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Evaluation of Cool Season Cover Crops in the Intermountain West

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ABSTRACT

Cool season cover crops provide multiple benefits between cash crops, including suppressing weeds, reducing erosion, adding nitrogen, increasing organic matter and improving soil health. Numerous varieties of cover crop species are available, but information on which varieties are best adapted to specific regions is largely unknown. The purpose of this study was to evaluate fifty-nine commercially available varieties of eight different cool season annual cover crop species for their adaptation to conditions in the Intermountain West. Species evaluated at the Aberdeen Plant Materials Center in 2016-17 and 2017-18 included hairy vetch (*Vicia villosa* Roth) including woolypod vetch [*Vicia villosa* Roth ssp *varia* (Host) Corb], winter pea (*Pisum sativum* L.), balansa clover (*Trifolium michelianum* Savi), crimson clover (*Trifolium incarnatum* L.), red clover (*Trifolium pratense* L.), oat (*Avena sativa* L. and *Avena strigosa* Schreb.), cereal rye (*Secale cereale* L.), and oilseed (daikon) radish (*Raphanus sativus* L.). Varieties of these species were evaluated for field emergence, winter hardiness, days after planting to 50% bloom, plant height, and disease and insect resistance. Vetch exhibited excellent winter survival, except for 'Lana', the only variety of woolypod vetch, which winter-killed in one year of the trial. Winter pea field emergence was different between varieties, with 'Survivor 15' and 'Arvica 4010' having the highest ratings. 'Survivor 15' was the only winter pea variety to survive to bloom both years, though 'Frost Master' and 'Windham' also survived in 2017-18. 'Fixation' balansa clover demonstrated better field emergence and winter survival than 'Frontier' balansa clover. There were differences in crimson clover field emergence and varying degrees of winter hardiness when temperatures reached below -5 ^{o}F. All red clover varieties had moderate to good field emergence and at least 93% winter survival. Oat exhibited good emergence and growth through the fall. 'Soil Saver' black oat winter-killed both years, while 'Cosaque' black seeded oat had 50% and 75% winter survival in 2017 and 2018 respectively. Most cereal rye varieties exhibited good to excellent field emergence. There were differences in cereal rye winter survival, with 'FL 401' and 'Merced' suffering winterkill both years. Differences in cereal rye height indicate there could be differences in biomass production. Oilseed radish varieties with the exception of 'Graza' had favorable field emergence and provided weed suppression in the fall before they winter-killed. The best performing cover crop varieties need additional evaluation to determine their biomass production capability and further characterize their adaptation to the Intermountain West.

INTRODUCTION

Cover crops have been found to provide numerous benefits to soils and the environment. Incorporating cover crops into a cropping system improves soil health, conserves energy, builds resilience in the cropping system, and helps sequester atmospheric CO_2. (Lal, 2004; Reicosky

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and Forcella, 1998; Hargrove, 1986; Reeves, 1994; Follett, 2001). Leguminous cover crops species provide a nitrogen source for subsequent commodity crops (Singh et al., 2004; Smith et al., 1987), while non-leguminous cover crops such as small grains and radishes can scavenge post-season nitrogen, reduce soil erosion, and suppress weeds (Meisinger et al., 1991). However, for cover crops to produce optimal benefits, they must both meet the objectives of the producer and be adapted to the environmental conditions of the location where they are planted.

NRCS State Agronomists, Soil Health Specialists, and Plant Materials Center staff selected commercially available varieties of several cool season cover crop species to evaluate at the Natural Resources Conservation Service (NRCS) Plant Materials Centers in different geographical locations across the U.S. The objective of this study is to evaluate the growth characteristics and attributes of commercially available varieties of selected cool-season cover crops to determine which are best adapted to regional conditions.

Figure 1. Seeding the cover crop trial on 25 August 2016.

MATERIALS AND METHODS

The cover crop adaptation trial was conducted at the Aberdeen Plant Materials Center over two growing seasons, 2016-17 and 2017-18, on a Declo silt loam soil. First year plots were planted on 25 August 2016 using a modified Tye Pasture Pleaser drill (The Tye Company, Lockney, TX) with 7 planters on 10-inch centers in 20-ft long plots. Second year plots were planted in a new location on 17 August 2017 with an Almaco cone plot planter (The Almaco Company, Nevada, IA) with 6 planters on 9.5-in centers in 20-ft long plots. Planting dates are within a typical window for common row crop rotations in the Aberdeen area.

Soil tests were taken both years, and the results were used to develop fertilizer application rates. In 2016-17, 80 lb N, 50 lb P, 30 lb K, and 50 lb S per acre was broadcast (granular) prior to seeding and incorporated with irrigation on 19 August 2016. In 2017-18, 40 lb N, 50 lb P, 30 lb K, and 50 lb S per acre was broadcast a week after seeding and incorporated with sprinkler irrigation. Plots received 5, 2-in irrigations between 26 August 2016 and 13 September 2016, a total of 10 in. In 2017, plots received 4, 2-in irrigations between 17 August 2017 and 20 September 2017, a total of 8 in. No additional irrigation water was applied in either trial year.

