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Evaluation of Annual Cool Season Cover Crop Varieties for the Inland Pacific Northwest

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ABSTRACT

Cool season, annual cover crops can provide multiple benefits to production agriculture such as weed suppression, erosion control, nitrogen fixation, and increased soil organic matter. However, cover crop success depends on the selection of the best adapted variety of the cover crop species. The purpose of this study was to evaluate forty-three commercially available varieties of seven common annual, coo1 season species for their adaptation to the Inland Pacific Northwest. Black seeded oat (*Avena sativa* L.) and black oat (*Avena strigosa* Schreb.), 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, plant height, maturity date, and disease and insect resistance at the Pullman, WA Plant Materials Center in 2016-2017 and 2017-2018. Balansa clover varieties had slow field emergence both years but 'Fixation' had good field emergence at 28 days after planning (DAP) in 2016. 'Cosaque' black seeded oats exhibited 33-98% winter hardiness while 'Soil Saver' completely winterkilled in 2017 but had 88% winter hardiness in 2018. Winter hardiness of crimson clover varieties was 83 ± 11% in 2017 and 9 ± 15% in 2018. Hairy vetch varieties exhibited some winter hardiness in 2017 with winter hardiness of 57% ± 17%. 'Lana' woollypod vetch bloomed about 16 days earlier than the other varieties. In 2017, there was considerable variation in percent winter hardiness among varieties of daikon radishes with 'Defender' having the most at 51%. In 2018, 'Concorde', 'Control', and 'Graza' had better winter hardiness. All planted varieties of red clover had 56% winter hardiness or greater in 2017 with 'Cinnamon Plus', 'Cyclone II', 'Dynamite', and 'Mammoth' having 86% - 94% winter hardiness. Austrian winter pea varieties 'Whistler', 'Frost Master', 'Lynx' and 'Windham' had greater than 75% winter survival but lacked the same winter hardiness in 2018. 'Lynx' exhibited 75% winter hardiness in 2018 but other varieties exhibited much less winter hardiness. To maximize cover crop usage, the best performing varieties need additional study to determine appropriate planting dates and to further characterize their adaptation to the inland Pacific Northwest.

INTRODUCTION

The mission of the USDA-NRCS Plant Materials Program is to assemble and evaluate plants for use in conservation activities to solve natural resource concerns of which, improving soil health is a central tenant. Cover crops are a management practice known to improve soil structure, increase water infiltration, reduce nutrient leaching, decrease soil compaction, increase soil aggregate stability, and increase soil organic carbon (Vezzani et al., 2018; Zhou et al., 2016; Morrow et al., 2017; Poeplau and Don, 2015). However, widespread adoption of cover crop usage in cropping systems in the inland Pacific Northwest region is lacking. The conservation benefits of cover crops are not achieved unless the best adapted varieties are planted that meet the planting objectives (i.e. weed suppression, nitrogen scavenging, reduce soil erosion) and the end-user'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 the inland Pacific Northwest.

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MATERIALS AND METHODS

The study was conducted at the USDA-Natural Resources Conservation Service Plant Materials Center, Pullman, WA in 2016-2017 and 2017-2018. Annual, cool season species were planted on a pure live seed (PLS) basis (Table 1). Legumes were inoculated with appropriate rhizobia before seeding. Plots were planted into a Palouse silt loam soil 21 September 2016 and 26 September 2017 with a Great Plains no-till drill equipped with a Kincaid cone seeder (Kincaid Equipment, Haven KS) on 7.5" row spacing. Plot size was 5.5-ft x 10-ft. Plots were moved to a new field location in 2017 to avoid contamination from the previous year. Monthly rainfall (September-May) and the minimum low temperature were recorded in 2016-2017 and 2017-2018 (Figures 1 and 2).

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%). 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 variety), but no apparent disease or insect damage was observed on any varieties during the study. Winter survival (winter hardiness) was evaluated from a 3-ft section of an interior row marked in each plot. Seedlings in a 3 ft span were counted at 1-inch increments in the fall (November) and following spring green-up (March) of the 2016-2017 and 2017-2018 fall to spring season. Bloom period was monitored by noting the date of beginning bloom and 50% bloom. Average plant height was determined from measurements taken from the interior rows of the plot.

