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Evaluation of Cool Season Cover Crops in Maryland

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ABSTRACT

Cool season, annual cover crops provide a variety of benefits to production agriculture such as suppressing weeds, controlling soil erosion, adding nitrogen, and numerous soil health improvements including improving soil organic matter, water holding capacity, soil structure, and nutrient retention and cycling. However, success of achieving these benefits with cover crop plantings depends on selecting species and varieties best adapted to local growing conditions and cropping system and goals. The purpose of this study was to evaluate sixty commercially available varieties of eight common annual, cool season species for their adaptation to Maryland and the surrounding region. Oats (*Avena sativa* L. and *Avena strigosa* Schreb.), cereal rye (*Secale cereal* L.), Austrian winter pea (*Pisum sativum* L.), daikon radish (*Raphanus sativus* L.), crimson clover (*Trifolium incarnatum* L.), red clover (*Trifolium pretense* L.), balansa clover (*Trifolium michelianum* Savi), and hairy vetch [*Vicia villosa* (Roth) and *Vicia villosa* Roth ssp. *varia* (Host) Corb] were evaluated for field emergence, winter hardiness, beginning of regrowth, days after planting to 50% bloom, and disease and insect resistance at the National Plant Materials Center in Beltsville, MD in 2015-2016, 2016-2017 and 2017-2018. Most species in general performed well, except for balansa clover and winter pea. Balansa clover showed poor fall, winter and early spring growth and survival. Some varieties of winter pea had poor winter survival and varieties that overwintered showed disease susceptibility in the spring. Crimson clover varieties had faster emergence, spring growth, and bloom than red clover varieties and exhibited good to excellent field emergence and good winter hardiness, with 'Kentucky Pride' exhibiting the best winter hardiness and the latest bloom. 'Cosaque' black seeded oats exhibited good winter hardiness while 'Soil Saver' black oats exhibited poor winter hardiness with a winter low of 8° F in 2017 and no winter hardiness with a winter low of 4° F in 2016 and -4° F in 2018. Cereal rye varieties had good to excellent field emergence with variation in beginning of growth and bloom time. Above ground growth of 'Florida 101' and 'Merced' winter-killed both years with subsequent weak shoot regrowth in the spring. Hairy vetch varieties exhibited excellent winter hardiness except 'Lana', which was susceptible to winter damage after excessive fall growth. The daikon radishes exhibited considerable variation in fall growth and winter hardiness between varieties and years. Smaller and lower-to-the-ground Daikon radishes survived the milder winters in 2016 and 2017, whereas all varieties winterkilled in 2018 due to large and exposed aboveground biomass during the much colder winter. Further evaluations of biomass production, in combination with different planting dates, are needed to determine adaptation of varieties for agriculture cropping systems.

INTRODUCTION

Integrating cover crops into cropping systems improves soil health, conserves energy, builds resilience, and manages climate risk (Lal, 2004; Reicosky and Forcella, 1998; Hargrove, 1986; Reeves, 1994). Leguminous cover crop species such as hairy vetch and crimson clover reduce nitrogen input requirements of subsequent commodity crops (Singh et al., 2004; Smith et al., 1987). Non-leguminous cover crops, such as small grains, effectively limit nitrate leaching and soil erosion (Meisinger et al., 1991). However, these benefits are not fully achieved unless the varieties planted are best adapted to meet the planting objectives (i.e. weed suppression, nitrogen scavenging, reducing soil erosion) and the producer's expectations. The purpose of this study is to evaluate growth characteristics of annual, cool season grass, legume, and forb varieties to determine their adaptation for cover cropping in Maryland and

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the surrounding region. Date of maturity and winter hardiness are important characteristics for choosing varieties suitable for specific cover cropping goals. For example, mechanical termination at the optimal stage of maturity can be aided by choosing varieties that mature at time required by the cropping system.

MATERIALS AND METHODS

The study was conducted at the USDA-Natural Resources Conservation Service Norman A. Berg National Plant Materials Center, Beltsville, MD in 2015-2016, 2016-2017 and 2017-2018. Annual, cool season cover crops were planted on a pure live seed (PLS) basis (Table 1). Legumes were inoculated with appropriate rhizobia before seeding. Plots were drilled planted 15 September 2015, 16 September 2016 and 15 September 2017, into rototilled and packed soil, with a conventional cone seeder on 6" rows on a Downer-Hammonton Complex Loamy Sand in 2015 and 2016 and on Christiana-Downer Complex silt loam with some Russet-Christiana Complex fine sandy loam in 2017. Plot size was 3-ft x 10-ft. Entries received 40 lb N/acre, 60 lb P/acre and 30 lb K/acre each year. A 3-wire electric fence was installed after planting to control deer browsing of the planted cover crops. Plots received a single irrigation immediately following planting each year using overhead sprinklers to initiate germination, but no additional irrigation was required. Monthly rainfall (October-April) and the minimum low temperature were recorded in 2015-2016, 2016-2017 and 2017-2018 (fig.1).

