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Guide to Using Annual Forages in the Northeast

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A Guide to Using Annual Forages in the Northeast

Introduction

Perennial grasses are the main forage source for most dairy farms in the Northeastern United States (referred to hereafter as the *Northeast)*. However, annual forages have been increasing in popularity throughout the region, especially on grass-based farms where these forages can be used to boost stored feed reserves and pasture productivity throughout the season. Several factors are leading farmers to consider annual forages. First, cool season pasture perennials such as timothy, orchardgrass, and clover are prone to slow recovery periods and reductions in overall productivity when conditions get hot and dry, a phenomenon colloquially as "summer slump". Additionally, the Northeast continues to face increasingly extreme and unpredictable weather conditions that further challenge the productivity of our traditional forage production systems. Unfavorable weather conditions can impede perennial forage stand establishment, survival, productivity, and quality. Furthermore, as feed prices increase and milk prices decrease, farmers are seeking strategies to increase production of homegrown forages to supplement pasture and minimize the cost of purchasing feed.

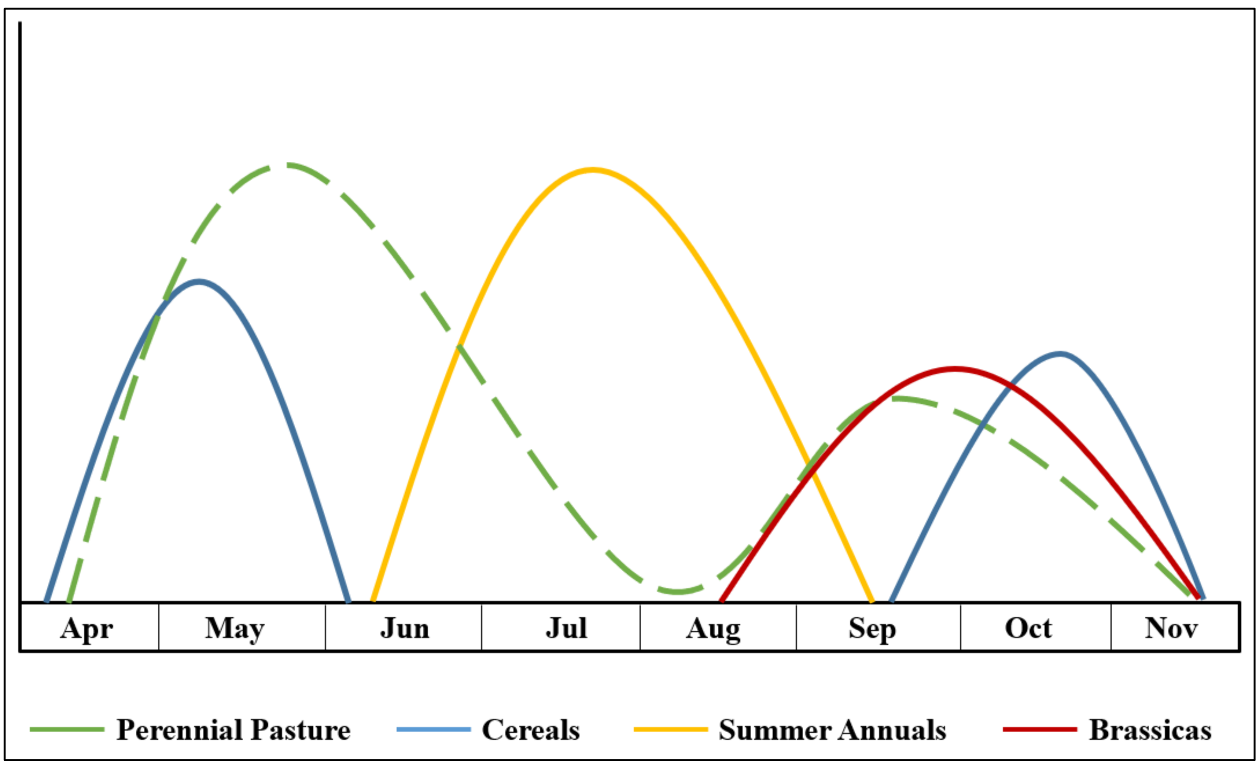


Figure 1. Dry matter production throughout the season

Maintaining adequate on-farm forage supplies across the entire season often requires a diversity of strategies, different crop types, and multiple species. (Figure 1). Annual forages can help buffer farmers against climate and economic challenges by filling in the gaps left by perennial cool season grasses. Annual forages can be planted for grazing as well as for stored feed to supplement existing feedstocks. With their quick growth, these crops can also serve as emergency forage sources if perennial stands experience winterkill or poor establishment. If renovating or replanting pasture, they can act as an excellent interim crop. They also fit into operations with standard “haymaking” equipment. For these reasons, adding annual forages to your operation can increase farm resiliency by increasing forage options and potentially decreasing the necessity for purchased feed.

Annual forages suitable for the Northeast include both warm season and cool season species. Warm season annuals, generally referred to as summer annuals, include grasses such as sudangrass, sorghum, and millet; summer legumes such as berseem clover, crimson clover, and sunn hemp; and other broadleaf crops like brassicas and buckwheat. These annuals grow best under hot conditions and can help supply much needed forage in summer months when cool season pasture plants are slow to grow. Cool season annuals, such as annual ryegrass, cereals, winter peas, and brassicas, grow in the cool conditions of the spring and fall. These are primarily used in the spring and fall to extend the grazing season beyond the capacity of summer annuals and perennial pastures. In addition to these two categories, there are other species that are typically used as cover crops in field and row crops that can also be utilized as forage in addition to cover crops. Winter cereals, such as wheat, rye, triticale, and barley, could be seeded in the fall after a cash crop, such as corn silage or other cereals, has been harvested. These cereals will grow both in the fall when planted and in the following spring, allowing for a considerable amount of additional forage if weather conditions permit and managed properly. Each of these options have benefits and limitations, including where they fit within the grazing season; some options may not be a reasonable solution for every operation. Figure 2 below illustrates the planting window and grazing availability of various annuals in different rotations. Although the text below provides some general nutrient recommendations, it is always best to consult a current soil test report for fertility recommendations.

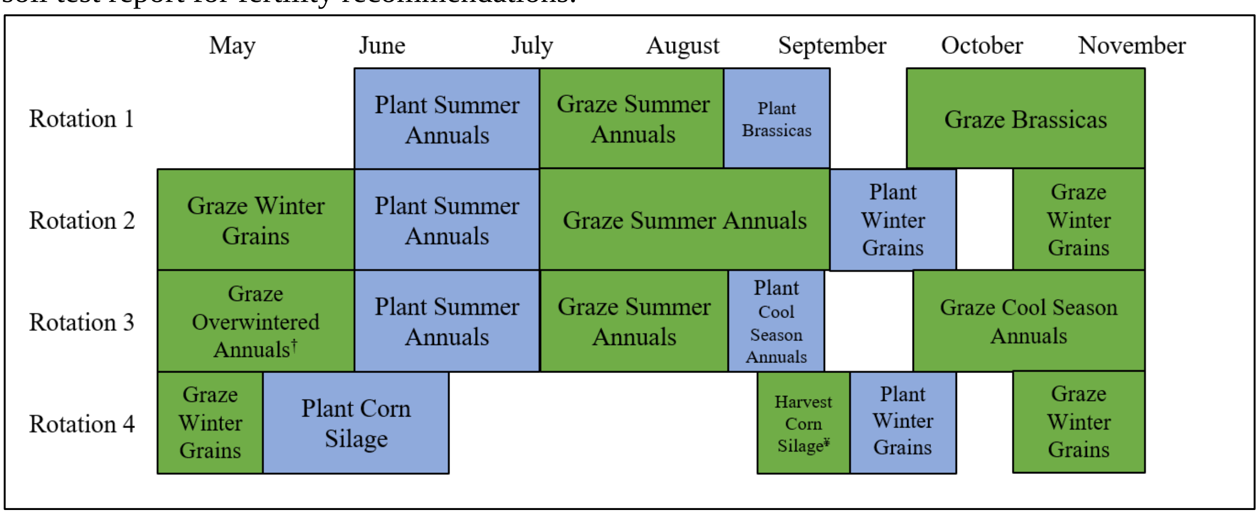


Figure 2. Example annual forage rotations

† Overwintered annuals may be winter cereals or cool season forages like annual ryegrass which may overwinter depending on location and winter climate.

‡ Requires harvest of corn silage by mid-September to allow for timely planting of winter grain if fall grazing is desired.

