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Brooksville Plant Materials Center
Brooksville, Florida

Cool Season Cover Crop Variety Adaptation Trial

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ABSTRACT

Conservation planners need better information on emergence rate, winter survival, and flowering date of cool season cover crop species at the selection or cultivar level when making planting decisions, particularly for mixtures. As a component of a USDA-Natural Resources Conservation Service (NRCS), Plant Materials Program national study, all readily available selections or cultivars of radish (*Raphanus sativa*, n=12), hairy vetch (*Vicia villosa*, n=6), winter pea (*Pisum sativum*, n=8), crimson clover (*Trifolium incarnatum*, n=6), red clover (*T. pratense*, n=8), cereal rye (*Secale cereale*, n=16), and black oat (*Avena strigosa*, n=1), were planted two years (2016-17 and 2017-18) at the USDA, NRCS, Brooksville Plant Materials Center (PMC), Brooksville, FL. Plantings were rated for quick cover (emergence 7, 14, 21, and 28 days after planting), percent winter survival, disease and insect damage (none, low, medium, and high), and date of 50% bloom (2017-18 only). Given minimum temperatures at the Brooksville PMC (20-25^{o}F, USDA Plant Hardiness Zone 9a), there was 100% survival of all cover crop species tested and disease and insect issues were minimal within and across cover crop species. There were differences between selections within cover crop species tested for emergence rate and 50% bloom date. Selections of cereal rye and red clover developed in northern US and/or Canada had poor emergence; variable emergence for crimson clover appeared to be related lack of adaptation and to seed quality. Flowering date for cover crops tested ranged between March 1 through May 14. Selections of most species flowered within a 30-day window; flowering date for cereal rye extended over a 45-day period. Selections of cereal rye, crimson clover, red clover, hairy vetch, and winter pea developed for the northern US and/or Canada often failed to flower.

INTRODUCTION

Conservation planners and producers are aware that cover crops can address a wide range of conservation and crop production concerns. The Natural Resources Conservation Service (NRCS) Cover Crop Conservation Practice Standard (CPS 340) states that cover crops can reduce soil erosion from wind and water, help maintain or increase soil health and organic matter, reduce impacts to water quality from excessive soil nutrients, suppress weeds and other pests, improve soil moisture, and minimize compaction. Despite this knowledge, use of cover crops in southern production systems is limited. Based on 2017 Census of Agriculture, cover crops are planted on only about 3.9%, 7%, and 15% of the harvested crop area in Alabama, Florida, and Georgia, respectively (https://www.nass.usda.gov/AgCensus/index.php).

A 2016 survey of producers, extension agents, and NRCS conservation planners in Florida (https://floridafoodandag.com/wp-content/uploads/2020/07/Florida-CC-Priorities-Results-ADA-EDIT.docx) found that two-thirds of survey participants felt that producers were reluctant to adopt cover crops due to lack of knowledge about timing for establishment and termination of

the cover crop in their production system. Proper timing of establishment and termination of the cover crop was also believed to be a big issue with producers currently using cover crops, as was not having good cover crop varieties adapted to their production system.

Current cool season cover crop recommendations are fairly generic; most often limited to gross differences related to species or functional group (Clark, 2012.) Additionally, cool season cultivar or variety recommendations are based on either forage or grain production not specifically on cover crop use (Wallau et al., 2021). The objective of this study was to provide NRCS conservation planners and producers in Florida and southern Alabama and Georgia more detailed information on commercially available selections or cultivars of some regionally and nationally important cool season species when used as a cover crop.

MATERIALS AND METHODS

Cool season cover crops listed in Table 1 were evaluated at the United Stated Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), Brooksville Plant Materials Center (PMC) in Brooksville, FL, in the 2016-2017 and again in the 2017-2018 growing season. Plots were planted on Electra variant fine sand, 0 to 5% slope (sandy, siliceous, hyperthermic Oxyaquic Alorthods) in 2016 and moved to a Sparr fine sand, 0 to 5% slope (loamy, siliceous, hyperthermic Grossarenic Paleudults) in 2017 due to wildlife predation. Plots were planted on October 26, 2016, and January 10, 2018, using a no-till drill at species recommended planting depth based on the pure live seed (PLS) planting method. Because this study was a component of a NRCS, Plant Materials Program National Cover Crop Adaptation Study (Cover Crop Performance and Adaptation Trials at PMCs | NRCS Plant Materials Program (usda.gov)), seeding rates (Table 1) used were the average of the recommended seeding rates from NRCS cover crop standards and specifications across the country to allow for uniform data analysis. Legumes were inoculated with appropriate rhizobia prior to planting. Non-legumes were fertilized with 40 lb/acre N, and all entries received 60 lb/acre P and 30 lb/acre K both years.

Table 1. Cover crop species and Pure Live Seed (PLS) planting rates used both years.

Common Name	**Species**	**PLS lb/Acre**
black oats	*Avena strigosa*	60
black-seeded common oats	*Avena sativa*	60
cereal rye	*Secale cereale*	100
crimson clover	*Trifolium incarnatum*	18
radish	*Raphanus sativus*	9
hairy vetch	*Vicia villosa*	18
red clover	*Trifolium pratense*	9
winter pea	*Pisum sativum*	70

Cover crop varieties or selections tested were all that were readily commercially available for a given cover crop species in 2016. See Results and Discussion section for each cover crop species for a list of the variety or selections tested. All cover crops were evaluated for:

- Quick fall cover—Emergence at 7, 14, 21, and 28 days after planting (DAP): 0 = Poor (<25%), 1 = Moderate (25-60%), 2 = Good (61-90%), 3 = Excellent (>90%);
- Winter survival—Plant survival rating of Excellent >75%, Good 51-75%, Fair 25-50%, Poor <25%;

- Maturity date—Days after planting to 50% bloom (2017 only, 2016 data lost due to deer damage); and
- Disease and insect ranking—Damage observed was None, Low, Fair, or High.

Rainfall (in/day), daily minimum temperature (°F), and daily maximum temperature (°F) during the 2016-2017 and 2017-2018 growing season are shown in Figure 1. The experimental design was a randomized, complete block with 4 replicates each year. Mean and standard deviation for selections within species was determined for emergence and maturity date using Statistix 10 (Analytical Software, 2013).

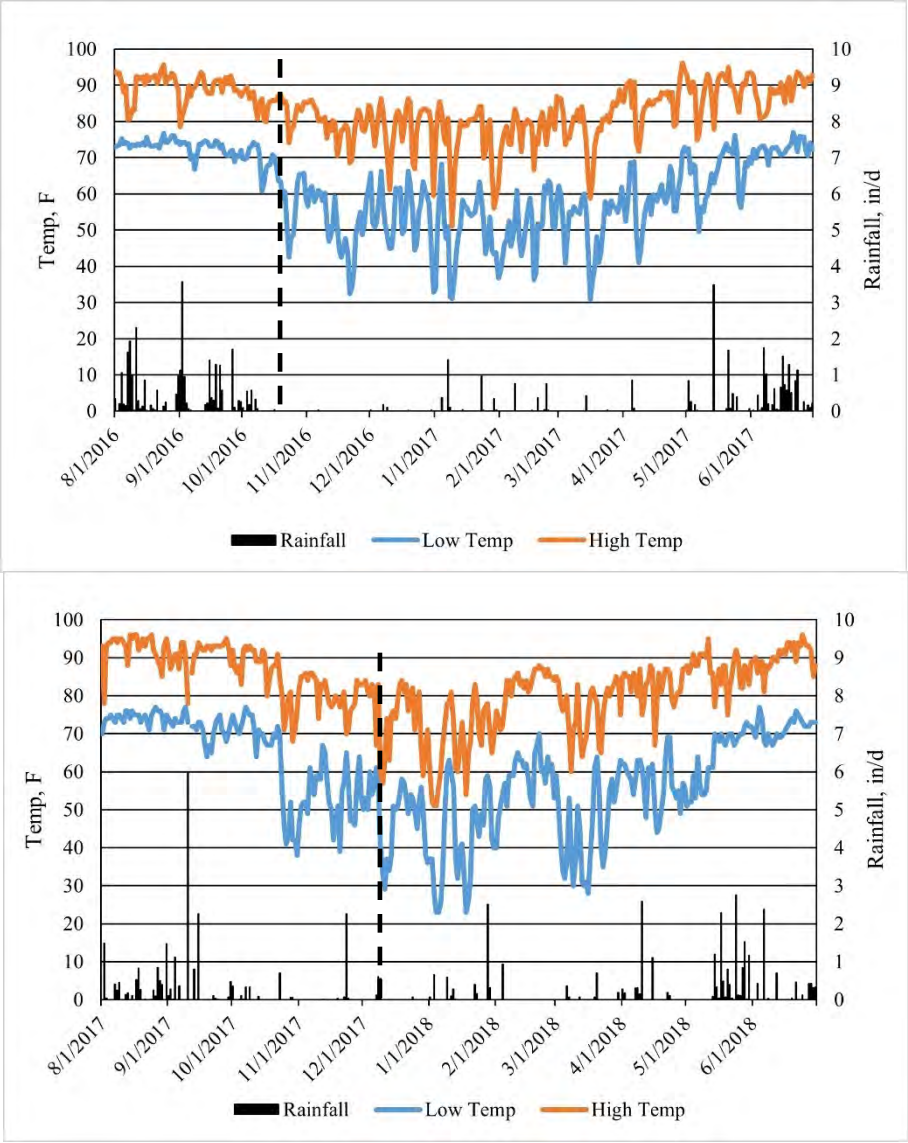

Figure 1. Lines indicate minimum and maximum daily temperatures (° F) and bars indicate rainfall (in/day) during 2016-2017 (top) and 2017-2018 (bottom) winter cover crop trial. Vertical dashed lines indicate date cover crop planted.

RESULTS AND DISCUSSION

Cereal Rye - The cereal rye (hereafter simply called rye) selections that were evaluated at the Brooksville PMC in planting year 2016 and 2017, their release date and location they were developed, and if they currently recommended in FL, GA, LA, or by the Southern Cover Crops Council (SCCC; https://southerncovercrops.org/) are listed in Table 2. As was expected based on minimum temperatures in planting year 2016 and 2017 (Fig. 1), none of the rye selections winter killed. Rye is known to be one of the most cold-tolerant small grains (Bruckner and Raymer, 1990).

Table 2. Cereal rye (*Secale cereal*e) cultivars or selections tested at the USDA, NRCS, Brooksville PMC in planting year 2016 and 2017. Cultivar or selection shaded in grey were dropped from analysis because 2-yr avg. stand rating <65% by 28 days after planting.

