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One Year Evaluation of Warm Season Cover Crops in the Intermountain West

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ABSTRACT

Warm season cover can provide Intermountain Western producers a means of building soil health between crops and providing summer forage for livestock. Aberdeen Plant Materials Center (IDPMC) conducted a one-year study to compare adaptation of commercially available warm season cover crops to the cool, arid irrigated Intermountain West. Forty-two different cultivars of 38 cover crop species were evaluated on a Declo silt loam for field emergence, days after planting to 50% bloom, percent cover, canopy height, biomass, and forage value. Cool early season temperatures in June 2020 affected the emergence and early growth of some warm season species. Some accessions such as 'Hubam' annual white sweetclover recovered and produced abundant biomass (7,530 lb/ac dry weight), while other species emerged well but performed poorly after emergence ('BMR 84' grazing corn, 'Mini Mix' pumpkin, '2120' sorghum, and '400 BMR' sorghum). The highest biomass (dry weight) was produced by black oilseed sunflower (12,218 lb/ac), Hubam annual white sweetclover (7,530 lb/ac), 'Lavina' spring barley (5,505 lb/ac), 'Surge' spring triticale (5,326 lb/ac), and 'Graza' forage radish (5,090 lb/ac). 'AC Greenfix' chickling vetch, '4010' spring forage pea, and fenugreek all produced forage comparable to the relative feed value, % crude protein, and % total digestible nutrients of premium alfalfa hay. Well adapted warm season cover crops need additional evaluation to further characterize their adaptation to the region, as well as to determine the optimal seeding rate for each species.

INTRODUCTION

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 & Forcella, 1998; Hargrove, 1986; Reeves, 1994; Follett, 2001). Leguminous cover crops species further provide a nitrogen source for subsequent commodity crops (Singh et al., 2004; Smith et al., 1987), while non-leguminous cover crops can scavenge post-season nitrogen, reduce soil erosion, and suppress weeds (Meisinger et al., 1991). Cover crops can also provide grazing for livestock (Brummer et al., 2015). 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.

Currently, warm season cover crops are not widely used in the arid Intermountain West, but they can be incorporated into crop rotations to serve a variety of purposes. These include enhancing soil health by adding a diversity of plant functional groups, providing weed/pest suppression, enhancing

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habitat for pollinators and beneficial insects, and providing good quality supplemental livestock feed (Clark, 2012). There are many commercially available warm season cover crops grown in other parts of the United States that may be adapted to the summer climate of the Intermountain West where regional conditions include hot days, cool nights, and a short growing season. To better understand the adaptability of warm season cover crops to the region, 42 cultivars of 38 species were evaluated at IDPMC for their performance as warm season cover crops in the Intermountain West. This study was a one-year adaptation trial to determine the suitability of various cover crops for the cool-summer irrigated areas of the Inland Northwest, as well as their forage value. The objective of this study is to evaluate the adaptation of different warm season cover crop species and varieties to environmental conditions of the Upper Snake River Plain and by extension, the irrigated Intermountain West.

MATERIALS AND METHODS

Warm season cover crop species were selected for this evaluation based on tolerance of drought and cooler summer temperatures, low to medium water use, and availability of seed on the commercial market. Seeding rates are based on the lower end of the recommended seeding rate ranges from available literature and industry recommendations. Cover crop species, cultivars, and seeding rates used in this trial are given in Table 1. The investigated species are here divided into three functional groups-broadleaf species, grasses, and legumes.

Broadleaf

The trial contained entries of 11 broadleaf species. Buckwheat is a short-season cover crop used for weed control and green manure (Clark, 2012; Pavek, 2016). Forage chicory is a deep taprooted perennial that provides summer slump forage with high nutrient and mineral content. It is tolerant of drought and is bred to produce leafy growth (Hall & Jung, 1994). Lacy phacelia is fairly competitive, establishes well in cover crop mixes, is palatable to livestock, and provides good pollinator habitat (Kilian, 2016; Smither-Kopperl, 2018). Forage plantain has rapid emergence and deep roots that extract nutrients from deeper soil depths (Stewart, 1996). Pumpkins have been shown to be competitive against weeds once the canopy has closed (Orzolek et al., 2012); they can also be grazed. Safflower is a drought tolerant crop with a deep taproot. Spineless varieties are used as forage (Montana State University, 2015). Sunflower is deep rooted and brings up nutrients from deep in the soil profile (St. John et al., 2017). Forage radish resists bolting, regrows after grazing, and produces a taproot that breaks up compacted soil layers (Jacobs, 2012; Green Cover, 2020). African (also known as Ethiopian) cabbage is a tall forage brassica with a branching taproot that can break up soil compaction (St. John et al., 2017). Forage collard is a brassica that requires vernalization to bolt; if planted in spring it will not bolt until the following spring (Green Cover, 2020). Florida broadleaf mustard is a popular green vegetable, but it has also been grown as a component of cover crop mixes for weed suppression and grazing (Björkman et al., 2015; Green Cover, 2020).

