



## Recommended Hay and Pasture Forages for Michigan

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Perennial legume and grass forages are the backbone of Michigan forage production. The popularity of forage species as cover crops has led to an explosion of availability in annual species that also have value as forage. This abundance of choices can lead to confusion when deciding which species is best for a given situation. There is a vast number of forage species used worldwide, and they are not all suitable for Michigan.

This publication provides planting information on forage species that have proven track records and are therefore recommended for use in Michigan. Functional type, life cycle, adaptation to common environmental conditions, recommended seeding rates and depths, suitability as hay, haylage, pasture, or cover crop, and potential animal health problems are included.

Forage species that are not included in this publication may not be cold-tolerant enough to grow reliably in Michigan, may have noxious weed status in Michigan and are therefore illegal to plant, or we simply may not have reliable data about their performance in Michigan. If you are unsure which is the case regarding an unusual forage species, contact Michigan State University Extension for assistance. When planting something new to your farm, it is always wise to start with a small acreage to test suitability for your specific conditions.

Forage crop species are classified into four functional groups according to their physiology and morphology.

1. **Cool-season grasses** prefer cool weather and grow best in spring and fall, slowing down considerably in summer.
2. **Warm-season grasses** rejoice in heat and grow best in summer, but may not have enough cold tolerance to survive a Michigan winter or even a killing frost.

3. **Legumes** are broadleaf, non-woody plants that are able to obtain nitrogen from air through their symbiotic relationship with Rhizobia bacteria living in root nodules, a process known as nitrogen fixation.
4. **Forbs** are broadleaf, non-woody plants that do not fix nitrogen.

Within the four functional groups, forage species are further classified into three life cycles.

1. **Annual species** grow quickly, flower once, produce seed, and then die, often within a single growing season. Some annuals require a cold period called vernalization before flowers can be produced. This type is called a **winter annual** and can be seeded in fall, overwinter, and then flower and die the following spring. Annuals that do not require vernalization are called **spring annuals**.
2. **Biennial species** require vernalization and are programmed to live for two growing seasons. Biennial species often look very different in their two years of life, taking a short rosette growth habit the first year and consisting of tall flowering stalks in the second year, a process known as bolting. Like annuals, biennials die after flowering.
3. **Perennial species** do not die after flowering and can potentially live to flower again and again for many years under optimal conditions. The tendency of a perennial to be long-lived is called persistence. Persistence of a particular species depends on: its inherent vigor; disease and pest resistance; tolerance to heat, cold, drought, flooding, poor fertility, shade and other environmental factors; and management decisions that affect survival. Persistence is a valuable trait for improved perennial forage varieties and is selected for by plant breeders.

**Table 1. Characteristics and management recommendations for Michigan forage grasses.**

Species	Life Cycle <sup>a</sup>	RECOMMENDED USES						SEEDING CHARACTERISTICS				Expected stand life (yrs)	Yield potential (Ton DM/acre/yr)
		Hay	Silage/baleage	Pasture	Cover crop	Wildlife food plot	Conservation	Seeding rate (lb PLS/acre)	Planting depth <sup>b</sup>	Avg seeds/lb	Minimum soil temperature <sup>c</sup>		
<b>PERENNIAL COOL-SEASON GRASSES</b>													
Festulolium	P	x	x	x				20-30	M	207000	mod	2-3	2-4
Kentucky Bluegrass	P			x				8-15	S	2056000	mod	5+	2-3
Meadow Bromegrass	P	x	x	x			x	15-20	M	93000	warm	5+	3-4
Meadow Fescue	P	x	x	x				15-20	M	280000	mod	3-4	2-4
Orchardgrass	P*	x	x	x			x	10-12	M	536000	mod	3-5	3-5
Perennial Ryegrass	P		x	x				20-30	M	278500	mod	2-5	2-4
Reed Canarygrass	P	x	x	x				6-8	M	509000	warm	5+	3-4
Smooth Bromegrass	P	x	x	x			x	12-15	M	139000	warm	5+	3-4
Tall Fescue	P	x	x	x				12-15	M	218000	mod	5+	3-5
Timothy	P	x	x	x				6-8	M	1199000	mod	5+	3-5

<b>ANNUAL COOL-SEASON GRASSES</b>													
Annual Ryegrass (Westerwolds)	A		x	x	x	x		20-30	B, M	209000	cool	1	1-3
Barley (winter, spring)	A	x	x	x	x	x		75-120	0.75-1.5"	14000	cool	1	1-2
Italian Ryegrass	A*		x	x	x	x		20-30	B, M	226000	cool	1-2	1-3
Oats	A	x	x	x	x	x		64-80	0.5-1.5"	17800	cool	1	2-3
Rye (cereal)	A	x	x	x	x	x		60-120	0.5-1.5"	17000	cold	1	1-3
Triticale (winter, spring)	A	x	x	x	x	x		50-120	0.5-1.5"	16000	cool	1	1-2
Wheat (winter, spring)	A	x	x	x	x	x		75-150	0.5-1.5"	13000	cool	1	1-3

<b>PERENNIAL WARM-SEASON GRASSES</b>													
Big Bluestem	P	x	x	x			x	10	M	140000	mod	5+	3
Indiangrass	P	x	x	x			x	10	M	185000	mod	5+	2
Switchgrass	P	x	x	x			x	5-8	M	314400	mod	5+	2-3