Cultivar or Selection	Year Released	Location Developed	Recommended*
'Aroostook'	1981	NY	
'Bates'	1996	OK	GA, SCCC
'Brasetto' (Hybrid)	2009	KWS/Canada	
'Elbon'	1956	OK	FL, GA, LA, SCCC
'FL 401'	1986	FL	FL, GA, SCCC
Guardian™		La Crosse Seed	
'Hazlet'	2006	Canada	
'Maton'	1975	OK	FL, LA, SCCC
'Maton II'	2007	OK	FL, LA, SCCC
'Merced'	1947	CA	
'Oklon'	1993	OK	FL, LA, SCCC
'Prima'	1984	Canada	
'Rymin'	1973	MN	
'Wheeler'	1972	MI	
'Wintergrazer 70'	1978	GA	LA
'Wrens Abruzzi'	1970	GA	FL, SCCC

*Recommended for grain, forage, or cover crop by state extension service or Southern Cover Crops Council (SCCC).

Figure 2 shows the average emergence rating for cereal rye selections that reached a minimum stand rating >65% by 28 days after planting (EMG28DAP). Rapid emergence and cover are desirable characteristics for a cover crop selection to provide competition for weed control, to reduce wind and water erosion potential, and for nutrient uptake. All FL, GA, or LA state extension recommended selections or ones recommended by SCCC (Table 2) reached >65% emergence by 14 DAP and many exceeded 90% by 28 DAP.

'Brasetto', Guardian™, 'Hazlet', 'Prima', 'Rymin', and 'Wheeler' failed to reach a 2-yr average minimum emergence rating of 65% by 28 DAP. This was due to very low emergence ratings (<30%) in 2017 for those selections. Lower emergence ratings were also noted for Brasetto, Guardian™, Prima, and Rymin in 2017 at the GAPMC (McGhee, 2020), but only Guardian™ and Wheeler had lower ratings in 2017 at the MSPMC (Richard and Alison, 2020) and only Guardian™ had lower average rating of the selections in 2017 at the MOPMC (Hergert, 2020).

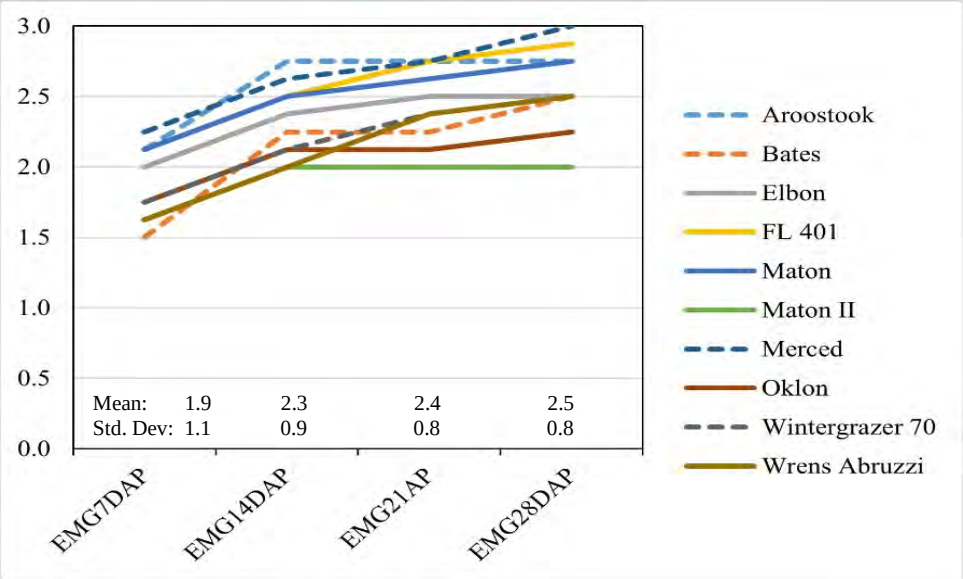

Figure 2. Average emergence rating for cereal rye (*Secale cereale*) selections at 7, 14, 21, and 28 days after planing (DAP) in 2016 and 2017 at Brooksville PMC. Emergence rating scale: 0 = Poor (<25%), 1 = Moderate (25-60%), 2 = Good (61-90%), 3 = Excellent (>90%). Solid line indicate selection recommended as grain, forage or cover crop in FL, GA, LA, or by Southern Cover Crops Council.

Since all PMC plantings were using the same seed, lower stand ratings for these selections, particularly at Brooksville, most likely resulted from a lack of adaptation. All of the poor performing selections in Florida, except Guardian™, were developed for grain production in the northern US, Canada, or Europe; Guardian™ is advertised as a winter hardy, cover crop selection sold by La Crosse Seed in La Crosse, WI. Although disease issues were not reported, rye selections developed for northern latitudes have been found to be more susceptible to soil borne diseases, have reduced fall growth, and have more issues with rust (*Puccinia* spp.) than selections developed in the southeast (Wallau et al., 2021). An exception to this generalized regional adaptation was 'Aroostook' which had a 2-yr average emergence rating of >65% by 14 DAP. Aroostook is a cold hardy cultivar selected for rapid fall and spring growth. It is a cooperative release from USDA NRCS Big Flats Plant Materials Center (2015), the New York State College of Agriculture and Life Sciences, Cornell University, and the Maine Department of Agriculture, Division of Plant Industry.

The southeastern regional publication that combined information from the Brooksville PMC, GAPMC, and MSPMC (USDA-NRCS, 2020) divided the rye selections tested into early (<140 DAP), mid- (141-160 DAP), and late-season (>161 DAP) maturity groups. Although not listed that way in the regional publication, all the rye selections that flowered at the Brooksville PMC did so between 70-119 DAP (Mar 22 – May 9) due to the late planting date in the 2017 planting season (January 10, 2018). Figure 3 shows the calendar date that the rye selections reached 50% anthesis in spring of 2018 and the emergence rating at 14 DAP.

In agreement with the regional grouping, 'FL401' and 'Merced' were the earliest maturing at Brooksville. 'Wrens Abruzzi', 'Wintergrazer 70', and 'Bates' flowered 7 to 14 days later, while 'Maton', 'Maton II', 'Oklon', 'Elbon', and Aroostook flowered about 30 days later than FL401 and Merced. Regionally, Brasetto, Guardian™, Prima, Rymin, and Wheeler were considered

late-season maturity, while Hazlet was considered a mid-season maturity rye. None of those selections flowered at Brooksville in 2017 which, like low emergence ratings, may have been due to inadequate vernalization caused by the January planting date (see Fig. 1). Data from a Florida Automated Weather Network (FAWN https://fawn.ifas.ufl.edu/data/) site located 10 miles north of Brooksville indicated no cumulative hours below 45°F after the January 2018 planting date. These selections did consistently flower between April 28 – May 4 at the GAPMC when planted during the last 2 weeks in October. This was about a 2-week later maturity date than currently recommended rye selections in Georgia and suggest that these selections might have value in southern Georgia and northern Florida as cover crop if disease, as was reported at the ETXPMC (Brakie and Shadow, 2020), does not occur. Usefulness for the central part Florida, even with the recommended mid-October planting date is questionable.

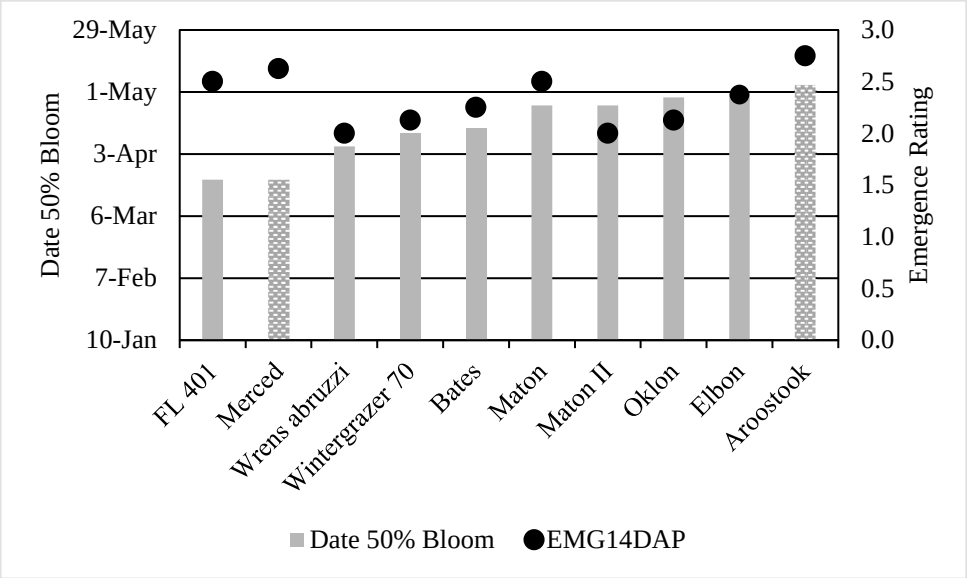

Figure 3. Maturity (bars) based on days after planting (2017 planting season only) until 50% flowering (Date 50% Bloom; Mean = Apr 17, SD = 28 days) and two year average emergence rating (circles) at 14 days after planting (EMG14DAP; Mean = 2.3, SD = 0.8) for cereal rye (*Secale cereale*) cultivars planted in 2016 and 2017 at the Brooksville PMC. Emergence rating scale: 0 = Poor (<25%), 1 = Moderate (25-60%), 2 = Good (61-90%), 3 = Excellent (>90%). Solid bars are selections recommended as grain, forage, or cover crop in FL, GA, LA, or by Southern Cover Crop Council.

Black Oat and Black-Seeded Oat – Often lumped together in the popular literature or even simply misidentified, black-seeded oat and black oat are both members of the oat genus Avena and have the common characteristic of being the least winter hardy of the small grains. But black-seeded oat is a type of common oat, Avena sativa, with black hulls, while black oat is a different species, A. strigosa. In much of the US, common oat is often planted as a spring crop or, when fall planted, managed as a winter-killed annual cover crop. Common oat will winter kill in USDA Plant Hardiness Zone 6 or colder and will often winter kill in most of Zone 7 (Clark, 2012). Black oat is less winter hardy species than common oat and can winter kill at temperatures below 19oF (Dial, 2014). Black oat is generally considered to only have reliable winter survival in USDA Plant Hardiness Zone 8b and higher (Dial, 2014).

Emergence was excellent for both 'SoilSaver' and 'Cosaque' (Fig. 4) with emergence rating between 65-80% by 14 DAP for both cultivars. Emergence rated >90% by 28 DAP at the Brooksville PMC and at all other PMC in southeastern US (USDA-NRCS, 2020).