Table 1. Species, cultivars and seeding rates of annual cool seasons planted in 2015-2017 at the USDA NRCS Beltsville, Maryland, Norman A. Berg National Plant Materials Center.

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
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*	Prima**	100	95	106
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

* = Not planted in 2015, ** = Not Planted in 2016 and 2107

Approximately every 7 days, field emergence was estimated in each plot for four weeks after planting using the following rating scale: 0 = poor (<25% germination), 1 = moderate (30-60%), 2 = good (65–85%), 3 = excellent 90-100%). Field emergence data was taken only at day 28 in 2015. Entries were evaluated twice for disease and pest damage (rated from 0–5, where 0 = no damage and 5 = severe damage) following spring green-up (early March) and at 50% bloom (varied by species and cultivar). Very little apparent disease or insect damage was observed on most varieties during the study except significant disease of winter pea cultivars in the spring. Winter survival was evaluated from a 3-ft

Table 1 (cont.). Species, cultivars and seeding rates of annual, cool seasons planted in 2015-2017 at the USDA NRCS Beltsville, Maryland, Norman A. Berg National Plant Materials Center.

Common name	Species	Cultivar	PLS lb/acre	% PLS	Seeding rate lb/acre
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*	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*	Defender	9	97	9
Oilseed radish	*Raphanus sativus*	Driller	9	97	9
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*	Nitro	9	98	9
Oilseed radish	*Raphanus sativus*	Sodbuster Blend	9	94	10
Oilseed radish	*Raphanus sativus*	Tillage	9	90	10
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

* = Not planted in 2015

section of an interior row marked in each plot. Seedlings were counted at 1-inch increments across 36-inches in the fall (November) and following spring green-up (March) of the 2016-2017 and 2017-2018. Stem counts from a 3-ft section of interior row were used to determine winter survival in 2015-2016 for balansa clover, black and black seeded oats, and daikon radish varieties only. Bloom period was monitored and date of 50% bloom was recorded. Average plant height was determined from measurements taken from the interior rows of the plot to the average absolute height at the time of 50% bloom. Biomass samples for dry matter yield were taken in 2016 at 50% bloom from a 3 square foot area. Biomass samples for daikon radish and 'Soil Saver' black oats were taken November 2015 in anticipation of heavy winter damage. Biomass samples were dried in a drying oven at 55° C for a minimum of 48 hours.

The experimental design was a randomized complete block with 4 replications. To determine variation among varieties within a species, a mean and standard deviation were reported for field emergence, % winter hardiness, plant height, and days after planting (DAP) to 50% bloom using Statistix 10 (Analytical Software, Tallahassee, FL).

RESULTS AND DISCUSSION

Monthly rainfall for October through April in 2015-2016, 2016-2017 and 2017-2018 was recorded from a USDA weather station located near the study (fig. 1). Irrigation was applied immediately following planting each year to provide adequate moisture for germination but was not required thereafter. Total precipitation for the September through May growing season was 30 inches in 2015-2016, 24 inches in 2016-2017 and 25 inches in 2017-2018, compared to the normal of 31 inches. The first killing frost occurred in October 2015, 2016, and 2017 with the lowest temperature occurring in January 2016 (4° F), January 2017 (8° F) and January 2018 (-4° F) (fig. 2.).

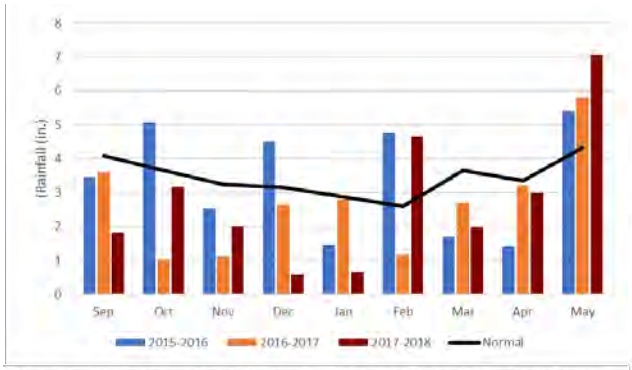

Fig.1. Monthly and normal rainfall in Sep-May 2015-2016, 2016-2017 and 2017-2018 Beltsville, MD.

Fig. 2. Monthly lowest temperature in Sep-May in 2015-2016, 2016-2017 and 2017-2018, Beltsville, MD.