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

Table 1. Species, varieties and seeding rates of annual cool seasons planted in 2016 and 2017 at the USDA NRCS Pullman, Washington Plant Materials Center.

Common name	Species	Cultivar	PLS lb/acre	% PLS	Seeding rate lb/acre
Austrian winter pea	*Pisum sativum*	Arvica 4010	60	94	64
Austrian winter pea	*Pisum sativum*	Dunn	60	85	71
Austrian winter pea	*Pisum sativum*	Frost Master	60	85	71
Austrian winter pea	*Pisum sativum*	Lynx	60	90	67
Austrian winter pea	*Pisum sativum*	Maxum	60	90	67
Austrian winter pea	*Pisum sativum*	Survivor 15	60	94	64
Austrian winter pea	*Pisum sativum*	Whistler	60	81	74
Austrian winter pea	*Pisum sativum*	Windham	60	90	67
Balansa clover	*Trifolium michelianum*	Fixation	12	22	55
Balansa clover	*Trifolium michelianum*	Frontier	12	57	21
Black oats	*Avena sativa*	Cosaque	84	83	101
Black seeded oats	*Avena strigosa*	Soil Saver	84	98	86
Crimson clover	*Trifolium incarnatum*	AU Robin	22	55	40
Crimson clover	*Trifolium incarnatum*	AU Sunrise	22	42	52
Crimson clover	*Trifolium incarnatum*	AU Sunup	22	91	24
Crimson clover	*Trifolium incarnatum*	Contea	22	60	37
Crimson clover	*Trifolium incarnatum*	Dixie	22	84	26
Crimson clover	*Trifolium incarnatum*	KY Pride	22	98	22

Table 1 (cont.). Species, varieties and seeding rates of annual, cool seasons planted in 2016 and 2017 at the USDA NRCS Pullman, Washington Plant Materials Center.

Common name	Species	Cultivar	PLS lb/acre	% PLS	Seeding rate lb/acre
Hairy vetch	*Vicia villosa*	CCS Groff	24	90	27
Hairy vetch	*Vicia villosa*	Purple Bounty	24	90	27
Hairy vetch	*Vicia villosa*	Purple Prosperity	24	90	27
Hairy vetch	*Vicia villosa*	Villana	24	90	27
Woollypod vetch	*Vicia villosa* subsp. *varia*	Lana	24	90	27
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

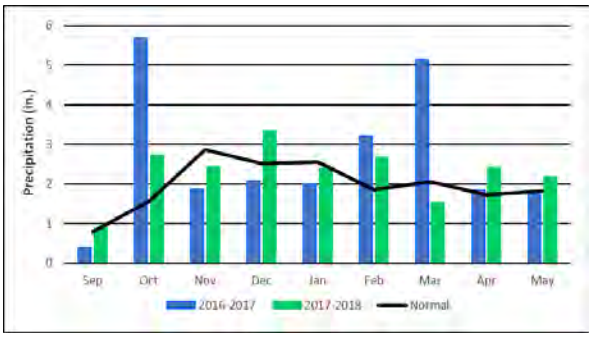

Figure 1. Monthly and normal precipitation in Sep-May 2016-2017 and 2017-2018 at Pullman, WA.

Figure 2. Monthly and lowest temperatures in Sep-May 2016-2017 and 2017-2018 at Pullman, WA.

RESULTS AND DISCUSSION

Monthly rainfall for September through May in 2016-2017 and 2017-2018 was recorded from an official weather station near the study (Fig. 1). Total precipitation for the September through May growing season was 23.96 inches in 2016-2017 and 20.6 inches in 2017-2018 compared to the normal of 17.75 inches. The first killing frost for the 2016-2017 season occurred in October 2016 with the lowest temperature occurring in December 2016 at -11 °F (Fig. 2.). The first killing frost for the 2017-2018 season was in October 2017 with the lowest temperature of -7.1 °F recorded in February 2018 (Fig. 2.).