Warm Season Annual Forages

Sudangrass, Sorghum, and Sorghum-Sudangrass Hybrids

Sudangrass, sorghum, and sorghum-sudangrass hybrids are popular summer annuals. They can produce a lot of biomass, grow well during the typical "summer slump" period, and develop extensive root systems that can scavenge for nutrients and water in your soil that would be unavailable to other crops. In general, sudangrasses grow very tall with thin stems. Grain type forage sorghums are shorter than the forage sorghums which can be quite tall. Sorghum-sudangrass hybrids are typically taller than sudangrass with thicker stems. Sudangrass is commonly used as a cover crop but can also fit into a grazing system as it regrows rapidly once. Subsequent sudangrass regrowth is slower. The large quantity of biomass complicates drying for producing hay although mower-conditioners and wide swathing can be used to accelerate drying. In addition, the higher ratio of fibrous stem material at later stages of maturity decreases quality and palatability. Sorghum is commonly grown for grain. However, some sorghum varieties have been developed for forage production and are typically harvested at the soft dough stage similar to corn silage. Sorghum regrows more slowly and can contain higher levels of toxic prussic acid than sudangrass and sorghum-sudangrass hybrids making them less suitable for grazing, however they are generally safe when ensiled for 6-8 weeks prior to feeding. Sorghum's thick stems can also complicate drying making haying quite difficult. Forage sorghum are generally single cut crops suited for silage. Sudangrass and sorghum-sudangrass hybrids can typically be grazed or cut twice during a typical year beginning about 4-7 weeks after planting and then 4-6 weeks later depending on weather. Grazing can begin when they reach heights of 18-24 inches and should not be grazed below 6 inches for optimal regrowth and to avoid issues with prussic acid. Haying can begin at heights of 30-36 inches and should not be mowed below 4 inches. At heights above 36 inches these grasses begin to produce seed heads, which decreases crude protein and digestibility. Prussic acid poisoning is more of risk in certain growing conditions. Refrain from grazing these grasses following extreme drought conditions or after a killing frost as prussic acid concentrations may be dangerously high, particularly if plants are young or primarily regrowth.

> Prussic acid can be formed when rumen microorganism enzymes act on the cyanogenic glycosides in the plant to form highly poisonous hydrogen cyanide (HCN).

Variety selection

Sudangrass, sorghum, and sorghum-sudangrass hybrids also vary from one another in terms of yield potential. Production can vary depending on the region, but typically these grasses produce three or more tons of dry matter per acre. In New York, brown mid-rub (BMR) sorghum-sudangrass hybrids yield 2.5-5.0 dry matter tons per acre and sudangrass yields 2.5-3.5 dry matter tons per acre (Cornell, Annual Crops for Forage). In Vermont, these grasses produce between 2.8 and 3.5 tons of dry matter per acre over two harvests in a typical year in Vermont (Figure 3).

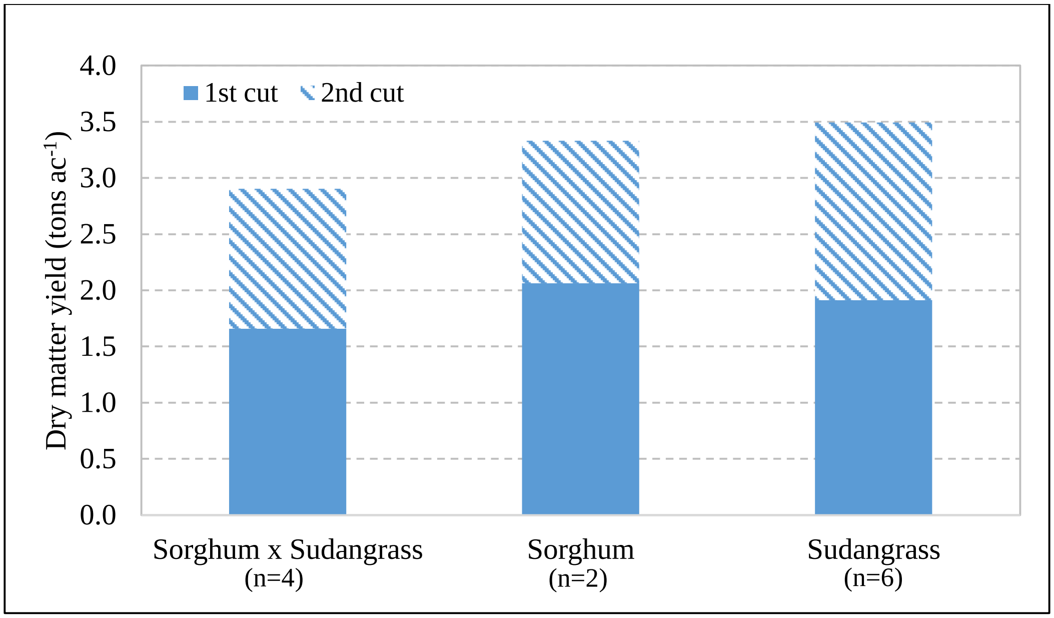


Figure 3. Dry matter yield of three summer annual grasses with data for three or more years, 2012-2019, Vermont.

With increasing popularity more varieties are being developed with improved forage characteristics including highly digestible brown mid-rib (BMR) varieties as well as dwarf varieties for higher leaf to stem ratios which also increases the overall digestibility of the forage. Numerous varieties of these grasses are commercially available. However, varieties do vary in their yield, regrowth, and quality potential (Figure 4). For example, research conducted in New York shows that with the most economic rates of nitrogen application, brown mid-rib sorghum-sudangrass can range between 3.6 to 6.2 tons dry matter per acre, depending on variety (Ketterings, et al., 2007) and in some cases under optimal management up to 18 tons/acre at 35% dry matter (Kilcer, et al., 2007). In addition, some varieties may possess different growth habits, such as bunching (producing many tillers from the crown) or dwarf stature (shorter than other cultivars), which may have implications for their suitability in a particular system.

Brown mid-rib (BMR) traits are characterized by a dark brown coloring in the center vein of the leaf and are associated with higher digestibility and energy content which can result in increased daily livestock weight grain or milk production.

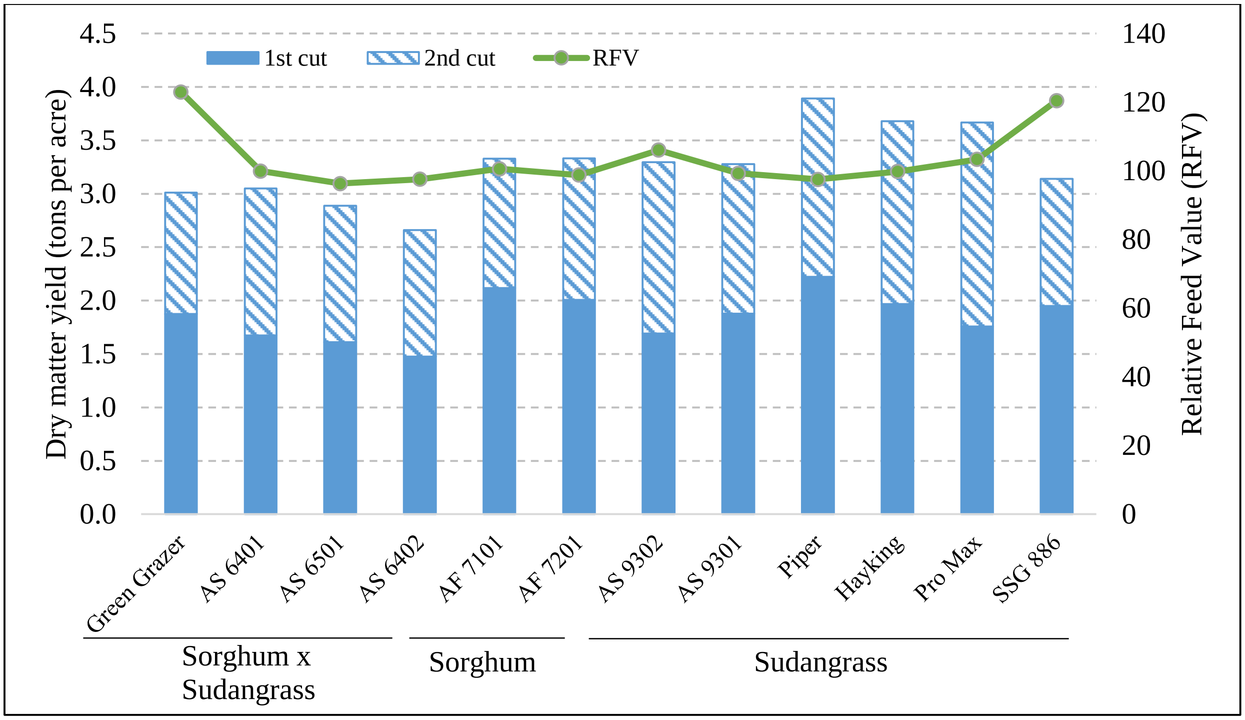


Figure 4. Dry matter yield and RFV of 12 summer annual grasses with data for three or more years 2012-2019, Vermont.

