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Virginia NRCS Cover Crop Planning Manual 1.0

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Part I. Introduction & Purpose

The overall purpose of this Technical Note is to help NRCS planners, clients, and partners implement the Virginia NRCS 340 Cover Crop Practice Standard.

The specific objectives of this Technical Note are:

1. To explain the concept of cover crop "functional groups" for categorizing cover crop choices and to convey related planning considerations (Part II).
2. To explain the concept of cover crop "seasonal niches" for further categorizing and narrowing down cover crop choices (Part III).
3. To provide lists of recommended cover crop species for each seasonal niche, plus brief descriptions of each species (Part IV).
4. To provide establishment specifications (seeding rate, date, depth, etc.) for each recommended species and niche (Part IV).
5. To provide guidance on a range of associated cover crop planning issues, including timing of cover crop termination (Part IV).

Part II. Cover Crop Functional Groups

Introduction to Cover Crop Functional Groups

A first step in narrowing down cover crop choices is dividing cover crops into functional groups – broad categories of species with similar characteristics.

This document divides cover crops into the following three groups: grasses, legumes, and non-legume broadleaf species. Non-legume broadleaf species are then further split into brassicas and forbs.

Start your cover crop planning by selecting functional groups. This usually helps sharpen your focus on the cover crop's core purpose, without being distracted by the many details associated with species selection. Once functional groups have been considered, then species can be chosen from within each desired group.

The paragraphs below summarize the characteristics of each functional group. Keep in mind that for each broad generalization made below about a particular functional group, there is usually at least one cover crop species within the group that is an exception to that generalization.

If a particular species has one more characteristics that is unusual for its functional group, that fact will likely be noted in the description for that crop in Part IV.

Functional Group Descriptions

Grass Functional Group

Grass cover crops include many species traditionally grown for grain (wheat, barley, etc.) and others commonly grazed or harvested for forage (annual ryegrass, sorghum-sudangrass, etc.). Grass cover crop options also include perennial forages such as tall fescue and orchardgrass.

Grasses are not able to "fix" or take nitrogen (N) directly from the air for their nutrition. Thus, grasses require an ample supply of soil N for fast growth and high yield. Consequently, grass cover crops tend to be very good scavengers of soluble soil N.

Grasses typically produce more above-ground biomass than either legumes or broadleaf species. Grass residues also tend to be more resistant to decay and are longer-lasting than legume or broadleaf residues.

Therefore, grasses are generally the best choice for producing large amounts of organic matter and lasting ground cover.

Most grasses grow relatively quickly. They also tend to have extensive, fibrous (net-like) rooting systems that help knit together surface soil.

Grass cover crops can send roots very deep into the soil to help fight compaction, but the hair-like nature of most grass roots means the diameter of pores they leave behind are relatively small.

Some grasses have been shown to suppress weeds through alleleopathy as well as through competition for light and nutrients. Alleleopathy refers to release of chemicals that are antagonistic to germination or growth of other plants.

Grasses generally offer the broadest range of seeding date options among the functional groups, especially in the fall. This means that when practical constraints require late seeding, grasses are sometimes the only available cover crop choice.

All of the above characteristics help explain why grasses have traditionally been and continue to be the functional group of choice for many core cover crop purposes such as erosion prevention, building soil organic matter, scavenging N, and out-competing weeds.

Grass cover crops generally contain relatively high levels of carbon (C) compared to nitrogen (N) (i.e., they have a high C:N ratio). This helps explain why they are more slowly digested by soil microbes and why grass residues tend to be longer-lasting.

This tendency for grass residues to have high C:N ratios and to break down slowly is linked to how mature the grass was at the time of termination. Residues of young, vegetative grass plants have low C:N ratios and are similar to spring-time lawn clippings. Once grasses begin their reproductive phase, their carbon content and C:N ratio begin to climb quickly and residues are more similar to straw.

This means grass residues become progressively more resistant to breakdown as the plants mature. The high C:N ratios in reproductive-stage grass residues can have potentially very important implications for N supply to subsequent crops. This key cover crop planning issue is explained in the section below on C:N ratios.

Grass cover crops are generally wind- or self-pollinated, meaning species in this group are typically not top choices for improving pollinators. However, some cover crop grasses are useful for building beneficial insect habitat.

Many grass cover crop species make excellent forage if grazed or harvested at the right stage of maturity.

Despite these broad similarities among grass cover crops, individual species within the group can have very different characteristics. For example, grass cover crops include cool-season annuals such as cereal rye, warm-season annuals such as pearl millet, and cool-season perennials such as tall fescue.

Warm-season perennial grasses such as bermudagrass are not usually recommended as cover crops in Virginia, because they are slow to establish and have a relatively long winter dormant period. Neither characteristic is desirable for typical cover cropping purposes.

Legume Functional Group

Legume cover crops are broadleaf plants, including some traditionally harvested for seed (e.g., soybean, cowpea) and others often grown for forage (e.g., hairy vetch, red clover).

The key distinguishing characteristic of legumes is their ability to “fix” or utilize atmospheric nitrogen (N). Although legumes have many useful characteristics, this N fixation ability is typically the single most important reason for using them as cover crops.

Legumes fix N through a mutually beneficial association with Rhizobium bacteria in the soil. When the proper bacteria and conditions exist in the soil, nodules form on legume roots indicating that N fixation is taking place.

Legume seeds can be inoculated with the appropriate bacteria prior to planting to increase the probability of successful N fixation. Different legume species may require different rhizobium bacteria, so the same inoculant will not work for all legumes. However, almost every legume species will “cross-inoculate” with at least one other legume species.

Matching legumes to the proper inoculant can be confusing, so when planning always consult a good reference on legume inoculants.

If the recommended Rhizobium bacteria is already present in the soil, then legume seed inoculation prior to planting may not be necessary. If the field’s recent cropping history includes successfully growing the legume or a “cross-inoculating” species, this generally indicates that the necessary bacteria are already present.

Given that N fixation is almost always a high priority when growing legume covers, inoculating legume seed prior to planting is still recommended in every case as a form of cheap insurance.

In almost all cases, legumes take some of the N they need to build their tissues from the soil and some from the atmosphere. When soil N supply is low, legumes can fix large amounts of atmospheric N. When N is readily available in the soil, legumes will preferentially use soil N rather than fix atmospheric N. So legumes can take up soil N, but they are generally the least effective cover crop functional group for N scavenging.

When legume residues return to the soil and are broken down through microbial action, the N in those residues – including the N originating from the atmosphere – is released and becomes potentially available for use by other plants. In this way, legumes can transfer significant amounts of N from the air to the soil and thereby increase the supply of N available for subsequent crops.

The amount of N fixed and/or taken up by legumes is proportional to the amount of legume biomass produced. A traditional recommendation for maximizing legume cover crop N fixation and supply to subsequent crops is to terminate at early to mid-bloom. Flowering in this case serves as an indicator that maximum biomass has been achieved. Flowering is not necessary for N fixation – as stated above, the process is associated above all with biomass production.

Unless reseeding is desired, terminating legume cover crops prior to seed formation is important both to prevent N from being tied up in the seed and to minimize future weed concerns.

Legume residues at all stages of maturity tend to have low carbon to nitrogen (C:N) ratios. Thus, all legume residues, including those from plants in the early to mid-reproductive stage, can be relatively easily digested and recycled by soil microbes. This means legume residues tend to disappear quickly from the soil surface and not provide long-lasting cover. This also means the nutrients in legume residues, including potentially high levels of N, tend to be quickly released into the soil.

Cover crop legumes tend to be relatively slow to establish compared to grasses and broadleaf species. In general, they produce less total biomass than the other two functional groups. In addition, legumes are not generally recognized for suppressing weeds through alleleopathy. Thus, legume cover crops tend to be less competitive against weeds or other species in a mix than grass or non-legume broadleaf species.

Soil N levels influence the competitiveness of legumes. If soil N supply is high, legumes are less competitive with grasses and non-legumes. If soil N supply is low, legumes tend to be much more competitive.

Legume species tend to require earlier planting dates that grasses and more time to achieve their core purposes than brassicas or grasses. Therefore, legumes are often a poor fit when the growing window for cover crops is relatively short.

All of the above characteristics help explain why legumes are generally the least effective cover crop functional group for providing lasting ground cover, preventing erosion, building soil organic matter, and competing with weeds.

Legume cover crop species generally have taproots with moderate potential for creating macropores in compacted soil. Notable exceptions include some biennial and perennial legumes like alfalfa and yellow blossom sweet clover, which are top subsoilers if they can grow for adequate periods of time.

The legume cover crop group includes many species with blooms attractive to both pollinators and people. Some also have extra-floral nectaries (nectar sources on plant parts other than flowers) that are highly attractive to beneficial insects.

Most legume cover crop species make high quality forage.

Despite these general similarities, individual legume species can have very different characteristics. Legume cover crop choices includes warm season annuals (soybeans, cowpeas, etc.), cool-season annuals (hairy vetch, crimson clover, etc.), and a very important group of biennial or perennial species (red clover, white clover, etc.).

Non-Legume Broadleaf Functional Group

The distinguishing characteristic of this group of cover crops is that they are broadleaf (dicotyledons) like legumes, but they are similar to grasses in that they do not fix atmospheric N.

Non-legume broadleaf cover crops can be further subdivided into two subgroups: brassicas and forbs.

Brassicas

The brassica cover crop subcategory includes forage radish, mustard, rapeseed, and forage turnip. These crops have explosive growth potential, especially in the mild conditions of late summer through mid-fall in Virginia.

Brassicas need lots of soil N to fuel their rapid growth and generally have deep root systems, so they can be excellent N scavengers.

Forage radish and rapeseed in particular are known for their fast-growing, cylindrical taproots that can “biodrill” four or more feet down in a short-time and produce impressive macropores. Not all brassicas have this subsoiling potential; for example, some mustard cultivars are reported to have fibrous root systems.

Brassicas tend to be intermediate between grasses and legumes with respect to C:N ratio of residues and the digestibility of those residues by soil microbes. Thus, residues of brassicas generally break down and release nutrients faster than residues of grasses, but slower than legumes (assuming all were terminated near maturity).

The brassica group therefore tends to be intermediate between grasses and legumes in terms of its potential to fulfill traditional cover crop purposes like providing ground cover, preventing erosion, and building soil organic matter.

Brassicas are excellent at suppressing weeds because of their very fast growth rate. Some like radish also have strong alleleopathic properties that can temporarily suppress weed seed germination even after their residues have disappeared.

All brassicas contain and can release chemical compounds that may be toxic to a broad range of soil organisms, including plant-pathogenic fungi, nematodes, and weeds. Brassica “biofumigation” has been used as a substitute for chemical soil fumigation ahead of a wide range of high-value crops, with varying levels of success. Mustards have the highest biofumigant potential and some cultivars have been developed specifically for that purpose.

The biotoxic compounds in brassicas are high in sulfur (S). This helps explain why brassicas require more S than many other plant species.

It is important to understand that maximizing the brassica soil biofumigant effect requires very purposeful management, including careful timing of cover crop termination, mowing the cover to rupture plant cells and release bio-toxic compounds, and incorporation of the mowed residue into the soil with tillage. Simply growing a brassica cover crop will not likely produce the same biofumigant effect, although well-planned rotation to brassicas may help break cycles of particular pests. The key point is that brassicas are not silver a bullet for eliminating problems with plant-parasitic nematodes or other soil pests (see below for more on pest suppression with cover crops).