Balansa Clover

Balansa clover varieties emerged slowly after planting in 2016 and 2017 but 'Fixation' achieved good emergence 28 days after planting (DAP) in 2016 (Table 2). The slow emergence was likely due to low available moisture in the first 28 days after planting. 'Fixation' had a winter hardiness of about 90% and 'Frontier' had a winter hardiness of about 75% over the 2016-2017 winter (Table 3). However, both varieties exhibited low winter hardiness in 2017-2018 with 'Fixation' having about 26% surviving plants while 'Frontier' had about 10% surviving plants (Table 3). In the spring of 2017, 'Fixation' had a mean plant height of 20 inches and 'Frontier' about 10 inches (Table 3). In the spring of 2018, there were not enough plants that survived the winter to get a height measurement. In the later spring of 2018, there were a few plants that started growing after the winter hardiness measurements were taken and those plants reached 50% bloom about 227 DAP. Over the 2016-2017 season there was about a seven-day difference between 50% bloom dates with 'Frontier' getting to 50% bloom 247 DAP and 'Fixation' reaching 50% bloom 254 DAP (Table 3).

Table 2. Mean values and standard deviations of emergence groups (see below) of balansa clover at 7, 14, 21 and 28 days after planting in 2016-2017. USDA-NRCS Pullman, WA.

Cultivar	Days after planting/Year							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
Fixation	0[1/]	0	0	0	0	0	2	0
Frontier	0	0	0	0	0	0	0	0
Mean	0	0	0	0	0	0	1	0
SD[2/]							1	

[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 for balansa clover in 2017 and 2018 at the USDA-NRCS Pullman, WA.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
Fixation	90	26	20		254	227[2/]
Frontier	75	10	10		247	227[2/]
Mean	83	18	15		250	227[2/]
SD[1/]	13	18	7		5	

[1/] Standard deviation.[2/] Estimate from small number of persisting plants.

Black Oats and Black Seeded Oats

Percent field emergence of black oats ('Soil Saver') and black seeded oats ('Cosaque') ranged from poor to good by 28 DAP (Table 4). The slow emergence was likely due to low available moisture in the first 28 days after planting. Cosaque exhibited 33-98% winter hardiness while Soil Saver was completely winterkilled in 2017 but had 88% winter hardiness in 2018 (Table 5). Plant height of Cosaque ranged from 28 inches in 2017 to 12 inches in 2018 (Table 5). Plant height of Soil Saver was not measurable in 2017 and was 12 inches in 2018 (Table 5). In 2017, Cosaque reached 50% bloom 253 DAP, while in 2018 Cosaque and Soil Saver both were at 50% bloom 223 DAP (Table 5). The winter hardiness of both Cosaque and Soil Saver seem to be dependent on the amount of aboveground biomass accumulation prior to the first killing frost and how cold and long the temperatures in the winter remain. Both varieties had better winter hardiness in 2018 when the winter was not as harsh. Producers should recognize that black oats or black seed oats may or may not winter winterkill and plan accordingly.

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 2016-2017. USDA-NRCS Pullman, WA.

Cultivar	Days after planting/Year							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
Soil Saver	0[1/]	0	0	0	0	1	2	1
Cosaque	0	0	0	0	0	0	1	0
Mean	0	0	0	0	0	0	0	1

[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 for black oats varieties in 2017 and 2018 at the USDA-NRCS Pullman, WA.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
Soil saver	0	88		12		223
Cosaque	33	98	28	12	253	223
Mean	17	93	28	12	253	223
SD[1/]	20	10	5			

[1/] Standard deviation

Crimson Clover

Mean percent field emergence was moderate to good for crimson clover varieties by 28 DAP in 2016 and poor to moderate by 28 DAP in 2017 (Table 6). The slow emergence was likely due to low available moisture in the first 28 days after planting. Mean percent winter hardiness was 83 ± 11% in 2017 but 9 ± 15% in 2018 (Table 7). 'AU Robin', 'AU Sunrise', 'Dixie' and 'Kentucky Pride' exhibited

more than 85% winter hardiness in 2017; however, the survival of all varieties declined to 20% or less in 2018 (Table 7). Plant height varied among varieties and ranged from 19 inches to 31 inches in 2017 (Table 7). 'AU Robin' was the only variety that had a measurable height in 2018 with 3 inches (Table 7). Mean days after planting to 50% bloom was 247 ± 2 days in 2017 and 227 days in 2018 (Table 7). Additional comparative trials are needed to verify areas of adaptation of these varieties in other regions of Washington where crimson clover is grown for cool season forage, cover cropping, and other conservation plantings.