Although availability of any given variety will differ across the region, these examples highlight the importance of carefully selecting the variety that is the right fit for your operation. It is important to pay attention to local varietal evaluations when they are available. For information specific to your location, contact your local seed provider or Extension office.

Fertility

Sudangrasses and sorghums have similar nutrient requirements to that of a corn crop and are best managed using split applications of nitrogen, as is common after harvest of perennial grass crops. If planting into a terminated sod field, starter fertilizer is generally not necessary. However, when planting into a field that has been under continuous annual crop production, starter fertilizer should supply 70 lbs of nitrogen (N) per acre in well to moderately well drained fields and 90 lbs of nitrogen (N) per acre in somewhat poorly drained, poorly drained, or excessively drained fields. After the first harvest another 50-75 lbs N per acre should be applied. For newly rotated fields out of perennial production, N applications of 30-50 lbs N per acre following harvest are likely sufficient. Nitrogen application rates should be decreased if manure is to be used in combination with fertilizer. These grasses, as well as millet, have the ability to accumulate nitrates which, in high concentrations, can become toxic to feeding livestock. To avoid this risk, additional N should be applied in multiple small applications. Furthermore, these grasses should not be grazed when under stress from drought, immediately following a frost, or when under 6 inches tall. Phosphorus and potassium requirements are similar to that of corn silage and should be based on soil test results.

Seeding
Sudangrasses and sorghums should be planted when soil temperatures reach at least 60°F. This is generally in the first two weeks of June in many parts of the Northeast. Although adequate yields can still be obtained by seeding through mid-July, to maximize the growing season they should be planted early. These grasses should be seeded with a drill at rate of 50 lbs/acre at a depth of 0.5-1.0 inches into a well prepared, even seedbed. Good seed-to-soil contact is imperative for successful germination and adequate stand establishment. Seeds that are planted too deep will not germinate well and can result in poor, patchy stands leading to weed problems. In addition, wet and cool conditions at planting can also slow emergence and lead to similar issues. In these situations, it may be advantageous to delay planting until weather conditions improve. Avoid planting in areas with very heavy soils that crust or are prone to becoming excessively wet.

Millets

Millets are another warm-season grass that can be utilized much like sorghum and sudangrass. They tend to grow more slowly and produce lower yields than sorghum and sudangrass, however they do not contain prussic acid, making them a more versatile option for grazing operations. In addition, millets typically produce higher protein forage with similar digestibility to BMR sudangrass and sorghums. Grazing can begin once the plant reaches 18 inches which is typically 5-8 weeks after planting depending on weather. *It is recommended to leave at least 6 inches of stubble to allow for optimal regrowth.* A second harvest can occur approximately 4-6 weeks after the first harvest.

> Cutting or grazing millet below 6 inches can significantly reduce regrowth potential.

Variety Selection
As much of the varietal improvement has focused on sudangrasses and sorghums, fewer varieties of millet are typically available. Pearl, Brown Top, and Japanese are types of millets commonly used for forage. Pearl millet has wide leaves and both dwarf and tall cultivars. Dwarf Pearl millet is leafier and tall millet producers more seeds (Sheahan, 2014a). Brown Top millet leaves tend to be shorter than Peal or Japanese millets and the nodes a slightly hairy (Sheahan, 2014b). Japanese millet grows much like its close relative barnyard grass, producing much thinner leaves and stems than pearl millets which can resemble sorghum-sudangrass hybrids in stature. Millets generally yield about 2.25-3.0 tons of dry matter per acre varying slightly between varieties (Figure 5). Protein levels range from about 15-20%. Japanese millet generally has lower protein levels than pearl millets. Japanese millet, with its finer leaves and stems, can be less weed competitive than the leafier pearl millets. BMR varieties are also available.

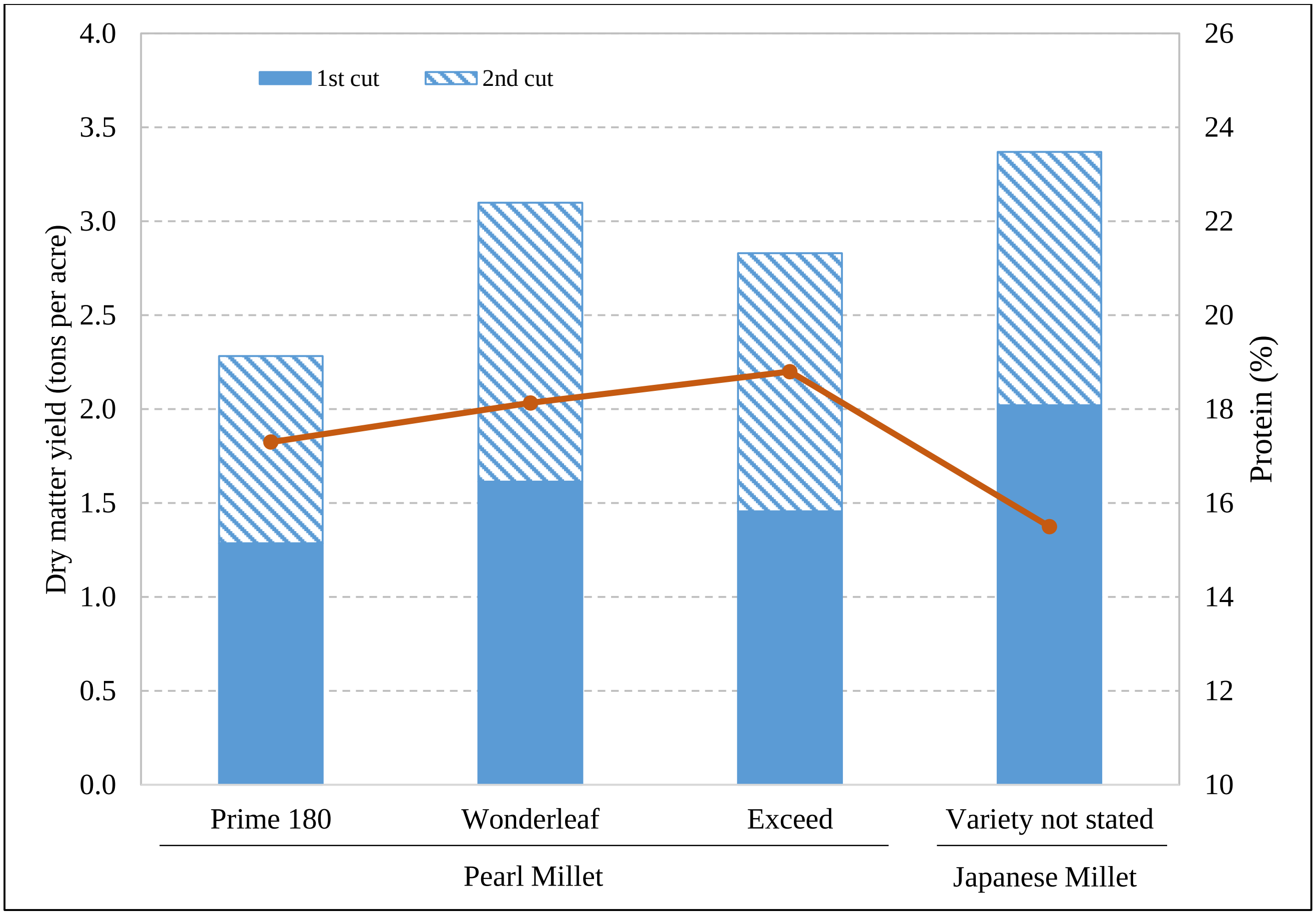


Figure 5. Dry matter yield and protein of four millet varieties 2012-2019, Vermont.

Fertility
Millet has similar fertility requirements to the sorghums and sudangrasses. If additional nitrogen is to be applied, it should be done in multiple, smaller applications to avoid over-fertilization as these grasses have the tendency to accumulate nitrates which can poison livestock.

Seeding
Millet should be seeded much like sorghum and sudangrass, into a well prepared, firm seedbed, when soil temperatures reach at least 60°F. It can be drilled or broadcast and cultipacked, at a rate of 20 lbs/acre at a depth of 0.5 to 1 inch. Good seed-to-soil contact is imperative for successful germination and ~~adequate~~ stand establishment. Seeds that are planted too deep will not germinate well and can result in poor, patchy stands which can lead to weed problems, especially for the less competitive Japanese millet.