Precipitation and temperature were obtained from AgriMet (2019) and NOWData (2019) for the Aberdeen, ID weather station. Growing degree day data were obtained from AgriMet (2019). Aberdeen, ID is in USDA Zone 5b (USDA-ARS, 2012).

Cool season cover crop species included hairy vetch and woolypod vetch, winter pea, balansa clover, red clover, crimson clover, oilseed (daikon) radish, black oat, black seeded oat, and cereal rye. Species and seeding rates are listed in Table 1. Prior to planting, legume seeds were inoculated with the appropriate rhizobium. Seeds were wetted with a solution of either corn syrup or sweetened condensed milk in water, shaken with the rhizobium powder in a small can, and spread on paper to dry.

Data collection included field emergence, flowering period, plant height, disease and insect resistance, winter hardiness, and beginning of spring regrowth. Field emergence is an indicator of how quickly the cover crop species will establish and start providing soil protection and weed suppression. The following scale was used to rate field emergence based on visual determination: 0 = poor (<25% germination); 1 = moderate (30-60% germination); 2 = good (65-85% germination); 3 = excellent (90-100% germination). Ratings were conducted at 7, 14, 21, and 28 days after planting (DAP) for each species and variety within each replication. Flowering period data shows how quickly the plants reach their reproductive stage. It can also be used to assess cover crop benefits to pollinators, as well as to indicate the period of optimum N content in many legume species. Bloom and anthesis were observed as they began and progressed for each species, and the date recorded when each variety was estimated to have reached 50% of peak bloom/anthesis. Plant height can be correlated to aboveground biomass and can also be used to as an indicator for ease of managing the cover crop. Height measured was the average height of canopy growth based on three random measurements, not the absolute plant height including inflorescences. Plant height was measured at 50% bloom/anthesis for each cultivar/variety, which tied the height measurement to a date. Disease and insect resistance ratings provide an estimate of the cover crop’s general resistance, or lack thereof, to local insect pests and diseases. Damage symptoms were observed, and plant resistance was rated on the following scale: 0 = no damage; 1 = slight damage; 3 = moderate damage; 5 = severe damage. Two evaluations occurred: 1) at the recorded date for 50% bloom/anthesis; 2) at spring regrowth. Winter hardiness, or winter survival, is the percentage of seedlings that emerge in the fall and survive over the winter. Survival was determined by counting plants from 1 meter marked in each row in the fall and counting the same area again in the spring after the start of regrowth.

The experimental design was a randomized complete block with four replications (blocks). Species were grouped within each replication, but cultivars/varieties were randomized within each species. Statistical analysis was done using Statistix 10 (Analytical Software, Tallahassee, FL). 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 to 50% bloom/anthesis.

Table 1. Species, cultivars and seeding rates of annual cool season cover crops planted in 2016 and 2017 at the USDA NRCS Aberdeen 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 oat	*Avena sativa*	Cosaque	60	83	72
Black seeded oat	*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*	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

Table1 (cont.). Species, cultivars and seeding rates of annual, cool seasons planted in 2016 and 2017 at the USDA NRCS Aberdeen, ID Plant Materials Center.

Common name	Species	Cultivar	PLS lb/acre	% PLS	Seeding rate lb/acre
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

RESULTS AND DISCUSSION

During the 2016-17 trial year, high temperatures reached the mid 90’s ^{o}F after planting in August 2016 and again the following June (Figure 2). The first frost occurred on 7 October 2016. Last frost was on 18 May 2017. Winter temperatures in 2016-17 were below the long-term average (NOWData, 2019). The lowest temperature recorded during the 2016-17 growing season was -23 ^{o}F on 6 January 2017. For the period from planting on 26 August to 1 December 2016, 687 growing degree days (base 50 ^{o}F) accumulated (AgriMet, 2019). Precipitation between planting and 1 June 2017 totaled 13.2 in. Total accumulated moisture including irrigation was 23.2 in. The 2017-18 trial experienced similar high temperatures in the mid-90’s ^{o}F in August 2017 and again the following June (Figure 3). The first frost date was 23 September 2017. Last frost was on 2 May 2018. Winter temperatures in 2017-18 were above the long-term average (NOWData, 2019). The lowest temperature was -5 ^{o}F, measured on 23 February 2018. Between 17 August and 1 December 2017, 741 growing degree days (base 50 ^{o}F) accumulated (AgriMet, 2019). Precipitation between planting and 1 June 2018 totaled 7.0 in. Total accumulated moisture including irrigation was 15 in.

