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

Nutrient Recommendations

Annual Forages – Warm Season

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Forage Sorghum

Crop Highlights
• Target pH: 6.2 • Not safe for horses; glucosides can release cyanide gas. • Do not apply nitrogen (N) until crop is 2 to 4 inches tall to avoid stimulating weeds. • Apply sulfur (S) with or without N to prevent S deficiency. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Forage sorghum is not safe for use as horse hay or for grazing horses. The highest digestibility is with brown mid-rib (BMR) hybrids. Plant forage sorghum in rows or drill seed in late May or early June. Begin grazing forage sorghum when the plants are 12 to 18 inches tall. Forage sorghum can contain glucosides that release cyanide gas; allow frost damaged hybrids to dry before grazing, ensiling, or making hay. Leave 6 to 8 inches of stubble after grazing or cutting for best regrowth. High N rates and certain environmental conditions can lead to high nitrate levels in this crop; test forage, hay, or silage for nitrate content if this is a concern. If cut for silage, forage sorghums must be wilted to lower the moisture content to the correct level for making silage.

Yield Goal

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

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

Target pH: 6.2

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

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

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

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

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

Nitrogen

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

1. Do not apply N at seeding to avoid stimulating weed competition.
2. When seedlings are 2 to 4 inches tall, broadcast N at a rate of 20 lb/ac if weed pressure is not at a competitive level.
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 tons/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 forage sorghum forage crop as a function of Mehlich-3 soil test phosphorus (M3-P) at 5.0 ton/ac yield goal.

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

1. If M3 soil test P (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), broadcast and plow down the recommended rate of phosphate (P_2O_5) fertilizer prior to seeding.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), broadcast and incorporate P_2O_5 fertilizer prior to seeding or surface broadcast at or shortly after planting.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of phosphorus in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 15 lb/ac for each additional ton of expected yield above 5.0 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 forage sorghum forage crop as a function of Mehlich-3 soil test potassium (M3-K) at 5.0 ton/ac yield goal.

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

1. Broadcast and incorporate potash (K_2O) fertilizer at or prior to seeding.
2. Application rates of 120 lb/ac of K_2O or higher should be split into two applications. Apply ½ of the recommended rate after the first cutting and the remainder in late August or September.
3. Increase recommended K_2O application rate by 50 lb/ac for each additional ton of expected yield above 5.0 ton/ac.

Magnesium

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

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

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

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

Sulfur

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

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

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

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

Manganese

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

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

Where:

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

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

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

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

Zinc

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

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

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 warm season annual forage crops. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.

Pearl Millet

Crop Highlights
• Target pH: 6.2 • Safe for horses, but nitrate can accumulate in lower stalks. • Do not apply nitrogen (N) until crop is 2 to 4 inches tall to avoid stimulating weeds. • Apply sulfur (S) with or without N to prevent S deficiency. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Pearl millet is safe for use as for grazing or haying horses. Plant pearl millet in rows or drill in late May or early June. Begin grazing pearl millet when the crop is 12 to 18 inches tall. If cutting for hay or silage, harvest at mid- to late-heading. Leave 6 to 8 inches of stubble after grazing or cutting for best regrowth. Pearl millet has potential to accumulating nitrates in the lower 6 inches of the stalks; test forage, hay, or silage for nitrate content if this is a concern.

Yield Goal

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

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

Target pH: 6.2

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

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

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

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

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

Nitrogen

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

1. Do not apply N at seeding to avoid stimulating weed competition.
2. When seedlings are 2 to 4 inches tall, broadcast N at a rate of 20 lb/ac if weed pressure is not at a competitive level.
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 tons/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 pearl millet forage crop as a function of Mehlich-3 soil test phosphorus (M3-P) at 3.0 ton/ac yield goal.

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

1. If M3 soil test P (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), broadcast and plow down the recommended rate of phosphate (P_2O_5) fertilizer prior to seeding.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), broadcast and incorporate P_2O_5 fertilizer prior to seeding or surface broadcast at or shortly after planting.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of phosphorus in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 15 lb/ac for each additional ton of expected yield above 3.0 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 pearl millet forage crop as a function of Mehlich-3 soil test potassium (M3-K) at 3.0 ton/ac yield goal.

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

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

Magnesium

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

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

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

1. Magnesium (Mg) is recommended when M3-Mg is less than 40 FIV.
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 pearl millet grown on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Newly planted forage crops are susceptible to S deficiency because their shallow root systems do not allow the crop to tap into subsoil stores of S. Cutting hay also removes a significant amount of S from the soil and increases the risk of S deficiency. Legumes are more susceptible to S deficiency than grass species.

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

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

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

Manganese

Manganese (Mn) needs are predicted by an availability index (MnAI) that includes M3 soil test Mn (M3-Mn) and soil pH. Interpretation of MnAI is crop specific (Table 5). Annual 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 pearl millet.

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 pearl millet.

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 warm season annual forage crops. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.