Teff

Teff is a grass native to Ethiopia where it is grown as a cereal crop. In the Northeast, recent interest has surrounded this crop for its potential value as an annual forage. Trials thus far have showed varied results in successfully establishing adequate teff stands. Teff produces very thin, fine stems and leaves, similar to annual ryegrass, which make it more desirable for hay production than the sudangrasses and millets. It can also be grazed or chopped. Unlike sudangrasses and millets, teff does not accumulate nitrates or release prussic acid, making it easier to manage for grazing livestock. Teff can be grazed or harvested approximately 6-9 weeks after planting. Generally, a second harvest can be expected in another 4-6 weeks after the first harvest. In this region, a third harvest is rare. In New York, teff produce 2 tons/acre dry matter in one harvest for the year and with adequate nitrogen supplied, average crude protein ranged between 15 and 16% (Hunter, et al., 2007). For optimal regrowth, do not graze/harvest teff below 4 inches.

Variety Selection
Teff is a very new crop to this region, so access to different varieties may be limited. As this crop becomes more popular, new and improved varieties may become available.

Fertility
Teff is generally considered a low input crop, requiring a total of about 50-90 lbs/acre of nitrogen depending on yields. If a planting of teff is following a sod crop, additional fertility may not be necessary. However, following an annual crop such as a small grain or corn, additional fertility may be required. Applications of fertilizer or manure can be made following the first harvest.

Seeding
Due to teff's exceptionally small seed size and slow growth, care should be taken to adequately prepare the seedbed prior to planting. It is best to seed teff at a rate of 6 lbs/acre and a depth of 0.25 to 0.5 inches to ensure decent establishment. Seeding at depths deeper than 0.5 inches may result in poor stand establishment and weed pressure issues. Cultipacking after seeding may be beneficial on lighter textured soils that do not hold moisture well.

Cool Season Annual Forages

Brassicas

Brassica forage crops are cool season broadleaf annual plants that belong to the mustard family which includes crops such as turnips, kale, cabbage, broccoli, and radishes. These plants grow best in the cool temperatures of the spring and fall making them a wonderful compliment to summer annual forage options. In addition, they can withstand light frost and persist late into the fall when most other plants have stopped growing. Although they do not pose concerns with prussic acid concentrations, they can accumulate nitrates under high fertility conditions or stress. *In addition, they are extremely digestible and should be fed in moderation as bloating and other livestock health issues can occur. To avoid tainting milk with off-flavors from grazing brassicas it is recommended to limit the intake of these plants to less than 30% of the dry matter intake of lactating dairy cows.* To combat some of these complications, brassicas can be seeded in combination with small cereals or other cool season annuals that are described in this section to introduce more fiber and produce a more balanced ration. Brassicas have very high moisture content making them unsuitable for mechanical harvesting or as stored feed. Grazing can begin once the plant has reached a height above 12 inches, which is typically 3-4 weeks after planting. In the Northeast, brassicas are typically grazed or harvested once; however, if planted early enough and grazed for short intervals without too much trampling or overgrazing and leaving adequate plant material behind, brassicas can sometimes regrow if given enough time in the season prior to a hard frost. If planted between mid-August and the beginning of September, brassicas can produce 1,500-2,500 lbs/acre dry matter into late October or even November (Figure 6).

Species/Variety Selection

Several types of brassicas are used for forage: turnips, kales, mustards, rapeseed, rutabagas, radishes, and hybrids. Rutabagas, as well as some turnips and radishes produce bulbs or swollen stems that can also be consumed in addition to foliage if allowed to grow large enough. Hybrid varieties are typically leafier while rape, kale, and mustards tend to grow taller with tougher stems. If you are planting brassicas alone for grazing, taller varieties with more stems may be less desirable and animals may selectively feed on the leaves only. Conversely, leafier species, such as radishes and turnips, may outcompete other forage species when planted in mixtures.

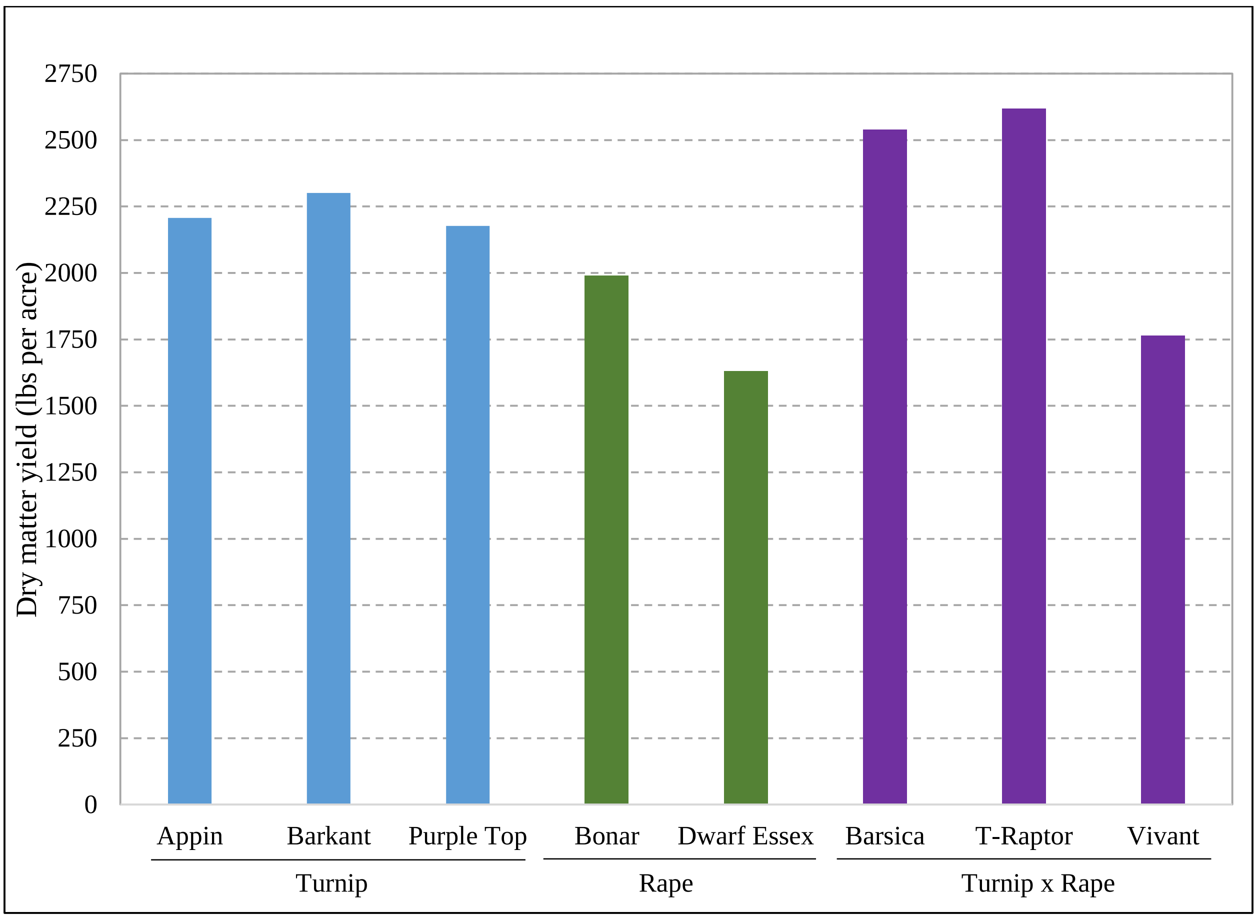


Figure 6. Average dry matter yields of eight brassica varieties in Vermont.

In addition to choosing a type of brassica suitable for your system, you may want to consider varietal differences affecting yield and quality potential. Differences of as much as 1,000 lbs/acre have been seen between varieties of the same type (Figure 6). Local performance information may be available through your local seed dealer or extension office.

Fertility

It is recommended that leafy brassicas receive 75 lbs/acre of nitrogen at planting. Forage brassicas generally do not require additions of macronutrients phosphorus and potassium; however, they do require higher amounts of boron, sulfur and other micronutrients compared to other crops. It is best to test soil prior to sowing brassicas to evaluate the soil nutrient content and fertilize accordingly. If your soil test indicates that the soil is below optimum for phosphorus, it may be beneficial to apply some starter phosphorus fertilizer at planting. Otherwise, additional fertility is not typically required. However, if brassicas are no-till drilled into high residue, an addition of nitrogen may be beneficial. Soil tests can help determine site specific nutrient needs.

Seeding

In the Northeast, brassicas are typically planted in late summer to extend the fall grazing season. Seeding should take place between mid-August and early September to ensure enough time prior to a killing frost for adequate growth and utilization. In some cases, brassicas can be planted in spring for mid-summer grazing. Brassica seed varies in size by type but for the most part is quite small. It is best drilled in 6-8 inch rows into a well prepared seed bed at a depth of 0.5 inches. If seed is broadcast, a cultipacker can be used after to ensure good seed-soil contact for successful germination. Brassicas should be planted at a rate of 4-6 lbs/acre with higher rates being used when broadcasting.