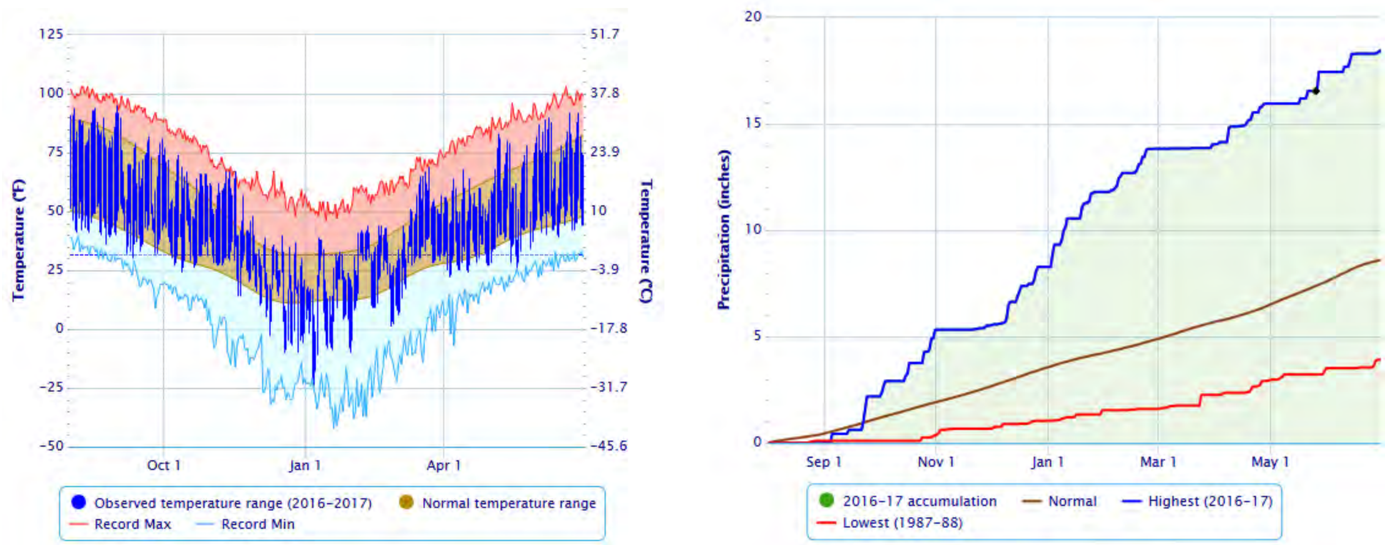

Figure 2. Daily temperature (left) and accumulated precipitation (right) for the period from 1 August 2016 through 30 June 2017 for the Aberdeen Experiment Station, Aberdeen, ID (NOWData, 2019)

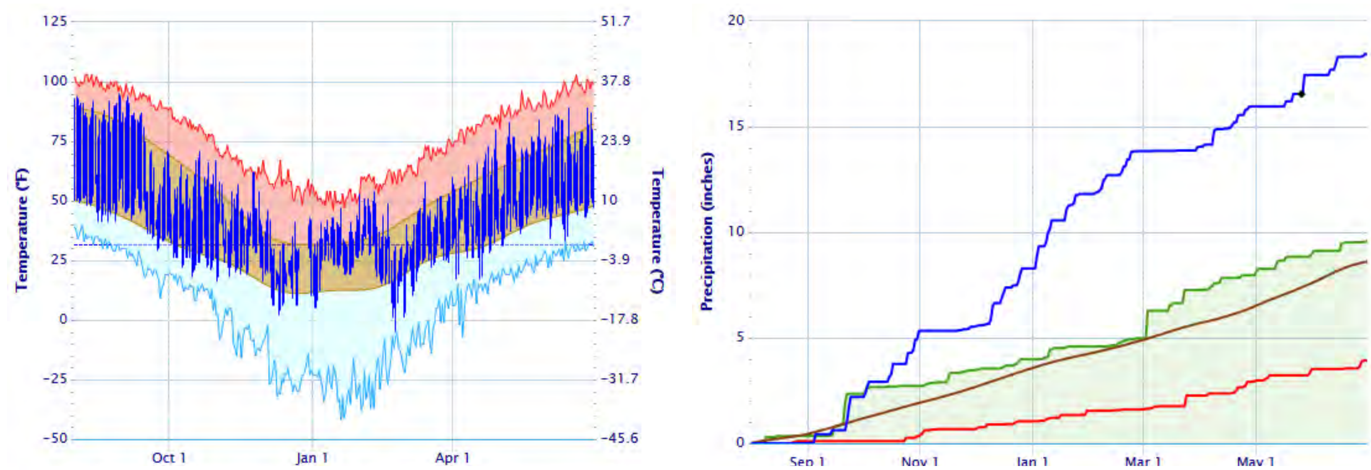

Figure 3. Daily temperature (left) and accumulated precipitation (right) for the period from 1 August 2017 through 30 June 2018 for the Aberdeen Experiment Station, Aberdeen, ID (NOWData, 2019).

Hairy Vetch. Hairy vetch emerged relatively slowly, with inconspicuous seedlings and poor early emergence ratings in both years of the trial. By 28 DAP, hairy vetch was demonstrating moderate to excellent emergence (Table 2).

Table 2. Mean values and standard deviations for field emergence of emergence groups (see below) of hairy vetch cultivars at 7, 14, 21 and 28 days after planting on 26 August 2016 and 17 August 2017. USDA-NRCS Aberdeen, ID.

