Tab to Goals, Cropping System Context, Purposes

Tab to Seasonal Niche Diagram, Species Lists, Planting Specs & Date Charts

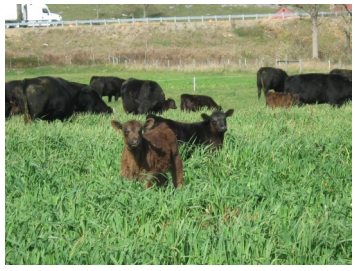
Virginia Cooperative Extension
Virginia Tech • Virginia State University

Mid-Atlantic ~~Virginia~~ Cover Crop College

Take Your Cover Cropping to the Next Level

USDA United States Department of Agriculture
Natural Resources Conservation Service






2020 Delmarva Soil Summit
Pre-Conference Intensive:
Purposeful Cover Crop Planning 101

February 26, 2020 - 9:00 am to noon

Class Notes

and selected excerpts from

VA NRCS Cover Crop Planning Manual, 2nd Edition (DRAFT)

Presented by:

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discover THE COVER

Download class materials, calculators & this document from Dr. Wade Thomason's "Virginia Tech Cover Crop College Page". Start at:

www.grains.cses.vt.edu

Tab to Appendices

Tab to Cover Crop Mix Guidance & Examples

2020 Delmarva Soil Summit Pre-Conference Intensive:

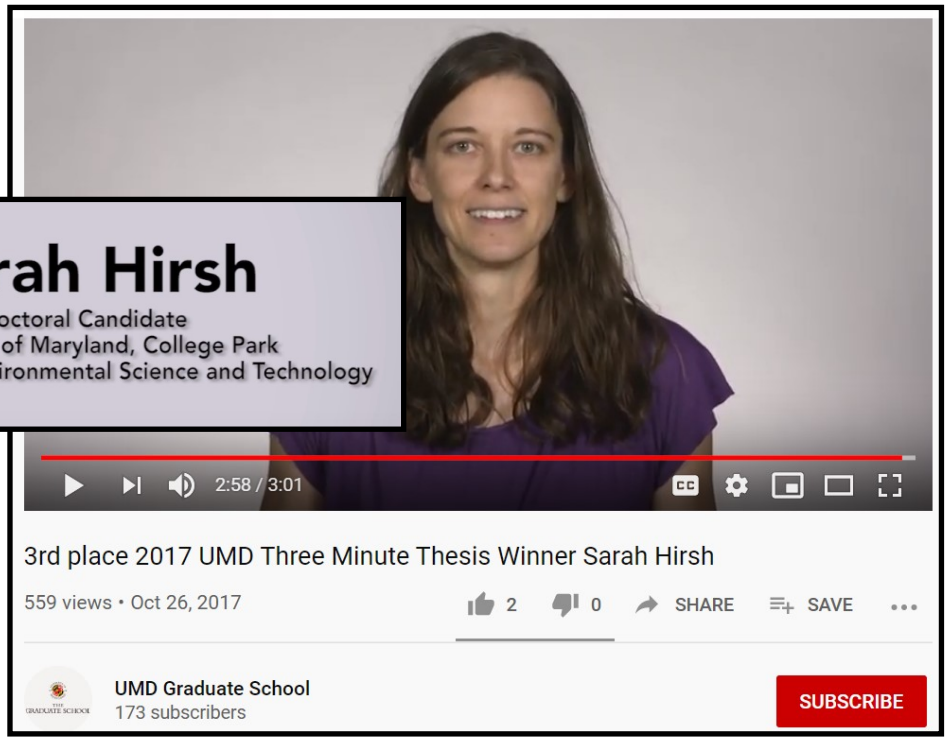
Purposeful Cover Crop Planning 101

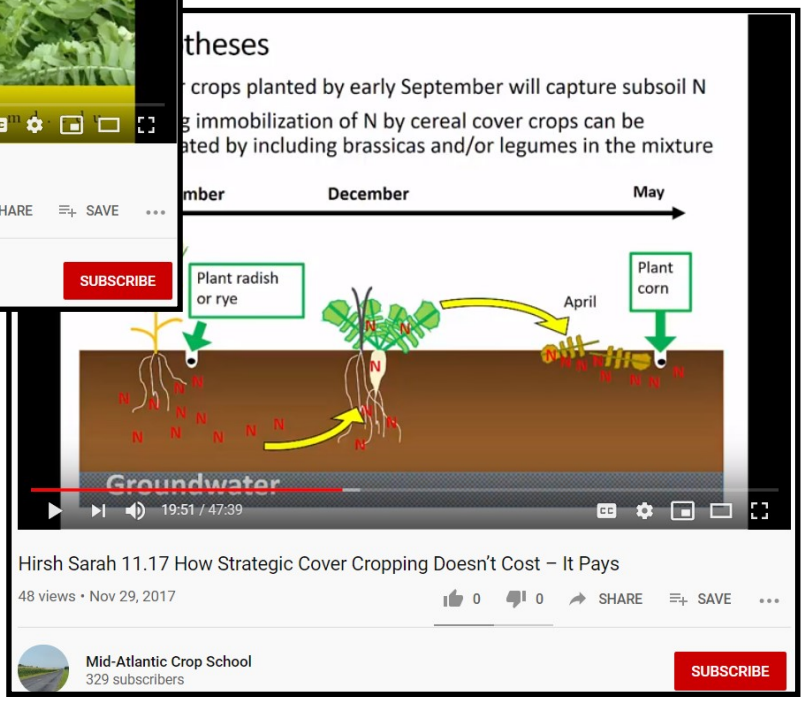
with Chris Lawrence of VA NRCS & Sarah Hirsh of UME

AGENDA

Start	Topic and Speaker
9:00	**Introduction & Plan of Action** • How we got here / The radish roots that bind us • Overview of objectives, agenda, handout
9:20	**Case Study 1: Deep N Recovery & Cycling in Mid-Atlantic Region** • Including key findings from Sarah's dissertation research
9:40	**Understanding Your Cover Cropping Options: 30+ Species, 6 Seasonal Niches, 3 Functional Groups** • Seasonal niche framework and associated tools from VA NRCS Cover Crop Planning Manual
10:00	**BREAK**
10:10	**Understanding Your Cover Cropping Goals: 10 Cover Crop Purposes (1 Long-term + 9 Short-term)** • Case Studies 2 & 3: Watch & analyze videos, ask "what purpose(s) does that cover fulfill?" (link here to video on Weed Control Benefits of High Biomass Rye Cover Crops")
10:40	**Getting Purposeful Cover Cropping On The Ground: The Promise & The Practical** • Understanding your cropping system context, with emphasis on crop rotation diagramming • Case Study 4: How do we integrate forage radish and other diverse covers into grain systems?
11:10	**BREAK**
11:15	**Capstone Case Study / Case Study 5: Ol' Turtle Farm Advanced Cover Cropping System Video Analysis** • Watch & analyze 7-minute video about farmer with advanced cover cropping system in organic veggie production; diagram rotations & discuss her niches, functional groups, species, strategies.
11:50	**Final Q&A and Comments** • Lighting round individual action plans – Will you do anything new/different as result of this class?
Noon	**ADJOURN**

Recommended videos about Sarah's research





DEEP SOIL NITROGEN CAPTURE AND RECYCLING BY EARLY-PLANTED, DEEP-ROOTED COVER CROPS

Date
2018

Author
Hirsh, Sarah Marie

Advisor
Weil, Ray R

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The overall purpose of this study was to improve the efficiency of nitrogen (N) cycling in Mid-Atlantic cropping systems through the use of cover crops. Our focus was on describing soil inorganic N pools (0-210 cm deep) and investigating the potential for cover crops to scavenge and recycle deep soil N. Few agronomic studies consider soil properties and processes deeper than the upper 20 to 30 cm, as the majority of roots, amendments, and practices such as fertilizer application or tillage occur on the soil surface or in the topsoil. We 1) assessed amounts of deep soil N on 29 farms in the Mid-Atlantic region, 2) used 15N tracer to investigate the capacity of various cover crops with early- or late-planting dates to capture and recycle deep soil N, and 3) investigated early-planted cover crop systems on 19 farm trials to assess their performance on farms with various soils with diverse management practices. We found that on average 253 kg N ha-1 of inorganic N remained in the soil following summer crops, 55% from 90-210 cm deep. Soil following soybean had the same amount or more of inorganic N than soil following corn throughout the soil profile. Using 15N isotopic tracer, we determined that radish, rye, and radish/rye mixes with and without crimson clover all could capture N from deep soil (60+ cm), but in order for cover crops to capture agronomically meaningful amounts of nitrate-nitrogen (NO3-N) from deep soil, they had to be planted by early-September. Cover crop trials on 19 farms indicated that, while variable site-by-site, early-planted cover crops tended to accumulate substantial N in the fall and reduce residual soil NO3-N levels substantially in the fall and spring. Cover crops also impacted subsequent corn growth and yield, with winter cereal tending to cause lower yields or increased corn N fertilizer needs compared to a no cover crop control, and forage radish sometimes leading to higher yields compared to the control. Overall, cover crops are effective at scavenging deep soil N in the fall, before winter leaching occurs, and under certain conditions, can release N for subsequent crops.

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Research Letters

Deep Soil Cores Reveal Large End-of-Season Residual Mineral Nitrogen Pool

Sarah M. Hirsh* and Ray R. Weil

Core Ideas

- Residual mineral N in 0- to 210-cm-deep soil following summer crops was evaluated.
- Soils contained a mean of 253 kg ha^{-1} mineral N, 115 kg ha^{-1} as NO_3–N.
- 55% of mineral N was 90- to 210-cm deep, where it is most at risk for leaching loss.
- More residual NO_3–N remained after soybean than after corn.
- Awareness of residual deep N levels is essential to develop N conservation practices.

Abstract: The amount of mineral N remaining after cash crops informs agronomic and conservation practices. Few studies investigate mineral N below 30 cm, yet deeper N is more at risk for leaching to groundwater. We found, on average, 253 kg ha^{-1} of mineral N, 115 kg ha^{-1} in the NO_3–N form, remaining after summer cash crop growth in the mid-Atlantic region. Of this residual mineral N, 55% was 90 to 210 cm deep. More residual NO_3–N remained after soybean than after corn. These substantial pools of mineral N remaining deep in the soil profile after productive cash crops, even unfertilized soybean, suggest that practices should be designed to scavenge residual N from deep soil layers in the fall, before it is lost over winter.

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Nitrogen (N) loading to water bodies in humid temperate regions occurs primarily by leaching during the nongrowing season when evapotranspiration is minimal (Meisinger and Delgado, 2002). In the mid-Atlantic United States, where corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] are the main annual crops (USDA NASS, 2012), NO_3–N commonly leaches >1 m between fall and spring (Angle, 1990; Forrestal et al., 2014; Meisinger and Delgado, 2002). Here, corn typically ceases N uptake by early September when maturity is approached (Ciampitti et al., 2013; Hanway, 1963). Excessive N contributes to eutrophication and hypoxia in the Chesapeake Bay (Ator and Denver, 2015; Phillips and Caughron, 2014), motivating the Maryland legislature to mandate nutrient management plans (Parker, 2000) that regulate N application to crops (Maryland Department of Agriculture, 2014). Even with mandated efforts, however, N leaching continues to be a concern in Maryland (USEPA, 2017).

Spatiotemporal patterns of soil N influence the accessibility of N to growing crops and its susceptibility to leaching. End-of-growing-season residual N, especially in deeper soil layers, is at risk of leaching below the root zone of subsequent crops and eventually into groundwater (Thorup-Kristensen, 1994). Even when crops are fertilized at recommended rates, substantial mineral N (N_{min}) remains in the soil at the end of the growing season. In Pennsylvania, following corn fertilized at economic optimum rates, 74 and 94 kg NO_3–N ha^{-1} remained in the upper 120 cm of nonmanured and manured soils, respectively (Roth and Fox, 1990). Furthermore, fall uptake of 80 to 220 kg N ha^{-1} by early-planted cover crops (Dean and Weil, 2009; Wang and Weil, 2018) suggests that substantial soil N remains following even high yields of cash crops.

Data on the amounts and depth distribution of residual N_{min} in fall could assist in optimizing N conservation practices, such as cover cropping.

Materials and Methods

Twenty-nine row-crop fields were sampled across the Piedmont, Ridge and Valley, and Coastal Plain regions of Maryland and southeastern Pennsylvania between 2014 and 2016. Fields were selected from farm operations that responded

to our request via county extension educators and agronomy news outlets. The area has a temperate humid climate, with 11°C mean annual temperature and 1044 mm mean annual precipitation uniformly distributed among all months (Maryland Department of State Planning, 1973; Polsky et al., 2000). Soil infiltration rates are typically 6 to 15 cm h^{-1} in the Piedmont and 13 to 28 cm h^{-1} in the Coastal Plain (Markewich et al., 1990). The crop grown prior to sampling was corn on 20 fields, soybean on 4, perennial grasses on 2, fertilized winter wheat (*Triticum aestivum* L.) on 2, and tobacco (*Nicotiana tabacum* L.) on 1 field. Most fields were managed with no-tillage or other conservation tillage and practiced winter cover cropping. Fields included a range of dairy or poultry manure histories: 11 with no manure, 11 with regular manure applications, and 7 with occasional manure (one to two applications in past 10 yr, or a history of regular manure applications but none applied in the past 3 yr). The 23 fields in Maryland applied N according to N-based nutrient management plans. The fields were grouped by their soil parent materials: Coastal Plain sediments, acidic rocks, and calcareous rocks.

To evaluate effects of previous crop on residual N, four pairs of adjacent corn and soybean fields were sampled in 2016. Three pairs had Coastal Plain sediments (Coastal Plain region) and one pair had acidic rock (Piedmont region) parent materials. The cropping histories included corn, soybean, small grain, and hay (see Fig. 1). Paired fields were sampled on the same day and had the same soil series, manure, and tillage history.

Soil Sampling and Analysis

Soil cores 210 cm deep were collected using hand-driven probes (Dean and Weil, 2009; Veihmeyer, 1929) from 14 fields between 20 August and 20 September in 2014, from 7 fields between 17 August and 25 September in 2015, and from 8 fields between 24 September and 29 October in 2016. In 2014 and 2016, two soil cores were collected at five points along a straight transect; in 2015, three soil cores were collected at four points within the field. Points were 20 to 50 m apart, depending on the size and shape of the field; cores at a point were less than 1 m apart. In 2014 and 2016, soil was divided into 15-cm increments, and two soil cores taken from each point along the transect were composited for each depth increment. In 2015, soil was divided into 30-cm increments, and the values of the three cores per point were averaged after soil analysis.

The soil was dried and sieved to 2 mm, and NO_3–N and NH_4–N were extracted (2 g soil in 20 mL solution) with 0.5 M potassium sulfate (K_2SO_4) and filtered. A Lachat QuikChem 8500 Automated Ion Analyzer (Hach Company) was used to analyze the filtrate for NH_4–N (salicylate method) and for NO_2–N + NO_3–N (cadmium reduction method). Stocks of NO_3–N and NH_4–N (kg ha^{-1}) were calculated from concentrations of NO_3–N and NH_4–N using soil bulk density values (core method). Soil particle size analysis was performed by the modified pipette method (Gavlak et al., 2005).

Statistical Analysis

All analyses were performed using SAS version 9.4 (SAS Institute, 2012). The level of probability considered significant

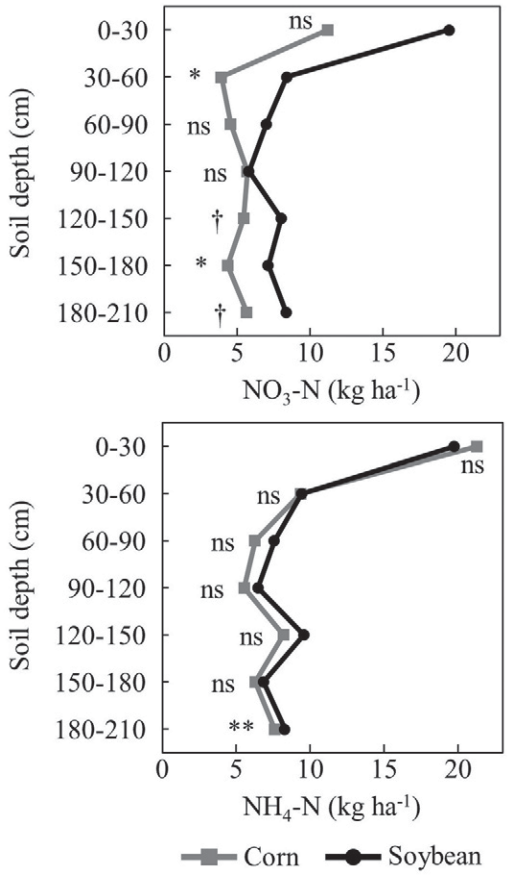

Fig. 1. NO_3–N and NH_4–N (kg N soil $layer^{-1}$ ha^{-1}) in four pairs of adjacent corn and soybean fields. Crop history of fields included Field 1A: 2016 corn, 2013–2015 Timothy hay; Field 1B: 2016 soybean, 2015 corn silage, 2014 corn, 2013 sorghum; Field 2A: 2016 corn, 2015 wheat–soybean, 2014 corn, 2013 wheat–soybean; Field 2B: 2016 soybean, 2015 wheat–soybean, 2014 soybean, 2013 wheat–soybean; Field 3A: 2016 corn, 2015 wheat–soybean, 2014 soybean, 2013 soybean; Field 3B: 2016 soybean, 2015 wheat–soybean, 2014 soybean, 2013 corn; Field 4A: 2016 corn, 2015 soybean, 2014 corn, 2013 soybean; Field 4B: 2016 soybean, 2015 soybean, 2014 soybean, 2013 corn. Corn and wheat received 123 to 168 kg N ha^{-1}, and hay received 73 kg N ha^{-1}. All fields had winter cover crops or small grains for the previous 5 yr. No-till was practiced for 5 yr on three pairs and 2 yr on one pair. Three pairs had no manure applied; one pair had one to two applications of dairy manure in the past 10 yr. *, **, †, ns indicate $p < 0,05$, 0.01, 0.1, and not significant, respectively.

was $p < 0.05$, unless otherwise stated. All ANOVA tests were performed using Proc Mixed. An ANOVA was performed to compare the NO_3–N or NH_4–N amounts among parent material groups for 0- to 210-cm, 0- to 30-cm, 30- to 90-cm, 90- to 150-cm, and 150- to 210-cm depth increments, with parent material group as the fixed effect and field as a random effect. A Pearson product-moment correlation was performed using Proc Corr to relate the soil NO_3–N and NH_4–N to soil percentages of sand and clay by depth. Proc Means was used to calculate the coefficient of variation (CV) among the four to five points in the field (each point averaging two to three cores) of the total 0 to 210 cm NO_3–N and NH_4–N for 19 of the fields. To compare pools of inorganic N following corn versus soybean, for the paired fields, an ANOVA was performed for each 30-cm-increment soil depth on the stocks of

NO_3–N and NH_4–N, with crop type (corn or soybean) as the fixed effect and field as a random effect.

Results

Following summer crop senescence, 253 kg ha^{-1} of N_{min} on average remained in the upper 210 cm of soil, with 22% located at 0 to 30 cm, 23% at 30 to 90 cm, 27% at 90 to 150 cm, and 28% at 150 to 210 cm depth. Across the 29 fields, 115 kg ha^{-1} of the total N_{min} was NO_3–N and 138 kg ha^{-1} was NH_4–N. Nitrate-N levels for Coastal Plain sediments fields were lower than acidic rock fields in the 90 to 150 cm depth and lower than calcareous rock fields in the 150 to 210 cm depth ($p < 0.10$; Table 1).

Across the 29 fields, sand percentage was negatively correlated with NO_3–N concentration ($p < 0.10$) at depths 0 to 30 cm, 90 to 150 cm, and 150 to 210 cm, but neither sand nor clay percentage was correlated with NH_4–N concentration. Within-field CV of 0- to 210-cm total stock of NO_3–N was on average 35% (SE = 5.1, $N = 19$) and of NH_4–N was on average 44% (SE = 5.0, $N = 19$). The CVs for the two N species were uncorrelated.

Based on the four pairs of adjacent corn and soybean fields sampled in 2016, there was significantly more soil NO_3–N following soybean than corn at 30–60 cm, 120–150 cm, 150–180 cm, and 180–210 cm. Levels of soil NH_4–N differed between corn or soybean only at 180–210 cm (Fig. 1).

Table 1. Soil NO_3–N, NH_4–N, and mineral N (N_{min}) (kg N ha^{-1}) for depths 0–30 cm, 30–90 cm, 90–150 cm, 150–210 cm, and 0–210 cm. Values are means with standard error (SE) in parenthesis for all fields ($N = 29$), Coastal Plain sediments fields ($N = 14$), calcareous rock fields ($N = 6$), and acidic rock fields ($N = 9$).

Soil parent material	Depth increment	NO_3–N	NH_4–N	N_{min}
	cm	kg N ha^{-1} (SE)		
All fields	0–210	115 (12.5)	138 (15.6)	253 (23.5)
	0–30	24.9 (3.83)	31.3 (2.74)	56.3 (5.43)
	30–90	25.2 (3.27)	33.6 (3.90)	58.7 (5.89)
	90–150	30.8 (3.66)	37.0 (4.70)	67.7 (7.16)
	150–210	33.9 (5.61)	36.0 (4.94)	69.9 (8.27)
Coastal Plain sediments	0–210	88.4 (17.8)a†	137 (24.6)a	226 (37.8)a
	0–30	23.9 (5.08)a	30.0 (3.86)a	53.9 (8.22)a
	30–90	23.8 (6.11)a	33.5 (5.98)a	57.3 (10.4)a
	90–150	20.0 (3.55)a*	35.7 (6.63)a	55.7 (9.43)a
	150–210	20.7 (4.27)a‡	38.1 (8.61)a	58.8 (11.5)a
Acidic rocks	0–210	136 (45.4)a	153 (51.0)a	289 (96.5)a
	0–30	24.1 (8.03)a	35.9 (12.0)a	60.0 (20.0)a
	30–90	25.2 (8.41)a	36.2 (12.1)a	61.4 (20.5)a
	90–150	44.5 (14.8)b*	43.0 (14.3)a	87.5 (29.2)a
	150–210	42.4 (14.1)ab‡	38.1 (12.7)a	80.5 (26.8)a
Calcareous rocks	0–210	144 (58.8)a	117 (47.6)a	261 (106)a
	0–30	28.5 (11.6)a	27.8 (11.4)a	56.3 (23.0)a
	30–90	28.1 (11.5)a	29.9 (12.2)a	58.0 (23.7)a
	90–150	35.3 (14.4)ab*	30.9 (12.6)a	66.3 (27.1)a
	150–210	52.2 (21.3)b‡	28.0 (11.4)a	80.2 (32.7)a

* $p < 0.05$.