Cereals – oats, barley, spelt, triticale, wheat, and rye

Cereals are a very versatile option as they can be planted for forage harvest or grazing and can provide spring or fall forage or both! In this region, barley should be planted in the spring as it often is not hardy enough to survive the winter. Oats are typically planted in the spring but may also be planted in the fall depending on the needs of the farm for fall forage as they will winterkill in this region. Triticale, wheat, and rye can be planted in the fall and if planted early enough can provide vegetative forage in the fall as well as the following spring. These cereals are often planted as winter cover crops in corn and other annual row crop cropping systems. Managing these cover crops as forage crops can help maximize forage production on the farm utilizing existing land and resources and without disrupting current crop production. The versatility of cereals makes them extremely useful as an annual forage in the Northeast.

Cereals can be harvested for forage at multiple growth stages. Yield and quality can vary between species and varieties. These factors should be considered when choosing a small grain to fit your operation's goals. Table 1 below summarizes yield and quality of cereals (oats, barley, triticale, and spelt) harvested at three growth stages in northern Vermont (Darby et al., 2010). The boot stage is reached when the grain head is just about to emerge from the leaf sheath. As the plant matures and enters reproductive stages, milk and dough stages, nutrients are utilized in the filling grain head and the foliage increases in lignin to provide more support for this transition. This increases the fiber fraction of the forage, decreasing nutritive value as intake and digestibility are negatively impacted.

Harvest can take place during different times of maturity with earlier harvests often higher in quality and later harvests often higher in yield. Sometimes, a matter of days can have a big impact on yield. For example, it took 2-3 days for cereal rye, triticale, and winter wheat to mature from flag leaf to boot stage and resulted in a 20% increase in yield (Liebert et al., 2015). Harvesting at the boot stage is a trade-off between lower yield and higher quality than at later stages of maturity, in which yields are higher but quality is reduced. Crude protein and digestibility are often higher in the boot stage than at later maturities, making boot stage harvest forage suitable for high producing dairy cows. The quality is typically similar to first cut perennial forages. Harvesting at the milk and soft dough stages produce similar yield and quality. If the goal is to produce forage for dry cows or heifers, harvesting at the soft dough stage, when the grain is still gummy, will optimize yield and produce adequate quality for those animals. For silage, harvest during early dough stages to ensure proper ensiling as the moisture will be too low when harvest is prolonged into late dough stages. *Small grains can mature from the boot stage to dough stages quite rapidly so monitoring their progress is imperative for maintaining quality consistent with your goals.*

Table 1. Dry matter yield and forage quality characteristics of cereals at various harvest stages.

Harvest stage	DM at harvest	DM yield	Forage quality characteristics					
			CP	ADF	NDF	dNDF	TDN	NE_L
	%	lbs ac^{-1}		% DM		% NDF	% DM	Mcal lb^{-1}
Boot	14.8[†b]	2,030[b]	19.2[a]	29.0[a]	44.4[a]	64.1[a]	63.4[a]	0.660[a]
Milk	27.5[a]	5,680[a]	10.2[b]	38.3[b]	59.5[b]	51.1[b]	58.6[b]	0.590[b]
Soft Dough	26.3[a]	5,830[a]	10.0[b]	37.4[b]	54.9[b]	47[b]	57.9[b]	0.590[b]
LSD‡	1.32	329	0.54	0.770	1.57	1.70	0.58	0.010
Mean	22.9	4510	13.1	34.9	52.9	54.0	60.0	0.610

† Within a column, treatments with that same letter did not perform significantly different from each other.
‡ LSD – Least Significant Difference at p=0.10.

Yield potential and maturation timing are important aspects of small cereal management that varies between species and types (forage or grain). Although oats, with their upright stems and leafy growth, are typically high yielding cereals, yield and protein of spring-seeded cereals in the Northeast harvested at the boot stage is typically not significantly different among species. However, digestibility tends to be higher in barley, oats, and triticale than spelt (Table 2).

Table 2. Dry matter yield and forage quality of various cereals harvested in the boot stage.

Small grain at **boot** stage	DM yield	Forage quality characteristics			
		CP	NDF	NDFD	NEL
	lbs ac^{-1}	% DM		% NDF	Mcal lb^{-1}
Barley	1,840	19.6	42.6[†a]	64.1[a]	0.650[b]
Oats, cv. Everleaf	2,010	19.1	43.9[a]	67.6[a]	0.680[a]
Oats (60%) and ryegrass (40%)	1,760	18.4	48.9[b]	66.4[a]	0.650[b]
Spelt	1,820	19.9	38.9[a]	57.6[b]	0.640[b]
Oats, cv Spur	2,370	18.6	48.4[b]	66.3[a]	0.660[a]
Triticale	2,360	19.7	43.7[a]	62.3[a]	0.650[b]

LSD‡	NS¥	NS¥	5.75	5.67	0.020
Mean	2,030	19.2	44.4	64.1	0.660

† Within a column, treatments with that same letter did not perform significantly different from each other.
‡ LSD – Least Significant Difference at p=0.10.
¥ NS – No significant difference was determined among the treatments.

Timing of maturity for these cereals also differs and can influence the suitability within a particular system. From field trials in northern Vermont between 2008 and 2013, it was found that spring seeded barley and wheat matured into subsequent growth stages approximately 7-10 days earlier than oats and triticale. Furthermore, in a trial in northern Vermont between 2015 and 2016, fall seeded rye matured to the boot stage an average of 19 days earlier the following spring than triticale and wheat. Research conducted in New York showed that cereal rye yields average 3,240 lbs/acre and triticale yields can vary between 3,000 and 4,500 lbs/acre depending on planting date (Hanchar, 2015; Kilcer et al., 2010). If the goal is to maximize forage dry matter production early in the season, oats, although they typically produce the most total dry matter, may not fit your system as well as winter barley or rye, planted in the fall and harvested early in the growing season.

Species Selection

In addition to the differences between small grain cereal species, there can also be significant varietal differences. As use of small cereals as forage becomes more popular, development of forage specific varieties is increasing. Forage varieties typically have a higher leaf to stem ratio and remain in vegetative stages longer than cereal varieties. When both cereal and forage varieties of oats were trialed in northern Vermont, the cereal variety matured to the boot stage an average of 14 days earlier than the forage oat variety. If small grain cereals are going to be grazed or harvested in the boot stage, forage specific varieties will produce more high-quality forage and will provide a wider window of harvest than grain varieties. If forage specific varieties are not available, choose a late maturing variety. If small grain cereals are going to be harvested in the dough stages, early maturing grain varieties are adequate and will allow more time for a subsequent crop to be established.

Fertility

Spring cereals require relatively low soil fertility levels and often produce well without additional fertilizer, especially in fields that have been adequately rotated or have a history of manure application. When seeded for forage, about 50 lbs/acre N should be applied. Reduce this rate to 20 lbs if manure is also applied during the growing season. In trials in northern Vermont dry matter yield increased by half a ton, from 1.55 to 2.05 tons/acre, by adding 25 lbs/acre N in the early spring compared to adding no additional fertilizer. Yields were not further increased when nitrogen rates were increased to 50 lbs/acre.

