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Cover Crop Variety Adaptation Trials in Corvallis, OR
Second Year Progress Report

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ABSTRACT

Cover crops have the potential to provide many soil health and crop production benefits, but their success depends upon selection and use of species and varieties adapted to the local climate and soils. In order to evaluate the adaptation and growth potential of common, commercially available cover crop species and varieties, the NRCS Plant Materials Center in Corvallis, Oregon is participating in a 3-year variety trial along with 22 other Plant Materials Centers across the country. The national study includes a total of 60 varieties of 8 species that are being evaluated for germination and establishment, pest and disease resistance, winter hardiness, bloom time, and mature plant height. This progress report summarizes preliminary first and second year results and observations from the Corvallis variety trials. Results so far indicate good adaptation of most varieties of oat, cereal rye, hairy vetch, crimson clover, and Balansa clover. Higher than average early spring rainfall both years resulted in ponding that, combined with a few ice storms, winter-killed all varieties of Austrian winter peas tested. The ponding and wetter than average conditions also led to high levels of fungal leaf spot disease among most daikon radish varieties that limited their canopy cover and biomass production. With their slow establishment, lack of cover over the winter, and susceptibility to weeds and slugs, the red clover varieties tested did not appear to be a promising choice as a winter annual cover crop in western Oregon. One more season of data will be collected in the 2017-2018 growing season, and final variety recommendations for western Oregon will be based on all three years of data.

INTRODUCTION

Incorporating cover crops into a cropping system improves soil health, conserves energy, builds resilience, and manages climate risk (Lal, 2004; Reicosky and Forcella, 1998; Hargrove, 1986; Reeves, 1994). Cover crops can be leguminous or non-leguminous. Leguminous cover crop species provide a nitrogen source for subsequent commodity crops (Singh et al., 2004; Smith et al., 1987). Non-leguminous cover crops, such as small grains, are effective in reducing nitrate leaching and soil erosion (Meisinger et al., 1991). Utilizing a mix of leguminous and non-leguminous cover crop species can provide multiple benefits. 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 the producer's expectations.

The purpose of this trial is to evaluate growth characteristics and production attributes of commercially available varieties of important and commonly-used cover crops identified by Natural Resources Conservation Service (NRCS) Agronomists, Soil Health Specialists, and Plant Materials staff. This study will provide cover crop adaptation and growth data for different geographical regions of the U.S., and inform local recommendations for cover crops, as well as future soil health studies.

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MATERIALS AND METHODS

The Corvallis Plant Materials Center (PMC) is participating in a nationally-coordinated cover crop variety trial being conducted at 23 USDA-NRCS Plant Materials Centers across the country. We conducted a trial run of the study in 2015-2016, and completed the first year of the full replicated study, with some additional varieties, in 2016-2017. The final year of the study will be completed in the 2017-2018 growing season. Cover crop species/varieties included in the study and seeding rates are listed in Table 1; the same varieties and seed lots are being evaluated at all PMCs, although we added a few species/varieties of local interest to the Corvallis study (indicated by footnote 1 in Table 1). Data are also reported for certain species in a previous cover crop adaptation trial conducted at the Corvallis PMC

Table 1. Cover crop species, varieties, average seeds per pound, and seeding rates used in adaptation trials at the Corvallis Plant Materials Center.

Species	Common Name	Variety	Seeds per Pound	Seeding Rate (PLS* seeds/ft^2)	Seeding Rate (PLS lb/ac)	Year Planted
Avena sativa[1/]	common oat	Cayuse	14,000	34	105	2014, 2016
Avena sativa	oat, black-seeded	Cosaque	12,000	42	152	2015, 2016
Avena strigosa	black oat	Soil Saver	30,000	42	60	2015, 2016
Hordeum vulgare[1/]	barley, winter	Verdant	12,000	29	107	2014, 2016
Lolium perenne ssp. *multiflorum*[1/]	annual ryegrass	Tillage RootMax	192,000	65	15	2014, 2016
Secale cereale	cereal rye	Aroostook	23,000	42	79	2015, 2016
Secale cereale	cereal rye	Bates RS4	22,000	42	84	2016
Secale cereale	cereal rye	Brasetto hybrid	21,000	42	86	2015, 2016
Secale cereale	cereal rye	Elbon	32,000	42	57	2015, 2016
Secale cereale	cereal rye	FL 401	24,000	42	76	2015, 2016
Secale cereale	cereal rye	Guardian	15,000	42	122	2015, 2016
Secale cereale	cereal rye	Hazlet	13,000	42	138	2015, 2016
Secale cereale	cereal rye	Maton	21,000	42	88	2015, 2016
Secale cereale	cereal rye	Maton II	22,000	42	85	2015, 2016
Secale cereale	cereal rye	Merced	30,000	42	61	2015, 2016
Secale cereale	cereal rye	Oklon	20,000	42	89	2015, 2016
Secale cereale	cereal rye	Prima	13,000	42	141	2015
Secale cereale	cereal rye	Wheeler	21,000	42	86	2015, 2016
Secale cereale	cereal rye	Wintergrazer-70	23,000	42	79	2015, 2016
Secale cereale	cereal rye	Wrens Abruzzi	19,000	42	94	2015, 2016
x Triticosecale[1/]	triticale	variety not stated	9,400	30	138	2014, 2016
Triticum aestivum[1/]	wheat, white winter	variety not stated	11,000	28	109	2014, 2016
Pisum sativum	Austrian winter pea	Arvica 4010	3,300	6	78	2015, 2016
Pisum sativum	Austrian winter pea	Dunn	3,000	6	86	2015, 2016
Pisum sativum	Austrian winter pea	Frost Master	2,800	6	94	2015, 2016
Pisum sativum	Austrian winter pea	Lynx	3,500	6	75	2015, 2016
Pisum sativum	Austrian winter pea	Maxum	2,300	6	113	2015, 2016
Pisum sativum	Austrian winter pea	Survivor 15	3,800	6	68	2015, 2016
Pisum sativum	Austrian winter pea	Whistler	2,800	6	95	2015, 2016
Pisum sativum	Austrian winter pea	Windham	3,100	6	85	2015, 2016
Raphanus sativus	daikon radish	Big Dog	27,000	5	8	2016
Raphanus sativus	daikon radish	Concorde	40,000	5	5	2016

Species	Common Name	Variety	Seeds per Pound	Seeding Rate (PLS* seeds/ft^2)	Seeding Rate (PLS lb/ac)	Year Planted
Raphanus sativus	daikon radish	Control	45,000	5	5	2016
Raphanus sativus	daikon radish	Defender	27,000	5	8	2015, 2016
Raphanus sativus	daikon radish	Driller	27,000	5	8	2015, 2016
Raphanus sativus	daikon radish	Eco-till	27,000	5	8	2015, 2016
Raphanus sativus	daikon radish	Graza	30,000	5	7	2016
Raphanus sativus	daikon radish	Groundhog	27,000	5	8	2015, 2016
Raphanus sativus	daikon radish	Lunch	27,000	5	8	2015, 2016
Raphanus sativus	daikon radish	Nitro	27,000	5	8	2015, 2016
Raphanus sativus	daikon radish	Sodbuster Blend	27,000	5	8	2015, 2016
Raphanus sativus	daikon radish	Tillage	27,000	5	8	2015, 2016
Trifolium alexandrinum[1/]	berseem clover	Frosty	200,000	57	12	2014, 2015
Trifolium fragiferum[1/]	strawberry clover	O'Conners	313,000	60	8	2016
Trifolium hirtum[1/]	rose clover	variety not stated	127,000	53	18	2016
Trifolium hybridum[1/]	alsike clover	variety not stated	543,000	47	4	2016
Trifolium incarnatum	crimson clover	AU Robin	142,000	62	19	2015, 2016
Trifolium incarnatum	crimson clover	AU Sunrise	90,000	62	30	2015, 2016
Trifolium incarnatum	crimson clover	AU Sunup	129,000	62	21	2015, 2016
Trifolium incarnatum	crimson clover	Contea	73,000	62	37	2015, 2016
Trifolium incarnatum	crimson clover	Dixie	129,000	62	21	2015, 2016
Trifolium incarnatum	crimson clover	Kentucky Pride	129,000	62	21	2015, 2016
Trifolium michelianum	Balansa clover	Fixation	319,000	26	3	2015, 2016
Trifolium michelianum	Balansa clover	Frontier	482,000	57	5	2015, 2016
Trifolium pratense	red clover	Cinnamon Plus	232,000	56	11	2016
Trifolium pratense	red clover	Cyclone II	247,000	56	10	2016
Trifolium pratense	red clover	Dynamite	247,000	56	10	2016
Trifolium pratense	red clover	Freedom!	196,000	56	12	2016
Trifolium pratense	red clover	Kenland	222,000	56	11	2016
Trifolium pratense	red clover	Mammoth	246,000	56	10	2016
Trifolium pratense	red clover	Starfire II	211,000	56	12	2016
Trifolium pratense	red clover	Wildcat	258,000	56	9	2016
Trifolium repens[1/]	white clover	White Dutch	470,000	107	10	2014, 2016
Trifolium resupinatum[1/]	Persian clover	variety not stated	252,000	69	12	2016
Trifolium subterraneum[1/]	subterranean clover	variety not stated	52,000	23	19	2014, 2016
Vicia faba[1/]	fava	variety not stated	650	6	398	2015, 2016
Vicia sativa[1/]	common vetch	variety not stated	7,200	7	40	2015, 2016
Vicia villosa	hairy vetch	CCS-Groff	20,000	7	15	2015, 2016
Vicia villosa	hairy vetch	Lana	12,000	7	25	2015, 2016
Vicia villosa	hairy vetch	Purple Bounty	17,000	7	18	2016
Vicia villosa	hairy vetch	Purple Prosperity	16,000	7	19	2015, 2016
Vicia villosa	hairy vetch	TNT	18,000	7	17	2015, 2016
Vicia villosa	hairy vetch	Villana	14,000	7	22	2015, 2016