There was 100% survival both years for Cosaque common oat at the Brooksville PMC (20-25°F, Zone 9a), at the GAPMC (10-15°F, Zone 8a), and at MSPMC (5-10°F, Zone 7b; USDA-NRCS, 2020). As would be expected, there was essentially 100% survival Soil Saver black oat at the Brooksville PMC and the GAPMC (McGee, 2020), but SoilSaver black oat had <38% survival at the MSPMC (Richard and Allison, 2020).

The southeast regional publication (USDA-NRCS, 2020) grouped SoilSaver black oat and Cosaque common oat as both being in the mid-season maturity group (141-160 DAP), but both selections flowered in <120 days at the Brooksville PMC (late-April to mid-May, Fig. 5). This was slightly later than occurred at the GAPMC (mid- to late-April; McGee, 2020) in 2017 planting year and was probably due to the late planting date that year at the FLPMC (Jan. 10, 2018). SoilSaver was about 2 weeks earlier flowering than Cosaque at the Brooksville PMC and GAPMC, but not at the MSPMC (McGee, 2020; Richard and Allison, 2020). Later flowering of SoilSaver MSPMC may have been due to cooler temperatures.

Cosaque black-seeded, common oat is an oat cultivar developed in Kentucky and recommended as a cover crop by the Southern Cover Crop Council. It is not recommended for forage or grain in Florida or Georgia (Dr. Ann Blount, 2022, personal communication). Crown rust (*Puccinia coronata*) has been particularly severe in recent years (Buck et al., 2019; Wallau et al., 2021), and Cosaque has been shown to be particularly susceptible to rust in one Florida trial (Debuex et al., 2016). No disease was noted for Cosaque or SoilSaver at the Brooksville PMC either year, but Cosaque had moderate to severe disease ratings both years as the GAPMC and the ETXPMC (15-20°F, Zone 8b), while SoilSaver exhibited only slight disease issues at those locations (McGee, 2020; Brakie and Shadow, 2020). Crown rust is less of a problem when oats are grazed than when oats are raised for grain and Ryan et al. (2021) did not report any disease issues with Cosaque in a 90-day grazing trial in southern Alabama. It is possible Cosaque might escape rust issues in cover crop mixes, but oat cultivars such as Horizon 306 or Horizon 720, which are known to have some resistance to crown rust and recommended both for forage and grain in FL and GA, are probably a safer bet as a cover crop most years.

Black oat is widely used as a cover crop in South America, and SoilSaver was developed as a black oat cultivar for cover crop use in the US (Bauer and Reeves, 1999; Patterson et al., 1996; Reeves et al., 1997). Where not subject to winter damage, black oat can produce cover crop biomass similar to rye and provide similar levels of weed control (Reeves et al., 2005). Black oat has been reported to have lower C:N ratio at maturity than other small grains, as low as 28:1 compared to 48:1 for rye and 38:1 for wheat (*Tripsacum sativum*; reported in Bauer and Reeves, 1999). This C:N ratio for black oat is thought to be an advantage because at C:N ratios below 30:1, starter N will not be necessary for subsequent commercial crop (Clark, 2012). The reported C:N ratio advantage of black oat compared to other small grains should be viewed with caution since C:N ratios interact strongly with plant maturity, which is often not stated in study reports. Ashford and Reeves (2003) in a two-year study found the C:N ratios at anthesis of rye (25:1 to 44:1), black oat (34:1 to 38:1), and wheat (31:1 to 32:1) were similar. From anthesis through soft dough, black oat and wheat continued to have similar C:N ratios (36:1 to 45:1), but C:N ratio for rye (48:1 to 64:1) was higher at later maturity stages. Producers who chose to use

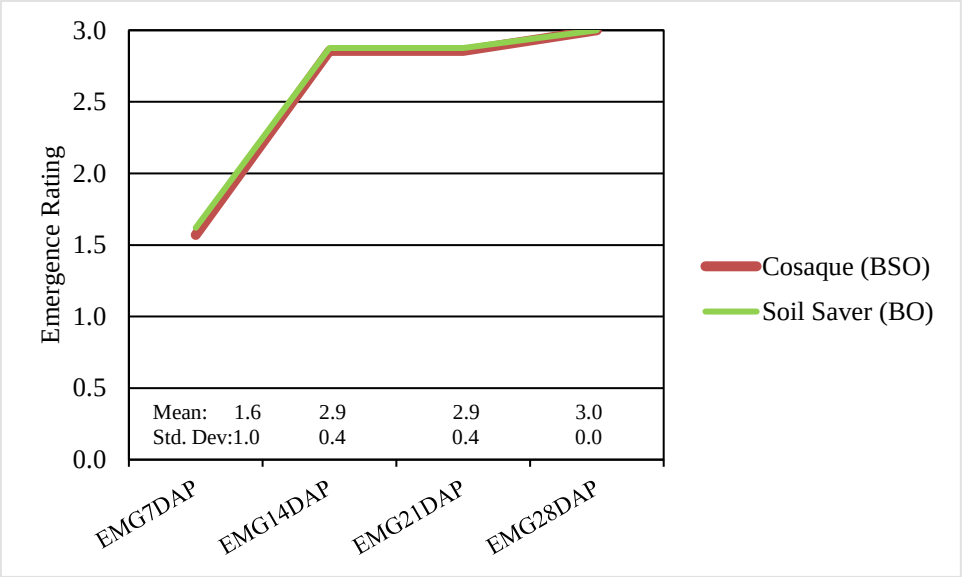

Figure 4. Average emergence rating for 'SoilSaver' black oat (BO, *Avena strigosa*) and 'Cosaque' black-seeded common oat (BSO, *A. sativa*) at 7, 14, 21, and 28 days after planing (DAP) in 2016 and 2017 at the Brooksville PMC. Emergence rating scale: 0 = Poor (<25%), 1 = Moderate (25-60%), 2 = Good (61-90%), 3 = Excellent (>90%). Solid line indicate selection recommended as cover crop in FL, GA, LA, or by Southern Cover Crops Council (SCCC). Only SCCC recommends Cosaque common oat.

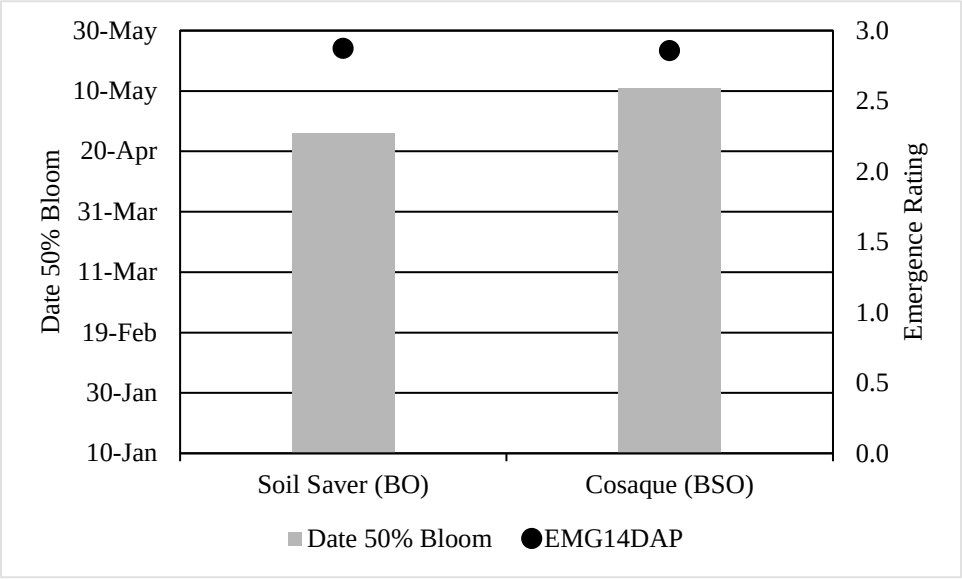

Figure 5. Maturity (bars) based on days after planting (2017 planting season only) until 50% flowering (Date 50% Bloom; Mean = May 2, SD = 8 days) and two year average emergence rating (circles) at 14 days after planting (EMG14DAP; Mean = 2.9, SD = 0.4) for 'SoilSaver' black oat (BO, *Avena strigosa)* and 'Cosaque' black-seeded common oat (BSO, *A. sativa*) planted in 2016 and 2017 at the Brooksville PMC. Emergence rating scale: 0 = Poor (<25%), 1 = Moderate (25-60%), 2 = Good (61-90%), 3 = Excellent (>90%). Solid bars are selections recommended as cover crop in FL, GA, LA, or by Southern Cover Crop Council (SCCC). Only the SCCC recommends Cosaque common oat.

SoilSaver as a means of saving on starter N costs are advised to terminate solid stands of SoilSaver no later than early anthesis or use a mixture of SoilSaver and some adapted legume species.

Crimson Clover – The crimson clover cultivars that were evaluated at the Brooksville PMC in planting year 2016 and 2017, their release date and location they were developed, and if they currently recommended by FL, GA, or LA state extension or by SCCC are listed in Table 3. There was 100% winter survival (data not reported) at the Brooksville PMC and >99% survival at the GAPMC (McGee, 2020) of the cultivars tested.

Table 3. Crimson clover (*Trifolium incarnatum*) cultivars tested at the USDA, NRCS, Brooksville PMC in planting year 2016 and 2017.

Cultivar	Year Released	Location Developed	Recommended*
AU Robin	1991	AL	FL, GA, SCCC
AU Sunrise	2000	AL, GA	FL**, SCCC
AU Sunup	2012	AL, GA	SCCC
Contea		Italy	
Dixie	1953	GA	FL, GA, SCCC
Kentucky Pride	2016	KY	

*Recommended as forage or cover crop in FL, GA, LA, or by Southern Cover Crops Council (SCCC).
**Not currently recommended in FL due to limited seed availability; if seed becomes more available, will be recommended (Dr. A. Blount, 2022, personal communication).

Consistently across years, emergence ratings of the crimson clover cultivars evaluated at the Brooksville PMC showed two groupings, poor to moderate (≤60%) and good (61-90%, see Fig. 6). ‘AU Robin’, ‘AU Sunup’, ‘Contea’, and ‘Dixie’ were in the poor to moderate group at Brooksville, but only AU Sunup and Contea rated ≤60% at the other southeastern PMCs (McGee, 2020; Richard and Allison, 2020). Consistent poor emergence for AU Sunup and Contea may indicate poor seed quality (see discussion below) and/or a lack of adaptation of the Italian cultivar, Contea. In contrast, AU Robin and Dixie, which had poor emergence at the Brooksville PMC, had good to excellent (90-100%) emergence at least one year at the other southeastern PMCs (McGee, 2020; Richard and Allison, 2020).