† Within a mineral N type and depth increment, values followed by the same letter do not differ significantly among Coastal Plain sediments, acidic rock, and calcareous rock fields.

‡ $p < 0.1$.

Discussion

Why So Much Residual Nitrogen?

The large pools of residual N represent both fertilizer N unused by summer crops (Wang and Weil, 2018) and N mineralized from soil and plant organic matter (Dahnke and Johnson, 1990; Weil and Brady, 2017). Residual soil N is often assumed to be a result of N fertilizer overapplication or low N uptake during drought years (Forrestal et al., 2012); hence, N management and policies to reduce N loading primarily focus on N-fertilized fields (Maryland Department of Agriculture, 2014). However, we believe that large pools of residual N_{min} are more universal. Our data, in agreement with previous studies (Gentry et al., 2001; Jaynes et al., 2001; Kessavalou and Walters, 1999; Pantoja et al., 2016; Rembon and MacKenzie, 1997), indicate soybeans without N fertilizer can leave even more residual nitrate in the soil profile than corn receiving fertilizer. Compared with corn, soybean creates a high N environment with fewer (and lower C/N ratio) residues, and therefore less N is immobilized (Angle, 1990; Gentry et al., 2001; Green and Blackmer, 1995).

While stocks of NO_3–N and NH_4–N in the soil profiles were similar, our results suggest that NO_3–N is more transient, leaching through the soil, whereas NH_4–N is accumulating through cation exchange sorption. For example, crop (corn versus soybean) affected NO_3–N levels much more than NH_4–N levels. Similar results were found in Wisconsin (Bundy et al., 1993) for the upper 90 cm of soil in spring. Kristensen and Thorup-Kristensen (2004) and Bergström (1986) also found that crop species affected residual NO_3–N more than residual NH_4–N. The negative correlation between sand and soil NO_3–N concentration (but not NH_4–N concentration) supports the expected faster NO_3–N leaching in sandier soils. The lack of correlation between clay and NH_4–N concentration is not surprising as the NH_4–N ions measured would occupy only a small fraction of the cation exchange sites on any of the soils.

Importance of Vertical Location of Nitrogen

Many studies report how soil N is affected by cover crops (Chu et al., 2017; Ebelhar et al., 1984; Kuo and Jellum, 2002; Ladoni et al., 2015; Ruffo et al., 2004; Sainju et al., 2006) or other cropping practices (Anderson and Peterson, 1973; Poudel et al., 2002; Rice et al., 1986; Scalise et al., 2015) after sampling only 15 to 30 cm of soil. However, it is the deeper N (1–2 m deep) that is most at risk for leaching to groundwater before plants can take it up. Across all our fields, 57% (65 kg N ha^{-1}) of NO_3–N and 55% (138 kg N ha^{-1}) of total N_{min} to 210 cm was at 90 to 210 cm.

Land Management Implications

In regions such as the mid-Atlantic, with yearlong rainfall, favorable mineralization conditions during much of the "off-season," and permeable soil types, scavenging residual N as soon as possible after crop harvest will be important to prevent N from leaching beyond rooting depth. We suggest that early-planted, deep-rooted cover crops could be used to accomplish such N conservation.

Acknowledgments

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Rotation, diversity, multi-faceted defense needed to manage nematodes

April 2, 2018

With many agronomic challenges, the gist of any thoughtful response is usually rotation, rotation, rotation. Change up your management strategy every year, so that the pest or weed doesn't get habituated to whatever you're doing. When it comes to nematodes – unsegmented, microscopic round worms that live in the soil and can be plant and animal-parasitic – the answers are much the same. Although "rotation" can be a big part of the answer, there's a common belief that that is synonymous with "cover cropping."

SCN females on infected roots. *Photo by Iowa State, https://www.plantpath.iastate.edu/scn/sym*

Soybean cyst nematode (SCN) is a common pest in soybean fields, but also infects varieties of beans, peas, birdsfoot trefoil, chickweed, clover, lespedeza, vetch, and cowpeas. This nematode injects a compound into root structures, altering the root cell biology. The worms embed in the tissue and after a few weeks, they grow so large that they rupture out of the tissue they are feeding on. With high populations of SCN, symptoms may become visible. Otherwise, above-ground symptoms may go undetected, or may manifest as a stunted, chlorotic appearance that can be mistaken for compaction, nutrient deficiencies, drought stress, herbicide injury, and other plant diseases. SCN is a stealthy threat, and can feed off of roots for quite some time before anyone notices above-ground crop damage. Meanwhile, it can cause a yield loss of 30-40 percent with no visual symptoms (above-ground symptoms usually come well after root symptoms are widespread), and costs about $1 billion in total losses annually. After infection of the plant's root, the first symptoms will be root stunting, discoloration, and fewer nitrogen-fixing root nodules. Females can be seen with the naked eye. In the field, the infected plants will often form a circular or oval area. The only way to make an accurate diagnosis is to observe the adult females and cysts on the roots. SCN populations can also be monitored in soil tests. Egg counts over 2000/half cup of soil are a cause for concern. If they keep increasing on a non-host, you know they have adapted.

SCN is not very mobile in soil, so the soil and nematodes have to be moved by machinery, vehicles, tools, wind, water, animals, or workers for the infestation to spread. SCN is very adaptable, however, building resistance and becoming more aggressive in a field over time if a variety of control strategies are not used. Infestation is usually cumulative over time if no action is taken, and even a year of using an SCN susceptible variety or good host crop in a problem field can set you back several years.

Root-knot nematode (RKN) is a cousin of SCN and a similar threat to agricultural and horticultural crops, with an even wider host range. RKN establishes feeding sites within plant roots, causing enlargement of root cells (the visible "knots" or swollen areas that form on the roots). Both SCN and RKN can be hosted by a range of weed species, such as henbit and deadnettle, which makes good rotation and weed management even more critical.

Do cover crops work? It depends

SCN is still one of the most yield-suppressing pathogens, in spite of rising cover crop use in recent years. Be careful when planning your IPM strategy. One of the best assets cover crops bring to the table is diversity, which in turn promotes below-ground diversity in soil fauna. Many cover crops can be a host to SCN – largely legume cover crops. When it comes to SCN and other harmful nematodes,

grass crops are often the least likely to be hosts, while almost all legumes host some populations of nematodes. The most basic rotation recommendation for SCN is to incorporate non-hosts like corn, wheat, and alfalfa, as well as SCN-resistant soybean varieties, into the rotation, but be sure to rotate these as well. The less chance the pest has for adaptation, the better.

The right cover crops can suppress nematodes directly and indirectly, using four main mechanisms (these apply to many pest-suppressing cover crops) –

1. Production of biofumigant/nematicidal compounds – crops in the brassica family produce methyl-isothiocyanates as they decompose.
2. Trap crop – Juveniles that hatch in a cover crop's roots are trapped and die.
3. Pest starver – non-host
4. Induced hatching of juveniles – The root exudates from cover crops that grow in the "off" season stimulate hatching of SCN juveniles in fall or spring. Hatching at these cooler times when there is no food source means they die of starvation.
5. Producing inhibitory allelochemicals – either while living or decomposing.
6. Foster biological control – Cover crops have a long-term effect of enhancing soil health, which increases nematode diversity, including predatory nematodes they prey on plant-parasitic nematodes.

The data on cover crop suppression of SCN is inconsistent, but we know that **many common cover crop species, especially cereals, are not good hosts, and may work for suppression. Cereal rye** has shown good potential for reducing populations. Rye planted earlier in the fall is more successful in reducing SCN populations, as it has more growing time to produce allelochemicals. **Annual ryegrass** is also a good option. The Illinois Soybean Association reports that no-tilling soybeans into wheat stubble can be effective. As far as summer annuals, **sorghum-sudan** has shown to be a non-host across various nematodes, as have many species of **brassica.**

It can be difficult to interpret studies and gauge effectiveness of various cover crop species, because cooler temperatures mean that SCN isn't very active in the typical winter annual cover crop growing window to begin with. Greenhouse studies on SCN are likewise hard to translate to the field, because the hot temperatures activate the pathogen at a time when it may not normally be active.

Complicating matters further, there are regional differences in the host range, so SCN might be able to feed and reproduce on a host in one region but not another. This leads to mixed information about what is a good host, but legumes are certainly a common theme for good hosts. Almost all legumes are considered hosts somewhere in the US, and the pea and vetch families tend to be universally better hosts. For example, Ohio State University lists alsike clover, Birdsfoot trefoil, green beans, dry beans, common and hairy vetch, cowpeas, crimson clover, lespedeza, peas, white and yellow lupine, and sweetclover as good hosts. The list from other states will vary, and even different varieties of the same species will have varying susceptibility levels.

This brings us back to the main point – **the key to managing SCN and most agronomic challenges is diversity and rotation, not a cover crop cure-all. Rotate not only your main crop, but also your cover crop.** Most cover crops will also provide food for beneficial nematodes. Suppressive crops can reduce populations enough that you can grow host crops reasonably well.

In addition to cover crops, other control approaches can be used, including resistant varieties and chemical controls, such as a seed treatment nematicide. Fallow is also somewhat effective, since it provides no host, but leaves all the risks associated with bare soil, such as erosion and loss of vital biodiversity in soil life that also relies on living roots for food and shelter.

Lawrence, Chris - NRCS, Richmond, VA

Subject: FW: followup on nematode discussion from April 12

From: Mehl, Hillary <hlmehl@vt.edu>
Sent: Friday, February 8, 2019 9:28 AM
To: Lawrence, Chris - NRCS, Richmond, VA <Chris.Lawrence@va.usda.gov>
Subject: Re: followup on nematode discussion from April 12

Chris,

I am actually giving a webinar today on cover crops and nematode management. While putting this together I did a thorough search of the scientific literature on the topic, and there is very little data to support any of the claims that are being made. However, several of my colleagues in the Midwest have started doing research on cover crops and their impacts on nematodes, and I am hoping to start similar research in the next year or two.

We have been looking at the ability of RKN and SCN to reproduce on different cover crop species in the greenhouse, but we do not have the data yet. **The reality of the situation is that claims have been made about the ability to manage nematodes with cover crops without any data to support those claims. Cover crops can be a valuable tool as part of an integrated, long-term approach to nematode management, but growers need to know it will not be a quick fix to their nematode problems and the effectiveness will be very field-specific.**

The article from King's Agriseed supports my thoughts on the subject.

In terms of summer rotation or cover crops to reduce nematode problems, sorghum and sudangrass are both considered non-hosts for SCN and RKN, and there is some information in the literature that suggests they may produce nematode suppressive compounds in the soil. However, this can to some extent be cultivar-specific, and some sorghum hybrids do support reproduction of RKN. Corn can also be a relatively good rotation crop. It is a non-host for SCN, and a moderately poor host for RKN relative to other crops. In general, grass/monocot crops are the best rotation/cover crops for fields with nematode problems.

I hope this helps, and let me know if you have any additional questions. I will keep you updated as we generate data on cover crops and nematodes, and I will likely ask you for funding at some point ☺

Thanks,

Hillary

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K-STATE Research and Extension

Agronomy eUpdate

Prev Issue 734 March 1st, 2019 Next

Palmer amaranth resistance to 2,4-D and dicamba confirmed in Kansas

Palmer amaranth is one of the most economically-damaging and difficult-to-control broadleaf weeds across the United States. Previously, Palmer amaranth in Kansas has developed resistance to group 2 (ALS), 5 (atrazine), 9 (glyphosate), and 27 (hppd – mesotrione, Huskie, Laudis, Impact, and Armezon) herbicides, leaving growers with very few postemergence options to manage this weed. Dicamba and 2,4-D (group 4) have been used for many years to help control Palmer amranth, but farmers have complained about poor control in recent years. Recent research at K-State has confirmed the occurrence of dicamba and 2,4-D resistance in a Palmer amaranth population collected from a long-term conservation tillage study at the K-State Agronomy Ashland Bottoms Experiment Field in southern Riley County. This is the first confirmed case of resistance to dicamba and 2,4-D in Palmer amaranth, further magnifying the challenge to manage this weed in conservation tillage systems.

To confirm 2,4-D resistance, plants that survived the field recommended rate (1X) of 2,4-D (0.5 lb ae/a) applied in the summer of 2018 were transferred to a greenhouse attached to the Department of Agronomy at K-State and were allowed to set seeds. Upon maturity, the seeds were collected, and Palmer amaranth progeny were raised. Using these progeny, a 2,4-D dose-response study was conducted to understand the level of resistance in the suspected resistant population relative to two known 2,4-D-susceptible populations. Results at 21 days after 2,4-D application showed that the resistant progeny survived up to a 16X (8 lb ae/a) dose of 2,4-D, while susceptible plants were completely killed with 1 lb ae/a or less (Figure 1). This population exhibits about 8- to 10-fold resistance to 2,4-D.

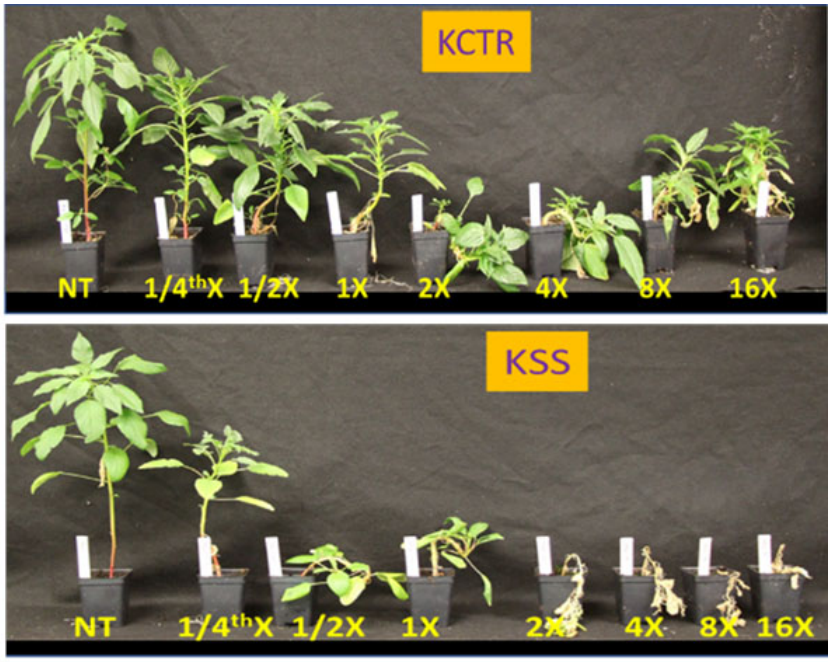

Figure 1. Palmer amaranth response to 2,4-D 21 days after treatment (1X = 1/2 lb. ae/a; NT = no treatment). Top panel: Resistant population from long-term no-till sorghum plots. Lower panel: Susceptible population harvested from nearby several years earlier. Photos provided Dept. of Agronomy, K-State Research and Extension.

The progeny of the same seed referenced above were also treated with a field-recommended rate of dicamba (0.5 lb ae/a) and showed a high rate of survival (81%), while the susceptible populations were controlled (Figure 2). Cross-resistance to different herbicides in group 4 herbicides has been reported in many other weeds. Experiments are in progress to determine the level of resistance to dicamba and other group 4 herbicides.

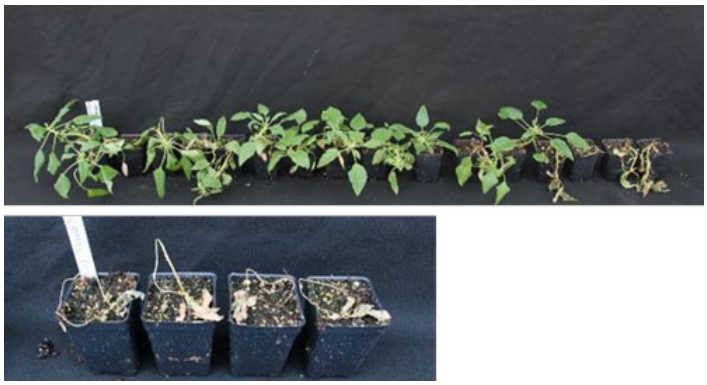

Figure 2. Palmer amaranth response to dicamba 21 days after treatment (0.5 lb. ae/a dicamba). Top panel: Resistant population from long-term no-till sorghum plots. Lower panel: Susceptible population harvested from nearby several years earlier. Photos provided Dept. of Agronomy, K-State Research and Extension.

Resistance to other herbicide sites of action

In addition to development of resistance to group 4 herbicides, preliminary research also indicates that this Palmer amaranth population survived application of group 27 (3 oz/a Callisto) and group 14 (10 oz/a Cobra) herbicides. Although resistance to group 27 herbicides in Palmer amatanth is increasing in KS, this population appears to have more survivors (88%) and a much higher level of resistance than previously reported. Resistance to lactofen is not yet officially reported in Palmer amaranth in Kansas. Our data suggests a high percentage of survivors (69%) in response to Cobra treatment compared to a known susceptible population that was completely controlled. Although group 14 herbicides can be effective in controlling pigweeds, thorough coverage on small weeds is essential for good control. We strongly suspect this population of Palmer amaranth is also resistant to atrazine, glyphosate, ALS herbicides, and perhaps s-metolachlor based upon field observations. Additional research will be conducted to further determine the extent of herbicide resistance in the Palmer amaranth.

This population of Palmer amaranth was found in a long-term conservation tillage experiment initiated over 45 years ago to compare different tillage systems and crop rotations. Palmer amaranth became increasingly difficult to control, especially in the continuous no-till grain sorghum systems. The plots were exposed to repeated use of herbicides labeled for grain sorghum, including group 5, 9, 14, 15, and 27 herbicides. These herbicides are known to be excellent options to control broadleaf species. Likewise, the adjacent plots were continuous no-till soybeans, with similar repeated herbicide programs in soybeans. These types of monocropping systems are the perfect scenario to develop herbicide resistance, but were established many years ago to compare the different cropping systems prior to the time when herbicide resistance was much of a concern. This example further demonstrates the importance of a diversified crop rotation and weed control program utilizing multiple effective herbicide sites of action through time.

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Cover Crop/Forage Tech Sheet

Ray's Crazy Fall Mix

Diverse winter annual cover crop mix that can double as high energy forage

This is a versatile cool season mix made up of grasses, legumes, and brassicas that can be used a short-term cover crop, a soil-building transition crop to renovate depleted soils, a grazing mix, and a wildlife food plot. It also contains several blooming species that, if left to grow and flower, will attract beneficial species. The mix is beneficial for both no-till and conventional-till soils and consists of all Non-GMO seeds.

Winter peas, hairy vetch and crimson clover grow through the winter and fix nitrogen. N production will be maximized if the hairy vetch and clover are left to grow to bloom in the spring.

Oats grow quickly in the fall, providing weed suppression, nutrient uptake, and shelter for the slower-growing species in the mix. The oats winterkill with hard frosts. The turnips and radishes also winterkill with a hard frost, but like the oats, grow quickly in the fall, suppressing weeds and scavenging nutrients with their deep tap roots. They also help to break pest cycles. Ryegrass and triticale grow over winter, anchoring and building soil with their dense, fibrous root systems. (Note: In the Piedmont and Coastal Plain VA, NC, SC regions, the oats and turnips may not winter kill depending on variety and winter hardiness.)

If grazing use is intended, increase the seeding rate. The crop can be grazed in late fall and/or early spring. The mix of species will provide an ideal balance of effective fiber and protein, if taken for forage when grasses reach boot stage.

If more emphasis is placed on the mix being a cover crop, let it grow until the clovers and vetch bloom. For maximum nitrogen production, wait until the legumes flower before grazing or harvesting.

King's AgriSeeds Inc.

1828 Freedom Rd.
Suite 101
Lancaster, PA 17601
(717) 687-6224

High Energy Forages and Soil Building Cover Crops

At A Glance

Product Formula (by weight)

Austrian Winter Pea– 23.8%
Foragemaker 50 Oats– 20%
Triticale- 20%
Hairy Vetch– 12.6%
Crimson Clover– 10%
Marshall Ryegrass– 7.6%
Daikon Radish– 3.4%
Barkant Turnips– 2.6%

Establishment

Seeding Rate: 50 lbs/A (for forage or cover crop)

Seeding Depth: 1/2" - 1"

Seeding Dates: Late summer/early fall

Possible grazing dates (depending on weather and growing conditions): Late fall, late spring

WHAT IS TOTAL FRACTION OF BASE RATE (FBR) FOR THIS MIX AT RECOMMENDED SEEDING RATE?

WHAT IS FBR FOR EACH INDIVIDUAL SPECIES?

Cool Season Cover Crop Mix

Selected Excerpts from VA NRCS Cover Crop Planning Manual, 2nd Edition (04/25/19 DRAFT)

Figure 1.1: Planning Manual Goals & Definitions

Three Key Goals:

1. More purposeful cover cropping
2. More innovative cover cropping
3. A useful resource for all Virginia cover cropping, from basic to advanced

Three Key Definitions:

1. Cover crop:
   - A crop grown primarily, but not exclusively, to benefit the soil, environment, or other crops.
   - Not limited to program or payment parameters.
2. Purposeful cover cropping:
   - Managing cover crops with mindset typically reserved for harvested "money crops."
   - One or more clear objectives in mind.
   - Attention to detail from seed selection and planting through termination
   - Integration of cover and crop rotation planning
3. Innovative cover cropping:
   - Can mean different things on different farms.
   - Something meaningfully different from the grower's typical species, management, etc.
   - In many cases, anything beyond typical fall-seeded, winter-hardy, small grain monoculture.
   - Purposeful innovation is not same as wishful experimentation

Figure 1.2: Planning Manual Guiding Principles

1. There's a cover for every farmer and purpose:
   - Cover crops fit somewhere on every farm.
   - The fit might be a traditional option that can be grown on many acres.
   - The fit might be an unusual option that only makes sense to grow on a very small area.
2. The same cover crop planning concepts can apply to every sector, scale, style of agriculture.
3. Purposeful cover crop planning is worth investing time and effort.
4. No book on cover crops can teach you as much as growing them in the field.

