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Elsberry Plant Materials Center
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Evaluation of Selected Cool Season Cover Crop Varieties in Northeast Missouri

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ABSTRACT

Cover crops are beneficial to agricultural systems because they provide a living root in the soil year-round. They can improve soil nutrient and moisture content, reduce runoff, increase helpful soil biota, suppress and compete with weeds, control pests and offer many other benefits to farms. Management of cover crops can be influenced by regional and site-specific factors. Environmental factors cause plants to develop special adaptations to live in certain locations. These same features potentially make it difficult for the plant to survive in a newly introduced environment. Cover crop varieties offer a multitude of specific criteria that can fulfill the special requirements of diverse farms. Special consideration must be taken when selecting cover crop varieties in order to optimize their use in agroecosystems. Balansa clover (*Trifolium michelianum*), black oat (*Avena strigosa*), black seeded oat (*Avena sativa*), cereal rye (*Secale cereale*), crimson clover (*Trifolium incarnatum*), hairy vetch (*Vicia villosa*), daikon radish (*Raphanus sativus*), red clover (*Trifolium pratense*) and winter pea (*Pisum sativum*) were evaluated for field emergence, canopy cover, winter hardiness, spring regrowth, plant height, days from planting to 50% bloom, biomass, and disease and insect resistance to determine which varieties would be best adapted to the Elsberry Plant Materials Center service area (Illinois, Iowa and Missouri). Sixty varieties of eight cover crop species were evaluated over a three year period. Some species tested had a wide range of results among varieties (i.e. winter pea) while others did not (i.e. daikon radish). Results of this study can help to influence varietal selection of cover crop species when used in conservation practices in an agricultural setting.

INTRODUCTION

Incorporating cover crops into a cropping system improves soil health, conserves energy, and builds resilience and manages climate risk (Hargrove, 1986; Reeves, 1994; Reicosky and Forcella, 1998; Lal, 2004). While cover crops provide numerous agronomic and environmental benefits, these benefits are not fully achieved unless cover crop varieties are planted that meet the objective of the cover crop planting and producer’s expectations. The purpose of this study is to evaluate growth characteristics and production attributes of commercially available varieties of selected cover crops identified by NRCS State Agronomists, Soil Health Specialists and Plant Materials Program staff.

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MATERIALS AND METHODS

Experimental Design and Implementation

Experiments were conducted in the 2015-2016, 2016-2017 and 2017-2018 growing seasons at the USDA NRCS Plant Materials Center (PMC) in Elsberry, MO. Weather in this location consist of average annual high/low temperatures of 67/46 °F and total precipitation of 42 inches (Figure 1). Separate but nearby sites were used each year to prevent contamination of plots from seed that failed to germinate the previous year. Soil was Portage clay (very-fine, smectitic, mesic Vertic Endoaquolls).

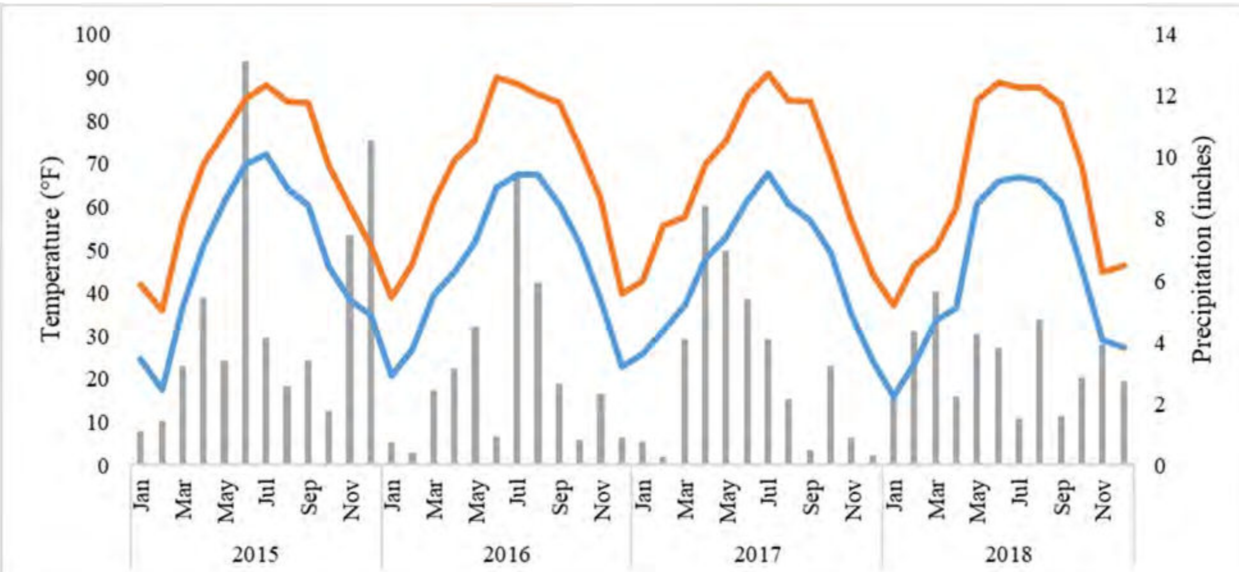

Figure 1. Weather at the Elsberry Plant Materials Center, Missouri, for the duration of the study. Total monthly precipitation is shown in grey columns, average monthly high temperature represented as an orange line and average monthly low temperature shown in blue.