Better emergence ratings seemed to be related to better rainfall at those PMCs. Low emergence ratings for AU Robin and Dixie both years at the Brooksville PMC may reflect poor moisture conditions. The University of Florida does not recommend planting crimson clover on soil types similar to those at the Brooksville PMC without supplemental irrigation (Newman et al., 2014). Consistent better emergence ratings for AU Sunrise and Kentucky Pride compared to the other cultivars tested across both planting years at the Brooksville PMC (Fig. 6) and the GAPMC (McGee, 2020) indicate that soil moisture was not the only factor affecting crimson clover emergence. Crimson clover is known to be a “poor keeper” and seedling vigor can deteriorate faster than actual germination rate (Helmer et al., 1962). Even though all cultivars were planted on a PLS basis, variations in seed quality, which is a combination of germination and vigor, may also have affected emergence ratings for AU Sunup, AU Robin, Dixie, and Contea, particularly under less than optimum moisture conditions. Producers should pay attention to harvest year and storage conditions when purchasing any seed, but particularly with crimson clover seed.

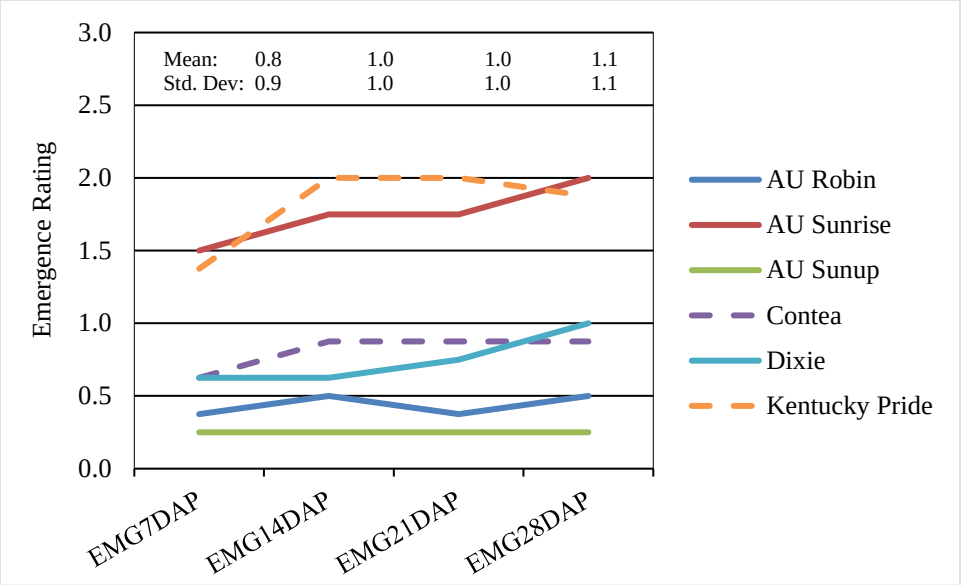

Figure 6. Average emergence rating for crimson clover (*Trifolium incarnatum*) selections at 7, 14, 21, and 28 days after planing (DAP) in 2016 and 2017 at the Brooksville PMC. Emergence rating scale: 0 = Poor (<25%), 1 = Moderate (25-60%), 2 = Good (61-90%), 3 = Excellent (>90%). Solid line indicate selection recommended as forage or cover crop in FL, GA, LA, or by Southern Cover Crops Council.

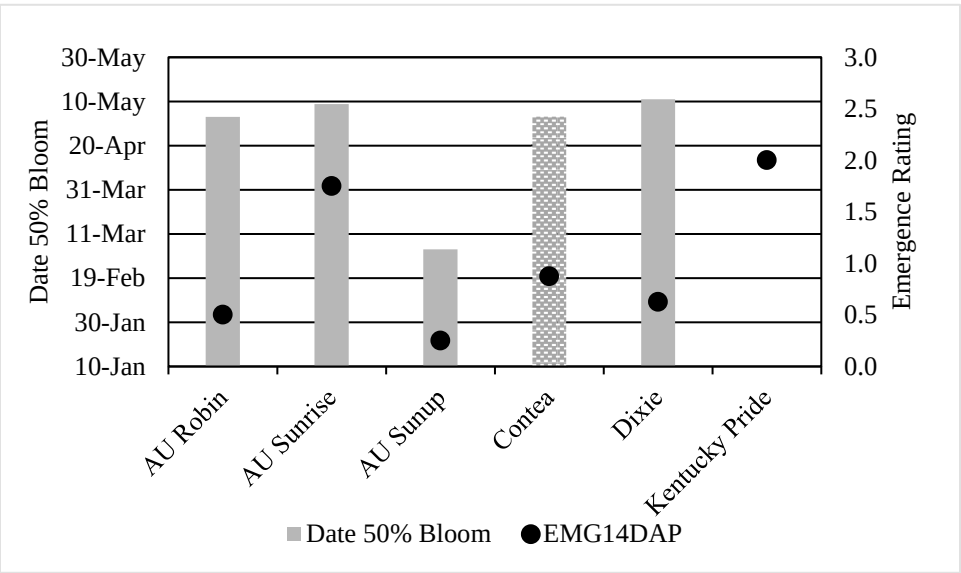

Figure 7. Maturity (bars) based on days after planting (2017 planting season only) until 50% flowering (Date 50% Bloom; Mean = Apr 24, SD = 31 days) and two year average emergence rating (circles) at 14 days after planting (EMG14DAP; Mean = 2.3, SD = 0.9) for crimson clover (*Trifolium incarnatum*) selections planted in 2016 and 2017 at the Brooksville PMC. Emergence rating scale: 0 = Poor (<25%), 1 = Moderate (25-60%), 2 = Good (61-90%), 3 = Excellent (>90%). Solid bars are selections recommended as forage or cover crop in FL, GA, LA, or by Southern Cover Crop Council.

All crimson clover cultivars except Kentucky Pride flowered at Brooksville (Fig. 7), and flowering dates were <140 days. Individual cultivar 50% flowering dates were consistent with the relative range reported in the southeast summary (USDA-NRCS, 2020). AU Sunup flowered first and AU Robin, AU Sunrise, Dixie, and Contea all flowered within an 8-day period about 60 days later. Flowering dates at Brooksville were about 30 days later than for the same year at the GAPMC, again probably due to the January planting date at the Brooksville PMC. Butler et al. (2002) found that later planting dates delayed or even completely prevented flowering in some crimson clover cultivars. Kentucky Pride is a relatively new cultivar that had not been tested in Florida previously and failure to flower may have been related to the late planting date

An exception to later flowering at the Brooksville PMC than at the GAPMC was AU Sunup which flowered earlier at Brooksville (March 4) than at the GAPMC (March 23) in 2018. All cultivars except Kentucky Pride flowered within about a 2-week period at the GAPMC (McGee, 2020) with AU Sunup and AU Sunrise first, only 3 days apart; AU Robin flowered about a week later; and Contea and Dixie flowered at the end of the 2-week period. Kentucky Pride flowered about 2 weeks later than Dixie and Contea.

Red Clover - The red clover cultivars or selection that were evaluated at the Brooksville PMC in planting year 2016 and 2017, their release date and location they were developed, and if they currently recommended by FL, GA, or LA state extension or by SCCC are listed in Table 4. There was 100% survival at the Brooksville PMC of all cultivars or selections of red clover tested (data not reported).

Table 4. Red clover (*Trifolium pratense*) cultivars or selections tested at the USDA, NRCS, Brooksville PMC in planting year 2016 and 2017.

Cultivar or Selection	Clover Type	Year Released	Location Developed	Recommended*
'Cinnamon Plus'	Medium	2002	IN	GA (north only)
'Cyclone II'	Medium			
'Dynamite'	Medium			
'Freedom!'	Medium	2001	KY	
'Kenland'	Medium	1950	KY	GA, LA (north only)
Mammoth	Single cut			
'Starfire II'	Medium	2007	MI	
'Wildcat'	Medium	1997	WI	

*Recommended as forage or cover crop in FL, GA, LA, or by Southern Cover Crops Council (SCCC).

Red clover is a weak perennial species, generally functioning as a biannual throughout most of the upper South but is managed as an annual from central Georgia southward. Of the selections tested, only 'Cinnamon Plus' and 'Kenland' are recommended for forage, but only in northern areas of Georgia or Louisiana. At this time, the SCCC does not recommend red clover as a cover crop. As a perennial species, it is considered slower starting and can be somewhat harder to kill than annual clover species (Clark, 2012).

Emergence ratings at the Brooksville PMC (Fig. 8) were poor (<25%) to moderate (25-60%) by 14 DAP and essentially remained unchanged after that date. Emergence ratings at the GAPMC (McGee, 2020) showed similar trends with maximum emergence occurring at about 14 DAP and

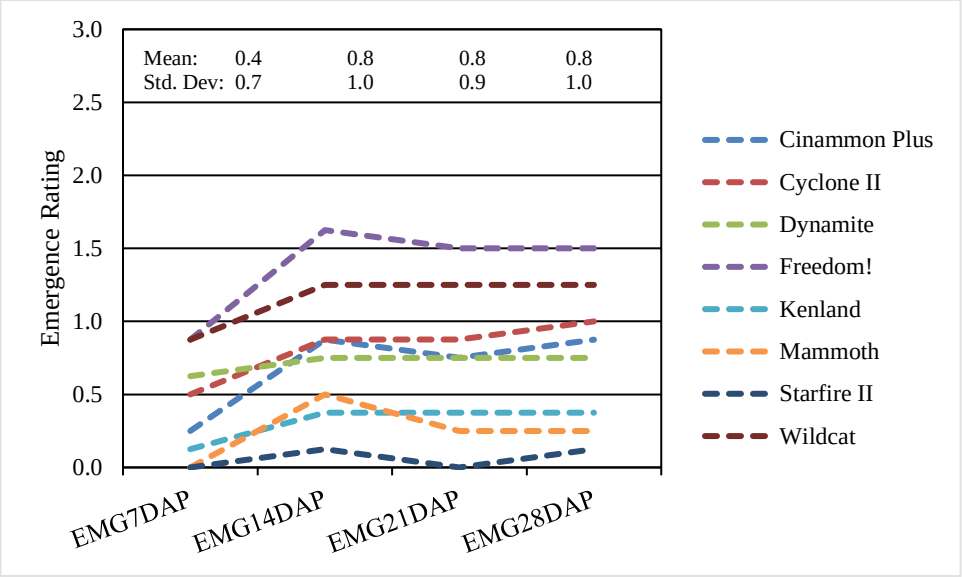

Figure 8. Average emergence rating for red clover (*Trifolium pratense*) selections at 7, 14, 21, and 28 days after planing (DAP) in 2016 and 2017 at the Brooksville PMC. Emergence rating scale: 0 = Poor (<25%), 1 = Moderate (25-60%), 2 = Good (61-90%), 3 = Excellent (>90%). Dotted lines indicate selection not recommended as forage or cover crop in FL, southern GA or LA, or by Southern Cover Crops Council.

no or only slight improvements in emergence rating by 28 DAP. Also, like what was found with crimson clover, red clover emergence at the GAPMC was better in the wet year

None of the red clover selections flowered at the Brooksville PMC (data not reported) in 2018. Unlike cereal rye, red clover is thought to require little or no vernalization and flowering is controlled by photoperiod, requiring long days, minimally 12-14 hr, to initiate flowers (Bowley et al., 1987). Red clover does go through a "juvenile phase", where the plant will not flower even if daylength is long enough and the juvenile phase is longer in late-flowering lines than early flowering lines (Jones, 1974). All selections tested are considered winter dormant which means they are late flowering (Quesenberry and Blount, 2006). This means that the red clover cultivars tested probably failed to flower at the Brooksville PMC in 2018 even when days were long enough, because they never matured past their juvenile phase due to the January planting date that year.