*pure live seed; [1/]Local species/variety of interest in Corvallis; not part of the national variety trial.

in 2014-2015. Target seeding rates for each species in our study were standardized based on pure live seeds (PLS) per square foot, so actual pounds per acre seeding rates were adjusted accordingly for the seed size (seeds per pound) and purity/germination of each seed lot.

The soil type at the Corvallis PMC where plots were installed is Amity and Willamette silt loam, 0–3% slopes. Soil tests in 2015 and 2016 showed a pH of 5.9 to 6.3, Bray's P in the high range (50 to 90 ppm), K in the medium to high range (180 to 325 ppm), SO_4-S of 4 to 13 ppm, Mg in the medium range (0.5 to 0.7 meq/100 g), and Ca of 4.9 to 9.4 meq/100 g (Kuo Testing Labs, Othello, WA). All fields were limed with 2 ton/ac agricultural lime in Sep. 2015, and lime was incorporated during field preparation. All non-legume plots (cereal rye, black oat, and radish) were fertilized with 40 lb N/ac in the fall once their true leaves had emerged. Additional P and K fertilizer were not added, as soil tests for both nutrients were already in the medium to high range. Plots did not receive any supplemental irrigation during the trial. In general, the 2014-2015 season in Corvallis was warmer and drier than average, the 2015-2016 season was warmer and wetter than average, and the 2016-2017 season was cooler and much wetter than average (Figure 1). Total precipitation for the October through May growing season was 35 inches in 2014-2015, 47 inches in 2015-2016, and 57 inches in 2016-2017, compared to an average of 39 inches.

Fields were disked and rolled in September each year to create a firm, well-prepared seedbed. All legume seeds were inoculated with the appropriate rhizobia prior to planting. The 9 x 20-ft plots were drill seeded using a Hege cone seeder (Wintersteiger Inc., Salt Lake City, UT) on 9-inch row spacing. Plots for the three years reported were seeded the week of Oct. 3–7, 2014, the week of Sep. 29 – Oct. 2, 2015, and Sep. 29–30, 2016. Metaldehyde slug bait was applied to all plots according to manufacturer's recommendations as soon as seedlings emerged in the fall. The clover plots were hand-weeded once each year in the early spring to reduce competition for light and nutrients.

Germination/emergence were visually estimated in each plot approximately every 7 days for the first four weeks after planting using the following rating scale: 0 = poor (<25% germination), 1 = moderate (25–64%), 2 = good (65–85%), 3 = excellent (>85%). Every 30 days, all plots were rated for canopy cover by a visual estimate of the percentage of ground covered by the plant, rated on the following scale:

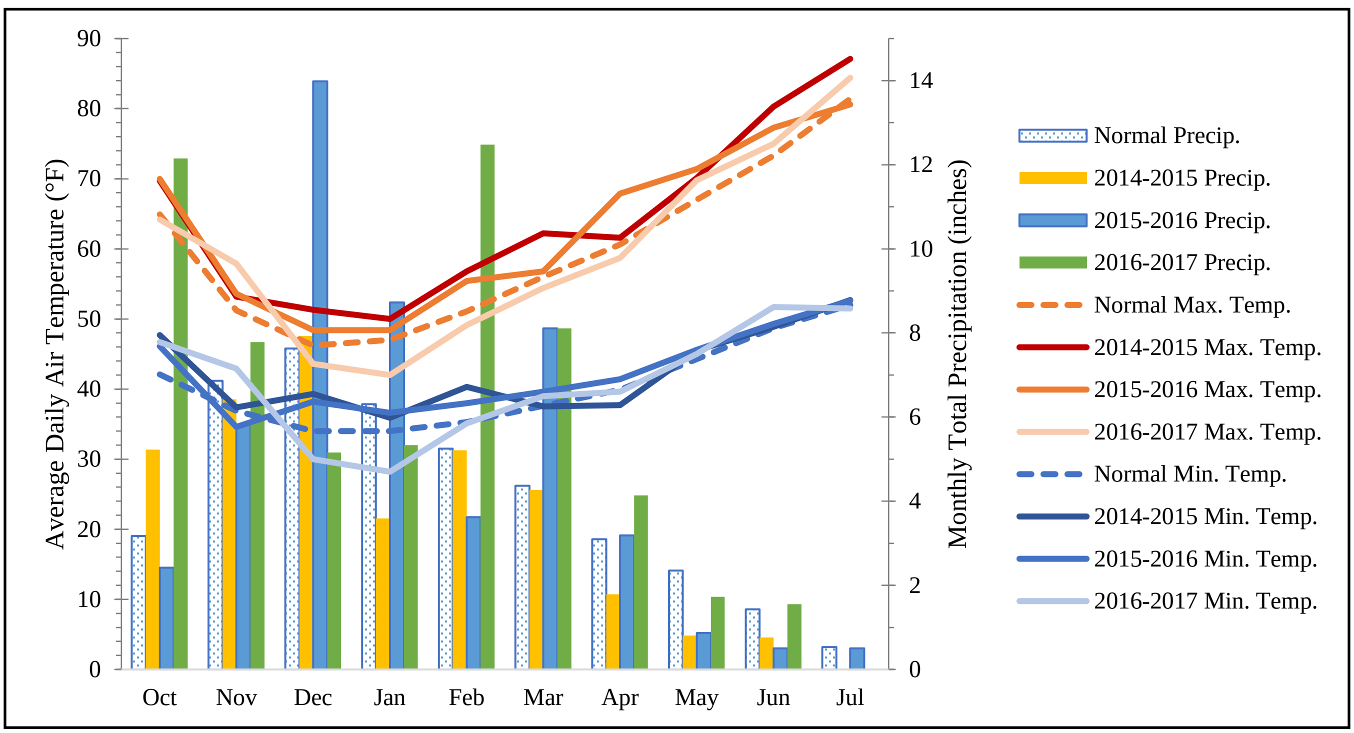

Figure 1. Weather data from Oregon State University's Hyslop Weather Station comparing monthly data from the 2014-2015, 2015-2016, and 2016-2017 seasons to 20-year Normal (average) data at the Corvallis Plant Materials Center.

1 = 1–20%, 2 = 21–40%, 3 = 41–60%, 4 = 61–80%, 5 = 81–100%. All plots 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). To evaluate winter survival, 1-yard sections of an interior row were marked in each plot, and seedling counts were conducted in fall (November) and following "spring green-up" (March) of the 2014-2015 and 2016-2017 seasons.

Bloom period was monitored by noting the date of beginning bloom and 50% bloom. When plants reached 50% bloom or anthesis, aboveground biomass samples were clipped at ground level from 0.5 x 1.0-m subplots in the center of each plot. Biomass samples were oven dried at 120°F to a steady weight to calculate dry matter biomass on a pound per acre basis. Dried biomass samples were analyzed for total Kjeldahl nitrogen (TKN) (Kuo Testing Labs, Othello, WA). Average plant height (height of lush canopy growth, not including blooms or inflorescences) was calculated from 5 measurements in each plot at the time aboveground biomass was harvested.

