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Evaluation of Annual Cool Season Cover Crop Varieties in the Western Coastal Plain

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ABSTRACT

Annual cool season cover crops benefit soil health by increasing soil organic matter, nutrient cycling, suppressing weeds, and improving water infiltration. Successful cover crop plantings depend on selecting adapted varieties that meet soil health goals. The purpose of this study was to evaluate growth characteristics of fifty-nine commercially available and widely used cool season cover crops for adaptation to the Western Coastal Plain. The study was conducted at the USDA Natural Resources Conservation Service (NRCS) East Texas Plant Materials Center, Nacogdoches, Texas in 2016-2017 and 2017-2018. Cereal rye (*Secale cereal* L.), oats (*Avena sativa* L. and *Avena strigosa* Schreb.), crimson clover (*Trifolium incarnatum* L.), balansa clover (*Trifolium michelianum* Savi), red clover (*Trifolium pretense* L.), hairy vetch (*Vicia villosa* Roth) and [*Vicia villosa* Roth ssp. *varia* (Host) Corb], Austrian winter pea (*Pisum sativum* L.), and daikon radish (*Raphanus sativus* L.) varieties were evaluated for plant emergence, winter hardiness, days after planting to 50% bloom, and disease and insect resistance. Plots were seeded on 4 October 2016 and 27 October 2017. Austrian winter pea, crimson clover, vetch, and red clover exhibited increased emergence when planted in early October 2016 when soil temperature was warmer. 'Arvica 4010', 'Dunn', and 'Maxum' Austrian winter pea had less than 10% average winter survival when planted early, but significantly improved with a later planting date in 2017. 'AU Sunup' crimson clover was slow to emerge both years and 'Contea' was slower when planted later compared to other crimson clover varieties. Hairy vetch varieties had good winter survival and 'Lana' woollypod vetch reached 50% bloom three weeks earlier than the other varieties. Red clover cold hardiness improved with the planting date in 2017. Later planting slowed red clover growth which kept the seedlings close to the soil surface and insulated them from freezing temperatures. Cereal rye field emergence was good to excellent both study years. Cereal rye varieties 'Rymin', 'Hazlet', 'Guardian', and 'Brasetto' had severe rust (*Puccinia* sp.) infection and are not recommended for use in the Western Coastal Plain. 'Soilsaver' black oats had better winter survival when planted in late October and showed less disease symptoms compared to 'Cosaque' black seeded oats. Balansa clover and daikon radish show potential as cool season cover crops in the Western Coastal Plain, but study data is limited to 2017-2018 due to winterkill in 2016-2017. Further study is needed of balansa clover and daikon radish.

INTRODUCTION

Ancient societies such as China, Greece, and Rome used plants to improve soil quality. They seeded green manure crops in their fields to improve soil fertility and subsequent crop yield (Magdoff and Van Es, 2009). Roman poet Columella recommended lupines as a green manure crop for poor soils (Magdoff and Van Es, 2009). Today, cover crops are utilized for soil conservation, soil improvement, and organic N production. Grass cover crops conserve soil by reducing raindrop impact and their residue increases water infiltration, improving growing conditions for the proceeding cash crop (Clark, 2012). Legumes such as red clover and hairy vetch provide nitrogen for the subsequent crop which reduces fertilizer costs. Broadleaf cover crops suppress weeds by shading out seedlings and compete for moisture and nutrients. Mustard cover crops produce allelopathic chemicals inhibiting weed establishment (Clark, 2012). Cover crop mixes of grasses, legumes, and brassicas provide high quality winter forage for livestock grazing (University of Kentucky, 2012). Selecting adapted cover crop varieties is essential for

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uniting stand objectives and land managers expectations. The purpose of this study was to evaluate growth characteristics of commercially available annual cool season grass, legume, and forb varieties to determine adaptation to climatic conditions of the Western Coastal Plain.

MATERIALS AND METHODS

The study was conducted at the USDA-Natural Resources Conservation Service East Texas Plant Materials Center (ETPMC), Nacogdoches, TX in 2016-2017 and 2017-2018. Cover crop varieties were planted on a pure live seed (PLS) basis (Table 1). Legumes were inoculated with appropriate rhizobia before seeding. Plots were drill planted with a Hege Model 1000 precision cone planter (Hege Equipment Company, Colwich, Kansas) on 8 inch row spacing on 4 October 2016 and 27 October 2017. The 2017 seeding was delayed until a high fence was completed around the ETPMC field evaluation area. Plot size was 3.3-ft x 35-ft in a randomized complete block design with four replications. Plots were planted on Woden fine sandy loam and Bernaldo-Besner complex soils in 2016 and Woden fine sandy loam, Bernaldo-Besner complex, and Mollville-Besner complex soils in 2017. Non-legume varieties received 65 lb N/acre/year and all varieties received 65 lb P and K both years. Plots were moved to a new location in 2017 to avoid contamination with hard seed from the previous year. Plots were irrigated after planting to encourage uniform emergence but received no additional irrigation both study years. Rainfall was recorded from October to June both study years (Table 2).