The red clover cultivars tested, except Mammoth, are all medium-type and flowered at the GAPMC between May 14-24 (McGee, 2020); the Mammoth single-cut selection flowered about 30 days later, on June 18. McGee (2020) considered that the mid-May flowering date was too late to fit most crop production systems in Georgia. This does not mean that producers in central Georgia and further south should not consider red clover for a cover crop, particularly in mixtures. Maximum biomass (and consequently N) production for most cover crop species is generally associated with flowering (Clark, 2012), but this does not mean that there is no biomass when terminated earlier. Studies in North Florida have shown that Freedom!, Cinnamon Plus, and Kenland, although not recommended as a forage, can produce between 800 - 2000 lb/acre of dry matter in early to mid-April (Quesenberry and Blount, 2006; Quesenberry and Blount, 2012; Quesenberry et al., 2015). Additionally, southern producers should consider red clover cultivars that have been bred for less winter dormancy and flower earlier. Forage

breeding programs at FL, GA, and AL have all produced red clover cultivars that are better suited for the lower south with little or no winter dormancy which means earlier spring growth and earlier flowering. These less dormant red clovers such as 'AU Red Ace', 'Barduro', and 'Southern Belle' can produce between 2000 - 5000 lb/dry matter at first harvest in early to mid-April (Quesenberry and Blount, 2006; Quesenberry and Blount, 2012; Mosjidis, 2011).

Although root and shoot C:N ratios and shoot % total N release (mineral N + organic N) are similar for crimson clover and red clover, studies have shown that % total N release over a 10-week period from red clover roots was about 40% higher than for crimson clover roots, and thus more red clover root N was available for subsequent cash crop than that from crimson clover roots (Yang et al., 2020). Based on the availability of less dormant cultivars and higher % total N release rates, NRCS conservation planners and producers in Florida and southern Alabama and Georgia should consider using red clover as a cover crop, particularly if expected cultivar maturity date fits within desired cover crop production window.

Hairy Vetch - The hairy vetch cultivars or selection that were evaluated at the Brooksville PMC in planting year 2016 and 2017, their release date and location they were developed, and if they currently recommended by FL, GA, or LA state extension or by SCCC are listed in Table 5. There was 100% survival at the Brooksville PMC of all cultivars or selections of hairy vetch tested (data not reported).

Table 5. Hairy vetch (*Vicia villosa*) cultivars or selections tested at the USDA, NRCS, Brooksville PMC in planting year 2016 and 2017.

Cultivar or Selection	Year Released	Location Developed	Recommended*
CCS Groff		PA	
'Lana' (woolypod; *V. villosa* spp. *dasycarpa*)	1960	CA	SCCC
'Purple Bounty'	2020	MD	SCCC
'Purple Prosperity'	2020	MD	
Tilth Pro TNT	2012	IL	
'Villana'			

*Recommended as forage or cover crop in FL, GA, LA, or by Southern Cover Crops Council (SCCC).

Unlike with the crimson clover (Fig. 6) and red clover (Fig. 8) cultivars tested, emergence ratings were similar for all hairy vetch selections evaluated (Fig. 9) with all selections rated as moderate (25-60%) by 14 DAP and good (61-90 %) by 28 DAP. The GAPMC and the MSPMC also found essentially no difference between hairy vetch selections for emergence within years (McGee, 2020; Richard and Allison, 2020).

All selections tested flowered at the Brooksville PMC between April 17 to April 30 except Tilth Pro TNT which did not flower (Fig. 10). 'Lana' woolpod vetch was the earliest flowering selection, flowering on April 17, and the remainder flowered between April 24-30. At the GAPMC, Lana flowered first on April 3 and the remainder flowered between April 9-26 except for Tilth Pro TNT which flowered May 7 (McGee, 2020).

Flowering and biomass production in hairy vetch is almost entirely determined by temperature and accumulation of Growing Degree Days (GDD 40^{o} F) not photoperiod, but selections differ in their GDD requirements (Teasedale et al., 2004; Iannucci et al., 2008). Teasdale et al. (2004)

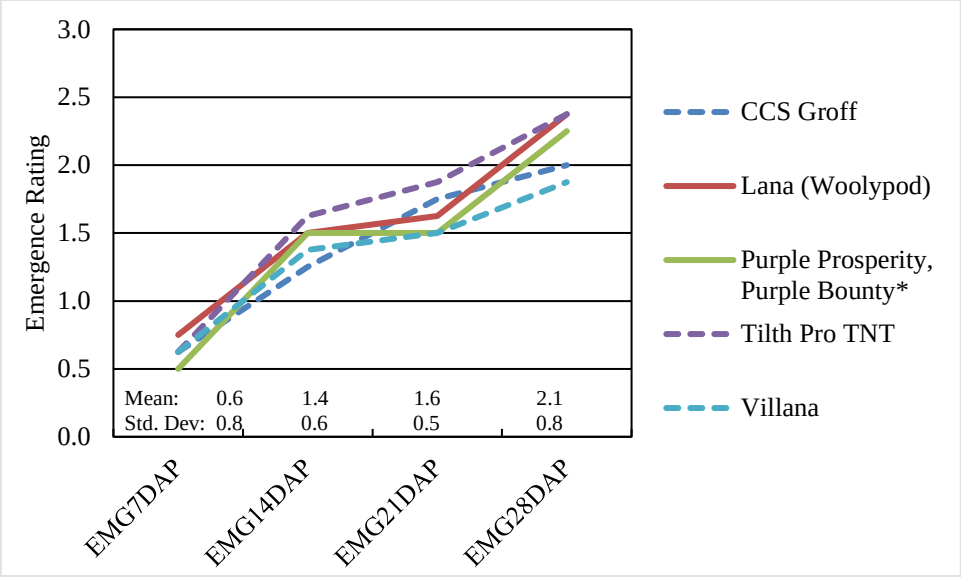

Figure 9. Average emergence rating for hairy vetch (*Vicia villosa*) selections at 7, 14, 21, and 28 days after planing (DAP) in 2016 and 2017 at the Brooksville PMC. Emergence rating scale: 0 = Poor (<25%), 1 = Moderate (25-60%), 2 = Good (61-90%), 3 = Excellent (>90%). Solid lines indicate selections recommended as forage or cover crop in FL, GA, or LA, or by Southern Cover Crops Council. *Due to zero emergence for Purple Bounty for unknown reason in 2016 and similar Purple Bounty and Purple Prosperity emergence in 2017, average Purple Bounty emergence reported the same as Purple Prosperity.

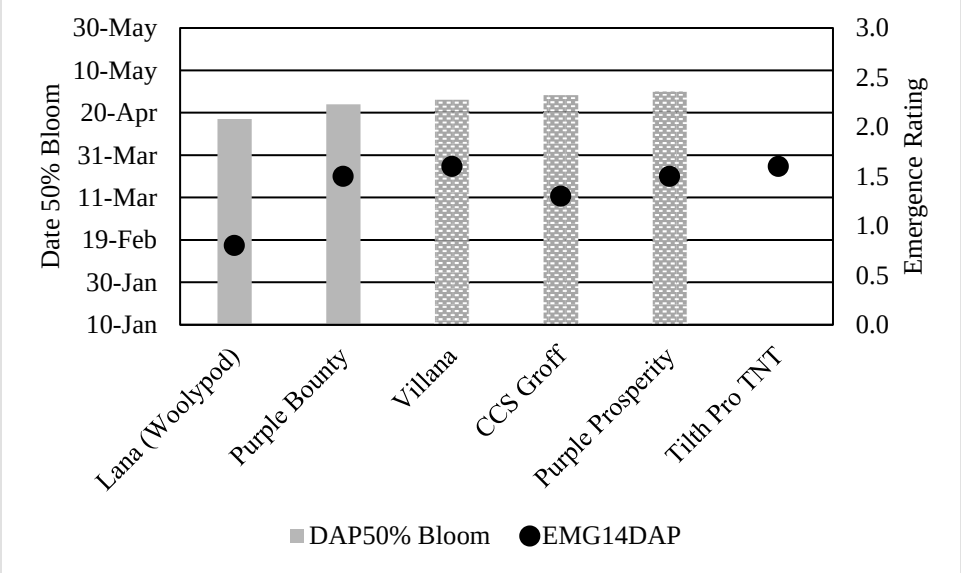

Figure 10. Maturity (bars) based on days after planting (2017 planting season only) until 50% flowering (Date 50% Bloom; Mean = Apr 18, SD = 25 days) and two year average emergence rating (circles) at 14 days after planting (EMG14DAP; Mean = 1.4, SD = 0.6) for hairy vetch (*Vicia villosa*) selections planted in 2016 and 2017 at the Brooksville PMC. Emergence rating scale: 0 = Poor (<25%), 1 = Moderate (25-60%), 2 = Good (61-90%), 3 = Excellent (>90%). Solid bars are selections recommended for forage or cover crop in FL, GA, LA, or by Southern Cover Crop Council.

found that 'AU Early Cover', a cultivar developed in Alabama for earlier flowering date and dry matter production, required <1000 GDD compared to a non-specified selection commonly used by growers which required >1300 GDD to reach 50% flower. Lana woolypod vetch, which is a different subspecies of vetch than the other vetches tested, is less cold tolerant and known to flower earlier than most hairy vetch selections. Controlled temperature studies in Virginia showed that Lana had almost twice the DM production of AU Early Cover at 400 GDD (417 vs. 226 lb/acre; Fleming and Thomason, 2020).