Balansa Clover

Balansa clover varieties achieved moderate emergence in 2015 and 2016 (Table 2). 'Frontier' achieved moderate emergence and 'Fixation' achieved good to excellent emergence in 2017. 'Fixation' and 'Frontier' remained juvenile plants, often less than ½ inch tall through the fall and winter and exhibited very poor winter hardiness in all years of the study (Table 3). Due to very poor survival, biomass was not measured for 'Frontier'. 'Fixation' produced 0.4 tons per acre from the few surviving plants.

Table 2. Mean values and standard deviations of emergence groups (see below) of balansa clover cultivars at 7, 14, 21 and 28 days after planting in 2015-2017. USDA-NRCS Beltsville, MD.

Cultivar	Days after planting/Year								
	7		14		21		28		
	2016	2017	2016	2017	2016	2017	2015	2016	2017
Fixation	1[1/]	2.5	1	2.8	1	2.8	1	1	2.8
Frontier	1	1	1	1	1	1	1	1	1
Mean	1	1.8	1	1.9	1	1.9	1	1	1.9
SD[2/]		1.1		1.2		1.2			1.2

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

Table 3. Mean values and standard deviations for % winter hardiness, plant height and days after planting to 50% bloom in 2016-2018 for balansa clover cultivars at the USDA-NRCS Beltsville, MD.

Cultivar	% Winter hardiness			Plant height (in.)			DAP to 50% bloom		
	2016	2017	2018	2016	2017	2018	2016	2017	2018
Fixation	14	5	15	16	22		248	236	232
Frontier	8	0	21	7			248		232
Mean	11	2.3	18	11			248		232
SD[1/]	3.9	3.2	4.1	6.6					

[1/] Standard deviation.

Black Oats

Black oats ('Soil Saver') and black seeded oats ('Cosaque') provided excellent percent field emergence in all years (Table 4). 'Cosaque' exhibited excellent winter hardiness each year while Soil Saver had 35% winter hardiness in 2017 and was completely winterkilled in 2016 and 2018 (Table 5). Soil Saver has been winter hardy in plant hardiness zone 8b but is not recommended north of this zone due to insufficient cold hardiness (USDA-ARS, 2016; USDA-ARS, 2012). Soil Saver may be a good choice for producers needing a quick growing cool season cover crop requiring no chemical or mechanical termination prior to planting the cash crop in the spring. Plant heights were similar among varieties. Biomass samples for 'Soil Saver' black oats were taken in November since it was not expected to be winter hardy. 'Cosaque' produced 1.5 tons per acre dry matter and 'Soil Saver' 0.4 tons per acre.

Table 4. Mean values and standard deviations of emergence groups (see below) of black seeded oats and blacked oats at 7, 14, 21 and 28 days after planting in 2015-2017. USDA-NRCS Beltsville, MD.

Cultivar	Days after planting								
	7		14		21		28		
	2016	2017	2016	2017	2016	2017	2015	2016	2017
Cosaque	2.5[1/]	3	2.8	3	2.8	3	3	2.8	3
Soil Saver	2.5	3	3	3	3	3	3	3	3
Mean	2.5	3	2.9	3	2.9	3	3	2.9	3
SD[2/]			0.2		0.2			0.2	

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

Table 5. Mean values and standard deviations for % winter hardiness, plant height and days after planting to 50% bloom in 2016-2018 and dry matter in 2016 for black seeded oats and black oats at the USDA-NRCS Beltsville, MD.

Cultivar	% Winter hardiness			Plant height (in.)			DAP to 50% bloom			Dry matter (tons/acre)
	2016	2017	2018	2016	2017	2018	2016	2017	2018	2016
Cosaque	100	100	95	23	34	25	259	238	251	1.5
Soil saver	0	35	0	7	29			234		0.4[2/]
Mean	50	68	48	15	32			236		0.9
SD[1/]	71	46	67	11	3.2			2.8		0.8

[1/] Standard deviation. [2/] Biomass samples collected November 2015.

Cereal Rye

Cereal rye varieties had good to excellent emergence in all years (Table 6). Winter cover crops that quickly emerge and accumulate fall growth are important attributes for protecting the soil from sheet and rill erosion, suppressing problematic weeds, and scavenging residual soil nitrate nitrogen after commodity crops have matured (Shipley et al, 1992; Matias et al., 2004). Percent winter hardiness ranged from 100 to 57% with a mean of 98 ± 4.4% (mean and standard deviation) in 2017 and 96% ± 12% in 2018 (Table 7).

Table 6. 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 2015-2017. USDA-NRCS Beltsville, MD.