Field emergence ratings, disease and insect ratings, winter survival, bloom period, and average foliage height were recorded for each plot both study years. Field emergence was visually estimated using a scale where 0=poor (less than 25%), 1=moderate (30-60%), 2=good (65-85%), and 3=excellent (90-100%) 7, 14, 21, and 28 days after planting (DAP). Disease and insect ratings were recorded visually on a 0-5 scale where 0=no damage and 5=severe damage. Plots were rated for disease at spring regrowth and at 50% bloom. Winter survival was determined by marking a one meter section of row in each plot and conducting plant counts prior to frost and again after spring regrowth. Bloom period was determined by recording beginning bloom and 50% bloom. Average foliage height was calculated by averaging the sum of three plant measurements taken from interior rows of each plot.

Study data for field emergence, % winter survival, days after planting to 50% bloom, and foliage height was analyzed in Statistix10 (Analytical Software, Tallahassee, FL) using mean and standard deviation to determine variation among varieties within a species.

Table 1. Species, cultivars and seeding rates of annual cool seasons planted in 2016 and 2017 at the USDA NRCS East Texas Plant Materials Center, Nacogdoches, Texas.

Common name	Species	Cultivar	PLS lb/acre	% PLS	Seeding rate lb/acre
Austrian winter pea	*Pisum sativum*	Arvica 4010	70	95	74
Austrian winter pea	*Pisum sativum*	Dunn	70	85	82
Austrian winter pea	*Pisum sativum*	Frost Master	70	85	82
Austrian winter pea	*Pisum sativum*	Lynx	70	98	71
Austrian winter pea	*Pisum sativum*	Maxum	70	92	76
Austrian winter pea	*Pisum sativum*	Survivor 15	70	80	88
Austrian winter pea	*Pisum sativum*	Whistler	70	90	78
Austrian winter pea	*Pisum sativum*	Windham	70	80	88
Balansa clover	*Trifolium michelianum*	Fixation	5	47	11
Balansa clover	*Trifolium michelianum*	Frontier	5	58	9
Black oats	*Avena sativa*	Cosaque	60	83	72
Black seeded oats	*Avena strigosa*	Soil Saver	60	98	61

Table 1 (cont.). Species, cultivars and seeding rates of annual, cool seasons planted in 2016 and 2017 at the USDA NRCS East Texas Plant Materials Center, Nacogdoches, Texas.

Common name	Species	Cultivar	PLS lb/acre	% PLS	Seeding rate lb/acre
Cereal Rye	*Secale cereale*	Aroostook	100	90	111
Cereal Rye	*Secale cereale*	Bates	100	88	113
Cereal Rye	*Secale cereale*	Brasetto	100	92	109
Cereal Rye	*Secale cereale*	Elbon	100	88	114
Cereal Rye	*Secale cereale*	FL 401	100	80	126
Cereal Rye	*Secale cereale*	Guardian	100	93	108
Cereal Rye	*Secale cereale*	Hazlet	100	84	119
Cereal Rye	*Secale cereale*	Maton	100	90	111
Cereal Rye	*Secale cereale*	Maton II	100	91	110
Cereal Rye	*Secale cereale*	Merced	100	84	119
Cereal Rye	*Secale cereale*	Oklon	100	90	112
Cereal Rye	*Secale cereale*	Rymin	100		
Cereal Rye	*Secale cereale*	Wheeler	100	82	122
Cereal Rye	*Secale cereale*	WinterGrazer 70	100	78	128
Cereal Rye	*Secale cereale*	Wren's Abruzzi	100	84	119
Crimson clover	*Trifolium incarnatum*	AU Robin	18	56	32
Crimson clover	*Trifolium incarnatum*	AU Sunrise	18	42	43
Crimson clover	*Trifolium incarnatum*	AU Sunup	18	91	20
Crimson clover	*Trifolium incarnatum*	Contea	18	60	30
Crimson clover	*Trifolium incarnatum*	Dixie	18	53	34
Crimson clover	*Trifolium incarnatum*	KY Pride	18	98	18
Hairy vetch	*Vicia villosa*	CCS Groff	18	90	20
Hairy vetch	*Vicia villosa*	Purple Bounty	18	78	23
Hairy vetch	*Vicia villosa*	Purple Prosperity	18	90	20
Hairy vetch	*Vicia villosa*	TNT	18	75	24
Hairy vetch	*Vicia villosa*	Villana	18	89	20
Woollypod vetch	*Vicia villosa* subsp. *varia*	Lana	18	98	18
Oilseed radish	*Raphanus sativus*	Big Dog	9	93	10
Oilseed radish	*Raphanus sativus*	Concorde	9	88	10
Oilseed radish	*Raphanus sativus*	Control	9	88	10
Oilseed radish	*Raphanus sativus*	Eco-till	9	88	10
Oilseed radish	*Raphanus sativus*	Graza	9	93	10
Oilseed radish	*Raphanus sativus*	Groundhog	9	85	11
Oilseed radish	*Raphanus sativus*	Lunch	9	93	10
Oilseed radish	*Raphanus sativus*	Sodbuster Blend	9	94	10
Oilseed radish	*Raphanus sativus*	Tillage	9	90	10
Oilseed radish	*Raphanus sativus*	Defender	9	97	9
Oilseed radish	*Raphanus sativus*	Driller	9	97	9
Oilseed radish	*Raphanus sativus*	Nitro	9	98	9