Failure of Tilth Pro TNT to flower at the Brooksville PMC is probably related to GDD requirements for the IL selection. The historic GDD for the Nov-May period at the GAPMC where the Tilth Pro TNT flowered is about 2800 GDD, compared to historically only 1800 GDD for the Jan-Mar growing season at Brooksville PMC in 2018 (Growing Degree Days Calculator – AgroClimate – historic GDD for FLPMC based on Floral City, FL, weather data; GDD for GAPMC based on weather data from Plains, GA). In contrast, CCS Groff, also a northern developed selection, did flower at the Brooksville PMC (Fig. 10). CCS Groff is a PA farmer-developed selection that was developed from a population of AU Early Cover selected for winter hardiness and is still considered "early flowering" (Maul et al., 2011). Purple Bounty and Purple Prosperity cultivars are also considered early flowering (Maul et al., 2011) and relative flowering dates at the Brooksville PMC were consistent with previous research which has found that Purple Bounty to be somewhat earlier than Purple Prosperity or CCS Groff (Moore et al., 2020).

Flowering time is important for managing hairy vetch for several reasons. Mechanical termination is usually successful when hairy vetch has reached 50% flower; prior to that some form of chemical or chemical/mechanical combination is needed (Mischler et al., 2010; Clark, 2012). Additionally, since vegetative growth ceases when flowering starts, the number GDD between planting and flowering sets the limit on maximum dry matter yield and N production. Studies have shown that, if nothing else is limiting, hairy vetch will produce about 400 – 500 lb/acre dry matter for every 100 GDD (Teasedale et al., 2004; Mirsky et al., 2017). Based on about 3% N per pound of hairy vetch DM, producers can expect a maximum of between 12 -15 lb/acre N per every 100 GDD. If the subsequent crop is corn, a producer will need a minimum of 4000 – 5000 lb/acre hairy vetch dry matter to provide 120-150 lb/acre N (Clark et al., 1995; Mischler et al., 2010). This means that a hairy vetch cover crop would need a bare minimum of 1000 GDD to produce the 4000 – 4500 lb/acre dry matter to meet the N requirements of a corn crop. Given that moisture and fertility are rarely perfect, a conservative estimate would be 2000 GDD to reach the 4000 – 5000 lb/acre dry matter goal.

It is not difficult to get a minimum of 2000 GDD in Florida or southern Georgia or Alabama (Growing Degree Days Calculator – AgroClimate). This gives southern producers a pretty wide window for planting; the issue is to match needed GDD, termination time, and termination method to meet producer needs. For example, in the panhandle of Florida and the coastal plain of Georgia, the recommended window for planting corn is roughly the 60-day period during the months of March and April (Lee, 2014; Wright et al., 2017). The flowering date found at both the Brooksville PMC or the GAPMC for the hairy vetch selections tested and even Lana woolypod vetch, does not fit with mechanical termination for the corn planting window. This is more a problem for organic producers than conventional row crop producers who have more chemical options. Producers desiring an earlier flowering date should consider 'AU Merit' (Mosjidis, 2002), which is recommended by the Univ. Florida (Wallau, et al., 2021). It has a

flowering date of around April 1 in south Alabama, similar to AU Early Cover (Mosjidis et al., 1995) which is no longer commercially available.

Winter Pea (a.k.a., Austrian winter pea, field pea, dry pea, forage pea, common pea) – "Winter" peas are types of garden peas (*Pisum sativum*) that are generally planted in the fall because they can acclimate to low temperatures and have mechanisms to delay flowering until after frost periods (Bourion et al., 2003). Winter peas will usually overwinter in USDA Plant Hardiness Zones 8a (10-15^{o}F; Clark, 2012) or higher. Winter peas can also be planted in the spring or early summer in those areas where summer temperatures do not limit growth although yields are usually lower than would have occurred if planted in the fall (Auld et al., 1982). True "spring" pea selections lack any mechanism for developing freeze tolerance or delay flowering if planted in the fall and may not reliably survive even in Zone 8a (10-15^{o}F) (Bourion et al., 2003). 'Arvika' is listed as a "spring" pea by its developer (https://selgen.eu/legumes/field-pea/arvika/) but is lumped with winter pea cover crop selections in this study (Table 6).

The winter pea cultivars or selection that were evaluated at the Brooksville PMC in planting year 2016 and 2017, their release date and location they were developed, recommended planting season, plant appearance, flower color, and if they currently recommended by FL, GA, or LA state extension or by SCCC are listed in Table 6.

Table 6. Winter pea (*Pisum sativum*) cultivars or selections tested at the USDA, NRCS, Brooksville PMC in planting year 2016 and 2017.

Cultivar or Selection	Year Released	Location Developed	Planting season	Plant Appearance*	Flower Color	Recommended**
'Arvika'	1972	Czechoslovakia	spring	normal leaf, tall	purple	
Dunn (Dun)	1893	Australia (England)	winter	normal leaf, tall	purple	
Frost Master			winter	normal leaf, tall	white	SCCC
'Lynx'	2013	WA	winter	semi-leafless, short	white	
Maxum			winter/ spring	normal leaf, tall	purple	SCCC
'Survivor'		OR (GOSeed)	winter	normal leaf, tall	white	SCCC
'Whistler'	2007	WA (ProGene)	winter	semi-leafless, short	white	FL, SCCC
'Windham'	2007	WA	winter	semi-leafless, medium	white	SCCC

*See Clark, 2019.
**Recommended as forage or cover crop in FL, GA, LA, or by Southern Cover Crops Council (SCCC).

There was 100% survival at the Brooksville PMC (20-25°F, Zone 9a) of all cultivars or selections of winter pea tested (data not reported), but winter survival of early flowering selections, Arvika, Dunn, and Maxum (Fig. 12), varied the most of the winter pea selections tested at the GAPMC (10-15 °F, Zone 8a), at the MSPMC (5-10°F, Zone 7b), and at the ETXPMC (15-20°F, Zone 8b). There was a trend for the earlier flowering selections to exhibit increasingly poorer survival as minimum temperature decreased between the Brooksville PMC, the GAPMC, and the MSPMC. Selections Dunn and Maxum had only 55% and 74% winter survival, respectively, at the GAPMC compared to >90% for all other selections, including Arvika (McGee, 2020). At the MSPMC, survival of Arvika, Dunn, and Maxum was lower than at the GAPMC and varied with year, ranging from a high 45% in 2017 to a low 25% in 2018 (Richard and Allison, 2020). Winter survival of later flowering selections at the MSPMC also differed between years, ranging between 87-100% in 2017 when minimum temperature was around 10°F and 47-87% in 2018 when minimum temperature was about 5°F.

The ETXPMC, which is in a warmer plant hardiness zone than the GAPMC, was an exception to this minimum temperature trend. Winter survival of Arvika, Dunn, and Maxum was <10% in 2016-17 but ranged from 55-69% in 2017-18. They attributed the improved survival of early flowering selections in 2017-18 due cooler soil temperatures that were a consequence of a 3 weeks later planting date that year. Cooler soil temperatures resulted in slower emergence of all winter pea selections tested and delayed the flowering time of Arvika, Dunn, and Maxum, but had no effect on flowering time of later flowering selections (Brakie and Shadow, 2020). At the early planting date in 2016-17 when survival was <10%, Arvika, Dunn, and Maxum flowered at 59, 100, and 89 DAP, respectively, but these early flowering selections flowered within 126-128 DAP when planted 3 weeks later in 2017-18. Peas in reproductive phase are generally more susceptible to frost injury (Lejeune-Hénaut et al., 1999), and the cooler soil temperatures in 2017-18, which delayed emergence and transition from vegetative to reproductive phases, resulted in better survival that year of the early flowering selections.

The regional survival results combined with the ETXPMC data, suggest that Dunn and Maxum are not true or at least modern “winter” pea selections as described by McGee et al. (2017), and are more appropriately classified as “spring” peas for management purposes. “Spring” types, such as Arvika, Dunn, and Maxum, might be useful to producers in Florida and southern Alabama and Georgia if fall planting dates that ensure overwintering can be reliably determined. Additionally, they might also be useful in certain production systems that need early maturing cover crops.

Emergence by 14 DAP at the Brooksville PMC was considered in the good range (61-90%) for most winter pea selections tested (Fig. 11) except ‘Lynx’, Frost Master, and ‘Whistler’. All selections except Lynx were rated as approaching excellent (>90%) emergence by 28 DAP; Lynx only rated good. The MSPMC reported that emergence, also between good and excellent, continued to improve up to 28 DAP, but the GAPMC reported emergence maxed out in the good range by 14 DAP (McGee, 2020; Richard and Allison, 2020).

All winter pea selections tested flowered at the Brooksville PMC between 73 to 84 DAP, which corresponds to the calendar dates of March 23 and April 4, 2018, except for ‘Survivor’ which did not flower at the Brooksville PMC (Fig. 12). Survivor flowered in mid-May 2018 at the GAPMC (McGee, 2020). Although the flowering date range was rather compressed at only 10 days at the Brooksville PMC, Arvika, Dunn, and Maxum all flowered at the start of the period

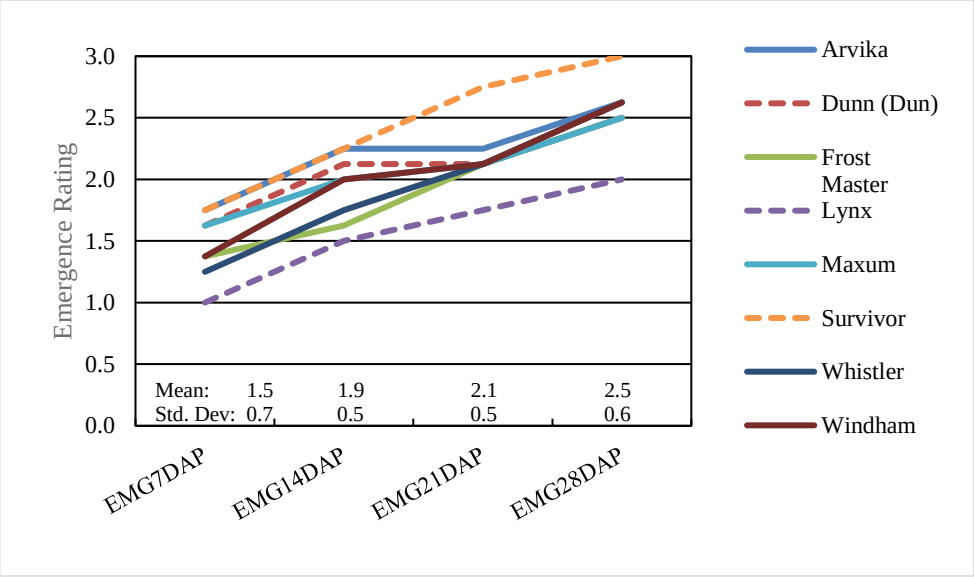

Figure 11. Average emergence rating for winter pea (*Pisum sativum*) selections at 7, 14, 21, and 28 days after planing (DAP) in 2016 and 2017 at the Brooksville PMC. Emergence rating scale: 0 = Poor (<25%), 1 = Moderate (25-60%), 2 = Good (61-90%), 3 = Excellent (>90%). Solid line indicates selections recommended as forage or cover crop in FL, GA, LA or by Southern Cover Crops Council.