The experimental design was a randomized complete block with 4 replications (3 replications in 2014-2015) and results were analyzed in Statistix 10 (Analytical Software, Tallahassee, FL) using the analysis of variance procedure (AOV) and Kruskal-Wallis one-way AOV. Mean separation was performed within each species at α=0.05 by Dunn's or Tukey Honestly Significant Difference (HSD). Red clover plots were not replicated in 2015-2016, so data were analyzed for the 2016-2017 season only.

RESULTS AND DISCUSSION

Oats

All three oat varieties performed relatively well, with good emergence (greater than 60%) at 14 days after planting (DAP) and excellent emergence (greater than 85%) by 21 DAP (data not shown). Winter survival was high for all three varieties (Table 2), and they had few observed pests and moderate disease susceptibility, mostly leaf rusts, likely induced by waterlogged spring soils. All three provided over 40% canopy cover by 60 DAP in early December, but the 'Cayuse' common oat suffered more cold damage than the 'Cosaque' black-seed oat or 'Soil Saver' black oat, and didn't provide as much cover over the winter as Soil Saver (Figure 2). However, by maturity in late spring, cover was similar for all three varieties. Soil Saver reached 50% anthesis about two weeks earlier than Cosaque, in mid- to late May 2016, but maturity for both was shifted to early June in 2017 due to our cold, wet spring. Aboveground biomass dry matter production was lower for all varieties in 2017 than 2015/2016, again likely due to stunting from ponding and disease damage over the cool, wet spring, but Cosaque suffered less damage than the other two varieties (Table 2). Biomass sampled in 2016 had an average nitrogen content of 0.8% N for all three varieties.

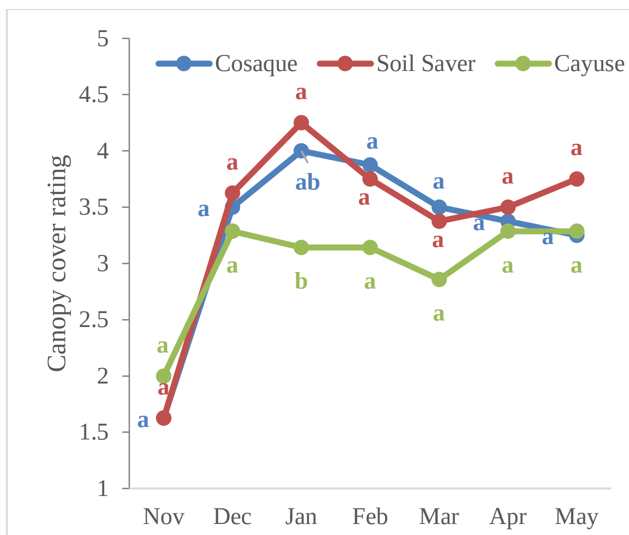

Figure 2. Average canopy cover ratings for three varieties of oats planted at the Corvallis Plant Materials Center in fall 2014 (Cayuse only), 2015 (no Cayuse), and 2016. Cover was rated on a scale from 1 to 5, where 1=0–20% cover and 5=80–100% cover. For each date, cover ratings indicated by the same letter are not significantly different at *P*<0.05.

Table 2. Average winter survival, date of 50% anthesis, mature plant height, and aboveground biomass dry matter production of three oat varieties in trials at the Corvallis Plant Materials Center planted in fall 2014 (Cayuse only), 2015 (no Cayuse), and 2016.

Crop	Variety	Winter survival	Date of 50% anthesis		Mature Height		Biomass (lb/ac)			
		%			in		2015/2016		2017	
Common oat	Cayuse	97	5/22/2015	6/7/2017	31	a*	9,641	ab	3,686	c
Common oat, black-seeded	Cosaque	100	5/24/2016	6/7/2017	33	a	10,070	a	7,127	b
Black oat	Soil Saver	87	5/11/2016	6/7/2017	40	a	10,822	a	3,370	c
Mean		93			36		10,178		4,728	

*Means in columns followed by the same letter are not significantly different at $P<0.05$.

Cereal Rye and Other Grasses

Germination and emergence were quick for all cereal rye varieties, with good emergence by 7 DAP and good to excellent emergence by 14 DAP (data not shown). All varieties except 'Hazlet' reached greater than 40% canopy cover by 60 DAP in early December, and by 90 DAP in early January, most varieties provided over 60% cover (Figure 3). Winter survival was over 80% for all varieties (Table 3), and pest incidence was generally low. 'Merced' had the highest incidence of disease, which was mostly leaf rust. There was a five-week spread in bloom time among the different varieties in 2016, but only a two-week spread in 2017 that was shifted later into May with our cold, wet spring (Table 3, Figure 4). On average, Merced and 'FL 401' bloomed earliest at about 206 DAP, and both suffered more winter damage due to initiating their reproductive phase in the middle of winter when we were still getting ice and snow. The latest varieties (Guardian, Wheeler, Bates RS4, Brasetto, Hazlet, and Prima) matured an average of 223 to 233 DAP. The tallest varieties were Elbon, Wheeler, Maton, Maton II, Wrens Abruzzi, and Oklon, at a mature height of around 4½ ft, while Merced was the shortest variety at around 3 ft. Aboveground dry matter biomass production was higher in 2016 than 2017. Merced produced the least biomass, at a two-year average of about 3,000 lb DM/ac, while the top producing varieties (Wheeler, Maton, Guardian, Maton II, and Wrens Abruzzi) yielded over 5,000 lb DM/ac (Table 3). Total nitrogen content of the aboveground biomass for all varieties tested in 2016 ranged from 0.5 to 1.5%. Based on these two years

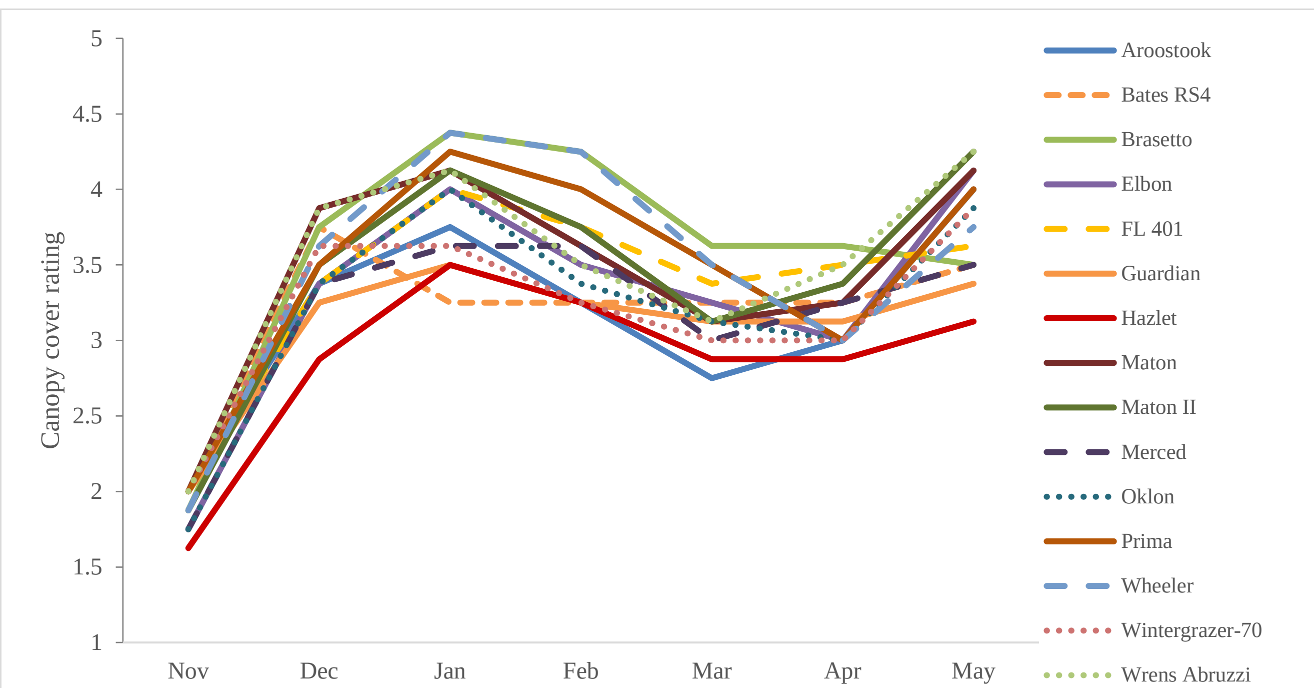

Figure 3. Average canopy cover ratings for fifteen varieties of cereal rye planted at the Corvallis Plant Materials Center in fall 2015 and 2016. Cover was rated on a scale from 1 to 5, where 1=0–20% cover and 5=80–100% cover.

of data, Merced and FL 401 do not appear to be well adapted to our region, as they began their reproductive growth stages earlier than the other varieties, and thus suffered more freeze damage and stress leading to greater disease and pest damage, and less biomass production. All the other cereal rye varieties appear well adapted, providing good early canopy cover and substantial organic matter.