Sorghum/Sudangrass Hybrid

Crop Highlights
• Target pH: 6.2 • Not safe for horses; glucosides can release cyanide gas. • Do not apply nitrogen (N) until crop is 2 to 4 inches tall to avoid stimulating weeds. • Apply sulfur (S) with or without N to prevent S deficiency. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Sorghum/sudangrass hybrids are not safe for use as horse hay or for grazing horses. The highest digestibility is with brown mid-rib (BMR) hybrids. Plant sorghum/sudangrass hybrids in rows or drill seed in late May or early June. Begin grazing sorghum/sudangrass when the plants are 12 to 18 inches tall. Sorghum/sudangrass can contain glucosides that release cyanide gas; allow frost damaged hybrids to dry before grazing, ensiling, or making hay. Leave 6 to 8 inches of stubble after grazing or cutting for best regrowth. High N rates and certain environmental conditions can lead to high nitrate levels in this crop; test forage, hay, or silage for nitrate content if this is a concern.

Yield Goal

A realistic yield goal for a sorghum/sudangrass hybrid forage crop is 4.0 ton/ac in a good to average year. However, yield is dependent upon several factors, including grass species, seeding rate, seeding date, degree of stand establishment, stand composition, soil type and water-holding capacity, nutrient and water availability, weed, insect and disease pressure, crop management practices, and grazing management practices.

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

Target pH: 6.2

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

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

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

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

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

Nitrogen

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

1. Do not apply N at seeding to avoid stimulating weed competition.
2. When seedlings are 2 to 4 inches tall, broadcast N at a rate of 20 lb/ac if weed pressure is not at a competitive level.
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 tons/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 sorghum/sudangrass hybrid forage crop as a function of Mehlich-3 soil test phosphorus (M3-P) at 4.0 ton/ac yield goal.

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

1. If M3 soil test P (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), broadcast and plow down the recommended rate of phosphate (P_2O_5) fertilizer prior to seeding.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), broadcast and incorporate P_2O_5 fertilizer prior to seeding or surface broadcast at or shortly after planting.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of phosphorus in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 15 lb/ac for each additional ton of expected yield above 4.0 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 sorghum/sudangrass hybrid forage crop as a function of Mehlich-3 soil test potassium (M3-K) at 4.0 ton/ac yield goal.

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

1. Broadcast and incorporate potash (K_2O) fertilizer at or prior to seeding.
2. Application rates of 120 lb/ac of K_2O or higher should be split into two applications. Apply ½ of the recommended rate after the first cutting and the remainder in late August or September.
3. Increase recommended K_2O application rate by 50 lb/ac for each additional ton of expected yield above 4.0 ton/ac.

Magnesium

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

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

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

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

Sulfur

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

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

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

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

Manganese

Manganese (Mn) needs are predicted by an availability index (MnAI) that includes M3 soil test Mn (M3-Mn) and soil pH. Interpretation of MnAI is crop specific (Table 5). Annual 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 sorghum/sudangrass hybrid.

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 sorghum/sudangrass hybrid.

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 warm season annual forage crops. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.

Spring Oats

Crop Highlights
• Target pH: 6.2 • Quick growing crop is excellent emergency forage. • Do not apply nitrogen (N) until crop is 2 to 4 inches tall to avoid stimulating weeds. • Apply sulfur (S) with or without N to prevent S deficiency. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Spring are a quick growing crop that is useful as an emergency forage. Spring oats require a short (60-day) growing period before they can be grazed or cut for hay or silage. Spring oats can be summer seeded from May through August. Increase seeding rate to 2 bu/ac when grown for grazing, hay, or silage. Spring oat cultivars generally respond to day length (require long days) to flower, but seldom require a cold period to flower. If planted late in the summer (July to August) as an emergency forage crop, seed heads may not form. Forage quality declines as seed heads emerge, flower, and mature seed.

Yield Goal

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

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

Target pH: 6.2

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

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

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

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

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

Nitrogen

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

1. Do not apply N at seeding to avoid stimulating weed competition.
2. When seedlings are 2 to 4 inches tall, broadcast N at a rate of 20 lb/ac if weed pressure is not at a competitive level.
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 tons/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 spring oat forage crop as a function of Mehlich-3 soil test phosphorus (M3-P) at 2.0 ton/ac yield goal.

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

1. If M3 soil test P (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), broadcast and plow down the recommended rate of phosphate (P_2O_5) fertilizer prior to seeding.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), broadcast and incorporate P_2O_5 fertilizer prior to seeding or surface broadcast at or shortly after planting.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of phosphorus in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 15 lb/ac for each additional ton of expected yield above 2.0 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 spring oat forage crop as a function of Mehlich-3 soil test potassium (M3-K) at 2.0 ton/ac yield goal.

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

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

Magnesium

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

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

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

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

Sulfur

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

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

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

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

Manganese

Manganese (Mn) needs are predicted by an availability index (MnAI) that includes M3 soil test Mn (M3-Mn) and soil pH. Interpretation of MnAI is crop specific (Table 5). Annual 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 spring oat.

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 spring oat.

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 warm season annual forage crops. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.