Table 1 (cont.). Species, cultivars and seeding rates of annual, cool seasons planted in 2016 and 2017 at the USDA NRCS East Texas Plant Materials Center, Nacogdoches, Texas.

Common name	Species	Cultivar	PLS lb/acre	% PLS	Seeding rate lb/acre
Red clover	*Trifolium pratense*	Cinnamon Plus	9	59	15
Red clover	*Trifolium pratense*	Cyclone II	9	60	15
Red clover	*Trifolium pratense*	Dynamite	9	59	15
Red clover	*Trifolium pratense*	Freedom	9	59	15
Red clover	*Trifolium pratense*	Kenland	9	80	11
Red clover	*Trifolium pratense*	Mammoth	9	88	10
Red clover	*Trifolium pratense*	Starfire	9	59	15
Red clover	*Trifolium pratense*	Wildcat	9	59	15

Results and Discussion

Temperature data for the study was recorded from A.L. Mangham Jr. Regional Airport 5.8 miles northeast of the ETPMC. Table 2 shows monthly average high and low temperatures. The first frost occurred 47 DAP on 20 November 2016. The first frost in 2017 was on 29 October, two days after planting. Monthly precipitation was recorded using a visual rain gauge at the ETPMC. Total rainfall was 39.3 inches in 2016-2017 and 26.7 inches in 2017-2018 during the study period, compared to an average of 38.1 inches for the same time frame from 2001 to 2015.

Table 2. Monthly average high and low temperatures and precipitation amounts for Nacogdoches, Texas during 2016-2017 and 2017-2018 cool season cover crop evaluations. USDA NRCS East Texas Plant Materials Center.

	Study Months									
Mean high temperature (F°)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Mean
2016-2017	83	73	61	64	72	74	78	84	87	75
2017-2018	66	73	59	55	64	74	74	87	1/--	69
Mean low temperature (F°)										
2016-2017	57	48	43	44	49	50	53	66	69	53
2017-2018	38	49	36	30	47	50	49	63	1/--	45
Monthly precipitation (in)										Total
2016-2017	2.7	3.5	6.2	3.5	2.5	1.9	5.6	12.9	0.5	39.3
2017-2018	0	3.5	4.6	2.9	6.1	5.8	3.6	0.2	1/--	26.7
Historic average total precipitation (in)2/										38.1

1/-- = no data was recorded for June 2018 because study was terminated in May 2018, 2/=historic average total precipitation during the study months from 2001 to 2015.

The 2016-2017 study was seeded 23 days earlier than the 2017-2018 evaluation. Warmer soil temperatures the first 28 DAP in 2016 aided seedling emergence of crimson clover, red clover, hairy vetch, Austrian winter pea, and daikon radish, and is in agreement with Butler et al. (2002), Wheaton (1993), and Teasdale et al. (2004) who recommend earlier planting of crimson clover, red clover, and hairy vetch, respectively. Krall et al. (2006) suggests planting winter pea into warm soils that are 40°F and rising at a depth of 2-3 inches for quick germination and seedling emergence.

