass hay as a function of Mehlich-3 soil test potassium (M3-K) at 5 ton/ac yield goal.

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

1. Topdress potash (K_2O) fertilizer after the first cutting.
2. Application rates of 120 lb/ac of K_2O or higher should be split into two applications. Apply ½ of the recommended rate after the first cutting and the remainder in late August or September.
3. Increase recommended K_2O application rate by 50 lb/ac for each additional ton of expected yield above 5 ton/ac.

Magnesium

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

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

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

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

Sulfur

Sulfur (S) deficiency is occasionally observed in bermudagrass hay on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for 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.

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

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

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for bermudagrass hay.

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

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

Zinc

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

Table 6. Interpretation of zinc availability index for bermudagrass hay.

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

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

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

Boron

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

Big Bluestem Hay - Established Stand

Crop Highlights
• Target pH: 6.2 • This native warm-season grass produces hay with good to excellent palatability. • 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; it produces good quality hay. This grass is intermediate in maturity (heads in mid-summer). Harvest big bluestem at early- to mid-heading to quality or at full head for heavier yield. Big blue stem stores its residual or regrowth carbohydrates in the lower stem base. Leave 6 to 8 inches of stubble when cutting to promote regrowth. If cutting the crop again after seed head emergence, allow adequate time for regrowth before frost. Stems are thick and hay will require conditioning by crimping.

Yield Goal

A realistic yield goal for a big bluestem hay crop is 3 ton/ac in a good to average year. However, yield is dependent upon several factors, including grass species, seeding rate, seeding date, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop and grazing management practices.

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

Target pH: 6.2

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

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

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

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

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

Nitrogen

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

1. Apply an initial N application of 40 to 60 lb/ac when growth begins in mid- to late-spring, followed by additional N in early June as needed.
2. After each cut, apply an additional 20 to 40 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 40 to 80 lb/ac of N if the expected yield of the next cut is 2 ton/ac.
3. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.

Phosphorus

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

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

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

1. If M3 soil test phosphorus (M3-P) is "Low" or "Medium" (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is "Optimum" (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is "Excessive" (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 0 lb/ac for each additional ton of expected yield above 3 ton/ac.

Potassium

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

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

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

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

Magnesium

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

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

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

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

Sulfur

Sulfur (S) deficiency is occasionally observed in big bluestem hay on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of NONE 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.

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

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

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for big bluestem hay.

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

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

Zinc

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

Table 6. Interpretation of zinc availability index for big bluestem hay.

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

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

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

Boron

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

Eastern Gamagrass Hay - Established Stand

Crop Highlights
• Target pH: 6.5 • Produces hay with excellent palatability. • 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. Take initial harvest at mid- to late-heading. Eastern gamagrass can be harvested 3 to 4 times a year if a 6- to 8-inch stubble is left to assist recovery. Eastern gamagrass performs well when round baled.

Yield Goal

A realistic yield goal for a eastern gamagrass hay crop is 4 ton/ac in a good to average year. However, yield is dependent upon several factors, including grass species, seeding rate, seeding date, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop and grazing management practices.

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

Target pH: 6.5

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

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

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

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

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

Nitrogen

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

1. Apply an initial N application of 40 to 60 lb/ac when growth begins in mid- to late-spring, followed by additional N in early June as needed.
2. Additional applications of N may be needed in the summer to promote maximum production.
3. After each cut, apply an additional 40 to 60 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 80 to 120 lb/ac of N if the expected yield of the next cut is 2 ton/ac.
4. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.

Phosphorus

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

Table 2. Recommended broadcast phosphorus fertilizer application rates for eastern gamagrass hay as a function of Mehlich-3 soil test phosphorus (M3-P) at 4 ton/ac yield goal.

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

1. If M3 soil test phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 20 lb/ac for each additional ton of expected yield above 4 ton/ac.

Potassium

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

Table 3. Recommended potassium fertilizer application rate for eastern gamagrass hay as a function of Mehlich-3 soil test potassium (M3-K) at 4 ton/ac yield goal.

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

1. Topdress potash (K_2O) fertilizer after the first cutting.
2. Application rates of 120 lb/ac of K_2O or higher should be split into two applications. Apply ½ of the recommended rate after the first cutting and the remainder in late August or September.
3. Increase recommended K_2O application rate by 50 lb/ac for each additional ton of expected yield above 4 ton/ac.

Magnesium

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

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

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

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

Sulfur

Sulfur (S) deficiency is occasionally observed in eastern gamagrass hay on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of 20 to 40 lb/ac to ensure that adequate S is available to meet crop needs.
3. Sulfate-S is available immediately for crop uptake immediately after application. If a reduced form of S is applied (e.g., thiosulfate or elemental S), allow adequate time for 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.

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

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

Manganese

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

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

Where:

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

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

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

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

Zinc

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

Table 6. Interpretation of zinc availability index for eastern gamagrass hay.

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

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

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

Boron

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

Indiangrass Hay - Established Stand

Crop Highlights
• Target pH: 6.2 • Potential for prussic acid (cyanide) poisoning with indiangrass. • 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 cut for hay. Once established, limit the number of cuttings to maintain stand quality. 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 realistic yield goal for a indian grass hay crop is 3 ton/ac in a good to average year. However, yield is dependent upon several factors, including grass species, seeding rate, seeding date, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop and grazing management practices.