Figure 3.1: Diagram of VA NRCS Cover Crop Planning & Selection Process

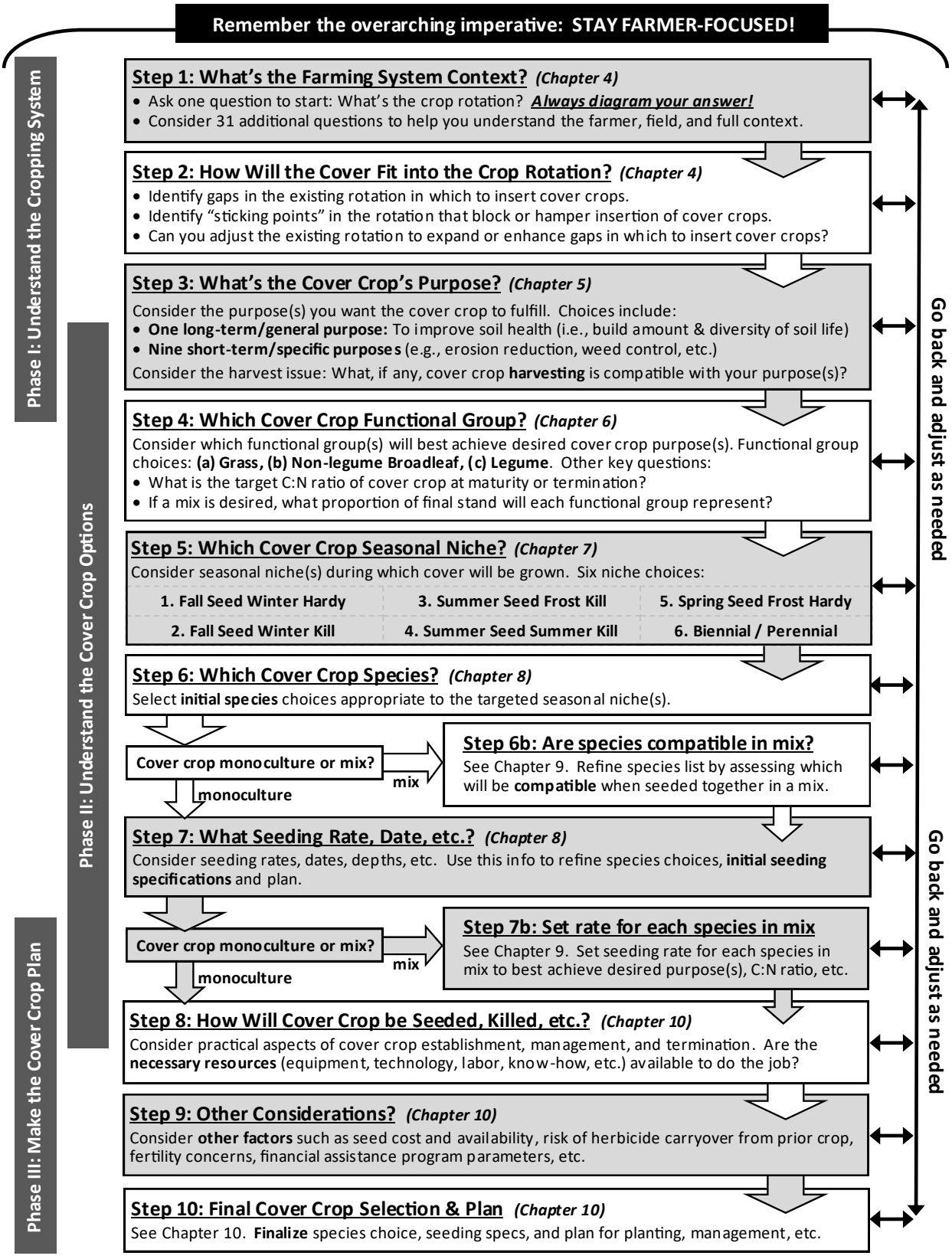


Figure 4.1: 32 Questions to Help You Understand the Farmer, Field, and Full Cropping System Context

Single Most Useful Question to Start

1. What's the crop rotation? *(diagram answer using format like this ↓)*

	Spring			Summer			Fall			Winter		
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Year 1	→			Corn Grain								
Year 2				Soybeans								→

Overall Farming Operation

2. What are the farm's key **crops and enterprises**?
3. What is the farmer's production **style or philosophy?** (i.e., conventional, certified organic, etc.)
4. What is the farmer's approach to **tillage**?
5. What equipment is available for managing cover crops? (i.e., planting, terminating, managing residues, etc.?)
6. Are there other aspects of the production system, such as use of **manures or irrigation**, that should be considered?
7. What opportunities does the farmer see for **improving** the crop rotation or production system?
8. What is the farmer's **attitude** about investing in cover crops that might not result in immediate yield increases?
9. Can the farmer **afford** to invest in cover crops that might not result in immediate yield increases?

Climate, Soils, and Natural Resources

10. Is there anything special about **local climate or micro-climate** that could influence cover crop selection or success?
11. What are the **inherent (permanent) characteristics of soils** on the farm or target field(s)? Factors to consider: slope, soil type, drainage class, yield potential, etc.
12. What is the **long-term management history of soils** on the farm or target field(s)? What is the resulting condition of those soils? Factors to consider: soil organic matter, tilth, fertility/nutrient availability, pest populations, etc.
13. What opportunities does the farmer see for **improving** soils on the farm or target field(s)?
14. Are there specific **natural resource concerns** on the farm or target field(s) that cover crops might help address?

Cover Crop Experience & Expectations

15. What is the farmer's **prior experience** with cover crops? (i.e., what has done well on the farm before? what hasn't?)
16. What are the farmer's **expectations** or goals with respect to future use of cover crops?
17. Are there cover crop purposes, seasonal niches, or species the farmer specifically **wants to try or wants to avoid**?
18. What is the farmer's approximate **budget** for cover crops?

Crop Grown Before the Cover Crop

19. **What** crop will be grown immediately **before** the cover crop?
20. **When** will that prior crop be harvested? (i.e., when will the field be available for cover crop planting?)
21. What will be the **condition of the field**, amount of residue present, etc. after that prior crop is harvested?
22. Could soil **fertility** or **herbicides** from the prior crop **carry over** and positively or negatively impact the cover?
23. Should any other factors about the prior crop be considered when planning the cover crop?

Crop To Be Planted After the Cover Crop

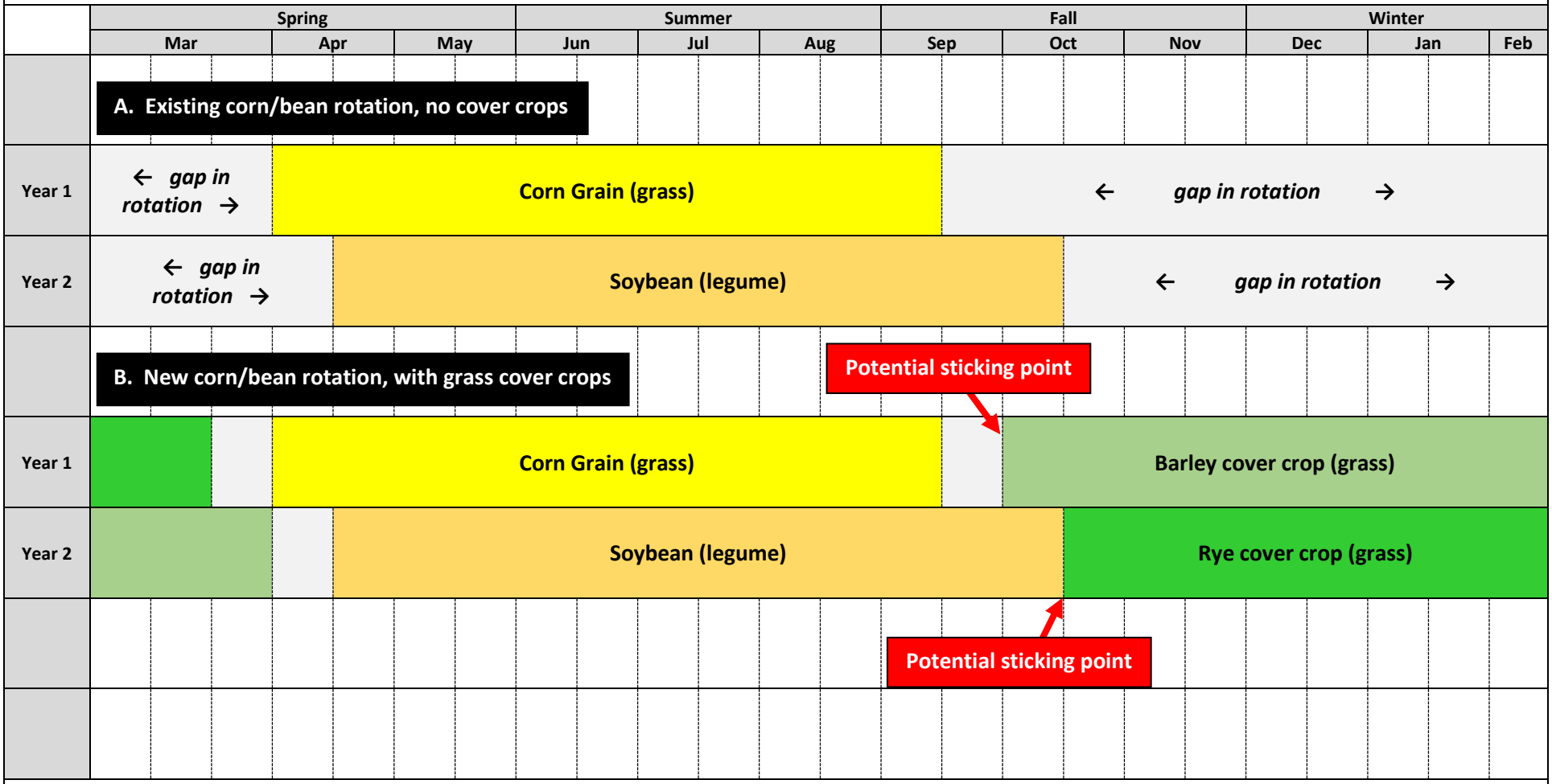
24. **What** crop will be planted immediately **after** the planned cover crop?
25. **When** is the ideal time for planting the next crop? (i.e., when must the cover crop be terminated?)
26. **How** will the next crop be planted? (i.e., will cover crop residues be left standing, tilled into the soil, etc.?)
27. Could **too much cover crop residue** be a concern for planting the next crop?
28. Could **N immobilization** (i.e., too much high-C:N-ratio residue) be a concern for the next crop?
29. Could **too much water uptake** by the cover crop just before termination be a concern for the next crop?
30. Could the next crop benefit from **large amounts of lasting cover crop residues** to suppress weeds, retain water?
31. Could the next crop benefit from the cover crop **fixing a large amount of N** and releasing it for the next crop?
32. Are there **other factors** about the next crop that should be considered when planning the cover?

Figure 4.2: Example of crop rotation and cover crop diagramming *(using template from Appendix 1)*

Crop Rotation Diagramming & Cover Crop Planning Template (VACCPM, 2nd Ed.)

Purpose: To help you visualize crop rotation(s), cover crop options, and how to improve both.

Instructions: (1) Diagram existing rotation(s), noting crop families or groups, etc. (colored pens can help); (2) ID existing gaps in which to insert cover crops; (3) ID "sticking points" that block insertion of cover crops; (4) adjust rotation(s) to expand gaps or eliminate "sticking points."



Notes: (obstacles to overcome, issues to research, etc.)

G = Grass. L = Legume. Potential sticking points indicated with arrows. To seed barley at optimum time, must seed prior to harvesting cash crops in some other fields. To seed rye timely, must chase harvester with cover crop planter.

Figure 4.3: Taking Cover Crops to the Next Level with Crop Rotation Principles – A Case Study Example

Diagram A below shows grower's two-year grain rotation in the VA Coastal Plain region (average first freeze Nov. 1) with no cover crops.

A	Spring			Summer			Fall			Winter		
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Year 1	→			Corn Grain								
Year 2					Soybeans							→

In Diagram B, gaps in the rotation are filled with simplest cover crop choices: small grains terminated two weeks ahead of next planting.

B	Spring			Summer			Fall			Winter		
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Year 1	→			Corn Grain				Barley Cover Crop				
Year 2					Soybeans				Rye Cover Crop			→

Grower wants to try a radish / triticale / clover cover ahead of corn. This would diversify functional groups and provide more bio-drilling, N fixation, and faster N cycling ahead of corn. However, there is not enough time between soybean harvest and corn planting to grow the new cover crop (this problem is illustrated in Diagram C by red bars showing "sticking points" between cash and cover crops).

C	Spring			Summer			Fall			Winter		
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Year 1	→			Corn Grain				Barley Cover Crop				
Year 2					Soybeans				Radish / Triticale / Crimson Clover			→

Diagram D shows how "stacking" corn behind corn plus shifting to earlier planting of first-year corn and later planting of second-year corn can open a wider gap for cover crops ahead of half the corn acres in the system. There are pros and cons to this strategy, but it achieves the grower's objective of trying the new early-fall cover crop ahead of corn with no major change to the farm's existing cash crop lineup.

D	Spring			Summer			Fall			Winter		
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Year 1	→			Corn Grain				Forage Radish / Triticale / Crimson Clover Cover Crop				
Year 2					Corn Grain				Barley Cover Crop			
Year 3					Soybeans				Rye Cover Crop			
Year 4					Soybeans				Rye Cover Crop			→

Grower wants to further diversify by trying summer covers and by enhancing soil building, bio-drilling, and N fixation ahead of ***all*** corn crops. Diagram E shows one option: wheat for grain replaces soybeans in fourth year of rotation. Now four money crops are still grown every four years, but a major new opening is created for cover crops ahead of first-year corn. If this seems too ambitious, remember it can be tried on a single field to start! This illustrates how putting just one new cash crop into a highly simplified rotation can offer many potential benefits.

E	Spring			Summer			Fall			Winter		
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Year 1	→			Corn Grain				Forage Radish / Triticale / Crimson Clover Cover Crop				
Year 2					Corn Grain				Barley Cover Crop			
Year 3					Soybeans				Wheat for Grain			
Year 4		Wheat for Grain			Summer Cover Crop Mix			Forage Radish / Spring Oat / Winter Pea Cover Crop				→

Diagram F shows how further diversifying with grazing can produce income from covers while retaining or even enhancing their soil- and yield-boosting potential. Well-managed strip grazing in late August and early September of Year 4 could enhance availability of nutrients contained in the summer cover crop biomass. This would enhance uptake of those nutrients by the fall cover, which will in turn be terminated early enough in the spring so that many of those same nutrients will be available to the subsequent corn. For many growers, putting cattle on cropland like this would involve many challenges, starting with adding fences and waterers to the field. Remember that this strategy, like all others above, can potentially be tried on a small acreage to start. It doesn't fit everywhere, but it can fit somewhere in VA. More importantly, remember our goal here: to inspire you to do your own creative thinking that best fits your situation. This is just one example!

F	Spring			Summer			Fall			Winter		
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Year 1	→			Corn grain				Forage Radish / Triticale / Crimson Clover Cover Crop				
Year 2					Corn Grain				Rye Cover Crop - GRAZED			
Year 3					Soybeans				Wheat for Grain			
Year 4		Wheat for grain			Summer Cover Mix - GRAZED			Forage Radish / Spring Oat / Winter Pea Cover Crop				→

Note how some gaps (white spaces) between crops in Diagram A are filled by the time we reach Diagram E. This illustrates how a more purposeful cover cropping mindset often involves maximizing sunlight capture to grow as much organic matter as possible – for the soil, for harvest, or both. This demands more management from the grower, including new strategies such as "planting green" (termination of the living cover just before, or even after, the next crop is seeded into it). Note, however, that none of the above diagrams assume over-seeding of cover crops – i.e., broadcasting cover crop seed over the top of cash crops standing in the field. Over-seeding can work well, but we don't recommend it in this manual because it is not as reliable as traditional methods that insert seed into soil (see Chapter 8 for details).

Figure 5.1: Top 10 Cover Crop Purposes/Benefits

One General / Long-term Purpose:

Improve soil health and function by maximizing implementation of the following principles:

a. **Keep soil covered**
   With living canopy as well as surface residue

b. **Minimize soil disturbance**
   From tillage, compaction, toxic materials

c. **Maximize living roots**
   Both yield/quantity and duration/continuity

d. **Energize with diversity**
   Of crops, livestock, enterprises

Nine Specific / Short-term Purposes:

- Reduce soil erosion
- Manage soil moisture or temperature
- Suppress weeds
- Reduce soil compaction / bio-drill
- Recover soil N & supply to future crops
- Recover soil P, K, etc. & supply to future crops
- Fix atmospheric N & supply to next crop
- Help manage insect, disease, and other pests
- Other – pollinators, aesthetics, etc.

Figure 6.1: Carbon to Nitrogen (C:N) Ratio of Various Residues and N-availability and Decomposition Trends

Material	C:N Ratio
Rye straw	82:1
Wheat straw	80:1
Oat straw	70:1
Rye cover crop (anthesis)	37:1
Pea straw	29:1
Rye cover crop (vegetative)	26:1
Mature alfalfa hay	25:1
Ideal microbial diet	24:1
Rotted barnyard manure	20:1
Legume hay	17:1
Beef manure	17:1
Young alfalfa hay	13:1
Hairy vetch cover crop	11:1
Soil microbes (average)	8:1

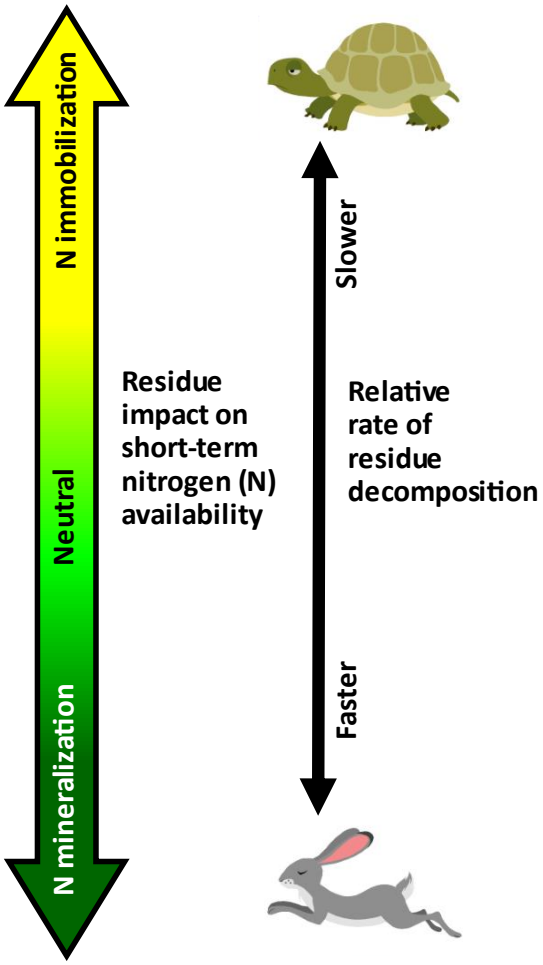
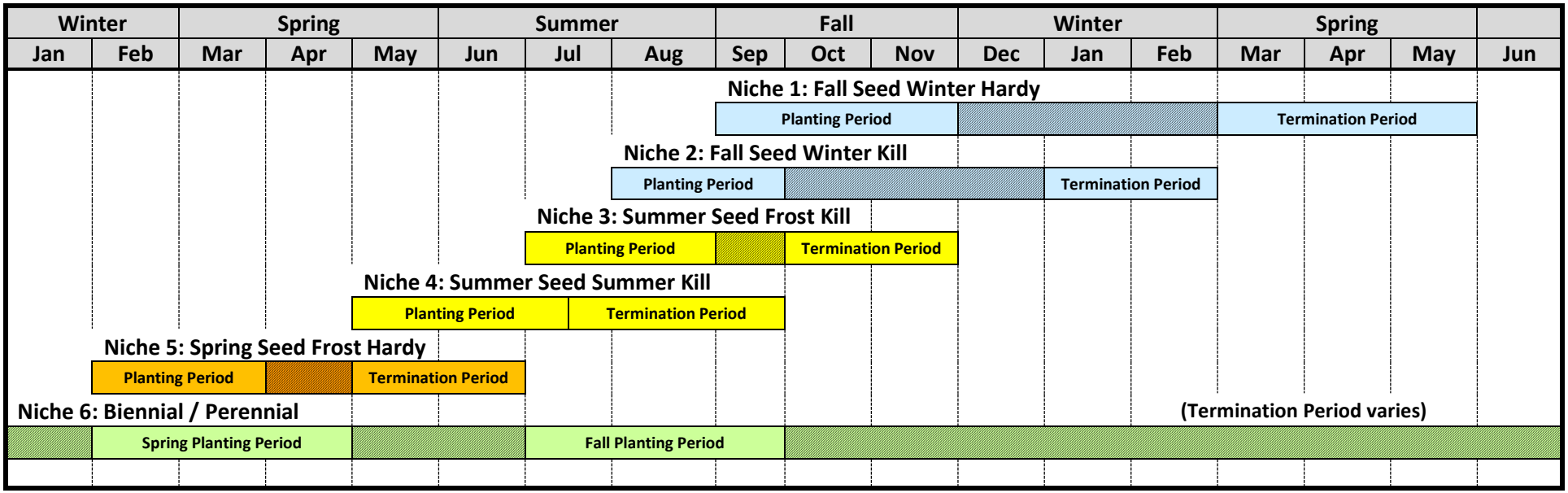


Figure 7.1: Virginia Cover Crop Seasonal Niche Diagram and Matrix of Recommended Species



Seasonal Niche Name	Seasonal Niche Description	Functional Group & Species			
		Grass	Broadleaf Non-legume		Legume
			Brassica	Forb	
1. Fall Seed Winter Hardy	Winter-hardy cool-season annual planted in fall and terminated in spring.	annual ryegrass; winter oat; barley; wheat; triticale; rye	rapeseed; forage turnip		red clover; crimson clover; winter pea; woollypod vetch; hairy vetch
2. Fall Seed Winter Kill	Fast-growing, frost-hardy annual seeded in early fall, with planned termination by winterkill (at 12 to 20° F.)	spring oat	forage radish; mustard	phacelia	spring pea
3. Summer Seed Frost Kill	Warm-season annual planted in mid- to late summer, with planned termination by freeze-kill (at 28 to 32° F.)	sorghum-sudangrass; pearl millet; foxtail millet		buckwheat; black oil sunflower	forage soybean; cowpea; sunnhemp
4. Summer Seed Summer Kill	Warm-season annual seeded early to mid-summer and terminated in time to plant back before winter.				
5. Spring Seed Frost Hardy	Fast-growing, frost-hardy cool-season annual planted in late winter or early spring.	spring oat; winter or spring small grain, annual ryegrass	rapeseed; forage turnip; forage radish; mustard	phacelia	spring pea; winter pea; woollypod vetch; hairy vetch
6. Biennial / Perennial	Biennial or perennial grown for at least one summer (typically 18 months or more)	tall fescue; orchardgrass			alfalfa; red clover; white clover; yellow sweetclover

Figure 8.1: Interpretation of Winterkill Probability Ratings from Establishment Specifications for Fall-Seeded Cover Crops

Rating	Suggested Interpretation
Very low:	Reliably winter-hardy 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.