Some varieties of brassicas like forage radish and mustard grown in Virginia appear to have a strong photoperiod response. When planted in the late summer or fall as day length decreases, they put on lots of vegetative growth and do not bolt or go to flower When planted in the spring as day length increases, they produce much less biomass and go to flower quickly.

Flowering brassicas like rapeseed or mustard can produce beautiful fields of yellow flowers that are attractive to pollinators.

Some brassicas can provide excellent grazing for livestock and a range of brassica hybrids and cultivars are marketed for this purpose.

Within the brassica subgroup, there can be significant especially strong variability in characteristics between cultivars of the same plant species.

<u>Forbs</u>

The forb subgroup is a catch-all category for non-legume, non-brassica broadleaf cover crop species with many differing characteristics. The forbs recommended in this document are buckwheat, black oilseed sunflower, and phacelia.

Like brassicas, these forb cover crops do not fix atmospheric N and need ample soil N to thrive. However, they do not generally have the deep roots or very fast growth rate of brassicas. Therefore, the forb subgroup has much lower N scavenging potential.

The C:N ratio and durability of forb residues vary. Buckwheat and phacelia residues tend to disappear quickly; mature sunflower residues can be longer-lasting.

All three forbs are similar in that they produce blooms very attractive to pollinators and beneficial insects.

Another similarity is that none of these crops is traditionally used for livestock forage in Virginia.

Buckwheat and sunflower are summer annuals. Phacelia grows best under mild conditions in the fall and spring in Virginia and is generally not expected to overwinter.

Functional Group Selection: C:N Ratio Considerations

Cover crop C:N ratio refers to the ratio of carbon (C) to nitrogen (N) in cover crop biomass. The cover crop C:N ratio controls two very important factors:

1. How quickly cover crop residues will decompose.
2. If and how quickly N in the cover crop residues or the soil will be available to the next crop.

Purposeful cover crop planning means trying to predict and control these two factors. Therefore, C:N ratio is something worth considering for cover crop planners!

C:N Ratio Technical Details

To help you understand how C:N ratio influences the rate of cover crop residue decomposition, consider the following core concept: the soil microbes most responsible for fresh residue decomposition (mostly bacteria) have a C:N ratio of approximately 8:1, but their ideal food has a C:N ratio of approximately 24:1. These microorganisms will use about two thirds of the C they consume for energy. This means that for every 24 units of C consumed, about 16 units will be respired as CO_2. The remaining eight units of C and one unit of N will be integrated into new microbial biomass. Remember: 24:1 makes ideal soil microbe food!

Now consider the following three scenarios:

Mid C:N Ratio Scenario

Assume cover crop residues with an intermediate C:N ratio of 24:1 are returned to the soil. This would be similar to killing rye (grass functional group) in the vegetative stage (prior to seed head emergence).

In this case, there would be neither an excess nor a shortage of N for microbial consumption of the residues. The residues would be broken down at a moderate pace and the soil would be protected for an intermediate period of time.

Most of the N in the residues would be integrated into microbial biomass (then slowly cycled over time for future plant use). We would not expect a meaningful amount of N in the residues to be rapidly released all at once for use by the next crop, in the near term or long term.

Low C:N Ratio Scenario (Mineralization)

Assume cover crop residues with a C:N ratio of 12:1 (also known as 24:2) are returned to the soil. This would be similar to killing a hairy vetch cover crop (legume functional group) at mid bloom. These residues contain significantly more N than soil microbes need in order to digest it. The residues would be broken down quickly and protection of the soil surface provided by those residues would disappear rapidly. The extra N in the residues would be quickly released into the soil for use by the next crop. This net increase in available soil N is called N mineralization.

The speed and amount of N mineralized in this situation would typically increase if the residues were tilled into the soil and if conditions were warm and moist.

High C:N Ratio Scenario (Immobilization)

Assume cover crop residues with C:N ratio of 48:1 (also known as 24:½) are returned to the soil. This would be similar to killing a rye cover crop in the grain fill stage.

These residues contain significantly less N than soil microbes need to consume it. The residues would be broken down slowly and protection of the soil surface provided by those residues would be long-lasting.

The microbes would take the additional N needed for digestion of these residues from the pool of available soil N. This would result in a net decrease in soil N availability and potential N deficiencies in grasses and other non-legume crops. This short-term net decrease in available soil N during microbial digestion of high-C:N-ratio residues is called N immobilization.

The resulting N deficiencies in crops like corn will generally be more severe in cold soils and no-till conditions where supplemental N fertilizer has been spread over the top of high C:N ratio residues.

C:N Ratio Planning Considerations

Select target C:N ratio first, then select functional groups to achieve it

Purposeful cover crop planning means thinking ahead about the quality (i.e., the C:N ratio) of the residues you want to return to the soil when the cover is terminated. Do you want a thick, long-lasting mulch of mature small grain with a high C:N ratio? Do you want low C:N ratio residues that will quickly release extra N for uptake by the next crop? Or do you want something in between?

Estimate early in the planning process what cover crop C:N ratio you hope to see at termination. Functional group selection one of the single biggest factors controlling the final C:N ratio of your cover crop. Therefore use your target C:N ratio as the basis for selecting functional groups.

Mix functional groups to moderate your C:N ratios

Both very high and very low cover crop C:N ratios can be problematic. High C:N ratios in the range of 50:1 or greater can cause severe short-term soil N immobilization and N deficiencies in subsequent crops. Low C:N ratios in the range of 15:1 or less can lead to rapid mineralization of cover crop N. Although it originates from an organic source, this N can be quickly converted to soluble forms and potentially leached or lost almost as easily as fertilizer N.

Mixing cover crop functional groups in a single cover crop planting can help moderate the C:N ratio of residues at termination. The result is residue that breaks down at an intermediate pace and does not cause N immobilization.

A mix of rye and hairy vetch provides a classic example. An equal mix of headed-out rye with a C:N ratio of 48:1 and flowering hairy vetch with a C:N ratio of 12:1 produces material with an overall C:N ratio of 60:2, which is the same as 30:1 (neutral to very mild N immobilization)

Watch for N immobilization behind grass cover crops!

Be on the lookout for instances where an N-fertilized cash crop like corn will be planted behind a mature grass cover crop. This situation sends up a red flag due to the potential for N immobilization.

For example, be very cautious about planting no-till corn into a mature, high-biomass rye cover crop. Note that planting a legume crop like soybeans into the same residue can work very well, since soybeans fix the own N from the air.

Consider the following ideas for reducing the risk of N deficiencies to corn or another grass or N-fertilized cash crop following a grass cover crop:

1. Moderate the overall C:N ratio of the cover crop by including legumes or brassicas in the mix.
2. The C:N ratio of cover crop grasses increases quickly after stem elongation and the reproductive phase begins. Terminate the grass cover crop earlier to keep C:N ratios lower.
3. Consider not only the quality, but also the quantity of cover crop material. The more high-C:N material you have, the greater the amount and duration of potential soil N tie-up. If the amount of residue is low, immobilization may not be a major concern.
4. Consider weather and similar factors. The risk of N immobilization and associated crop deficiencies is higher in colder weather.
5. Provide supplemental early-season N and S fertilizer (or low C:N ratio manure) to help offset the effects of N immobilization. In a no-till situation, consider injecting those nutrients in a band below the residue.

Functional Groups: Rotation & Diversity Considerations

Alternate functional groups in rotations

When planning crop rotations, a good rule of thumb is to alternate between crops from different functional groups. This applies to both harvested crops and non-harvested cover crops.

For example, grass or brassica cash crops (corn, canola) will benefit from the N fixed and quickly released by a preceding legume cover crop. In turn, legume cash crops like soybeans often thrive when no-till planted into high-C:N-ratio small grain residues.

Mix groups to increase cover crop functionality

Mixing multiple cover crop functional groups in a single planting can do far more than simply help moderate the C:N ratios of residues.

Well-planned mixes can produce a blend of functions (subsoiling from brassicas, pollinator habitat from legumes, etc.) that would be very difficult to achieve with monocultures.

Understand limits & benefits of cover crops for soil pest management

Rotating functional groups is not a soil pest cure-all

It is tempting to assume that plants from different functional groups are not subject to the same pests, such as soil-borne fungal diseases and plant-parasitic nematodes. This would make crop rotation planning for control of soil pests very easy. Unfortunately, this is not a safe assumption.

If a particular field has a known problem with a soil pest or pathogen affecting a particular cash crop, growers are often interested in finding a cover crop that are not a host to that pest or pathogen (or even better, that is actively antagonistic to it).

In this instance, simply rotating to a different functional group is no guarantee. Finding the non-host or antagonistic cover crop usually comes down to species-specific or even variety-specific research.

Use cover crops to help create pest-suppressive soils and systems, not to “kill” pests

Following up on the previous point, here is a related rule of thumb for anyone thinking about cover crops as a tool for controlling soil pests: Use cover crops to help add diversity to rotations with soil pest problems; do not try to use cover crops in the “off-season” to eliminate pests in low-diversity cash crop systems.

This concept is best explained with an example. Growers with long-term low-diversity rotations (e.g., continuous soybeans, continuous strawberries, etc.) tend to have problems with soil-borne pests and diseases that get worse over time. These growers are often eager to find cover crops that can be grown in the “off-season” (when their chosen cash crop is not in the ground) that will reduce the severity of the soil-borne pests.

Unfortunately, these growers are not typically interested in modifying the key feature of the crop rotation that is the true cause of the problem – they want to continue growing the same narrow range of cash crop(s) every year. These growers are looking for a cover crop that will serve the same purpose as a pesticide – they want to selectively kill a pest. Although brassicas carefully managed for soil biofumigation might help, cover crops will probably not help meet this particular goal.

A more promising approach in such cases is to recommend much more aggressive changes to the underlying crop rotation. The goal should be to rotate to non-host crops for multiple seasons or years and to restore diversity and balance to the below-ground soil ecosystem. Both cash crops and cover crops can help provide the aboveground diversity of plants that will restore soil health below ground.

Part III. Cover Crop Seasonal Niches

Introduction to Seasonal Niches

A Core Concept for Cover Crop Planning

In Virginia there are six distinct “seasonal niches” or appropriate periods across the calendar year for growing different types of cover crops. Understanding these seasonal niches is the next step in narrowing down your cover crop choices.