<b>ANNUAL WARM-SEASON GRASSES</b>													
Forage Sorghum	A	x	x	x	x	x		10-15	0.5-2.0"	26000	warm	1	2-5.5
Foxtail (German) Millet	A	x	x	x	x	x		20-30	0.5-2.0"	216000	warm	1	2-5
Pearl Millet	A	x	x	x	x	x		20-30	0.5-2.0"	83000	warm	1	2-4
Sudex (sorghum x sudangrass)	A	x	x	x	x	x		30-60	B, 0.5-2.0"	24000	warm	1	2-6
Sudangrass	A	x	x	x	x	x		20-30	B, 0.5-2.0"	49000	warm	1	2-5
Teff (Lovegrass)	A	x	x	x	x			6-10	S	1226000	warm	1	1-4

<sup>a</sup> Life Cycle Key: A=annual, WA=winter annual, B=biennial, P=perennial.

<sup>b</sup> Planting depth key: B=broadcast, S=0.12-0.25 inch, M=0.25-0.50 inch, D=>0.50 inch

<sup>c</sup> Soil germination temperature key: cold (34-40 F), cool (40-49 F), moderate (50-59 F), warm (60-69 F).

<sup>d</sup> Heading date key: VE=very early spring, E=early spring, L=late spring, VL=very late spring, S=summer.

<sup>e</sup> The minimum required soil pH should not be considered preferable to optimum soil pH which is 6.0 to 7.0 for most species.

<sup>f</sup> Issues key: A=alkaloids, B=bloat, GSN=glucosynolates, NP=nitrate poisoning, PA=prussic acid, PE=phytoestrogens, PEM=polioencephalomalacia, PS=photosensitization, SARA=subacute ruminal acidosis, SL=slobbers, W=weediness

**Table 1. Continued**

Species	Minimum harvest height (inches)	Heading Date <sup>d</sup>	Sod-forming	Minimum soil pH <sup>e</sup>	RATING (1=exc, 3=avg, 5=poor)								Precautions <sup>f</sup>
					Ease of establishment	Competitiveness in mixes	Tolerates low fertility	Tolerates wet soil	Tolerates drought	Tolerates heat	Tolerates cold	Tolerates shade	
Festulolium	3-4	E-L	yes	6	1	4	5	2	3	5	2	3	
Kentucky Bluegrass (Junegrass)	1-2	VE	yes	5.8	3	2	4	3	5	5	1	2	
Meadow Bromegrass	4	M	yes	6.0	5	4	5	5	2	-	1	-	
Meadow Fescue	6	E	yes	5.5	1	4	5	2	4	4	1	2	
Orchardgrass	4	VE	no	5.8	1	2	3	3	2	3	2	1	
Perennial Ryegrass	3-4	VL	yes	5.6	1	3	5	2	5	5	4	4	
Reed Canarygrass	3-4	VL	yes	5.5	5	1	1	1	1	3	1	2	A
Smooth Bromegrass	4	M	yes	5.8	5	3	4	5	2	2	1	4	
Tall Fescue	2-4	E	yes	5	1	3	1	2	1	1	3	2	A
Timothy	3-6	VL	no	5.4	1	3	4	2	5	3	1	4	

**ANNUAL COOL-SEASON GRASSES**

Annual Ryegrass (Westerwolds)	3-4	E	no	5.6	1	3	4	2	5	5	4*	4	W
Barley (winter, spring)	3-4	-	no	6	1	3	1	3	2	4	4	4	B, NP
Italian Ryegrass	3-4	L	no	6	1	3	5	2	5	5	4*	4	W
Oats	3-4	-	no	4.5	1	3	2	3	4	4	4	4	B, NP
Rye (cereal)	3-4	-	no	5	1	3	1	3	2	4	1	2	B, NP, W
Triticale (winter, spring)	3-4	-	no	5.2	1	3	1	3	2	4	2	2	B, NP
Wheat (winter, spring)	3-4	-	no	6	1	3	1	3	2	4	1	2	B, NP

**PERENNIAL WARM-SEASON GRASSES**

Big Bluestem	6	S	no	5.4	5	5	3	5	2	1	1	5	
Indiangrass	6	S	no	5.4	5	5	3	2	1	1	1	4	
Switchgrass	6-12	S	yes	5.4	5	5	3	2	2	1	1	4	

**ANNUAL WARM-SEASON GRASSES**

Forage Sorghum	4-6	-	no	6	1	2	2	5	1	1	5	5	NP, PA, cystitis
Foxtail (German) Millet	4-8	-	no	5.5	2	3	2	4	2	1	5	-	NP, awns
Pearl Millet	4-6	-	no	5.5	1	3	1	5	1	1	5	5	NP
Sudex (sorghum x sudangrass)	4-6	-	no	6	1	2	2	5	1	1	5	5	NP, PA, cystitis
Sudangrass	4-6	-	no	6	1	2	2	5	1	1	5	5	NP, PA
Teff (Lovegrass)	4	-	no	5.5	5	5	3	2	1	2	5	2	

<sup>a</sup> Life Cycle Key: A=annual, WA=winter annual, B=biennial, P=perennial.