Table 3. Average winter survival in the 2016-2017 season, date of 50% anthesis, average mature plant height, and aboveground biomass dry matter production of 15 varieties of cereal rye in trials planted at the Corvallis Plant Materials Center in fall 2015 and 2016.

Variety	Winter survival	Date of 50% anthesis		Mature Height	Biomass (lb/ac)	
	%			in	2016	2017
Aroostook	86	4/25/2016	5/18/2017	53	5,328	2,958
Bates RS4	80	----[2/]	5/18/2017	53	----[2/]	4,867
Brasetto	86	5/11/2016	5/24/2017	39	5,940	3,741
Elbon	93	4/25/2016	5/18/2017	56	5,306	3,483
FL 401	84	4/5/2016	5/12/2017	39	4,744	3,021
Guardian	84	5/11/2016	5/31/2017	47	6,698	3,799
Hazlet	90	5/11/2016	5/24/2017	43	6,285	2,829
Maton	87	4/25/2016	5/18/2017	55	6,025	4,497
Maton II	91	4/25/2016	5/18/2017	56	6,108	4,274
Merced	90	4/5/2016	5/12/2017	35	3,574	2,524
Oklon	95	4/25/2016	5/18/2017	53	4,825	4,343
Prima	----[1/]	5/11/2016	----[1/]	48	5,770	----[1/]
Wheeler	96	5/11/2016	5/31/2017	56	6,204	4,917
Wintergrazer-70	81	4/25/2016	5/18/2017	50	4,907	3,642
Wrens Abruzzi	93	4/25/2016	5/18/2017	55	5,921	4,155
Mean	88			49	5,516	3,789
LSD $_{(0.05)}$[3/]	NS[4/]			3	1,588	1,368

[1/]not planted in 2016; [2/]not planted in 2015; [3/]least significant difference; [4/]not significant

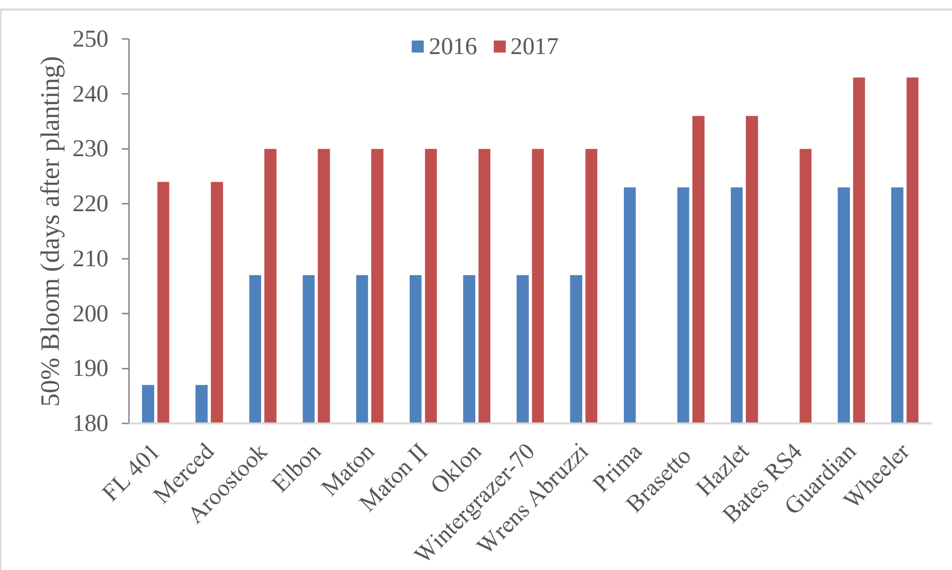

Figure 4. Days after planting to 50% bloom for fifteen varieties of cereal rye planted at the Corvallis Plant Materials Center in fall 2015 and 2016.

Table 4. Average winter survival, date of 50% anthesis, mature plant height, and aboveground dry matter biomass production of four cool season grass species planted at the Corvallis Plant Materials Center in fall 2014 and 2016.

Crop	Variety	Winter survival	Date of 50% anthesis		Mature Height	Biomass (lb/ac)	
		%			in	2015	2017
annual ryegrass	Tillage RootMax	82	5/29/2015	6/7/2017	42	7,318	4,558
triticale	VNS[1/]	87	5/5/2015	5/24/2017	41	17,811	7,145
white winter wheat	VNS	97	5/13/2015	5/31/2017	25	8,196	5,026
winter barley	Verdant	93	5/5/2015	5/24/2017	33	16,141	3,260
	Mean	90			35	12,366	4,997
	LSD $_{(0.05)}$ [2/]	11			4	7,742	NS[3/]

[1/]variety not stated; [2/]least significant difference; [3/]not significant

At the Corvallis PMC, we also tested four other grass species of local interest as cool season cover crops that were not a part of the national variety trial: annual ryegrass, triticale, white winter wheat, and winter barley. Germination and emergence of these species was very similar to the cereal rye, with good emergence by 7 DAP and good to excellent emergence by 14 DAP (data not shown). Winter survival was over 80% for all species (Table 4), and insect damage was low. The white winter wheat had moderate disease damage from leaf rust, particularly in the cool, wet spring of 2017, which also affected the winter barley and triticale to a lesser extent; annual ryegrass had very little incidence of disease. The annual ryegrass was slower than other species to provide cover over the fall and winter, while the 'Verdant' winter barley provided over 60% cover by 60 DAP in early December (Figure 5). The triticale, barley, and wheat matured around the same time as the latest varieties of cereal rye, while the annual ryegrass bloomed a couple weeks later (Table 4). Like the cereal rye, plants were stunted and biomass production was lower in 2017, likely due to ponding stress. However, in 2015 all four species produced over 7,000 lb DM/ac, and the triticale and barley produced over 16,000 lb DM/ac, more than double the biomass production of any cereal rye variety.

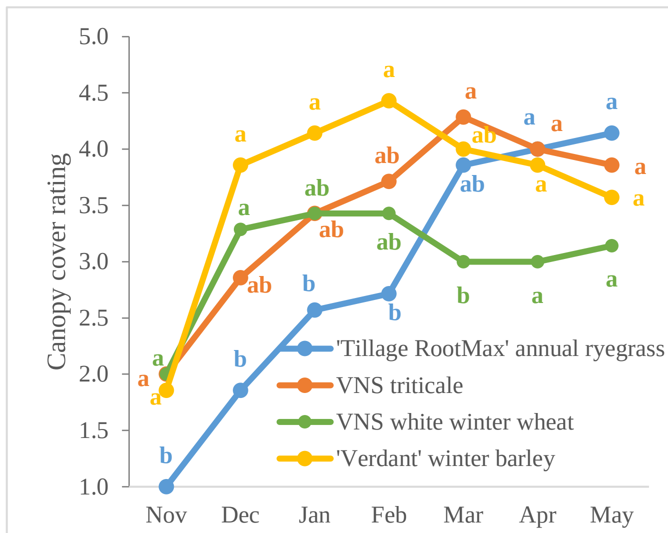

Figure 5. Average canopy cover ratings for four cool season grass species planted at the Corvallis Plant Materials Center in fall 2014 and 2016. Cover was rated on a scale from 1 to 5, where 1=0–20% cover and 5=80–100% cover. For each date, cover ratings indicated by the same letter are not significantly different at $P<0.05$.

Austrian Winter Peas

All pea varieties had at least good germination and emergence by 21 DAP, and good to excellent emergence by 28 DAP (Table 5). There were no significant differences in disease or pest susceptibility among the eight varieties, with all having low to moderate ratings. By early December at 60 DAP, only 'Maxum,' 'Dunn,' and 'Arvica 4010' had reached greater than 20% canopy cover (Figure 6), but cover declined after January as plants began to winter-kill, particularly in February and March, likely due to a combination of saturated soils and freezing temperatures after they had begun active spring growth. Due to complete winter-killing of all varieties both years, we had no bloom and were not able to collect mature plant height or biomass data. Better results for the Austrian winter peas may be attained with early spring planting, a common practice for pea seed production here in the Willamette Valley.