Cultivar	Days after planting								
	7		14		21		28		
	2016	2017	2016	2017	2016	2017	2105	2016	2017
Aroostock	3[1/]	3	3	3	3	3	3	3	3
Bates	3	3	3	3	3	3	NP[3/]	3	3
Brasetto	2.8	2.3	2.8	2.3	2.8	2.3	2	2.8	2.3
Elbon	2.8	3	2.8	3	2.8	3	3	2.8	3
FL 101	2.8	3	3	3	3	3	3	3	3
Guardian	2.8	2.5	2.8	2.5	2.8	2.5	2	2.8	2.5
Hazlet	2.8	2.8	2.8	2.8	2.8	2.8	1.8	2.8	2.8
Maton	2.8	3	3	3	3	3	3	3	3
Maton II	2.8	2.3	3	2.8	3	2.8	3	3	2.8
Merced	2.8	3	2.8	3	2.8	3	3	2.8	3
Oklon	3	3	3	3	3	3	2.3	3	3
Prima	NP[3/]	NP[3/]	NP[3/]	NP[3/]	NP[3/]	NP[3/]	1.5	NP[3/]	NP[3/]
Rymin	3	3	3	3	3	3	NP[3/]	3	3
Wheeler	3	2.5	3	3	3	3	1.8	3	3
Wintergrazer 70	3	3	3	3	3	3	3	3	3
Wren Abruzzi	2.8	3	3	3	3	3	3	3	3
Mean	2.9	2.8	2.9	2.9	2.9	2.9	2.5	2.9	2.9
SD[/2]	0.1	0.3	0.1	0.2	0.1	0.2	0.6	0.1	0.2

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence); 2 = good (65-85% emergence); 3 = excellent (90-100% emergence). SD[2/] standard deviation. NP[3/] Not Planted.

'Florida 101' and 'Merced' suffered winter damage (> 21% loss) in 2017 when temperatures reached 8° F in January 2017 and more significant damage (> 32% loss) at -4° F in January 2018. 'Florida 101' and 'Merced' in the fall of all years grew elongated stems, up to and including boot stage. This fall growth was severely winter damaged to the point of having no living material visible above the ground, but surviving plants grew new weak stems (34-38 inches) in the spring. All other varieties maintained greater than 99% winter hardiness in 2017 and 100% in 2018 despite a low temperature of -4° F in January 2018. Mean dry matter was 2.0 ± 0.9 tons per acre. 'Wren Abruzzi' had the greatest dry matter at 3.5 tons per acre. The mean plant height of varieties was 39 ± 7.52 inches in 2016, 48 ± 7.5 inches in 2017 and 46 ± 6.6 inches in 2018 (Table 7). Mean DAP to 50% bloom was 239 ± 8.7 days in 2016, 225 ± 5.2 days in 2017 and 240 ± 3.3 days in 2018. The existence of earlier blooming varieties, which can be terminated with a roller crimper may eliminate the need for herbicide termination and may extend the season for the main crop.

Table 7. Mean values and standard deviations for % winter hardiness, plant height and days after planting to 50% bloom in 2016-2018 and dry matter in 2016 for cereal rye cultivars at the USDA-NRCS Beltsville, MD.

Cultivar	% Winter hardiness		Plant height (in.)			DAP to 50% bloom			Dry matter (tons/acre)
	2017	2018	2106	2017	2018	2016	2017	2018	2016
Aroostock	100	100	40	52	47	232	220	239	1.8
Bates	100	100	NP[2/]	51	49	NP[2/]	220	237	NP[2/]
Brasetto	100	100	33	37	34	247	234	243	1.4
Elbon	99	100	39	54	50	232	222	239	1.9
FL 101	86	57	27	34	38	247	222	237	0.5
Guardian	100	100	44	48	45	247	233	246	1.7
Hazlet	100	100	37	47	44	247	232	244	1.4
Maton	100	100	45	51	52	232	222	237	2.3
Maton II	100	100	45	53	54	227	222	239	3
Merced	88	77	25	34	35	247	222	239	0.7
Oklon	100	100	42	55	52	232	222	239	3.3
Prima	NP[2/]	NP[2/]	39	NP[2/]	NP[2/]	247	NP[2/]	NP[2/]	1.4
Rymin	100	100	NP[2/]	45	41	NP[2/]	227	245	NP[2/]
Wheeler	100	100	53	57	53	247	233	245	2.7
Wintergrazer 70	100	100	39	51	47	232	222	239	2.0
Wren Abruzzi	100	100	44	50	54	227	221	237	3.5
Mean	98	96	39	48	46	239	225	240	2.0
SD[1/]	4.4	12	7.2	7.5	6.6	8.7	5.2	3.3	0.9

[1/]SD - Standard deviation. NP[2/] Not Planted.