<sup>b</sup> Planting depth key: B=broadcast, S=0.12-0.25 inch, M=0.25-0.50 inch, D=>0.50 inch

<sup>c</sup> Soil germination temperature key: cold (34-40 F), cool (40-49 F), moderate (50-59 F), warm (60-69 F).

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**Table 2. Characteristics and management recommendations for Michigan forage legumes and forbs.**

Species	Life Cycle <sup>a</sup>	RECOMMENDED USES						SEEDING CHARACTERISTICS				Expected stand life (yrs)	Yield potential (ton DM/acre/yr)
		Hay	Silage/baleage	Pasture	Cover crop	Wildlife food plot	Conservation	Seeding rate (lb PLS/acre)	Planting depth <sup>b</sup>	Avg seeds/lb	Minimum soil temperature <sup>c</sup>		
<b>LEGUMES</b>													
Alfalfa	P	x	x	x	x		x	12-16	M	213000	cool	3-5+	2-8
Alsike Clover	P	x	x	x		x	x	3-5	M	667000	cool	2	1-3
Berseem Clover	A	x	x	x	x	x		8-25	M	207000	cool	1	1-1.5
Birdsfoot Trefoil	P	x	x	x		x		6-10	S	371000	cool	2-3	1-4
Crimson Clover	A	x	x	x	x	x		20-30	B,S	150000	cool	1-2	1-1.8
Field/Winter Pea	A	x	x	x	x	x		30-180	D	3400	cool	1	1-3
Kura Clover	P	x	x	x		x		4-12	M	223000	cool	5+	1-2.5
Red Clover	P	x	x	x	x	x	x	8-12	B, M	262000	cool	2	1-4
Soybean	A	x	x	x		x		60-80	1.5-2"	3400	warm	1	2-4
White Clover	P	x	x	x		x	x	2-3	B, M	822000	cool	2-5	1-2.5

<b>FORBS</b>													
Chicory	P		*	x		x		4-6	B,M	426000	warm	3-4	1-5
Collards	B		*	x	x	x		4-6	M	175000	mod	1	1
Kale	B		*	x	x	x		4-6	B, M	144000	mod	1	1-5
Radish	A		*	x	x	x		5-12	B, M	32500	mod	1	1-5
Rape	B		*	x	x	x		4-6	B, M	148000	mod	1	1-5
Turnip	B		*	x	x	x		4-6	B,M	183000	mod	1	1-3

<sup>a</sup> Life Cycle Key: A=annual, WA=winter annual, B=biennial, P=perennial.

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\*Most forbs are not suitable as silage when grown alone because of high moisture content, but can be ensiled if mixed with drier forage.



Table 2. Continued

Species	Minimum harvest height (inches)	Heading Date <sup>d</sup>	Sod-forming	Minimum soil pH <sup>e</sup>	RATING (1=exc, 3=avg, 5=poor)								Precautions <sup>f</sup>
					Ease of establishment	Competitiveness in mixes	Tolerates low fertility	Tolerates wet soil	Tolerates drought	Tolerates heat	Tolerates cold	Tolerates shade	
<b>LEGUMES</b>													
Alfalfa	2-4	L	no	6.8	1	3	5	5	2	2	1	4	B, PE
Alsike Clover	3-4	E	no	6	1	3	4	1	4	3	1	4	B, SL, PS
Berseem Clover	3-4	-	no	6	2	3	4	2	1	1	5	4	B
Birdsfoot Trefoil	3-4	E-L	no	6	3	4	2	2	2	3	2	4	
Crimson Clover	3-4	-	no	5.5	2	3	1	5	2	2	4	2	B
Field/Winter Pea	-	-	no	6	1	3	4	5	4	4	2-5	4	
Kura Clover	2	VL	yes	6	5	1	4	2	2	2	1	1	B
Red Clover	2	E	no	6.2	1	3	3	2	4	3	1	1	B, PE, SL
Soybean	-	-	no	6.2	1	3	5	4	2	2	5	4	B, PE
White Clover	2	VE	yes	6	2	3	4	2	4	4	1	4	B, PE, SL

<b>FORBS</b>													
Chicory	2	E	no	6	2	2	2	5	2	2	3	3	NP
Collards	-	-	no	6	2	2	4	5	2	3	1	4	B, NP, PEM, GSN, SARA
Kale	-	-	no	6	2	2	4	5	2	3	1	4	B, NP, PEM, GSN, SARA
Radish	4	-	no	6	2	2	4	5	2	2	2	4	B, NP, PEM, GSN, SARA
Rape	6-10	-	no	6	2	2	4	5	2	4	1	4	B, NP, PEM, PS, GSN, SARA
Turnip	4	-	no	5.3	2	2	5	5	4	3	2	4	B, NP, PEM, GSN, SARA

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\*Most forbs are not suitable as silage when grown alone because of high moisture content, but can be ensiled if mixed with drier forage.



## SEEDING RATE

Monoculture (single species) forage seeding rates for small-seeded perennials are usually designed to place approximately 100 to 125 seeds per square foot. Planting more seeds than this is counterproductive in a monoculture because the seedlings will crowd each other. Annual forages with large seeds are usually planted at much lower seed densities.