Cereal rye

Cereal rye seedling emergence 14 DAP was similar regardless of planting date (Table 3). Popular forage varieties in east Texas, 'Maton', 'Oklon', 'Bates' and 'Elbon', had good to excellent emergence 14 DAP both years (Vendramini et al., 2006) (Table 3). 'Wintergrazer70', 'MatonII', 'Elbon', and 'Bates' showed the highest winter survival while 'FL401' and 'Merced' had the least in 2017 (Table 4). January 2017 temperatures were warmer compared to January 2018 when varieties had more winter damage. 'Aroostook', 'Wintergrazer 70', 'Maton', 'Merced', and 'Elbon' had greater than 60% winter damage (Table 4) but recovered by early spring. 'FL 401' and 'Merced' were selected for their early maturity and forage production (Briggle, 1959; Pfahler et al., 1985) and were earliest maturing varieties both study years (Table 4). These two varieties would be useful to producers wanting an early maturing cereal rye in their cover crop mix. 'Wheeler', 'Guardian', and 'Brasetto' were the latest maturing varieties in the study (Table 4). Northern varieties, 'Rymin', 'Hazlet', 'Guardian', and 'Brasetto', exhibited severe disease damage compared to other varieties in the 2017-2018 evaluation. Thornburg (1982) reports northern varieties moved too far south of their area of adaptation show increased disease susceptibility. These northern varieties are not recommended for the Western Coastal Plain.

Table 3. Mean values and standard deviations for field emergence of emergence groups (see below) of cereal rye cultivars at 7, 14, 21 and 28 days after planting in 2016 and 2017. USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Cultivar	Days after planting							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
Aroostook	3	1.7	3	3	3	3	3	3
Bates	3	1.5	3	2.2	3	2.2	3	2.7
Brasetto	3	0.7	3	1.5	3	1.5	3	1.5
Elbon	3	2.2	3	2.5	3	2	3	2.5
FL 401	3	1.2	3	2.5	3	2	3	2.2
Guardian	3	1	3	1.2	3	1.2	3	1.5
Hazlet	3	1.7	3	2.7	3	2.5	3	2.5
Maton	3	2.2	3	2.7	3	2.7	3	3
Maton II	3	1.2	3	2	3	2	3	2.5
Merced	3	2	3	2.7	3	2.5	3	2.7
Oklon	3	1.2	3	2.7	3	2.2	3	2.7
Rymin	3	2.2	3	3	3	3	3	3
Wheeler	3	2	3	2.7	3	3	3	3
Wintergrazer 70	3	2	3	3	3	2.7	3	3
Wren's Abruzzi	3	1.5	3	2.2	3	2	3	3
Mean	3	1.6	3	2.5	3	2.3	3	2.6
SD[2/]	0	0.8	0	0.8	0	0.8	0	0.7

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence); 2 = good (65-85% emergence); 3 = excellent (90-100% emergence), [2/]SD - standard deviation.

Table 4. Mean values and standard deviations for % winter hardiness, plant height and days after planting to 50% bloom for cereal rye cultivars in 2017 and 2018. USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
Aroostook	94	32	31	34	159	157
Bates	98	55	42	38	136	157
Brasetto	95	68	33	30	172	177
Elbon	98	39	35	38	169	158
FL 401	76	50	45	44	77	138
Guardian	94	68	29	31	183	181
Hazlet	80	53	25	27	172	173
Maton	96	37	37	37	146	154
Maton II	99	44	40	38	138	159
Merced	60	37	32	35	64	139
Oklon	97	49	36	34	157	158
Rymin	79	45	31	34	172	175
Wheeler	93	40	33	36	184	173
Wintergrazer 70	100	35	37	38	133	156
Wren's Abruzzi	97	60	41	43	146	153
Mean	90	48	35	36	147	159
SD[1/]	15	16	7	5	36	13

[1/]SD - Standard deviation.

Black Oats

'Cosaque' black seeded oats and 'Soilsaver' black oats had similar emergence both study years (Table 5). 'Soilsaver' showed increased winter survival in 2018 when planted later. Later planting of 'Soilsaver' is recommended in USDA Plant Hardiness Zone 8b to reduce potential winterkill (USDA ARS, 2016). 'Soilsaver' exhibited better disease resistance both years compared to 'Cosaque'. 'Cosaque' was severely infected by leaf rust (*Puccinia* sp.) both years, which limits its use in the Western Coastal Plain.