Table 5. Average emergence rating at 28 days after planting and disease and pest ratings at spring green-up for 8 varieties of Austrian winter pea planted at the Corvallis Plant Materials Center in fall 2015 and 2016.

Variety	Emergence[1/] @ 28 DAP		Disease[2/]		Pests[2/]	
Arvica 4010	2.5	ab*	2.5	a	2.0	a
Dunn	2.8	ab	1.8	a	2.0	a
Frostmaster	2.0	b	1.9	a	2.9	a
Lynx	2.1	ab	2.4	a	2.4	a
Maxum	2.9	a	1.8	a	1.5	a
Survivor 15	2.4	ab	2.5	a	2.3	a
Whistler	2.8	ab	2.5	a	1.8	a
Windham	2.3	ab	2.0	a	2.4	a

[1/]Emergence rated on the following scale: 0=poor (<25% germination), 1=moderate (25-60%), 2=good (61-85%), and 3=excellent (>85%). [2/]Disease and pest damage rated 0 to 5, where 0=no damage and 5=severe damage (scored at spring green-up in early March). *Means in columns followed by the same letter are not significantly different at $P<0.05$.

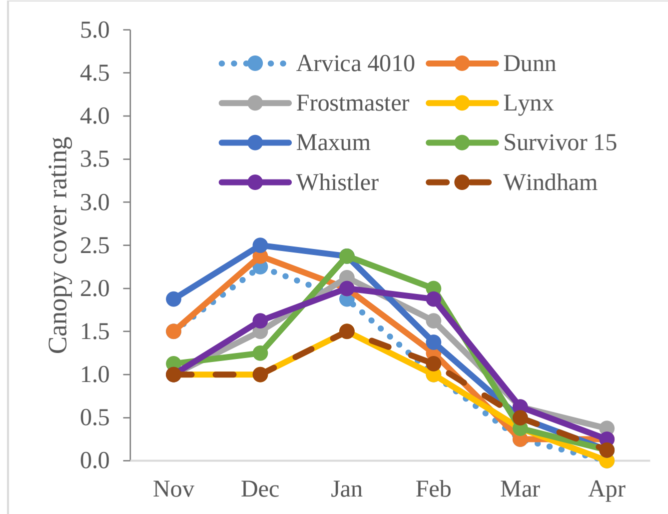

Figure 6. Average canopy cover ratings for 8 varieties of Austrian winter pea planted at the Corvallis Plant Materials Center in fall 2015 and 2016. Cover rated on the following scale: 1=1-20%, 2=21-40%, 3=41-60%, 4=61-80%, 5=81-100%.

Daikon Radish

Radish germination and emergence were a bit slow, with moderate germination by 21 DAP, and generally good to excellent germination by 28 DAP; 'Sodbuster Blend' only attained moderate germination (<60%) by 28 DAP, but there were no significant differences among varieties (data not shown). 'Eco-till' and 'Nitro', at less than 70%, had lower winter survival than 'Lunch', at 100%, and most other radish varieties had at least 80% survival (Table 6).With their broadleaved rosettes, all radish varieties were quick to provide at least moderate canopy cover by early December, generally peaking in January, and then declining through the spring as they bolted and flowered (Figure 7). All varieties had slight pest ratings, with cucumber beetles and slugs causing the majority of observed damage. Disease ratings were moderate to severe for all varieties (Table 6), with fungal leaf spot diseases inflicting the most damage, likely exacerbated by early spring ponding and saturated soils. 'Defender,' 'Concorde,' 'Control', and 'Graza' reached 50% bloom about two weeks later than the other varieties. Like many of the cereal grains, radish plants were taller and produced more biomass in 2016 than 2017 (Table 6). For the radishes, this was likely caused by high rates of leaf spot and other fungal disease exacerbated by long periods of saturated soils in the spring of 2017. Defender was the top biomass producer in both years. Total nitrogen content of the aboveground biomass for all varieties tested in 2016 averaged 1.6%.

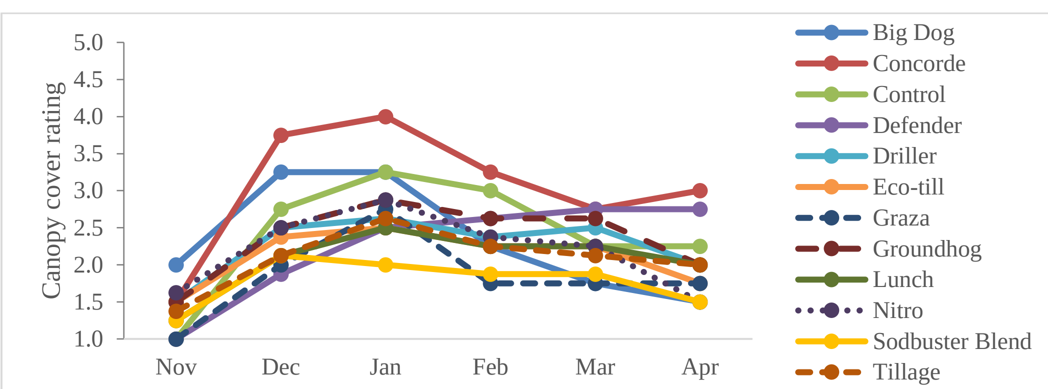

Figure 7. Average canopy cover ratings for 12 varieties of radish planted at the Corvallis Plant Materials Center in fall 2015 and 2016. Cover rated on the following scale: 1=1-20%, 2=21-40%, 3=41-60%, 4=61-80%, 5=81-100%.

Table 6. Average winter survival, bloom date, height, and aboveground dry matter biomass production of 12 varieties of radish planted at the Corvallis Plant Materials Center in fall 2015 and 2016.

Variety	Winter Survival (%)		Date of 50% bloom		Height (in)				Biomass (lb/ac)				Disease	
	2017		2016	2017	2016		2017		2016		2017			
Big Dog	84	ab*	----[1/]	4/11/2017	----[1/]		16	cd	----[1/]		239	c	4.8	a
Concorde	96	ab	----[1/]	4/21/2017	----[1/]		25	a	----[1/]		1,385	a	3.5	a
Control	94	ab	----[1/]	4/21/2017	----[1/]		21	abc	----[1/]		984	ab	3.8	a
Defender	97	ab	4/5/2016	4/21/2017	33	a	23	ab	5,119	a	1,422	a	3.1	a
Driller	91	ab	3/24/2016	4/11/2017	28	abc	14	d	3,109	ab	322	bc	4.0	a
Eco-till	64	b	3/24/2016	4/11/2017	29	abc	16	cd	2,178	b	406	bc	3.8	a
Graza	96	ab	----[1/]	5/5/2017	----[1/]		25	a	----[1/]		1,240	a	2.8	a
Groundhog	88	ab	3/24/2016	4/11/2017	29	ab	15	d	3,044	ab	286	c	3.9	a
Lunch	100	a	3/24/2016	4/11/2017	23	c	17	cd	1,953	b	473	bc	3.4	a
Nitro	65	b	3/24/2016	4/11/2017	26	bc	14	d	2,684	b	317	bc	3.9	a
Sodbuster Blend	74	ab	3/24/2016	4/11/2017	28	abc	15	cd	2,709	b	259	c	3.8	a
Tillage	88	ab	3/24/2016	4/11/2017	29	abc	18	bcd	2,875	b	351	bc	3.8	a
Mean	86				28		18		2,959		640		3.7	

*Means in columns followed by the same letter are not significantly different at *P*<0.05. [1/]not planted in 2015

Crimson Clover

All of the crimson clover varieties tested had good germination and emergence by 21 DAP, and excellent emergence by 28 DAP, except ‘AU Sunup,’ which was slower to germinate and never reached greater than 85% emergence (Figure 8). ‘AU Sunrise,’ ‘Contea,’ and ‘Dixie’ were a bit quicker than the other varieties to establish canopy cover over the winter, and all varieties except AU Sunup had greater than 80% cover by early April (Figure 9). All varieties had greater than 85% winter survival in counts conducted in 2016-2017 (Table 7). Disease and pest pressure were low for all varieties, and slugs were the only real pest issue when the seedlings were first emerging. AU Robin, AU Sunrise, and AU Sunup reached 50% bloom a few days before Contea and Dixie in 2016, while Kentucky Pride bloomed about two weeks later than the other varieties in both years. All varieties except AU Sunup reached over 1½ ft tall at maturity and produced about 3,000 lb DM/ac, with an average nitrogen content of 2%. This resulted in an average estimated 14 lb PAN/ac from all crimson clover varieties except AU Sunup according to calculations from the OSU Cover Crop Calculator (Andrews et al., 2010). AU Sunup plants appeared yellowed and stunted, with less branching and flowering than the other varieties, perhaps due to a lower tolerance for our saturated soil conditions in early spring.