In the tables, seeding rates are shown as a range for planting a single species as a monoculture and are based on pure live seed (PLS) that is not coated. To calculate percent PLS for your seed, multiply % germination times % purity times 100. By law, these germination and purity numbers will be found on your seed tag. Seeding rates are presented as ranges because they need to be adjusted according to your specific conditions. Seeding rates in the lower end of the recommended ranges are used when planting conditions are near ideal and soil-seed contact is ensured by placing seed in the ground with a drill. When broadcasting seed or planting under less-than-ideal site preparation or environmental conditions, the higher end of the range should be used.

Forage seeds are often sold with proprietary coatings and seed treatments designed to improve germination, growth, survival, or seed flow through planting equipment. Coatings reduce the weight of PLS in a bag of seed by up to 50%, but they are designed to improve germination and establishment so that less seed per acre is needed to get a good stand. Like any other planting decision, whether or not to adjust planting rates for coatings must be considered on a case by case basis. Keep in mind that coatings are likely to affect seed flow through planting equipment and thus invalidate the species settings in your planter manual. Because seed size will also vary between seed lots, seeding rates should always be validated with a physical calibration using the actual seed and planter being used. See Teutsch (2009) for an excellent tutorial on how to calibrate forage seeding equipment.

## SEEDING DEPTH

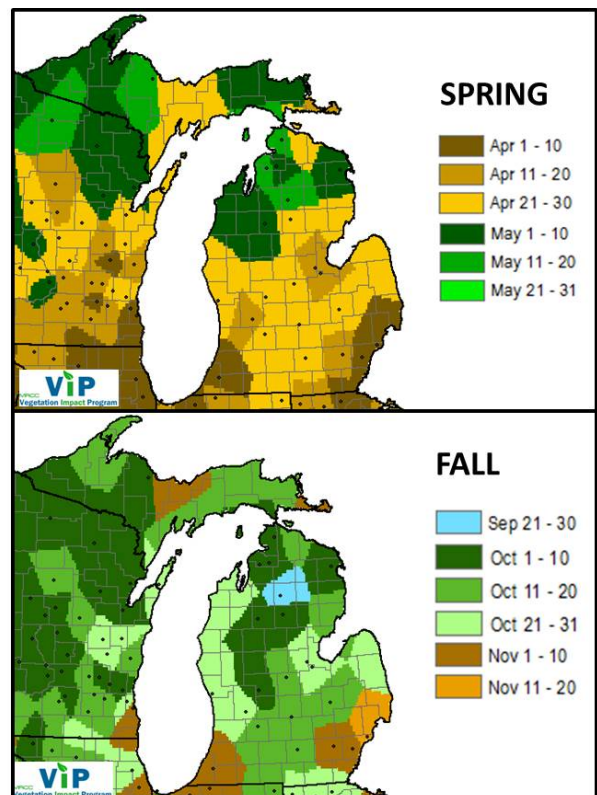
Planting small forage seeds too deep is the most common reasons for failed establishment. It is critical to pay attention to recommended seeding depth in the tables and make sure equipment is placing seed accurately at the desired depth. When mixture components have no overlap in recommended seeding depth, it may be beneficial to make two seeding passes to accommodate the different seeding depths. However, small seeds may successfully emerge from deeper than recommended depths if they can “follow” the path of larger seeds in the mixture.

## WHEN TO PLANT

Recommended spring planting dates are based on soil temperature. Optimum germination temperatures for each species are listed in Tables 1 and 2 as cold (34-40 F), cool (40-49 F), moderate (50-59 F), and warm (60-69 F). Species that germinate in cool or cold soil can be planted early into cold or

even frozen soil where seeds will wait for appropriate soil temperatures before germinating. Species that require moderate to warm soil for germination should not be planted until soil has reached the recommended temperature because cold-stressed seedlings may be permanently damaged and never develop their full yield potential even if they survive. Local soil temperatures can be monitored using a soil thermometer or the MSU Enviroweather weather monitoring system. Warm season forages can be killed by frost and should not be planted until after the last frost (Figure 1).

Recommended late-season planting dates are based on the time required for perennial forage seedlings to develop strong root systems that can reliably survive their first winter and thus reduce the risk of establishment failure. For most species this requires six to eight weeks of above-freezing temperatures after planting. Figure 1 shows median dates of first killing frost across the state. When winter comes late, planting after the cutoff date may be successful, but the probability of success should be carefully weighed against the cost of site preparation, planting, and seed purchase. A few annual forages like rye, triticale, and wheat can survive winter when planted close to or even after fall frost, but in this case do not expect any harvestable forage until spring.



**Figure 1. Median date of last spring and first fall freeze (28°F) in Michigan (adapted from ViP - Midwestern Regional Climate Center, 2019) 30-year average 1980-2010). Half of all years fall before and half after the median date.**

For species with wide planting date ranges, planting early in the season has the advantages of better moisture availability and allowing more cuttings and yield in the seeding year, but usually has more weed, insect, and disease pressure. Late summer planting avoids most pest pressure, but risks drought and the early arrival of winter, and may not provide any yield the first year.