Figure 8.2: List of Recommended Fall-seeded Cover Crop Species (Seasonal Niches 1 & 2)		
	Species	**Key Characteristics** *(gray shading indicates Niche 2 – expected to winterkill)*
Grasses	**Spring Oat (SO)** *Avena sativa*	Compare to winter oat. Goal for SO seeded in fall is winterkill: select varieties accordingly, plant early for lush growth. Oat is least hardy small grain (SG), but may not winterkill in SE VA. Grows fast in mild fall conditions. Lower C:N, shorter-lived residue vs. typical SG. Needs good fertility. Good weed suppressor, moderate N scavenger, high forage quality. No vernalization required to head out – might do so in fall. Top nurse crop (use low rate) for fall legumes. Mix with radish, peas. See also Niche 5.
	Annual Ryegrass (AR) *Lolium multiflorum* aka Italian Ryegrass	Popular cover in Corn Belt, much less in VA. AR is key weed in small grain (SG). Do not allow to set seed. Can be hard to kill with herbicides. Dense fibrous root system, top soil conditioner, good weed fighter and N scavenger, top-quality forage. Establishes well in tough conditions, but needs fertility for high biomass. Tolerates wet feet better than SG. Not good in heat or drought. Winter-hardiness can vary – select cultivar accordingly. Shorter than SG, lower C:N, mixes well with crimson clover. See also Niche 5.
	Winter Oat (WO) *Avena sativa*	Compare to spring oat above. Goal for WO is overwintering: select varieties accordingly. WO rarely grown in VA. Unlikely to overwinter in western VA; best fit is Coastal Plain. Vernalization (overwintering) triggers heading. Planted early in fall, 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, slightly lower C:N, lower tolerance for dry / wet extremes.
	Barley (BA) *Hordeum vulgare*	Widely used in VA. More winter-hardy 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 and 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. Not good for SG cash crop rotations (host for same diseases and pests).
	Wheat (WH) *Triticum aestivum*	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 well-timed grazings can still produce 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 for SG cash crop rotations (host for same diseases and pests).
	Triticale (TR) *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 slightly 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).
	Rye (RY) *Secale cereale* aka Cereal Rye	Top winter cover for many purposes, most winter-hardy, best on poor/acid soils. Top SG for biomass, N scavenging, weed control, tolerance of wet soil. Can plant later than any SG, but goes to head early in spring – only barley is earlier. RY 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, especially in SG cash crops. Good forage, but low quality after heading. Mix with vetch, pea.
Brassicas	**Forage Radish (FR)** *Raphanus sativus* aka Daikon or Daichon Radish	Top Niche 2 (winterkill) option. May overwinter in SE VA. Early planting + light seeding rate = large lush plants, better winterkill. Late planting + heavy seed rate = smaller plants, more winter-hardy. With good fertility, fastest-growing fall cover option. Top biomass, subsoiler, N-scavenger, forage. Winterkilled residues disappear and N releases fast. Top weed suppressor. Good in mixes, but caution not to out-compete companions. Different growth pattern if spring seed, see Niche 5. Substitute oilseed radish.
	Mustard (MU) **White/Yellow:** *Sinapis alba* **Brown/Indian:** *Brassica juncea* **Black:** *B. nigra (L.)*	Similar to other brassicas (see above, below), but best use in VA is probably pest suppression, adding diversity to mixes. Most bio-toxic compounds, best brassica for bio-fumigation (requires soil incorporation, etc.). With fertility, potential for fast fall growth, high biomass, good N scavenging. Not known for subsoiling, some varieties may not have taproot. Winter-hardiness, day-length response, other characteristics may vary by cultivar. Research & match varieties to your need. See also Niche 5.

continued next page

Figure 8.2 continued: List of Recommended Fall-Seeded Cover Crop Species *(Seasonal Niches 1 & 2)*		
	Species	**Key Characteristics** *(gray shading indicates Niche 2 – expected to winterkill)*
Brassicas / Forbs	**Forage Turnip (FT)** *Brassica rapa var. rapa*	Similar to radish (above) or rapeseed (below), but much less taproot – instead makes bulb on surface. Good forage, probably fits best if cover is to be grazed. With fertility, potential for fast fall growth, high biomass, good N scavenging. Cultivars can vary in bulb-vs.-leaf ratio, winter-hardiness, day-length response. Do your research, find varieties to meet your needs. Big bulbs can be slow to break down, can interfere with subsequent operations like planting. See also Niche 5.
	Phacelia (PH) *Phacelia tanacetifolia* aka Lacy Phacelia	Unique forb with fernlike biomass. Fibrous shallow roots tops for soil aggregation. Well known cover in Europe. New to VA, info limited, seed costly. Fast growth in mild fall temperatures, 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.
	Rapeseed (RS) *Brassica rapa* aka Canola; Rape	Top brassica for Niche 1. Winter-hardy cousin to forage radish (see above). Reliably winter-hardy if seeded on time except at very highest elevations in VA. 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 due to competitiveness. Caution: Hard to kill in late spring with herbicides. See also Niche 5.
Legumes	**Canadian Spring Pea (SP)** *Pisum sativum subsp. Arvense* aka Yellow Field Pea	Compare with winter pea below. Goal for fall-seeded spring pea is winterkill; rarely used this way in VA. Plant early for lush growth! 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 (RC) *Trifolium pratense*	Short-lived perennial, rarely used in Niche 1. Slower growing, must be seeded earlier, killed later than other Niche 1 legume options. Establishes readily, shade tolerant, very winter-hardy, inexpensive. 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 or wheat/triticale companion. Inoculate! Cross inoculates with crimson or white clover. See also Niche 6.
	Crimson Clover (CC) *Trifolium incarnatum*	Popular in VA. May not reliably overwinter at highest elevations in VA. Earlier seeded, more fall growth, earlier spring bloom than hairy vetch. Short, upright growth habit. Good forage, good N-fixer, typically with slower residue breakdown & N release than vetch. Shade tolerant. Showy red blooms, good for pollinators. Can reseed quickly & become weed. Mixes especially well with barley, annual ryegrass. Host to some problem nematodes. Inoculate! Cross-inoculates with red or white clover.
	Austrian Winter Pea (WP) *Pisum sativum subsp. Arvense* aka Black Field Pea	Compare to spring pea above. Goal for winter pea is winter-hardiness: select accordingly, avoid planting too early or late. May not reliably overwinter at highest elevations in VA. Top N-fixer, good biomass & forage. Succulent residues disappear & release N faster than vetch. Low risk of reseeding & becoming weed. Vining habit, will climb small grain in mixes. Caution: Sclerotinia crown rot can take out whole fields, rotate to reduce risk. Inoculate seed! Cross inoculates with vetch. See also Niche 5.
	Woollypod Vetch (WV) *Vicia villosa ssp. dasycarpa* aka Lana Vetch	One of multiple vetches 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 winter-hardy. Likely to overwinter 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 wooly-pod is really wooly-pod. Common vetch (*Vicia sativa)* is possible substitute with larger seed (increase seed rates 10%). See also Niche 5.
	Hairy Vetch (HV) *Vicia villosa*	Reliable & widely used, but avoided by some due to weed concerns. Very winter-hardy. Little fall growth, but fast, vining spring growth makes it tops for N fixation, biomass. Residues release N fast. Good forage. Climbs small grain (SG) in mixes, also wraps up in equipment! Mixes especially well with rye. Up to 20% of 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.

Figure 8.3: Establishment Specifications for Fall-Seeded Cover Crops *(Seasonal Niches 1 & 2, Winter-Hardy & Winterkill)*

Species (gray shading indicates Niche 2 – expected to winterkill)		Winterkill probability	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 Oct 10 average first freeze*		Piedmont (PM) *based on Oct 20 average first freeze*		Coastal Plain (CP) *based on Nov 1 average first freeze*		Before or after avg. first freeze in fall *DBFF or DAFF*		
			Drill	Bcast + incorp	Drill	Bcast + incorp		Preferred	Possible	Preferred	Possible	Preferred	Possible	Preferred	Possible	
Grasses	Spring Oat (SO)	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
	Annual Ryegrass (AR)	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	???
	Winter Oat (WO) *PM &*	low	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
	Barley (BA)	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
	Wheat (WH)	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 out (MB) in May
	Triticale (TR)	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
	Rye (RY)	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 / Forbs	Forage Radish (FR)	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
	Mustard (MU)	high	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
	Forage Turnip (FT)	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
	Phacelia (PH)	high	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
	Rapeseed (RS)	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
	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
	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
	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
	Woolypod Vetch	low	20	30	15 to 25	25 to 40	0.5 to 1.0	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
	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

Figure 8.4: List of Recommended Summer-seeded Cover Crop Species *(Seasonal Niches 1 & 2)*		
	Species	**Key Characteristics**
Grasses	**Sorghum-Sudangrass (SX)** *Sorghum bicolor x S. bicolor var. sudanese* aka Sudex, Sudax	Top summer grass choice. Heat-loving, fast-growing, 6-12 ft tall, big biomass potential with lots of soil N. Top weed suppressor thru competition, alleleopathy (caution if 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 & weed potential can overwhelm: mow or kill timely! Mix with cowpea, sunnhemp. Can substitute forage sorghum or sudangrass. Sugarcane aphid, new pest of sorghum species in VA, may be a problem.
	Pearl Millet (PM) *Pennisetum glaucum* aka Cattail Millet	Heat-loving, fast-growing option very similar to SX (see above). Compared to SX: 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 PM 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 (FM) *Setaria italica* (aka German or Hay Millet)	Shorter, finer-stemmed, lower-biomass option compared to SX or PM (see above). Key difference: FM is reliably killed with single mowing. Also FM matures faster, not as good on weeds or drought. Some report that FM 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 FM not available.
Forbs	**Black Oilseed Sunflower (SF)** *Helianthus annus*	Rarely used in VA, but strong potential. SF blooms very attractive to people, pollinators, wildlife. Low seeding rate means low cost. Deep branched taproot, good reputation for pulling up nutrients (but not necessarily subsoiling). Good heat and drought tolerance once established. OK weed suppressor. Adaptable 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 (BW) *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: kill or mow within 7 to 10 days after first bloom. Sets seed 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 good for unlocking soil phosphorous (P).
Legumes	**Forage Soybean (FS)** *Glycine max*	Similar to cowpea 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 FM. Not good rotation for grain systems with cash crop soybeans. Low reseeding & weed risk. Inoculate! Does not cross-inoculate with other legumes in this manual.
	Cowpea (CP) *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 key for beneficial insects. Some suppression for problem nematodes. Some shade tolerance = good for mixes. Many varieties available; use forage or cover crop cultivars, with bush types for short mixes, vine or runner types for tall mixes. Needs heat; caution in VA mountains. Low reseeding & weed risk. Inoculate! Cross-inoculates with peanut, sunnhemp.
	Sunnhemp (SH) *Crotolaria juncea L.* aka Sunnhemp	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 = seems better choice for mixes than monoculture. Becomes stemmy as matures. Some VA users report good forage potential in VA. Interesting yellow blooms; low weed risk, but with enough time can set viable seed. Mix with SX, PM, SF. Inoculate seed! Cross-inoculates with CP.

Figure 8.5: Establishment Specifications for 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 freeze, Oct 10 first freeze*		Piedmont *based on Apr 20 last freeze, Oct 20 first freeze*		Coastal Plain *based on Apr 10 last freeze, Nov 1 first freeze*		Days after last spring freeze *(DALF)* & days before first fall freeze *(DBFF)*			
		Drill	Bcast+ incorp	Drill	Bcast+ incorp		Preferred	Possible	Preferred	Possible	Preferred	Possible	Preferred	Possible		
Grasses	Sorghum-Sudangrass (SX)	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: 65 to 75 days after plant (DAP)
	Pearl Millet (PM)	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: 60 to 70 days after plant (DAP)
	Foxtail Millet (FT)	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: 60 DAP VS: 75 DAP
Forbs	Black Oil Sunflower (SF)	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
	Buckwheat (BW)	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 *(Inoculate!)*	Forage Soybean (FS)	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)
	Cowpea (CP)	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
	Sunnhemp (SH)	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 VS: 120+ DAP

** 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.*

Figure 8.6: List of Recommended Spring-seeded Cover Crop Species *(Seasonal Niche 5)*		
	Species	**Key Characteristics & Considerations**
Grasses	**Spring Oat (SO)**	See fall-seeded species list for details on SO. Top spring grass choice. Select spring types that go to stalk/head/seed without vernalization. At maturity, SO has lower C:N than other small grains (SG). Use low rate as nurse for spring-seeded perennials. Classic spring mix is SO + peas. SO is also Niche 2 option.
	Small Grains (SG) Barley, wheat, triticale, rye	See fall-seeded species list for details on these SG options. Most SG in VA is winter type – needs vernalization to produce stalk/head/seed. Winter SG seeded in spring might not vernalize; if does not vernalize, in theory will stay short with no stalk. This might be good or bad – depends on your purpose. If stems/residue needed, seed winter types early or use spring oat or spring type SG.
	Annual Ryegrass (AR)	See fall-seeded species list for details on AR. 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 / Forbs	**Forage Radish (FR)**	See fall-seeded species list for details on FR. For typical VA varieties, spring seeding gives different result from fall seeding. Much less root and top growth, bolts and flowers very quickly. Attractive white flowers. Thus, plant in spring primarily to add fast bloom, diversity to mixes. Some varieties may differ.
	Mustard (MU)	See fall-seeded species list for details on MU. Spring growth pattern may vary by cultivar; research & match variety to meet needs. Initial observations in VA indicate spring results similar to radish – much less biomass, bolts & flowers quick. Use in spring mainly for adding diversity, yellow blooms to mixes.
	Phacelia (PH)	See fall-seeded species tables for details on PH. Initial observations indicate spring seeding is best for producing PH blooms. Expect modest spring PH biomass, but longer growth period before flowering than radish, mustard. Showy blue PH blooms very good for pollinators, main reason to seed in spring.
	Forage Turnip (PH)	See fall-seeded species tables for details on FT. Spring seeding likely provides similar results to radish and mustard (see above) – limited biomass, fast flowering. Spring results may be highly cultivar-specific. Do your own research and match varieties to your needs.
	Rapeseed (RS)	See fall-seeded species tables for details on RS. Like small grain, winter and spring types are available. We observed spring-seeded winter RS put on more biomass than radish or mustards before flowering, but still less biomass than if fall seeded. May vary by cultivar – do your own research.
Legumes	**Canadian Spring Pea (SP)**	See fall-seeded species list for details on SP. Top legume choice for early spring seeding. Select fast-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 for Niche 2.
	Austrian Winter Pea (WP)	See fall-seeded species list for details on WP. Expect slightly slower growth and less biomass than with spring pea (see above), but often similar results. Lower total biomass potential if spring seeded compared to standard fall seeding. Inoculate! Cross-inoculates with vetch. See also Niche 1.
	Woollypod Vetch (WV)	See fall-seeded species list for details on WV. Our second choice for short-term spring N fixation (peas are first choice). One of multiple specialty vetches similar to hairy vetch (HV). Typically expected to provide 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 winter-hardiness, but might be better spring options. Do your own research. Inocluate! Cross-inoculates with pea.
	Hairy Vetch (HV)	See fall-seeded species list for details on HV. May not grow as well when spring-seeded as WV or other specialty vetches (see above), but advantage of HV is availability. Inoculate! Cross-inoculates with peas.

Figure 8.7: Establishment Specifications for Spring-seeded, Frost-hardy Cover Crop 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 freeze)*		Piedmont *(based on Apr 20 average last freeze)*		Coastal Plain *(based on Apr 10 average last freeze)*		Days before average last spring freeze *(DBLF)*		
		Drill	Bcast + incorp	Drill	Bcast + incorp		Preferred	Possible	Preferred	Possible	Preferred	Possible	Preferred	Possible	
Grasses	Spring Oat (SO)	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 90 days after planting (DAP)
	Barley, Wheat, Triticale, Rye	Obtain seeding rate and depth for selected small grains from fall-seeded cover crop specs					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 (AR)	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	???
Brassicas / Forbs	Forage Radish (FR)	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 70 DAP; little root; quick to bloom
	Mustard (MU)	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 70 DAP; quick to bloom; cultivars vary
	Forage Turnip (FT)	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	Cultivars vary
	Phacelia (PH)	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; showy blue blooms 60 to 90 DAP
	Rapeseed (RS)	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 & bloom than FR
Legumes *(inoculate!)*	Canadian Spring Pea (SP)	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 (WP)	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 (WV)	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 (HV)	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)

Figure 8.8: List of Recommended Perennial Cover Crop Species *(Seasonal Niche 6)*		
	Species	**Key Characteristics**
Grasses	**Tall Fescue (TF)** *Festuca arundinacea*	Most competitive, persistent perennial cool-season grass in VA, especially in warmer regions. Top choice for low-maintenance cover, erosion control, soil 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 persistent stands. Hay, graze, or clip to minimize seed set, keep stand vegetative. If managed like hay or occasionally clipped, mix with red clover, alfalfa. If managed like turf with continuous low mowing or grazing, mix with white clover. Best if fall-seeded, but spring can work. Consider seeding with small grain nurse crop that will be harvested/mowed off to release the perennial.
	Orchardgrass (OG) *Dactylis glomerata*	Widely-adapted perennial cool-season grass, especially in cooler regions of VA. Higher forage quality than TF (see above), but not as tolerant of heat, drought, heavy grazing, low mowing, poor soils. Tops for forage and good for biomass, erosion control, soil building on fields with strong 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 on good soils. Hay, graze, or clip to minimize seed set, keep stand vegetative. Will not persist unless mow high/rotationally graze. Mix with red clover, alfalfa. Fall seeding is best. Consider seeding with small grain nurse crop that will be harvested/mowed off to release the perennial.
Legumes	**Alfalfa (AL)** *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 cool-season perennial grass (e.g., orchardgrass) or overseed with annual grass (e.g, wheat) for winter cover and to moderate C:N ratio at termination. Cut for hay or clip occasionally 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 (RC) *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 problem 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 rate 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 (WC) *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 (SC) *Melilotus officinalis*	Biennial known for deep subsoiling, N fixation. Prefers mild conditions, but most drought-tolerant legume once established. Not for wet soils. 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 is also seeded in spring, but doesn't overwinter.