Table 5. Mean values and standard deviations of emergence groups (see below) of black oats and seeded black oats at 7, 14, 21 and 28 days after planting in 2016 and 2017. USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Cultivar	Days after planting							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
Cosaque	2.7	0.5	3.0	1.5	3.0	1.2	3.0	1.5
Soil Saver	3.0	0.2	3.0	1.2	3.0	1.2	3.0	1.5
Mean	2.9	0.4	3.0	1.4	3.0	1.2	3.0	1.5
SD[2/]	0.3	0.5	0	0.7	0	0.9	0	0.9

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence); 2 = good (65-85% emergence); 3 = excellent (90-100% emergence), [2/]SD - Standard deviation.

Table 6. Mean values and standard deviations for % winter hardiness, plant height and days after planting to 50% bloom for black oats cultivars in 2017 and 2018. USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
Cosaque	87	46	37	34	183	178
Soil saver	9	48	35	37	182	168
Mean	48	47	36	35	182	172
SD[1/]	44	11	3	5	2	6

[1/]SD – Standard deviation.

Crimson clover

'AU Sunup' was slow to emerge both years and 'Contea' was slow in 2018 when planted later (Table 7). Slow emergence of 'AU Sunup' or 'Contea' make them less suitable choices for early season weed suppression or soil protection. 'Dixie' or 'Kentucky Pride' would be better choices as they had highest emergence 14 DAP both years. All crimson clover varieties showed good winter survival in the evaluation (Table 8). Days after planting to 50% bloom was 157 ± 15 days in 2017 compared to 146 ± 7 days in 2018 when planted later (Table 8). Later planted crimson clover varieties have a shorter growing season compared to early plantings (Butler, 2002). 'AU Sunup' and 'AU Sunrise' were selected for early flowering in the southeastern US for row crop agriculture and were earliest maturing both years (Mosjidis, 2001; USDA NRCS Jimmy Carter Plant Materials Center, 2012). 'Kentucky Pride' was the latest maturing variety both years.

Table 7. Mean values and standard deviations of emergence groups (see below) of crimson clover cultivars at 7, 14, 21 and 28 days after planting in 2016 and 2017. USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Cultivar	Days after planting							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
AU Robin	1.5	0.7	2.2	1.2	2.5	1	3	1.5
AU Sunrise	1.2	1.5	2.5	1.5	2.5	2	3	2
AU Sunup	0.5	0	0.5	0	1	0	1.5	0
Contea	1.2	0.2	2.2	0.2	2.5	0.2	3	0.2
Dixie	1.5	2	3	2	3	2	3	2.5
Kentucky Pride	2	1.5	2.5	2	2.5	2	3	2.2
Mean	1.3	1	2.1	1.2	2.3	1.2	2.7	1.4
SD[/2]	1.1	1.1	1	1	0.8	1.1	0.6	1.2

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence; 2 = good (65-85% emergence); 3 = excellent (90-100% emergence), [2/]SD - Standard deviation.

Table 8. Mean values and standard deviations for % winter hardiness, plant height and days after planting to 50% bloom for crimson clover cultivars in 2017 and 2018. USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
AU Robin	87	100	17	21	157	146
AU Sunrise	95	100	20	19	144	139
AU Sunup	59	95	17	14	140	135
Contea	99	100	18	21	155	150
Dixie	99	100	16	22	162	150
Kentucky Pride	88	100	22	19	182	153
Mean	87	99	18	19	157	146
SD[1/]	16	4	4	4	15	7

[1/]SD - Standard deviation.

Balansa clover

Balansa clover failed to make a stand in 2016 because the small seeds were planted too deeply with a drill planter. Top dressing or broadcasting are preferable seeding methods. The few plants that emerged winterkilled, and data was not recorded for the 2016-2017 evaluation. Field emergence was poor in 2017 but the varieties eventually made a stand (Table 9). Frontier had 100% winter survival compared to 'Fixation' at 94% (Table 10). 'Fixation' was later maturing and more than twice as tall as 'Frontier' (Table 10). Balansa clover shows potential as a cool season cover crop in this region but additional study is needed before recommending this species.

Table 9. Mean values and standard deviations of emergence groups (see below) of balansa clover at 7, 14, 21 and 28 days after planting in 2016 and 2017. USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Cultivar	Days after planting/Year							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
Fixation	0	0.5	0.7	0	1.2	0.2	0.5	0
Frontier	0	0	0	0	0.2	0	0.2	0
Mean	0	0.2	0.4	0	0.7	0.1	0.4	0
SD[2/]	0	0.7	0.7	0	0.9	0.3	0.5	0

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence); 2 = good (65-85% emergence); 3 = excellent (90-100% emergence), [2/]SD - Standard deviation.