## RECOMMENDED SPECIES

### COOL-SEASON PERENNIAL GRASSES

**Bromegrasses** (*Bromus spp.*) are cool-season rhizomatous, sod-forming grasses that are high in forage quality and yield. **Smooth bromegrass** is one of the most winter-hardy grasses in Michigan and can be grown on a wide range of soil types. Smooth bromegrass has poor regrowth potential, producing most of its yield in the first cutting, and it should not be grazed or cut during stem elongation or early heading to prevent a reduction in tillering. **Meadow brome** has better regrowth potential and heat tolerance than smooth brome. Hybrid crosses between smooth and meadow brome, sometimes called **intermediate brome**, can have the best traits of both parents.

**Fescues** (*Schedonorus spp.*) are cool-season sod-forming grasses known for good fall growth and stockpiling potential. **Tall fescue** is persistent under frequent short grazing, heavy traffic, heat, drought, and poor drainage on a range of soil types, but has less cold tolerance for Northern Michigan than many other grasses. Because of tough leaves, it is generally less palatable to pastured livestock than many other species, but soft-leaf varieties exist. Tall fescue naturally contains an endophytic fungus that aids plant stress tolerance, but produces alkaloids toxic to livestock eating the forage. Many improved varieties of tall fescue are endophyte-free or contain “friendly” novel endophytes that are not toxic to animals. In Michigan, planting endophyte-free varieties is recommended. Avoid turfgrass varieties of tall fescue because these are not bred for high yields. **Meadow fescue** has better forage quality, palatability, and cold tolerance than tall fescue and does not contain toxic endophytes, but it yields about 25% less than tall fescue in MSU variety tests.

**Festuloliums** (*Schedonorus x Lolium spp.*) are hybrid crosses between a fescue (meadow or tall fescue) and a ryegrass (perennial or Italian ryegrass), thus combining the persistence and productivity of fescue with the palatability and nutritive quality of ryegrass. The large number of possible parent combinations results in a large range of appearance, yield and quality characteristics among festulolium varieties—some resemble the fescue parent while others resemble ryegrass. Therefore, it is impossible to generalize the characteristics of festuloliums, and it is essential to pay attention to the specific variety being purchased.

**Kentucky bluegrass** (*Poa pratensis*), sometimes called Junegrass, is a relatively short, sod-forming perennial cool-season grass that is very palatable when vegetative. It persists under frequent, close grazing and is very winter hardy in

Michigan, but is unpalatable when heading and quickly goes dormant under hot, dry summer conditions. Because of short stature potential, Kentucky bluegrass is more suitable for pastures than for hayfields. This species is also used as a turfgrass, so be sure to purchase varieties bred specifically for forage in order to get the best yield.

**Orchardgrass** (*Dactylis glomerata*) is a high-yielding, competitive, perennial cool-season bunchgrass that grows more rapidly than most other Michigan forages in the early spring. Orchardgrass grows well on a wide range of soil types, but is not suited for wet sites. Orchardgrass has similar nutritive characteristics to timothy and smooth bromegrass, and is often grown together with alfalfa. Choose late-maturing varieties of orchardgrass to better match alfalfa maturity when the two are grown in mixture. In mixtures with alfalfa, orchardgrass seeding rates should be limited to no more than 2 lb/acre unless a grass-dominant stand is wanted.

**Reed Canarygrass** (*Phalaris arunifera*) is a high yielding but relatively low quality, perennial sod-forming, cool-season grass. It is extremely tolerant of poor drainage and flooding and also tolerant of drought. It establishes slowly but once established, it is very competitive and therefore does not perform well in mixtures. Plant only low alkaloid varieties to improve palatability when growing as a forage crop.

**Ryegrasses** (*Lolium spp.*) are sod-forming cool-season bunchgrasses that are noted for extremely high forage quality and good regrowth potential. **Perennial ryegrass** is suitable for rotational grazing and multiple harvests for haylage, but it lacks the winterhardiness of many other grasses in Michigan, will go dormant under hot, dry conditions, and is difficult to dry as hay because of its waxy leaf cuticle. It requires high fertility and performs best under irrigation in Michigan. Avoid turfgrass varieties of perennial ryegrass because these are not bred for forage conditions. **Annual (Westerwold)** and **Italian ryegrasses** are short-lived species that differ from each other primarily in vernalization requirement for flowering. Italian ryegrass requires a cold period to initiate heading and annual ryegrass does not. Italian and annual ryegrasses are generally similar to perennial ryegrass in adaptation and use characteristics, except that many varieties are not winterhardy in Michigan. Annual ryegrass is often added to perennial pasture mixes as a nurse crop to provide fast ground cover while the slower-developing perennials take root. It will not persist past its first flowering and should not consist of more than 25% of perennial mixtures by weight.

**Timothy** (*Phleum pratense*) is a cool-season bunchgrass that forms an open sod and persists well under poorly drained conditions. It is best known for its winterhardiness and ability to survive under ice sheeting. Timothy is a late-maturing grass that produces most of its yield in the first cutting and requires a long rest period after harvest, making it undesirable for harvest systems with more than two cuttings. New timothy varieties are bred for better regrowth potential and earlier maturity that is more compatible in alfalfa mixtures.