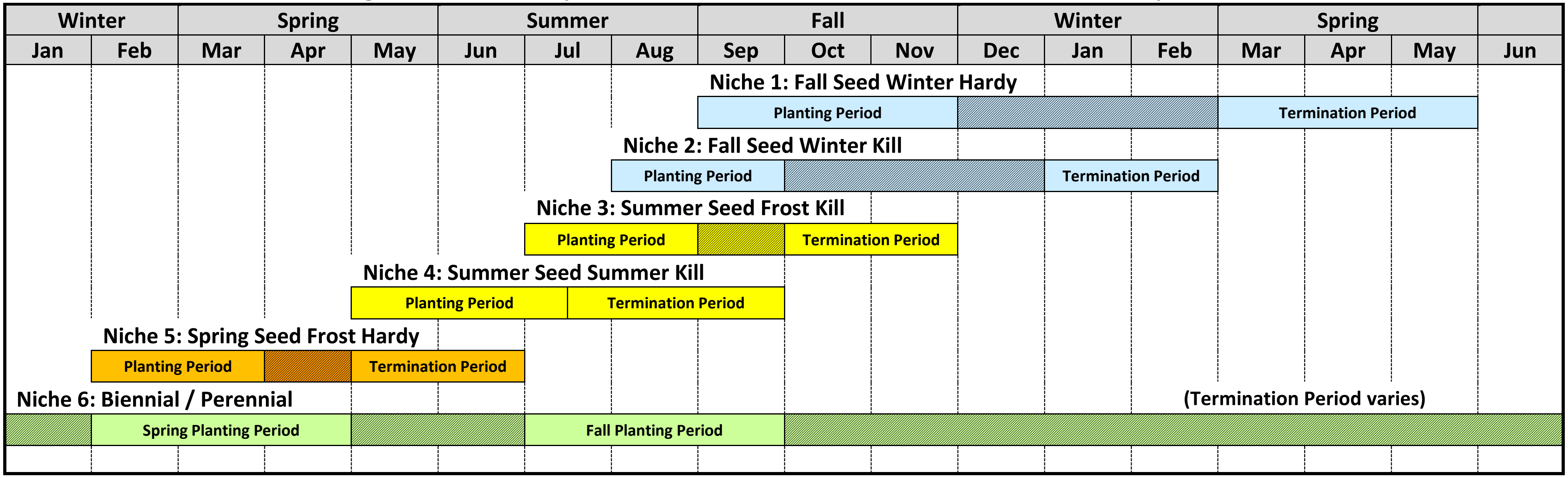
Understanding seasonal niches is also crucial if you want to use this document effectively, because all of the cover crop recommendations and seeding rates, dates, and depths in the following pages are categorized by seasonal niche.

Study “Seasonal Niche Calendar” Diagram

One of the best ways to understand the seasonal niche concept is to study the “Cover Crop Seasonal Niche Calendar & Matrix of Recommended Species” diagram below. This information is formatted to fit on one side of a page so that it can be used as a handout or posted in a convenient location for easy reference.

Use the calendar of seasonal niches diagram only for its intended purpose, which is to give you a general understanding of the six seasonal niches. Do not use it to select specific planting or termination dates for a particular cover crop species you intend to grow. Use the establishment specifications later in this document for that purpose.

Figure 1. Cover Crop Seasonal Niche Calendar & Matrix of Recommended Species



Niche Name	Description	Functional Groups & Recommended Species		
		Grass	Broadleaf / Forb	Legume
1. Fall Seed Winter Hardy	Winterhardy cool-season annual planted in fall and terminated in spring.	annual ryegrass; small grains (barley, oat, wheat, triticale, rye)	rapeseed; forage turnip	red clover; crimson clover; Austrian winter pea; woollypod vetch; hairy vetch
2. Fall Seed Winter Kill	Fast-growing, frost-hardy annual seeded in early fall. Expected to freeze-kill mid-winter (at 15 to 20° F.)	spring oat	forage radish; mustard, phacelia	Canadian spring pea
3. Summer Seed Frost Kill	Frost-tender, warm-season annual planted in mid to late summer. Expected to winterkill at first frost.	sorghum-sudangrass; pearl millet; foxtail millet	buckwheat; black oil sunflower	forage soybean; cowpea; sunnhemp
4. Summer Seed Summer Kill	Frost-tender, warm-season annual seeded early summer. Terminated in time to plant back another crop in summer or fall.	sorghum-sudangrass; pearl millet; foxtail millet	buckwheat; black oil sunflower	forage soybean; cowpea; sunnhemp
5. Spring Seed Frost Hardy	Fast-growing, frost-hardy cool-season annual planted in late winter/early spring.	spring oat; winter (or spring) small grains (barley, wheat, triticale, rye)	forage radish; mustard; phacelia; rapeseed; forage turnip;	Canadian spring pea; Austrian winter pea; woolypod vetch; hairy vetch
6. Biennial / Perennial	Biennial or perennial, grown at least one summer, typically 18 months	tall fescue; orchardgrass		alfalfa; red clover; white clover; yellow blossom sweetclover

Part IV. Cover Crop Species Lists & Establishment Specifications

Introduction to Species Lists & Establishment Specifications

In the following pages, you will find the following:

1. Lists and descriptions of recommended cover crop species for each of the six seasonal niches
2. Corresponding establishment specifications ("specs") that provide seeding rate, date, depth, and other information for each recommended species

This key information is found in nine tables, which are formatted so they can be readily extracted from this document for use as handouts, etc.

The species lists and establishment specs were designed to be used together. Consult both as you select cover crop species, then plan seeding details.

In the following pages that precede the species lists and establishment specification tables, you will find definitions of terms, guidance on using the tables, and other considerations for planning good cover crops.

Note that the establishment specifications provide seeding recommendations for traditional monocultures. Advice on formulating and setting seeding rates for cover crop mixes are found in the next chapter.

How species lists are organized

Within each species list and establishment specs table, species are first categorized by functional group. Within each functional group, species are then listed roughly in order of time of planting timing (i.e., earliest to be planted are listed first).

For Latin names and some common aliases ("aka") for each species, see the species description tables.

The lists of recommended species are designed to provide a range of choices, not an exhaustive list of every possible option. In some cases, related species can potentially be substituted for one of the listed cover crops (e.g., common vetch instead of woollypod vetch), as noted in the description of the species.

If you are interested substituting a cover crop species that is not listed, contact NRCS State Resource Conservationist (SRC) staff.

Winterkill Probability

Whether or not a cover crop will winterkill is an important question only for fall-seeded crops in Niches 1 and 2 (all summer-seeded crops in Niches 3 and 4 will winterkill). Therefore, the column "Winterkill Probability" appears only in Establishment Specs A for fall-seeded species. Use the following guidance to help interpret the information provided in that column.

Species with a high probability of winterkill fit into Seasonal Niche 2 (Fall Seed Winterkill). These are highlighted with gray shading. All other species in the Establishment Specs A table fall into Seasonal Niche 1 (Fall Seed Winter-Hardy).

"Winterkill" in this case refers to cover crop termination by cold in mid-winter. It does not refer to cold damage caused by late spring freezes after the cover crop has broken dormancy, which can damage even very cold-hardy speices in some years.

See Table 1 for interpretations of winterkill probability ratings (these definitions are specific to this document and may not be consistent with how the terms are used in other documents).

Table 1. Interpretation of Winterkill Probability Ratings from Establishment Specs A for Fall-Seeded Cover Crops

Rating	Suggested Interpretation
Very low:	Reliably winterhardy throughout Virginia; typically survives temperatures below 0° F.
Low:	Reliably winterhardy in most of Virginia; winterkills in coldest regions of state in some years; may survive temperatures as low as 0° F.; variety selection may influence hardiness.
Mid:	Variable winter-hardiness across Virginia; likely to winterkill in colder regions, survive in warmer regions; may survive temperatures between 15° and 20° F.; variety selection may significantly influence hardiness and makes winterhardiness difficult to predict.
High:	Reliably winterkills in most of Virginia; overwinters in warmest regions of state in some years; not likely to survive temperatures between 15° and 20° F., variety selection may influence hardiness.
Very high:	Reliably winterkills throughout Virginia; typically does not survive temperatures below 28° F.

The winterkill probability ratings assume the crop will be seeded in the preferred date range. Crops seeded outside the recommended planting window or depth may be more or less vulnerable to winter damage (see additional discussion of seeding date impact on winter-hardiness below).

Disclaimer: The winterkill ratings provided are very general estimates. They may prove incorrect for some crops in some years, especially in the warmest and coldest regions of Virginia. For some species, winter-hardiness can vary significantly between cultivars. For additional information about winter-hardiness of individual species or varieties, consult the species lists, other references, and/or vendors and local experts.

Seeding Rates

Definitions and Interpretation of Terms in Establishment Specs

Base or default rate vs. acceptable range of rates

The "base / default" seeding rate is the recommended rate for achieving typical cover crop purposes for this species in this particular seasonal niche. Use the base rate as a starting point for planning or as a default – i.e., in the absence of more details about the situation or intended purpose, use the base rate.

An "acceptable range" of seeding rates is also provided. Use rates in the acceptable range that are higher or lower than the base rate if the grower has a specific cover crop purpose or situation that is more likely to be achieved with that rate. For some less typical purposes, more or less than the base rate may be best.

In some cases, the grower's primary cover crop purpose would be best achieved by planting the base rate, but cost or other factors cause him to seed a lower rate. In these instances, some cover crop benefits may still be gained by planting in the acceptable rate range, but the probability of achieving that key primary purpose may be reduced. For example, if the grower has signed up for a payment that requires achieving a minimum level of cover or biomass by a specific deadline, do not assume that any and all seeding rates in the acceptable range will achieve that goal.

Drill vs. broadcast rates

"Drill" rates are recommended seeding rates for planting with a typical conventional or no-till grain drill on 7.5-inch row spacing.

"Bcast + incorp" rates are recommend seeding rates for broadcasting seed (by hand, with a spin spreader, or by airplane), then using a harrow, roller, or other operation to help ensure seed-to-soil contact. Broadcasting seed without any incorporation, especially when the soil is covered with residue, can work but is not recommended. For more on issue of broadcasting seed with or without incorporation, see the section on seeding depth below.

Pros & Cons of Higher vs. Lower Seeding Rates

Since the establishment specs offer ranges of acceptable seeding rates, some generalizations about the pros and cons of higher vs. lower rates are provided below. Consult species lists and other resources or experts for additional information on particular species.

Higher seeding rates generally provide more soil coverage in a shorter time. For example, if the goal is maximum nutrient uptake and soil cover ahead of winter by a small grain crop, that purpose will be best met with relatively high seeding rates.

Increasing seeding rates above the recommended base rate is especially useful when the primary cover crop purpose is weed control. Higher rates can also help with (but not solve) problems with suboptimal planting conditions, such as late seeding, soil crusting that interferes with seedling emergence, etc.

Crowded plants may be taller and more vulnerable to lodging. When nutrients and water are limiting, closely packed plants may be stunted because due to excessive competition between plants. This could be an advantage for weed control or other purposes, or a major disadvantage in other situations.

When the focus is on later-season benefits, standability, and larger individual plants, lower seeding rates may be beneficial. Here are two possible examples:

1. If the goal is small grain that stands well for wind erosion prevention next spring, lean towards lower seeding rates to minimize lodging potential.
2. Lower rates of forage radish will produce larger tubers (and presumably deeper roots) than high rates.

Seeding Depth

Deeper vs. Shallower Seeding Depths

The establishment specs show a range of seeding depths for each species. In general, use the shallower end of the range when soil is moist, conditions are cool, or crusting may interfere with emergence. Use the deeper end of the range to place seeds into moist soil when conditions are warmer and drier.

Broadcasting Seed without Incorporation: Not Recommended

When seed is broadcast, a subsequent operation is recommended to help ensure seed-to-soil contact. Depending on the situation, the subsequent operation could be harrowing, raking, rolling or even irrigating. Incorporation is especially important when broadcasting seed over the top of heavy residues that block seed-to-soil contact.