Crimson Clover

Crimson clover showed good to excellent field emergence in all years for all varieties except 'Contea' and 'AU Sunup' (Table 8). Mean winter hardiness was 91 ± 6.9% in 2017 and 92 ± 8.2% in 2018 (Table 9). 'Kentucky Pride' was the only crimson clover cultivar not to exhibit winter damage in 2016 or 2017. All other varieties exhibited good to excellent winter hardiness. Mean dry matter was 2.6 ± 0.5 tons per acre and 'Kentucky Pride' had the greatest dry matter at 3.3 tons per acre. Mean plant height was similar among varieties (15 ± 2.9 inches in 2016, 19 ± 2 inches in 2017, 16 ± 1.5 inches in 2018). 'AU Sunup' was consistently among the shortest and 'Kentucky Pride' was the tallest cultivar each year (Table 9). Mean DAP to 50% bloom was 239 ± 6.1 days in 2016, 222 ± 3.6 days in 2017 and 236 ± 3.3 days in 2018 (Table 9). 'Kentucky Pride' bloomed seven days later than other varieties in 2016, three days later in 2017, and 6 days later in 2018. The bloom period of 'Kentucky Pride' was later than the mean for cereal rye varieties each year (seven days later in 2016, and two days in 2017 and 2018). 'Kentucky Pride' could make a suitable companion to mid to late blooming cereal rye varieties where a synchronous bloom time is desired to achieve adequate termination with a roller crimper without an herbicide application.

Table 8. Mean values and standard deviations of emergence groups (see below) of crimson clover cultivars at 7, 14, 21 and 28 days after planting in 2015-2017. USDA-NRCS Beltsville, MD.

Cultivar	Days after planting								
	7		14		21		28		
	2016	2017	2016	2017	2016	2017	2015	2016	2017
AU Robin	2[1/]	3	2.8	3	2.8	3	3	2.8	3
AU Sunrise	2.3	3	2.8	3	2.8	3	3	2.8	3
AU Sunup	1	2	1	2	1	2	2	1	2
Contea	0.3	1.5	0.3	1.5	0.3	1.5	2.5	0.3	1.5
Dixie	2.3	3	2.8	3	2.8	3	2.5	2.8	3
Kentucky Pride	2.5	3	3	3	3	3	3	3	3
Mean	1.7	2.6	2.1	2.6	2.1	2.6	2.7	2.1	2.6
SD[/2]	0.9	0.7	1.2	0.7	1.2	0.7	0.4	1.2	0.7

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

Table 9. Mean values and standard deviations for % winter hardiness, plant height and days after planting to 50% bloom in 2016-2018 and dry matter in 2016 for crimson clover cultivars at the USDA-NRCS Beltsville, MD.

Cultivar	% Winter hardiness		Plant height (in.)			DAP to 50% bloom			Dry matter (tons/acre)
	2017	2018	2016	2017	2018	2016	2017	2018	2016
AU Robin	90	99	12	19	15	232	221	235	2.2
AU Sunrise	87	94	15	19	15	240	220	235	2.5
AU Sunup	88	81	12	16	14	232	217	232	2.0
Contea	97	84	16	17	15	240	224	236	3.1
Dixie	81	97	15	20	17	241	223	236	2.6
Kentucky Pride	100	100	20	21	18	248	227	242	3.3
Mean	91	92	15	19	16	239	222	236	2.6
SD[1/]	6.9	8.2	2.9	2	1.5	6.1	3.6	3.3	0.5

[1/]SD - Standard deviation.

Hairy Vetch

Hairy vetch varieties had good to excellent field emergence in all years by 28 DAP (Table 10). Hairy vetch varieties exhibited excellent winter hardiness in 2017 and 2018 except for 'Lana' (Table 11). 'Lana' wooly pod vetch (*Vicia villosa* subsp. *varia*) may not have the same well documented winter hardiness as hairy vetch (Clark, 2012). Nearly all plants of 'Lana' winter-killed in 2016 following vigorous fall growth that was uncharacteristic of winter-hardy hairy vetch varieties. Surviving 'Lana' plants yielded only 0.3 tons/acre compared to the 2.12 tons/acre average of the other varieties. Mean vetch height was 19 ± 4.8 inches in 2016, 27 ± 1.3 inches in 2017, and 25 ± 2.6 inches in 2018 (Table 11). Mean DAP to 50% bloom was 256 ± 4.9 days in 2016, 242 ± 8.6 days in 2017 and 248 ± 9.8 days in 2018. 'Lana' woollypod vetch reached 50% bloom 7, 19 and 12 days sooner than the other hairy vetch varieties in 2016, 2017 and 2018. 'Lana' vetch bloomed synchronously with many cereal rye varieties in this study and could make a good choice for planting as a mix where termination with a roller crimper without herbicide application is desired.