## COOL-SEASON ANNUAL GRASSES

**Small Grains** are cool-season annual grasses that make excellent forage. While **oats** and **triticale** are most often thought of as forage crops, **wheat**, **rye**, and **barley** can also be grazed, hayed, or ensiled. Spring types of any small grain can be planted spring to midsummer to provide forage in the same year. Winter triticale, wheat, rye, and barley can be planted in fall and harvested as forage in spring. Oats will winterkill in Michigan. Rye, triticale, and wheat are the best options if overwintering is desired for a spring forage harvest.

## WARM-SEASON PERENNIAL GRASSES

**Switchgrass** (*Panicum virgatum*), **big bluestem** (*Andropogon gerardii*), and **Indiangrass** (*Sorghastrum nutans*) are native perennial warm-season grasses that are primarily used as conservation plantings for wildlife in Michigan. These native species take a full year or more to establish and therefore do not perform well in mixes with introduced cool season species in Michigan. They can be grazed or harvested as hay, but the effective growing season in Michigan is short, forage quality is relatively low and regrowth after grazing/cutting is poor.

## WARM-SEASON ANNUAL GRASSES

**Forage sorghum and sudangrass** (*Sorghum* spp.) are annual warm-season grasses. Hybrids of forage sorghum and sudangrass are often referred to as sudex. These forages require the warmest soil for germination among our recommended species. They also require average daily temperatures of 80°F or greater to achieve maximum yield potential. Sorghums contain prussic acid and may cause poisoning if livestock consume wilted forage, such as frosted pasture or immature green chop. Sorghum and sorghum-sudangrass should not be grazed or chopped until shoots are 18-24 inches tall. Prussic acid dissipates after hay, haylage, or baleage is fully cured or fermented (three to four weeks). Sorghums can be difficult to dry for hay in Michigan because thick stems dry slowly, but make good haylage and baleage. Sorghums should not be fed to horses because they can cause cystitis.

**Millets** are a group of fast-growing warm-season annual grasses characterized by small round seeds. Pearl (*Pennisetum glaucum*) and foxtail (*Setaria italica*, also known as German millet) millets are the best yielding choices in Michigan. They can provide one to two cuts or grazings per year. Cultural requirements and cautions are similar to sorghums, with the advantage that millets do not contain prussic acid.

**Teff** (*Eragrostis tef*), sometimes called lovegrass, is an annual, frost-tender, warm-season grass with extremely small seeds and fast seedling growth that may be harvestable within 45 days after planting. It can be difficult to establish unless the seedbed is extremely firm and smooth, but can provide multiple cuttings of high quality hay suitable for all livestock species.

## LEGUMES

**Alfalfa** (*Medicago sativa*) is the standard to which all other perennial forages are compared. It has the greatest yield potential among perennial options in Michigan and excellent nutritive value when harvested at late bud stage. However, it is a high maintenance crop. It requires excellent drainage, the greatest soil pH among recommended forages (pH 6.8), high soil fertility for P, K, and S, and attention to insect and disease control for best performance. For more information about alfalfa, see Undersander et al. (2015).

**Alsike Clover** (*Trifolium hybridum*) is a short-lived perennial clover that is similar in management requirements and characteristics to red clover, but without the leaf hairs. Alsike clover is suitable forage for cattle, sheep, and goats, but is toxic to horses and is not recommended for horse hay or pasture.

**Berseem clover** (*Trifolium alexandrinum*) is an annual clover with fast establishment and poor winter survival potential. Berseem regrows readily and can provide multiple grazings or hay cuttings if sown early in the season. The pasture bloat risk of berseem clover is low.

**Birdsfoot Trefoil** (*Lotus corniculatus*) is a perennial legume with lower yield potential than alfalfa, but similar forage quality. Birdsfoot trefoil is the only confirmed non-bloating legume recommended for Michigan pastures, and it also may provide some protection against gastrointestinal nematodes in pastured sheep and goats.

**Crimson Clover** (*Trifolium incarnatum*) is an annual clover whose forage use is primarily as a grazed cover crop. It may overwinter in Michigan if the winter conditions are mild. Regrowth is poor after grazing.

**Kura clover** (*Trifolium ambiguum*) is a short-stature, long-lived perennial clover that spreads via vigorous rhizomes and is better suited for pasture than hay. Kura popularity is limited because it is extremely slow to establish, taking three years of careful management to reach full productivity.

**Peas** (*Pisum sativum*) come in two types differing primarily in cold tolerance. Field peas will usually winterkill. Austrian winter peas have better cold tolerance, but still do not reliably overwinter in Michigan. Peas are best used as a short-rotation silage, baleage, or grazed crop when grown in combination with a fast-growing small grain like oats to help support the vining growth habit of peas.

**Red Clover** (*Trifolium pratense*) is a short-lived perennial legume with good yield and quality potential throughout Michigan. It has good tolerance of poor drainage and is among the best choices for shade and frostseeding. Red clover hay tends to be difficult to dry and dusty due to the presence of leaf hairs, but reduced hair varieties are available.

**Soybeans** (*Glycine max*) can be used as silage, baleage, pasture, and hay. Varieties developed specifically as forage have greater biomass and leaf production with fewer beans than bean varieties.



**White Clover** (*Trifolium repens*) is a long-lived perennial legume that spreads via creeping stolons and has several types. The type with short height, dense stolons and small leaves is known as **Dutch White Clover** and is suited only for pastures. Taller, larger-leaved varieties are often called **Ladino or Intermediate White Clover**, and work well in both pastures and hay mixtures.