Table 10. Mean values and standard deviations for % winter hardiness, plant height and days after planting to 50% bloom for balansa clover cultivars in 2017 and 2018. USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
Fixation	[1/]	94	[1/]	13	[1/]	161
Frontier		100		6		136
Mean		96		10		150
SD [2/]		9		4		14

[1/]=cultivars winterkilled in 2016-2017 evaluation, [2/]SD -Standard deviation.

Red clover

'Freedom' and 'Dynamite' had the highest emergence at 28 DAP both study years (Table 11). 'Kenland', 'Mammoth', and 'StarfireII' were slow to emerge in 2017 (Table 11). Later planting in 2017 allowed seedlings to be insulated by ground temperatures during freeze events and increased winter survival from 49% in 2017 to 99% in 2018. 'Freedom', 'Cyclone II', 'Dynamite', and 'Cinnamon Plus' grew tall enough to close their canopies making them useful for weed suppression. Mean DAP to 50% bloom ranged from 212 ± 5 days in 2017 to 182 ± 5 days in 2018 (Table 12). The shorter interval between planting date to 50% bloom in 2018 is attributed to later planting date which shortened the growing season. 'Dynamite' was the earliest maturing and 'Wildcat' latest maturing both years. 'Mammoth' did not reach 50% bloom either year because it does not flower the year of seeding (Miller, 1984) (Table 12). Red clover was the latest maturing species in the evaluation both years at the ETPMC.

Table 11. Mean values and standard deviations of emergence groups (see below) of red clover cultivars at 7, 14, 21 and 28 days after planting in 2016 and 2017. USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Cultivar	Days after planting							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
Cinnamon Plus	1.2	0.7	1	0.5	1.2	0.7	1.7	1
Cyclone II	0.7	0.5	1.2	0.2	1	0.7	1.7	0.7
Dynamite	0.7	0.7	1.7	0.5	1.7	0.2	2	1
Freedom	2	0.7	2	0.7	2	1	3	1
Kenland	0.5	0.5	0.2	0	0.5	0	0.7	0
Mammoth	1	0.7	0.7	0	1	0	1	0.2
Starfire II	0.7	0.2	1.5	0	1.5	0	1.5	0
Wildcat	1.7	1	2	0.5	2.2	0.5	2.5	0.5
Mean	1	0.7	1.3	0.3	1.4	0.4	1.8	0.6
SD/2	1	0.7	1	0.6	1.1	0.6	1.2	0.7

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence; 2 = good (65-85% emergence); 3 = excellent (90-100% emergence), [2/]SD - Standard deviation.

Table 12. Mean values and standard deviations for % winter hardiness, plant height and days after planting to 50% bloom for red clover cultivars in 2017 and 2018. USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
Cinnamon Plus	43	98	23	23	214	183
Cyclone II	48	100	24	28	215	179
Dynamite	63	100	24	28	211	178
Freedom	61	100	20	26	211	179
Kenland	36	98	24	24	206	184
Mammoth	38	100	[2/]	[2/]	[2/]	[2/]
Starfire II	60	100	25	19	213	186
Wildcat	44	94	22	17	216	186
Mean	49	99	23	22	212	182
SD[1/]	20	4	4	6	5	5

[1/]SD - Standard deviation, [2/] - Mammoth normally does not bloom the first growing season.

Hairy vetch

Emergence was delayed until 14 DAP and 'Villana' lagged behind other varieties both study years (Table 13). All varieties, except 'Villana', had 66% to 92% winter hardiness in 2017 (Table 13). 'Villana' was lowest at 42%. 'Villana' had the highest winter hardiness of 75% and 'TNT' the lowest at 57% in 2018. 'CCS Groff', 'Lana', 'TNT', 'Purple Bounty', and 'Purple Prosperity' had lower winter survival when January temperatures were colder in 2018 (Table 2) (Table 13). 'Villana' and 'CCS Groff' were the tallest varieties at 27 and 28 inches both years and would be useful for weed suppression. 'Lana' woollypod vetch was earliest maturing as it reached 50% bloom 22 and 23 days ahead of the earliest hairy vetch 'Purple Prosperity' (Table 14). 'Lana' produces 100 to 300 lb N/acre under good growing conditions and would be a good N source for producers planting early spring crops (USDA NRCS California Plant Materials Center, 2017).

Table 14. Mean values and standard deviations for % winter hardiness, plant height and days after planting to 50% bloom for hairy vetch cultivars in 2017 and 2018. USDA NRCS East Texas Plant Materials Center, Nacogdoches, Texas.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
CCS Groff	80	63	27	28	182	171
Lana	83	71	26	20	153	145
Purple Bounty	66	67	26	27	180	169
Purple Prosperity	80	66	25	26	175	168
TNT	92	57	24	28	187	181
Villana	42	75	27	28	183	187
Mean	74	66	26	26	176	170
SD[1/]	25	16	3	4	13	14

[1/]SD - Standard deviation.