Figure 8.9: Cover Crop Establishment Specifications for 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. freeze, Oct 10 first avg. freeze*		Piedmont *based on Apr 20 last avg. freeze, Oct 20 first avg. freeze*		Coastal Plain *based on Apr 10 last avg. freeze, Nov 1 first avg. freeze*		Days before first fall freeze *(DBFF)*, days before last spring freeze *(DBLF)*	
		Drill	Bcast + incorp	Drill	Bcast + incorp		Preferred	Possible	Preferred	Possible	Preferred	Possible	Preferred	Possible
Grasses	Tall Fescue (TF)	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 (OG)	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 (AL)	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 (RC)	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 (WC)	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 (SC)	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

Figure 9.1: Planting Date Calendar for Late Summer- & Fall-seeded Species – Dates Adjusted for Georgetown, DE

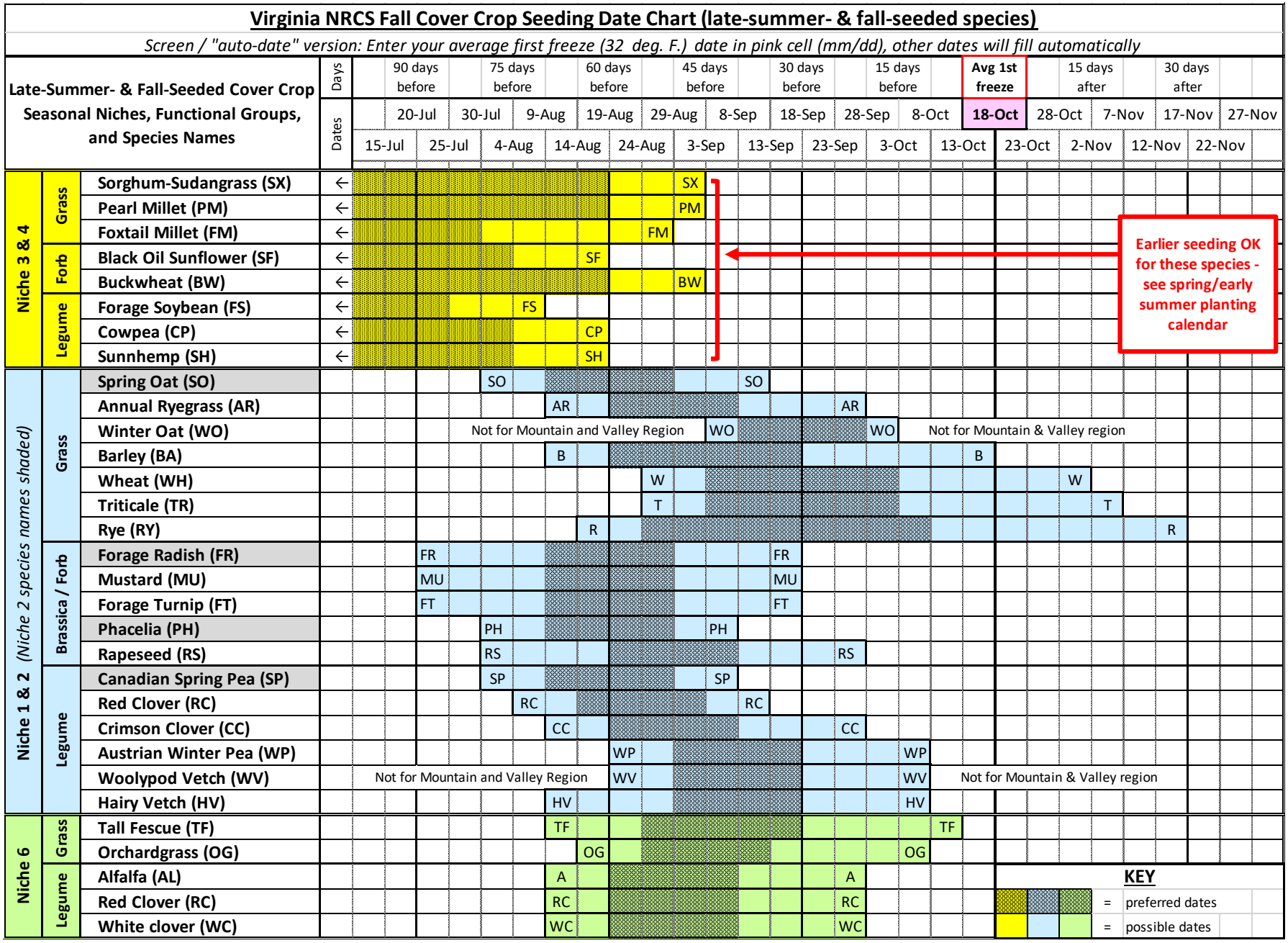


Figure 9.2: Planting Date Calendar for Spring- & Early Summer-Seeded Species – Dates Adjusted for Georgetown, DE

Virginia NRCS Spring Cover Crop Seeding Date Chart (spring- & early-summer-seeded species)

Screen / "auto-fill" version: Enter average last freeze (32 deg. F.) date in pink cell, other dates will automatically fill

Spring- & Early-Summer-Seeded Cover Crop Seasonal Niches, Functional Groups, and Species Names			Days	75 days before	60 days before	45 days before	30 days before	15 days before	**Avg. last freeze**	15 days after	30 days after	45 days after	60 days after
			Dates	11-Feb	21-Feb	2-Mar	12-Mar	22-Mar	1-Apr	11-Apr	**21-Apr**	1-May	11-May	21-May	31-May	10-Jun	20-Jun
				6-Feb	16-Feb	26-Feb	7-Mar	17-Mar	27-Mar	6-Apr	16-Apr	26-Apr	6-May	16-May	26-May	5-Jun	15-Jun	
Niche 3 & 4	Grass	Sorghum-Sudangrass (SX)													SX			→
		Pearl Millet (PM)													PM			→
		Foxtail Millet (FM)													FM			→
	Forb	Black Oil Sunflower (SF)											SF					→
		Buckwheat (BW)												BW				→
	Legume	Forage Soybean (FS)																→
		Cowpea (CP)													CP			→
		Sunnhemp (SH)													SH			→
Niche 5	Grass	Spring Oat (SO)				SO					SO							
		Rye (RY)				R					R							
		Triticale (TR)				T					T							
		Wheat (WH)				W					W							
		Barley (BA)				B					B							
		Annual Ryegrass (AR)						AR				AR						
	Brassica / Forb	Forage Radish (FR)						FR				FR						
		Mustard (MU)						MU				MU						
		Forage Turnip (FT)						FT				FT						
		Phacelia (PH)						PH				PH						
		Rapeseed (RS)						RS				RS						
	Legume	Canadian Spring Pea (SP)					SP				SP							
		Austrian Winter Pea (WP)					WP				WP							
		Woolypod Vetch (WV)						WV				WV						
		Hairy Vetch (HV)						HV				HV						
Niche 6	Grass	Tall Fescue (TF)				TF					TF							
		Orchardgrass (OG)		Not for C. Plain region		OG				OG		Not for Coastal Plain region						
	Legume	Alfalfa (AL)					A				A							
		Red Clover (RC)					RC				RC							
		White Clover (WC)					WC				WC							
		Yellow Bl. Sweetclover (SC)						SC				SC						

Later seeding dates OK for these species - see late summer/fall planting calendar

KEY

= preferred dates

= possible dates

Notes:

Figure 9.3: Mixes: Top Tips & Key Concepts

Top Tips for Mastering Cover Crop Mixes

1. Study and try the species listed in this manual
2. Study and try the mixes listed in this manual
3. Plan, plant, and learn from your own mixes

Cover Crop Mix Key Concepts

1. Mixes let you fit more into a single seeding:
   - More purposes, functional groups, and/or seasonal niches
   - More balanced C:N ratios
   - More adaptability to site, seasonal, and/or seed variability
2. Try to make mixes your default option, monocultures your fallback alternative
3. Mixes mean tradeoffs and aren't always best
   - Limited plant production resources are divided between multiple purposes
4. Focus on purpose(s) and practicality first, diversity next
5. What's your mix strategy: Functional diversity, functional redundancy, or both?
   - Functional diversity: Include species that each perform different functions.
   - Functional redundancy: Include multiple species that perform the same function.
6. Reality check: Does a mix really fit your situation?
   - Multi-purpose mixes typically need to be planted earlier, terminated later, or both.
   - Multi-purpose mixes typically involve more complexity and planning.

Figure 9.4: Are Species in the Mix Compatible?

1. Are seeding dates compatible?
2. Are maturity and termination dates compatible?
3. Are growth habit and rates compatible?
4. Are seeding depths & methods compatible?

Figure 9.5: Setting Seeding Rates in Mixes

1. To set seeding rates in mixes, we recommend:
   a. Fraction-of-base-rate (FBR) method
   b. Our mix seeding rate worksheets
2. The FBR Method, step by step:
   a. Choose your base rate for each species
   b. Assign your desired FBR to each species
      - See Fig. 9.7 for guidance on FBR selection
   c. Sum species FBR values to get total mix FBR
   d. Compute seeding rate for each species
   e. Sum species seed rates to get total mix rate
   f. Compute % of seed mix by weight by species
   g. Sum % of seed mix by weight for each species to get check that sum equals 100%

Figure 9.6: Setting Seeding Rates for Two Mixtures using Fraction-of-base-rate (FBR) Method and Our Worksheets

Late Summer- & Fall-Seeded Cover Crop Seasonal Niches, Functional Groups, and Species Names			A	B	C	D1	E1	F1	D2	E2	F2
			Chosen base rates (lb/ac)			Example Mix 1: RY & RS			Example Mix 2: Diverse Mix		
			Drill rate	Bcast + incorp rate	Drill Rate	Fraction of base rate (FBR)	Species rate (lb/ac)	% of mix by weight	Fraction of base rate (FBR)	Species rate (lb/ac)	% of mix by weight
Niche 3 & 4	Grass	Sorghum-Sudangrass (SX)	35	45	35						
		Pearl Millet (PM)	20	30	20						
		Foxtail Millet (FM)	20	30	20						
	Forb	Black Oil Sunflower (SF)	5	10	5						
		Buckwheat (BW)	60	80	60						
	Legume	Forage Soybean (FS)	60	90	60						
		Cowpea (CP)	50	80	50						
		Sunnhemp (SH)	20	30	20						
Niche 1 & 2 *(Niche 2 species names shaded)*	Grass	Spring Oat (SO)	80	110	80				0.15	12.0	22%
		Annual Ryegrass (AR)	15	25	15						
		Winter Oat (WO)	80	110	80						
		Barley (B)	100	140	100						
		Wheat (W)	120	160	120						
		Triticale (T)	110	145	110						
		Rye (R)	110	145	110	0.50	55.0	95%	0.15	16.5	31%
	Brassica / Forb	Forage Radish (FR)	8	14	8				0.15	1.2	2%
		Mustard (MU)	8	12	8						
		Forage Turnip (FT)	5	10	5						
		Phacelia (PH)	8	12	8						
		Rapeseed (RS)	6	12	6	0.50	3.0	5%	0.15	0.9	2%
	Legume	Canadian Spring Pea (SP)	60	90	60						
		Red Clover (RC)	10	12	10						
		Crimson Clover (CC)	15	25	15				0.35	5.3	10%
		Austrian Winter Pea (WP)	50	75	50				0.35	17.5	33%
		Woolypod Vetch (WV)	20	30	20						
		Hairy Vetch (HV)	20	30	20						
Niche 6	Grass	Tall Fescue (TF)	20	25	20						
		Orchardgrass (OG)	12	16	12						
	Legume	Alfalfa (A)	20	25	20						
		Red Clover (RC)	10	12	10						
		White clover (WC)	5	10	5						
					Totals	1.00	58.0	100%	1.30	53.4	100%
					Number of species in mix:	2			6		

This illustrates using FBR method and our mix seeding rate worksheets to compute seeding rates for two mixes.

Example Mix 1 is a bi-culture of rye (RY) and rapeseed (RS).

Example Mix 2 is a six-way poly-culture of spring oat (SO), rye (RY), forage radish (FR), rapeseed (RS), crimson clover (CC), and Austrian winter pea (WP).

Drill rates were used as the chosen base rate for each species in both mixes (see Column C).

Fraction-of-base-rate (FBR) values (see Columns D1 and E1) for all species were selected first, using approach explained in Figure 9.5 (and in narrative text of this chapter).

Seeding rates (Columns E1 and E2) for each species were then computed by multiplying chosen base rates x FBR.

Finally, % of mix by weight values (Columns F1 and F2) were computed using seeding rate values.

Figure 9.7: Selecting Fraction of Base Rate (FBR) for Setting Seeding Rates in Mixes: Six Basic Steps

1. **Visualize the stand**
   Visualize the cover crop in the field. What fraction or percentage of the stand does each functional group (or individual species) represent? Use these values as a starting point for fraction of base rate (FBR).

2. **Express FBR as a decimal**
   Convert your initial FBR values to decimal form. For example: ½ or 50% = 0.50; ¾ or 75% = 0.75; etc.

3. **Consider functional group competitiveness**

   Grasses: Planted under optimal conditions, grasses tend to be strong competitors. If your goal is a balanced mix of all functional groups, consider aiming for a total FBR for grasses in the **0.25 to 0.50** range. If there are multiple grasses in the mix, divide the grass FBR between those grass species.

   Brassicas: Planted under optimal conditions, brassicas tend to be strong competitors. If your goal is a balanced mix of all functional groups, consider aiming for total FBR for brassicas in the **0.25 to 0.50** range. If there are multiple brassicas in the mix, divide the brassica FBR between those brassica species.

   Legumes: Even when planted under optimal conditions, legumes tend to be weak competitors. If your goal is a balanced mix of all functional groups, consider aiming for total FBR for legumes in the **0.67 to 1.00** range. If there are multiple legumes in the mix, divide the legume FBR between those legume species.

4. **Consider species competitiveness**
   Keep in mind that some species are especially strong competitors when planted under optimal conditions. For example, if your goal is a balanced mix of species/functional groups, be cautious about exceeding the following rates:
   - Sorghum-sudangrass 15 lb/ac; oats 30 lb/ac; cereal rye 40 lb/ac; forage radish 2.5 lb/ac; rapeseed 2 lb/ac.

5. **Consider other mix- and site-specific factors**
   Consider other relevant questions, such as:
   - How will my planting date, soil fertility levels, etc. influence the competitiveness of various species in the mix?
   - If one or more components of the mix will winterkill, is there adequate FBR for the overwintering species to fulfill their spring function?

6. **Consider total FBR for the overall mix**
   Add up FBR values for all species in the mix. Total FBR for the overall mix should be in the range of 1.00, although values as low as 0.75 or as high as 2.00 to 3.00 could be appropriate depending on the situation. If total FBR for the mix is not consistent with your goals, go back and adjust FBR for individual species accordingly.

Figure 9.8: Learning List of 40 Cover Crop Mixes: Organization & Definition of Terms

Organization: Mixes are grouped by seasonal niche into five tables. Within each table, mixes are listed in approximate order of planting (i.e., fall-seeded mixes that must be planted earliest are listed first; mixes that may be planted latest are last, etc.) **Definitions for timing of seeding:** DBFF = Days before first freeze (in fall) DAFF = Days after first freeze (in fall) DBLF = Days before last freeze (in spring) DALF = Days after last freeze (in fall)	**Definitions for functional groups:** G = Grass B = Brassica F = Forb L = Legume **Definitions for C:N ratio of mature residue:** Low = C:N ratio below 20:1 Mid = C:N ratio in range of 20:1 to 30:1 High = C:N ratio above 30:1 **Definitions for relative seeding rates** Light = total FBR for mix around 0.50 Moderate = total FBR for mix around 1.00 Heavy = total FBR for mix around 1.50

Figure 9.9: Index to Learning List of 40 Cover Crop Mixes

Mix ID	Niche(s)†	Mix Name	Species‡, Groups, and Species Counts				
			Grass	Brassica	Forb	Legume	Count
Fall 01	3 2	Sudex/Radish/Sunnhemp Winterkill Mix	SX	FR		SH	3
Fall 02	3 2	Sudex/Radish Winterkill Mix	SX	FR			2
Fall 03	3 2 1	Very High Diversity Late Summer Mix	SX, SO, RY	FR, RS	SF	SH, CC, HV	9
Fall 04	2	Fall-seeded Oat/ Pea Winterkill Mix	SO			SP	2
Fall 05	2 1	Very High Diversity Early Fall Mix	SO, TR, RY	FR, RS	PH	CC, WP, HV	9
Fall 06	2	Oat/Radish Winterkill Mix	SO	FR			2
Fall 07	2 1	Crimson Clover w. Spring Oat Nurse	SO			CC	2
Fall 08	2 1	Rye/Radish Subsoiler & N-Scavenger Mix	RY	FR			2
Fall 09	2 1	Two-season All Grass/Brassica Mix	SO, BA	FR, RS			4
Fall 10	2 1	Early Fall All Grass Multi-Cut Forage Mix	SO, AR, TR				3
Fall 11	2 1	Early Fall Oat/Ryegrass/Clover Forage Mix	SO, AR			CC	3
Fall 12	2 1	Early Fall Brassica Mix w. Barley/Pea	BA	FR, RS		WP	4
Fall 13	2 1	Early Fall All Brassica Mix		FR, MU, RS			3
Fall 14	2 1	Early Fall N-scavenge/Spring N-Fix Mix	SO	FR			4
Fall 15	2 1	Triticale/Radish/Crimson Mix	TR	FR		CC	3
Fall 16	1	High Biomass Barley/Crimson Clover Mix	BA			CC	2
Fall 17	1	Wheat/Rapeseed/Winter Pea Mix	WH	RS		WP	3
Fall 18	1	Rye/Rapeseed/Legume Mix	RY	RS		WP, HV	4
Fall 19	1	Mid Fall High Diversity Mix	BA, WH, TR	RS		CC, WP, HV	7
Fall 20	1	Rye/Vetch Mix	RY			HV	2
Summer 01	4	Foxtail Millet/Soybean N-Fixer	FM			FS	2
Summer 02	4	All-legume Summer N-Fixer				FS, CP, SH	3
Summer 03	3 or 4	Low-cost Short Summer Cocktail	PM, FM		BW, SF	FS, CP	6
Summer 04	3 or 4	Pearl Millet/Cowpea Big Biomass Mix	PM			CP	2
Summer 05	3 or 4	Sudex/Sunnhemp Tall Summer Cover	SX			SH	2
Summer 06	3 or 4	Sudex/Sunflower Low-cost Tall Mix	SX		SF		2
Summer 07	4	Short Three-Way Summer Mix	FM		SF	CP	3
Summer 08	3 or 4	Tall Three-Way Summer Mix	SX		SF	SH	3
Summer 09	3 or 4	Summer Forage & Biomass Cocktail	SX, PM		BW, SF	CP, SH	6
Summer 10	3 or 4	Summer Grass & Buckwheat Biomass Mix	SX, PM		BW		3
Spring 01	5	Spring-seeded Spring Oat/Spring Pea	SO			SP	2
Spring 02	5	Spring-seeded Winter Rye/Winter Pea	RY			WP	2
Spring 03	5	Low-cost Spring Oat/Rapeseed/Pea	SO	RS		SP	3
Spring 04	5	High-diversity Spring N-Fix Mix	SO	RS		SP, WP, WV, HV	6
Spring 05	5	High-diversity Spring Flower Mix	SO	FR, MU, RS	PH	SP, WV	7
Perennial 01	3 6	Fall-seed Red Clover w. Sudex Nurse	SX			RC	2
Perennial 02	2 6	High-quality Mixed Hay w. Oat Nurse	SO, OG			AL, RC	4
Perennial 03	6	Fescue/White Clover Living Mulch	TF			WC	2
Perennial 04	1 6	Fescue w. Wheat Nurse	WH, TF				2
Perennial 05	5 6	Spring Sweetclover w. Oat Nurse	SO			SC	2

†See Chapter 7 for seasonal niche definitions & considerations.
‡See Chapter 8 for species descriptions, name abbreviations, etc.

Figure 9.10: Fall-Seeded Cover Crop Mix Examples *(Seasonal Niches 1 & 2)*

Timing of seeding	Mix ID	Species	Group	Seeding rate: lb/ac in mix	Seeding rate: Fraction of base rate	Seeding rate: % of mix by weight	Description & Notes
90 to 60 DBFF	Fall Mix 01	Sorghum-sudangrass (SX)	G	15.5	0.44	55%	**LATE-SUMMER/EARLY-FALL BALANCED THREE-WAY MIX; 100% WINTERKILL; EMPHASIS: N-SCAVENGE, BIODRILL, BIOMASS.** Mix gives all three functional groups, explosive fall growth potential, and complete winterkill. This overall seeding rate (fraction of base rate 1.25) is moderate to heavy, suitable for strong cover or possible grazing. High soil N will favor SX, FR, biomass; low soil N will favor SH. If grazed, note SX prussic acid concerns. SX & SH die at first freeze; FR dies mid-winter in most of VA. Expect modest spring residue and N retention – seed next crop early! Inoculate SH seed to optimize N fixation. Options: replace SX with pearl millet; replace SH with cowpea.
		Forage radish (FR)	B	2.5	0.31	9%	
		Sunnhemp (SH)	L	10	0.50	36%	
		Seasonal niche: 2+4	**Totals:**	28	1.25	100%	
		Expected C:N ratio of mature residue: Low to mid					
		Name: "Sudex/Radish/Sunnhemp Winterkill Mix"					
90 to 45 DBFF	Fall Mix 02	Sorghum-sudangrass (SX)	G	10	0.29	71%	**LATE-SUMMER/EARLY-FALL GRASS/BRASSICA MIX; 100% WINTERKILL; EMPHASIS: N-SCAVENGE, BIODRILL.** Mix gives fast early-fall cover, N-scavenging, subsoiling, then total winterkill. Light to moderate overall seeding rate (fraction of base rate 0.79) for larger FR tubers, lower cost. Rate ratio favors FR over SX. Ample soil N and early planting are key. SX dies at first freeze, FR dies mid-winter in most of VA. Expect low residue and fast N release in spring – seed next crop early! Options: replace SX with pearl millet; increase SX for more residue.
		Forage radish (FR)	B	4	0.50	29%	
		Seasonal niche: 2+4	**Totals:**	14	0.79	100%	
		Expected C:N ratio of mature residue: Low to mid					
		Name: "Sudex/Radish Winterkill Mix"					
85 to 45 DBFF	Fall Mix 03	Sorghum-sudangrass (SX)	G	5	0.14	10%	**LATE-SUMMER/EARLY-FALL NINE-WAY MIX; PARTIAL WINTERKILL; EMPHASIS: BALANCED DIVERSITY, BIOMASS/FORAGE, BIODRILL, N-SCAVENGE & FIX.** Mix fills three seasonal niches and many functions with one seeding. Compromise approach – some species will be seeded outside optimum dates. Earlier planting in recommended window favors summer species, later favors winter species. SX, SF, SH give late-summer biomass, then die in first freezes. SO and FR give fast fall growth, then die mid-winter in most of VA. Four remaining species overwinter and provide spring biomass, N scavenging, bio-drilling, N fixation, and showy CC and RS blooms (note: RS may be hard to spray-kill in late spring). This overall seeding rate (fraction of base rate 1.70) is heavy to very heavy, suitable for high-performance grazing or cover. Winter-killed species will disappear, however, so final rate of remaining overwintering species (fraction of base rate 0.84) is light to moderate. Inoculate legume seed to optimize N fixation. Options: adjust rates to favor one or more functions; remove one or more species.
		Spring oat (SO)	G	12	0.15	24%	
		Rye (RY)	G	17	0.15	33%	
		Black oil sunflower (SF)	F	1	0.20	2%	
		Forage radish (FR)	B	1	0.13	2%	
		Rapeseed (RS)	B	1	0.17	2%	
		Sunnhemp (SH)	L	5	0.25	10%	
		Crimson clover (CC)	L	4	0.27	8%	
		Hairy vetch (HV)	L	5	0.25	10%	
		Seasonal niche: 1+2+4	**Totals:**	51	1.70	100%	
		Expected C:N ratio of mature residue: Mid					
		Name: "Very High Diversity Late Summer Mix"					
80 to 40 DBFF	Fall Mix 04	Spring Oat (SO)	G	40	0.50	50%	**EARLY-FALL BALANCED GRASS/LEGUME MIX; 100% WINTERKILL; EMPHASIS: N-SCAVENGE & FIX, BIOMASS**. Frost-hardy mix likely to winterkill in most of VA. Early seeding and ample biomass are key to winterkill. This overall seeding rate (fraction of base rate 1.17) is moderate to heavy, suitable for strong cover crop or possible grazing. Ratios give balance of SO & SP functions. Inoculate legume to optimize N fixation. Good biomass, N fixation, rich forage are possible by late fall. After mid-winter freeze-kill, residue melts away & N releases fast – plant back in early spring or modify mix to include winter-hardy grass. Options: adjust rates to favor either SO or SP. This mix is good option for spring seeding (see Niche 5).
		Canadian spring pea (SP)	L	40	0.67	50%	
		Seasonal niche: 2	**Totals:**	80	1.17	100%	
		Expected C:N ratio of mature residue: Low					
		Name: "Fall-seeded Spring Oat/Spring Pea Winterkill Mix"					