## FORBS

**Chicory** (*Cichorium intybus*) is a short-lived perennial forb. Some forage chicory varieties are strongly biennial, but most will persist for three to five years. Chicory is best suited as part of a forage mixture. Chicory seedlings are very competitive, so seed proportions in mixtures should be kept low. Chicory flowers aggressively with large coarse stems that dry slowly, and is better suited for pastures than hay mixes.

**Brassicac**s (*Brassica* and *Raphanus* spp.) are annual or biennial forbs with high yield potential and outstanding forage quality. Species most suitable as forage crops in Michigan include **turnips, rape, kale, collards, radishes**, and hybrids of these species. Any variety can be used including those popular as cover crops, but varieties developed specifically as forage usually have greater yield potential and greater proportion of leaf versus stem or bulb. The best use of brassicas is as pasture. They have extremely high moisture content and are not suitable as hay. They can be harvested as haylage if grown in a mixture that brings total mix dry matter content into the range of 40 to 60% at ensiling.

## MIXTURES

Planting mixtures of forage species is desirable because it adds biodiversity to the farm ecosystem. This helps improve resilience to environmental stresses like drought, cold, heat, and pests, and thus increases stand life. Mixtures often display a more even seasonal yield distribution because each component peaks at a slightly different time, especially when components come from different functional groups. This also means the specific proportion of species will change over the growing season and this can cause variation in potential forage quality. Grass/legume mixtures tend to be predominantly grass in the spring, with a greater proportion of legume in regrowth. Mixtures that include legumes can eliminate the need to apply purchased nitrogen, and also improve nutritional value of the forage for livestock. Growing alfalfa in mixtures with grasses can improve the rate of hay drying and is especially marketable as horse hay.

Growing forage mixtures is as much art as science. The sheer number of possible combinations of forage species is overwhelming, and there is usually more than one acceptable mixture for any purpose and site. Despite best-laid plans, it is likely that the actual proportion of species in the established stand will be different from what was planted. This happens because fields are never uniform in soil type, fertility, or

microenvironment. Each forage species in the mixture will segregate to fit their preferences for environmental conditions within the field. This can be a good thing because the grower does not have to decide exactly what and where to plant specific species based on site characteristics. However, use of species that are poorly suited for large portions of a field can drive up seed costs and reduce establishment success. When planning a mixture, the most important considerations are suitability of the included species for site conditions, intended use of the forage (harvest method, animal species and class), expected stand life, and compatibility of the species with each other.

There is more than one possible mixture that is suitable for almost every situation. Do not be afraid to experiment on your farm, but start out small when trying something new. If it works, you can expand the acreage. For hayfields, two-species mixtures of one grass and one legume may be easiest to manage for harvest scheduling and predictable forage quality. A good rule of thumb for Michigan pastures is to mix at least four species that come from the cool-season grass and legume groups. In pastures, legumes should be limited to 40% or less of the pasture to help prevent pasture bloat. Hay does not cause bloat, so greater proportions of legume can be used in hayfields. Because the native warm-season perennial grasses suitable to Michigan are very slow to establish, they usually do poorly when mixed with the aggressive cool-season grasses, but they can be mixed with a low rate of legumes. Annual mixtures can be effectively selected from all four functional groups.

In a perennial mixture, species in different functional groups often do not compete for the same resources, so seed density targets up to about 150 seeds per square foot can be used. The easiest way to adjust for this is to simply plant 15-20% more of the mixed seed per acre. To design your own mixture, reduce the monoculture seeding rate of each component to the proportion of plant density you want in the established stand. Then adjust targets because individual plants of different species are not the same size and will therefore differ in yield potential (for example, tall fescue is a much larger plant than Kentucky bluegrass). These targets should also be adjusted to compensate for the ease of establishment and competitiveness of the species in mixtures (see species tables). Species that are both easy to establish and highly competitive in mixtures (rating =1 or 2 in both categories) are likely to dominate the mix unless seeding rates are reduced 50-75%. Species that are hard to establish and poorly competitive in mixtures (rating of 4 or 5 in both categories) may need to be planted at the full monoculture rate to have a chance of success. The sidebar gives an example for designing a complex seed mix.

Many seed marketers sell pre-mixed forage seed combinations aimed at specific uses. These can be an economical approach provided they consist of species that are suitable for your planned purpose. However, these often limit your options if you want to use specific species or varieties. Species, varieties, and seed proportions used in premixes may change from year to year—be sure to read the seed label so you know what you are getting each time you buy. Keep in mind that, by law, the



percentage of a species or variety in a mixture on a seed tag is based only on seed weight, not target stand density or expected contribution to harvested forage yields. Many seed distributors and some elevators will do custom seed mixing based on your specifications. A mixing and bagging fee may be charged.