Table 13. Mean values and standard deviations of emergence groups (see below) of hairy vetch cultivars at 7, 14, 21 and 28 days after planting in 2016 and 2017. USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Cultivar	Days after planting							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
CCS Groff	0	0.3	1.7	0.5	2	1	3	1
Lana	0	0	2	0.3	2.2	0.7	3	1
Purple Bounty	0	0	1.7	0	2.2	1	3	1
Purple Prosperity	0	0.5	1	0.5	1.5	1	3	1
TNT	0	0	2	0.5	2.5	1	3	1.7
Villana	0.3	0	1.7	0	2	0.3	2.7	0.7
Mean	0	0.1	1.7	0.3	2.1	0.8	3	1
SD[/2]	0.2	0.4	1	0.5	0.7	0.4	0.2	0.6

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence); 2 = good (65-85% emergence); 3 = excellent (90-100% emergence), [2/]SD - standard deviation.

Winter Pea

Austrian winter pea varieties emerged by 7 DAP in 2016. Later planting delayed emergence until 14 or 21 DAP in 2017 (Table 15) while 'Frostmaster' and 'Lynx' had poor emergence at 28 DAP. 'Maxum', 'Dunn', and 'Arvica 4010' had less than 10% winter hardiness when planted early but improved when planted later in October (Table 16). An early or late seeding date for these three varieties would depend on their desired use in the cover crop mix. 'Arvica 4010', 'Dunn', and 'Maxum' matured an average of 65 and 37 days earlier than Whistler in 2017 and 2018 and would be suitable N sources for producers wanting short duration cover crops (Table 16). 'Survivor 15' was latest maturing both years (Table 16). Diseases such as powdery mildew (*Erysiphe* sp.) and *Fusarium* rot were observed in the plots but did not impact plant growth during evaluations.

Table 15. Mean values and standard deviations of emergence groups (see below) of winter pea cultivars at 7, 14, 21 and 28 days after planting in 2016 and 2017. USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Cultivar	Days after planting							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
Arvica 4010	2	0	2.7	0	3	1	3	1.2
Dunn	1.7	0	2.7	0	2.7	1	3	1.2
Frost Master	1.2	0	2.7	0	2.7	0	2.7	0.2
Lynx	1.2	0	2.2	0	2.2	0	2.5	0
Maxum	1.7	0	2.7	0.2	2.7	1	3	1.2
Survivor 15	2.7	0	2.7	0.7	3	1.2	3	1.5
Whistler	1.7	0	2.7	0.2	2.7	0.7	3	0.7
Windham	1.5	0	2.5	0.2	2.5	1	3	1
Mean	1.7	0	2.6	0.2	2.7	0.7	2.9	0.9
SD[/2]	0.7	0	0.5	0.4	0.5	0.5	0.3	0.6

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence); 2 = good (65-85% emergence); 3 = excellent (90-100% emergence), [2/]SD -Standard deviation.

Table 16. Mean values for % winter hardiness, plant height and days after planting to 50% bloom for winter pea cultivars in 2017 and 2018. USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
Arvica 4010	5	60	10	22	59	126
Dunn	8	55	11	21	100	127
Frost Master	67	72	28	27	163	166
Lynx	55	88	17	19	163	161
Maxum	4	69	10	24	89	128
Survivor 15	90	65	25	29	182	178
Whistler	78	77	20	22	148	164
Windham	81	74	17	18	157	161
Mean	48	70	19	22	140	151
SD[1/]	37	21	7	5	44	20

[1/]SD - Standard deviation.

Daikon Radish

Radish varieties had good emergence by 14 DAP and grew rapidly in October 2016. All varieties winterkilled when subjected to below freezing temperatures in November 2016. Older plants are more vulnerable to cold damage than seedlings in rosette stage (Gruver et al., 2017). Later planting in 2017 slowed emergence and plant development, but increased winter survival to 91% (Table 18). Winter survival was due to seedlings being close to the ground in rosette stage and protected from freezing temperatures. 'Graza' and 'Groundhog' had the highest winter survival of 100% and 'Big Dog' the lowest at 77% (Table 18). 'Concorde' was the tallest at 34 inches and 'Lunch' shortest at 20 inches (Table 18). Most radishes reached 50% bloom by 126 DAP (Table 18). 'Concorde', 'Control', and 'Defender' matured later at 132 and 135 days (Table 18). 'Concorde' and 'Control' are medium maturity varieties (Allied Seed LLC, 2019). 'Graza' matured latest at 145 DAP (Table 18). Graza remains in a vegetative stage longer than other cover crop radishes (Gruver et al., 2017). Radish show promise as a cover crop species in the western coastal plain region but further study is needed on an optimum planting date.