Cultivar	Days after planting							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
CCS Groff	0.3[1]	0	1	1.5	1	2	1.8	2
Lana	0.3	1.3	2	2.5	1.8	3	2.5	3
Purple Bounty	0	0	1.5	1.5	1	2	1.8	2.3
Purple Prosperity	0	0.8	1.8	2	1.5	2.8	1.8	2.8
TNT	0	0.8	1	3	0.8	3	1.5	3
Villana	0.5	0.3	1.5	2	1.8	2.5	2	3
Mean	0.2	0.5	1.5	2.1	1.3	2.5	1.9	2.7
S.D.[2/]	0.4	0.6	0.7	0.7	0.7	0.6	0.7	0.5

[1/]0 = poor (<25% germination), 1 = moderate (25-64%), 2 = good (65-85%), 3 = excellent (>85%).
[2/]Standard deviation.

All hairy vetch varieties except ‘Lana’ exhibited good winter survival in both years of the trial (Table 3). ‘Lana’ winter-killed in 2016 and had 66% winter survival in 2017. This variety was developed in Oregon and is better adapted to warm winter areas of the Pacific Northwest and California (Clark, 2012). Additionally, ‘Lana’ belongs to the woolypod hairy vetch subspecies *varia*, while the other varieties belong to the subspecies *villosa*, which may account for the difference in winter hardiness. All varieties except ‘Lana’ were cold hardy and appeared to have grown over the winter. This lack of complete dormancy allowed the seedlings to begin rapid regrowth in the spring. Plant height was difficult to measure in spring 2017, as the vetch plants climbed weeds in the plots and grew higher than they would have without support. Mean plant height in 2016-17 was 39±6 inches. Plant height in 2017-18 was not affected by weeds and reached a mean of 15±3 inches. In 2018, ‘Lana’ reached 50% bloom earlier than the other vetch varieties, at 267 days compared to 293±12 days for all vetch varieties. At 50% bloom, all surviving varieties were providing good cover and had likely produced benefits in terms of biomass production and N fixation. There were no signs of disease or insect damage on any hairy vetch variety in either year of the study.

Figure 4. Hairy vetch plots, 2018. Photo by Terron Pickett.

Table 3. Mean values and standard deviations for % winter hardiness, plant height and days after planting to 50% bloom for hairy vetch in 2017 and 2018 at the USDA-NRCS PMC, Aberdeen, ID.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
CCS Groff	81	99	40	15	287	298
Lana	0	66	--	12	--	267
Purple Bounty	94	98	40	15	286	298
Purple Prosperity	89	99	39	18	287	294
TNT	91	99	38	14	287	300
Villana	91	99	38	14	287	302
Mean	74	93	39	15	287	293
SD[1/]	36	15	6	3	0.4	12

[1/]SD – Standard deviation.

Winter Pea. Winter pea varieties had poor to moderate early emergence in 2016 and 2017. By 28 DAP, there were large differences in emergence between varieties in both years. 'Lynx' and 'Frost Master' showed poor emergence both years at 28 DAP, while 'Survivor 15' had good emergence in 2016. In 2017, 'Arvica 4010' and 'Dunn' exhibited good emergence and 'Survivor 15', 'Maxum', and 'Whistler' showed excellent emergence by 28 DAP (Table 4).

Table 4. Mean values and standard deviations for field emergence of emergence groups (see below) of winter pea cultivars at 7, 14, 21 and 28 days after planting on 26 August 2016 and 17 August 2017. USDA-NRCS Aberdeen, ID.

Cultivar	Days after planting							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
Arvica 4010	1.8[1/]	1.8	2.3	2.5	3	2.3	2.5	2.5
Dunn	1.5	1.8	2	3	2.8	3	2	2.5
Frost Master	0.3	0.8	0	1	0.8	0.5	0.3	0.8
Lynx	0.3	0	0.3	1	0.5	0.5	0.3	0.5
Maxum	0.8	2	0.3	2.8	2	3	1.8	3
Survivor 15	1.8	2	2.3	3	2.5	3	2.5	3
Whistler	1	1.8	2	2.8	2	2.5	1.8	3
Windham	0.8	0.8	1.3	2	1.5	1.8	1.8	1.8
Mean	1	1.3	1.4	2.3	1.9	2.1	1.6	2.1
S.D.[2/]	0.8	0.8	0.9	0.8	1.0	1.1	0.9	1.0

[1/]0 = poor (<25% germination), 1 = moderate (25-64%), 2 = good (65-85%), 3 = excellent (>85%).
[2/]Standard deviation.

Percent winter hardiness varied among winter pea varieties (Table 4). Clark (2012) reported that temperatures below 10 ^{o}F can damage pea plants. In both years of the trial, temperatures fell below 10 °F by early December. 'Arvica 4010', 'Dunn', and 'Maxum' all winter-killed both years. In 2016-17, 'Survivor 15' was the only variety to survive until bloom in all four plots, with a mean survival rate of 66% (Table 5). Milder winter temperatures in 2017-18 allowed 100% survival of 'Survivor 15', 'Frost Master', and 'Windham'. Mean plant height in 2018 was 23±3 inches. Mean bloom date was 294±5 days. A slight (rating = 1) amount of fungal disease was observed on all winter pea varieties both years (data not shown).