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Figure 9.10 (continued): Fall-Seeded Cover Crop Mix Examples

Timing of seeding	Mix ID	Species	Group	Seeding rate: lb/ac in mix	Seeding rate: Fraction of base rate	Seeding rate: % of mix by weight	Description & Notes
80 to 40 DBFF	Fall Mix 05	Spring oat (SO)	G	10	0.13	20%	**EARLY FALL BALANCED VERY HIGH DIVERSITY MIX; PARTIAL WINTERKILL; EMPHASIS: N SCAVENGE; BIODRILL; BIOMASS; N-FIX; FLOWERS.** Two-season diversity with multiple species from each functional group. With early seeding and ample fertility, SO, FR, PH give fast fall growth, then winterkill in most of VA. Remaining six species are winter-hardy, providing balanced spring stand with biomass, biodrilling, N scavenging & fixation, residues with mid C:N ratio, plus RS and legume blooms (note: RS can be hard to spray-kill in late spring). This overall seeding rate (fraction of base rate 1.32) is moderate to heavy, typical of forage or high-performance cover. Winter-killed species will likely disappear, however, so final rate of remaining spring species (fraction of base rate 0.91) is light to moderate. Inoculate legume seed to optimize N fixation. Options: adjust rates to favor one or more functions; replace TR or RY with barley or wheat; remove one or more species.
		Triticale (TR)		10	0.09	20%	
		Rye (RY)		10	0.09	20%	
		Forage radish (FR)	B	1	0.13	2%	
		Rapeseed (RS)		1	0.13	2%	
		Phacelia (PH)	F	1	0.17	2%	
		Crimson clover (CC)	L	3	0.20	6%	
		Austrian winter pea (WP)		10	0.20	20%	
		Hairy vetch (HV)		4	0.20	8%	
		Seasonal niche: 1+2	**Totals:**	50	1.32	100%	
		Expected C:N ratio of mature residue: Mid					
		Name: "Very High Diversity Early Fall Mix"					
80 to 35 DBFF	Fall Mix 06	Spring Oat (SO)	G	30	0.38	91%	**EARLY-FALL BALANCED GRASS/BRASSICA MIX; 100% WINTERKILL; EMPHASIS: N-SCAVENGE; BIODRILL.** Popular mix with fast early-fall biomass, subsoiling, grazing potential, and winterkill in most of VA. Light to moderate overall seeding rate (fraction of base rate 0.76) for larger FR tubers, lower cost. Ample soil N and early planting are key. Expect low residue and quick N release in early spring – plant back promptly. Options: increase SO rate for more residue. This mix also found in Chapter 2 "Top 20" list, but with higher seeding rate.
		Forage radish (FR)	B	3	0.38	9%	
		Seasonal niche: 2	**Totals:**	33	0.76	100%	
		Expected C:N ratio of mature residue: Low to mid					
		Name: "Oat/Radish Winterkill Mix"					
75 to 35 DBFF	Fall Mix 07	Spring oat (SO)	G	28	0.35	65%	**EARLY-FALL WINTERHARDY LEGUME & NURSE; PARTIAL WINTERKILL; EMPHASIS: N FIX; FLOWERS.** SO nurse crop gives fall cover, weed suppression, protection to legume seedlings. SO winterkills in most of VA, leaving monoculture spring CC with high N fixation potential, spring blooms, low C:N residues. If this light rate of SO does not fully winterkill, core spring N-fixing function can still be fulfilled. CC reaches maximum biomass and N fixation earlier than other fall-seeded legume choices. This overall seeding rate (fraction of base rate 1.35) is moderate to heavy, typical of forage or high-performance cover. SO will likely winter-kill, so final rate of remaining CC (fraction of base rate 1.00) is in fact moderate. Inoculate CC seed to optimize N fixation. Options: replace CC with winter pea or hairy vetch.
		Crimson clover (CC)	L	15	1.00	35%	
		Seasonal niche: 1+2	**Totals:**	43	1.35	100%	
		Expected C:N ratio of mature residue: Low					
		Name: "Crimson Clover with Spring Oat Nurse"					
75 to 35 DBFF	Fall Mix 08	Rye (RY)	G	84	0.76	50%	**EARLY-FALL GRASS/BRASSICA MIX; PARTIAL WINTERKILL; EMPHASIS: N-SCAVENGE, BIODRILL, BIOMASS.** Repeated from Chapter 2 "Top 20" list, this mix has balance of fall brassica and spring grass function. With early seeding & ample fertility, FR gives fast fall growth, biodrilling, grazing option, and winterkill in most of VA. After FR dies, RY gives winter cover, N retention, spring biomass. This overall seeding rate (fraction of base rate 1.26) is moderate to heavy, suitable for strong cover crop or possible grazing. FR will die out, however, so rate of overwintering RY is light to moderate (fraction of base rate 0.76). Options: replace RY with other small grain.
		Forage radish (FR)	B	4	0.50	50%	
		Seasonal niche: 1+2	**Totals:**	88	1.26	100%	
		Expected C:N ratio of mature residue: High					
		Mix name: "Rye/Radish Subsoiler & N-scavenger Mix"					
75 to 35 DBFF	Fall Mix 09	Spring oat (SO)	G	32	0.40	42%	**EARLY-FALL GRASS/BRASSICA MIX; PARTIAL WINTERKILL; EMPHASIS: N-SCAVENGE; BIODRILL; BIOMASS.** Mix gives balance of fall and spring grass and brassica function. Seed early with good fertility for fall biomass and N uptake from all species, biodrilling from brassicas. SO & FR will freeze-kill by mid-winter in most of VA. BA & RS are winter-hardy, give spring biomass, N retention, plus RS blooms (note: RS can be hard to spray-kill in late spring). This overall seeding rate (fraction of base rate 1.38) is moderate to heavy, suitable for grazing or strong cover crop. SO & FR will die out, however, so rate of remaining species (fraction of base rate 0.73) is light to moderate. Options: replace BA with other small grain.
		Barley (BA)		40	0.40	53%	
		Forage Radish (FR)	B	2	0.25	3%	
		Rapeseed (RS)		2	0.33	3%	
		Seasonal niche: 1+2	**Totals:**	76	1.38	100%	
		Expected C:N ratio of mature residue: High					
		Mix name: "Two-season All Grass/Brassica Mix"					

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Figure 9.10 (continued): Fall-Seeded Cover Crop Mix Examples

Timing of seeding	Mix ID	Species	Group	Seeding rate: lb/ac in mix	Seeding rate: Fraction of base rate	Seeding rate: % of mix by weight	Description & Notes
65 to 35 DBFF	Fall Mix 10	Spring oat (SO)	G	33	0.41	33%	**EARLY-FALL ALL GRASS MIX; PARTIAL WINTERKILL. EMPHASIS: MULTI-HARVEST FORAGE, VERY HIGH BIOMASS, N-SCAVENING.** This mix makes fine N-scavenging cover, but at this very heavy seeding rate might be used as multi-cut, top-quality forage. If seed early with high soil N, SO gives fast fall growth & rich feed, then winterkills in most of VA. With adequate fertility, AR & TR give up to two spring harvests of high-quality forage. This overall seeding rate (fraction of base rate 2.29) is very heavy, suitable for high-priority forage or high biomass/weed suppressive cover crop. SO will likely die out, but rate of overwintering AR & TR is still very heavy. Caution: AR is weed concern for some farmers and situations. Options: reduce seeding rate but retain ratios to cut cost yet maintain functions.
		Annual ryegrass (AR)		22	1.47	22%	
		Triticale (TR)		45	0.41	45%	
		Seasonal niche: 1+2	Totals:	100	2.29	100%	
		Expected C:N ratio of mature residue: High					
		Mix name: "Early Fall All Grass Multi-Cut Forage Mix"					
65 to 35 DBFF	Fall Mix 11	Spring oat (SO)	G	36	0.45	60%	**EARLY-FALL GRASS/LEGUME MIX; PARTIAL WINTERKILL; EMPHASIS: FORAGE, VERY HIGH BIOMASS, N SCAVENGE & FIX; FLOWERS.** This mix makes fine cover, but at this rate is primarily high-quality forage. If seed early with good fertility, SO gives fast fall growth & rich forage, then winterkills in most of VA. AR & CC are winter-hardy, well matched in height & timing. AR & CC have high spring yield potential, showy CC blooms, high forage quality for grazing or chopping, and mid C:N residues. This overall seeding rate (fraction of base rate 2.05) is very heavy, suitable for forage production or high-biomass cover. SO will likely die out, but remaining rate of overwintering AR & CC is still very heavy. Inoculate CC to optimize N fixation. Caution: AR is weed concern for some farmers and situations. Options: reduce overall seeding rate, but retain ratios.
		Annual ryegrass (AR)	G	12	0.80	20%	
		Crimson clover (CC)	L	12	0.80	20%	
		Seasonal niche: 1+2	Totals:	60	2.05	100%	
		Expected C:N ratio of mature residue: Mid					
		Mix name: "Early Fall Oat/Ryegrass/Crimson Forage Mix"					
80 to 30 DBFF	Fall Mix 12	Barley (BA)	G	30	0.30	60%	**EARLY-FALL DIVERSE MIX WITH BRASSICA FOCUS; PARTIAL WINTERKILL; EMPHASIS: BIODRILL; N SCAVENGE; FLOWERS; BIOMASS; LOW COST**. If seed early with ample soil N, FR & RS give fast fall growth, biodrilling, N scavenging. FR winterkills in most of VA. Remaining species are winter-hardy, give balanced spring stand with biodrilling, N scavenging, some N fixation, mid-C:N residues, RS & WP blooms (note: RS can be hard to spray-kill in late spring). Relatively cheap BA & RS help reduce overall seed costs. This overall seeding rate (fraction of base rate 1.46) is heavy, typical of strong cover crop or possible forage. FR will likely die out, however, so remaining rate of overwintering species (fraction of base rate 1.08) is in fact moderate. Inoculate WP to optimize N fixation. Options: replace B with wheat or triticale or WP with crimson clover.
		Forage radish (FR)	B	3	0.38	6%	
		Rapeseed (RS)		3	0.50	6%	
		Austrian winter pea (WP)	L	14	0.28	2%	
		Seasonal niche: 1+2	Totals:	50	1.46	100%	
		Expected C:N ratio of mature residue: Mid					
		Name: "Early Fall Brassica Mix with Barley/Pea"					
80 to 30 DBFF	Fall Mix 13	Forage radish (FR)	B	2	0.25	25%	**EARLY-FALL ALL-BRASSICA MIX; PARTIAL WINTERKILL; EMPHASIS: BIODRILL, N SCAVENGE, BIOMASS.** Brassica-only mix offers change from typical VA winter cover crop grass and legume species. If seeded early with ample soil N and sulfur (S), expect big fall biomass, biodrilling. FR & MU are likely to winterkill in most of VA. Winter-hardy RS gives N retention, moderate biomass, showy flowers in spring (note: RS can be hard to spray-kill in late spring). This overall seeding rate (fraction of base rate 1.17) is moderate to heavy, suitable for strong cover crop. FR & MU will likely die out, however, so rate of overwintering RS is light to moderate (fraction of base rate 0.67). This mix a possible substitute for soil fumigant if managed for that purpose (mowed & tilled in just ahead of cash crop). Options: adjust ratios to favor more or less fall or spring function.
		Mustard (MU)		2	0.25	25%	
		Rapeseed (RS)		4	0.67	50%	
		Seasonal niche: 1+2	Totals:	8	1.17	100%	
		Expected C:N ratio of mature residue: Mid					
		Mix name: "Early Fall All Brassica Mix"					

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Figure 9.10 (continued): Fall-Seeded Cover Crop Mix Examples

Timing of seeding	Mix ID	Species	Group	Seeding rate: lb/ac in mix	Seeding rate: Fraction of base rate	Seeding rate: % of mix by weight	Description & Notes
70 to 30 DBFF	Fall Mix 14	Spring oat (SO)	G	20	0.25	45%	**EARLY-FALL MULTI-FUNCTION MIX; PARTIAL WINTERKILL; EMPHASIS: FALL N-SCAVENGE & BIODRILL; SPRING N FIX & FLOWERS.** Mix with distinct two-season functionality. If seeded early with good fertility, SO & FR give fall cover, N uptake, FR biodrilling, then winterkill in most of VA. CC & WP are both winter-hardy, provide pure stand of spring legume with strong N fixation potential, blooms, fast N release, and short-lived low-C:N residue. This overall seeding rate (fraction of base rate 1.50) is very heavy, suitable for high-priority forage or cover crop. SO and FR will likely die out, however, so remaining rate of overwintering CC & WP (fraction of base rate 1.00) is moderate. Inoculate legumes to optimize N fixation. Options: replace CC with vetch; add winter-hardy grass for more spring residue.
		Forage radish (FR)	B	2	0.25	5%	
		Crimson clover (CC)	L	12	0.80	27%	
		Austrian winter pea (WP)		10	0.20	23%	
		Seasonal niche: 1+2 Totals:		44	1.50	100%	
		Expected C:N ratio of mature residue: Low					
		Mix name: "Fall N-Scavenge/Spring N-Fix Mix					
70 to 30 DBFF	Fall Mix 15	Triticale (TR)	G	33	0.30	81%	**EARLY-FALL THREE-WAY MIX; PARTIAL WINTERKILL; EMPHASIS: FALL BIODRILL; SPRING N-SCAVENGE & FIX WITH FLOWERS.** If seeded early with ample soil N, FR gives fast fall growth & biodrilling prior to winterkill in most of VA. TR & CC are winter-hardy, give balanced spring grass/legume stand, good cover, showy CC blooms, mid-C:N residues. This overall seeding rate (fraction of base rate 1.01) is moderate, suitable for typical cover crop. FR will likely die out, so remaining rate of overwintering TR & CC is light to moderate (fraction of base rate 0.63) – expect modest spring biomass. Inoculate CC to optimize N fixation. Option: increase seeding rates; replace TR with barley or wheat.
		Forage radish (FR)	B	3	0.38	7%	
		Crimson clover (CC)	L	5	0.33	12%	
		Seasonal niche: 1+2 Totals:		41	1.01	100%	
		Expected C:N ratio of mature residue: Mid					
		Name: "Triticale/Radish/Crimson Mix"					
70 to 20 DBFF	Fall Mix 16	Barley (BA)	G	72	0.72	83%	**MID-FALL WINTER-HARDY GRASS/LEGUME MIX; EMPHASIS: HIGH BIOMASS; FORAGE; N SCAVENGE & FIX; FLOWERS**. Classic winter-hardy Virginia cover crop combination (also found in Chapter 2 "Top 20" list, but at a lower seeding rate). May be planted mid-fall, but does best planted earlier! CC & BA are well matched on height, timing of seeding and maturity. This overall seeding rate (fraction of base rate 1.72) is heavy to very heavy, suitable for forage or high-performance cover. Although mix includes full rate of legume, strong grass component moderates N release potential, enhances biomass-related functions (erosion & weed control, forage, etc.). This mix will reach maximum biomass and N fixation earlier than rye/vetch. Inoculate CC to optimize N fixation. Options: replace CC with winter pea; replace BA with other small grain.
		Crimson clover (CC)	L	15	1.00	17%	
		Seasonal niche: 1 Totals:		87	1.72	100%	
		Expected C:N ratio of mature residue: Mid					
		Name: "High Biomass Barley/Crimson Mix"					
60 to 20 DBFF	Fall Mix 17	Wheat (WH)	G	30	0.25	58%	**MID-FALL BALANCED THREE-WAY WINTERHARDY MIX; EMPHASIS: N-SCAVENGE & FIX; BIODRILL; BIOMASS; LOW COST.** Can be planted later than most fall mixes, but does best seeded earlier! Winter-hardy mix with balance of three functional groups, mix of N-scavenging and fixation, plus biodrilling from RS. Expect mid-C:N ratio residues at maximum biomass in spring. Species selected for relatively low cost and for farmers who prefer to avoid rye and vetch. RS gives showy blooms in late spring, but can also be hard to spray-kill at that time – caution. This overall seeding rate (fraction of base rate 0.98) is moderate, suitable for average cover crop. Good fertility needed for strong biomass. Inoculate WP to optimize N fixation. Option: replace W with triticale.
		Rapeseed (RS)	B	2	0.33	4%	
		Austrian winter pea (WP)	L	20	0.40	38%	
		Seasonal niche: 1 Totals:		52	0.98	100%	
		Expected C:N ratio of mature residue: Mid					
		Name: Wheat/Rapeseed/Pea Mix.					
60 to 20 DBFF	Fall Mix 18	Rye (RY)	G	15	0.14	36%	**MID-FALL WINTERHARDY N-FIX MIX WITH DIVERSITY; EMPHASIS: SPRING N-FIX; BIODRILL; BIOMASS; LOW COST.** Can be planted later than most fall mixes, but does best seeded earlier! Winter-hardy mix with full rate of legumes and modest rates of grass and brassica. RY and RS give improved cover, biodrilling, trellis system for legumes to climb in spring. RS gives showy blooms in late spring, but can also be hard to spray-kill at that time – caution. WP and HV are latest fall-seeded legume options; to achieve maximum N fixation benefits, must be allowed to grow into late spring. This overall seeding rate (fraction of base rate 1.31) is moderate to heavy, suitable for strong N-fixing cover crop or possible grazing. Inoculate legumes to optimize N fixation. Option: increase R and RS rate for more emphasis on those functions, slower spring N release.
		Rapeseed (RS)	B	1	0.17	2%	
		Austrian winter pea (WP)	L	10	0.20	24%	
		Hairy vetch (HV)		16	0.80	38%	
		Seasonal niche: 1 Totals:		42	1.31	100%	
		Expected C:N ratio of mature residue: Low					
		Name: Rye/Rapeseed/Legume Mix					

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Figure 9.10 (continued): Fall-Seeded Cover Crop Mix Examples

Timing of seeding	Mix ID	Species	Group	Seeding rate: lb/ac in mix	Seeding rate: Fraction of base rate	Seeding rate: % of mix by weight	Description & Notes
70 to 15 DBFF	Fall Mix 19	Barley (BA)	G	10	0.10	19%	**MID-FALL BALANCED HIGH-DIVERSITY WINTERHARDY MIX; EMPHASIS: N SCAVENGE & FIX; BIOMASS; FLOWERS; BIODRILL.** All winter-hardy mix with functional diversity & redundancy. May be planted mid-fall, but does best if planted earlier! Ratios selected for balance of fall N-scavenging and spring N-fixation functions with mid C:N ratio residues at maximum biomass. This overall seeding rate (fraction of base rate 1.29) is moderate to heavy, suitable for strong cover crop or possible forage. RS & legumes give flowers in late spring (note: RS can be hard to spray-kill in late spring). Options: drop one or more species.
		Wheat (WH)		10	0.08	19%	
		Triticale (TR)		10	0.09	19%	
		Rapeseed (RS)	B	1.5	0.25	3%	
		Crimson clover (CC)	L	4	0.27	8%	
		Austrian winter pea (WP)		12.5	0.25	24%	
		Hairy vetch (HV)		5	0.25	9%	
		Seasonal niche: 1	**Totals:**	53	1.29	100%	
		Expected C:N ratio of mature residue: Mid					
		Name: Mid-fall High Diversity Mix					
70 to 10 DBFF	Fall Mix 20	Rye (RY)	G	84	0.76	82%	**LATE-FALL WINTER-HARDY GRASS/LEGUME MIX; EMPHASIS: HIGH BIOMASS; FORAGE; N FIX & SCAVENGE; ROLLING**. Classic winter-hardy Virginia cover crop combination (also found in Chapter 2 "Top 20" list, but at a lower seeding rate). Can be planted later than any other fall grass/legume mix, but does best planted early! RY and HV are well matched on timing of seeding and maturity; tall RY provides trellis for HV to climb. This overall seeding rate (fraction of base rate 1.66) is heavy to very heavy, suitable for forage or high-performance cover. Although mix includes almost full rate of legume, strong grass component moderates N release potential, enhances biomass-related functions (erosion & weed control, forage, etc.). Good candidate for rolling at time of maximum biomass (HV flowering). Inoculate HV to optimize N fixation. Options: reduce RY rate for faster N release to next crop; replace HV with winter pea.
		Hairy vetch (HV)	L	18	0.90	18%	
		Seasonal niche: 1	**Totals:**	102	1.66	100%	
		Expected C:N ratio of mature residue: Mid					
		Name: Rye/Vetch Mix					