Table 17. Mean values and standard deviations of emergence groups (see below) of daikon radish sources at 7, 14, 21 and 28 days after planting in 2016 and 2017. USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Cultivar	Days after planting							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
Big Dog	2.2	0.2	2.7	0.7	2.7	1.2	3	2
Concorde	2.5	0.2	3	0.7	3	0.7	3	1.7
Control	2.5	0.5	2.7	1	2.7	1.2	3	1.5
Defender	1.7	0	2.2	0	2.5	0.5	2.7	0.5
Driller	2.2	0	2.7	0.5	2.7	1	2.7	1.5
EcoTill	2.2	0.2	2.7	0.5	2.7	1	2.7	1.2
Graza	0.2	0	0.7	0	1	0	1.7	0.2
Groundhog	2.5	0	3	1.2	3	1.2	3	1.7
Lunch	1.7	0	2.2	0.5	2.5	0.7	2.5	1.2
Nitro	2	0.2	2	1	2.7	1.2	2.7	1.7
Sodbuster	1.5	0	2.2	0.5	2.7	0.7	3	1
Tillage	2.2	0	2.2	0.7	2.5	1.5	2.5	1.7
Mean	2	0.1	2.4	0.6	2.6	0.9	2.7	1.3
SD[2/]	0.8	0.3	0.9	0.5	0.7	0.6	0.6	0.9

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence); 2 = good (65-85% emergence); 3 = excellent (90-100% emergence), [2/]SD - Standard deviation.

Table 18. Mean values for % winter hardiness, plant height and days after planting to 50% bloom for daikon radish sources in 2017 and 2018 at the USDA-NRCS East Texas Plant Materials Center, Nacogdoches, TX.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
Big Dog	[1/]	77	[1/]	24	[1/]	126
Concorde	[1/]	98	[1/]	34	[1/]	132
Control	[1/]	96	[1/]	31	[1/]	135
Defender	[1/]	85	[1/]	29	[1/]	132
Driller	[1/]	88	[1/]	24	[1/]	125
Eco Till	[1/]	87	[1/]	22	[1/]	125
Graza	[1/]	100	[1/]	28	[1/]	146
Groundhog	[1/]	100	[1/]	23	[1/]	126
Lunch	[1/]	96	[1/]	20	[1/]	126
Nitro	[1/]	90	[1/]	22	[1/]	126
Sodbuster	[1/]	91	[1/]	27	[1/]	126
Tillage	[1/]	89	[1/]	24	[1/]	126
Mean		91		26		129
SD[2/]		12		5		6

[1/] All varieties winterkilled in 2017, [2/]SD - Standard deviation.

Conclusions

Crimson clover, red clover, hairy vetch, Austrian winter pea, and most cereal rye varieties along with 'Soilsaver' black oats performed well showing good adaptation based on seedling emergence, percent winter survival, and days to 50% bloom. Early planting of crimson clover and vetch is recommended as 28 DAP emergence was two to three times higher respectively compared to later planting with only a 12% difference in winter hardiness. Later planting of all radish and red clover varieties, 'Arvica4010' winter pea, 'Dunn' winter pea, 'Maxum' winter pea, and 'Soilsaver' black oats improved their winter survival. Cereal rye varieties 'Aroostook', 'Wintergrazer70', 'Maton', 'Merced', and 'Elbon' had more than 60% winter damage in 2018 but recovered in spring. Northern cereal rye varieties 'Rymin', 'Hazlet', 'Guardian', 'Brasetto' and 'Cosaque' black seeded oats showed increased disease infection and are not recommended for the Western Coastal Plain. Radish was the earliest maturing species beginning bloom in late February while red clover was the latest providing excellent growth into late June. 'FL401' cereal rye, 'Merced' cereal rye, 'AU Sunrise' crimson clover, 'AU Sunup' crimson clover, 'Arvica4010' winter pea, 'Dunn' winter pea, 'Maxum' winter pea, and 'Lana' woollypod vetch were early maturing varieties. Information from this study will be useful to USDA-NRCS personnel and land managers when selecting cover crop varieties for conservation plantings. Further study of optimum planting dates and adaptation of radish and balansa clover varieties is needed before making additional recommendations regarding these species.

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