Table 5. Mean values and standard deviations for % winter hardiness, plant height and days after planting to 50% bloom for winter pea cultivars in 2017 and 2018 at the USDA-NRCS PMC, Aberdeen, ID.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
Arvica 4010	0	0	--	--	--	--
Dunn	0	0	--	--	--	--
Frost Master	31	100	30	22	294	298
Lynx	36	43	--	22	--	292
Maxum	0	0	--	--	--	--
Survivor 15	66	100	38	21	294	301
Whistler	13	91	--	27	--	291
Windham	10	100	--	21	--	289
Mean	19	60	36	23	294	294
SD[1/]	29	23	8	3		5

[1/]SD - Standard deviation.

There were two main groups of winter pea, those with a taller, more viny habit and relatively fewer tendrils, and those with a compact habit and many tendrils. The taller varieties, **'**Arvica 4010', 'Dunn', and 'Maxum', all showed good field emergence, but winter-killed in both years of the trial, leaving a mulch which appeared to suppress a few winter annual weeds in the late fall. These varieties would be an acceptable choice in situations where there is a short cover crop window or where winterkill is desirable. 'Survivor 15' had consistently strong emergence and was the only variety that survived in both years of the trial, making it the best adapted variety for our area.

Figure 5. Height measurement of winter pea at 50% bloom, late spring 2018. Photo by Terron Pickett.

Balansa Clover. 'Fixation' showed better emergence and performance overall in both years of the study. By 21 and 28 DAP, there were notable differences each year in emergence between the two varieties (Table 6). 'Fixation' had good to excellent emergence, while 'Frontier' had poor to moderate emergence.

Table 6. Mean values and standard deviations for field emergence of emergence groups (see below) of balansa clover cultivars at 7, 14, 21 and 28 days after planting on 26 August 2016 and 17 August 2017. USDA-NRCS Aberdeen, ID.

Cultivar	Days after planting							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
Fixation	2.8[1/]	3	2.8	2.5	2.5	2.3	2.8	2.5
Frontier	1.8	2	2	0	1	0	1.8	0.8
Mean	2.3	2.5	2.4	1.3	1.8	1.1	2.3	1.6
S.D.[2/]	0.7	0.5	0.5	1.4	0.9	1.2	0.7	1.0

[1/]0 = poor (<25% germination), 1 = moderate (25-64%), 2 = good (65-85%), 3 = excellent (>85%).
[2/]Standard deviation.

Balansa clover is considered marginally adapted to USDA Zone 6B (-5 to 0 ^{o}F) (Clark, 2012); however, both balansa clover varieties survived the winter temperatures in 2016-17, which fell to -23 ^{o}F. Snow cover in Aberdeen likely provided enough insulation to allow the plants to survive at lower temperatures that year. 'Fixation' had higher winter survival both years of the trial, 83 and 98% vs. 52 and 51% for 'Frontier' (Table 7). 'Fixation' plants were on average much taller, reaching a mean height of 17 inches in 2017 and 24 inches in 2018, while 'Frontier' only reached 4 and 3 inches respectively. While 'Frontier' reached 50% bloom earlier, 278 and 257 days vs. 286 and 287 days for 'Fixation', its weak performance showed it was not well adapted to conditions in Aberdeen. Neither variety showed signs of disease or insect damage in either year of the trial.

Table 7. 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 at the USDA-NRCS PMC, Aberdeen, ID.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
Fixation	83	98	17	24	286	287
Frontier	52	51	4	3	278	257
Mean	67	74	13	20	282	272
SD[1/]	28	32	7	10	4	16

[1/]SD - Standard deviation.

Crimson Clover. There were differences in emergence between crimson clover varieties at all dates after planting in both years of the study (Table 8). 'AU Robin', 'AU Sunrise', 'Dixie', and 'Kentucky Pride' all had good to excellent emergence by 28 DAP, while 'AU Sunup', and 'Contea' had only moderate emergence by 28 DAP and appeared less vigorous than the other varieties.

Table 8. Mean values and standard deviations for field emergence of emergence groups (see below) of crimson clover cultivars at 7, 14, 21 and 28 days after planting on 26 August 2016 and 17 August 2017. USDA-NRCS Aberdeen, ID.

Cultivar	Days after planting							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
AU Robin	2.5[1/]	1.5	2.8	2	2.3	2	2.5	2.5
AU Sunrise	2.8	2	2.8	3	2.3	3	3	3
AU Sunup	0.8	0	0.8	1	0.8	1	1.8	1
Contea	1.3	0	1.3	1.8	1	1.8	1.8	1.8
Dixie	2	1.5	2.8	2.3	2.5	2.3	3	2.5
Kentucky Pride	2.5	1.3	2.8	2.3	2.3	2	2.3	2.5
Mean	2.0	1.0	2.2	2	1.8	2	2.4	2.2
S.D.[2/]	1.1	0.9	1.0	0.8	0.8	0.7	0.6	0.8

[1/]0 = poor (<25% germination), 1 = moderate (25-64%), 2 = good (65-85%), 3 = excellent (>85%).
[2/]Standard deviation.