It should be noted that broadcast seeding cover crops into standing unharvested crops without incorporation has been successful for many Virginia growers. This method can work and sometimes can work very well. However, it is not as reliable as seeding methods that ensure more consistent seed-to-soil contact. Therefore, VA NRCS generally recommends drilling or otherwise incorporating all cover crop seed to the depths listed in the establishment specs.

There are exceptions to every rule. One specific example is frost-seeding clover into pastures or small grains in late winter. This is a special practice where the combination of very small seed, exposed soil, and frost action can provide acceptable results.

Seeding Dates

Definitions and Interpretation of Terms in Establishment Specs

Calendar dates vs. "relative-to-frost" seeding dates

The establishment specs provide cover crop seeding date recommendations in two ways:

1. Traditional calendar date ranges are provided for each of three Virginia physiographic regions.
2. Seeding date ranges are also presented relative to average frost dates.

The simplest approach for most users is to refer to the traditional calendar date ranges for seeding recommendations.

Why are seeding dates relative to frost included? The seeding date recommendations in this document were developed by first selecting planting timeframes before or after average fall or spring frost dates. These relative date ranges were then used to derive the traditional calendar dates shown in the establishment specs. The relative-to-frost dates are listed in order to give you the option to customize seeding date recommendations for your local climate.

To learn more about how to (a) gauge whether the traditional calendar date ranges listed are representative for your location and (b) customize seeding date recommendations to your local climate, see Appendix I.

Preferred vs. possible seeding dates

Whether you are looking at calendar or relative-to-frost dates in the establishment specs, you will see two sets of recommended date ranges.

The "preferred" seeding date range is the best time to plant in order to achieve typical cover crop purposes for the specified species and seasonal niche. Use the preferred range as a starting point for planning or as a default – i.e., in the absence of more details and planning about the situation or intended purpose, use the preferred dates.

The "possible" seeding date range offers a wider planting window. Use dates in the possible range that are earlier or later than the preferred date if the grower has a specific cover crop purpose or objective that is more likely to be achieved by planting outside the preferred window. For some less typical purposes, planting outside the preferred date range may be best.

In some cases, the grower's primary cover crop purpose would be best achieved by planting in the preferred date range, but practical constraints (late harvest of preceding crop, etc.) prevent that from happening. In this case, some cover crop benefits may still be gained by planting in the possible date range, but the probability of achieving that key primary purpose may be significantly reduced. For example, if the grower has signed up for a program that requires achieving a minimum level of cover or biomass by a specific deadline, do not assume that any and all plantings in the possible date range will achieve that goal.

Pros & Cons of Earlier vs. Later Seeding

Since ranges of seeding dates are provided in the establishment specs, the following generalizations about earlier vs. later seeding dates are offered below as a starting point for planning. Consult species lists and other resources and experts for additional details for particular species and situations.

For fall-seeded species (Niches 1 and 2), seeding earlier provides more overall sunlight energy before the onset of winter. Sunlight energy is usually, but not always, the most limiting factor for fall cover crop growth.

For some species, achieving adequate development prior to the onset of winter is important for winter-hardiness. For example, rapeseed is less winter-hardy if it is late planted. But excessive growth in the fall can also make some species vulnerable to winterkill. If the goal is for the crop to overwinter, very lush fall growth may be a disadvantage for some species (e.g., Austrian Winter Peas grown in Seasonal Niche 1). If the grower's goal is for the cover to winterkill, lush growth can be an advantage (e.g., Canadian Spring Peas grown in Seasonal Niche 2).

In general, if a fall-seeded cover crop's core purpose is spring production of biomass, later seeding is less of problem and can even be an advantage. For example, early-seeded small grains such as barley and wheat are vulnerable to Hessian fly damage. For this reason, small grain seeding for grain production is often purposely delayed in the fall until after the "fly-free date". Planting in this later range (which falls into the "possible range" in Establishment Specs A) can be acceptable for small grain cover crops. But if the primary purpose is fall and winter N scavenging and maximum winter cover, then earlier planting is the priority and Hessian fly concerns are secondary.

Delayed planting can be a core part of the cover cropping strategy for cover seeded in late summer for Niche 3. In this case, the goal may be to plant a summer crop like sorghum-sudangrass early enough to get good growth, but late enough that the crop will not set seed before frost kills it.

Cover Crop Maturity & Termination Timing

Purposeful cover crop planning usually requires more than selecting a seeding date. It also requires forecasting when the cover crop will reach one or more stages of maturity, which can be critical for planning the timing of termination.

The species lists and establishment specs provide limited maturity information for some species and niches. This information is provided as a starting point for planning the timing of termination, mowing, or related activities. Depending on the species, maturity information is provided in terms of days after planting (DAP), calendar date ranges, or timing relative to other species.

Disclaimer: Use this maturity information only as a general guideline. It may prove incorrect for some crops in some years, as maturity timing can be affected by a wide range of factors including variety, day length, weather, and crop condition. For additional information about maturity timing of individual species or varieties, consult other references and experts, including vendors.

Timing of Cover Crop Maturity: Why It Matters

Here are three examples of reasons why you should always consider maturity timing when planning covers:

<u>To ensure sufficient biomass production</u>

Some cover crop purposes are best achieved by maximizing biomass production. For example, if the farmer's purpose is to capture atmospheric N with a legume cover and reduce fertilization of the subsequent crop, then ideal termination timing for the legume is typically early reproductive stage (mid-bloom). At this time, the cover has generally achieved both maximum biomass and maximum N fixation, but translocation of N from tissue to new seed has not yet started.

<u>To avoid too much biomass production.</u>

Some purposes are best achieved by stopping cover crop growth well ahead of maximum biomass. For example, if they are allowed to reach maximum biomass, grasses like rye or sorghum-sudangrass have the potential to produce large amounts of hard-to-manage, high C:N ratio residue than can be overwhelming for some growers.

<u>To stop seed set and future weed problems</u>

Many cover crops can produce large amounts of seed in a relatively short time. For example, buckwheat can produce viable seed in as little as 45 days. Self-seeded cover crops that volunteer in subsequent crops can be very competitive weeds.

Cover Crop Maturity & Termination Timing: Checklist for Planning

Growers should not be too intimidated by the potential problems with over-mature cover crops described above, as long as cover crop maturity and termination timing is considered ahead of time. Try to address each of these steps before the cover crop is in the ground:

1. Maturity timing is a much greater concern for some cover crops and situations than others. Know the characteristics of the species to be grown and cropping system context.
2. Try to predict the approximate stage of cover crop development that would be best for termination or other action, such as mowing, to set back biomass and/or seed production).
3. Have a general idea of the calendar date when the target termination or mowing stage is likely to be reached. This will always be just an approximation.
4. Have a plan to monitor cover crop development and know up front what growth stage indicator (e.g., height, heading, bloom, etc.) will be trigger for action. In-field monitoring can be crucial because the time it takes for the cover crop to reach its target growth stage can be influenced by site-specific factors such as weather, fertility, and variety.
5. Make sure the necessary personnel, equipment, etc. will be available to carry out termination or mowing when needed.

Table 2. Cover Crop Species List A, Part 1: Recommended Fall-Seeded Species *(Seasonal Niches 1 & 2)*		
	Species	**Key Characteristics & Considerations**
Grasses	**Spring Oat** *Avena sativa*	Compare to winter oat below. Goal here is winterkill (Niche 2): select varieties accordingly, plant early for lush growth. Oat is least hardy small grain (SG), but may not winterkill in SE VA. Grows very fast in mild fall/spring. Much lower C:N, shorter-lived residue vs. typical SG. Needs good fertility. Good weed suppressor, moderate N scavenger, high forage quality. No vernalization required; may head out in fall but viable seed unlikely. Top nurse crop for fall legumes (use low rate). Mix with radish, peas. See also Niche 5.
Grasses	**Annual Ryegrass** *Lolium multiflorum* aka Italian Ryegrass	Popular cover in Corn Belt, much less in VA. Major weed in small grain (SG). Do not allow to set seed. Can be hard to kill with herbicides – timing is key. Dense fibrous root system, top soil conditioner, good weed suppresser, good N scavenger, top quality forage. Establishes well in tough conditions, but needs good fertility. Tolerates wet feet better than any SG. Not good in heat or drought. Winter-hardiness can vary – select cultivars accordingly. Shorter than SG, lower C:N, mixes well with crimson clover. See also Niche 5.
Grasses	**Winter Oat** *Avena sativa*	Compare to spring oat above. Goal here is overwintering (Niche 1): select varieties accordingly. Winter oat not common in VA. Unlikely to overwinter in western VA; best fit is Coastal Plain. Needs vernalization for heading. Planted early (like barley), but last SG to mature in spring. Good weed suppressor, ok N scavenger, high forage quality. Good rotation for other SG – not host for take-all disease. Good nurse crop. Compared to other SG: lowest biomass producer, slightly lower C:N, lower tolerance for extremes of dry and wet.
Grasses	**Barley** *Hordeum vulgare*	Widely used in VA. More winterhardy than oat, less than wheat/rye. Planted earlier in fall, matures earlier in spring than wheat. Best small grain (SG) for drought, heat, salty or alkaline soils. Quick growth & high biomass if fertility good. Good weed suppressor, N scavenger, forage. Retains feed quality after heading. Not for wet or acid soils. Good nurse for legumes. Timing, height match crimson clover, rapeseed. Poor choice for rolling. Not good for rotations with SG cash crops (will host same diseases and pests).
Grasses	**Wheat** *Triticum aestivum*	Versatile & widely used in VA. Compared to barley: planted later in fall, matures later in spring, tolerates wetness better (but not flooding), higher spring biomass potential (but requires high fertility). Very good N scavenger. Top quality forage – after multiple grazings can still produce high spring biomass or grain. Fine nurse crop for legumes. Mixes well with winter peas, hairy vetch. Shorter, slower to head means residue easier to manage than rye. Not good for rotations with SG cash crops (will host same diseases and pests).
Grasses	**Triticale** *Triticum secale*	A cross between rye and wheat, with characteristics intermediate between the two. High biomass yield potential is similar to wheat and rye. Matures later than rye, a little later than wheat. Plant height at heading shorter than rye. Therefore, spring residue is easier to manage than rye and (assuming same kill date) C:N ratio will be lower than rye. Triticale feed quality generally better than rye, but not as good as wheat (i.e., chop triticale for silage at boot stage).
Grasses	**Rye** *Secale cereale* aka Cereal Rye	Top winter cover for many purposes, most winterhardy, best on poor/acid soils. Top SG for N scavenging, biomass, seed suppression, tolerance of wet soils. Can plant later than any SG in fall, but matures early in spring – only barley is earlier. Rye alleleopathy inhibits weeds, but maybe also next crop if small-seeded. Height, biomass, high C:N at maturity can be overwhelming. Top choice for rolling. Potential weed if sets seed; caution in SG crop system. Good forage, but low quality after heading. Mix with vining vetch, pea.
Brassicas (B)	**Forage Radish (B)** *Raphanus sativus* aka Daikon; Daichon; Fodder Radish	Top Niche 2 (winterkill) option. May overwinter in SE VA. Early plant + mid seed rate = large lush plants, better winterkill. Late plant + high seed rate = smaller plants, more hardy. With good fertility, fastest-growing fall cover option. Top biomass, subsoiler, N scavenger, forage. Winterkilled residues disappear, N releases fast. Top weed suppressor (competition + alleleopathy). Good in mixes, caution not to out-compete companions. Different growth pattern if spring seed, see Niche 5. Can substitute oilseed radish.
Brassicas (B)	**Mustard (B)** **White/Yellow:** *Sinapis alba* **Brown/Indian:** *Brassica juncea* **Black:** *B. nigra (L.)*	Similar to other brassicas (see above, below), but best use in VA probably pest suppression, adding diversity to mixes. The brassica with most biotoxic compounds, best for biofumigation (requires soil incorporation, etc.). With fertility, potential for very fast fall growth, high biomass, good N scavenging. Not known for subsoiling, some varieties may not have taproot. Winter-hardiness, day length responses, other characteristics may vary by cultivar. Research & match varieties to your need. See also Niche 5.