Cover crop species selected for the study included balansa clover, black oats, cereal rye, crimson clover, daikon radish, hairy vetch, red clover and winter pea (Table 1). Balansa clover is an annual cool-season small-seeded legume, with white to pink flowers that attract pollinators and can grow to heights of three feet tall with thick hollow stems. Black oats is an annual cool-season grass that grows upright to five feet tall, with wide flat rough blades and produces and open drooping panicle. Cereal rye is an annual cool-season grass growing up to six feet tall, with flat leaf blades and produces dense flower spikes. Crimson clover is an annual cool-season legume that grows up to three feet tall, with compound leaves consisting of three leaflets and produces crimson-red flowers. Daikon radish is an annual cool-season brassica that can grow up to three feet with basal rosette leaves, develops a thick, white taproot, and produces small pinkish flowers in the spring. Hairy vetch is an annual cool-season, vining legume growing two to five feet long, with compound leaves and purple flowers. Red clover is a biennial, cool-season legume with hollow hairy stems growing to two feet, compound leaves and rose-pink flowers. Winter pea is an annual, cool-season legume with vines growing between two to nine feet long with a smooth waxy appearance, compound leaves and flowers colored white, purple or pink.

Commercially available varieties of the cover crop species were arranged in a randomized complete block design with four replications in 10-ft × 20-ft plots. The number of varieties within a species studied ranged from two to sixteen and were chosen based on their average use and availability. The cropping system followed a corn-soybean rotation, however, no cash crops were planted as part of this study.

Table 1. Cover crop species, varieties, seeding rates and planting years at the USDA NRCS Plant Materials Center, Elsberry, MO.

Common Name	Species	Variety	Seeding Rate (PLS lb/ac)	Years Planted		
				2015-2016	2016-2017	2017-2018
Balansa Clover	*Trifolium michelianum*	Fixation	5	x	x	x
Balansa Clover	*Trifolium michelianum*	Frontier	5	x	x	x
Black Oats	*Avena sativa*	Cosaque	60	x	x	x
Black Oats	*Avena strigosa*	Soil Saver	60	x	x	x
Cereal Rye	*Secale cereale*	Aroostook	100		x	x
Cereal Rye	*Secale cereale*	Bates RS4	100		x	x
Cereal Rye	*Secale cereale*	Brasetto	100		x	x
Cereal Rye	*Secale cereale*	Elbon	100		x	x
Cereal Rye	*Secale cereale*	FL 401	100		x	x
Cereal Rye	*Secale cereale*	Guardian	100		x	x
Cereal Rye	*Secale cereale*	Hazlet	100		x	x
Cereal Rye	*Secale cereale*	Maton	100		x	x
Cereal Rye	*Secale cereale*	Maton II	100		x	x
Cereal Rye	*Secale cereale*	Merced	100		x	x
Cereal Rye	*Secale cereale*	Oklon	100		x	x
Cereal Rye	*Secale cereale*	Prima	100		x	
Cereal Rye	*Secale cereale*	Rymin	100		x	x
Cereal Rye	*Secale cereale*	Wheeler	100		x	x
Cereal Rye	*Secale cereale*	Wintergrazer 70	100		x	x
Cereal Rye	*Secale cereale*	Wrens Abruzzi	100		x	x
Crimson Clover	*Trifolium incarnatum*	AU Robin	18	x	x	x
Crimson Clover	*Trifolium incarnatum*	AU Sunrise	18	x	x	x
Crimson Clover	*Trifolium incarnatum*	AU Sunup	18	x	x	x
Crimson Clover	*Trifolium incarnatum*	Contea	18	x	x	x
Crimson Clover	*Trifolium incarnatum*	Dixie	18	x	x	x
Crimson Clover	*Trifolium incarnatum*	Kentucky Pride	18	x	x	x
Daikon Radish	*Raphanus sativus*	Big Dog	9		x	x
Daikon Radish	*Raphanus sativus*	Concord	9		x	x
Daikon Radish	*Raphanus sativus*	Control	9		x	x
Daikon Radish	*Raphanus sativus*	Defender	9	x	x	x
Daikon Radish	*Raphanus sativus*	Driller	9	x	x	x
Daikon Radish	*Raphanus sativus*	EcoTill	9	x	x	x
Daikon Radish	*Raphanus sativus*	Graza	9		x	x
Daikon Radish	*Raphanus sativus*	Groundhog	9	x	x	x
Daikon Radish	*Raphanus sativus*	Lunch	9	x	x	x
Daikon Radish	*Raphanus sativus*	Nitro	9	x	x	x
Daikon Radish	*Raphanus sativus*	Sodbuster Blend	9	x	x	x
Daikon Radish	*Raphanus sativus*	Tillage	9	x	x	x

Table 1 (cont.). Cover crop species, varieties, seeding rates and planting years at the USDA NRCS Plant Materials Center, Elsberry, MO.