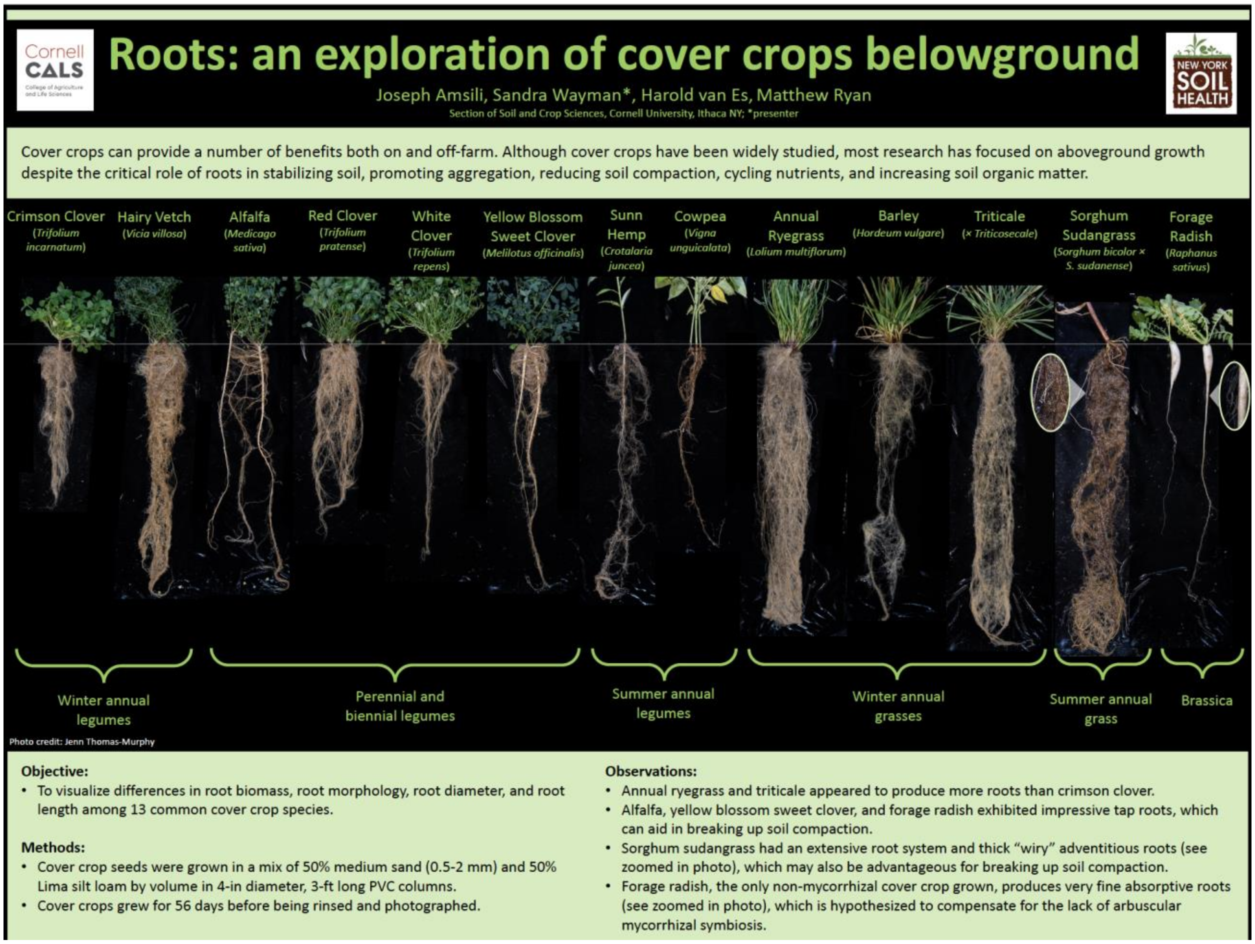
Seeding

In the Northeast, spring cereals are planted as soon as soils can be worked, typically mid-April to early May. Planting date trials in northern Vermont have shown that planting as early as possible in April can lead to lower weed pressure and higher yields. Delaying planting into mid-late May can lead to significant weed pressure which will decrease yield and quality of the forage. Yield may also be lower in later plantings because spring cereal’s reproductive development is triggered by day length meaning there is less time for growth between planting and maturity. Spring cereals should be seeded into a well-prepared seed bed with a grain drill at a rate of 100-125 lbs/acre. Barley is more sensitive to wet soils than the other spring cereals and should not be planted on poorly drained soils.

If cereals are fall seeded, plant by mid-September for best establishment and potential fall forage. Winter cereal planting date trials in northern Vermont indicate highest establishment and fall heights when planted in the first two weeks in September. Cereals planted after mid-September will not be of a harvestable size by the end of the growing season in this region. When planted on time in the fall, forage yields of almost 1 ton of dry matter per acre can be attained into late October. The following spring an additional 1-2 tons of dry matter per acre can be harvested. If planting must be delayed in the fall, forage yields of over 1.5 tons/acre of dry matter can still be attained in the spring. Winter cereals fit well into corn silage cropping systems in this region if corn can be harvested in a timely manner in the fall to allow for winter cereal planting in September.

Annual Ryegrass

Annual ryegrass, including the 'Italian' cultivar which grows more like a biennial, is a fast growing, cool season bunch grass that can provide large quantities of highly palatable, high quality forage very quickly. Because of this characteristic, it can be used as an emergency forage or pasture rejuvenator if perennial forages experience winterkill, or as a nurse crop to establish slower growing species such as legumes or perennial grass/legume mixtures. It can also help extend the grazing season in the early spring or late into the fall, but will be dormant during the hot months of the summer. Its extensive, fibrous root system can utilize excess nutrients from a previous cash crop and stabilize the soil. In some temperate locations annual ryegrass can overwinter and persist. Allowing it to reseed in the spring can cause issues in following crops. In far northern parts of the Northeast and at higher elevations annual ryegrass does not typically overwinter. It prefers to grow on well-drained, fertile soils but will perform well on a wide variety of soil types and drainage conditions. It generally tolerates wet soils better than small grain cereals. Yields vary depending on variety, time of planting, and management, but generally can reach upwards of 4-6 tons/acre of dry matter. If grazing annual ryegrass, grazing can begin when the crop reaches heights of 8-10 inches and can be grazed down to a height of about 3 inches. If planted in the spring for grazing, pay close attention to the stage of maturity as annual ryegrass can mature very quickly and therefore decline in quality. If annual ryegrass is being harvested for haylage, forage should be harvested in the boot stage for the highest quality and yield.



Variety Selection
Annual ryegrass is a popular forage across the central and southern U.S. Therefore, there are many improved forage varieties available on the market. Annual ryegrass is grouped into two broad categories based on the number of chromosomes in each cell. Tetraploids generally have larger leaves and seeds, create a less dense cover, and have higher sugar content compared to diploids. Diploids tend to produce more biomass once established and persist better than tetraploids. Although many of these varieties are marketed as having exceptional winter hardiness, they will still likely winterkill in the Northeast. Variety trials from universities or seed dealers can help identify varieties that have performed well in your particular area.

Fertility
Annual ryegrass responds well to and can take up a lot of nitrogen. When seeded in late summer/fall after other crops, annual ryegrass can utilize excess nitrogen left behind. However, depending on the history of the field and the conditions at planting, annual ryegrass may benefit from additional fertility at the time of seeding.

Seeding
Annual ryegrass seed is very small and needs to be planted at a shallow depth of 0.25-0.5 inches. It can be seeded with a no-till drill, brillion seeder, or broadcast and cultipacked. Annual ryegrass can also be frost seeded and can be used to provide a boost to declining pastures and hay

meadows. Annual ryegrass should be seeded at 10-20 lbs/acre when drilled and 20-30 lbs/acre if broadcast. If planted as a companion crop to perennial grasses or in grass/legume mixtures, it should not exceed 4 lbs/acre as higher rates will lead to high competition with the desired perennial species.

Annual Forage Mixtures

Annual warm season or cool season mixtures can be one way to capture the benefit of multiple species while safeguarding against possible poor establishment or yield. Benefits of mixtures can include specie and varietal differences that withstand poor weather conditions (dry, hot, wet, cool), disease pressure, and pest pressure. In the face of adverse conditions, mixtures have the potential to have better quality and higher yield with better establishment and regrowth potential. However, it can be difficult to establish well balanced mixtures to receive the benefit of all species or varieties that make the cost worth with addition.

Warm Season Annual Mixtures

Warm season annual mixtures can be planted in early June. In organic production in cool temperatures or with excessive rainfall, warm season mixtures may be slow to establish, leaving them susceptible to weed pressure. Often, two harvests are typical for warm season mixtures. If the conditions are cool with excessive rainfall, the first cut may be in late June. If the conditions are dry, the first cut may be in early August. Typically, a second harvest occurs in late August.

Research conducted in northern Vermont in 2016, indicates that there are no yield differences when seeding rate of a grass are equal to that of the legume (Table 4). The pollinator mix and legume only treatments (chickling vetch and berseem clover) did not regrow after first cut and a second harvest was not possible. This is an example of how planting a mixture can off-set poor growth of a particular species. Trials conducted in 2015-2016 indicate that protein levels or other quality parameters do not significantly increase when a legume is added to a grass mixture.

Table 4. Warm annual forage mixtures, seeding rates, total yield, first cut protein, 2016.