Table 6. Mean values and standard deviations of emergence groups (see below) of crimson clover varieties at 7, 14, 21 and 28 days after planting in 2016-2017. USDA-NRCS Pullman, WA.

Cultivar	Days after planting/Year							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
AU Robin	0[1/]	0	0	0	0	0	2	1
AU Sunrise	0	0	0	0	0	0	2	1
AU Sunup	0	0	0	0	1	0	1	0
Contea	0	0	0	0	1	0	1	0
Dixie	0	0	0	0	0	0	2	1
Kentucky Pride	0	0	0	0	0	0	2	1
Mean	0	0	0	0	0	0	2	1
SD[/2]					1		1	1

[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 7. Mean values and standard deviations for % winter hardiness, plant height and days after planting to 50% bloom for crimson clover varieties in 2017 and 2018 at the USDA-NRCS Pullman, WA.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
AU Robin	89	10	20	3	245	227
AU Sunrise	86	4	31		246	227[2/]
AU Sunup	69	10	19		247	
Contea	82		23		247	
Dixie	87	20	23		246	227[2/]
Kentucky Pride	86	3	28		250	
Mean	83	9	24	3	247	227
SD[1/]	11	15	5		2	

[1/]SD - Standard deviation. [2/] Estimate from small number of persisting plants.

Hairy Vetch and Woollypod Vetch

All hairy vetch varieties and the woollypod vetch failed to emerge by 28 DAP in 2016 and 2017 (Table 8). The slow emergence was likely due to low available moisture in the first 28 days after planting. The varieties exhibited some winter hardiness in 2017 with a mean winter hardiness of 57% ± 17% but in 2018 'CCS Groff' and 'Villana' winterkilled and the other varieties exhibited poor winter hardiness in 2018 (Table 9) probably due to not getting enough growth in the fall going into winter. Mean

plant height was between 63 inches and 69 inches in 2017 for all varieties except 'Lana' woollypod vetch with a mean plant height of 32 inches (Table 9). 'Lana' woollypod vetch has been documented as being able to produce more dry matter than other vetch species and may have fast growth in the spring when enough moisture is present (Clark, 2012), potentially making it an ideal vetch species in some cropping systems. In 2018, 'TNT' was the only surviving variety and reached a plant height of 8 inches (Table 9). Mean DAP to 50% bloom was 257 ± 6 days in 2017 for all varieties and 'TNT' at 228 days in 2018 (Table 9). 'Lana' woollypod vetch reached 50% bloom approximately 2 weeks earlier than the other hairy vetch varieties in 2017 (Table 9). As an earlier blooming vetch, 'Lana' may be beneficial as a nitrogen producing cover crop when a shorter season for cover crops are needed in production systems in the inland Pacific Northwest.

Table 8. Mean values and standard deviations of emergence groups (see below) of hairy vetch varieties at 7, 14, 21 and 28 days after planting in 2016-2017. USDA-NRCS Pullman, WA.

Cultivar	Days after planting/Year							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
CCS Groff	0[1/]	0	0	0	0	0	0	0
Lana	0	0	0	0	0	0	0	0
Purple Bounty	0	0	0	0	0	0	0	0
Purple Prosperity	0	0	0	0	0	0	0	0
TNT	0	0	0	0	0	0	0	0
Villana	0	0	0	0	0	0	0	0
Mean	0	0	0	0	0	0	0	0

[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 for hairy vetch varieties in 2017 and 2018 at the USDA-NRCS Pullman, WA.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
CCS Groff	62		68		261	
Lana	56	24	32		245	
Purple Bounty	69	15	66		261	
Purple Prosperity	45	5	63		260	
TNT	56	44	65	8	261	228
Villana	55		69		260	
Mean	57	24	60	8	258	228
SD[1/]	17	16	15		6	

[1/]SD - Standard deviation.