Table 10. Mean values and standard deviations of emergence groups (see below) of hairy vetch cultivars at 7, 14, 21 and 28 days after planting in 2015-2017. USDA- Beltsville, MD.

Cultivar	Days after planting								
	7		14		21		28		
	2016	2017	2016	2017	2016	2017	2015	2016	2017
CCS Groff	2[1/]	2	2.8	3	2.8	3	3	2.8	3
Lana	2.3	1.5	3	3	3	3	3	3	3
Purple Bounty	2.3	1.8	2.8	3	2.8	3	3	2.8	3
Purple Prosperity	2	2	2.5	3	2.5	3	3	2.5	3
TNT	2	1.8	2.8	3	2.8	3	3	2.8	3
Villana	2	1.5	2.3	3	2.3	3	3	2.3	3
Mean	2.1	1.8	2.7	3	2.7	3	3	2.7	3
SD[/2]	0.1	0.2	0.3		0.3			0.3	

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

Table 11. Mean values and standard deviations for % winter hardiness, plant height and days after planting to 50% bloom in 2016-2018 and dry matter in 2016 for hairy vetch cultivars at the USDA-NRCS Beltsville, MD.

Cultivar	% Winter hardiness		Plant height (in.)			DAP to 50% bloom			Dry matter (tons/acre)
	2017	2018	2016	2017	2018	2016	2017	2018	2016
CCS Groff	97	100	23	27	24	255	247	247	2.5
Lana	92	67	12	28	22	248	225	232	0.3
Purple Bounty	100	100	25	27	25	255	245	244	2.4
Purple Prosperity	98	100	18	26	22	259	244	247	1.9
TNT	100	96	18	25	26	259	247	258	2
Villana	97	97	16	29	29	262	245	258	1.8
Mean	97	93	19	27	25	256	242	248	1.8
SD[1/]	3.1	13	4.8	1.3	2.6	4.9	8.6	9.8	0.8

[1/]SD - Standard deviation.

Daikon Radish

Percent field emergence of daikon radish varieties were moderate in 2015, moderate to excellent in 2016 and good to excellent in 2017 except for 'Graza' with poor and moderate emergence in 2016 and 2017 (Table 12). There was considerable variation in percent winter hardiness among varieties in 2016 and 2017, and none survived the winter in 2018 (Table 13). All daikon radish varieties exhibited small growth in fall 2016 with tubers often not exposed above ground, whereas all varieties grew very large in fall 2017 with all tubers exposed well above ground and were subsequently winterkilled (Table 13). 'Concorde', 'Control', 'Defender', and 'Graza' averaged 57% to 75% winter survival in 2017. All other varieties ranged from 3% to 16% winter survival in 2017 except for 'Tillage' (0%). Radish plants that overwintered often received some winter damage that resulted in rotting and eventual death prior to bloom. 'Concorde', 'Control', 'Defender', 'Graza', and 'EcoTill' were the only varieties with healthy individuals surviving through bloom in 2017. 'Concorde', 'Control', 'Defender', and 'Graza' bloom heights ranged from 16 to 23 inches in 2017 (Table 13). DAP to 50% bloom in 2017 was similar among surviving varieties with a mean of 221 ± 2.2 days. Daikon radish biomass samples were taken in November 2015 since the plants were not expected to be winter hardy. Dry matter was similar among varieties with a mean of 0.4 ± 0.1 tons per acre.

Table 12. Mean values and standard deviations of emergence groups (see below) of daikon radish sources at 7, 14, 21 and 28 days after planting in 2015-2017. USDA-NRCS Beltsville, MD.

Cultivar	Days after planting								
	7		14		21		28		
	2016	2017	2016	2017	2016	2017	2015	2016	2017
Big Dog	2.3[1/]	2.8	2.3	2.8	2.3	2.8	NP[3/]	2.3	2.8
Concorde	2.8	2.5	3	3	3	3	NP[3/]	3	3
Control	2.8	3	3	3	3	3	NP[3/]	3	3
Defender	1.3	1.8	1.3	2	1.3	2	1.3	1.3	2
Driller	2.5	2.5	2.5	2.8	2.5	2.8	1.3	2.5	2.8
EcoTill	2.5	3	2.5	3	2.5	3	1.3	2.5	3
Graza	0.5	1.3	0.5	1.3	0.5	1.3	NP[3/]	0.5	1.3
Groundhog	2.8	3	2.8	3	2.8	3	1	2.8	3
Lunch	1.3	2.3	1.5	2.3	1.5	2.3	1	1.5	2.3
Nitro	2.3	2.3	2.8	3	2.8	3	1	2.8	3
Sodbuster	1.3	2	1.8	2.3	1.8	2.3	1.5	1.8	2.3
Tillage	2	3	2	3	2	3	1	2	3
Mean	2	2.4	2.1	2.6	2.1	2.6	1.2	2.1	2.6
SD[2/]	0.8	0.6	0.8	0.6	0.8	0.6	0.2	0.8	0.6

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence); 2 = good (65-85% emergence); 3 = excellent (90-100% emergence). SD[2/] standard deviation. NP[3/] Not Planted.