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Table 3. Cover Crop Species List A, Part 2: Recommended Fall-Seeded Species *(Seasonal Niches 1 & 2)*		
	Species	**Key Characteristics & Considerations**
Brassicas (B) / Forbs	**Phacelia** *Phacelia tanacetifolia* aka Lacy Phacelia	Unique crop with fernlike biomass. Fibrous shallow roots tops for soil aggregation. Not a brassica, adds diversity. Widely used in Europe. New to VA, info limited, seed costly. Fast growth in mild fall conditions, moderate biomass, residue not long-lasting. Winterkill expected in most of VA; may overwinter in SE VA; manage for lush growth to increase winterkill potential. Appears to have daylength response: in fall vegetative growth only; in spring goes to flower. Showy blue blooms tops for pollinators. See also Niche 5.
	Forage Turnip (B) *Brassica rapa var. rapa*	Similar to radish (above) or rapeseed (below), but less impressive taproot – instead makes bulb on surface. Good forage, probably fit best where cover will be grazed. With fertility, potential for fast fall growth, high biomass, good N scavenging. Big varietal differences possible, including major differences in bulb vs. top (leaf) ratios. Winter-hardiness, day length responses may vary also. Research cultivars to match your need. Big bulbs can be slow to break down, not ideal for subsequent planting or field operations. See also Niche 5.
	Rapeseed (B) *Brassica rapa* aka Canola; Rape	Top brassica option for Niche 1. Winter-hardy cousin to forage radish (see above), similar characteristics. Reliably winter-hardy if seeded on time, except maybe highest VA elevations. With fertility, gives biomass, forage, deep branched taproot, N scavenging, weed suppression. Spring flowers attract pollinators. Low cost to seed. Range of choices (canola for seed, hybrids for grazing, etc.), characteristics may differ. Good in mixes, but caution not to outcompete companions. Spring termination sometimes tricky. See also Niche 5.
Legumes	**Canadian Spring Pea** *Pisum sativum subsp. Arvense* *aka Yellow Field Pea*	Compare with winter pea below. Goal here is winterkill (Niche 2); rarely used this way in VA. Aim for lush growth – plant early! May not reliably winterkill in Coastal Plain. Select fastest growing spring types. Some contradictory info in literature about winterkill potential of peas. If fails to winterkill, easy to kill with other methods. Expect lower biomass & total N fixation compared to overwintered peas. Mixes well with spring oat, forage radish. Inoculate! Cross inoculates with vetch. See also Niche 5.
	Red Clover *Trifolium pratense*	Short-lived perennial, rarely used in this niche. Slow growing, must be seeded earlier, killed later than other annual legumes choices. Establishes readily, shade tolerant, very winter-hardy, inexpensive, resistant to some nematodes. Moderate N fixation. Best on good soils with high fertility; tolerates some wetness. For this niche, use multi-cut medium or one-cut mammoth varieties. Consider spring oat nurse crop or wheat/triticale companion. Inoculate! Cross inoculates with crimson or white clover. See also Niche 6.
	Crimson Clover *Trifolium incarnatum*	Popular in VA. May not reliably overwinter at very high elevations in VA. Earlier seeded, more fall growth, earlier spring bloom than hairy vetch. Short, upright growth habit. Good forage & weed suppressor. Good N fixer with slower residue breakdown & N release than vetch. Shade tolerant. Showy blooms, good for pollinators. Can reseed quickly & become weed. Host to some problem nematodes. Mixes esp. well with barley, annual ryegrass. Inoculate! Cross-inoculates with red or white clover.
	Austrian Winter Pea *Pisum sativum subsp. Arvense* aka Black Field Pea	Compare to spring pea above. Goal here is overwintering (Niche 1): select winterhardy accordingly, avoid planting too early or late. May not reliably overwinter at very high elevations in VA. Top N fixer, good biomass & forage. Succulent residues disappear & release N faster than vetch. Low reseeding & weed risk. Vining habit, mix with small grain to climb. Caution: Sclerotinia crown rot can take out whole field, risk increases with more peas in rotation. Inoculate seed! Cross inoculates with vetch. See also Niche 5.
	Woolypod Vetch *Vicia villosa ssp. dasycarpa* aka Lana Vetch	One of multiple vetch choices similar to hairy vetch (HV) – see below for HV description. Compared to HV, woollypod generally grows faster, produces more biomass, fixes more N, is less winterhardy. Likely to overwinter ok in eastern VA most years; limited info on winter survival in western VA. Caution: looks like HV, some vendors caution that not all seed sold as woollypod is woollypod. Common vetch (*Vicia sativa)* is possible substitute (increase seed rate 10%), might have less biomass potential. See also Niche 5.
	Hairy Vetch *Vicia villosa*	Reliable & widely used, but avoided by some due to weed concerns. Very winterhardy. Little fall growth, but fast vining spring growth makes it tops for N fixation, biomass. Residues release N fast. Good forage. Climbs well in mixes, also wraps up in equipment! Rye-vetch is top mix, or match with triticale, etc. Up to 20% of planted seed is hard, will germinate in future as weed. Host to some problem nematodes. Inoculate seed! Cross inoculates with peas. See above for other vetch types. See also Niche 5.

Table 4. Establishment Specifications A: Fall-Seeded Cover Crops *(Seasonal Niches 1 & 2, Winter-Hardy & Winterkill)*

Group	Species (gray shading indicates Niche 2 – expected to winterkill)	Winterkill probability	Seeding rates (lb/ac, for monocultures): Base / default – Drill	Base / default – Bcast + incorp	Acceptable range – Drill	Acceptable range – Bcast + incorp	Seed depth (inch)	Seeding dates: Mountain & Valley (based on Oct 10 average first frost) – Preferred	Mountain & Valley – Possible	Piedmont (PM) (based on Oct 20 average first frost) – Preferred	Piedmont (PM) – Possible	Coastal Plain (CP) (based on Nov 1 average first frost) – Preferred	Coastal Plain (CP) – Possible	Before or after avg first frost in fall (DBFF or DAFF) – Preferred	Before or after avg first frost in fall – Possible	Approx. maturity MB = max. biomass; VS = viable seed ***(use as general guideline only)***
Grasses	Spring Oat	high to mid	80	110	65 to 125	100 to 165	0.5 to 1.5	Aug 1 to Aug 20	Jul 20 to Sep 5	Aug 10 to Sep 1	Aug 1 to Sep 15	Aug 20 to Sep 10	Aug 10 to Sep 25	70 to 50 DBFF	80 to 35 DBFF	Winterkills before VS
Grasses	Annual Ryegrass	low	15	25	10 to 20	20 to 30	0.25 to 0.5	Aug 10 to Sep 1	Aug 1 to Sept 20	Aug 20 to Sep 10	Aug 10 to Oct 1	Sep 1 to Sep 20	Aug 20 to Oct 10	60 to 40 DBFF	70 to 20 DBFF	Similar timing to barley
Grasses	Winter Oat *PM & CP only*	low to mid	80	110	65 to 125	100 to 165	0.5 to 1.5	not suited	not suited	Sep 10 to Sep 30	Sep 5 to Oct 5	Sep 20 to Oct 10	Sep 15 to Oct 15	40 to 20 DBFF	45 to 15 DBFF	Similar timing to wheat
Grasses	Barley	very low	100	140	50 to 150	75 to 200	0.75 to 2.0	Aug 10 to Sep 10	Aug 1 to Oct 10	Aug 20 to Sep 20	Aug 10 to Oct 20	Sep 1 to Oct 1	Aug 20 to Nov 1	60 to 30 DBFF	70 to 0 DBFF	Earlier to head than wheat
Grasses	Wheat	very low	120	160	60 to 180	90 to 240	0.5 to 1.5	Aug 25 to Sep 25	Aug 15 to Oct 25	Sep 5 to Oct 5	Aug 25 to Nov 5	Sep 15 to Oct 15	Sep 5 to Nov 15	45 to 15 DBFF	55 DBFF to 15 DAFF	Heads late Apr to early May
Grasses	Triticale	very low	110	145	60 to 170	90 to 225	0.75 to 2.0	Aug 25 to Sep 25	Aug 15 to Nov 1	Sep 5 to Oct 5	Aug 25 to Nov 10	Sep 15 to Oct 15	Sep 5 to Nov 20	45 to 15 DBFF	55 DBFF to 20 DAFF	Later to head than wheat
Grasses	Rye	very low	110	145	60 to 170	90 to 225	0.75 to 2.0	Aug 15 to Oct 1	Aug 5 to Nov 10	Aug 25 to Oct 10	Aug 15 to Nov 20	Sep 5 to Oct 20	Aug 25 to Dec 1	55 to 10 DBFF	65 DBFF to 30 DAFF	Earlier to head than barley
Brassicas (B) / Forbs	Forage Radish (B)	high	8	14	6 to 12	12 to 18	0.25 to 0.5	Aug 1 to Aug 20	Jul 10 to Sep 10	Aug 10 to Sep 1	Jul 20 to Sep 20	Aug 20 to Sep 10	Aug 1 to Oct 1	70 to 50 DBFF	90 to 30 DBFF	Winterkills before VS
Brassicas (B) / Forbs	Mustard (B)	high to mid	8	12	5 to 12	10 to 18	0.25 to 0.5	Aug 1 to Aug 20	Jul 10 to Sep 10	Aug 10 to Sep 1	Jul 20 to Sep 20	Aug 20 to Sep 10	Aug 1 to Oct 1	70 to 50 DBFF	90 to 30 DBFF	Winterkills before VS
Brassicas (B) / Forbs	Forage Turnip (B)	mid	5	10	2 to 8	8 to 12	0.25 to 0.5	Aug 1 to Aug 20	Jul 10 to Sep 10	Aug 10 to Sep 1	Jul 20 to Sep 20	Aug 20 to Sep 10	Aug 1 to Oct 1	70 to 50 DBFF	90 to 30 DBFF	Spring VS or winterkills
Brassicas (B) / Forbs	Phacelia	high to mid	8	12	7 to 12	10 to 14	0.25 to 0.5	Aug 1 to Aug 20	Jul 20 to Sep 1	Aug 10 to Sep 1	Aug 1 to Sep 10	Aug 20 to Sep 10	Aug 10 to Sep 20	70 to 50 DBFF	80 to 40 DBFF	Winterkills before VS
Brassicas (B) / Forbs	Rapeseed (B)	low	6	12	4 to 10	8 to 14	0.25 to 0.5	Aug 10 to Sep 1	Jul 20 to Sep 20	Aug 20 to Sep 10	Aug 1 to Oct 1	Sep 1 to Sep 20	Aug 10 to Oct 10	60 to 40 DBFF	80 to 20 DBFF	MB late Apr / early May
Legumes *(inoculate!)*	Canadian Spring Pea	high to mid	60	90	50 to 80	75 to 120	1.5 to 2.5	Aug 1 to Aug 20	Jul 20 to Sep 1	Aug 10 to Sep 1	Aug 1 to Sep 10	Aug 20 to Sep 10	Aug 10 to Sep 20	70 to 50 DBFF	80 to 40 DBFF	Winterkills before VS
Legumes *(inoculate!)*	Red Clover	very low	10	12	8 to 10	10 to 12	0.25 to 0.5	Aug 5 to Aug 25	Jul 25 to Sep 5	Aug 15 to Sep 5	Aug 5 to Sep 15	Aug 25 to Sep 15	Aug 15 to Sep 25	65 to 45 DBFF	75 to 35 DBFF	MB late May to mid June
Legumes *(inoculate!)*	Crimson Clover	low	15	25	15 to 20	20 to 30	0.25 to 0.5	Aug 10 to Sep 1	Aug 1 to Sept 20	Aug 20 to Sep 10	Aug 10 to Oct 1	Sep 1 to Sep 20	Aug 20 to Oct 10	60 to 40 DBFF	70 to 20 DBFF	MB late April to early May
Legumes *(inoculate!)*	Austrian Winter Pea	low	50	75	50 to 80	75 to 120	1.5 to 2.5	Aug 20 to Sep 10	Aug 10 to Oct 1	Sep 1 to Sep 20	Aug 20 to Oct 10	Sep 10 to Oct 1	Sep 1 to Oct 20	50 to 30 DBFF	60 to 10 DBFF	MB early to mid May
Legumes *(inoculate!)*	W.pod Vetch *PM & CP only*	low to mid	20	30	15 to 25	25 to 40	0.5 to 1.0	not suited	not suited	Sep 1 to Sep 20	Aug 20 to Oct 10	Sep 10 to Oct 1	Sep 1 to Oct 20	50 to 30 DBFF	60 to 10 DBFF	MB early to mid May
Legumes *(inoculate!)*	Hairy Vetch	very low	20	30	15 to 25	25 to 40	0.5 to 1.0	Aug 20 to Sep 10	Aug 1 to Oct 1	Sep 1 to Sep 20	Aug 10 to Oct 10	Sep 10 to Oct 1	Aug 20 to Oct 20	50 to 30 DBFF	70 to 10 DBFF	MB early to mid May