Daikon Radish

Percent field emergence of daikon radish varieties were moderate by 28 DAP in 2016, except for 'Graza' (Table 10). Percent field emergence in 2017 ranged from poor to moderate by 28 DAP (Table 10). There was considerable variation in percent winter hardiness among varieties in 2017 with

'Defender' having the highest at 51% (Table 11). In 2018, most varieties exhibited less cold hardiness than in 2017, except for 'Concorde', 'Control', and 'Graza' which had better winter hardiness but

Table 10. Mean values and standard deviations of emergence groups (see below) of daikon radish sources at 7, 14, 21 and 28 days after planting in 2016-2017. USDA-NRCS Pullman, WA

Cultivar	Days after planting/Year							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
Big Dog	0[1/]	0	0	0	0	0	1	1
Concorde	0	0	0	0	0	0		1
Control	0	0	0	0	0	0	1	1
Defender	0	0	0	0	0	0		1
Driller	0	0	0	0	0	0		1
EcoTill	0	0	0	0	0	0	1	1
Graza	0	0	0	0	0	0	0	0
Groundhog	0	0	0	0	0	0	1	1
Lunch	0	0	0	0	0	0	1	1
Nitro	0	0	0	0	0	0	1	0
Sodbuster	0	0	0	0	0	0	1	1
Tillage	0	0	0	0	0	0	1	1
Mean	0	0	0	0	0	0	1	1
SD[2/]							0	1

[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 for daikon radish varieties in 2017 and 2018 at the USDA-NRCS Pullman, WA.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
Big Dog	8	4				
Concorde	10	21	22	11	247	227
Control	12	14	18	11	246	230
Defender	51	0	17		247	
Driller	6	0	17		244	
EcoTill	6	0	17		246	
Graza	22	33			254	
Groundhog	1	0	20		247	
Lunch	21	2	16		244	
Nitro	6	0	14		247	
Sodbuster	2	0	14		247	
Tillage	0	0				
Mean	12	5	17	11	246	229
SD[1/]	19	13	4		3	2

[1/]SD - Standard deviation.

unacceptable cover for soil protection or suppressing weeds (Table 11). Radishes are tolerant of light frosts but are killed when temperatures fall below 20°F (Sundermeier, 2008). Plant height and DAP to 50% bloom similar among varieties (Table 11).

Red Clover

Red clover varieties had moderate to good emergence by 28 DAP in 2016 but had poor emergence by 28 DAP in 2017 (Table 12). All planted varieties had 56% winter hardiness or greater in 2017 with 'Cinnamon Plus', 'Cyclone II', 'Dynamite', and 'Mammoth' having 86% - 94% winter hardiness. However, in 2018, 'Freedom' was the only variety that exhibited winter hardiness, with 15% (Table 13). Red clover is generally winter hardy in USDA Plant Hardiness Zone 4 and warmer (Clark, 2012), which includes most of the inland Pacific Northwest, except for the highest elevations of the

Table 12. Mean values and standard deviations of emergence groups (see below) of red clover varieties at 7, 14, 21 and 28 days after planting in 2016-2017. USDA-NRCS Pullman, WA.

Cultivar	Days after planting/Year							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
Cinnamon Plus	0[1/]	0	0	0	0	0	1	0
Cyclone II	0	0	0	0	0	0	2	0
Dynamite	0	0	0	0	0	0	2	0
Freedom	0	0	0	0	0	0	2	0
Kenland	NP[3/]	0	NP	0	NP	0	NP	0
Mammoth	0	0	0	0	0	0	1	0
Starfire II	0	0	0	0	0	0	1	0
Wildcat	0	0	0	0	0	0	2	0
Mean	0	0	0	0	0	0	1	0
SD[/2]							1	

[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 for red clover varieties in 2017 and 2018 at the USDA-NRCS Pullman, WA.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
Cinnamon Plus	86		9			
Cyclone II	94		9			
Dynamite	87		12		260	
Freedom	77	15	9	3	260	227
Kenland	NP[2/]		NP		NP	
Mammoth	89		8			
Starfire II	57		10		257	
Wildcat	81		12		254	
Mean	81	15	10	3	258	227
SD[1/]	21		3		3	

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

mountains. Mean plant height was 10 ± 3 inches in 2017 and 3 inches in 2018. Mean DAP to 50% bloom were 258 ± 3 days in 2017 to 227 days in 2018, again with 'Freedom' being the winter surviving variety (Table 13).