**Premium Hay.** Hay, haylage, and baleage for lactating dairy cattle or grass-finishing beef and lamb needs to be of utmost quality. Alfalfa is the leading forage for this purpose, but there is increasing interest in mixing alfalfa with high quality grass to improve fiber digestibility, prolong stand life past the typical three to four years, limit weed invasion, and improve hay drying characteristics. Variety matters when mixing grasses and alfalfa. For orchardgrass, tall fescue, and meadow fescue, choose late maturing varieties to better match the maturation rate of alfalfa. For timothy, choose early varieties. To obtain hay yields of approximately 70-75% alfalfa and 25-30% grass, plant 12-15 lb/acre alfalfa with 1-3 lb orchardgrass or timothy, 3-4 lb/acre tall fescue, or 6-8 lb/acre meadow fescue or festulolium (all seeding rates on PLS basis). Regardless of what is planted, keep in mind that the most critical factor controlling forage quality in hay or haylage is harvest management, not species. The mix with the best potential quality can still yield poor forage if it is harvested too late or not preserved properly.

**Horse Hay.** Today's horse hay market focuses on hay that is grass-based with less than 50% legume, bright green color, soft texture, and free of dust and mold. The most marketable grass hays for horses are timothy, orchardgrass, and teff. Tall fescue hay is suitable for horses as long as it is an endophyte-free variety, but marketability is poor. Alfalfa is the most marketable legume for horse hay mixes. To obtain hay yields with less than 50% alfalfa as harvested yield, plant 6-8 lb/acre of alfalfa with 5-6 lb/acre of timothy or 8-10 lb/acre of orchardgrass (PLS basis).

**High Performance Pasture.** Premium pasture mixes for livestock with high nutrient needs such as grazing dairy cattle or grass-finished beef or lamb are based on high digestibility grasses like perennial ryegrass, meadow fescue, or festulolium, with legumes like alfalfa, ladino white clover, red clover, and birdsfoot trefoil. If alfalfa, white clover, or red clover comprise more than 40% of the available dry matter in the pasture, extra precautions must be taken to prevent pasture bloat. Many of these high quality forage species are not long-lived, so high-performance pastures will likely need to be replaced or renovated every three to four years.

**Horse Pasture.** Horse pastures are traditionally based on Kentucky bluegrass and white clover because these species tolerate high stocking density, hoof traffic, and short grazing heights. Timothy and ryegrasses are also palatable to horses, but less durable. Tall fescue is not palatable to horses, but it is safe to graze if an endophyte free variety is used, and its high traffic tolerance makes it useful for maintaining ground cover in horse pastures. Grasses are more durable than legumes under traffic, so legume seeding density should be kept below 30% of the seed mix.

**Low Maintenance Hayfield/Pasture.** The search for the perfect mix that performs well and persists forever with zero to low inputs is the holy grail of forages. Unfortunately, no one has found it yet. While MSUE recommends that all pastures and hayfields be well managed, it is true that some species tolerate more neglect than others. Grasses with rhizomes that form sods and legumes that can reseed themselves are often more persistent than bunchgrasses and non-reseeding legumes. Good choices for marginal management situations in Michigan include endophyte-free tall fescue, Kentucky bluegrass, smooth brome grass, orchardgrass, birdsfoot trefoil, and white clover.

## How to Formulate a Forage Seeding Mixture

- Step 1. Decide which species to use according to your needs and species characteristics (see species tables).
- Step 2. Select a starting point for seeding density of each species based on a target percentage of the monoculture seeding density (number of seeds planted per ft<sup>2</sup>, see species tables.) An equal proportion seeding density is a reasonable starting point.
- Step 3. Adjust the target seeding density for yield potential (see species tables) in the harvested mix, because small plants do not yield as much as large plants when seeded at the same density. You may deliberately want an unequal proportion of a given component in the yields—for example, 50% alfalfa.
- Step 4. Adjust the target seeding density for ease of establishment and competitiveness in mixtures (see relevant columns in species table). Reduce the proportion in mix for highly competitive species that are easy to establish (rating 2 or 1 in both categories) and increase it up to the full monoculture rate for poor competitors that are hard to establish (rating 4 or 5 in both categories).
- Step 5. Multiply target seeding density by monoculture seeding rate and divide by 100 to get mix seeding rate in lb PLS/acre for each component. If you are having a custom mix made, give these numbers to your seed supplier and they will do the rest of the calculations based on PLS of their seed sources.
- Step 6. If mixing your own seed, divide mix seeding rate in lb PLS/acre by PLS (from your seed tag: PLS = % germination x % purity / 100) and multiply by 100 to get mix seeding rate in lb seed/acre.
- Step 7. Add the weights of each component from step 6 to get the total seeding rate per acre of the seed after mixing.
- Step 8. To calculate the proportion of each seed type, divide weight (lb seed/acre) of each component by total seeding weight per acre and multiply by 100 to get the percentage of seed by weight in the planting mix.
- Example. Calculate a five-species grass/legume pasture mix that is 40% legume by seeding density.

Species	Monoculture seeding rate (lb PLS/ac)	Desired seeding density, % of sole rate	Mix seeding rate (lb PLS/ac)	PLS, %	Mix seeding rate (lb seed/acre)	Mix seed proportion by weight, %
Birdsfoot trefoil	10	30	3.3	80	4.12	30
White clover	2	10	0.2	90	0.22	2
Orchardgrass	10	40	4.0	92	4.35	32
Meadow brome	15	25	3.8	85	4.47	33
Kentucky bluegrass	8	5	0.4	95	0.42	3
<b>Total</b>					<b>13.58</b>	<b>100</b>



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