Sudangrass

Crop Highlights
• Target pH: 6.2 • Not safe for horses; glucosides can release cyanide gas. • Do not apply nitrogen (N) until crop is 2 to 4 inches tall to avoid stimulating weeds. • Apply sulfur (S) with or without N to prevent S deficiency. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Sudangrass is not safe for use as horse hay or for grazing horses. The highest digestibility is with brown mid-rib (BMR) sudangrass cultivars. Plant sudangrass in rows or drill seed in late May or early June. Begin grazing sudangrass when the plants are 12 to 18 inches tall. Sudangrass can contain glucosides that release cyanide gas; allow frost damaged hybrids to dry before grazing, ensiling, or making hay. Leave 6 to 8 inches of stubble after grazing or cutting for best regrowth.

Yield Goal

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

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

Target pH: 6.2

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

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

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

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

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

Nitrogen

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

1. Do not apply N at seeding to avoid stimulating weed competition.
2. When seedlings are 2 to 4 inches tall, broadcast N at a rate of 20 lb/ac if weed pressure is not at a competitive level.
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 tons/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 sudangrass forage crop as a function of Mehlich-3 soil test phosphorus (M3-P) at 3.0 ton/ac yield goal.

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

1. If M3 soil test P (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), broadcast and plow down the recommended rate of phosphate (P_2O_5) fertilizer prior to seeding.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), broadcast and incorporate P_2O_5 fertilizer prior to seeding or surface broadcast at or shortly after planting.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of phosphorus in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 15 lb/ac for each additional ton of expected yield above 3.0 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 sudangrass forage crop as a function of Mehlich-3 soil test potassium (M3-K) at 3.0 ton/ac yield goal.

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

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

Magnesium

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

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

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

1. Magnesium (Mg) is recommended when M3-Mg is less than 40 FIV.
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 sudangrass grown on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Newly planted forage crops are susceptible to S deficiency because their shallow root systems do not allow the crop to tap into subsoil stores of S. Cutting hay also removes a significant amount of S from the soil and increases the risk of S deficiency. Legumes are more susceptible to S deficiency than grass species.

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

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

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

Manganese

Manganese (Mn) needs are predicted by an availability index (MnAI) that includes M3 soil test Mn (M3-Mn) and soil pH. Interpretation of MnAI is crop specific (Table 5). Annual 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 sudangrass.

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 sudangrass.

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 warm season annual forage crops. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.

Teff

Crop Highlights
• Target pH: 6.2 • Best use is hay since due to shallow root system. • Do not apply nitrogen (N) until crop is 2 to 4 inches tall to avoid stimulating weeds. • Apply sulfur (S) with or without N to prevent S deficiency. • Forage and hay crops are moderately sensitive to manganese (Mn) deficiency.

Management Notes

Teff is best used as a hay crop because of the potential for grazing animals to pull plants up due to a shallow root system. Suppress existing sod with herbicide or heavy grazing before planting teff. Plant in late May or early June once soil temperatures have warmed. Teff has very small seed; use coated seed and apply at a higher seeding rate. If grazing, begin at early to mid-heading for best chance for multiple grazing cycles. If cutting for hay or silage at early- to mid-heading or very early bloom for best chance at a second cutting. Leave 4 to 6 inches of stubble after grazing or cutting to help regrowth as carbohydrate reserves are stored in lower stems.

Yield Goal

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

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

Target pH: 6.2

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

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

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

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

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

Nitrogen

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

1. Do not apply N at seeding to avoid stimulating weed competition.
2. When seedlings are 2 to 4 inches tall, broadcast N at a rate of 20 lb/ac if weed pressure is not at a competitive level.
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 tons/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 teff forage crop as a function of Mehlich-3 soil test phosphorus (M3-P) at 3.0 ton/ac yield goal.

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

1. If M3 soil test P (M3-P) is “Low” or “Medium” (i.e., 50 FIV or less), broadcast and plow down the recommended rate of phosphate (P_2O_5) fertilizer prior to seeding.
2. If M3-P is “Optimum” (i.e., 51 to 100 FIV), broadcast and incorporate P_2O_5 fertilizer prior to seeding or surface broadcast at or shortly after planting.
3. If M3-P is “Excessive” (i.e., greater than 100 FIV), the application of phosphorus in fertilizers or manures is NOT RECOMMENDED.
4. Increase recommended P_2O_5 application rate by 15 lb/ac for each additional ton of expected yield above 3.0 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 teff forage crop as a function of Mehlich-3 soil test potassium (M3-K) at 3.0 ton/ac yield goal.

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

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

Magnesium

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

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

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

1. Magnesium (Mg) is recommended when M3-Mg is less than 40 FIV.
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 teff grown on Delaware soils. Symptoms include reduced growth and a general yellowing of the plant. Newly planted forage crops are susceptible to S deficiency because their shallow root systems do not allow the crop to tap into subsoil stores of S. Cutting hay also removes a significant amount of S from the soil and increases the risk of S deficiency. Legumes are more susceptible to S deficiency than grass species.

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

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

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

Manganese

Manganese (Mn) needs are predicted by an availability index (MnAI) that includes M3 soil test Mn (M3-Mn) and soil pH. Interpretation of MnAI is crop specific (Table 5). Annual 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 teff.

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 teff.

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 warm season annual forage crops. If symptoms are observed in the field, contact your county agent for assistance with diagnosis and corrective treatments.