Table 7. Average winter survival (2016-2017 season), bloom dates, mature plant height, aboveground biomass dry matter, and estimated plant available nitrogen for six varieties of crimson clover planted at the Corvallis Plant Materials Center in fall 2015 and 2016.

Variety	Winter survival		Date of 50% bloom		Mature Height (in)		Biomass (lb/ac)		Estimated PAN[1/] (lb/ac)	
AU Robin	88%	a*	4/19/2016	5/9/2017	16	a	2,115	bc	9	ab
AU Sunrise	100%	a	4/19/2016	5/9/2017	19	a	3,267	a	15	ab
AU Sunup	100%	a	4/19/2016	5/9/2017	12	b	1,153	c	7	b
Contea	95%	a	4/22/2016	5/9/2017	19	a	3,162	ab	13	ab
Dixie	100%	a	4/22/2016	5/9/2017	18	a	3,132	ab	15	ab
Kentucky Pride	100%	a	5/6/2016	5/15/2017	18	a	3,024	ab	16	a

[1/]Plant available nitrogen; *Means in columns followed by the same letter are not significantly different at *P*<0.05.

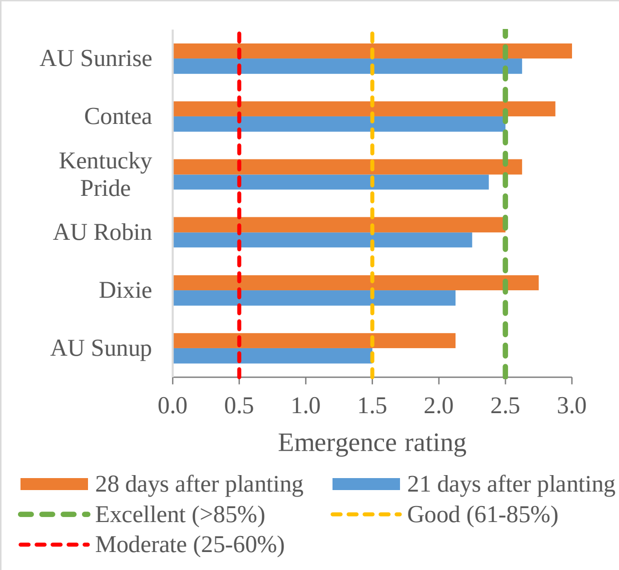

Figure 8. Average germination/emergence ratings for six varieties of crimson clover planted at the Corvallis Plant Materials Center in fall 2015 and 2016.

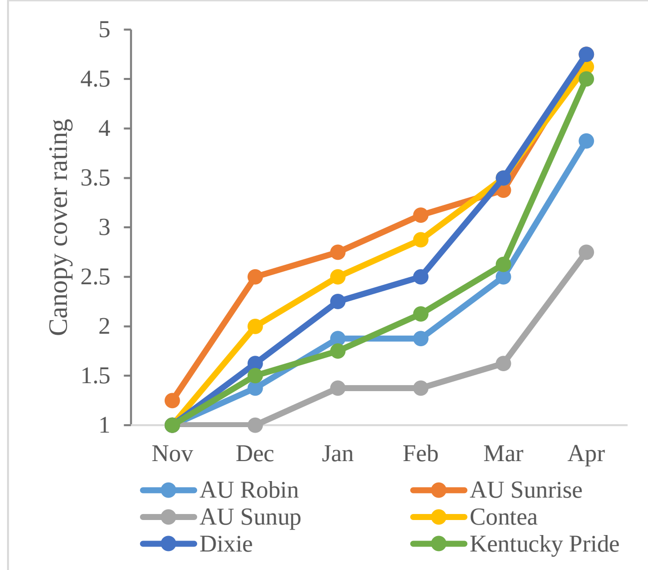

Figure 9. Average canopy cover ratings for six varieties of crimson clover planted at the Corvallis Plant Materials Center in fall 2015 and 2016. Cover was rated on a scale from 1 to 5, where 1=0–20% cover and 5=80–100% cover.

Red Clover

The red clover varieties generally had slow germination and remained as very tiny rosettes over most of the winter, only really beginning to put on substantial growth in April and May. They suffered substantial slug damage initially, followed by some freeze damage in January, and ponding in February to March, and would have been overcome by weed pressure if the plots had not been weeded in March. All varieties showed fairly uneven maturation, and did not reach 50% bloom until late June in 2016 and mid-July in 2017. All varieties averaged just over 1½ ft tall at maturity and produced an average of almost 3,000 lb DM/ac (Table 8). With an average N content of 1.9%, this translates into an estimated average contribution of just 10 lb PAN/ac for the subsequent crop. With their slow establishment, lack of cover over the winter, and susceptibility to weeds and slugs, red clovers do not appear to be a promising choice as a winter annual cover crop in western Oregon.

Table 8. Average winter survival, aboveground biomass dry matter, and estimated plant available nitrogen for 8 varieties of red clover in non-replicated 2015 planting and replicated 2016 planting at the Corvallis Plant Materials Center.

Variety	Winter survival	Biomass (lb/ac)	Estimated PAN[1/] (lb/ac)
Cinnamon Plus	92%	3,024	8
Cyclone II	78%	2,466	9
Dynamite	88%	2,787	8
Freedom!	82%	3,528	15
Kenland	77%	3,141	12
Mammoth	90%	1,891	6
Starfire II	76%	3,753	20
Wildcat	86%	2,207	6
Mean	84%*	2,850*	10*

[1/]plant available nitrogen; *no significant differences at P<0.05.

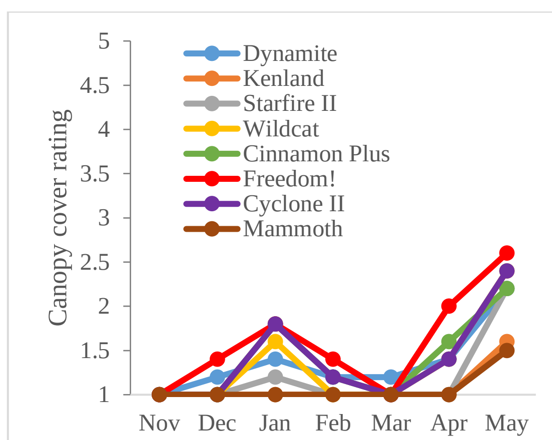

Figure 10. Average canopy cover ratings for eight varieties of red clover planted at the Corvallis Plant Materials Center in fall 2015 and 2016. Cover was rated on a scale from 1 to 5, where 1=0–20% cover and 5=80–100% cover.

Balansa and Other Clovers

Both varieties of Balansa clover were relatively slow to germinate and emerge, but both had good germination (>60%) by 28 DAP and 100% winter survival (Table 9). Both varieties were slow to provide canopy cover, with growth finally taking off in March as temperatures warmed (Figure 11). Incidence of pest damage and disease was low for both varieties. 'Frontier' had a much lower growth habit than 'Fixation,' reaching an average height of only 11 inches at 50% bloom in late April to early May, while Fixation reached 24 inches tall by the time it attained 50% bloom three weeks later in mid- to late May. Fixation produced more aboveground biomass than Frontier (Table 9), and with an average N content of 2.2%, both yielded about 12 lb PAN/ac. Fixation's later bloom time allows it to potentially be grazed and/or terminated later in the spring than Frontier without the risk of setting viable seed.

Of the other seven clover species evaluated at the Corvallis Plant Materials Center, 'Frosty' berseem clover and subterranean clover were the most impressive varieties so far. Both had good germination and winter survival and provided over 80% canopy cover by early May (Table 9, Figure 11). Frosty reached a mature height of over 2 ft tall and produced an impressive 10,000 lb DM/ac at 50% bloom in early June. Subterranean clover was one of the earliest blooming legumes, beginning bloom in late March and continuing to bloom while also setting seed over the next month; it is unlikely that its tiny white flowers provide any pollen or nectar for pollinators before burying themselves in the soil. Subterranean clover was the shortest statured clover at just 3 inches tall, growing close to the ground with layers of spreading stolons, but still managed to produce almost 3,000 lb DM/ac.