None of the crimson clover varieties winter-killed in either year of the trial. ‘Kentucky Pride’ performed well under the harsh winter conditions of 2016-17, with 98% winter survival, while ‘AU Sunup’ and ‘Contea’ had the lowest survival rates. Mean winter survival was 66±27% in 2017 and 95±5% under the milder winter conditions in 2018 (Table 9). Mean plant height was 14±3 inches in 2017 and 10±3 inches in 2018. Mean time to 50% bloom was 278±1 DAP in 2017, and 305±6 DAP in 2018. None of the varieties showed disease or insect damage in either year of the trial.

Table 9. 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 at the USDA-NRCS PMC, Aberdeen, ID.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
AU Robin	56	96	13	10	278	305
AU Sunrise	75	96	15	11	279	305
AU Sunup	42	91	11	6	278	306
Contea	53	91	13	10	278	305
Dixie	73	98	17	10	278	306
Kentucky Pride	98	98	16	12	280	306
Mean	66	95	14	10	278	305
SD[1/]	27	5	3	3	1	6

[1/]SD - Standard deviation.

Figure 6. Crimson clover in bloom. Photo by Terron Pickett.

Red Clover. There were noticeable differences in emergence between red clover varieties (Table 10). By 28 DAP in 2016, 'Dynamite' was approaching excellent emergence, while 'Cinnamon Plus' had moderate emergence. Mean emergence rating in 2016-17 was good, 2±0.7. In 2017-18, mean emergence was also good, 2.1±0.7. 'Cyclone II' and 'Dynamite' had the highest ratings at 2.8, good to excellent.

Table 10. Mean values and standard deviations for field emergence of emergence groups (see below) of red clover cultivars at 7, 14, 21 and 28 days after planting on 26 August 2016 and 17 August 2017. USDA-NRCS Aberdeen, ID.

	Days after planting							
Cultivar	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
Cinnamon Plus	1.8[1/]	1	1.5	2	1	1.8	1	1.8
Cyclone II	2	1.5	2.5	3	2.3	3	2	2.8
Dynamite	2.3	1.3	2.8	2.8	2	2.8	2.8	2.8
Freedom	2.8	1	2.5	2.3	2.8	2.5	2.5	2.5
Kenland	2	0.5	2.3	1.5	2.3	2	2.3	2
Mammoth	1	1.3	1.5	1.8	1.3	2	1.5	2
Starfire II	1.3	0.5	1.5	1.5	1.5	1.8	1.5	1.5
Wildcat	2.8	0.5	2.8	2	2.5	1.3	2.5	1.8
Mean	2	0.9	2.1	2.1	1.9	2.1	2	2.1
S.D.[2/]	0.8	0.7	0.7	0.6	0.8	0.7	0.7	0.7

[1/]0 = poor (<25% germination), 1 = moderate (25-64%), 2 = good (65-85%), 3 = excellent (>85%).
[2/]Standard deviation.

All varieties of red clover had over 90% winter survival in both years if the trial (Table 11). Mean winter survival was 98±4% in 2017 and 97±5% in 2018. Mean plant height at 50% bloom was 16±5 inches in 2017 and 19±2 inches in 2018. All varieties except 'Mammoth' reached 50% bloom at similar times each year, at 294 DAP in 2017 and 301±4 DAP in 2018. 'Mammoth' had not bloomed by termination in June 2018. If the cover crop objective is blooms for pollinator habitat 'Mammoth' would not be a suitable choice for southern Idaho. None of the varieties showed any disease damage in either year of the trial. All varieties exhibited slight insect damage (rating of 1 = slight damage) by the second evaluation (at 50% bloom) in both years of the trial (data not shown).

Figure 7. Honey bee foraging on red clover flower. Photo by Terron Pickett.

Table 11. Mean values and standard deviations for % winter hardiness, plant height and days after planting to 50% bloom for red clover in 2017 and 2018 at the USDA-NRCS PMC, Aberdeen, ID.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
Cinnamon Plus	94	95	14[1/]	19[1/]	294	305
Cyclone II	98	97	19	20	294	298
Dynamite	98	97	15	19	294	296
Freedom	99	95	15	18	294	300
Kenland	100	98	15	20	294	298
Mammoth	100	99	16	15	294	--
Starfire II	98	93	16	18	294	300
Wildcat	99	98	16	20	294	307
Mean	98	97	16	19	294	301
SD[1/]	4	5	5	2		4

[1/]SD - Standard deviation.

Oat. ‘Soil Saver’ black seeded oat began emergence more slowly than ‘Cosaque’ black oat in 2016, but by 28 DAP, both oat species showed good emergence. In 2017, both oat species had good emergence by 7 DAP in 2017 and excellent emergence by 28 DAP (Table 12).

Table 12. Mean values and standard deviations for field emergence of emergence groups (see below) of oat cultivars at 7, 14, 21 and 28 days after planting on 26 August 2016 and 17 August 2017. USDA-NRCS Aberdeen, ID.