Table 13. Mean values and standard deviations for % winter hardiness, plant height and days after planting to 50% bloom in 2016-2018 and dry matter in November 2015 for daikon radish cultivars at the USDA-NRCS Beltsville, MD.

Cultivar	% Winter hardiness			Plant height (in.)		DAP to 50% bloom		Dry matter (tons/acre)
	2016	2017	2018	2017	2018	2017	2018	Nov 2015
Big Dog	NP[2/]	4	0					NP[2/]
Concorde	NP[2/]	57	0	17		220		NP[2/]
Control	NP[2/]	64	0	23		219		NP[2/]
Defender	10	51	0	16		222		0.4
Driller	14	3	0					0.3
EcoTill	2	7	0	2		223		0.3
Graza	NP[2/]	75	0	19		224		NP[2/]
Groundhog	6	7	0					0.4
Lunch	8	4	0					0.3
Nitro	6	9	0					0.3
Sodbuster	2	16	0					0.4
Tillage	0	0	0					0.5
Mean	6	25	0	15		221		0.4
SD[1/]	4.5	28		8		2.2		0.1

[1/]SD - Standard deviation. NP[2/] Not Planted.

Red Clover

Red clover varieties had moderate to good field emergence in 2016 and good to excellent in 2015 and 2017 but needed 21 DAP in 2016 and 14 DAP in 2017 to reach full emergence for all varieties (Table 14). All varieties in 2017 sustained moderate winter damage with a winter hardiness mean of 79% ± 8.9%, except 'Cinnamon Plus' with excellent winter hardiness of 97% (Table 15). All varieties exhibited excellent winter hardiness in 2018 with a mean of 98% ± 3.6%. Mean plant height was 16 ± 0.7 inches in 2016, 21 ± 1.4 inches in 2017 and 22 ± 2 inches in 2018. Mean DAP to 50% bloom was 259 ± 2.5 days in 2017 to 258 ± 11 days in 2018 (Table 15). 'Mammoth' reached 50% bloom 5 and 26 days later than other varieties in 2017 and 2018, respectively. Mean dry matter was 0.9 ± 0.2 tons per acre. 'Dynamite' had the greatest dry matter at 1.3 tons per acre.

Table 14. Mean values and standard deviations of emergence groups (see below) of red clover cultivars at 7, 14, 21 and 28 days after planting in 2015-2017. USDA-NRCS Beltsville, MD.

Cultivar	Days after planting								
	7		14		21		28		
	2016	2017	2016	2017	2016	2017	2015	2016	2017
Cinnamon Plus	2[1/]	2.8	2.8	3	2.8	3	2.8	2.8	3
Cyclone II	1.5	2.8	2.5	2.8	2.5	2.8	2.8	2.5	2.8
Dynamite	1.8	3	3.	3	3	3	3	3	3
Freedom	2	3	2.3	3	2.3	3	3	2.3	3
Kenland	1.3	1.5	1.5	2	1.8	2	2	1.8	2
Mammoth	1.3	2.8	1.8	2.8	1.8	2.8	NP[3/]	1.8	2.8
Starfire II	1	1.5	1	1.8	1.3	1.8	2	1.3	1.8
Wildcat	1.8	3	2.3	3	2.3	3	2.5	2.3	3
Mean	1.6	2.5	2.1	2.7	2.2	2.7	2.6	2.2	2.7
SD[/2]	0.4	0.6	0.7	0.5	0.6	0.5	0.4	0.6	0.5

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence; 2 = good (65-85% emergence); 3 = excellent (90-100% emergence). SD[2/] standard deviation. NP[3/] Not Planted.

Table 15. Mean values and standard deviations for % winter hardiness, plant height and days after planting to 50% bloom in 2016-2018 and dry matter in 2016 for red clover cultivars at the USDA-NRCS Beltsville, MD.

Cultivar	% Winter hardiness		Plant height (in.)			DAP to 50% bloom		Dry matter (tons/acre)
	2017	2018	2016	2017	2018	2017	2018	2016
Cinnamon Plus	97	100	16	22	24	259	256	0.6
Cyclone II	75	100	16	22	19	229	255	0.7
Dynamite	72	99	16	21	20	257	253	1.3
Freedom	74	96	16	22	22	256	254	0.8
Kenland	79	100	18	21	22	257	252	1
Mammoth	69	91	NP[2/]	18	25	264	284	NP[2/]
Starfire II	86	100	17	20	22	259	254	1
Wildcat	77	94	16	22	23	259	256	0.7
Mean	79	98	16	21	22	259	258	0.9
SD[1/]	8.9	3.6	0.7	1.4	2	2.5	11	0.2

[1/]SD - Standard deviation. NP[2/] Not Planted.