Common Name	Species	Variety	Seeding Rate (PLS lb/ac)	Years Planted		
				2015-2016	2016-2017	2017-2018
Hairy Vetch	*Vicia villosa*	Groff	18	x	x	x
Hairy Vetch	*Vicia villosa*	Lana	18	x	x	x
Hairy Vetch	*Vicia villosa*	Purple Bounty	18		x	x
Hairy Vetch	*Vicia villosa*	Purple Prosperity	18	x	x	x
Hairy Vetch	*Vicia villosa*	TNT	18	x	x	x
Hairy Vetch	*Vicia villosa*	Valana	18	x	x	x
Red Clover	*Trifolium pratense*	Cinnamon Plus	9	x	x	x
Red Clover	*Trifolium pratense*	Cyclone II	9	x	x	x
Red Clover	*Trifolium pratense*	Dynamite	9	x	x	x
Red Clover	*Trifolium pratense*	Freedom	9	x	x	x
Red Clover	*Trifolium pratense*	Kenland	9	x	x	x
Red Clover	*Trifolium pratense*	Mammoth	9		x	x
Red Clover	*Trifolium pratense*	Starfire II	9	x	x	x
Red Clover	*Trifolium pratense*	Wildcat	9	x	x	x
Winter Pea	*Pisum sativum*	Arvica 4010	70	x	x	x
Winter Pea	*Pisum sativum*	Dunn	70	x	x	x
Winter Pea	*Pisum sativum*	Frost Master	70	x	x	x
Winter Pea	*Pisum sativum*	Lynx	70	x	x	x
Winter Pea	*Pisum sativum*	Maxum	70	x	x	x
Winter Pea	*Pisum sativum*	Survivor 15	70	x	x	x
Winter Pea	*Pisum sativum*	Whistler	70	x	x	x
Winter Pea	*Pisum sativum*	Windham	70	x	x	x

Fields were prepped by tilling and harrowing to ensure a smooth and even planting surface at the start of each growing season. Fertilizer was applied at a rate of 40:30:60 pounds of nitrogen, phosphorus and potassium, respectively. Glyphosate herbicide was sprayed at a rate of three pints per acre prior to planting as broad-spectrum weed control.

Cover crop seed was planted using a Haldrup no-till research plot drill (Haldrup USA Corporation, Ossian, Indiana) with 8 inch row spacing to a depth of approximately 0.25 inches. Seed was planted on September 16 in 2015, September 12 in 2016, and September 15 in 2017, with the goal of planting on or near the Missouri NRCS recommended planting date for cover crops of September 15 (MONRCS, 2020). Seeding rates were determined by averaging the recommended seeding rates from NRCS cover crop standards and specifications across the national Plant Materials Program service areas. Legume seed was inoculated with the appropriate strain of *Rhizobia* spp. before planting.

Data Collection

Plots were observed for seedling emergence at 7, 14, 21 and 28 days after planting (DAP). Emergence was measured by scoring plots based on visual observations (0 = < 25%; 1 = 30-60%; 2 = 65-85%; 3 = 90-100%).

Canopy cover estimates were visually taken each year in the fall prior to onset of winter and in the spring when plants reached 50% bloom and anthesis.

Winter hardiness was measured by counting the number of live seedlings within a one-meter section of a planted row. In the fall, seedlings were counted at 28 days after planting, and the beginning of each meter transect was marked with a permanent stake. Once plants began spring green-up, live plants that survived the winter were counted along the same marked, one-meter row. Winter hardiness was recorded as the percentage of plants that survived into the spring from those that were counted in the fall.

Spring regrowth data was recorded as the average date when spring green-up was achieved. Number of days after planting was the data used for analysis of this variable.

Average bloom time was recorded each spring for all cover crop varieties. Average bloom, or anthesis, time provides flowering data for pollinators and a time when nitrogen content is optimum in many legumes (Jensen, 1987). Plants were observed throughout their bloom period, and calendar dates were recorded when plots reached 50% bloom/anthesis; dates were then averaged across replications. The number of days after planting was the data used for analysis of this variable.

Plant height was recorded at average bloom time by measuring from the soil surface to the height of lush canopy growth from three random locations and averaged.

Disease and insect resistance were recorded at average bloom time in the spring. Both disease and insect resistance were visually rated using a scale of 0-5 where 0 = no damage, 1 = slight damage, 3 = moderate damage, 5 = severe damage.

Aboveground biomass was harvested at average bloom time from a 0.5 m^2 area at a random location representative of the entire plot and clipped at ground level. Biomass samples were placed in a labeled paper bag, dried in a forage oven dryer at 60°C for three days, and then weighed to the nearest gram.

Data Analyses

Data were analyzed separately for each cover crop species. Raw data are presented with means and standard deviations for statistical interpretations. All analyses were performed using Statistix 10 software (Analytical Software, Tallahassee, Florida).

RESULTS AND DISCUSSION

Balansa Clover

Balansa clover varieties had poor seedling emergence and low rates of fall canopy cover. Twenty-eight days after planting, balansa clover had less than 25% field emergence (Table 4). In the late fall, balansa clover covered approximately 12% of the planted field (Table 5).

Fixation outperformed Frontier for winter hardiness, spring regrowth, height, spring canopy cover and biomass (Tables 5 – 6). Fixation had an average rate of 64% winter survival, while only 25% of Frontier plants survived. Fixation started to green up around March 1, while regrowth for Frontier balansa clover began around March 15. Fixation grew taller than Frontier, at 19 versus 8 inches. Spring canopy cover favored Fixation at 52% while Frontier covered only

16% of the ground. Fixation had an overwhelming lead in biomass with 1,724 lb/ac compared with Frontier which produced only 321 lb/ac.

Frontier outperformed Fixation in average bloom time and insect resistance. Frontier bloomed earlier, around the end of April; Fixation's average bloom time occurred later, near mid May. At mid bloom time, Frontier had low predation rates, while Fixation exhibited an average of 75% insect predation.