Cultivar	Days after planting							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
Cosaque	2.5[1/]	2	2.8	2.5	2.5	2.5	2.8	3
Soil Saver	1.3	2	1.5	2	1.8	2.8	2	3
Mean	1.9	2	2.1	2.3	2.1	2.6	2.4	3
S.D.[2/]	0.8		0.8	0.5	0.8	0.5	0.9	

[1/]0 = poor (<25% germination), 1 = moderate (25-64%), 2 = good (65-85%), 3 = excellent (>85%).
[2/]Standard deviation.

‘Soil Saver’ black seeded oat grew taller in the fall, but winter-killed in both years of the trial. ‘Cosaque’ black oat had 50% winter survival in 2016-17 and 75% winter survival in 2017-18. At anthesis, ‘Cosaque’ had reached a mean height of 22±3 inches in 2017 and 27±3 inches in 2018. It reached 50% anthesis at 291 DAP and 284 DAP in 2017 and 2018 respectively (Table 13). Both oat species appeared to suppress winter annual weeds despite winterkill.

Figure 8. ‘Cosaque’ black oat beginning regrowth compared to ‘Soil Saver’ black seeded oat which winter-killed, 17 March 2017. Photo by Terron Pickett.

Table 13. Mean values for % winter hardiness, plant height and days after planting to 50% anthesis for oat cultivars in 2017 and 2018 at the USDA-NRCS PMC, Aberdeen, ID.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% anthesis	
	2017	2018	2017	2018	2017	2018
Cosaque	50	75	22	27	291	284
Soil Saver	0	0	--	--	--	--

Cereal Rye. In 2016, two varieties were not available by the planting date, and were planted later as they became available. ‘Hazlet’ was planted one week later, on 1 September 2016, and its emergence data was recorded from that date. ‘Rymin’ was planted 37 days late (25 September 2016) and only its 50% anthesis date was recorded. There were differences in emergence between varieties in both years of the trial (Table 14). All varieties had good to excellent field emergence by 28 DAP except for ‘Guardian’, which had moderate emergence.

Table 14. 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 on August 26, 2016 and August 17, 2017. USDA-NRCS Aberdeen, ID.

Cultivar	Days after planting							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
Aroostook	2.3[1/]	2.3	2.8	2.3	3	1.8	3	2.5
Bates	2.3	3	2.8	2.5	3	2.8	3	3
Brasetto	2.3	2.3	1.8	2.5	1.8	2.5	2.3	3
Elbon	2.3	2	2.5	2	2.5	1.3	3	2
FL 401	1.5	1.5	1.8	1.8	2.3	1	2.3	2
Guardian	0.5	1.8	0.8	0	1	0	1	1
Hazlet	2.8[3/]	2.5	2.5	3	2.3	3	--	3
Maton	2.5	2.5	2.3	2.5	2.8	2.3	3	3
Maton II	2	2	1.8	1.8	2	1.3	2.3	2.3
Merced	2.8	3	2.8	2.8	2.8	3	2.8	3
Oklon	2	2.3	2.5	2.3	2.5	1.8	3	2.8
Prima	0.8	1.3	1.8	2	2	1.5	2.5	2.3
Rymin	M	2.5	M	2.8	M	2.8	M	2.8
Wheeler	1.8	2.5	2.5	3	2.8	3	2.3	3
WinterGrazer 70	2.8	2.3	2.5	2.3	3	2	3	2.3
Wrens Abruzzi	2.5	2	2.5	2.3	2.5	2	3	3
Mean	2.1	2.2	2.2	2.2	2.4	2	2.6	2.5
S.D.[2/]	0.9	0.7	0.7	0.8	0.7	0.9	0.6	0.6

[1/]0 = poor (<25% germination), 1 = moderate (25-64%), 2 = good (65-85%), 3 = excellent (>85%).
[2/] Standard deviation.
[3/]Hazlet was planted and evaluated one week later than the other varieties in 2016. No evaluation was done at 28 DAP.

There were marked differences in winter hardiness between varieties, ranging from ‘FL 101’ and ‘Merced’, which winter killed both years of the trial, to ‘Brasetto’, ‘Hazlett’, and ‘Prima’, which maintained at least 90% winter survival both years (Table 15). Winter survival was lower in 2016-17, with a mean survival rate of 55±35%. In 2017-18, warmer winter temperatures resulted in a mean survival rate of 86±33%. Varieties that did not winter-kill all had over 90% survival. Mean height at anthesis was 43±7 inches in 2016-17 and 60±7 inches in 2017-18 (Table 15). While no biomass measurements were made in this trial, the heights indicate that adapted varieties of cereal rye can produce abundant biomass in our region.