With only one year of data so far, the Persian clover and rose clover also look promising, but some plots suffered significant ponding damage during the extremely wet spring of 2017. The Persian clover recovered to provide good canopy cover by the time it reached 50% bloom in early June (Figure 11), standing over 2½ ft tall and producing nearly 4,000 lb DM/ac (Table 9), with abundant flowers over a 3-week bloom period that appeared extremely attractive to honey bees as well as some native bees. The rose clover had a shorter mature height of about 1½ ft, but still produced over 3,000 lb DM/ac and an abundance of flowers in early June that were covered in honey bees and other pollinators.

As the only perennials in the current trial, alsike, strawberry, and white clover were slower to establish and generally provided less winter cover than the annuals (Figure 11). The alsike clover had moderate germination and only about 50% winter survival, perhaps due to ponding in the spring, although it is reported to tolerate acid, waterlogged soils and spring ponding up to 6 weeks (St. John and Ogle, 2008). The strawberry clover also had poor germination and low winter survival, producing less than 500 lb DM/ac. These perennial species do not appear to be well suited to use as winter annual cover crops in our region.

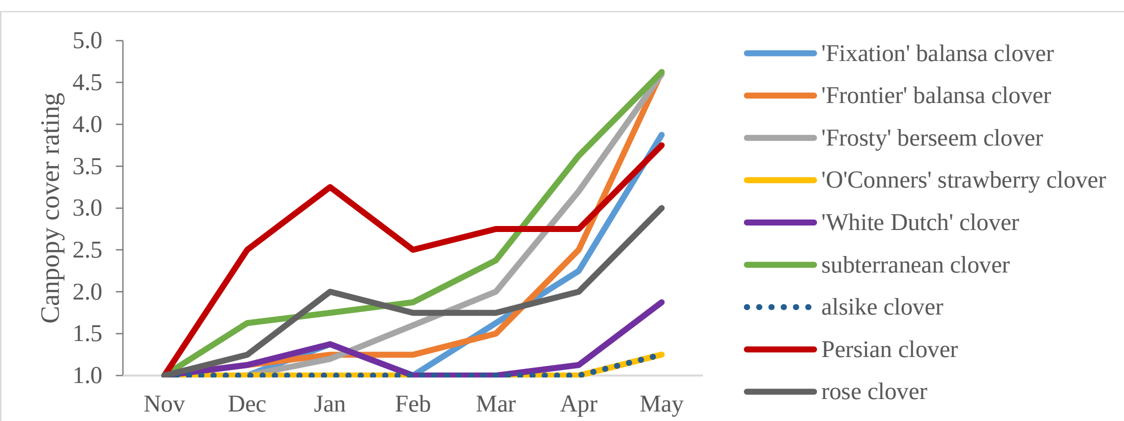

Figure 11. Average canopy cover ratings for two varieties of Balansa clover and seven other clover species planted at the Corvallis Plant Materials Center in fall of 2014, 2015, and 2016 (see Table 1 for years planted per species). Cover was rated on a scale from 1 to 5, where 1=0–20% cover and 5=80–100% cover.

Table 9. Average emergence, winter survival, date of 50% bloom, mature plant height, aboveground biomass dry matter, and estimated plant available nitrogen contribution for two Balansa clover varieties and seven other clover species including in 2014, 2015, and/or 2016 trials at the Corvallis Plant Materials Center.

Crop	Variety	Emergence at 21 DAP[1/]		Winter survival		Date of 50% bloom		Mature Height (in)		Biomass (lb/ac)		Estimated PAN[2/] (lb/ac)	
Balansa clover	Fixation	1.4	a*	100%	a	5/10/2016	5/24/2017	24	a	2,851	a	14	a
Balansa clover	Frontier	0.6	b	100%	a	4/18/2016	5/2/2017	11	b	1,680	b	10	a
berseem clover	Frosty	2.4		73%		6/10/2015	6/8/2016	27		10,351		24	
strawberry clover	O'Conners	1.3	b	30%	b	6/10/2015	7/11/2017	6	cd	469	c	2	b
white clover	White Dutch	2.8	ab	85%	a	6/10/2015	6/29/2017	10	c	2,496	abc	16	ab
subterranean clover	VNS[3/]	3.0	a	86%	a	5/13/2015	5/2/2017	3	d	2,901	ab	18	a
alsike clover	VNS	1.8	ab	55%	ab	----[4/]	6/19/2017	17	b	1,418	bc	6	ab
Persian clover	VNS	2.3	ab	83%	a	----[4/]	6/7/2017	28	a	3,864	a	18	a
rose clover	VNS	2.8	ab	80%	a	----[4/]	6/1/2017	17	b	3,420	ab	12	ab

[1/]days after planting; [2/]plant available nitrogen; [3/]variety not stated; [4/]not planted in 2014; *Means in columns followed by the same letter (for Balansa clovers, or all other clovers) are not significantly different at $P<0.05$. No statistics were performed on 'Frosty' berseem clover due to a lack of replicates in each year.

Vetch and Fava

All the vetch varieties had moderate to good emergence by 14 DAP and good to excellent emergence by 28 DAP (data not shown). All varieties of hairy vetch and the common vetch had over 85% survival in counts done in the 2016-2017 season (Table 10). From early January through March, ‘Lana’ hairy vetch and common vetch provided more canopy cover than most other vetches (Figure 12). ‘Villana’ showed less vigorous winter growth and provided less early spring canopy cover than most other hairy vetch varieties, perhaps due to a lower tolerance for ponding and saturated soil conditions experienced in February and March. All varieties put on most of their height and biomass in April and May as soil and air temperatures warmed and days got longer. Lana was the first to reach 50% bloom in early May, with the other varieties reaching 50% bloom in late May. The common vetch was slightly shorter than the other varieties at harvest, but the measured plant height was largely a function of the long vines getting matted down without the structure of a grass or other plant to climb. Biomass production for all varieties averaged 7,000 lb DM/ac, with an impressive 3 to 4% N content, yielding an average estimated 50 to 100 lb PAN/ac for use by the subsequent crop (Table 10).

Table 10. Average winter survival, date of 50% bloom, mature plant height, aboveground dry matter biomass production, and estimated plant available nitrogen for six varieties of hairy vetch, one common vetch, and one fava planted at the Corvallis Plant Materials Center in fall of 2015 and 2016.

Crop	Variety	Winter Survival (%)		Date of 50% bloom		Mature Height (in)		Biomass (lb/ac)				PAN[1/] (lb/ac)	
		2017		2016	2017	both years		2016		2017		both years	
hairy vetch	CCS-Groff	89	a*	5/24/16	5/31/17	33	a	7,781	a	6,956	ab	88	a
hairy vetch	Lana	99	a	5/11/16	5/8/17	28	ab	6,123	ab	4,247	bc	51	a
hairy vetch	Purple Bounty	87	a	----[2/]	5/31/17	35	a	----[2/]		7,078	ab	70	a
hairy vetch	Purple Prosperity	100	a	5/24/16	5/31/17	31	a	7,724	a	9,473	a	94	a
hairy vetch	TNT	87	a	5/24/16	5/31/17	32	a	6,720	ab	8,301	ab	89	a
hairy vetch	Villana	95	a	5/24/16	5/31/17	30	ab	6,862	ab	6,202	ab	102	a
common vetch	VNS[3/]	92	a	5/11/16	5/24/17	25	b	7,756	a	5,764	ab	106	a
fava	VNS	30	b	3/31/16	5/24/17	30	ab	4,700	b	886	c	19	a
Mean (hairy vetch only)		93				32		7,042		7,043		82	

[1/]plant available nitrogen; [2/]not planted in 2015; [3/]variety not stated; *Means in columns followed by the same letter are not significantly different at $P<0.05$.