Table 4. Balansa clover average emergence score[1] at 7, 14, 21 and 28 days after planting at the Elsberry Plant Materials Center.

Variety	Days after planting			
	7	14	21	28
Fixation	0.0	0.4	0.0	0.1
Frontier	0.0	0.3	0.0	0.1
Mean	0.0	0.3	0.0	0.1
SD[2]		0.5		0.3

[1]0 = < 25%; 1 = 30-60%; 2 = 65-85%; 3 = 90-100%
[2]Standard Deviation

Table 5. Average fall canopy cover, winter survival, spring regrowth and days to 50% bloom of balansa clover varieties at the Elsberry Plant Materials Center.

Variety	% Fall Canopy Cover	% Winter Survival	Spring Regrowth (DAP)	50% Bloom (DAP)
Fixation	12	64	167	235
Frontier	11	25	181	226
Mean	12	44	173	230
SD[1]	6	38	19	9

[1]Standard Deviation

Table 6. Average plant height, spring canopy cover, biomass, disease and insect scores of balansa clover varieties at the Elsberry Plant Materials Center.

Variety	Plant Height (in)	% Spring Canopy Cover	Biomass (lb/ac)	Disease Score[1]	Insect Predation Score[1]
Fixation	19	52	1,724	0.2	2.0
Frontier	8	16	321	0.0	0.3
Mean	14	34	1,023	0.1	1.3
SD[2]	6	25	1,182	0.3	1.1

[1]0 = < 25%; 1 = 30-60%; 2 = 65-85%; 3 = 90-100%
[2]Standard Deviation

Black Oats

Cosaque outperformed Soil Saver for winter hardiness, height, spring canopy cover and biomass (Tables 8 – 9). Soil Saver winter-killed in the second and third years of the study, while Cosaque survived all three. Cosaque plants grew taller than Soil Saver, at 26 versus 20 inches. In the spring, Cosaque black oats covered 42% of the ground, while Soil Saver covered only 19%. There was an incredible amount of variation between variety biomass production; Cosaque produced 3,139 lb/ac, while Soil Saver produced 910 lb/ac.

Average anthesis in the springtime differed between varieties by approximately three weeks, with Soil Saver blooming earlier than Cosaque (Table 8). Both black oats varieties performed similarly in seedling emergence, fall canopy cover, spring regrowth, as well as disease and insect resistance (Tables 7 – 9).

Table 7. Black oats average emergence score[1] at 7, 14, 21 and 28 days after planting at the Elsberry Plant Materials Center.

Variety	Days after planting			
	7	14	21	28
Cosaque	0.9	1.1	1.6	2.2
Soil Saver	1.0	1.0	1.8	1.9
Mean	0.9	2.0	1.7	2.0
SD[2]	1.0	1.1	0.5	0.9

[1]0 = < 25%; 1 = 30-60%; 2 = 65-85%; 3 = 90-100%
[2]Standard Deviation

Table 8. Average fall canopy cover, winter survival, spring regrowth and days to 50% bloom of black oats varieties at the Elsberry Plant Materials Center.

Variety	% Fall Canopy Cover	% Winter Survival	Spring Regrowth (DAP)	50% Bloom (DAP)
Cosaque	66	47	169	255
Soil Saver	61	7	174	233
Mean	64	26	170	249
SD[1]	21	33	23	11

[1]Standard Deviation

Table 9. Average plant height, spring canopy cover, biomass, disease and insect scores of black oats varieties at the Elsberry Plant Materials Center.

Variety	Plant Height (in)	% Spring Canopy Cover	Biomass (lb/ac)	Disease Score[1]	Insect Predation Score[1]
Cosaque	26	42	3,139	0.2	0.0
Soil Saver	20	19	910	0.0	0.0
Mean	24	36	2,582	0.2	0.0
SD[2]	6	28	2,546	0.4	0.0

[1]0 = < 25%; 1 = 30-60%; 2 = 65-85%; 3 = 90-100%
[2]Standard Deviation

Cereal Rye

On average, all varieties exhibited high rates of seedling emergence (Table 10). Guardian had the lowest amount of fall cover compared to all other varieties (Table 11). Most varieties had greater than 50% survival over the winter, except for FL 401 and Merced.

With the exception of FL 401 and Merced, all varieties started their spring regrowth around the same time (end of February) with little deviation from the mean. FL 401 and Merced, however, began their spring regrowth after all other varieties and exhibited greater variation in the regrowth date from year to year.

With the exception of FL 401 and Merced, the average spring anthesis date for all varieties was around mid May, with little deviation from the mean. During mild fall and winter weather conditions, FL 401 and Merced can potentially go through anthesis at the end of November.

Wheeler had the greatest average height (Table 12). FL 401, Brasetto and Merced had the shortest heights. FL 401 and Merced had the lowest spring canopy cover. Maton and Elbon produced the greatest biomass, while FL 401 and Merced produced the least. Prima exhibited the greatest resistance to disease, while Hazlet was most susceptible. All varieties exhibited high resistance to insect predation.

Table 10. Cereal rye average emergence score[1] at 7, 14, 21 and 28 days after planting at the Elsberry Plant Materials Center.