Figure 9.11:. Summer-Seeded Cover Crop Mix Examples *(Seasonal Niches 3 & 4)*

Timing of seeding	Mix ID	Species	Group	Seeding rate: lb/ac in mix	Seeding rate: Fraction of base rate	Seeding rate: % of mix by weight	Description & Notes
30 DALF to 70 DBFF	Summer Mix 01	Foxtail millet (FM)	G	5	0.25	8%	**EARLY- TO MID-SUMMER GRASS/LEGUME MIX; EMPHASIS: N-FIXATION; SHORT HEIGHT; EASY TO MOW-KILL; BIOMASS.** Simple, short-statured summer mix with strong legume component; similar mix found in Chapter 2 "Top 20" list. This overall seeding rate (fraction of base rate 1.25) is moderate to heavy and includes full rate (fraction of base rate 1.00) of legume, suitable for good N-fixing cover crop. Best for early- to mid-summer seeding (Niche 4). Poor candidate for Niche 3 frost kill – residues and fixed N will melt away over winter. These species not expected to regrow if mow or graze – an advantage for some purposes. Less drought-tolerant, less biomass potential than some other summer choices. Caution: FM goes to seed relatively fast. Inoculate FS seed to optimize N fixation. Options: replace FM with Japanese or browntop millet; replace FS with cowpeas.
		Forage soybean (FS)	L	60	1.00	92%	
		Seasonal niche: 4	**Totals:**	65	1.25	100%	
		Expected C:N ratio of mature residue: Low					
		Mix name: "Foxtail Millet-Soybean N-Fixer"					
30 DALF to 70 DBFF	Summer Mix 02	Forage soybean (FS)	L	12	0.20	21%	**ALL-LEGUME/N-FIXING SUMMER MIX; BIODRILL; BIOMASS.** Pure legume summer mix – mainly CP plus modest levels of FS and SH for species diversity and functional redundancy. This overall seeding rate (fraction of base rate 1.20) is moderate, suitable for typical N-fixing cover crop. Inoculate seed to optimize N fixation. FS & CP are short-statured; SH grows tall. High potential forage quality. Expect weak or no regrowth if mow or graze – an advantage for some purposes. Best for early- to mid-summer seeding (Niche 4). Not good for Niche 3 late-summer seeding/frost kill – FS and CP residues and N melt away quick over winter. Options: adjust ratios and/or rates; drop FS or SH from mix.
		Cowpea (CP)		40	0.80	71%	
		Sunnhemp (SH)		4	0.20	8%	
		Seasonal niche: 4	**Totals:**	56	1.20	100%	
		Expected C:N ratio of mature residue: Low					
		Mix name: "All-legume N-Fixer"					

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Figure 9.11 (continued): Summer-Seeded Cover Crop Mix Examples

Timing of seeding	Mix ID	Species	Group	Seeding rate: lb/ac in mix	Seeding rate: Fraction of base rate	Seeding rate: % of mix by weight	Description & Notes
30 DALF to 70 DBFF	Summer Mix 03	Pearl millet (PM)	G	2	0.10	8%	**DIVERSE SUMMER GRASS/FORB/LEGUME MIX; EMPHASIS: LOW-COST; LOW to MID HEIGHT; N SCAVENGE & FIX; BIODRILL; FLOWERS.** Short-statured diverse mix, but with high proportion of inexpensive SF to keep costs low. This overall seeding rate (fraction of base rate 1.10) is moderate, suitable when priority is diverse cover at moderate cost. Inoculate legume seed to optimize N fixation. BW grows and goes to flower quickly, gives pollinator-friendly blooms (caution if BW reseeding is a concern). FM also goes to seed relatively fast. FM is shallow-rooted with lower drought-tolerance, less biomass than some other summer grasses. SF and CP are deep-rooted. When mixed with these shorter companions, SF is expected to grow shorter. SF provides showy blooms. Choose dwarf PM to keep mix short. Moderate forage potential. Except for PM, most of mix not expected to regrow well after mow or graze – an advantage for some purposes. Best suited for early- to mid-summer seeding (Niche 4). Possible candidate for Niche 3 frost kill use. Options: adjust ratios and/or rates; drop one or more species; swap in other short grasses like Japanese or browntop millet.
		Foxtail millet (FM)	G	2	0.10	8%	
		Buckwheat (BW)	F	6	0.10	25%	
		Black oil sunflower (SF)	F	3	0.60	13%	
		Forage soybean (FS)	L	6	0.10	25%	
		Cowpea (CP)	L	5	0.10	21%	
		Seasonal niche: 4 or 3	**Totals:**	24	1.10	100%	
		Expected C:N ratio of mature residue: Mid					
		Mix name: "Low-cost, High-diversity Short Mix"					
30 DALF to 60 DBFF	Summer mix 04	Pearl millet (PM)	G	16	0.80	21%	**SUMMER GRASS/LEGUME MIX; EMPHASIS: HIGH BIOMASS; FORAGE; MID to TALL HEIGHT; N SCAVENGE & FIX; BIODRILL.** Simple mix with balance of grass and legume and high biomass potential. Note: similar mix is found in Chapter 2 "Top 20" list, but includes Sudex in place of PM. Grass in this mix will dominate if soil N is high, legume will dominate if soil N is low. This overall seeding rate (fraction of base rate 2.00) is very heavy, as might be used for high-priority forage or cover (e.g., for weed suppression in high-value cropping system, etc.). Good heat and drought tolerance. High forage quality, no prussic acid concern. Expect good PM regrowth if graze or mow. Possible candidate for Niche 3 winterkill use, esp. if lots of PM biomass. Height depends on PM – tall or dwarf cultivars are available. If using a taller PM, use vining CP. Inoculate CP seed to optimize N fixation. Options: replace PM with sorghum-sudangrass; replace CP with soybean if paired with a short PM cultivar.
		Cowpea (CP)	L	60	1.20	79%	
		Seasonal niche: 4 or 3	**Totals:**	76	2.00	100%	
		Expected C:N ratio of mature residue: Mid					
		Mix name: "Pearl Millet-Cowpea Big Biomass Mix"					
30 DALF to 60 DBFF	Summer Mix 05	Sorghum-sudangrass (SX)	G	25	0.72	71%	**SUMMER GRASS/LEGUME MIX; EMPHASIS: BIOMASS; TALL HEIGHT; N SCAVENGE & FIX; BIODRILL.** Simple, tall mix with emphasis on grass and biomass potential. SX expected to dominate, esp. if soil fertility is high, but also includes meaningful SH component for N fixation, diversity. This overall seeding rate is moderate to heavy suitable for strong cover crop or possible grazing. Excellent heat and drought tolerance, deep rooting potential. Good forage potential, note SX prussic acid concern. Expect strong SX regrowth after grazing or mowing; much less SH regrowth potential. Top candidate for Niche 3 winterkill use – both species at maturity have coarse biomass that benefits from breaking down over winter. Inoculate SH seed to optimize N fixation. Options: replace SX with pearl millet; replace SH with vining cowpea.
		Sunnhemp (SH)	L	10	0.50	29%	
		Seasonal niche: 4 or 3	**Totals:**	35	1.22	100%	
		Expected C:N ratio of mature residue: Mid to High					
		Mix name: "Sudex-Sunnhemp Tall Summer Cover"					
30 DALF to 60 DBFF	Summer Mix 06	Sorghum-sudangrass (SX)	G	5	0.14	50%	**SUMMER GRASS/FORB MIX; EMPHASIS: LOW-COST; TALL HEIGHT; N SCAVENGE; BIODRILL; BIOMASS; FLOWERS.** Simple, tall mix with potential for heat- and drought-tolerant biomass plus deep roots and showy flowers, yet emphasis on SF keeps cost low. This overall seeding rate is moderate to heavy (fraction of base rate 1.14), including full rate of SF. No legumes means need ample soil N for good yield. Low to moderate forage value, note SX prussic acid concern. Expect strong SX regrowth, low SF regrowth after grazing or mowing. Good for Niche 3 winterkill use, both species at maturity give coarse residues that break down over winter. Options: replace SX with pearl millet.
		Sunflower (SF)	F	5	1.00	50%	
		Seasonal niche: 4 or 3	**Totals:**	10	1.14	100%	
		Expected C:N ratio of mature residue: High					
		Mix name: "Sudex-Sunflower Tall, Low-cost Cover"					

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Figure 9.11 (continued): Summer-Seeded Cover Crop Mix Examples

Timing of seeding	Mix ID	Species	Group	Seeding rate: lb/ac in mix	Seeding rate: Fraction of base rate	Seeding rate: % of mix by weight	Description & Notes
30 DALF to 60 DBFF	Summer Mix 07	**Foxtail millet (FM)**	G	4	0.20	9%	**SUMMER GRASS/FORB/LEGUME MIX; EMPHASIS: N-FIXATION; LOW HEIGHT; BIODRILL; BIOMASS; FLOWERS.** Short-statured mix with legume emphasis and modest levels of grass and forb. This overall seeding rate (fraction of base rate 1.20) is moderate, includes nearly full rate (fraction of base rate 0.80) for CP, suitable for N-fixing cover crop. Best for early- to mid-summer seeding (Niche 4). Not good candidate for Niche 3 frost kill – FM and CP residues and N they contain will melt away quick over winter. When mixed with these shorter companions, SF expected to grow shorter. FM is shallow-rooted with lower drought-tolerance, less biomass than some other summer grasses. SF and CP are deep-rooted. Moderate forage potential. Strong regrowth not expected after mowing or grazing – an advantage for some purposes. Inoculate CP seed to optimize N fixation. Caution: FM goes to seed relatively fast. Options: replace FM with Japanese or browntop millet; CP with soybean.
		Black oil sunflower (SF)	F	1	0.20	2%	
		Cowpea (CP)	L	40	0.80	89%	
		Seasonal niche: 4 **Totals:**		45	1.20	100%	
		Expected C:N ratio of mature residue: Low to mid					
		Mix name: "Short Three-way Mix"					
30 DALF to 60 DBFF	Summer Mix 08	**Sorghum-sudangrass (SX)**	G	14	0.40	54%	**SUMMER GRASS/FORB/LEGUME MIX; EMHASIS: BIOMASS; TALL HEIGHT; N SCAVENGE & FIX; FORAGE; BIODRILL; FLOWERS.** Tall mix with balance of three functional groups. If soil fertility is high, expect high biomass dominated by SX. This overall seeding rate (fraction of base rate 1.30) is moderate to heavy, suitable for forage or strong cover crop. All species are heat- and drought-tolerant, deep rooted. Good for Niche 4 early- to mid-summer seeding; also good for Niche 3 late-summer seeding – all species at maturity leave coarse overwintering residues. When mixed with these taller companions, SF is expected to grow taller. Both SF and SH produce yellow flowers. Moderate forage quality, note SX prussic acid concern. After grazing or mowing, expect strong SX regrowth, weak SF and SH regrowth. Options: replace SX with pearl millet; SH with vining cowpea.
		Black oil sunflower (SF)	F	2	0.40	8%	
		Sunnhemp (SH)	L	10	0.50	38%	
		Seasonal niche: 4 or 3 **Totals:**		26	1.30	100%	
		Expected C:N ratio of mature residue: Mid to high					
		Mix name: "Tall Three-way Mix"					
30 DALF to 60 DBFF	Summer Mix 09	**Sorghum-sudangrass (SX)**	G	10	0.29	19%	**DIVERSE SUMMER GRASS/FORB/LEGUME MIX; EMPHASIS: HIGH BIOMASS; FORAGE; MID to TALL HEIGHT; N SCAVENGE & FIX; BIODRILL; FLOWERS.** Tall, diverse mix with balance of all functional groups. Expect grasses to dominate if soil N is high. This overall seeding rate (fraction of base rate 1.64) is heavy, suitable for forage or high-biomass cover. Good fertility needed for biomass. BW is short-statured, grows and goes to seed quickly, gives pollinator-friendly blooms (caution if BW reseeding is a concern). When mixed with these taller companions, SF is expected to grow taller. For tall mix, select vining CP and taller PM varieties. SX, PM, SF, CP are deep-rooted with subsoiling potential. SF & SH give yellow blooms. Most species in mix are heat- and drought-tolerant. Mid to high forage quality, note SX prussic acid concern. After grazing or mowing, expect strong regrowth from SX and PM, weak regrowth from others. Good for Niche 4 early- to mid-summer seeding; also good for Niche 3 late-summer seeding if planted early enough for SX, PM, SF, SH to achieve coarse biomass. Inoculate legume seed to optimize N fixation. Options: adjust ratios and/or rates; drop one or more species from mix.
		Pearl millet (PM)		6	0.30	11%	
		Buckwheat (BW)	F	15	0.25	28%	
		Black oil sunflower (SF)		1	0.20	2%	
		Cowpea (CP)	L	15	0.30	28%	
		Sunnhemp (SH)		6	0.30	11%	
		Seasonal niche: 4 or 3 **Totals:**		53	1.64	100%	
		Expected C:N ratio of mature residue: Low					
		Mix name: "High-diversity Forage & Biomass Mix"					
30 DALF to 45 DBFF	Summer Mix 10	**Sorghum-sudangrass (SX)**	G	15	0.43	38%	**SUMMER GRASS/FORB MIX; EMPHASIS: BIOMASS; FORAGE; TALL HEIGHT; N SCAVENGE; BIODRILL.** Tall mix with grass emphasis and biomass potential. This overall seeding rate is moderate to heavy (fraction of base rate 1.34), suitable for strong cover crop or possible forage. No legumes means ample soil N needed for good yield. BW is minor component; grows and goes to flower fast, adds diversity, pollinator-friendly blooms (caution if BW reseeding is a concern). SX and PM give high biomass potential, N scavenging, subsoiling, good regrowth after grazing or mowing. Variety selection can impact feed quality; note also SX prussic acid concern. Good candidate for Niche 3 winterkill on high-fertility soils where SX and PM achieve good biomass. Options: adjust ratios and/or rates.
		Pearl millet (PM)		15	0.75	38%	
		Buckwheat (BW)	F	10	0.17	25%	
		Seasonal niche: 4 or 3 **Totals:**		40	1.34	100%	
		Expected C:N ratio of mature residue: High					
		Mix name: "Grass & Buckwheat Forage & Biomass Mix"					

Figure 9.12: Spring-Seeded Cover Crop Mix Examples *(Seasonal Niche 5)*

Timing of seeding	Mix ID	Species	Group	Seeding rate: lb/ac in mix	Seeding rate: Fraction of base rate	Seeding rate: % of mix by weight	Description & Notes
50 to 10 DBLF	Spring Mix 01	Spring Oat (SO)	G	40	0.50	50%	**SPRING GRASS/LEGUME MIX; EMPHASIS: BIOMASS; BALANCED FUNCTION; N SCAVENGE & FIX; FORAGE.** Classic cool-season annual mix spring-seeded for cover or forage. Also found in Chapter 2 "Top 20" list. This species combo is well-known, but not commonly grown in VA. This mix is formulated for balance of grass and legume – expect SO to dominate if soil N is high, SP to dominate if soil N is low. This overall seeding rate (total fraction of base rate 1.17) is moderate to heavy as might be used for a good cover crop or possible grazing. High potential feed quality. Neither species should require vernalization (exposure to cold) to trigger flowering/seed set, but cultivars may vary – select accordingly. Inoculate SP seed to optimize N fixation. Options: adjust ratios and/or rates; replace SO with any small grain; replace SP with winter pea or woolypod vetch (which is Spring mix 02, below).
		Canadian Spring Pea (SP)	L	40	0.67	50%	
		Seasonal niche: 5	**Totals:**	80	1.17	100%	
		Expected C:N ratio of mature residue: Low					
		Mix name: "Spring-seeded Spring Oat/Spring Pea"					
50 to 10 DBLF	Spring Mix 02	Rye (RY)	G	55	0.50	61%	**SPRING GRASS/LEGUME MIX; EMPHASIS: BIOMASS; BALANCED FUNCTION; N SCAVENGE & FIX; FORAGE.** Similar to/substitute for Spring Mix 01 (Spring Oat/Spring Pea). Classic fall-seeded VA winter annual mix that can be planted in spring. This mix formulated for balance of grass and legume. This overall seeding rate (total fraction of base rate 1.20) is moderate to heavy, suitable for strong cover crop or possible grazing. Potential feed quality is high. WP expected to grow more slowly in early spring than spring pea, but cultivars may vary. RY and WP seed in VA may need adequate vernalization (exposure to cold) to trigger flowering. Inoculate WP seed to optimize N fixation. Options: adjust ratios and/or rates; replace RY with any small grain; replace WP with woolypod vetch.
		Austrian Winter Pea (WP)	L	35	0.70	39%	
		Seasonal niche: 5	**Totals:**	90	1.20	100%	
		Expected C:N ratio of mature residue: Low					
		Mix name: "Spring-Seeded Winter Rye/Winter Pea"					
40 to 10 DBLF	Spring Mix 03	Spring Oat (SO)	G	20	0.25	47%	**SPRING GRASS/BRASSICA/LEGUME MIX; EMPHASIS: LOW-COST BRASSICA; N SCAVENGING.** Similar to/substitute for Spring Mix 01 (Spring Oat/Spring Pea). Half of grass and legume seed in Spring Mix 01 replaced with brassica (RS) to reduce total seed quantity and cost. Final mix has high proportion of RS, but still balanced with meaningful rates of SO and SP. Inoculate SP seed to optimize N fixation. This overall seeding rate (total fraction of base rate 1.08) is moderate as might be used when priority is good cover at low cost. High potential feed quality. RS is expected to stay vegetative longer than other brassicas when spring-planted (note: RS can be hard to spray-kill as approaches maturity). Timing of RS flowering, need for cold to trigger flowering (vernalization), etc. may vary by cultivar – select accordingly. Options: replace SO with any small grain; RS with other brassicas; SP with winter pea or woolypod vetch.
		Rapeseed (RS)	B	3	0.50	6%	
		Canadian Spring Pea (SP)	L	20	0.33	47%	
		Seasonal niche: 5	**Totals:**	80	1.08	100%	
		Expected C:N ratio of mature residue: Low					
		Mix name: "Low-cost Spring Oat-Rape-Pea Mix"					
40 to 10 DBLF	Spring Mix 04	Spring Oat (SO)	G	16	0.20	29%	**DIVERSE SPRING LEGUME MIX; EMPHASIS: N-FIXATION; BIOMASS; FLOWERS.** Diverse mix with legume emphasis. Includes a full rate of legumes (fraction of base rate 1.00) – mostly SP and WV, plus some WP and HV for diversity and functional redundancy. Grass and brassica in mix provide trellis for legumes to climb, additional diversity and biomass, some N-scavenging. This overall seeding rate (total fraction of base rate 1.36) is moderate to heavy, suitable when priority is good biomass for N-fixation or grazing in short spring growing window. High potential forage quality. Legumes and RS in this mix can also provide attractive blooms (note: RS can be hard to spray-kill as approaches maturity). RS was chosen as spring-seeded brassica that is slowest to bolt (bolting and bloom timing may vary by cultivar). Options: adjust ratios and/or rates; drop one or more species.
		Rapeseed (RS)	B	1	0.16	2%	
		Canadian Spring Pea (SP)	L	24	0.40	43%	
		Austrian Winter Pea (WP)		5	0.10	9%	
		Woolypod Vetch (WV)		8	0.40	14%	
		Hairy Vetch (HV)		2	0.10	4%	
		Seasonal niche: 5	**Totals:**	56	1.36	100%	
		Expected C:N ratio of mature residue: Mid					
		Mix name: "High-diversity Spring N-Fix Mix"					

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Figure 9.12 (continued): Spring-Seeded Cover Crop Mix Examples

Timing of seeding	Mix ID	Species	Group	Seeding rate			Description & Notes
				lb/ac in mix	Fraction of base rate	% of mix by weight	
40 to 0 DBLF	Spring Mix 05	Spring Oat (SO)	G	16	0.20	55%	**DIVERSE SPRING FLOWER MIX; EMPHASIS: DIVERSITY; BLOOMS. D**iverse mix formulated specifically for sequence of spring blooms as well as basic cover crop functions. Majority of mix (fraction of base rate 0.67) consists of PH and three brassicas; all are expected to bolt/bloom relatively fast when spring planted. Modest rate of legumes provides additional blooms and N fixation; modest rate of SO provides biomass and N scavenging. This overall seeding rate (total fraction of base rate 1.07), is moderate as might be used when goal is a compromise between (a) giving individual plants enough space to produce showy blooms and (b) still achieving enough biomass for core cover crop functions. First species to flower will likely be MU, FR; these seeds may approach maturity as wait for other species to bloom. Timing of bolting and blooming may vary by cultivar – select accordingly. Forage potential for this mix at this seeding rate is modest. Options: adjust ratios and/or rates; drop one or more species.
		Forage Radish (FR)	B	1	0.13	4%	
		Mustard (MU)		1	0.13	4%	
		Rapeseed (RS)		1	0.16	3%	
		Phacelia (PH)	F	2	0.25	7%	
		Canadian Spring Pea (SP)	L	6	0.10	21%	
		Woolypod Vetch (WV)		2	0.10	7%	
		Seasonal niche: 5	**Totals:**	56	1.07	100%	
		Expected C:N ratio of mature residue: Mid					
		Mix name: "High-diversity Spring Flower Mix"					

Figure 9.13: Perennial Cover Crop Mix Examples *(Seasonal Niche 6)*

Timing of seeding	Mix ID	Species	Group	Seeding rate			Description & Notes
				lb/ac in mix	Fraction of base rate	% of mix by weight	
70 to 45 DBFF	Perennial Mix 01	Sorghum-Sudangrass (SX)	G	15	0.43	50%	**BIENNIAL LEGUME with LATE SUMMER NURSE CROP. EMPHASIS: N-FIXATION; SOIL-BUILDING; BIOMASS; FORAGE; BIODRILL.** Example of creative combo of summer annual grass and biennial legume. Typical fit is a high-value cropping system in which ground will be "fallowed" to a soil-building/N-fixing cover for two winters and one summer. Mix is planted in late summer; SX grows fast, gives weed suppression and biomass, then dies at first freeze; RC is shade-tolerant, establishes under SX, then grows thru Winter 1. RC continues to grow thru Summer 1; RC must be mowed or harvested in Summer 1 to keep it vegetative. RC then grows thru Winter 2. RC behaves as biennial and should be relatively easy to terminate ahead of a cash crop in Summer 2. Seeding rate for RC (fraction of base rate 1.50) is heavy, suitable for priority forage or high-performance cover. SX nurse crop seeding rate is moderate (fraction of base rate 0.43). Inoculate RC seed to optimize N fixation. N release following RC may be very high – plan rotation accordingly. RC has good forage potential. Harvesting RC is possible, but will reduce N supply to next crop. Both SX and RC have subsoiling potential. Options: replace SX with other summer grass; for early fall or spring planting, use spring oat nurse; to moderate N fixation/release, replace a portion of RC with orchardgrass.
		Red Clover (RC)	L	15	1.50	50%	
		Seasonal niche: 4 + 6	**Totals:**	30	1.93	100%	
		Expected C:N ratio of mature residue: Low					
		Mix name: "Fall-seeded Red Clover with Sudex Nurse"					

(continued next page)