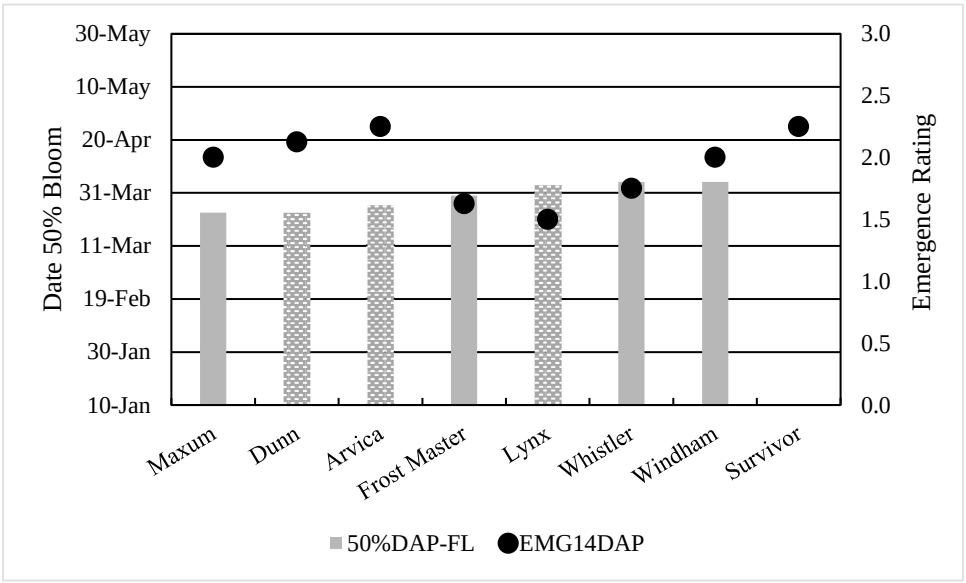

Figure 12. Maturity (bars) based on days after planting (2017 planting season only) until 50% flowering (Date 50% Bloom; Mean = Mar 29, SD = 13 days) and two year average emergence rating (circles) at 14 days after planting (EMG14DAP; Mean = 1.9, SD = 0.5) for winter pea (*Pisum sativum*) selections planted in 2016 and 2017 at the Brooksville PMC. Emergence rating scale: 0 = Poor (<25%), 1 = Moderate (25-60%), 2 = Good (61-90%), 3 = Excellent (>90%). Solid bars are selections recommended for grain, forage, or cover crop in FL, GA, LA, or by Southern Cover Crop Council.

(before March 26) with the remainder flowered at the end of the 10-day period (after March 30). Thus Arvika, Dunn, and Maxum maintained their regional designation (USDA-NRCS, 2020) of "early", most selections tested could be designated as "mid", and Survivor could be considered "late" (or not) flowering at the Brooksville PMC.

Flowering time in peas is controlled by a combination of photoperiod (long days) and temperature (Alcalde et al., 1999), but in general warmer temperatures will cause most pea selections to flower earlier and cool temperatures will delay flowering. Cool temperatures at the MSPMC in March and April 2018 where thought to be the reason the winter pea selections that survived the winter bloomed all at the same time about 30 days later in 2018 (Richard and Allison, 2020). Based on normal temperature range, producers in the panhandle of Florida can expect the winter peas tested to flower somewhat later than occurred at the Brooksville PMC and earlier than found at the GAPMC (McGee, 2020) assuming the day length requirements are met. Many modern winter pea lines, which are particularly cold tolerant based partly on late flowering, are genetically programed not to flower before a certain day length and may be relatively insensitive to warmer temperatures (Alcalde et al., 1999). Since maximum N in winter pea dry matter occurs shortly after flowering has initiated (Auld et al., 1982), producers in Florida or southern Georgia and Alabama, should be cautious about using winter pea selections with unknown flowering times in their given environment, particularly those advertised for better "frost tolerance", because it may not be needed and result in late flowering (e.g., as occurred with Survivor in Florida).

Conservation planners and producers also should consider the stem length and flower color of the selection when deciding what to use (Table 6). Plant breeders have been able to incorporate a naturally occurring mutation of winter peas that result in semi-leafless plant shape (see Clark, 2019, for photos), which has reduced plant height, improved lodging resistance, and reduced foliar disease without reducing forage or grain yield (Mikić et al., 2011). In addition, most modern semi-leafless types have also been selected for white flower which indicates reduced anthocyanin content which causes purple flowers and dark seed color (McGee, 2013). White flowered selections produce grains that can be marketed in food and feed classes and have forage with improved forage palatability (McGee, 2013; McGee et al., 2017). Improved palatability may be a consideration for producers planning on grazing a winter pea cover crop, although relative feed value of all winter peas, which is as high or higher than crimson clover and hairy vetch, has not been associated with flower color (Vann et al., 2021). And, although a shorter plant height is a benefit for grain production, lodging is less of a consideration when winter peas are used as a cover crop, particularly when grown in mixtures. Additionally, Australian work has demonstrated that taller, normal-leaved selections were more competitive with "weedy" grasses than short, semi-leafless types (McDonald, 2002). Thus, when weed control is the primary purpose for planting a cover crop that is going to be grazed, tall, white-flowered, normal leaf selections might be a better choice than white-flowered, semi-leafless types or tall, purple-flowered normal leaf selections.

Radish (a.k.a., daikon radish, oilseed radish, forage radish, fodder radish) – Radishes (*Raphanus sativus*) has been cultivated for many centuries by humans who have modified the plant to the extent that the species no longer exists in the wild (Clark, 2012). Human uses have included oil seed production, forage or fodder for animals, roots for culinary purposes (daikon-types), and, more recently, with attributes specifically as a cover crop (Gruver et al., 2019; Hybner, 2014; Jacobs, 2012). At one time there was a taxonomic classification associated with

end use and the literature still often sites *R. sativus* var. *oleiformis* for oil seed radish and *R. sativus* var. *longipinnatus* for forage and daikon-type radish (Weil et al., 2009), but such 'var.' designations are no longer considered correct (https://plants.usda.gov/home). For this report, the term 'radish' will be used for all cultivars or selections regardless of the original purpose they may have been selected for.

The radish cultivars or selection that were evaluated at the Brooksville PMC in planting year 2016 and 2017, their release date and location they were developed, and if they are currently recommended by FL, GA, or LA state extension or by SCCC are listed in Table 7. There was 100% survival at the Brooksville PMC (20-25°F, Zone 9a) of all radish cultivars or selections tested (data not reported); at the GAPMC (McGee, 2020) survival averaged 86.7% (53.5-100%). There was not even 100% winter kill of the radish selections at the MSPMC in 2017-18 planting season when minimum temperature reach 5°F.

Table 7. Radish (*Raphanus sativus*) cultivars or selections tested at the USDA, NRCS, Brooksville PMC in planting year 2016 and 2017.

Cultivar or Selection	Year Released	Location Developed	Recommended*
Big Dog™			
'Concorde'	2016	Germany	
'Control'	2016	Germany	
'Defender'	2005	Germany	SCCC
Driller		OR (GOSeed)	
EcoTill™			SCCC
'Graza' (3-way hybrid)	2004	NZ	
GroundHog™			
'Lunch'		NZ	SCCC
Nitro™			
Sodbuster		NZ	SCCC
Tillage® ('CCS779')	2012	US	

*Recommended as a cover crop in FL, GA, LA, or by Southern Cover Crops Council (SCCC).

Winter kill of radish is a function of minimum temperature (<23°F), duration (occurs several days in row), and growth stage (plants in rosette stage are more cold tolerant) (Brackie & Shadow, 2020; Clark, 2012; Hybner, 2014; Ngouajio & Mutch, 2014). Generally, when variation in winter kill was observed, the radish selections 'Concorde', 'Control', and 'Defender', which were developed in Germany, consistently exhibited the best winter survival. 'Graza', the New Zealand three-way hybrid, also exhibited winter survival similar to the German cultivars at both the GAPMC and the MSPMC (McGee, 2020; Richards and Allison, 2020). This is not unexpected given its parentage which includes seaside radish (*R. raphanistrum* subsp. *landra = R. maritimus*) and cabbage (*Brassica oleracea*) in addition to *R. sativus* (Stewart& Moorhead, 2004).

The results from the Brooksville PMC and GAPMC indicate that conservation planners and produces in Florida and southern Alabama and Georgia, who chose to use radish as a cover crop species, cannot plan on winter killing as a management tool. Some form of mechanical, chemical, or combination mechanical/chemical termination should be planned. Adaptation of

current radish selections to minimum temperatures in Florida and southern Alabama and Georgia, does indicate that radish should be useful as short season cover crop, alone or in a mixture, when planted in December or January following late season cotton or peanut harvest.

Emergence rating for radish selections, except for Graza, is shown in Fig. 13. Graza had essentially no emergence even at 28 DAP at the Brooksville PMC and its 28 DAP emergence was rated poor to moderate (26-60%) at the GAPMC and MSPMC (McGee, 2020; Richard and Allison, 2020). Nationally Graza was considered to have poorer and/or slower emergence than the other radish selections (Cover Crop Performance and Adaptation Trials at PMCs | NRCS Plant Materials Program (usda.gov)). Interestingly at the CAPMC where emergence was just considered slow, Graza produced average to above average DM production for the radishes tested (Bullard, 2019).