Variety	Days after planting			
	7	14	21	28
Aroostook	2.0	3.0	2.3	2.6
Bates	2.0	3.0	2.8	2.8
Brasetto	2.0	2.8	2.3	2.6
Elbon	2.0	2.8	2.5	2.4
FL 401	2.0	3.0	2.8	2.6
Guardian	1.0	0.8	0.5	1.5
Hazlet	1.8	2.3	2.0	2.1
Maton	2.0	3.0	2.5	2.6
Maton II	2.0	3.0	2.3	2.4
Merced	2.0	3.0	2.5	2.5
Oklon	2.0	2.8	2.5	2.6
Prima	2.0	2.8	2.0	2.3
Rymin	0.8	0.5	NDT[2]	3.0
Wheeler	2.0	3.0	2.0	2.8
Wintergrazer 70	2.0	2.8	2.5	2.9
Wrens Abruzzi	2.0	3.0	2.8	2.5
Mean	1.8	2.6	2.3	2.5
SD[3]	0.4	0.8	0.7	0.7

[1]0 = < 25%; 1 = 30-60%; 2 = 65-85%; 3 = 90-100%
[2]No Data Taken
[3]Standard Deviation

Table 11. Average fall canopy cover, winter survival, spring regrowth and days to 50% bloom of cereal rye varieties at the Elsberry Plant Materials Center.

Variety	% Fall Canopy Cover	% Winter Survival	Spring Regrowth (DAP)	50% Bloom (DAP)
Aroostook	91	79	165	240
Bates	92	81	164	239
Brasetto	89	75	168	239
Elbon	87	83	165	240
FL 401	75	31	178	153
Guardian	66	84	168	238
Hazlet	82	87	168	240
Maton	91	76	164	240

Table 11 (cont.). Average fall canopy cover, winter survival, spring regrowth and days to 50% bloom of cereal rye varieties at the Elsberry Plant Materials Center.

Variety	% Fall Canopy Cover	% Winter Survival	Spring Regrowth (DAP)	50% Bloom (DAP)
Maton II	91	64	164	239
Merced	79	18	187	153
Oklon	91	85	164	240
Prima	81	82	157	237
Rymin	78	85	161	232
Wheeler	96	77	166	238
Wintergrazer 70	90	85	164	239
Wrens Abruzzi	83	75	164	239
Mean	85	72	166	227
SD[1]	13	27	16	44

[1]Standard Deviation

Table 12. Average plant height, spring canopy cover, biomass, disease and insect scores of black oats varieties at the Elsberry Plant Materials Center.

Variety	Plant Height (in)	% Spring Canopy Cover	Biomass (lb/ac)	Disease Score[1]	Insect Predation Score[1]
Aroostook	57	91	9,330	0.5	0.1
Bates	59	90	9,439	0.5	0.0
Brasetto	39	83	7,614	0.8	0.0
Elbon	59	87	10,453	0.5	0.1
FL 401	39	23	1,261	0.3	0.2
Guardian	52	81	8,014	1.0	0.3
Hazlet	48	83	7,212	1.3	0.1
Maton	59	88	10,687	0.5	0.0
Maton II	59	89	8,998	0.5	0.1
Merced	33	15	1,108	0.7	0.2
Oklon	59	90	9,258	0.5	0.0
Prima	44	87	6,234	0.0	0.0
Rymin	53	88	6,432	0.8	0.1
Wheeler	60	89	7,607	0.4	0.1
Wintergrazer 70	58	89	7,952	0.5	0.0
Wrens Abruzzi	60	85	8,819	0.5	0.0
Mean	53	78	7,568	0.6	0.1
SD[2]	10	24	3,390	0.8	0.3

[1]0 = < 25%; 1 = 30-60%; 2 = 65-85%; 3 = 90-100%
[2]Standard Deviation

Crimson Clover

Kentucky Pride had the greatest seedling emergence and winter hardiness (Tables 13 – 14). All varieties had the same amount of coverage in the fall, averaging at 35% ground cover. All varieties started their spring regrowth around early March. Average bloom time was similar amongst varieties, occurring at the end of April, while Kentucky Pride typically bloomed a week later, on average. Spring height was similar among most varieties with AU Sunup growing slightly shorter than others (Table 15). All varieties had similar amounts of cover in the spring, averaging at 51%. Kentucky Pride produced more biomass compared to all other varieties. All varieties were highly resistant to both diseases and insects.

Table 13. Crimson clover average emergence score[1] at 7, 14, 21 and 28 days after planting at the Elsberry Plant Materials Center.

Variety	Days after planting			
	7	14	21	28
AU Robin	1.1	1.1	1.6	1.3
AU Sunrise	1.1	1.1	1.8	1.7
AU Sunup	1.0	1.0	1.0	1.4
Contea	1.1	1.1	1.5	1.3
Dixie	1.3	1.0	1.8	1.6
Kentucky Pride	1.1	1.5	1.8	1.9
Mean	1.1	1.2	1.6	1.5
SD[2]	0.9	1.2	0.6	0.7

[1]0 = < 25%; 1 = 30-60%; 2 = 65-85%; 3 = 90-100%
[2]Standard Deviation

Table 14. Average fall canopy cover, winter survival, spring regrowth and days to 50% bloom of crimson clover varieties at the Elsberry Plant Materials Center.