Table 5. Cover Crop Species List B: Recommended Summer-Seeded Species *(Seasonal Niches 3 & 4)*		
	Species	**Key Characteristics & Considerations**
Grasses	**Sorghum-Sudangrass** *Sorghum bicolor x S. bicolor var. sudanese* aka Sudex, Sudax	Top grass choice. Heat-loving, fast-growing, 6-12 ft tall, big biomass potential, but needs lots soil N. Top weed suppressor thru competition, alleleopathy (caution on next crop if small seeded). Top subsoiler with thicker roots than most grasses. Good forage, but caution on prussic acid, nitrates. Improved forage types available, cultivars may vary widely. Regrows well after mow/graze. Huge biomass, reseeding potential can overwhelm: mow or kill timely! Mix with cowpea, sunnhemp. Can swap in forage sorghum or sudangrass.
	Pearl Millet *Pennisetum glaucum* aka Cattail Millet	Heat-loving, fast-growing, high-biomass option very similar to sorghum-sudangrass (see above). Compared to sorghum-sudangrass: slightly lower biomass potential; better on acid & droughty soils; less alleleopathy potential; less reputation for subsoiling; no prussic acid forage toxicity (but nitrates still a concern). Some contradictory info on pearl millet regrowth potential, but generally expected to regrow well if mow/graze high. Improved forage types available, cultivars may vary widely. Mix with cowpea, sunhemp.
	Foxtail Millet *Setaria italica* (aka German or Hay Millet)	Much shorter, finer-stemmed, lower-biomass option compared to sorghum-sudan & pearl (see above). Key difference: foxtail is reliably killed with single mowing. Also foxtail matures faster, not as good on weeds or drought. Some report foxtail grows little in 2nd half of summer due to photoperiod, other don't – maybe a cultivar issue? Mix with cowpeas, soybeans. Japanese and browntop millet are similar, but might not mow kill as well and may mature faster/reseed more easily; substitute these species if foxtail not available.
Forbs	**Black Oilseed Sunflower** *Helianthus annus*	Rarely used in VA, primarily for adding diversity to mixes. Blooms very attractive to people, pollinators, wildlife. Very low cost seed. Deep branched taproot, good reputation for pulling up nutrients (but not necessarily subsoiling). Good heat & drought tolerance once established. OK weed suppressor. Seems to do well in mixes – some report it grows tall in tall mix, short in short mix. Varying reports on cold tolerance; most sources say more cold tolerant than other summer covers, but still winterkills at 28° F.
	Buckwheat *Fagopyrum esculentum*	Popular summer cover. Top weed suppressor due to very fast growth (not alleleopathy). Blooms & extra-floral nectaries tops for pollinators, beneficials. High risk of reseeding: terminate or mow within 7 to 10 days of first bloom. Matures faster than all other covers – if reseeding a concern, don't grow in mixes. Needs warm conditions, but very low tolerance to drought or high heat. Fine root system good for topsoil conditioning, but not subsoiling. Easy to kill. Books say excellent for unlocking soil phosphorous (P).
Legumes	**Forage Soybean** *Glycine max*	Similar to cowpea (see below) for cover crop use. Compared to cowpea: more tolerant of cool weather, wet soils; less tolerant of drought, pests, poor soil fertility. Good N fixation, biomass, and forage potential. Many varieties available; use late-maturing or forage cultivars for high biomass. Bushy growth habit, mixes better with short grasses like foxtail. Not good rotation for grain systems with cash crop soybeans. Low reseeding & weed risk. Inoculate! Does not cross inoculate with other legumes.
	Cowpea *Vigna unguiculata* aka Crowder or Southern or Blackeyed Pea	Top summer legume. Very heat & drought tolerant once established, deep taproot, tolerates low fertility. Grows fast, good biomass & forage, high N fixation potential, good weed suppressor. Extrafloral nectaries great for beneficial insects. Some pest nematode suppression. Many cultivars; select forage or cover types. Some shade tolerance = good for mixes. Use bush types for short mixes, vine for tall mixes. Needs heat, caution in VA mountains. Low reseeding & weed risk. Inoculate! Cross-inoculates with peanut, sunnhemp.
	Sunnhemp *Crotolaria juncea L.* aka Sunn Hemp	Tall tropical legume new to VA. Grows well in late summer, vendors encourage using it for winterkill (Niche 4). Reported to fix lots of N in short time. Spindly growth habit with narrow leaves = better choice for mixes than monoculture. Becomes very stemmy as matures. Low forage potential. Interesting yellow blooms; very low risk of reseeding and becoming weed. Mix with sudex, pearl millet, sunflower. Inoculate seed! Cross-inoculates with cowpea, sunnhemp.

Table 6. Cover Crop Establishment Specifications B: Summer-Seeded Species *(Seasonal Niches 3 & 4)**

	Species	Seeding rates (lb/ac, for monocultures)				Seed depth (inch)	Seeding dates								Probability crop regrows after mowing	Approx. maturity* MB = max. biomass; VS = viable seed ***(use as general guideline only)***
		Base / default		Acceptable range			Mountain & Valley *(based on May 1 last frost, Oct 10 first frost)*		Piedmont *(based on Apr 20 last frost, Oct 20 first frost)*		Coastal Plain *(based on Apr 10 last frost, Nov 1 first frost)*		Days after last spring frost *(DALF)* & before first fall frost *(DBFF)*			
		Drill	Bcast+ incorp	Drill	Bcast+ incorp		Preferred	Accept-able	Preferred	Accept-able	Preferred	Accept-able	Preferred	Accept-able		
Grasses	Sorghum-Sudangrass	35	45	20 to 50	30 to 70	0.5 to 1.0	Jun 20 to Aug 10	Jun 1 to Aug 25	Jun 10 to Aug 20	May 20 to Sep 5	Jun 1 to Sep 1	May 10 to Sep 15	50 DALF to 60 DBFF	30 DALF to 45 DBFF	very high	MB: 45 to 65 days after plant (DAP)
Grasses	Pearl Millet	20	30	10 to 30	20 to 40	0.5 to 1.0	Jun 20 to Aug 10	Jun 1 to Aug 25	Jun 10 to Aug 20	May 20 to Sep 5	Jun 1 to Sep 1	May 10 to Sep 15	50 DALF to 60 DBFF	30 DALF to 45 DBFF	high	MB: 45 to 70 days after plant (DAP)
Grasses	Foxtail Millet	20	30	15 to 30	20 to 40	0.25 to 0.75	Jun 20 to Jul 20	Jun 1 to Aug 20	Jun 10 to Aug 1	May 20 to Sep 1	Jun 1 to Aug 10	May 10 to Sep 10	50 DALF to 80 DBFF	30 DALF to 50 DBFF	very low	MB: 40 to 60 VS: 60 to 75 DAP
Forbs	Black Oil Sunflower	5	10	3 to 6	6 to 12	0.75 to 1.75	May 20 to July 25	May 10 to Aug 10	May 10 to Aug 5	May 1 to Aug 20	May 1 to Aug 15	Apr 20 to Sep 1	20 DALF to 75 DBFF	10 DALF to 60 DBFF	very low	MB: 80 DAP VS: 120 DAP
Forbs	Buckwheat	60	80	40 to 100	60 to 120	0.5 to 1.5	May 25 to Aug 10	May 15 to Aug 25	May 15 to Aug 20	May 5 to Sep 5	May 5 to Sep 1	Apr 25 to Sep 15	25 DALF to 60 DBFF	15 DALF to 45 DBFF	low	MB as fast as 30 DAP; VS as fast as 45 DAP
Legumes	Forage Soybean	60	90	40 to 100	60 to 130	0.75 to 1.5	Jun 10 to July 15	May 20 to Aug 1	Jun 1 to July 25	May 10 to Aug 10	May 20 to Aug 5	May 1 to Aug 20	40 DALF to 85 DBFF	20 DALF to 70 DBFF	low	MB: 50 to 75 days after plant (DAP)
Legumes	Cowpea	50	80	30 to 90	50 to 120	1.0 to 1.5	Jun 20 to Jul 25	Jun 1 to Aug 10	Jun 10 to Aug 5	May 20 to Aug 20	Jun 1 to Aug 15	May 10 to Sep 1	50 DALF to 75 DBFF	30 DALF to 60 DBFF	low	MB: 50 to 90 VS: 90 to 120 DAP
Legumes	Sunnhemp	20	30	15 to 45	25 to 60	0.5 to 1.0	Jun 20 to Jul 25	Jun 1 to Aug 10	Jun 10 to Aug 5	May 20 to Aug 20	Jun 1 to Aug 15	May 10 to Sep 1	50 DALF to 75 DBFF	30 DALF to 60 DBFF	very low	MB: 90 DAP Season too short for VS

*Use maturity information to estimate whether cover will reach maturity prior to frost. If not, use timely mowing to retard seed set and/or terminate using other methods.