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

Target pH: 6.2

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

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

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

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

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

Nitrogen

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

1. Apply an initial N application of 40 to 60 lb/ac when growth begins in mid- to late-spring, followed by additional N in early June as needed.
2. After each cut, apply an additional 20 to 40 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 40 to 80 lb/ac of N if the expected yield of the next cut is 2 ton/ac.
3. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.

Phosphorus

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

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

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

1. If M3 soil test phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 0 lb/ac for each additional ton of expected yield above 3 ton/ac.

Potassium

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

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

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

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

Magnesium

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

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

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

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

Sulfur

Sulfur (S) deficiency is occasionally observed in indian grass hay on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of NONE 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.

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

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

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for indian grass hay.

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

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

Zinc

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

Table 6. Interpretation of zinc availability index for indian grass hay.

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

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

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

Boron

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

Little Bluestem Hay - Established Stand

Crop Highlights

- Target pH: 6.2
- Lower yielding than other warm season grasses.
- 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 cut for hay. When cutting, leave 6 to 8 inches of stubble to improve regrowth potential.

Yield Goal

A realistic yield goal for a little bluestem hay crop is 1.5 ton/ac in a good to average year. However, yield is dependent upon several factors, including grass species, seeding rate, seeding date, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop and grazing management practices.

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

Target pH: 6.2

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

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

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

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

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

Nitrogen

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

1. Apply an initial N application of 40 to 60 lb/ac when growth begins in mid- to late-spring, followed by additional N in early June as needed.
2. After each cut, apply an additional 20 to 40 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 40 to 80 lb/ac of N if the expected yield of the next cut is 2 ton/ac.
3. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.

Phosphorus

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

Table 2. Recommended broadcast phosphorus fertilizer application rates for little bluestem hay as a function of Mehlich-3 soil test phosphorus (M3-P) at 1.5 ton/ac yield goal.

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

1. If M3 soil test phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 0 lb/ac for each additional ton of expected yield above 1.5 ton/ac.

Potassium

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

Table 3. Recommended potassium fertilizer application rate for little bluestem hay as a function of Mehlich-3 soil test potassium (M3-K) at 1.5 ton/ac yield goal.

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

1. Topdress potash (K_2O) fertilizer after the first cutting.
2. Application rates of 120 lb/ac of K_2O or higher should be split into two applications. Apply ½ of the recommended rate after the first cutting and the remainder in late August or September.
3. Increase recommended K_2O application rate by 50 lb/ac for each additional ton of expected yield above 1.5 ton/ac.

Magnesium

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

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

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

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

Sulfur

Sulfur (S) deficiency is occasionally observed in little bluestem hay on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of NONE 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.

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

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

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for little bluestem hay.

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

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

Zinc

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

Table 6. Interpretation of zinc availability index for little bluestem hay.

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

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

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

Boron

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

Switchgrass Hay - Established Stand

Crop Highlights
• Target pH: 6.2 • Can cause liver lesions if used as the sole feed source for ruminants. • 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 cut for hay. Do not cut or mow little bluestem during the first growing season (establishment phase) unless it produces a seed head. When cutting, leave 6 to 8 inches of stubble to improve regrowth potential. Switchgrass hay can cause liver lesions if used as the sole feed source for ruminants.

Yield Goal

A realistic yield goal for a switchgrass hay crop is 3 ton/ac in a good to average year. However, yield is dependent upon several factors, including grass species, seeding rate, seeding date, age of the stand and degree of establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop and grazing management practices.

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

Target pH: 6.2

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

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

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

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

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

Nitrogen

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

1. Apply an initial N application of 40 to 60 lb/ac when growth begins in mid- to late-spring, followed by additional N in early June as needed.
2. After each cut, apply an additional 20 to 40 lb/ac of N per ton of expected yield for the next cut if soil moisture is adequate for good regrowth. For example, apply 40 to 80 lb/ac of N if the expected yield of the next cut is 2 ton/ac.
3. Adjust the N application rate as expected yield changes from cut to cut and with expected weather conditions.

Phosphorus

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

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

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

1. If M3 soil test phosphorus (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), satisfactory growth is unlikely. Evaluate the stand density to decide if replanting is appropriate since broadcasting and plowing down the recommended rate of phosphate (P_2O_5) fertilizer will produce higher yields sooner than will topdress applications.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), topdress P_2O_5 fertilizer after the first cut.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of P in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 0 lb/ac for each additional ton of expected yield above 3 ton/ac.

Potassium

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

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

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

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

Magnesium

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

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

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

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

Sulfur

Sulfur (S) deficiency is occasionally observed in switchgrass hay on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Established forage crops have deeper root systems, allowing the crop to tap into subsoil stores of S. Cutting hay removes a significant amount of S from the soil and increases the risk of S deficiency. Monitor hay crops for S deficiency if not using an N source that contains S. Confirm S deficiency with a tissue test; collect a tissue samples from the top 6 inches of the shoots just before flowering. The sufficiency range for cool season grasses is 0.21 to 0.25% S in plant tissue.

1. Monitor hay for S deficiency or use ammonium sulfate as an N source to supply needed S.
2. If deficiency symptoms occur or the field has a documented history of S deficiency, apply S at a rate of NONE 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.

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

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

Manganese

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

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

Where:

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

Table 5. Interpretation of manganese availability index for switchgrass hay.

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

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

Zinc

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

Table 6. Interpretation of zinc availability index for switchgrass hay.

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

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

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

Boron

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