Species	Variety	Seeding rate lbs ac^{-1}	DM yield tons ac^{-1}	Crude protein % of DM†
Millet Berseem Clover	Wonderleaf Frosty	10 10	2.15	17.3^{bc}
Millet Berseem Clover	Wonderleaf Frosty	14 6	1.81	19.4^{abc}
Sudangrass Berseem Clover	Hayking Frosty	25 25	3.45	16.3^{bc}
Sudangrass Berseem Clover	Hayking Frosty	35 15	1.99	15.2^{c}
Millet Chickling Vetch	Wonderleaf AC Greenfix	10 10	1.86	20.5^{ab}
Millet Chickling Vetch	Wonderleaf Wonderleaf	14 6	1.63	18.1^{bc}

Sudangrass Chickling Vetch	Hayking AC Greenfix	25 25	1.88	17.4[bc]
Sudangrass Chickling Vetch	Hayking AC Greenfix	35 15	1.70	17.9[bc]
Pollinator mix: Peas & Oats Hairy vetch Crimson clover Buckwheat Rape Berseem clover Sunflower	Stockade and Haywire Purple bounty VNS VNS Trophy VNS Wildlife blend	26 16 16 16 10.5 10.5 10.5	1.40	17.8[bc]
Berseem clover	Frosty	15	0.829	23.1[a]
Pearl Millet	Wonderleaf	20	0.613	23.8[a]
Sudangrass	Hayking	50	2.33	16.0[bc]
Chickling vetch	AC Greenfix	60	2.15	18.4[bc]
Probability level			NS[¥]	0.0001
Mean			1.83	18.3

† Within a column, treatments with that same letter did not perform significantly different from each other.
¥ NS – No significant difference was determined among the treatments.

Cool Season Annual Mixtures

The optimal planting window for cool season annual mixtures is in mid-August. Typical harvest occurs in mid-October. In the Northeast, a second harvest in the spring is not common due to harsh winters preventing the cool season annuals from overwinter.

In research trials conducted in northern Vermont in 2016 and 2017, most forage treatments produced over 1.25 tons/acre. The highest yielding treatment was the oat/pea/turnip mixture which produced 1.92 tons/acre. The lowest yielding forages were monocultures of Lynx peas and Triticale 815, 0.64 and 1.01 tons/acre. respectively (Table 5). The monoculture pea had the highest crude protein (28.3%), but the addition of a legume into a mixture did not significantly increase crude protein. The lowest ADF was in the triticale/pea/turnip mix and the highest ADF was in the Everleaf oats and 815 Triticale monocultures. The lowest NDF was in the turnip monoculture and the highest NDF was in the Everleaf oats and 815 Triticale monocultures.

Table 5. Cool annual forage mixtures, seeding rates and average total yield, and quality, 2016 and 2017.

Variety and species	Seeding rate	DM yield	Crude protein	ADF	NDF
		Tons ac^{-1}	% of DM	% of DM	% of DM
Everleaf Oats Lynx Peas Appin Turnip	75 60 5	1.92	22.3	26.0	40.3
Triticale 815 Lynx Peas Appin Turnip	75 60 5	1.32	23.4	19.3	31.9
Kodiak Ryegrass Lynx Peas Appin Turnip	30 30 5	1.39	22.8	21.1	28.4
Triticale 815 Everleaf Oats Lynx Peas Appin Turnip	50 50 50 5	1.55	22.5	24.0	37.7
Triticale 815 Kodiak Ryegrass Lynx Peas Appin Turnip	60 20 30 5	1.67	21.9	20.4	29.5
Everleaf Oats	125	1.75	22.5	29.7	49.9
Triticale 815	125	1.01	23.9	26.9	46.9
Ryegrass	30	1.33	22.9	23.9	41.9
Lynx Peas	60	0.64	28.3	21.3	35.1
Appin Turnip	6	1.48	23.7	19.7	25.6
Trial Mean		1.41	23.4	23.2	36.7

Treatments in **bold** are top performers for that parameter.

Treatments with asterisks* performed statistically similarly to the top performer.

Mixture Challenges
Seeding rate and depth can be difficult with mixtures. Seed rate must be calibrated to meet goals. Grasses can outcompete legumes rendering little benefit of a mixture if the legumes do not establish and grow well. Seeding depth can be difficult with mixtures as some seeds may need to be planted deeper or shallower than others for best establishment. Typical seeding depths for warm and cool season annuals are 1.5 inches. Typical seeding depths for perennial mixtures are 0.5 inches. Harvesting can also be difficult in mixtures as different species may mature at different rates making it difficult to capture both optimal yield and quality in a single harvest

In some cases, variety can make a big impact. For example, in a 2018 research trial conducted in northern Vermont Kodiak annual ryegrass produced 1,136 lbs/acre dry matter, compared to Enhancer annual ryegrass with 656 lbs/acre and Tetraprime annual ryegrass with 294 lbs/acre. And some mixtures produce better in some years than others. For example, in 2018 the addition of turnips increased yields but in 2019 they decreased yields. For some mixtures, the cost per acre or cost per ton, may not be worth the yield. Table 6 shows average dry matter yield, crude protein, and cost for mixtures planted in 2015.

Table 6. Warm season forage mixtures, yield, and cost evaluated in Alburgh, VT, 2015.

Species	Seeding rate (lbs ac^{-1})		DM Yield	Crude Protein	Cost	
	Alone	In mixture	Tons ac^{-1}	% of DM†	Dollars ac^{-1}	Dollars DM ton^{-1}
Wonderleaf Millet	20	10	1.51	15.3	64.5	42.78
AC Greenfix Chickling Vetch	60	30				
TFL 200 Chicory	6	3				
Hayking Sudangrass	50	15	1.95	16.2	65.65	33.61
Berseem Clover	15	8				
TFL 200 Chicory	6	3				
Fria Annual Ryegrass	30	15	1.38	16.1	45.70	33.18
Berseem Clover	15	8				
TFL 200 Chicory	6	3				
Hayking Sudangrass	50	15	n/a†	n/a†	93.10	45.08
Wonderleaf Millet	20	10				
Berseem Clover	15	8				
AC Greenfix Chickling Vetch	60	30				
TFL 200 Chicory	6	3				
Wonderleaf Millet	20	10	2.07	16.6	34.80	18.91
Fria Annual Ryegrass	30	15				
AC Greenfix Chickling Vetch	60	30				
Berseem Clover	15	8				
TFL 200 Chicory	6	3				
Mean			1.72	16.1	67.24	38.66

† n/a indicates that the mixture established poorly and a harvest was not possible.

Forage Intercropping

Forage yield and weed biomass in a mixed intercropping with multiple species was tested in perennial and annual forage cropping systems as part of a multisite field experiment in NH, NY, and VT in 2017 and 2018. In this forage intercropping trial, both systems were planted at four levels of diversity in annual warm season, cool season, and perennial forage systems (Tables 7, 8, and 9). The Very Low treatments had one variety of one species, the Low treatments have four varieties of one species, the High treatments have one variety of four species, and the Very High treatments have four varieties of four species. Seeding rates were based on recommended seeding rates and adjusted based on germination rate and weight so that each variety or species was seeded at the same density. For example, mixtures of different species were seeded at the standard seeding rate divided by four (number of species in the mixture).

Table 7. Forage intercropping trial warm season treatments and seeding rates, 2017 & 2018. Percentages reported are based on total weight of mixture.

Annual system warm season treatments				
Very Low **52.9 lbs ac^{-1}**	**Low** **51.1 lbs ac^{-1}**	**High** **44.7 lbs ac^{-1}**	**Very High** **47.6 lbs ac^{-1}**	
Sudangrass (100%) *Hayking*	Sudangrass *Hayking* (25.9%) *Piper* (18.7%) *SSG886* (30.9%) *Promax* (24.5%)	Sudangrass (29.6%) *Hayking* Pearl millet (21.0%) *Wonderleaf* Sorghum sudangrass (32.9%) *Greengrazer* Ryegrass (16.5%) *Enhancer*	Sudangrass *Hayking* (6.9%) *Piper* (5.0%) *SSG886* (8.3%) *Promax* (6.6%) Pearl millet *Wonderleaf* (5.0%) *FSG315* (5.0%) *Exceed* (6.1%) *Trileaf* (5.2%)	Sorghum sudangrass *Greengrazer* (7.7%) *400 x 38* (9.2%) *AS6401* (9.5%) *Sweet 6* (10.2%) Ryegrass *Enhancer* (3.9%) *Tetraprime* (4.4%) *Marshall* (2.7%) *Kodiak* (4.3%)

Table 8. Forage intercropping trial cool season treatments and seeding rates, 2017 & 2018. Percentages reported are based on total weight of mixture.

Annual system cool season treatments				
Very Low **211.8 lbs ac^{-1}**	**Low** **211.8 lbs ac^{-1}**	**High** **154.1 lbs ac^{-1}**	**Very High** **154.1 lbs ac^{-1}**	
Triticale (100%) *Trical 815*	Triticale (25% each) *Trical 85* *Fridge* *NE426GT* *Hy octane*	Triticale (34%) *Trical 85* Cereal rye (34%) *Wheeler* Red clover (3%) *Mammoth* Winter pea (29%) *Austrian*	Triticale (34%) *Trical 85* *Fridge* *NE426GT* *Hy octane* Cereal rye (34%) *Wheeler* *Guardian* *Aroostook* *Spooner*	Red clover (3%) *Mammoth* *Freedom* *Starfire* *Duration* Winter pea (29%) *Austrian* *Frostmaster* *Whistler* *Windham*

Table 9. Forage intercropping trial perennial treatments, 2017 & 2018. Percentages reported are based on total weight of mixture.