Table 15. Mean values and standard deviations for % winter hardiness, plant height and days after planting to 50% anthesis for cereal rye cultivars in 2017 and 2018 at the USDA-NRCS PMC, Aberdeen, ID.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% anthesis	
	2017	2018	2017	2018	2017	2018
Aroostook	52	100	39	61	284	278
Bates	20	99	44	55	284	280
Brasetto	92	97	42	48	284	281
Elbon	72	99	35	62	284	281
FL 101	0	0	--	--	--	--
Guardian	81	100	54	66	283	282
Hazlet	90[3/]	99	46	60	286	286
Maton	70	99	39	58	284	279
Maton II	52	99	42	59	282	279
Merced	0	0	--	--	--	--
Oklon	74	99	42	62	282	283
Prima	95	99	47	63	282	286
Rymin	--[2/]	100	--	66	245	286
Wheeler	81	96	52	74	286	279
WinterGrazer 70	37	100	42	52	284	281
Wrens Abruzzi	5	91	40	56	284	279
Mean	55	86	43	60	284	281
SD[1/]	35	33	7	7	1	3

[1/]SD - Standard deviation.
[2/]No seed available at time of planting. Hazlet was planted 26 Aug 2016; all fall data taken one week later. Rymin was planted late on 25 Sept 2016; only the 50% anthesis date was recorded. (Note: despite being planted 37 days later, it reached 50% anthesis at the mean 50% anthesis date.)

Cereal rye cultivars that survived the winter reached 50% anthesis at similar times, 284±1 DAP in 2016-17 and 281±3 DAP in 2017-18. Despite late planting in 2016, ‘Rymin’ reached 50% anthesis at the same time as other varieties. No disease or insect damage was observed in either year of the trial. Cereal rye can become invasive in areas that grow small grains and is generally not recommended in areas where winter wheat is in rotation (St. John et al., 2017). However, varieties like ‘FL 101’ and ‘Merced’ that consistently winter-kill before setting seed may provide a low-risk cereal rye cover crop option for the Intermountain region.

Oilseed (Daikon) Radish. Most radish varieties had emerged moderately well by 7 DAP, with a mean of 1.1±0.7 (Table 16). By 28 DAP, the mean emergence rating was good to excellent, 2.7±0.7. The exception was ‘Graza’, which had poor emergence in both years of the trial. Radish cover persisted through the fall, providing good weed suppression that persisted even after removal for sampling and after winterkill. Weeds were not suppressed in the ‘Graza’ plots. All daikon radish varieties winter-killed by late fall, when temperatures fell well below freezing. A few individual plants of ‘Concorde’, ‘Control’, ‘Defender’, and ‘Graza’ survived the winter of 2017-18. No winter survival, height, bloom measurements, or disease and insect damage measurements were made.

‘Concorde’, ‘Control’, and ‘Defender’ radishes are known to be an effective biocontrol crop for Columbia root-knot nematodes (*Meloidogyne chitwoodi*) and sugar beet cyst nematodes (*Heterodera schachtii*) ‘Defender’ is also a biocontrol crop for stubby root nematodes (Tilley and Pickett, 2019). These biocontrol benefits are not dependent on winter hardiness.

Table 16. Mean values and standard deviations for field emergence of emergence groups (see below) of daikon radish cultivars at 7, 14, 21 and 28 days after planting on 26 August 2016 and 17 August 2017. USDA-NRCS Aberdeen, ID.

Cultivar	Days after planting							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
Big Dog	1.5[1/]	2.3	2.3	3	2.8	2.8	2.5	2.8
Concorde	1.3	1.5	2	2.5	1.8	2.3	2.5	2.8
Control	1	1	1.5	2.3	1.5	2.3	1.8	2.8
Defender	1.5	1.5	2	2.5	2.5	2.8	2.5	2.8
Driller	1.3	1.8	2.3	2.3	2.8	2.8	2.5	3
EcoTill	1.3	1.3	2.3	2.5	2.3	2.8	2.3	3
Graza	0	0	0	0.3	0	0	0	0.8
Groundhog	1.3	1.5	2.3	3	2.5	2.8	2.3	3
Lunch	0.5	1.5	1.5	2.8	2	2.5	1.8	2.8
Nitro	1.5	1.5	2	2.8	2	2.8	2.5	3
Sodbuster	0.8	1.5	1.5	2.5	1.5	2.5	1.5	2.8
Tillage	1.8	1.3	3	2.8	2.5	2.8	2.8	3
Mean	1.1	1.4	1.9	2.4	2	2.4	2	2.7
S.D.[2/]	0.7	0.8	0.9	0.8	0.9	0.9	0.9	0.7

[1/]0 = poor (<25% germination), 1 = moderate (25-64%), 2 = good (65-85%), 3 = excellent (>85%).
[2/]Standard deviation.

Figure 9. Oilseed (daikon) radish plots, fall 2017. The middle plot is ‘Graza.’ Photo by Terron Pickett.

CONCLUSION

The first step to a successful cover crop planting is to choose plants that are well adapted to local conditions and producer objectives. This 2-year evaluation of commercially available winter pea, balansa clover, red clover, crimson clover, oat, cereal rye and oilseed (daikon) radish provides a base of information on best-adapted varieties for the Intermountain West. Many of the varieties exhibited good adaptation based on field emergence, winter hardiness, height, and DAP to 50% bloom. Black seeded oat and some varieties of cereal rye demonstrated strong emergence and fall growth and then winter-killed, making them a good choice for producers who want the benefits of a fall cover crop without the need for chemical or mechanical termination. Most of the cover crops evaluated had no insect or disease issues, and none had more than slight insect or disease damage. Additional information is needed on biomass production of the best performing varieties to maximize cover crop benefits and to further describe their productivity and adaptation in the region.

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