Variety	% Fall Canopy Cover	% Winter Survival	Spring Regrowth (DAP)	50% Bloom (DAP)
AU Robin	37	46	166	226
AU Sunrise	37	54	167	227
AU Sunup	30	46	165	225
Contea	36	63	167	228
Dixie	35	66	168	227
Kentucky Pride	38	75	168	235
Mean	35	58	167	228
SD[1]	31	32	9	8

[1]Standard Deviation

Table 15. Average plant height, spring canopy cover, biomass, disease and insect scores of crimson clover varieties at the Elsberry Plant Materials Center.

Variety	Plant Height (in)	% Spring Canopy Cover	Biomass (lb/ac)	Disease Score[1]	Insect Predation Score[1]
AU Robin	21	55	2,128	0.2	0.2
AU Sunrise	21	52	2,082	0.2	0.1
AU Sunup	18	44	1,013	0.0	0.1
Contea	20	47	1,917	0.2	0.1
Dixie	20	52	2,288	0.2	0.2
Kentucky Pride	21	54	2,672	0.0	0.2
Mean	20	51	2,017	0.1	0.1
SD[2]	2	23	1,305	0.3	0.4

[1]0 = < 25%; 1 = 30-60%; 2 = 65-85%; 3 = 90-100%
[2]Standard Deviation

Daikon Radish

All varieties of daikon radish winter killed at the Elsberry PMC, therefore, the only variables measured were seedling emergence and fall canopy cover. All varieties, with the exception of Graza, performed similarly and had high seedling emergence and canopy cover in the fall (Tables 16 – 17). Twenty-eight days after planting, daikon radish averaged between 65-100% for field emergence. In the late fall, daikon radish covered approximately 91% of the planted area.

Table 16. Daikon radish average emergence score[1] at 7, 14, 21 and 28 days after planting at the Elsberry Plant Materials Center.

Variety	Days after planting			
	7	14	21	28
Big Dog	2.0	3.0	2.5	2.8
Concorde	2.0	3.0	3.0	3.0
Control	2.0	3.0	3.0	3.0
Defender	2.1	2.8	2.5	2.9
Driller	2.4	2.9	2.8	2.8
Eco-Till	2.5	3.0	2.8	3.0
Graza	1.0	2.0	1.0	1.6
Groundhog	2.3	3.0	3.0	2.9
Lunch	2.3	2.5	2.6	2.7
Nitro	2.4	3.0	2.8	2.9
Sodbuster	2.1	2.4	2.5	2.8
Tillage	2.4	3.0	2.9	2.8
Mean	2.2	2.8	2.7	2.8
SD[2]	0.5	0.4	0.6	0.5

[1]0 = < 25%; 1 = 30-60%; 2 = 65-85%; 3 = 90-100%
[2]Standard Deviation

Table 17. Average percent fall canopy cover for daikon radish varieties at the Elsberry Plant Materials Center.

Variety	% Fall Canopy Cover
Big Dog	90
Concorde	92
Control	91
Defender	93
Driller	91
Eco-Till	92
Graza	84
Groundhog	92
Lunch	91
Nitro	92
Sodbuster	92
Tillage	91
Mean	91
SD[1]	4

[1]Standard Deviation

Hairy Vetch

Hairy vetch varieties had similar seedling emergence, averaging at 75% after twenty-eight days (Table 18). Lana had the greatest fall canopy cover at 65% (Table 19). Most varieties had around 84% winter survival, except for Lana, which had 60% survival. Spring regrowth was similar amongst varieties, occurring around early March. Lana bloomed just slightly earlier than all other varieties in late April. All varieties had similar plant height in the spring (Table 20). Lana also had the least amount of canopy cover in the spring. All varieties produced significantly greater biomass than Lana. All varieties were highly resistant to diseases and insect predation.

Table 18. Hairy vetch average emergence score[1] at 7, 14, 21 and 28 days after planting at the Elsberry Plant Materials Center.

Variety	Days after planting			
	7	14	21	28
Groff	0.0	1.1	2.1	2.3
Lana	0.0	1.0	2.1	2.1
Purple Bounty	0.0	2.0	2.0	2.0
Purple Prosperity	0.0	1.1	2.1	2.3
TNT	0.0	1.1	2.4	2.3
Villana	0.0	1.6	2.3	2.2
Mean	0.0	1.3	2.2	2.2
SD[2]		0.9	0.4	0.4

[1]0 = < 25%; 1 = 30-60%; 2 = 65-85%; 3 = 90-100%
[2]Standard Deviation

Table 19. Average fall canopy cover, winter survival, spring regrowth and days to 50% bloom of hairy vetch varieties at the Elsberry Plant Materials Center.

Variety	% Fall Canopy Cover	% Winter Survival	Spring Regrowth (DAP)	50% Bloom (DAP)
Groff	51	87	165	252
Lana	65	60	179	228
Purple Bounty	57	84	168	250
Purple Prosperity	50	85	170	249
TNT	52	79	172	255
Villana	47	84	169	257
Mean	53	80	170	249
SD[1]	22	24	20	11

[1]Standard Deviation

Table 20. Average plant height, spring canopy cover, biomass, disease and insect scores of hairy vetch varieties at the Elsberry Plant Materials Center.

Variety	Plant Height (in)	% Spring Canopy Cover	Biomass (lb/ac)	Disease Score[1]	Insect Predation Score[1]
Groff	26	83	5,026	0.0	0.0
Lana	23	73	2,485	0.0	0.1
Purple Bounty	27	79	4,616	0.0	0.0
Purple Prosperity	26	80	4,663	0.0	0.0
TNT	24	85	5,373	0.0	0.0

Table 20 (cont.). Average plant height, spring canopy cover, biomass, disease and insect scores of hairy vetch varieties at the Elsberry Plant Materials Center.