Austrian Winter Pea

Austrian winter pea varieties had poor emergence by 28 DAP in 2016 and 2017 (Table 14). The slow emergence was likely due to low available moisture in the first 28 days after planting. Percent winter hardiness varied among varieties from 30% (Arvica 4010) to 93% (Windham) in 2017 with a mean of 65% (Table 15). In 2018, all varieties of Austrian winter pea exhibited low winter survival with

Table 14. Mean values and standard deviations of emergence groups (see below) of winter pea varieties at 7, 14, 21 and 28 days after planting in 2016-2017. USDA-NRCS Pullman, WA.

Cultivar	Days after planting/Year							
	7		14		21		28	
	2016	2017	2016	2017	2016	2017	2016	2017
Arvica 4010	0[1/]	0	0	0	0	0	0	0
Dunn	0	0	0	0	0	0	0	0
Frost Master	0	0	0	0	0	0	0	0
Lynx	0	0	0	0	0	0	0	0
Maxum	0	0	0	0	0	0	0	0
Survivor 15	0	0	0	0	0	0	0	0
Whistler	0	0	0	0	0	0	0	0
Windham	0	0	0	0	0	0	0	0
Mean	0	0	0	0	0	0	0	0

[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 15. Mean values for % winter hardiness, plant height and days after planting to 50% bloom for winter pea varieties in 2017 and 2018 at the USDA-NRCS Pullman, WA.

Cultivar	% Winter hardiness		Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018	2017	2018
Arvica 4010	30		27		261	
Dunn	36		21		261	
Frost Master	83	44	34		261	
Lynx	85	75	19	12	255	254
Maxum	41		17		261	
Survivor 15	74	43	21	11		254
Whistler	75	30	38		261	
Windham	93	54	30	10	256	255
Mean	65	47	25	11	259	254
SD[1/]	30	39	12	1	3	1

[1/]SD - Standard deviation.

'Arvica 4010', 'Dunn', and 'Maxum' lacking winter hardiness (Table 15). Despite the low temperatures in 2016-2017, 'Whistler', 'Frost Master', 'Lynx' and 'Windham' had greater than 75% winter survival but lacked the same winter hardiness in 2018 (Table 15). This is likely due to higher precipitation in

October of 2016, which allowed better establishment of the root system of the Austrian winter peas before winter. 'Lynx' exhibited 75% winter hardiness in 2018 but the other varieties exhibited much less with 'Windham' exhibiting a 54% winter hardiness (Table 15). 'Lynx' has a cold hardiness tolerance to -5°F, while 'Windham' is winter hardy to 0°F, and 'Whistler' to +5°F (McGee et al., 2017). In December 2016, the lowest temperature was -11°F and in February 2018 the lowest temperature was -7°F (fig.2).

CONCLUSIONS

Choosing the best adapted cover crop(s) to the region for the intended conservation purpose is the first step to a successful cover crop planting. The 2-year evaluation of commercially available crimson clover, hairy vetch, woollypod vetch, red clover, Austrian winter pea, balansa clover, black oats, and black seeded oats provided beneficial information on best adapted varieties for the inland Pacific Northwest. Some of the species and varieties exhibited some adaptation to the inland Pacific Northwest based on field emergence, winter hardiness, and DAP to 50% bloom. One of the major challenges for the success of fall planted cover crops in the Pacific Northwest is getting adequate fall moisture after the cover crops are planted to ensure enough fall growth before winter. Fall moisture is the biggest variable to the success or failure of growing cover crops in the inland Pacific Northwest. The Mediterranean weather pattern of the inland Pacific Northwest, coupled with the relative later harvest of the primary cash crops of winter and spring wheat in the region, limit the number of growing days with enough available moisture for cover crops to establish and grow before the onset of winter. Additional information is needed on timing of planting of the best performing varieties to maximize their use as a cover crop and to further characterize their adaptation to the inland Pacific Northwest.

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