Table 7. Cover Crop Species List C: Recommended Spring-Seeded Frost-Hardy Species *(Seasonal Niche 5)*		
Species		**Key Characteristics & Considerations**
Grasses	**Spring Oat** *Avena sativa*	See fall-seeded species table for details on oat. Top spring small grain (SG) choice. Select spring types that head/ seed without overwintering. At maturity, lower C:N than most SGs. At low rate, a good nurse crop option for spring seeded perennials. Oat/pea is classic mix. Use same types for Niche 2 (fall seed winterkill).
	Small Grains **(barley, wheat, triticale, rye)**	See fall-seeded species table for details on small grain (SG). Winter SG typical in VA – needs overwintering for heading/seed set. Winter SG seeded in spring might not vernalize; if not, stays short, no stalk. Might be good or bad – depends on purpose. If stems/residue needed, seed winter types early or use spring oat/SG.
	Annual Ryegrass *Lolium multiflorum*	See fall-seeded species table for details on ryegrass. Likely to provide good cover if seeded in spring; total biomass production, if and when will start reproductive phase, etc. less certain. Control before seed set. If still vegetative, will fade out fast in heat of summer.
Brassicas (B) / Forbs	**Forage Radish (B)** *Raphanus sativus*	See fall-seeded species table for details on radish. For typical VA varieties, spring seeding gives very different result from fall seeding. Much less root and top growth, bolts and flowers very quickly. Attractive white flowers. Thus spring use primarily to add fast bloom, diversity to mixes. Some varieties may differ.
	Mustard (B) *Sinapis alba; Brassica juncea; B. nigra (L.)*	See fall-seeded species tables for details on mustard. Spring growth pattern may vary by cultivar; research & match varieties to meet needs. Initial observations in VA indicate spring results similar to radish – much less biomass, bolts & flowers very fast. Thus spring use mainly for adding diversity, fast blooms in mixes.
	Phacelia *Phacelia tanacetifolia*	See fall-seeded species tables for details on phacelia. Initial observations indicate only spring seeding produces blooms; biomass is modest, but longer growth period before flowering than radish, mustard. Showy blue blooms very good for pollinators, probably key purpose for growing this in spring.
	Forage Turnip **(B)** *Brassica rapa var. rapa*	See fall-seeded species tables for details on turnip. Spring seeding likely provides similar results to radish and mustard (see above) – limited biomass, fast flowering. Spring results may be highly cultivar-specific. Research & match varieties to your needs.
	Rapeseed (B) *Brassica rapa* aka Canola; Rape	See fall-seeded species tables for details on rapeseed. Like small grain, winter & spring types are available. Initial observations with spring-seeded winter rape suggest more growth than radish or mustards before flowering, but still less biomass than if fall seeded. May vary by cultivar; research & match seed to needs.
Legumes	**Canadian Spring Pea** *Pisum sativum*	See fall-seeded species tables for details on spring peas. Top legume choice for early spring seeding. Select fastest-growing spring types. Expect lower biomass & total N fixation compared to overwintered peas. Mixes well with spring oat. Inoculate! Cross inoculates with vetch. Use same types as for See also Niche 2.
	Austrian Winter Pea *Pisum sativum*	See fall-seeded species tables for details on winter peas. Expect slightly slower growth and less biomass than with spring pea (see above), but typically similar results. Much lower total biomass potential if spring seeded compared to standard fall seeding. Inoculate! Cross inoculates with vetch. See also Niche 1.
	Woollypod Vetch *Vicia villosa ssp. dasycarpa*	See fall-seeded species tables for details on woollypod. 2^{nd} choice behind peas for short-term spring N fixation. One of multiple specialty vetches similar to hairy vetch (HV). Likely to be less winter-hardy, but faster growth, more biomass than spring-seeded HV. Common vetch (*Vicia sativa*) option is larger seeded, increase rate by 25%. Rare in VA are purple vetch and chickling vetch – likely low winterhardiness, but maybe better spring options. Research & select seed to meet needs. Inocluate! Cross-inoculates with pea.
	Hairy Vetch *Vicia villosa*	See fall-seeded species tables for details on hairy vetch. May not grow as well spring seeded as woollypod or other specialty vetches (see above), but readily available. Inoculate! Cross-inoculates with peas.

Table 8. Cover Crop Establishment Specifications C: Spring-Seeded, Frost-Hardy Species *(Seasonal Niche 5)*

	Species	Seeding rates (lb/ac, for monocultures)				Seed depth (inch)	Seeding dates								Approx. maturity MB = max. biomass; VS = viable seed ***(use as general guideline only)***
		Base / default		Acceptable range			Mountain & Valley *(based on May 1 average last frost)*		Piedmont *(based on Apr 20 average last frost)*		Coastal Plain *(based on Apr 10 average last frost)*		Days before average last spring frost *(DBLF)*		
		Drill	Bcast + incorp	Drill	Bcast + incorp		Preferred	Accept-able	Preferred	Accept-able	Preferred	Accept-able	Preferred	Possible	
--- Grasses ---	Spring Oat	80	110	65 to 125	100 to 165	0.5 to 1.5	Mar 15 to Apr 5	Mar 5 to Apr 20	Mar 5 to Mar 25	Feb 25 to Apr 10	Feb 25 to Mar 15	Feb 15 to Apr 1	45 to 25 DBLF	55 to 10 DBLF	MB 60 to 75 days after planting (DAP)
	Barley, Wheat, Triticale, Rye	Obtain seeding rate and depth for selected small grains from Establishment Specs A (fall seeded)					Mar 15 to Apr 5	Mar 5 to Apr 20	Mar 5 to Mar 25	Feb 25 to Apr 10	Feb 25 to Mar 15	Feb 15 to Apr 1	45 to 25 DBLF	55 to 10 DBLF	Winter types should head out if use preferred dates
	Annual Ryegrass	15	25	10 to 20	20 to 30	0.25 to 0.5	Apr 1 to Apr 20	Mar 20 to May 1	Mar 20 to Apr 10	Mar 10 to Apr 20	Mar 10 to Apr 1	Mar 1 to Apr 10	30 to 10 DBLF	40 to 0 DBLF	Uncertain; consult local experts
---- Brassicas (B) / Forbs ----	Forage Radish (B)	8	14	6 to 12	12 to 18	0.25 to 0.5	Apr 1 to Apr 20	Mar 20 to May 1	Mar 20 to Apr 10	Mar 10 to Apr 20	Mar 10 to Apr 1	Mar 1 to Apr 10	30 to 10 DBLF	40 to 0 DBLF	MB 50 to 60 DAP; little root; quick to bloom quick to bloom
	Mustard (B)	8	12	5 to 12	10 to 18	0.25 to 0.5	Apr 1 to Apr 20	Mar 20 to May 1	Mar 20 to Apr 10	Mar 10 to Apr 20	Mar 10 to Apr 1	Mar 1 to Apr 10	30 to 10 DBLF	40 to 0 DBLF	MB 50 to 60 DAP; quick to bloom; cultivars vary
	Forage Turnip (B)	5	10	2 to 8	8 to 12	0.25 to 0.5	Apr 1 to Apr 20	Mar 20 to May 1	Mar 20 to Apr 10	Mar 10 to Apr 20	Mar 10 to Apr 1	Mar 1 to Apr 10	30 to 10 DBLF	40 to 0 DBLF	Uncertain; cultivars may vary
	Phacelia	8	12	7 to 12	10 to 14	0.25 to 0.5	Apr 1 to Apr 20	Mar 20 to May 1	Mar 20 to Apr 10	Mar 10 to Apr 20	Mar 10 to Apr 1	Mar 1 to Apr 10	30 to 10 DBLF	40 to 0 DBLF	MB 60 to 80 DAP; very attractive blue blooms
	Rapeseed (B)	6	12	4 to 10	8 to 14	0.25 to 0.5	Apr 1 to Apr 20	Mar 20 to May 1	Mar 20 to Apr 10	Mar 10 to Apr 20	Mar 10 to Apr 1	Mar 1 to Apr 10	30 to 10 DBLF	40 to 0 DBLF	MB 60 to 80 DAP; slower to bolt and bloom than radish or
Legumes *(inoculate!)*	Canadian Spring Pea	60	90	50 to 80	75 to 120	1.5 to 2.5	Mar 20 to Apr 10	Mar 10 to Apr 20	Mar 10 to Apr 1	Mar 1 to Apr 10	Mar 1 to Mar 20	Feb 20 to Apr 1	40 to 20 DBLF	50 to 10 DBLF	MB 60 to 90 days after planting (DAP)
	Austrian Winter Pea	50	75	50 to 80	75 to 120	1.5 to 2.5	Mar 20 to Apr 10	Mar 10 to Apr 20	Mar 10 to Apr 1	Mar 1 to Apr 10	Mar 1 to Mar 20	Feb 20 to Apr 1	40 to 20 DBLF	50 to 10 DBLF	MB 60 to 90 days after planting (DAP)
	Woolypod Vetch	20	30	15 to 25	25 to 40	0.5 to 1.0	Apr 1 to Apr 20	Mar 20 to May 1	Mar 20 to Apr 10	Mar 10 to Apr 20	Mar 10 to Apr 1	Mar 1 to Apr 10	30 to 10 DBLF	40 to 0 DBLF	MB 60 to 90 days after planting (DAP)
	Hairy Vetch	20	30	15 to 25	25 to 40	0.5 to 1.0	Apr 1 to Apr 20	Mar 20 to May 1	Mar 20 to Apr 10	Mar 10 to Apr 20	Mar 10 to Apr 1	Mar 1 to Apr 10	30 to 10 DBLF	40 to 0 DBLF	MB 60 to 90 days after planting (DAP)