Grasses

Sixteen entries of 12 grass species were planted in the trial. Spring barley grows well in cool, dry areas and can be grazed by livestock. It is also used as a cover crop to suppress weeds and scavenge nutrients (Jacobs, 2016). Grazing corn refers to maize hybrids intended to produce high biomass for livestock during the summer growing season (Ditsch et al., 2004). Foxtail millet is fast growing and is used to suppress weeds (Sheahan, 2014c). Pearl millet is a low-input, high biomass crop and has been used as a N-scavenging cover crop (Sheahan, 2014b). Proso millet is fast growing, uses little water, and has been used as a catch crop. It is not good forage but produces grain for livestock or wildlife (Sheahan, 2014a; Green Cover, 2020). Spring oat provides forage, scavenges nutrients, and suppresses weeds (Curell, 2012). Sorghum has been used as a cover crop to suppress weeds and break up soil compaction, as well providing forage (Dial, 2012; St. John et al., 2017). Egyptian wheat is a variety of sorghum that can grow 8 to 12 feet tall. It is commonly grown in wildlife plots and can be used as a high-biomass cover crop (Green Cover, 2020). Sorghum-sudangrass tolerates heat and drought, puts on a large amount of biomass, and has roots that break up compaction (Clark, 2012). Sudangrass is easier to manage than sorghum-sudangrass hybrids because it suppresses weeds better and has narrower stems that make mowing easier. It can also tolerate earlier planting (Björkman & Shail, 2010). Teff is a fine-stemmed warm season grass that is gaining popularity as a livestock forage and can be used as a green manure (Creech et al., 2012; St. John et al., 2017). Triticale is a cross between wheat and rye that is used as a cover crop and forage crop (St. John et al., 2017).

Legumes

The trial included entries of 14 different legume species. Chickpea can be planted early into soil temperatures of 46-50 °F; it tolerates spring frost and high temperatures in summer. Its extensive root system allows it to cope with drought (Esslinger, 2015; Green Cover 2020). Cowpea is commonly used for human consumption, livestock forage, and a cover crop in the southern U.S. It has been used as a component of cover crop mixes in Montana (Sheahan, 2012; Henning and Kilian, 2018). Fava bean is used as a N-fixing cover crop, green manure, and forage (Tallman, 2017; Smither-Kopperl, 2019). Fenugreek (Figure 1) is an annual legume forage crop that has been evaluated in western Canada and Wyoming (Islam, 2013; Acharya, 2008). Lentil is adapted to cool, dry conditions and is grown as a cover and green manure crop in Montana and California (Pavek & McGee, 2016). Mung bean has been used successfully in cover crop mixes in Montana (Henning & Kilian, 2018). Soybeans have been grown in the irrigated Pacific Northwest both as a grain crop and as forage/silage (Norberg et al., 2010). Spring forage pea fixes nitrogen and can be grazed or used as a green manure (Pavek, 2012; Green Cover, 2020). Sunn hemp, a subtropical legume, grew slowly in a previous study at the Aberdeen PMC, but ultimately produced 1,800 lb/ac dry matter (St. John et al., 2017). Sweetclover is a biennial or annual that is very drought resistant. It has been used as a green manure, forage, and hay (Ogle et al., 2008). 'Hubam' is a cultivar of annual white sweetclover (Clark, 2012). Chickling vetch (grass pea) is adapted to arid regions and poor soil. It fixes large amounts of N and can be used as forage (Campbell, 1997; St. John et al., 2017). Common vetch is used extensively as a green manure and fodder crop (St. John et al., 2017). American vetch is a drought-tolerant native legume that has been used in wildlife and pollinator plantings but is not well known as a cover crop (Allen & Tilley, 2014).

Figure 1. Fenugreek cover crop. Photo by Mary Wolf.

Table 1. Cover crop species, cultivars, and seeding rates for the IDPMC warm season cover crop trial, Aberdeen, ID, planted 2 June 2020.

Cover Crop Species	Scientific Name	Cultivars	Planting Rate (lb/ac)
BROADLEAF			
buckwheat	*Fagopyrum esculentum*	Mancan	30
chicory, forage	*Cichorium intybus*	Endure	5
phacelia, lacy	*Phacelia tanacetifolia*	Super Bee	5
plantain, forage	*Plantago lanceolata*	Boston	5
pumpkin	*Cucurbita pepo*	Mini Mix	5
radish, grazing	*Raphanus sativus*	Graza	5
safflower	*Carthamus tinctorius*	Baldy (spineless)	15
sunflower	*Helianthus annuus*	black oilseed	5
African cabbage	*Brassica carinata*	VNS	5
collard, forage	*Brassica oleracea*	Impact	5
Florida broadleaf mustard	*Brassica juncea*	Shield	5
GRASSES			
barley, spring forage	*Hordeum vulgare*	Lavina (beardless)	50
corn, grazing	*Zea mays*	BMR 84[1/]	25
Egyptian wheat	*Sorghum bicolor*	VNS	10
foxtail millet	*Setaria italica*	White Wonder	15
pearl millet	*Pennisetum glaucum*	Tifleaf III hybrid	15
proso millet	*Panicum miliaceum*	White	15
oat, spring	*Avena sativa*	Hayden	50
sorghum, forage	*Sorghum bicolor*	Coes; 2120; 400 BMR[1/]	10
sorghum-sudangrass	*S. bicolor* ssp. *bicolor x S. bicolor* ssp. *drummondii*	Sweet Six BMR[1/]; Sweet Forever BMR[1/]	15
sudangrass	*Sorghum bicolor* ssp. *drummondii*	Piper	30
teff	*Eragrostis tef*	Haymaker, Selam	5
triticale, spring	*x Triticosecale*	Surge	60
triticale, winter	*x Triticosecale*	SY TF 813	60
LEGUMES			
chickpea	*Cicer arietinum*	Desi	60
cowpea	*Vigna unguiculata*	Red Ripper	50
fava bean	*Vicia faba*	Petite	60
fenugreek	*Trigonella corniculata*	VNS	15
lentil, spring	*Lens culinaris*	Indian Head	20
mung bean	*Vigna radiata*	VNS	20
pea, spring forage	*Pisum sativum*	4010	50
soybean	*Glycine max*	Hutchinson	45
sunn hemp	*Crotalaria juncea*	VNS	18
sweetclover, annual white	*Melilotus alba*	Hubam	8
sweetclover, yellow	*Melilotus officinalis*	VNS	8
vetch, American	*Vicia americana*	VNS	30
vetch, chickling/grass pea	*Lathyrus sativus*	AC Greenfix	50
vetch, common	*Vicia sativa*	VNS	20

[1/]Brown midrib (BMR) is a genetic trait that produces reduced lignin in the plant.