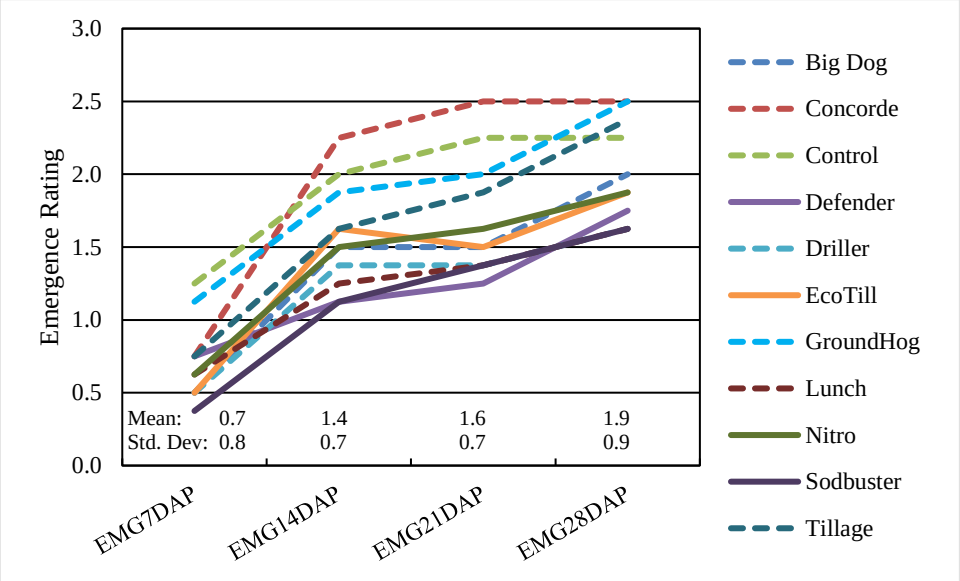

Figure 13. Average emergence rating for radish (*Raphanus sativus*) selections at 7, 14, 21, and 28 days after planing (DAP) in 2016 and 2017 at the Brooksville PMC. Emergence rating scale: 0 = Poor (<25%), 1 = Moderate (30-60%), 2 = Good (65-85%), 3 = Excellent (90-100%). Solid line indicates selections recommended as forage or cover crop by Southern Cover Crops Council.

All radish selections planted in the 2017-18 planting season flowered between March 23 – 29 at the Brooksville PMC (Fig. 14). In contrast at the GAPMC, all radish selections except Concorde, Control, Defender, and Graza were rated at 50% flower on March 2. That same year. Concorde, Control, and Defender were rated at 50% flower on March 23, while Graza did not reach 50% flower until April 3, 2018 (McGee, 2020).

Radish flowering is controlled by a combination of day length (long days) and vernalization (exposure to cold) (Erwin et al., 2002, Kang et al., 2016). Most radishes will eventually flower when days are long enough, but many selections will flower earlier when vernalization requirements are met (Erwin et al., 2002; Kang et al., 2016). The relatively narrow flowering observed at the Brooksville PMC and at PMC locations where the cover crops were planted as 'summer' species were probably a result of 'long enough' days (Jensen et al., 2019; Pokorny et al., 2020). But flowering differences between Brooksville PMC and the GAPMC suggest that

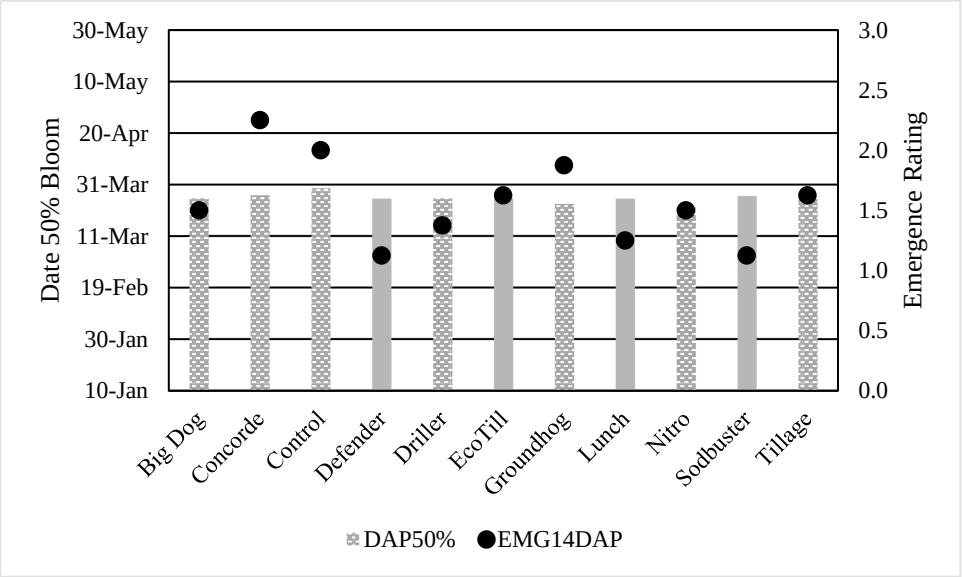

Figure 14. Maturity (bars) based on days after planting (2017 planting season only) until 50% flowering (Date 50% Bloom; Mean = Mar 25, SD = 3 days) and two year average emergence rating (circles) at 14 days after planting (EMG14DAP; Mean = 1.4, SD = 0.7) for radish (*Raphanus sativus*) selections planted in 2016 and 2017 at the Brooksville PMC. Emergence rating scale: 0 = Poor (<25%), 1 = Moderate (25-60%), 2 = Good (61-90%), 3 = Excellent (>90%). Solid bars are selections recommended for grain, forage, or cover crop in FL, GA, LA, or by Southern Cover Crop Council.

most of the radish selection tested have a vernalization requirement which may result in an earlier flowering date in Florida and southern Alabama and Georgia, than was observed at the Brooskville PMC in 2018 (see the vernalization discussion in the cereal rye section of this report). In contrast, Concorde, Control, and Defender did not exhibit an earlier flowering date at the GAPMC in 2018 (McGee, 2020). At most PMC locations where most of the radishes survived the winter, those cultivars were consistently 7-20 days later flowering than all other radish selections except Graza (McGee, 2020; Brakie and Shadow, 2020; Bullard, 2019; Young-Mathews, 2019). Graza, if it flowered, was consistently the latest flowering, usually 7 – 14 days later than Concorde, Control, or Defender.

Kang et al. (2016) showed that flowering date in radish is highly correlated with latitude of origin, and what they called the European group, which on average had the highest latitude of origin, were on average the latest flowering. Concorde, Control, and Defender cultivars developed in Germany fit this pattern. Graza from New Zealand, which is a lower latitude than Europe, does not fit this pattern. But Graza is not pure *R. sativus* and was specifically developed for repeated grazing events by adding genetics for seaside radish which is a biannual/perennial species that is very late to flower (Stewart & Moorhead, 2004). Later flowering means Graza might fit better into certain production windows in Florida and southern Alabama and Georgia; further testing is warranted before Graza can or cannot be recommended.

CONCLUSION

This study showed that producers in Florida and southern Alabama and Georgia can select at least one grass or legume cultivar or selection that matures within any 2-week interval between

March 1 and May 14 (Table 8). Radish cultivars or selections had a narrower maturity window with all cultivars or selections in flowering in March. Table 8 allows planners and producers to easily see what cultivar or selection might fit their cover crop window, but before deciding on a given cultivar or selection, review the appropriate specific species sections. In addition to flowering date, cultivars or selections often differed in establishment rate, disease, etc., which should be considered before making a final choice.

The following points also should be considered when making a cool season cover crop choice(s):

- Flowering dates can vary somewhat from year to year due to environmental differences, but relative maturity differences (e.g., early, mid, late) generally will remain the same.
- Failure to flower does not mean that a cultivar or selection cannot be used; it can be used as long as the cultivar or selection meets the purpose it was planted (e.g., enough biomass for erosion control, rapid emergence/cover for weed control, species diversity for soil health, etc.).
- Those cultivars or selections that mature around the time of cash crop planting date should maximize biomass and be the easiest to manage, particularly when a mixture is planted.
- If you have an option, rapid emergence should be the tie breaker within a maturity date group particularly when weed control is the purpose.
- Current crop insurance rules allow cover crops in Florida and southern Alabama and Georgia to be terminated at commodity crop planting or even later (https://www.rma.usda.gov), but earlier termination dates may be recommended (e.g., terminate a couple weeks prior to cash crop planting to minimize nutrient tie up by decomposing cover crop) and should be considered when making cultivar or selection choices.
- No cool season cover crop species will reliably winter kill in Florida or southern Alabama or Georgia; mechanical and/or chemical termination should be planned.
- Currently recommended material performed well in terms of establishment and flowering; additionally, this study identified cultivars or selections which might also be useful as cover crops in Florida and southern Alabama and Georgia, but they should be considered “experimental” and used with caution.
- When deciding between a cultivar, selection, trademark, or “common” or “VNS” (variety not stated) labelled seed, seed identified as “cultivar” will be the most consistent genetically and most likely to provide consistent year to year performance.

Table 8. Relative flowering date (based on Brooksville Plant Materials Center data unless otherwise noted) of different cultivars or selections of cool season cover crops when planted in central or north Florida (Rye = cereal rye; Oat = common oat; BO = black oat; CC= crimson clover; HV = hairy vetch; Woolypod = woolypod vetch; RC = red clover; WPea = winter pea; Radish = radish). **Bolded cultivar or selection names indicate they are currently recommended.**

Functional Group	March 1-14	March 15-30	April 1-14	April 15-30	May 1-14
Grass	**FL 401 (Rye)**		**Wrens abruzzi (Rye)**	**Bates (Rye)**	**Cosaque (Oat)**
	Merced (Rye)*		**Wintergrazer 70 (Rye)**	**Elbon (Rye)**	
			Horizon 306 (Oat)**	**Maton (Rye)**	
			Horizon 720 (Oat)**	**Maton II (Rye)**	
				Oklon (Rye)	
				Aroostook (Rye)*	
				Soil Saver (BO)	
Legume	**AU Sunup (CC)**	**Maxum (WPea)**	**Dixie (CC)**	Kentucky Pride (CC)*	**Survivor (WPea)§**
		Arvika (WPea)*	**AU Robin (CC)**	**Purple Bounty (HV)**	Cinammon Plus (RC)†
		Dunn (WPea)*	**AU Sunrise (CC)**	Villana (HV)*	Dynamite (RC)†
			Frost Master (WPea)	CCS Groff (HV)*	Freedom! (RC)†
			Whistler (WPea)	Purple Prosperity (HV)*	Kenland (RC)†
			Windham (WPea)	Tilth Pro TNT (HV)†	Starfire II (RC)†
			Lynx (WPea)*	**Barduro (RC)****	Wildcat (RC)†
			Lana (Woolypod)	Cyclone II (RC)†	
			AU Merit (HV)**		
			Southern Belle (RC)**		
			AU Red Ace (RC)**		
Forb	**Nitro (Radish)§**	**Defender (Radish)§**			
	Sodbuster (Radish)§	Concorde (Radish)*			
	EcoTill (Radish)§	Control (Radish)*			
	Big Dog (Radish)*				
	Driller (Radish)*				
	Lunch (Radish)*				
	Tillage (Radish)*				
	Groundhog (Radish)*				

*Currently not recommended but tested in this study and performed well; radish flowering date based on GA information; **use with caution**.
**Recommended but not tested in this study; flowering date based on literature.
†Currently not recommended but tested in this study; did not flower in FL, flowering date based on GA information; **use with caution**.
§Recommended and tested in study; flowering date based on GA information.

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