Table 9. Cover Crop Species List D: Recommended Biennial/Perennial Species *(Seasonal Niche 6)*		
	Species	**Key Characteristics & Considerations**
Grasses	**Tall Fescue** *Festuca arundinacea*	Most competitive, persistent perennial cool-season grass in VA, especially in warmer regions. Top choice for low-maintenance cover, erosion control, organic matter building. Low cost; deep roots; high biomass esp. in spring/fall with ample soil N; tolerant of drought, wet soils, poor soils. Most VA fescue infected with endophyte fungus – lowers forage value, but plants more durable. Forage and turf types available. Improved, endophyte-free cultivars are better forage, less persistant stands. Hay, graze, or clip to minimize seed set, keep stand vegetative. Mow high to maintain root reserves. If managed like hay, mix with red clover, alfalfa. If kept low with mowing (turf types) or grazing, mix with white clover. Best if fall-seeded, but spring works. Consider seeding with small grain that will be harvested/mowed to “release” perennial.
	Orchardgrass *Dactylis glomerata*	Widely-adapted perennial cool-season grass in VA, esp. in cooler regions. Higher forage quality than tall fescue (see above), but not as tolerant of heat, drought, heavy grazing, low mowing, poor soils. Tops for forage, biomass production, erosion control, soil building on with good fertility & management. Not long-lived in warmer regions of VA, but can fill perennial cover crop window of 1 to 3 summers anywhere in state. Hay, graze, or clip to minimize seed set, keep stand vegetative. Mow high/rotationally graze to maintain root reserves. Mix with red clover, alfalfa. Fall seeding is best, esp. in eastern VA. Consider seeding with small grain nurse crop that will be harvested/mowed off to “release” perennial understory.
Legumes	**Alfalfa** *Medicago sativa*	Top legume hay crop, very deep taproot, top N fixer. Expensive, best for longer windows (2 to 4 summers) and double-duty as forage & soil builder. Needs high soil pH, good fertility; not for wet soils. Super deep roots = drought tolerant. Dormant in winter; mix with hay-type grass (orchardgrass, etc.) for winter cover and to moderate C:N ratio at termination. Cut for hay or clip high to keep vegetative and maintain stand. For hay, 1st cut at bud stage, next cuts every 30-40 days (late bud to ¼ bloom), last cut in fall in time for 8” regrowth. Consider seeding with nurse of spring oats at low rate or small grains that will be harvested/mowed off to “release” perennial understory. Inoculate! Cross-inoculates with sweetclover.
	Red Clover *Trifolium pratense*	Short-lived perennial, often lasts two years. Multi-cut “medium” types best for this niche. Upright plant often used for hay, very winter-hardy, inexpensive, resists some nematodes, good taproot. Top N fixation, forage, blooms. Needs good soils & fertility; tolerates some wetness. Keep hayed (¼-⅓ bloom) or clipped high to avoid seed set, keep stand vegetative. Mix with grasses like orchardgrass or fescue to moderate C:N ratio at termination. Consider seeding with spring oat at low or small grain that will be harvested/mowed to “release” clover understory. Inoculate! Cross inoculates with crimson or white clover. See also Niche 1.
	White Clover *Trifolium repens* aka Intermediate, Common, or Dutch White Clover	Low-growing perennial, most tolerant clover for shade, traffic, tight mowing/grazing, acid/poor soil. As cover crop, a top use is as mowed living mulch in walkways, alleyways, understory. Shallow roots, spreads by lateral-growing stolons. Good N fixer, pollinator-friendly blooms. Persists and competes best if mowed low; can last many years. Two other types available: “wild white” is shorter; Ladino white is taller (for orchardgrass-type pastures). To make a mix with common white clover, use low-growing, mowing-tolerant fescue or other shorter grasses. Inoculate! Cross inoculates with crimson or red clover.
	Yellow Blossom Sweetclover *Melilotus officinalis*	Biennial known for deep subsoiling, N fixation. Prefers mild conditions, but most drought-tolerant legume once established. Note good on wet soil. Historically a top green manure. Now rarely grown, so practical info hard to find in VA – do your research and start small! Suggested use: plant early spring, growth 1st season is mostly underground, should not flower, avoid mowing. After overwintering, 2nd-season growth is above-ground – high biomass & N fixation, sweet-smelling blooms. Hard-seeded, some planted seed may germinate in future seasons. Lots of small seed, control before they are viable. Inoculate! Cross-inoculates with alfalfa. Option: Hubam annual white sweetclover; also seeded in spring, but doesn’t overwinter.

Table 10. Cover Crop Establishment Specifications D: Biennial/Perennial Species *(Seasonal Niche 6)*

	Species	Seeding rates (lb/ac, for monocultures)				Seed depth (inch)	Seeding dates							
		Base or default		Acceptable range			Mountain & Valley *(based on May 1 last avg. frost, Oct 10 first avg. frost)*		Piedmont *(based on Apr 20 last avg. frost, Oct 20 first avg. frost)*		Coastal Plain *(based on Apr 10 last avg. frost, Nov 1 first avg. frost)*		Days before first fall frost *(DBFF)*, days before last spring frost *(DBLF)*	
		Drill	Bcast + incorp	Drill	Bcast + incorp		Preferred	Possible	Preferred	Possible	Preferred	Possible	Preferred	Possible
Grasses	Tall fescue	20	25	15 to 20	20 to 25	0.25 to 0.50	Fall: Aug 15 to Sep 10	Fall: Aug 1 to Oct 5	Fall: Aug 25 to Sep 20	Fall: Aug 10 to Oct 15	Fall: Sep 5 to Oct 1	Fall: Aug 20 to Oct 25	Fall: 55 to 30 DBFF	Fall: 70 to 5 DBFF
							Spring: Mar 15 to Apr 5	Spring: Mar 1 to Apr 25	Spring: Mar 5 to Mar 25	Spring: Feb 20 to Apr 15	Spring: Feb 25 to Mar 15	Spring: Feb 10 to Apr 5	Spring: 45 to 25 DBLF	Spring: 60 to 5 DBLF
	Orchardgrass	12	16	8 to 15	12 to 20	0.25 to 0.50	Fall: Aug 15 to Sep 5	Fall: Aug 5 to Oct 1	Fall: Aug 25 to Sep 15	Fall: Aug 5 to Oct 10	Fall only: Sep 5 to Sep 25	Fall: Aug 25 to Oct 20	Fall: 55 to 35 DBFF	Fall: 65 to 10 DBFF
							Spring: Mar 15 to Apr 1	Spring: Mar 5 to Apr 15	Spring: Mar 5 to Mar 20	Spring: Feb 25 to Apr 5	NA	Spring: Feb 15 to Mar 25	Spring: 40 to 30 DBLF *(not C.Plain)*	Spring: 55 to 15 DBLF
Legumes *(inoculate!)*	Alfalfa	20	25	15 to 20	20 to 25	0.25 to 0.50	Fall: Aug 10 to Sep 1	Fall: Aug 1 to Sep 20	Fall: Aug 20 to Sep 10	Fall: Aug 10 to Oct 1	Fall: Sep 1 to Sep 20	Fall: Aug 20 to Oct 10	Fall: 60 to 40 DBFF	Fall: 70 to 20 DBFF
							Spring: Mar 20 to Apr 10	Spring: Mar 1 to Apr 20	Spring: Mar 10 to Apr 1	Spring: Mar 1 to Apr 10	Spring: Mar 1 to Mar 20	Spring: Feb 20 to Apr 1	Spring: 40 to 20 DBLF	Spring: 50 to 10 DBLF
	Red clover	10	12	8 to 12	10 to 15	0.25 to 0.50	Fall: Aug 10 to Sep 1	Fall: Aug 1 to Sep 20	Fall: Aug 20 to Sep 10	Fall: Aug 10 to Oct 1	Fall: Sep 1 to Sep 20	Fall: Aug 20 to Oct 10	Fall: 60 to 40 DBFF	Fall: 70 to 20 DBFF
							Spring: Mar 20 to Apr 10	Spring: Mar 1 to Apr 20	Spring: Mar 10 to Apr 1	Spring: Mar 1 to Apr 10	Spring: Mar 1 to Mar 20	Spring: Feb 20 to Apr 1	Spring: 40 to 20 DBLF	Spring: 50 to 10 DBLF
	White clover	5	10	3 to 9	5 to 14	0.25 to 0.50	Fall: Aug 10 to Sep 1	Fall: Aug 1 to Sep 20	Fall: Aug 20 to Sep 10	Fall: Aug 10 to Oct 1	Fall: Sep 1 to Sep 20	Fall: Aug 20 to Oct 10	Fall: 60 to 40 DBFF	Fall: 70 to 20 DBFF
							Spring: Mar 20 to Apr 10	Spring: Mar 1 to Apr 20	Spring: Mar 10 to Apr 1	Spring: Mar 1 to Apr 10	Spring: Mar 1 to Mar 20	Spring: Feb 20 to Apr 1	Spring: 40 to 20 DBLF	Spring: 50 to 10 DBLF
	Yellow blossom sweetclover	10	15	6 to 12	10 to 20	0.25 to 0.50	NA	NA	NA	NA	NA	NA	NA	NA
							Spring: Apr 1 to Apr 20	Spring: Mar 20 to May 1	Spring: Mar 20 to Apr 10	Spring: Mar 10 to Apr 20	Spring: Mar 10 to Apr 1	Spring: Mar 1 to Apr 10	Spring: 30 to 10 DBLF	Spring: 40 to 0 DBLF

Appendix I: Understanding and Using Seeding Ranges Relative to Average Frost Dates

Calendar Dates by Physiographic Region in Establishment Specs: A Closer Look

For the reader's convenience, planting dates relative to frost were converted to traditional calendar date ranges for each of Virginia's three physiographic regions.

How were frost dates selected for each region in order to come up with these calendar ranges? In reality, there is no single first frost or last frost date for an entire region. Therefore, representative weather stations within each region were selected as the basis for assigning first and last frost dates, as shown in the table below. Compare the representative stations used to your own local conditions. If your location is a climatic outlier for your region, such the higher elevations of western Virginia or the Tidewater area around Virginia Beach, consider using local frost dates to customize your own seeding calendar, as explained later.

Customizing Seeding Dates for Your Location

The seeding date ranges relative to frost in the spec tables can be used to customize calendar seeding dates for your location. The first step is to understand the following two terms:

Average First Frost: For fall or late summer plantings, seeding dates are listed in relation to the "average first frost date" in the fall. The average first frost date is the date upon which there is a 50% probability of having already had at least one temperature reading below 32.5° F. In the spec tables, days before average first fall frost is abbreviated "DBFF" and days after average first fall frost is abbreviated "DAFF".

Average Last Frost: For spring or early summer plantings, seeding dates are listed in relation to the "average last frost date" in the spring. The average last frost date is the date in the spring when there is a 50% probability of not seeing another temperature reading below 32.5° F. Days before average last spring frost is abbreviated "DBLF" and days after average last spring frost is abbreviated "DALF".

The following is an example of how to use this information to customize seeding dates for a particular location. The average first fall frost date at the Burke's Garden National Weather Service (NWS) observation station in the mountains of southwest Virginia is September 27. A planting date range of "30 DBFF to 60 DBFF" for Burke's Garden would correspond to calendar dates between July 27 and August 27.

The following is one strategy for finding average first and last frost dates for your area from National Weather Service observation stations:

1. Go to the following website: http://www.sercc.com/climateinfo/historical/historical_va.html
2. Identify and select one or more appropriate stations. Remember that the most representative station for your location may not be the one that is the shortest distance away. Elevation is one of multiple factors that can cause substantial differences in temperature patterns across short distances in some parts of VA. Also consider the period of record available – some stations have only old data.
3. Scroll down the left-hand menu to find "Spring Freeze Probabilities" and "Fall Freeze Probabilities".
4. After selecting one of these two options, you will get a graph. Click on "Tabular Output" under the graph.
5. Find the date in the table associated with 50% probability of 32.5° F. This is your average last frost or first frost date (depending on whether you are looking at spring or fall dates).

Table 11. Representative Locations Used to Assign Frost Dates to Physiographic Regions

Physiographic regions	Assigned frost dates in Establishment Tables		Representative NWS Observation Stations	Range of actual dates for these NWS stations	
	Average first fall frost	Average last spring frost		50% probability first fall frost	50% probability last spring frost
Mountain & Valley (MV)	October 10	May 1	Abingdon; Covington Filter Plant; Dale Enterprise (Harrisonburg); Timberville (Rockingham County)	October 9 to 11	April 29 to May 2
Piedmont (PM)	October 20	April 20	Bedford; Free Union (Albemarle County); Charlotte Courthouse; Ashland	October 20 to 22	April 11 to 20
Coastal Plain (CP)	November 1	April 10	Richmond Airport; Mathews; Williamsburg; Emporia	October 31 to November 3	April 8 to 11