The study was conducted at the Aberdeen PMC on a Declo silt loam. The field was prepared by disking and rolling in the spring to produce a firm, weed-free seedbed. Areas of weeds began to emerge immediately after rolling and were spot-sprayed with 64 oz/ac Roundup PowerMAX® one week prior to planting. Concerns about subsequent weed flushes led us to not apply fertilizer. All legume seeds were treated with the appropriate rhizobial inoculant prior to planting. A molasses and water mixture was used as a sticking agent. Inoculant was dusted onto the dampened seed and mixed to ensure even coating. Inoculated seeds were spread on paper to dry.

All cover crops were drill seeded to the industry-recommended depth in 5 x 20 ft plots (4 replications, see below) with an Almaco cone plot planter (The Almaco Company, Nevada, IA) with 6 planters on 9.5-inch centers. Plots were planted on 2 June 2020. Graza forage radish seed was not yet available on 2 June and was planted with a hand-pushed Almaco belt seeder on 5 June.

Irrigation water was applied with a hand line system as needed from 2 June through 28 August. Ten irrigation events resulted in 22 inches of water applied to the study. Alleys between plots were tilled to control weeds. A labor shortage precluded hand rogueing and there was considerable weed pressure on the plots. Plots were terminated on 30 September 2020, after susceptible species had been killed by frost.

Data collection included field emergence, bloom phenology, canopy height, % canopy cover, and biomass. Field emergence is an indicator of how quickly the cover crop species will establish and start providing soil cover and weed suppression. We evaluated percent emergence at 7, 21, and 28 days after planting (DAP). Only the 28 DAP data is included in this report. We counted emerging plants per foot of row and calculated % emergence as a proportion of the bulk seeds/linear foot planting rate.

To evaluate bloom phenology, we recorded the date at which each plot reached 50% bloom and calculated DAP at which that stage was reached. Bloom phenology 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.

At 50% bloom, we recorded canopy height by taking the average of three canopy (not inflorescence) height measurements. Aboveground biomass and % canopy cover were also measured at 50% bloom. The point-intercept method was used to measure and calculate % canopy cover. A 20 ft tape was stretched diagonally across the plot with a point evaluated every 6 in for the presence or absence of canopy cover, for a total of 40 points evaluated. Percent canopy cover represents the percentage of points that had canopy cover out of 40 possible points. For species that performed well but did not bloom, biomass and cover were measured on 8 September, immediately prior to the anticipated first frost that occurred on 9 September. To obtain biomass samples, plants were clipped at ground level from 0.5 x 1 m subplots in the center of each plot. Aboveground biomass samples were oven dried at 60 ^{o}C for 48 hours. Biomass dry weight was then calculated on a lb/ac basis. The four replications of dried biomass from each entry were combined and a composite sample of each was later analyzed for forage value by Ward Laboratories, Inc. (Kearney, NB). All cover crop species were analyzed on a dry basis for relative feed value (RFV), percent crude protein, percent acid detergent fiber (ADF), and percent total digestible nutrients (TDN). Most of the species were analyzed with near-infrared spectroscopy (NIRS). However, some cover crop species were not in the laboratory's NIRS forage library, necessitating analysis by wet chemistry. The laboratory analysis also included net energy (NE, MCal/lb) for maintenance, gain and lactation, and percent calcium and phosphorus The wet chemistry results lack values for % calcium and % phosphorus.

The experimental design was a randomized complete block with four replications. Statistical analysis was done using Statistix 10 (Analytical Software, Tallahassee, FL). Means and ±standard error of the mean (SE) are reported for field emergence, days after planting to 50% bloom, % canopy cover, canopy height, and biomass (dry weight).

RESULTS AND DISCUSSION

The last recorded spring frost of 2020 was on 16 May, slightly before the 20-year average last frost date of 27 May (NOWData, 2020). However, on 9 June we observed frost on the seedlings in the morning even though the recorded nighttime low temperature was 33 °F. Throughout June, although growing degree day accumulation was above normal (Figure 3), nighttime low temperatures were intermittently in the high 30's °F (Figure 2). Cool night temperatures negatively affected the early growth of many of the cover crops. Soil temperatures were probably cold, as well; however, AgriMet (2020) had no record of soil temperatures for Aberdeen or surrounding areas for the study period. Future warm season cover crop studies should include monitoring early soil temperatures. The first fall frost was on 9 September 2020, slightly before the 20-year average of 14 September (NOWData, 2020). Precipitation during the study period was close to long term normal for the period 1 June to 30 September 2020, about 2.5 in (Figure 2). Total accumulated moisture including irrigation was 24.5 in.

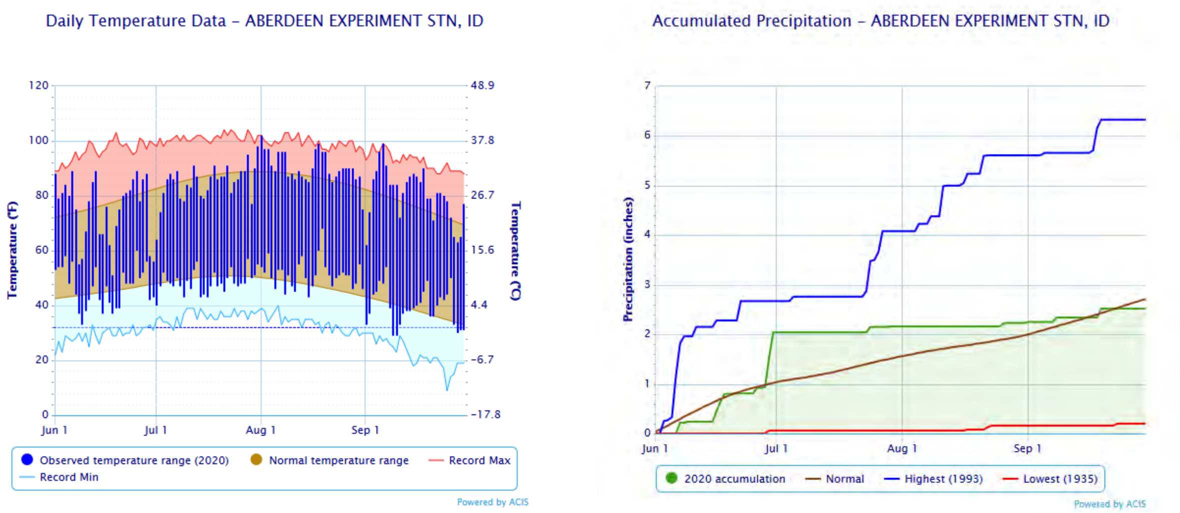

Figure 2. Daily temperature (left) and accumulated precipitation (right) for the period from 1 June 2020 through 30 September 2020 for the Aberdeen Experiment Station, Aberdeen, ID (NOWData, 2020).

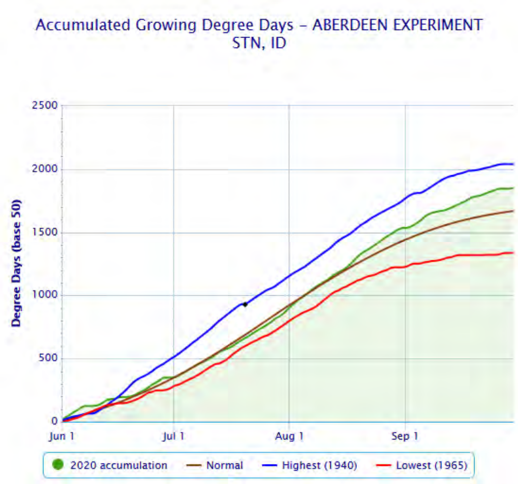

Figure 3. Accumulated growing degree days (base 50 °F) for the period from 1 June 2020 through 30 September 2020 for the Aberdeen Experiment Station, Aberdeen, ID (NOWData, 2020).

Emergence

Percent emergence at 28 DAP is presented in Table 2. Percent emergence is based on the number of seedlings observed compared to the bulk seeds/linear foot planting rate. Occasional values over 100% (sunflower, common vetch, and Petite fava bean) resulted when the species had a low seeding rate (< 8 bulk seeds/linear ft), uneven distribution by the plot seeder, and good germination.

Table 2. Percent emergence of cover crops at 28 days after planting (DAP) at the Aberdeen PMC, Idaho in 2020.

	Mean	SE[1/]
Common vetch	144	33.3
Sunflower, black oilseed	134	35.0
Fava bean, Petite	105	22.5
Lentil, Indian Head	96	17.2
Pumpkin, Mini Mix	79	9.1
Sorghum, 2120	73	6.6
Sorghum, 400 BMR	72	4.4
Barley, spring, Lavina	65	8.0
Plantain, Boston	64	10.3
Triticale, winter, SY TF 813	62	16.6
Chickpea, Desi	61	4.0
Collard, Impact	61	7.0
Florida mustard, Shield	60	9.3
Sweetclover, yellow	59	3.8
Egyptian wheat	59	17.8
Pea, 4010	58	10.6
Sorghum-sudan, Sweet Forever	58	13.5
Proso millet, White	57	8.6
Buckwheat, Mancan	55	12.8
Oat, Hayden	55	3.4
Sorghum, Coes	54	20.5
Sorghum-sudan, Sweet Six	51	9.3
Triticale, spring, Surge	51	5.3
Pearl millet, Tifleaf III hybrid	51	6.9
Foxtail millet, White Wonder	49	2.8
American vetch	49	10.5
Sudangrass, Piper	49	10.5
Safflower, Baldy	48	5.9
Corn, BMR 84	47	12.0
Fenugreek	41	11.0
Mung bean	38	5.4
Cowpea, Red Ripper	37	8.6
Chickling vetch, AC Greenfix	37	8.3
Phacelia, Super Bee	34	7.8
Radish, Graza	33	18.5
African cabbage	28	3.5
Sunn hemp	28	8.7
Teff, Selam	27	7.2
Sweetclover, Hubam	26	1.9
Chicory, Endure	20	4.8
Teff, Haymaker	13	4.5
Soybean, Hutchinson	0	0

[1/]Standard error of the mean.

Species that performed very poorly after emergence are shown in Table 3. Although some of these cover crops had good emergence at 28 DAP, by mid-July they had had few or no plants per plot and were not evaluated further. Surprisingly poor performers overall were BMR 84 grazing corn, which is used by producers in our area, as well as cowpea and mung bean, which have performed well in studies at the Montana PMC. Light frost and cold soil temperatures in early June were undoubtedly the cause for the poor performance of these sensitive crops. Pumpkin may be better suited as part of a cover crop mix where it can be protected from temperature extremes and be supported by taller plants. American vetch seed was much more expensive than the other cover crop seed at $50/lb. Given its high cost and poor performance in this trial, it may not be an appropriate cover crop in our region.

Table 3. Cover crops that were not evaluated beyond emergence at the Aberdeen PMC, Idaho in 2020 due to poor performance.

	Cultivar
Corn	BMR 84
Soybean	Hutchinson
Mung bean	VNS
Chickpea	Desi
Sorghum	Coes
Pearl millet	Tifleaf III hybrid
American vetch	VNS
Sunn hemp	VNS
Pumpkin	Mini Mix

Bloom Phenology

Bloom phenology (days after planting to reach 50% bloom) means for each accession is reported in Figure 5. The earliest cover crops to achieve 50% bloom were Mancan buckwheat, fenugreek, Super Bee phacelia, and Shield Florida mustard, which all reached that point by 50 DAP (22 July). These species would provide relatively quick benefits if pollinator habitat is one of the objectives for a cover crop planting. AC Greenfix chickling vetch, 4010 pea, and African cabbage had all reached 50% bloom by the first week of August (62 DAP). Hayden oat was the first small grain to reach 50% bloom, at 56 DAP (28 July). As expected, spring small grains reached bloom before winter small grains and warm season grains. White proso millet, White Wonder foxtail millet, and Piper sudangrass had some replications (plots) that included plants that had begun to bloom by the end of the season, while other plots did not. The number of blooming replications (n) is indicated in Figure 5. Cover crops not reported in Figure 5 did not bloom before first frost on 9 September.

Figure 4. Baldy spineless safflower at 50% bloom. Photo by Mary Wolf.

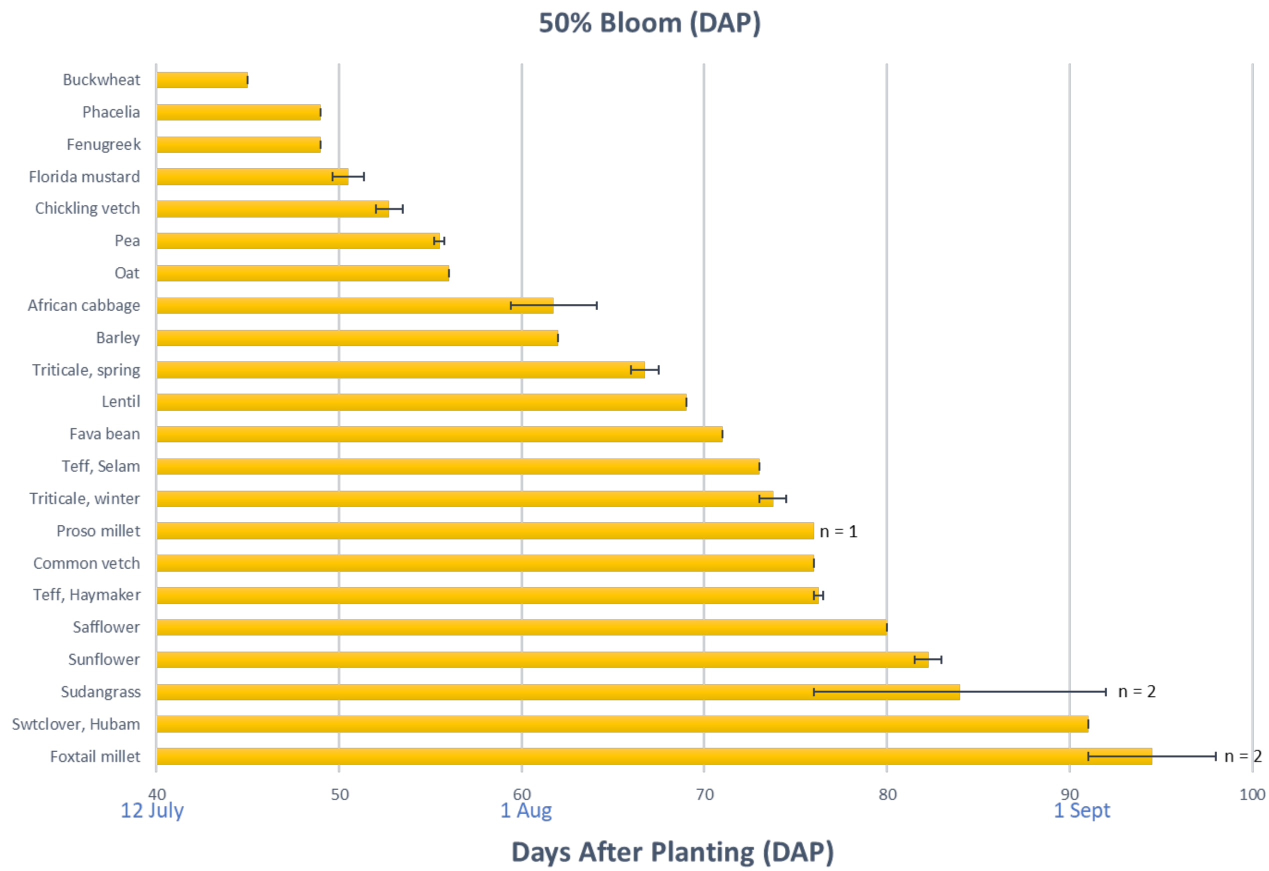

Figure 5. Mean days after planting (DAP) to 50% bloom of cover crops at the Aberdeen PMC, Idaho in 2020. All four replications (plots) bloomed (n = 4) except as indicated. Bars indicate the standard error of the mean (SE).

Percent Canopy Cover

Percent canopy cover for each entry was measured when it reached 50% bloom (Table 4). For cover crops that performed well but did not bloom, % canopy cover was measured on 8 September, prior to the anticipated first frost that occurred 9 September. These non-blooming cover crops included Endure forage chicory, Impact forage collard, Boston forage plantain, yellow sweetclover, Graza radish, Egyptian wheat, Sweet forever sorghum-sudan, Sweet Six sorghum-sudan, and 2120 sorghum, and 400 BMR sorghum. White Wonder foxtail millet, White proso millet and Piper sudangrass plots had not all begun to bloom by early September; those plots were also evaluated on 8 September.

Hubam annual white sweetclover had the greatest canopy cover at 89%. Common vetch, Endure forage chicory, Indian Head lentil, Haymaker teff, and Selam teff all had canopy cover of 80% or more. Hubam annual white sweetclover, Endure forage chicory and the teff varieties achieved this cover in spite of having less than 30% emergence at 28 DAP (Table 2).

Some of the species that did not provide good canopy cover, such as Mancan buckwheat, AC Greenfix chickling vetch, 4010 pea, and Super Bee phacelia, provide benefits to pollinators and are valuable forage and soil-building crops. They would do best planted in a mix with other species that provide better cover.

Table 4. Percent canopy cover of cover crops at 50% bloom (unless otherwise indicated) at the Aberdeen PMC, Idaho in 2020.

	% Cover	
	Mean	SE[3/]
Sweetclover, Hubam	89	1.3
Common vetch	84	1.3
Chicory, Endure[1/]	81	2.4
Lentil, Indian Head	81	3.8
Teff, Haymaker	80	7.1
Teff, Selam	80	0.0
Collard, Impact[1/]	76	4.7
Sweetclover, yellow[1/]	76	7.7
Florida mustard, Shield	73	6.3
Barley, Lavina	68	4.3
African cabbage	66	3.1
Fava bean, Petite	66	4.3
Triticale, spring, Surge	66	4.3
Safflower, Baldy	65	6.1
Triticale, winter, SY TF 813	61	3.8
Fenugreek	60	6.5
Sunflower, black oilseed	60	5.8
Plantain, Boston[1/]	58	10.9
Sorghum-sudan, Sweet Forever[1/]	58	4.8
Sorghum-sudan, Sweet Six[1/]	58	10.9
Oat, Hayden	56	11.3
Radish, Graza[1/]	55	9.4
Sudangrass, Piper[2/]	51	9.4
Foxtail millet, White Wonder[2/]	50	18.6
Buckwheat, Mancan	48	6.3
Chickling vetch, AC Greenfix	45	12.1
Egyptian wheat[1/]	44	5.9
Pea, spring, 4010	43	11.6
Proso millet, White[2/]	41	14.8
Sorghum, 400 BMR[1/]	40	13.4
Phacelia, Super Bee	40	4.6
Sorghum, 2120[1/]	36	12.1
All cover crops	61	1.8

[1/]No plots had bloomed by 8 September; % cover measured on 8 Sept.
[2/]Not all plots had bloomed by 8 September; % cover measured on 8 Sept.
[3/]Standard error of the mean.

Biomass and Canopy Height
For each cover crop entry, biomass samples were collected and canopy height was measured at the same time that % cover was measured, as described in the previous section. Means for biomass and height are reported in Table 5. Mancan buckwheat biomass was sampled, dried and sent for forage analysis but somehow missed being weighed first; its biomass values are missing from Table 5.

Highest biomass crops were black oilseed sunflower, Hubam annual white sweetclover, Lavina spring barley, Surge spring triticale, and Graza radish, all with mean biomass over 5,000 lb/ac dry weight. Sunflower and Hubam annual white sweetclover were the tallest cover crops, both with a mean height of 53 in. Sunflower mean biomass was 12,218 lb/ac with a large SE, ±4,503. One of the plots had a biomass almost twice the mean, 23,250 lb/ac. It appears that the plot was seeded unevenly as described above in the ‘Emergence’ section. Hubam annual white sweetclover produced twice the mean biomass (7,530 lb/ac) of biennial yellow sweetclover (3,778 lb/ac) in the year of this study.

Some entries demonstrated slow emergence at 28 DAP (Table 2) but produced abundant biomass by the time they were evaluated. Hubam annual white sweetclover, one of the top performers in this trial for biomass and % canopy cover, had only 26.5% mean emergence at 28 DAP. Yellow sweetclover had better emergence than Hubam annual white sweetclover but had produced half the biomass at the end of the season. Graza radish, African cabbage and Endure forage chicory also overcame a slow start to produce abundant biomass. Sorghum cultivars 2120 and 400 BMR had emerged strongly by 28 DAP, better than the other warm season grasses, but did not produce as much biomass as other warm season grasses.

We did not see an advantage to planting winter triticale over spring triticale, even with our cold spring temperatures. SY TF 318 winter triticale showed better emergence than Surge spring triticale (Table 2), but spring triticale had greater biomass and canopy cover later in the season. Surge spring triticale produced a mean value of 5,326 lb/ac dry weight, while SY TF 813 winter triticale produced a mean value of 4,100 lb/ac dry weight. Both had similar % canopy cover at 50% bloom (Table 4).

Figure 6. Shield Florida mustard (left) and Lavina spring barley (right) at 50% bloom, when they were evaluated for % canopy cover, height, and biomass. Photos by Mary Wolf.

Table 5. Biomass (lb/ac dry weight) and height (in) of cover crops at 50% bloom (unless otherwise indicated) at the Aberdeen PMC, Idaho in 2020.

	Biomass (lb/ac)		Height (in)	
	Mean	SE[4/]	Mean	SE[4/]
Sunflower, black oilseed	12218	4503	53	3.1
Sweetclover, Hubam	7530	726	53	1.9
Barley, Lavina	5505	759	24	1.0
Triticale, spring, Surge	5326	566	35	1.7
Radish, Graza[1/]	5090	537	23	1.8
Common vetch	4885	965	28	2.3
Safflower, Baldy	4773	703	32	0.5
African cabbage	4381	1205	35	1.9
Triticale, winter, SY TF 813	4100	403	33	0.8
Sudangrass, Piper[2/]	4077	2267	52	7.1
Sorghum-sudan, Sweet Forever[1/]	4033	3020	44	5.7
Collard, Impact[1/]	3943	751	25	2.1
Sweetclover, yellow[1/]	3778	1095	18	1.3
Fava bean, Petite	3743	811	34	1.3
Proso millet, White[2/]	3604	2006	22[3/]	3.8
Plantain, Boston[1/]	3261	1431	14	0.7
Sorghum-sudan, Sweet Six[1/]	3230	1429	40	5.7
Teff, Selam	3230	655	27	2.6
Oat, Hayden	3203	996	26	1.9
Lentil, Indian Head	2940	367	23	0.8
Foxtail millet, White Wonder[2/]	2378	936	30[3/]	4.9
Chicory, Endure[1/]	2306	390	22	0.4
Florida mustard, Shield	2079	500	25	3.4
Egyptian wheat[1/]	1847	1443	39	6.3
Teff, Haymaker	1445	495	30	1.0
Fenugreek	1258	135	18	1.5
Phacelia, Super Bee	1160	395	20	1.1
Pea, spring, 4010	995	292	29	2.7
Sorghum, 400 BMR[1/]	816	302	30[3/]	1.5
Chickling vetch, AC Greenfix	772	177	19	1.1
Sorghum, 2120[1/]	571	267	30[3/]	3.2
Buckwheat, Mancan	[5/]	[5/]	20	1.4
All cover crops	3499	292	30	1.0

[1/]No plots had bloomed by 8 September; evaluated on 8 Sept.
[2/]Not all plots had bloomed by 8 September; evaluated on 8 Sept.
[3/]For height only, n = 3 replications (one replication had no plants and was reported 0% cover).
[4/]Standard error of the mean.
[5/]Buckwheat biomass samples not weighed before they were sent for forage analysis.

Weed pressure was heavy during this study. Because the soybeans did not emerge, we used the soybean plots as control plots for sampling weed biomass at the end of the season (10 September). Weed biomass was 4,039±704 dry lb/ac. Weed species present included yellow foxtail (*Setaria pumila*), barnyard grass (*Echinochloa crus-galli*), kochia (*Bassia scoparia*), lambsquarters (*Chenopodium album*), and sow thistle (*Sonchus* spp.).

Forage Value

The highest RVF values were found in Impact forage collard, Graza forage radish, Endure forage chicory, Boston forage plantain, and 4010 pea, all of which had RFV values over 200 (Table 6). Crude protein was highest in the legumes, with a range from 16 to 26%. AC Greenfix chickling vetch, common vetch, and 4010 pea had the highest percentage of crude protein, with values over 24% (Table 6). Graza forage radish RFV was highest among the non-leguminous broadleaf species with 17% crude protein. Mancan buckwheat had nearly as much crude protein as the lowest-ranked legumes at 14%. AC Greenfix chickling vetch, 4010 pea, and fenugreek all produced forage comparable to the RFV, % crude protein, and % TDN of premium alfalfa hay (IHFA, 2021). RFV and crude protein were lowest for the grass cover crops; however, they had the highest % ADF. The high % ADF of African cabbage was the result of long stems that developed during bolting and inflorescence.

Net energy (NE) is a measure of how much energy it takes cattle to maintain weight, gain weight , or lactate (Lalman & Richards, 2017). These values are shown in Table 7, which is sorted in order of highest NE maintenance. AC Greenfix chickling vetch, Mancan buckwheat, common vetch, White proso millet, and yellow sweetclover had the highest NE scores for maintenance and gain. The highest NE scores for lactation were found in Impact forage collard, Graza forage radish, Boston forage plantain, and AC Greenfix chickling vetch.

Of the cover crops tested for calcium and phosphorus, AC Greenfix chickling vetch, 4010 pea, common vetch and Mancan buckwheat contained the most calcium, with over 1%. AC Greenfix chickling vetch, common vetch, and 4010 pea tested the highest for phosphorus, containing 0.33% or more (Table 7).

Figure 7. Boston forage plantain (left) and Impact forage collard (right) approximately 60 days after planting (DAP). Photo by Mary Wolf.

Table 6. Relative feed value, crude protein, acid detergent fiber, and total digestible nutrients of warm season cover crops sampled at 50% bloom or late season growth at the Aberdeen PMC, Idaho in 2020. NIRS analysis except as indicated. All analysis values are on a dry weight basis.

	Relative Feed Value	% Crude Protein	% Acid Detergent Fiber	% Total Digestible Nutrients
Collard, Impact[1/]	320	13	21	67
Radish, Graza[1/]	317	17	22	66
Chicory, Endure[1/]	248	11	27	62
Plantain, Boston[1/]	235	10	26	63
Pea, spring, 4010	201	24	26	63
Buckwheat, Mancan	185	14	29	70
Chickling vetch, AC Greenfix	180	26	28	70
Fenugreek[1/]	180	21	32	59
Alfalfa hay, premium[2/]	170-185	20-22	27-29	60.5-62
Sunflower, black oilseed[1/]	163	10	32	66
Florida mustard, Shield[1/]	159	12	33	65
Fava bean, Petite[1/]	147	22	34	57
Common vetch	146	25	30	68
Phacelia, Super Bee[1/]	145	9	35	56
Sweetclover, yellow	135	19	31	67
Lentil, Indian Head[1/]	131	16	37	55
Safflower, Baldy[1/]	127	10	37	55
Sweetclover, Hubam	125	19	33	65
Proso millet, White	107	8	31	68
Sorghum, Egyptian wheat	98	11	34	64
African cabbage[1/]	98	9	44	49
Barley, Lavina	93	8	36	62
Sorghum-sudan, Sweet Forever	93	8	35	63
Sorghum, 400 BMR	90	5	39	58
Sorghum-sudan, Sweet Six	90	5	38	59
Oat, Hayden	88	8	37	60
Sudangrass, Piper	87	8	37	61
Triticale, spring, Surge	86	9	37	60
Sorghum, 2120	85	5	39	58
Teff, Haymaker	81	8	39	58
Teff, Selam	81	6	39	58
Triticale, winter, SY TF 813	78	7	40	57
Foxtail millet, White Wonder	75	3	43	54

[1/]Forage analysis with wet chemistry rather than NIRS.
[2/]Premium alfalfa hay values are included for comparison (IHFA, 2021).

Table 7. Net energy (MCal/lb) and percent calcium and phosphorus content of warm season cover crops sampled at 50% bloom or late season growth at the Aberdeen PMC, Idaho in 2020. All analysis values are on a dry weight basis.

	---------Net Energy (MCal/lb)-------				
	Maintenance	Gain	Lactation	% Ca	% P
Chickling vetch, AC Greenfix	0.74	0.47	0.73	1.19	0.41
Buckwheat, Mancan	0.73	0.46	0.72	1.05	0.29
Common vetch	0.72	0.45	0.71	1.03	0.33
Proso millet, White	0.71	0.44	0.70	0.20	0.23
Sweetclover, yellow	0.70	0.43	0.69	0.95	0.28
Collard, Impact	0.69	0.42	0.79	[1/]	[1/]
Sunflower, black oilseed	0.69	0.42	0.69	[1/]	[1/]
Radish, Graza	0.68	0.41	0.78	[1/]	[1/]
Sweetclover, Hubam	0.67	0.40	0.67	0.85	0.26
Florida mustard, Shield	0.66	0.40	0.68	[1/]	[1/]
Sorghum, Egyptian wheat	0.65	0.39	0.66	0.29	0.23
Plantain, Boston	0.64	0.38	0.74	[1/]	[1/]
Pea, spring, 4010	0.64	0.37	0.64	1.55	0.33
Sorghum-sudan, Sweet Forever	0.63	0.37	0.64	0.28	0.23
Barley, Lavina	0.62	0.36	0.63	0.22	0.21
Chicory, Endure	0.62	0.36	0.71	[1/]	[1/]
Sudangrass, Piper	0.61	0.35	0.62	0.22	0.23
Oat, spring, Hayden	0.60	0.34	0.62	0.15	0.29
Triticale, spring, Surge	0.60	0.34	0.61	0.18	0.23
Sorghum-sudan, Sweet Six	0.59	0.33	0.61	0.15	0.23
Fenugreek	0.57	0.31	0.66	[1/]	[1/]
Teff, Selam	0.57	0.31	0.59	0.17	0.20
Sorghum, 400 BMR	0.57	0.31	0.59	0.18	0.25
Sorghum, 2120	0.57	0.31	0.59	0.19	0.25
Teff, Haymaker	0.56	0.30	0.59	0.24	0.21
Triticale, winter, SY TF 813	0.56	0.30	0.59	0.13	0.26
Fava bean, Petite	0.55	0.29	0.64	[1/]	[1/]
Phacelia, Super Bee	0.53	0.27	0.62	[1/]	[1/]
Lentil, Indian Head	0.52	0.26	0.61	[1/]	[1/]
Safflower, Baldy	0.51	0.26	0.60	[1/]	[1/]
Millet, foxtail, White Wonder	0.50	0.25	0.55	0.24	0.23
African cabbage	0.42	0.18	0.51	[1/]	[1/]

[1/] % Ca and P not measured with wet chemistry forage analysis.

CONCLUSION

It is essential to choose cover crops that are adapted to the local climate and that meet producer objectives. This cover crop trial provides basic information about the suitability of various warm season cover crops to the Intermountain West, their biomass production capabilities, and their value as livestock forage. Many of the cover crops evaluated exhibited good adaptation based on a single year of field emergence, % canopy cover, canopy height, and biomass. Some of the cover crops were found to have high forage values and may provide producers with additional summer forage opportunities where needed. Some of the cover crops that performed poorly, such as forage corn, sorghum, and sorghum-sudan may have been inhibited by cold early-season temperatures. Anecdotal evidence from the region suggests that these cover crops can succeed more often than not, and further evaluation is warranted. In the future, well-adapted warm season cover crops will be evaluated to determine optimal seeding rates for each species.

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