Austrian Winter Pea

Austrian winter pea varieties had moderate to good field emergence 7 DAP and good to excellent 14 DAP and thereafter in 2016 (Table 16). Emergence was excellent for all varieties in 2015 and 2017. Percent winter hardiness varied among varieties (Table 17). Clark (2007) reported winter damage to winter peas can occur at 10° F. Temperatures below 10° F occurred in January 2017 (8° F), December 2017 (8° F), January 2018 (-4° F) and February 2018 (7° F) (fig. 2). Despite lower temperatures in 2017-2018, mean winter hardiness was similar at 39% ± 39% and 39% ± 34% for 2017 and 2018 (Table 17). 'Frostmaster', 'Linx', 'Survivor', 'Whistler' and 'Windham' exhibited good winter survival. 'Arvica 4010', 'Dunn', and 'Maxum' exhibited 0% winter hardiness both years. All varieties that survived into spring 2016 and 2017 were damaged or killed from disease and plants did not make seed. Varieties that survived into spring 2018 were less affected by disease with some producing seed. 'Windham' had the highest dry matter yield with 0.8 tons per acre, with other varieties not exceeding 0.3 tons per acre.

Table 16. Mean values and standard deviations of emergence groups (see below) of winter pea cultivars at 7, 14, 21 and 28 days after planting in 2015-2017. USDA-NRCS Beltsville, MD.

Cultivar	Days after planting								
	7		14		21		28		
	2016	2017	2016	2017	2016	2017	2015	2016	2017
Arvica 4010	2[1/]	3	2.8	3	2.8	3	3	2.8	3
Dunn	2.5	3	2.8	3	2.8	3	3	2.8	3
Frost Master	2	3	2.8	3	2.8	3	2.8	2.8	3
Lynx	1	3	1.8	3	1.8	3	3	1.8	3
Maxum	1.5	3	2.8	3	2.8	3	2.8	2.8	3
Survivor 15	2.3	3	3	3	3	3	3	3	3
Whistler	1	3	2.5	3	2.5	3	3	2.5	3
Windham	1.5	3	2.8	3	2.8	3	3	2.8	3
Mean	1.7	3	2.6	3	2.6	3	2.9	2.6	3
SD[/2]	0.6		0.4		0.4		0.1	0.4	

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

Table 17. Mean values for % winter hardiness, plant height and days after planting to 50% bloom in 2016-2018 and dry matter in 2016 for winter pea cultivars at the USDA-NRCS Beltsville, MD.

Cultivar	% Winter hardiness		Plant height (in.)			DAP to 50% bloom		Dry matter (tons/acre)
	2017	2018	2016	2017	2018	2017	2018	2016
Arvica 4010	0	0						
Dunn	0	0						
Frost Master	14	63	10		21		250	0.3
Lynx	70	74	6	4	14	245	243	0.2
Maxum	0	0	10					0.1
Survivor 15	82	47	16	6	27	245	250	0.2
Whistler	84	44		14	14	243	243	
Windham	59	81	21		12		245	0.8
Mean	39	39	13	7.7	18	244	246	0.3
SD[1/]	39	34	5.7	5.2	6.3	1.3	3.6	0.3

[1/]SD - Standard deviation.

CONCLUSIONS

This 2-year evaluation of commercially available cereal rye, crimson clover, hairy vetch, daikon radish, red clover, Austrian winter pea, balansa clover, and black oats and black seeded oats provided beneficial information on best adapted varieties for Maryland and the surrounding region. Most of the species and varieties exhibited good adaptation based on field emergence, winter hardiness, and DAP to 50% bloom; however, balansa clover varieties exhibited poor fall growth and winter hardiness, and pea varieties exhibited either poor winter hardiness or poor disease resistance. Red clover varieties also exhibited poorer performance due to slower and lower field emergence and their usefulness as a cover crop is limited by later growth and bloom in the spring. Varieties of Cereal rye, crimson clover, hairy vetch, daikon radish, black oats and black seeded oats exhibited good performance but with significant variation between varieties in bloom period and winter hardiness. This bloom period and winter hardiness information can be used by producers to incorporate varieties into farming systems that meet their cropping goals.

Additional research on cultivar adaptation and biomass production are needed to further develop variety (s) recommendations for different agricultural cropping systems in the Mid-Atlantic region.

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