Variety	Plant Height (in)	% Spring Canopy Cover	Biomass (lb/ac)	Disease Score[1]	Insect Predation Score[1]
Villana	25	88	5,517	0.0	0.0
Mean	25	81	4,613	0.0	0.0
SD[2]	3	15	1,560		0.1

[1]0 = < 25%; 1 = 30-60%; 2 = 65-85%; 3 = 90-100%
[2]Standard Deviation

Red Clover

Overall, red clover had poor seedling emergence (Table 21). All varieties performed similarly for fall canopy cover (Table 22). Mammoth had the greatest winter survival at 69%. Cyclone II was the first variety to green up in the spring; typically, by early March. Almost all varieties bloomed around the same time in mid May, while Mammoth bloomed later at the end of May. Varieties had similar heights in the spring (Table 23). Mammoth produced the greatest average spring canopy cover and biomass. All varieties had little to no disease presence or insect predation.

Table 21. Red clover average emergence score[1] at 7, 14, 21 and 28 days after planting at the Elsberry Plant Materials Center.

Variety	Days after planting			
	7	14	21	28
Cinnamon Plus	1.0	0.6	0.3	0.4
Cyclone II	0.9	0.6	0.3	0.4
Dynamite	1.3	0.5	0.1	0.2
Freedom	0.8	0.5	0.3	0.3
Kenland	0.6	0.4	0.4	0.3
Mammoth	1.3	1.0	0.5	0.4
Starfire II	0.8	0.4	0.1	0.2
Wildcat	0.8	0.5	0.3	0.4
Mean	0.9	0.5	0.3	0.3
SD[2]	0.8	0.6	0.4	0.5

[1]0 = < 25%; 1 = 30-60%; 2 = 65-85%; 3 = 90-100%
[2]Standard Deviation

Table 22. Average fall canopy cover, winter survival, spring regrowth and days to 50% bloom of red clover varieties at the Elsberry Plant Materials Center.

Variety	% Fall Canopy Cover	% Winter Survival	Spring Regrowth (DAP)	50% Bloom (DAP)
Cinnamon Plus	25	52	187	249
Cyclone II	21	66	174	249
Dynamite	21	67	178	248
Freedom	20	63	182	248
Kenland	20	57	183	249
Mammoth	21	69	186	259
Starfire II	19	60	180	248

Table 22 (cont.). Average fall canopy cover, winter survival, spring regrowth and days to 50% bloom of red clover varieties at the Elsberry Plant Materials Center.

Variety	% Fall Canopy Cover	% Winter Survival	Spring Regrowth (DAP)	50% Bloom (DAP)
Wildcat	23	68	180	249
Mean	21	62	181	249
SD[1]	15	32	32	7

[1]Standard Deviation

Table 23. Average plant height, spring canopy cover, biomass, disease and insect scores of red clover varieties at the Elsberry Plant Materials Center.

Variety	Plant Height (in)	% Spring Canopy Cover	Biomass (lb/ac)	Disease Score[1]	Insect Predation Score[1]
Cinnamon Plus	18	36	1,689	0.0	0.3
Cyclone II	19	34	1,605	0.2	0.5
Dynamite	18	35	1,412	0.1	0.4
Freedom	19	39	1,979	0.2	0.3
Kenland	17	35	1,684	0.2	0.4
Mammoth	19	47	2,167	0.0	0.6
Starfire II	16	32	1,742	0.0	0.0
Wildcat	19	35	1,733	0.0	0.1
Mean	18	36	1,733	0.1	0.3
SD[2]	6	36	1,694	0.3	0.5

[1]0 = < 25%; 1 = 30-60%; 2 = 65-85%; 3 = 90-100%
[2]Standard Deviation

Winter Pea

All winter pea varieties had approximately 65-85% seedling emergence (Table 24). Lynx, Whistler and Windham had low fall canopy cover compared to all other varieties (Table 25). Arvica 4010, Dunn and Maxum winter pea varieties all winter killed and of the five surviving varieties, Windham performed the best with an average of 74% survival over the three year study. The winter-tolerant varieties all started to green up at the end of February. Lynx, Whistler and Windham bloomed the earliest compared to all other varieties. Survivor 15 and Whistler produced the tallest plants compared to all other varieties, averaging 21 inches (Table 26). Frost Master produced considerably low rates of cover and biomass in the spring compared to Lynx, Survivor 15, Whistler and Windham. There was very little presence of disease and insect predation for all winter pea varieties.

Table 24. Winter pea average emergence score[1] at 7, 14, 21 and 28 days after planting at the Elsberry Plant Materials Center.

Variety	Days after planting			
	7	14	21	28
Arvica 4010	1.5	2.6	2.5	2.3
Dunn	1.4	2.8	2.5	2.4
Frost Master	1.4	2.5	2.4	2.2
Lynx	0.9	2.4	2.4	2.3
Maxum	1.1	2.6	2.3	2.2

Table 24 (cont.). Winter pea average emergence score[1] at 7, 14, 21 and 28 days after planting at the Elsberry Plant Materials Center.