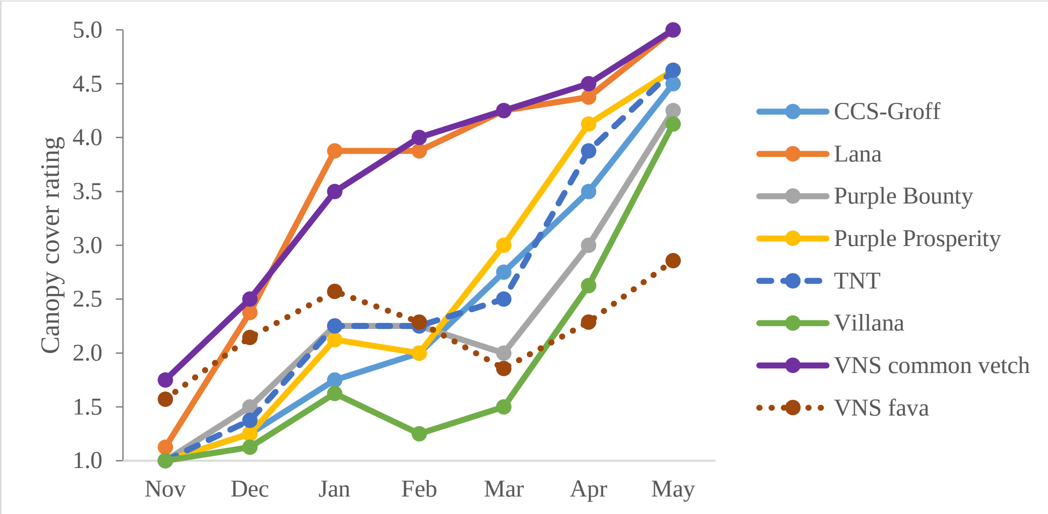

Figure 12. Average canopy cover ratings of six varieties of hairy vetch, one common vetch, and one fava planted at the Corvallis Plant Materials Center in fall of 2015 and 2016. Cover was rated on a scale from 1 to 5, where 1=0–20% cover and 5=80–100% cover.

The fava included in our trial was a “winter bulk” mix of material being evaluated and selected by cover crop breeders at the Agricultural Research Service (ARS) in Pullman, WA. While the fava was not particularly quick to germinate and emerge, eventual establishment was good, and cover had reached 40-60% by early January (Figure 12). Fava survival was only 30% in 2016-2017 (Table 10), but was 71% in the 2014-2015 season (no counts were conducted in 2015-2016). Their early flowering, starting in March most years and continuing through May, attracted many newly emerging bumble bee queens, as well as other pollinators foraging for nectar and/or pollen. The favas suffered very little disease or pest damage and continued to bloom while growing taller and fuller throughout April and May. At maturity, the plants were nearly 3 ft tall and produced over 4,000 lb DM/ac in 2016, but produced less than 1,000 lb DM/ac in 2017 due to severe winter-kill that year.

Correlation of Biomass and Plant Height

Not all PMCs are collecting biomass data as part of this study, but are instead taking mature plant heights for each variety at 50% bloom. Since we collected both sets of data, I was curious to test the relationship between plant height and aboveground biomass for each species to see how well correlated they were. Our data suggest that mature plant height was not a very good predictor of aboveground biomass production for most species (Figure 13). Only the fava and daikon radish models had R-squared values over 75%, indicating a fairly strong correlation between plant height and biomass production. The oat and crimson clover models both had R-squared above 50%, indicating a weaker correlation, while the vetch showed no relationship between height and biomass, with an R-squared value below 5%.

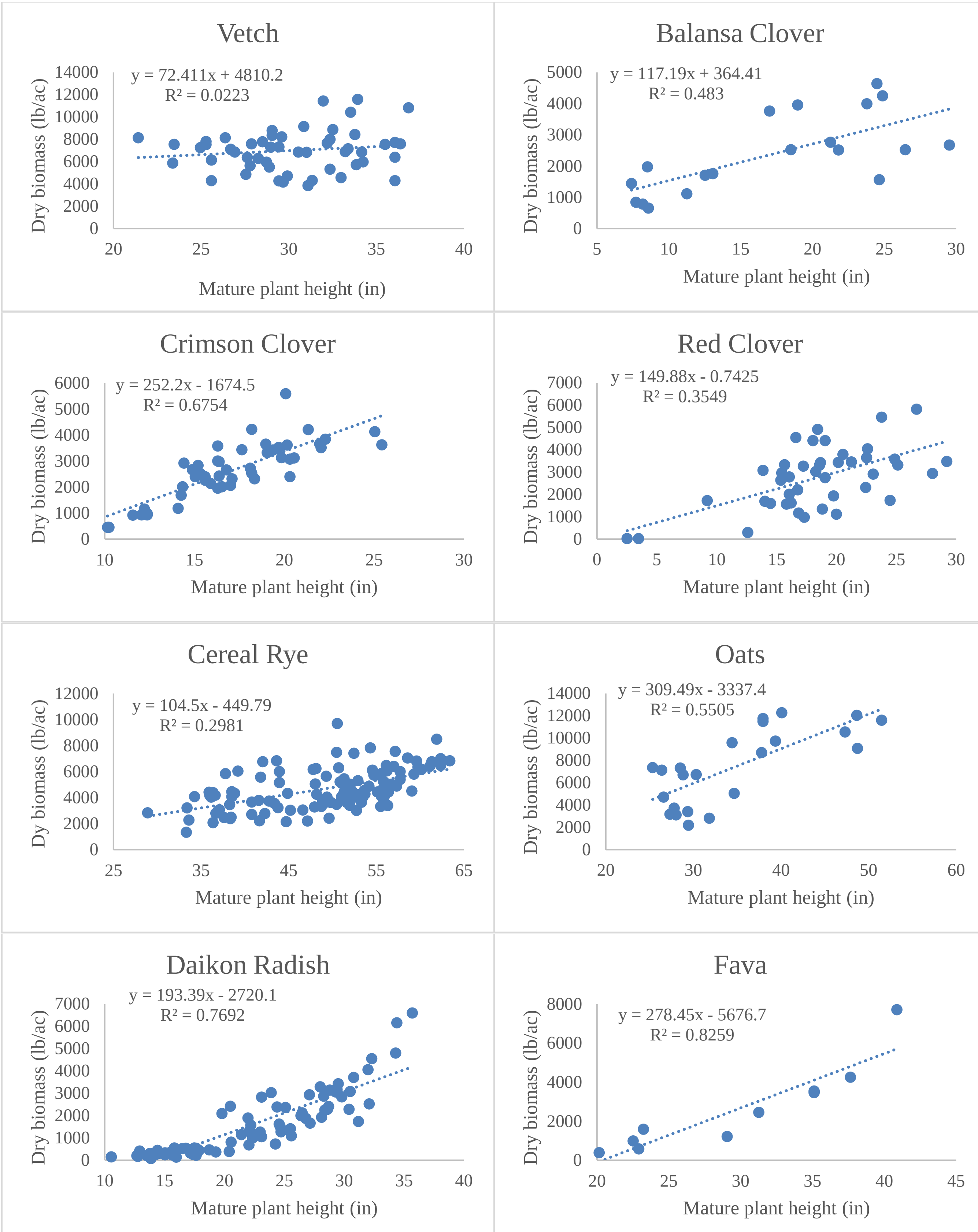

Figure 13. Graphs depicting the relationship between mature plant height and aboveground biomass dry matter for eight cover crop species planted in plots at the Corvallis Plant Materials Center in fall 2014, 2015, and 2016.

CONCLUSION

Based on two years of data from cover crop variety trials at the Corvallis PMC, most varieties of oat, cereal rye, hairy vetch, crimson clover, and Balansa clover appeared well adapted to the generally mild, Mediterranean climate of western Oregon. There were, however, some significant differences among varieties in bloom date, mid-winter canopy cover, biomass, and plant available nitrogen production, so this information should help growers and conservationists select appropriate species and varieties for their intended rotations and cover cropping purposes.

Higher than average early spring rainfall both years resulted in ponding that, combined with a few ice storms, winter-killed all varieties of Austrian winter peas tested. Peas are grown successfully as a winter cover crop in western Oregon, but are usually not grown as a monoculture, but rather in combination with a cereal grain that the pea vines can climb, keeping them off the ground and helping prevent disease; they are also noted to have no tolerance for waterlogged soils, so should only be grown on well drained sites (Sattell and Dick, 1998). The wetter than average conditions and ponding also led to high levels of fungal leaf spot disease among most daikon radish varieties that limited their canopy cover and biomass production. The recommendation for at least three-year rotations (longer in infested fields) to avoid infestations of black leg and other fungal leaf spot diseases (Andrews, 2017; Ocamb, 2016), combined with the required 3-mile isolation from seed production fields in Oregon's rapeseed control areas (Oregon State Legislature, 2017) severely limits the usefulness of daikon radish and other brassicas as cover crops in western Oregon. Red clover, with its slow establishment, lack of cover over the winter, late maturity date, and susceptibility to weeds and slugs, did not appear to be a promising choice as a winter annual cover crop in our region. Data from the last year of the trial will be compiled for 2017-2018, and cover crop variety recommendations for western Oregon will be based on final results.

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