Perennial System Treatments				
Very Low 23.5 lbs ac^{-1}	**Low 23.5 lbs ac^{-1}**	**High 17.4 lbs ac^{-1}**	**Very High 17.4 lbs ac^{-1}**	
Alfalfa (100%) *Viking 370HD*	Alfalfa (25% each) *Viking 370HD* *FSG 420LH* *KF Secure BR* *Roadrunner*	Alfalfa (34%) *Viking 370HD* Orchardgrass (34%) *Extend* Timothy (25%) *Climax* White Clover (7%) *Alice*	Alfalfa (34%/each) *Viking 370HD* *FSG 420LH* *KF Secure* *Roadrunner* Orchardgrass (34%/each) *Extend* *Benchmark Plus* *Niva* *Intensiv*	Timothy (25%/each) *Climax* *Summit* *Glacier* *Promesse* White Clover (7%/each) *Alice* *Liflex* *Ladino* *KopuII*

Benefits of diversity were dependent on crop, location, and year (for example, due to more favorable growing conditions, the summer annuals had higher yields in 2018 than in 2017). To summarize results, we pooled the data across sites and years. Overall, there were higher yields and greater weed suppression with increased diversity. When data is aggregated, the addition of different species or varieties did not significantly increase annual yield (Table 10). On average, the annual system produced 1.5X times more than the perennial system (Table 11). However, level of diversity did impact weed biomass in the warm season annuals, but not the cool season annuals or in the perennial system (Table 12).

Weed biomass of the warm season annuals was significantly higher in the Very Low treatment than in the Very High treatment. This may be because the Very High level of diversity contained plants that were better able to maximize ground cover and better compete for other resources. Weeds were lower in the cool season annuals than the warm season annuals. Weeds may have been more suppressed in the cool season annuals due to better forage growth competing for resources and colder, unfavorable weed growing climate conditions.

Table 10. Forage intercropping warm and cool season forage yields, 2017 & 2018.

Treatment	2017 dry matter yield			2018 dry matter yield		
	Cool	Warm	Total	Cool	Warm	Total
	tons ac^{-1}			tons ac^{-1}		
Very Low	2.41	1.24	3.65	1.37	3.48	4.84
Low	2.50	1.40	3.89	1.16	3.76	4.92
High	2.82	1.54	4.36	1.37	3.61	4.98
Very High	2.72	1.69	4.41	1.33	3.51	4.84
Trial mean	2.61	1.47	4.08	1.31	3.59	4.90

‡ LSD – Least Significant Difference at $p<0.05$.
¥ NS – No significant difference was determined among the treatments.

Table 11. Forage intercropping average total annual and perennial dry matter yields, 2017 & 2018.

Treatment	Annual	Perennial
	tons ac^{-1}	
Very Low	4.25	2.04†b
Low	4.41	2.12b
High	4.67	2.73a
Very High	4.63	2.73a
Trial mean	4.49	2.41

† Within a column, treatments with that same letter did not perform significantly different from each other.
‡ LSD – Least Significant Difference at p=0.05.
¥ NS – No significant difference was determined among the treatments.

Table 12. Weed biomass in cool season, warm season, and perennial forage systems.

Treatment	Cool	Warm	Perennial
	tons ac^{-1}		
Very Low	0.013	0.410†a	0.639
Low	0.011	0.294ab	0.702
High	0.012	0.295ab	0.075
Very High	0.011	0.261b	0.071
Trial mean	0.012	0.315	0.372

† Within a column, treatments with that same letter did not perform significantly different from each other.

In the fall of 2018, soil samples were collected in NY and VT and analyzed by Cornell's soil health laboratory for aggregate stability, active carbon, respiration, organic matter, and total soil health score. There were no differences among the parameters measured in the diversity treatments (Table 13). However, there were differences among forage systems (Table 14). The soil from the perennial system had 4.3% higher aggregate stability compared to annual systems. Active carbon and organic matter were higher in the annual system than the perennial system. This may be the result of higher forage biomass additions from the comparatively higher biomass in the annual system. Despite difference in these metrics of soil health, there were no differences in soil respiration or overall Cornell Comprehensive Assessment of Soil Health score among the forage systems. The Overall Quality Score is an average of all soil health indicator ratings it includes the aforementioned quality indicators as well as pH, phosphorus, and potassium levels. It should be considered as a general summary for soil quality. The scores range between 0-100%. Less than 20% is regarded as very low, 20-40% is low, 40-60% is medium, 60-80% is excellent, and greater than 80% is optimal.

These results indicate that the annual forage system, which was tilled prior to plantings, resulted in statistically similar soil health to the perennial system. Prior to the start of the experiment, the trial areas had been in annual crop production for. Hence these results indicate that aggregate stability is the most responsive soil health indicator to the change from an annual to a perennial system. Other changes in soil health may take more than two years to manifest.

Table 13. Soil quality in diversity treatments, NY & VT, 2018.

Forage system	Aggregate stability %	Active carbon mg/kg	Organic matter %	Soil respiration CO_2 mg/soil g	Overall Score
Very Low	29.6	600	4.15	0.761	76.8
Low	32.3	575	4.09	0.720	76.0
High	32.0	587	4.34	0.758	77.2
Very High	32.2	559	4.00	0.722	75.9
Trial Mean	31.5	580	4.14	0.740	76.5

Table 14. Soil quality in forage systems, NY & VT, 2018.

Forage system	Aggregate stability %	Active carbon mg/kg	Organic matter %	Soil respiration CO_2 mg/soil g	Overall Score
Annual	29.4[b†]	604[a]	4.28[a]	0.743	76.2
Perennial	33.7[a]	557[b]	4.01[b]	0.737	76.7
Trial Mean	31.5	580	4.14	0.740	76.5

† Within a column, treatments with that same letter did not perform significantly different from each other.

Annual and perennial forage systems are often part of a longer rotation that includes corn silage. Corn planted after the annual and perennial forages in forage intercropping trial, was evaluated for yield and quality. Research indicates that diversity levels in each of the forage systems did not impact subsequent corn silage yield. However, despite no difference among overall soil health scores between perennial and annual systems and higher weed pressure in the perennial system, corn silage yields were significantly higher in the perennial system (Table 15). The perennial system averaged three tons/acre more corn silage than the annual system. This may be because corn following perennial forage can take advantage of some soil health benefits and potentially nitrogen mineralization that allow it to produce significantly higher yields. As a result of higher yields, the perennial system also produced more than 3,900 milk lbs/acre more than the annual system. No differences were found in corn silage quality among the forage systems.

Table 15. Impact of cropping systems on corn silage quality, 2019.

Forage system	Dry matter yield tons ac^{-1}†	Dry matter %	CP % of DM	ADF % of DM	NDF % of DM	TDN % of DM	NE_L Mcal lb^{-1}	Milk lbs ton^{-1}	Milk lbs ac^{-1}
Annual	16.8[b]	40.7	7.10	21.7	39.3	65.1	1.50	3,382	19,869[b]
Perennial	19.8[a]	39.7	7.26	23.0	40.3	64.7	1.48	3,433	23,788[a]
LSD‡	2.02	NS¥	NS	NS	NS	NS	NS	NS	2,554
Trial mean	18.3	40.2	7.18	22.3	39.8	64.9	1.49	3,407	21,829

† Within a column, treatments with that same letter did not perform significantly different from each other.
‡ LSD – Least Significant Difference at p=0.10.
¥ NS – No significant difference was determined among the treatments.

Summary

On average, warm season forages produced between 2.3 – 3.8 tons/acre of dry matter and cool season forages produced 0.8 – 1.3 tons/acre of dry matter over the course of a full year. However, yields greatly depend on weather, variety planted, and seeding rate. This indicates that if subsequent cool and warm season forages were planted in one year, the yield can range between 3.1 – 5.1 tons/acre of dry matter in a growing season. In some cases, as seen with forage intercropping trial, annual production can exceed perennial production. It is important to consider your yield and quality goals, labor available, and land available when planning your field rotations. Other forage species like grazing corn, forage soybeans, rapeseed, and fenugreek are currently being explored for optimal planting rate, date, potential quality, and possible production capacity. Yield and quantity will vary depending on weather, soil conditions, seeding rate, species, variety, germination rate, and regrowth. Although general fertility recommendations are discussed in this text, it is best to consult a current soil test report to be ensure nutrient requirements of crops are met. Overall, annual forage production adds to farm resiliency because it is a high yielding source of feed and can be an excellent complement in rotation with other row crops and perennial systems.

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