Variety	Days after planting			
	7	14	21	28
Survivor 15	1.5	2.9	2.5	2.4
Whistler	1.1	2.4	2.3	2.2
Windham	0.9	2.3	2.3	2.3
Mean	1.2	2.5	2.4	2.3
SD[2]	0.5	0.5	0.5	0.5

[1]0 = < 25%; 1 = 30-60%; 2 = 65-85%; 3 = 90-100%
[2]Standard Deviation

Table 25. Average fall canopy cover, winter survival, spring regrowth and days to 50% bloom of winter pea varieties at the Elsberry Plant Materials Center.

Variety	% Fall Canopy Cover	% Winter Survival	Spring Regrowth (DAP)	50% Bloom (DAP)
Arvica 4010	72	0	WK[1]	WK
Dunn	71	0	WK	WK
Frost Master	72	24	167	250
Lynx	57	57	166	237
Maxum	72	0	WK	WK
Survivor 15	77	40	163	253
Whistler	60	62	165	238
Windham	52	74	167	237
Mean	67	32	165	242
SD[2]	13	37	9	10

[1]Winter Kill
[2]Standard Deviation

Table 26. Average plant height, spring canopy cover, biomass, disease and insect scores of winter pea varieties at the Elsberry Plant Materials Center.

Variety	Plant Height (in)	% Spring Canopy Cover	Biomass (lb/ac)	Disease Score[1]	Insect Predation Score[1]
Arvica 4010	WK[2]	WK	WK	WK	WK
Dunn	WK	WK	WK	WK	WK
Frost Master	18	20	532	0.0	0.2
Lynx	16	61	2,311	0.0	0.0
Maxum	WK	WK	WK	WK	WK
Survivor 15	21	58	1,771	0.1	0.0
Whistler	21	55	1,987	0.0	0.0
Windham	15	47	1,781	0.0	0.0
Mean	18	50	1,735	0.0	0.0
SD[3]	6	28	1,119	0.1	0.1

[1]0 = < 25%; 1 = 30-60%; 2 = 65-85%; 3 = 90-100%
[2]Winter Kill
[3]Standard Deviation

CONCLUSION

Cool season cover crop species and varieties evaluated in this trial exhibited a wide range of performance throughout the three year study period. In northeast Missouri, top species performers included crimson clover, hairy vetch and cereal rye. Daikon radish was also a top performer as it grew vigorously in the fall, but all varieties of this cover crop species winter-killed. Winter pea, balansa clover, red clover and black oats performed poorly compared to other species.

Kentucky Pride crimson clover proved to be a consistently favorable variety within the species. In the fall, it exhibited the best seedling emergence and canopy cover. Kentucky Pride also had the greatest rate of winter survival and produced the greatest amount of biomass in the spring. Lana hairy vetch frequently performed different than all other vetch varieties. This variety was released by the California Plant Materials Center in 1956 and was known for its early maturity (USDA NRCS, 2017). It had the highest amount of canopy cover in the fall and the earliest bloom time in the spring, however, it had the lowest scores for winter survival, height, spring canopy cover and biomass. Cereal rye was the top plant performer amongst cover crop species. Two varieties, FL 401 and Merced were visibly different from other varieties. FL 401 was developed by the Florida Agricultural Experiment Station in 1984, while Merced was developed by the University of California and released in 1947 (Pfahler et al., 1986; USNPGS, 1989). They had the least amount of canopy cover, winter survival and biomass. Additionally, they were the latest to green up in the spring and the earliest to bloom, often in the late fall while all other varieties bloomed in the spring. While daikon radish varieties performed very well and similarly, Graza radish had the poorest seedling emergence and fall canopy cover. This variety of radish was developed in New Zealand and was selected to withstand repeated grazing (Stewart and Moorhead, 2004).

Winter pea varieties, Arvica 4010, Dunn and Maxum had poor adaptation because of low winter survival. Of the five surviving varieties, Frost Master performed considerably worse than Lynx, Survivor 15, Whistler and Windham. Differences in pea varieties tested in this study may be due to the numerous uses they are selected for. For example, Arvica 4010 was cultivated as a forage pea while Whistler and Windham are grown as fall-planted field peas (Pavek, 2012). Balansa clover varieties had poor seedling emergence and low rates of canopy cover in the fall. In the springtime however, Fixation performed better than Frontier with greater winter hardiness, height, canopy cover, biomass and earlier regrowth. While Fixation was superior to Frontier, it was only mildly adapted to Elsberry as it had low germination and cover in the fall and moderate cover in the spring. Red clover varieties had poor seedling emergence and low rates of canopy cover in the fall. In the spring, red clover varieties performed very similarly, however, Mammoth had slightly greater numbers of canopy cover and biomass production and bloomed later than the other varieties. Most mammoth-types of red clover mature later than medium-types (St. John and Ogle, 2008). Soil Saver black oats was not adapted to the Elsberry Plant Materials Center service area as it winter-killed in the second and third years of the study. It could, however, be a good choice for producers needing cover that winter-kills to avoid termination expenses in the spring. This variety of black oats was selected for use as a winter cover crop in the U.S.'s lower Coastal Plain (USDA ARS, 2016). Cosaque black oats performed reasonably well and produced a high amount of biomass in the spring.

Choosing the right cover crop variety is important to achieve agronomic success. The species and varieties tested in this experiment displayed an array of growth characteristics, and as such, provide a multitude of choices for working towards specific goals or avoiding known problems. Objectives such as establishing ground cover in the fall, early flowering period for pollinators, or high resistance to disease, can be met by selecting appropriate cover crop species and varieties adapted to specific regions.

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