Figure 9.13 (continued): Perennial Cover Crop Mix Examples

Timing of seeding	Mix ID	Species	Group	Seeding rate: lb/ac in mix	Seeding rate: Fraction of base rate	Seeding rate: % of mix by weight	Description & Notes
Fall: 65 to 25 DBFF / Spr.: 50 to 15 DBLF	Perennial Mix 02	**Spring Oat (SO)**	G	30	0.38	59%	**PERENNIAL GRASS/LEGUME with OAT NURSE CROP; FALL SEEDING (statewide) or SPRING SEEDING (western VA); EMPHASIS: SOIL BUILDING; BIOMASS; FORAGE; BIODRILL; N-FIXATION.** Example of traditional perennial forage used as cover crop. Typical fit: breaking rotation of annual cash crops with one to three summers of sod. In eastern VA, seed this mix in fall. Elsewhere in VA, plant this mix fall or spring. SO nurse provides weed suppression and shelter for perennials. After fall planting, SO should winterkill; after spring planting, SO should be mowed or harvested off to release perennial understory. RC acts like biennial in VA, likely to disappear after two summers if not allowed to reseed. AF is longer-lived with deep taproot. OG is long-lived, but best adapted to western VA. If goal is for OG to persist for only one to three years, OG can be grown in all parts of VA. This overall seeding rate for perennials in this mix (fraction of base rate 1.57) is heavy, suitable for forage production or intensive cover crop. SO nurse crop seeding rate (fraction of base rate 0.38) is light. Perennials should be periodically mowed to keep all species vegetative. AF and RC can fix lots of N - inoculate seed to optimize N fixation potential. Potential feed value is high. If harvested for hay, soil benefits and N available for next crop may be reduced. AF in particular has very strong subsoiling potential. Options: replace SO with another small grain; on well-drained soils for longer-lived stands, increase AF relative to RC; for shorter-lived stands and lower seed cost, increase RC relative to AF.
		Orchardgrass (OG)	G	8	0.67	16%	
		Alfalfa (AF)	L	8	0.40	16%	
		Red Clover (RC)	L	5	0.50	10%	
		Seasonal niche: 2/5 + 6 **Totals:**		30	1.95	100%	
		Expected C:N ratio of mature residue: Mid					
		Name: "High-quality Mixed Hay with Spring Oat Nurse"					
Fall: 70 to 20 DBFF / Spr.: 50 to 10 DBLF	Perennial Mix 03	**Tall Fescue (TF)**	G	16	0.80	80%	**PERENNIAL GRASS/LEGUME MIX; FALL OR SPRING SEEDING; EMPHASIS: LIVING MULCH OR MOWING SITUATIONS; LOWER COST; SOIL-BUILDING.** Example of perennial ground cover for a walkway, drive lane, or other situation that will be kept mowed or grazed. Both species are mowing-tolerant, widely-adapted, and persistent across VA (with some potential to be invasive). Many cultivars are available – match the seed to the need. For mowed walkways, shorter turf-type TF and common WC may be a good fit. For grazing, forage-type TF and taller ladino WC may be preferred. Plant in fall or early spring; fall is preferred in warmer regions of VA. This overall seeding rate (fraction of base rate 1.60) is heavy, suitable for high-priority cover situation. Crop should be periodically mowed or grazed to keep all species vegetative. Inoculate WC seed to optimize N fixation. Forage potential depends on cultivars and management. Option: for taller mix to cut for hay, replace WC with red clover and/or alfalfa.
		White Clover (WC)	L	4	0.80	20%	
		Seasonal niche: 6 **Totals:**		20	1.60	100%	
		Expected C:N ratio of mature residue: Mid					
		Name: "Fescue-Clover Living Mulch / Mowing Mix"					
Fall: 60 to 5 DBFF	Perennial Mix 04	**Wheat (WH)**	G	60	0.50	79%	**PERENNIAL GRASS WITH SMALL GRAIN NURSE CROP; FALL SEEDING; EMPHASIS: N-SCAVENGING; BIOMASS; LOWER COST.** Example of simple perennial option to fill one or more years between annual cash crops. This mix is traditionally used to rebuild soil and reduce disease in VA tobacco rotations. After fall seeding, WH nurse can be harvested for grain or forage next spring or summer. This releases understory of TF, which forms permanent sod. Remaining stand of TF should be mowed, hayed, or grazed to keep it vegetative. TF is well-adapted and persistent across VA (with some potential to be invasive). This overall seeding rate is moderate, with light rate of WH nurse (fraction of base rate 0.50) and light to moderate rate of TF (fraction of base rate 0.80), as might be used where priority is both cover and lower cost. Forage potential depends on cultivars and management. If harvested for hay, soil benefits for next crop may be reduced. Options: adjust ratios and/or rates; replace WH with another small grain; add perennial legumes to mix.
		Tall Fescue (TF)	G	16	0.80	21%	
		Seasonal niche: 1 + 6 **Totals:**		76	1.30	100%	
		Expected C:N ratio of mature residue: High					
		Name: "Fescue with Wheat Nurse"					

(continued next page)

Figure 9.14 (continued): Perennial Cover Crop Mix Examples							
Timing of seeding	Mix ID	Species	Group	Seeding rate			Description & Notes
				lb/ac in mix	Fraction of base rate	% of mix by weight	
Spring: 40 to 10 DBLF	Perennial Mix 05	**Spring Oat (SO)**	G	40	0.50	73%	**BIENNIAL LEGUME with OAT NURSE CROP; SPRING SEEDING; EMPHASIS: BIODRILLING, N-FIXATION.** Example of simple biennial cover option to fill one to two years between annual cash crops. After spring seeding, SO nurse can be mowed down or harvested for forage or grain in early summer (Summer 1). This releases understory of biennial SC. During Summer 1, SC grows mostly underground with deep taproot, should not flower, should not be mowed. After overwintering, SC growth in Summer 2 is mostly above-ground with high biomass, N fixation, and sweet-smelling blooms. Terminate SC before it produces viable seed. SC should not persist beyond Summer 2. This overall seeding rate is very heavy, with a light rate of SO (fraction of base rate 0.50) and heavy rate of SC (fraction of base rate 1.50). Forage potential relatively low. If harvested for hay, soil benefits for next crop may be reduced. Options: adjust rates; replace SO with another small grain.
		Yellow Blossom Sweetclover (SC)	L	15	1.50	27%	
		Seasonal niche: 5 + 6	**Totals:**	55	2.00	100%	
		Expected C:N ratio of mature residue: Low					
		Name: "Spring Sweetclover with Spring Oat Nurse"					

Appendix 1: References & Additional Cover Crop Information Sources

This planning manual is intended to be used alongside (i.e., it does not fully replace) other resources about cover crops.

All of the documents recommended below are published by USDA, Land Grant Extension systems, or non-profit organizations. All of these documents (along with many others) were carefully reviewed during the creation of this planning manual. To the maximum extent possible, the planting recommendations in this planning manual are consistent with these documents. Where they differ, use the planning manual.

Many cover crop species are traditionally grown as harvested crops for seed and/or for forage. In most instances, cover crop purposes are best met by growing large amounts of biomass rather than by maximizing the quantity and quality of mature seed. Therefore, lean towards forage production recommendations when using Extension documents to help plan cover crops. This approach was used when preparing this planning manual.

All of documents below are available free-of-charge in pdf format from the internet. Some may also be purchased in book form. Saving copies of these documents in pdf format on your computer gives you the option of quickly searching hundreds of pages for key terms, such as the name of a cover crop species of interest. If you do not have internet access, contact your local NRCS, Soil & Water Conservation District, or Extension office for assistance in printing or ordering a hard copy.

Document Name, Publisher, Date, Length, and Web Link	**Comments**
Managing Cover Crops Profitably, 3rd Edition USDA (Sustainable Agriculture Research & Education (SARE), 2007, 244 pages. Obtain from: http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition	Best starting point for background info on cover crops. Detailed chapters on individual species. Does not address some species such as millets, soybean, alfalfa. Use additional documents below to help with those species.
Cover Crops for All Seasons VA Association for Biological Farming (VABF), 2006, 6 pages. Obtain from: http://vabf.files.wordpress.com/2012/03/seasonalcovercrops_sm.pdf	Good short summaries on most cover crop choices, including some not covered in Managing Cover Crops Profitably. Good for all audiences, but especially for direct-market organic vegetable producers.
Agronomy Handbook VA Cooperative Extension, 2000; 131 pages. Obtain from: https://pubs.ext.vt.edu/424/424-100/424-100.html	Traditional production recommendations, but still useful for cover crop planning. First 30 pages contain crop descriptions and Virginia planting and production recommendations for most grain and/or forage crops.
Virginia Cover Crops Fact Sheet Series No. 2: Cover Crop Performance Evaluation in Field and Controlled Studies. VA Cooperative Extension, 2015, 11 pages Obtain from: https://pubs.ext.vt.edu/CSES/CSES-121/CSES-121.html	Focus on fall-seeded covers. Includes brief descriptions of species, including some not addressed in Managing Cover Crops Profitably. Includes selected results (seeding rates, biomass yields, etc.) from recent VA Tech cover crop study.
Growing Small Grains for Forage in Virginia VA Cooperative Extension, 2009, 6 pages. Obtain from: https://pubs.ext.vt.edu/424/424-006/424-006.html	Traditional production recommendations, but still useful for cover crop planning. Focuses on growing winter small grains in VA for forage and biomass production.
Summer Cover Crops (Horticulture Information Leaflet) NC Cooperative Extension; 1999; approx. 12 pages (not in pdf format). Obtain from: http://content.ces.ncsu.edu/summer-cover-crops/	Good overview of summer cover crop choices, including some not addressed in Managing Cover Crops Profitably. Experimental results including rates used and comparisons of biomass yield and success of mechanical termination (mowing, rolling, etc.) for key species.
Warm-Season Annual Grasses for Summer Forage. VA Cooperative Extension, 2009, 8 pages. Obtain from: https://pubs.ext.vt.edu/418/418-004/418-004.html\	Traditional production recommendations, but still useful for cover crop planning. Focuses on warm season annual grasses for forage, including some not covered in Managing Cover Crops Profitably like pearl millet and foxtail (German) millet. Also covers livestock toxicity concerns associated with these crops.

Appendix 2: Understanding & Customizing "Relative to Freeze Date" Information

Calendar Dates by Physiographic Region: A Closer Look

For the reader's convenience, planting dates relative to freeze were converted to traditional calendar date ranges for each of Virginia's three physiographic regions. How were freeze dates selected for each region in order to come up with these calendar ranges? In reality, there is no single first freeze or last freeze date for an entire region. Therefore, representative weather stations within each region were selected as the basis for assigning first and last freeze 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 freeze dates to customize your own seeding calendar, as explained later.

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 (Hanover County)	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

Customizing Seeding Dates

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

- Average First Freeze: For fall or late summer plantings, seeding dates are listed in relation to the "average first freeze date" in the fall. The average first freeze 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 establishment specifications tables, days before average first fall freeze is abbreviated "DBFF" and days after average first fall freeze is abbreviated "DAFF".

- Average Last Freeze: For spring or early summer plantings, seeding dates are listed in relation to the "average last freze date" in the spring. The average last freeze 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 freeze is abbreviated "DBLF" and days after average last spring freeze 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 freeze 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 freeze 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 freeze or first freeze date (depending on whether you are looking at spring or fall dates).

Appendix 3: Blank Cover Crop Planning Templates & Worksheets

The pages that follow provide blank copies of the cover crop planning templates and worksheets, as described below.

1. **Crop Rotation Diagramming & Cover Crop Planning Template.**

   Use the following page either for printing and then filling out by hand or for on-screen use/modification. This template is not found in the Excel file associated with this manual.

2. **VA Cover Crop Fall Seeding Date Chart – “Fill-by-hand” Version.**

   This is derived from the Excel file associated with this manual. The Excel file will auto-fill dates after you enter your average first freeze date in the pink cell. Therefore, always use the Excel version if you can. Use the version provided here for printing and then entering dates by hand. Note that the “date-by-hand” version is also available in the Excel file

3. **VA Cover Crop Spring Seeding Date Chart –“Fill-by-hand” Version.**

   This is derived from the Excel file associated with this manual. The Excel file will auto-fill dates after you enter your average first freeze date in the pink cell. Therefore, always use the Excel version if you can. Use the version provided here for printing and then entering dates by hand. Note that the “date-by-hand” version is also available in the Excel file

4. **VA Fall Cover Crop Mix Seeding Rate Calculator.**

   This is derived from the Excel file associated with this manual. The Excel worksheet pre-loaded with formulas will greatly simplify your computations. Therefore, always use the Excel version if you can. Use the version provided here for printing and then entering dates by hand.

5. **VA Spring Cover Crop Mix Seeding Rate Calculator.**

   This is derived from the Excel file associated with this manual. The Excel file contains both a blank version like this and a version with formulas that will greatly simplify your computations. Therefore, always use the Excel version if you can. Use the version provided here for printing and then entering dates by hand.

Notes:

Crop Rotation Diagramming & Cover Crop Planning Template (VACCPM, 2nd Ed.)

Purpose: To help you visualize crop rotation(s), cover crop options, and how to improve both.

Instructions: (1) Diagram existing rotation(s), noting crop families or groups, etc. (colored pens can help); (2) ID existing gaps in which to insert cover crops; (3) ID "sticking points" that block insertion of cover crops; (4) adjust rotation(s) to expand gaps or eliminate "sticking points."

	Spring						Summer						Fall						Winter					
	Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Jan		Feb	

Notes: (obstacles to overcome, issues to research, etc.)

Virginia NRCS Fall Cover Crop Seeding Date Chart (late-summer- & fall-seeded species)

Print / "date-by-hand" version: Enter freeze (32 deg. F.) date in pink cell, then enter dates to left and right in five-day increments

Late-Summer- & Fall-Seeded Cover Crop Seasonal Niches, Functional Groups, and Species Names			Days	90 days before	75 days before	60 days before	45 days before	30 days before	15 days before	Avg 1st freeze	15 days after	30 days after
			Dates									
Niche 3 & 4	Grass	Sorghum-Sudangrass (SX)	←				SX					
		Pearl Millet (PM)	←				PM					
		Foxtail Millet (FM)	←				FM					
	Forb	Black Oil Sunflower (SF)	←			SF						
		Buckwheat (BW)	←				BW					
	Legume	Forage Soybean (FS)	←		FS							
		Cowpea (CP)	←			CP						
		Sunnhemp (SH)	←			SH						
Niche 1 & 2 *(Niche 2 species names shaded)*	Grass	Spring Oat (SO)			SO			SO				
		Annual Ryegrass (AR)				AR			AR			
		Winter Oat (WO)			Not for Mountain and Valley Region		WO		WO	Not for Mountain & Valley region		
		Barley (BA)				BA				BA		
		Wheat (WH)					WH				WH	
		Triticale (TR)					TR				TR	
		Rye (RY)				RY						RY
	Brassica / Forb	Forage Radish (FR)		FR				FR				
		Mustard (MU)		MU				MU				
		Forage Turnip (FT)		FT				FT				
		Phacelia (PH)			PH		PH					
		Rapeseed (RS)			RS				RS			
	Legume	Canadian Spring Pea (SP)			SP		SP					
		Red Clover (RC)				RC		RC				
		Crimson Clover (CC)				CC			CC			
		Austrian Winter Pea (WP)					WP			WP		
		Woolypod Vetch (WV)		Not for Mountain and Valley Region			WV			WV	Not for Mountain & Valley region	
		Hairy Vetch (HV)				HV				HV		
Niche 6	Grass	Tall Fescue (TF)				TF					TF	
		Orchardgrass (OG)					OG			OG		
	Legume	Alfalfa (AL)				AL			AL			
		Red Clover (RC)				RC			RC			
		White clover (WC)				WC			WC			

Earlier seeding OK for these species - see spring/early summer planting calendar

KEY

= preferred dates

= possible dates

Virginia NRCS Spring Cover Crop Seeding Date Chart (spring- & early-summer-seeded species)

Print / "date-by-hand" version: Enter freeze (32 deg. F.) date in pink cell, then enter dates to left and right in five-day increments

Spring- & Early-Summer-Seeded Cover Crop Seasonal Niches, Functional Groups, and Species Names			Days	75 days before	60 days before	45 days before	30 days before	15 days before	Avg. last freeze	15 days after	30 days after	45 days after	60 days after
			Dates										
Niche 3 & 4	Grass	Sorghum-Sudangrass (SX)									SX		
		Pearl Millet (PM)									PM		
		Foxtail Millet (FM)									FM		
	Forb	Black Oil Sunflower (SF)								SF			
		Buckwheat (BW)								BW			
	Legume	Forage Soybean (FS)								FS			
		Cowpea (CP)									CP		
		Sunnhemp (SH)									SH		
Niche 5	Grass	Spring Oat (SO)				SO		SO					
		Rye (RY)				R		R					
		Triticale (TR)				T		T					
		Wheat (WH)				W		W					
		Barley (BA)				B		B					
		Annual Ryegrass (AR)					AR		AR				
	Brassica / Forb	Forage Radish (FR)					FR		FR				
		Mustard (MU)					MU		MU				
		Forage Turnip (FT)					FT		FT				
		Phacelia (PH)					PH		PH				
		Rapeseed (RS)					RS		RS				
	Legume	Canadian Spring Pea (SP)				SP		SP					
		Austrian Winter Pea (WP)				WP		WP					
		Woolypod Vetch (WV)					WV		WV				
		Hairy Vetch (HV)					HV		HV				
Niche 6	Grass	Tall Fescue (TF)			TF				TF				
		Orchardgrass (OG)		Not for C. Plain region		OG		OG		Not for Coastal Plain region			
	Legume	Alfalfa (AL)				A		A					
		Red Clover (RC)				RC		RC					
		White Clover (WC)				WC		WC					
		Yellow Bl. Sweetclover (SC)					SC		SC				

Later seeding dates OK for these species - see late summer/fall planting calendar

KEY

= preferred dates

= possible dates

Mixed Cover Crop Planting Rate Worksheet for Late Summer & Fall-Seeded Species

Late Summer- & Fall-Seeded Cover Crop Seasonal Niches, Functional Groups, and Species Names			A	B	C	D1	E1	F1	D2	E2	F2	D3	E3	F3
			Chosen base rates (lb/ac)			Mix 1:			Mix 2:			Mix 3:		
			Drill rate	Bcast + incorp rate	Drill Rate	Fraction of base rate (FBR)	Species rate (lb/ac)	% of mix by weight	Fraction of base rate (FBR)	Species rate (lb/ac)	% of mix by weight	Fraction of base rate (FBR)	Species rate (lb/ac)	% of mix by weight
Niche 3 & 4	Grass	Sorghum-Sudangrass (SX)	35	45	35									
		Pearl Millet (PM)	20	30	20									
		Foxtail Millet (FM)	20	30	20									
	Forb	Black Oil Sunflower (SF)	5	10	5									
		Buckwheat (BW)	60	80	60									
	Legume	Forage Soybean (FS)	60	90	60									
		Cowpea (CP)	50	80	50									
		Sunnhemp (SH)	20	30	20									
Niche 1 & 2 *(Niche 2 species names shaded)*	Grass	Spring Oat (SO)	80	110	80									
		Annual Ryegrass (AR)	15	25	15									
		Winter Oat (WO)	80	110	80									
		Barley (B)	100	140	100									
		Wheat (W)	120	160	120									
		Triticale (T)	110	145	110									
		Rye (R)	110	145	110									
	Brassica / Forb	Forage Radish (FR)	8	14	8									
		Mustard (MU)	8	12	8									
		Forage Turnip (FT)	5	10	5									
		Phacelia (PH)	8	12	8									
		Rapeseed (RS)	6	12	6									
	Legume	Canadian Spring Pea (SP)	60	90	60									
		Red Clover (RC)	10	12	10									
		Crimson Clover (CC)	15	25	15									
		Austrian Winter Pea (WP)	50	75	50									
		Woolypod Vetch (WV)	20	30	20									
		Hairy Vetch (HV)	20	30	20									
Niche 6	Grass	Tall Fescue (TF)	20	25	20									
		Orchardgrass (OG)	12	16	12									
	Legume	Alfalfa (A)	20	25	20									
		Red Clover (RC)	10	12	10									
		White clover (WC)	5	10	5									
					Totals									
					Number of species in mix:									

Mixed Cover Crop Planting Rate Worksheet for Spring- & Early Summer-Seeded Species

Spring- & Early Summer-Seeded Cover Crop Seasonal Niches, Functional Groups, and Species Names			A	B	C	D1	E1	F1	D2	E2	F2	D3	E3	F3
			Chosen base rates (lb/ac)			Mix 1:			Mix 2:			Mix 3:		
			Drill rate	Bcast + incorp rate	Drill Rate	Fraction of base rate (FBR)	Species rate (lb/ac)	% of mix by weight	Fraction of base rate (FBR)	Species rate (lb/ac)	% of mix by weight	Fraction of base rate (FBR)	Species rate (lb/ac)	% of mix by weight
Niche 3 & 4	Grass	Sorghum-Sudangrass (SX)	35	45	35									
		Pearl Millet (PM)	20	30	20									
		Foxtail Millet (FM)	20	30	20									
	Forb	Black Oil Sunflower (SF)	5	10	5									
		Buckwheat (BW)	60	80	60									
	Legume	Forage Soybean (FS)	60	90	60									
		Cowpea (CP)	50	80	50									
		Sunnhemp (SH)	20	30	20									
Niche 1 & 2 *(Niche 2 species names shaded)*	Grass	Spring Oat (SO)	80	110	80									
		Rye (R)	110	145	110									
		Triticale (T)	110	145	110									
		Wheat (W)	120	160	120									
		Barley (B)	100	140	100									
		Annual Ryegrass (AR)	15	25	15									
	Brassica / Forb	Forage Radish (FR)	8	14	8									
		Mustard (MU)	8	12	8									
		Forage Turnip (FT)	5	10	5									
		Phacelia (PH)	8	12	8									
		Rapeseed (RS)	6	12	6									
	Legume	Canadian Spring Pea (SP)	60	90	60									
		Austrian Winter Pea (WP)	50	75	50									
		Woolypod Vetch (WV)	20	30	20									
		Hairy Vetch (HV)	20	30	20									
Niche 6	Grass	Tall Fescue (TF)	20	25	20									
		Orchardgrass (OG)	12	16	12									
	Legume	Alfalfa (A)	20	25	20									
		Red Clover (RC)	10	12	10									
		White clover (WC)	5	10	5									
		Yellow B. Sweetclover (SC)	10	15	10									
					Totals									
					Number of species in mix:									

Notes: