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Adaptation of Dryland and Irrigated Warm Season Cover Crops in Western Oregon – 2017 Progress Report

Annie Young-Mathews

Figure 1. Dryland 'Sweet Forever BMR' sorghum-Sudangrass 90 days after planting (left), bumble bee foraging on 'Finch' safflower (middle-left), bumble bee on 'AC Greenfix' chickling vetch (middle-right), and 'Viking 2265' soybean at 75 days after planting (right) at the Corvallis Plant Materials Center, 2017.

ABSTRACT

Warm season cover crops are not currently widely used in western Oregon, but they could be incorporated into crop rotations to serve a variety of purposes, including mitigating for an increasing possibility of longer summer droughts, increased heat stress, and restrictions on irrigation water availability. A two-year trial was initiated in 2017 at the USDA-NRCS Plant Materials Center in Corvallis, Oregon to evaluate the adaptation of 21 different warm season cover crop species or cultivars, both with and without supplemental irrigation. First year results indicate potential for Sudangrass and sorghum-Sudangrass hybrids, foxtail millet, safflower, sunflower, phacelia, buckwheat, chickling vetch, soybean, sunn hemp, cowpea, and chickpea under both dryland and irrigated management, while the fenugreek, guar, and okra did not appear to be promising cover crops for use in western Oregon under either management scenario. The trial will be repeated in 2018.

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INTRODUCTION

Warm season cover crops are not currently widely used in western Oregon, but they could be incorporated into crop rotations to serve a variety of purposes including adding diversity of plant functional groups to enhance soil health, providing weed/pest suppression, enhancing pollinator/beneficial insect habitat, fixing nitrogen, producing biomass to improve soil organic matter, and filling short periods between commercial crops (Clark, 2007). Current recommendations from Oregon State University only include two warm season cover crop species, buckwheat and Sudangrass (Sattell and Dick, 1998). However, there are many other commercially available warm season forage or cover crop species/cultivars commonly grown in other parts of the United States that are potentially adapted to western Oregon's Mediterranean climate. Table 1 summarizes agronomic requirements and tolerances of 18 warm season cover crops with potential for use in Oregon, discussed in further detail below.

The adaptation and use of Sudangrass or sorghum-Sudangrass hybrids (*Sorghum bicolor* ssp. *bicolor* x *S. bicolor* ssp. *drummondii*) and buckwheat (*Fagopyrum esculentum*) is well documented for western Oregon (Clark, 2007; Sattell and Dick, 1998). Sudangrass and sorghum-Sudangrass hybrids are warm season grasses known for their tremendous biomass production and the ability of their dense root systems to break up subsoil compaction (Clark, 2007; Sattell and Dick, 1998; UC SAREP, 1999). Buckwheat is a broadleaf whose rapid germination in 3 to 4 days produces a quick canopy cover effective at smothering weeds, and its abundant bloom 30 to 45 days after planting provides high quality nectar forage for honey bees and other beneficial insects (Clark, 2007; Opplinger et al., 1989; Sattell and Dick, 1998; UC SAREP, 1999).

Initial trials at the Corvallis Plant Materials Center (PMC) in 2015-2016 indicated that in addition to sorghum-Sudangrass and buckwheat, the following species appeared well adapted to the Willamette Valley as summer cover crops under irrigation: lacy phacelia (*Phacelia tanacetifolia*), safflower (*Carthamus tinctorius*), sunflower (*Helianthus annuus*), teff (*Eragrostis tef*), and pearl millet (*Pennisetum glaucum*) (Young-Mathews, 2017). Phacelia is a broadleaf with moderate weed suppression and biomass production, and flowers that are highly attractive to pollinators and beneficial insects during its 4 to 6 week bloom period (Green Cover Seed, 2017; Kilian, 2016). Safflower is a broadleaf plant with a deep taproot capable of mining moisture and nutrients below the rooting zone of many crops, and prolific blooms in late summer that attract pollinators and beneficial insects (Green Cover Seed, 2017; Oelke et al., 1992). Sunflower, like safflower, is slow to establish initially, so may be more prone to weed pressure than more vigorous crops like buckwheat and Sudangrass, but produces substantial biomass and abundant pollen for bees and beneficial insects (Green Cover Seed, 2017; Putnam et al., 1990). Teff is a quick-growing, fine-leaved, warm season C4 grass that produces high quality forage that is especially prized as horse feed (Barenbrug, 2011; Roseberg et al., 2005; Skerman and Riveros, 1990). Fertilization and nitrogen trials on teff in Medford, Oregon showed no effect of N fertilization on forage yield and optimal yield/quality with moderate irrigation (about 8 inches over the 70 days from planting to first cutting) (Roseberg et al., 2005). Pearl millet is a quick-growing, C4 forage grass that is used for abundant biomass production, to break up soil compaction with its deep root system, and in rotation to control root-lesion nematodes (Oelke et al., 1990; Sheahan, 2014b). Foxtail millet (*Setaria italica*) is another quick-growing, warm season C4 forage grass with high water-use efficiency that is good for biomass production and weed suppression (Oelke et al., 1990; Sheahan, 2014a).

Table 1. Summary of warm season cover crop agronomic traits from available literature: soil pH range, minimum germination temperature, relative water use, drought tolerance, low fertility tolerance, range of recommended drilled seeding rates, and best soil type.

Crop	pH range	Min. germ. temp.	Water use	Drought tolerance	Low fert. tolerance	Seeding rate lb/ac	Best soil type	References[1]
buckwheat	5.0-7.0	45F	low	fair	good	40-70	wide range	4, 27, 31, 35
chickling vetch	*	*	low	very good	very good	35-70	wide range, tolerates waterlogging	3, 12, 13, 15
chickpea	6.0-9.0	45F	low	very good	good	75-150	well-drained, fertile, sandy-loam	11, 12, 26
cowpea	4.5-7.5	58F	medium	good	excellent	30-90	well-drained, sandy loam, acid to neutral	4, 35
fenugreek	5.3-8.2	60F	medium	good	*	15-24	well-drained, rich	7, 8, 16
foxtail millet	5.5-7	65F	medium	good	fair	15-20	well-drained, loamy	12, 23, 32
guar/cluster bean	7.0-8.0	70F	medium	good	good	5-12	well-drained, fertile, med-text.	12, 37
mung bean	6.2-7.2	60F	medium	good	good	15-30	well-drained, fertile, sandy-loam	9, 12, 25
okra	6.0-7.0	75F	medium	fair	low	7	well-drained, sandy loam	10, 12
pearl millet	5.5-7	54F	medium	good	fair	12-15	well-drained, loamy	12, 23, 33
phacelia	5.5-8.5	40F	medium	fair	fair	4-12	well-drained, fertile, light-text.	12, 19
safflower	6	40F	high	very good	*	12-25	well-drained, fertile	12, 24
sesame	5.6-7	70F	medium	very good	*	1-3	well-drained, fertile, med-text., neutral	12, 28
soghum-Sudangrass	6.0-8.0	60-65F	medium	excellent	good	20-60	wide range	4, 12, 31, 35
soybean	6-7.7	60F	medium	fair	good	50-65	wide range	12, 22
sunflower	5.7-8	40F	high	fair	*	3-8	well-drained	12, 29
sunn hemp	5.0-8.4	60F	medium	good	very good	18-50	well-drained, acid	12, 18, 35
teff	6-8	65F	medium	good	fair	5-22	well-drained, sandy loams	2, 12, 30, 34

*No data available; [1]See Literature Cited below.

Performance of legumes in the 2015-2016 Corvallis PMC trial, including sunn hemp (*Crotalaria juncea*), soybean (*Glycine max*), and cowpea (*Vigna unguiculata*), was less impressive, with slower germination, lower vigor, and more susceptibility to weeds and disease, but eventual biomass production was comparable to the other forbs in the trial (Young-Mathews, 2017), and their importance as nitrogen-fixers warrants further attention. Chickling vetch (*Lathyrus sativus*), a cool season legume included in 2014-2015 fall- and spring-planted trials at the Corvallis PMC, also showed some promise for biomass production and pollinator habitat (Young-Mathews, 2016). The chickling vetch suffered some winter damage in that trial, but its documented adaptation to drought, poor soils, and waterlogging (Campbell, 1997; Hearne, 2012; Heuzé et al., 2016) make it a good candidate for a non-irrigated summer cover in western Oregon. Chickpea (*Cicer arietinum*) is another drought-tolerant, cool season legume that is grown in the summer in northern regions of the U.S. and southern Canada (Fleury, 2016; Oplinger et al., 1990). Other potentially interesting drought-tolerant, warm season legumes grown as specialty crops in other parts of the U.S. include guar (*Cyamopsis tetragonoloba*) (Undersander et al., 1991), fenugreek (*Trigonella foenum-graecum*) (Darby, 2004 and 2006; Islam, 2013), and mungbean (*Vigna radiata*) (Delate, 2013; Oplinger et al., 1990).

Okra (*Abelmoschus esculentus*) is a warm season broadleaf recommended as a component of cover crop mixes in the Midwest for its durable residue and flowers that attract beneficial insects (Green Cover Seed, 2017). Sesame (*Sesamum indicum*) is another warm season broadleaf that is drought-tolerant, said to help control some nematodes, and may attract beneficial insects (Oplinger et al., 1990).

Some farms in western Oregon do not have access to irrigation, while others have had their water rights cut off early in the summer over the last several years due to severe drought (Montesano, 2015). Current climate models predict a 10–15% decrease in summer rainfall in western Oregon over the next 50 years, along with a 2.0–2.5 inch increase in potential summer evapotranspiration, as well as decreased irrigation water availability from snowmelt-fed systems in the Cascade Range (Dalton et al., 2017). Dryland cover crops may be a way for farms to mitigate for this increasing possibility of longer summer droughts, increased heat stress, and restrictions on irrigation water availability. The objective of this study was to evaluate the adaptation of different warm season cover crop species/cultivars in the Willamette Valley of western Oregon, both with and without supplemental irrigation.

MATERIALS AND METHODS

In 2017, we began the two-year trial at the USDA-NRCS Corvallis Plant Materials Center (PMC) in Corvallis, OR. Warm season cover crop species were selected for this trial based on a low to medium water use rating and/or a medium to high drought tolerance rating from available literature, and availability of seed on the commercial market. Seeding rates were based on the low end of the recommended seeding range from available literature. Cover crop species, cultivars, and seeding rates used in this trial are given in Table 2.

The soil type where the trial was planted is mapped as an Amity silt loam, 0–3% slopes, somewhat poorly drained. Results from soil samples collected on 19 April 2017 are given in Table 3 (Kuo Testing Labs, Othello, WA); since soil pH was above 6.0 in both fields, no additional lime was added. Climate data were collected from the Oregon State University Hyslop weather station approximately one mile from the field trial (Figure 2). Daily maximum and minimum air temperatures over the summer growing season averaged 82 and 52°F, respectively.

Table 2. Warm season cover crop species, cultivars, average seeds per pound, and seeding rates for the adaptation trial at the Corvallis Plant Materials Center, 2017.

Species	Common Name	Cultivar	Crop Type	Seeds/lb	Drilled seeding rate (PLS*)	
					lb/ac	seeds/ft^2
Abelmoschus esculentus	okra	Emerald	broadleaf	7,400	7	1.2
Carthamus tinctorius	safflower	Finch	broadleaf	12,000	20	5.5
Fagopyrum esculentum	buckwheat	Koma	broadleaf	15,000	40	13.8
Helianthus annuus	sunflower	VNS[§] (black oil)	broadleaf	12,600	4	1.2
Phacelia tanacetifolia	phacelia	VNS	broadleaf	206,000	4	18.9
Sesamum indicum	sesame	VNS (light seeded)	broadleaf	152,000	3	10.5
Eragrostis tef	teff	Excaliber	grass	1,475,000	5	169.3
Pennisetum glaucum	pearl millet	Tifleaf 3	grass	56,000	12	15.4
Pennisetum glaucum	pearl millet	K Graze (hybrid)	grass	18,000	12	5.0
Setaria italica	foxtail millet	Golden German	grass	160,000	15	55.1
Sorghum bicolor ssp. bicolor x S. bicolor ssp. drummondii	soghum-sudangrass	Sweet Forever BMR	grass	17,000	30	11.7
Sorghum bicolor ssp. bicolor x S. bicolor ssp. drummondii	soghum-sudangrass	Sweet Six Dry Stalk	grass	15,000	30	10.3
Sorghum bicolor ssp. drummondii	Sudangrass	Piper	grass	40,000	30	27.5
Cicer arietinum	chickpea	Desi	legume	2,100	75	3.6
Crotalaria juncea	sunn hemp	Tillage Sunn	legume	8,000	25	4.6
Cyamopsis tetragonoloba	guar/cluster bean	Kinman	legume	15,000	5	1.7
Glycine max	soybean	Viking 2265	legume	2,500	50	2.9
Lathyrus sativus	chickling vetch	AC Greenfix	legume	2,800	50	3.2
Trigonella foenum-graecum	fenugreek	VNS	legume	31,000	15	10.7
Vigna radiata	mung bean	VNS	legume	7,800	20	3.6
Vigna unguiculata	cowpea	Iron & Clay	legume	4,500	50	5.2

*pure live seed; [§]variety not stated

Table 3. Soil test results from 0–6” samples of fields used for the warm season cover crop adaptation trial at the Corvallis Plant Materials Center, 2017.

Field ID	pH	OM	P (Bray)	K	Ca	Mg
		%	ppm	ppm	meq/100g	meq/100g
Dryland	6.1	2.53	78	227	8.4	0.5
Irrigated	6.2	3.81	58	213	9.1	0.6

Daily maximum and minimum soil temperatures at 4-inch depth averaged 79 and 69°F, respectively. Precipitation totaled 1.84 inches while evaporation totaled 32 inches, and there was a total accumulation of 2296 growing degree days between 24 May and 19 September, 2017. The fields were prepared by discing and rolling to produce a firm, well-prepared seedbed. All crops were drill-seeded in 4 replicate 5 x 20-ft plots with a Hege cone seeder (Wintersteiger Inc., Salt Lake City, UT) on 6-inch row spacing at a depth of about 1 to 2 inches (into moisture). Plots were planted on 24 May 2017, after our last frost date (May 15th). All legume seeds were inoculated with the appropriate rhizobia prior to planting.

All non-legume plots were broadcast fertilized with 60 lb N/ac as urea (46-0-0) on 10 July 2017, once their true leaves had emerged, and the irrigated plots received about 1 inch of sprinkler irrigation every two weeks, as needed, from June through September. Plots were hand-weeded once during the growing season to prevent excessive weed competition.

Germination/emergence was scored in each plot approximately every 7 days for the first four weeks after planting using the following scale: 0 = poor (<25% germination), 1 = moderate (25-65% germination), 2 = good (66-85% germination), 3 = excellent (>85% germination). Every 15 days, all plots were rated for the following: vigor (general health and growth, rated on a scale of 1–5, where 1=poor and 5=excellent); disease (visual estimate of foliar diseases, rated from 0–5, where 0=no damage and 5=severe damage); pests (visual estimate of insect damage, rated from 0–5, where 0=no damage and 5=severe damage); and canopy cover (visual estimate of the percentage of ground covered by the plant, estimated to the nearest 10%).

Bloom period was monitored and the date of 50% bloom was recorded. When plants reached 50% bloom, aboveground biomass samples were clipped at ground level from 0.5 x 1.0-m subplots in the center of each plot. Aboveground biomass samples were oven dried at 120°F to a steady weight (Undersander et al., 1993) and dry matter biomass was calculated on a pound per acre basis. Plant height measurements (height of lush canopy growth, not including blooms or inflorescences) were taken from 5 random locations in each plot at the time aboveground biomass was harvested. Dried biomass of each legume species was composited into a dryland and an irrigated sample and analyzed for total Kjeldahl nitrogen (TKN) (Kuo Testing Labs, Othello, WA). Plant available nitrogen in the aboveground biomass was calculated according to Andrews et al. (2010).

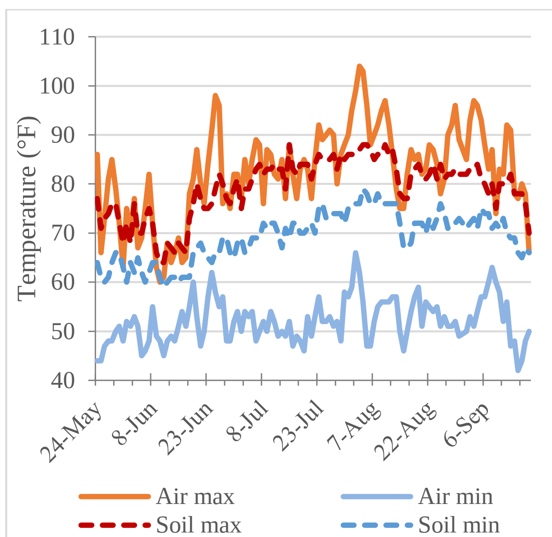


Figure 2. Maximum and minimum daily air temperatures and soil temperatures at 4-inch depth at Corvallis Plant Materials Center, 2017.

The 2-way factorial experimental was arranged as a randomized complete block design with 4 blocks (replications) of each crop variety (6 broadleaves, 7 grasses, and 8 legumes) at two levels of water management (dryland and irrigated); block 1 was arranged by crop type for demonstration/training purposes. Results were analyzed in Statistix 10 (Analytical Software, Tallahassee, FL) using the factorial analysis of variance procedure (AOV) and Kruskal-Wallis one-way AOV within each crop type (grasses, legumes, and broadleaves). Mean separation was performed at α=0.05 by Dunn's or Tukey Honestly Significant Difference (HSD).

RESULTS AND DISCUSSION

Broadleaves

Of the broadleaves included in our trial, the buckwheat had the best germination and quickest establishment, with over 90% germination and 70% cover by 28 days after planting (DAP) (Table 4). Safflower had good germination and over 40% cover by 28 DAP, while the sunflower, phacelia, and sesame all had moderate germination, but provided less early cover. The small-seeded phacelia appeared to have been planted too deeply this year; its germination and cover were better in past irrigated trials at the Corvallis PMC (Young-Mathews, 2017). The okra did not perform well; it is reported to germinate and grow best at soil temperatures of 75-90°F (Hemphill, 2010), so our early summer soil temperatures in the low to mid-60's resulted in poor establishment and low vigor that made it more susceptible to pests and disease, and very little cover for the okra throughout the growing season, particularly in the stunted dryland plots. Sesame germination and growth were also slow, again likely due to low early summer soil and air temperatures; reported optimal daytime temperatures for sesame are 77-80°F and growth is reportedly reduced below 68°F (Oplinger et al., 1990). However, the sesame had low incidence of pests and disease, and with irrigation it ended up providing cover and dry matter biomass production similar to many of the other crops tested (Figure 3).

As might be expected, the dryland plots had less cover and shorter plant heights than the irrigated plots, but dry matter biomass production was only significantly lower for sunflower (Table 4, Figures 3 and 4). Buckwheat and safflower provided the most cover at maturity (50% bloom) in both irrigated and dryland plots at over 80% and 60% cover, respectively.

Table 4. Average cover, germination, days to 50% bloom, vigor, disease, and pests for six warm season broadleaf cover crops in irrigated and dryland plots at the Corvallis Plant Materials Center, 2017.

Crop	Variety	Cover* at 28 DAP[¥]		Germ at 28 DAP		50% Bloom DAP		Cover at 50% Bloom				Vigor[£]		Disease[£]		Pests[£]	
				%		Irrig	Dry	Irrig		Dry							
okra	Emerald	1.0	c	20	d	76	72	2.3	b	1.3	b	1.6	c	1.8	a	3.4	a
safflower	Finch	4.3	ab	74	b	76	72	8.5	a	6.3	ab	4.3	a	1.0	b	1.9	bc
buckwheat	Koma	7.8	a	93	a	44	44	8.8	a	7.8	a	4.7	a	0.9	b	2.0	bc
sunflower	VNS[§]	2.0	bc	56	c	76	76	6.3	ab	4.3	ab	4.0	a	1.0	ab	2.4	ab
phacelia	VNS	3.3	abc	51	c	61	61	7.8	ab	4.8	ab	4.5	a	0.1	c	0.4	d
sesame	VNS	1.0	c	60	bc	91	105	6.8	ab	4.5	ab	2.6	b	0.8	b	1.6	c

*Visual estimate of ground cover at 28 days after planting and cover at 50% bloom, where 1=<10% and 10=90 to 100%; [¥]Days after planting; [£]Vigor, disease, and pests rated on a scale from 0 to 5, where 0=low vigor or no pest/disease damage and 5=high vigor or extensive pest/disease damage. Reported values are averages of biweekly ratings from germination to 50% bloom for each species in irrigated and dryland plots. [†]Means in columns followed by the same letters are not significantly different at $P<0.05$; [§]Variety not stated.

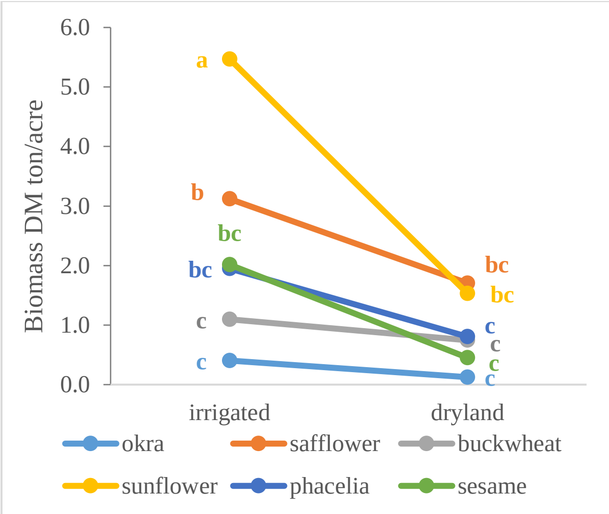


Figure 3. Average dry matter biomass production by six broadleaf warm season cover crops in irrigated and dryland plots at the Corvallis Plant Materials Center, 2017. Means with the same letters are not significantly different at $P<0.05$.

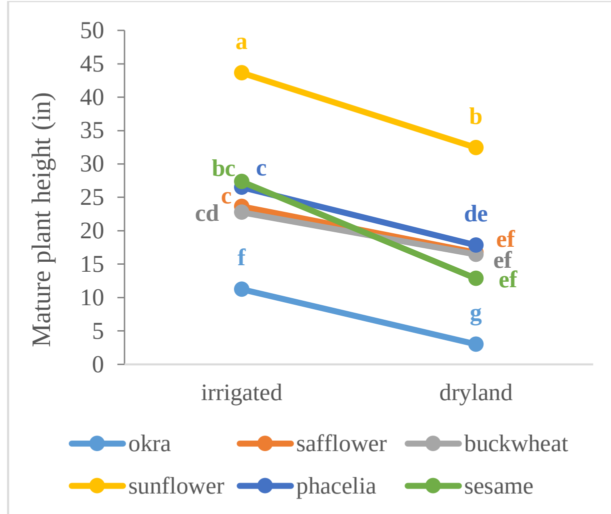


Figure 4. Average plant height at 50% bloom for six broadleaf warm season cover crops in irrigated and dryland plots at the Corvallis Plant Materials Center, 2017. Means with the same letters are not significantly different at $P<0.05$.

Sunflower produced the most biomass dry matter with irrigation, at about 5.5 tons/ac, while only sunflower and safflower produced more than 1.5 tons/ac biomass without irrigation (Figure 3). Incidence of pest and disease damage did not differ significantly between dryland and irrigated treatments. Phacelia had the lowest overall incidence of pest and disease damage, while okra had the highest (Table 4). At full bloom, the buckwheat, phacelia, and sunflower plots were abuzz with native bees and other insects, and the safflower also appeared fairly attractive to pollinators (Figure 1), while the sesame and okra had less blooms and few observed floral visitors.

Grasses

The 'Golden German' foxtail millet and Sudangrasses had over 70% germination and the highest cover by 28 DAP at over 40% (Table 5). The extremely small-seeded 'Excaliber' teff had poor germination and lower cover and vigor throughout the study, likely due to being planted too deep, but had among the lowest pest and disease ratings. Teff has performed well in past irrigated trials at the Corvallis PMC when it was seeded closer to the soil surface (Young-Mathews, 2017). The teff and 'Piper' Sudangrass had the earliest maturity dates of the warm season grasses tested, at just over 60 DAP, possibly lending themselves to short rotations where quick cover and modest biomass production are the goals. Both pearl millet varieties had relatively low germination rates, low vigor, and among the highest ratings for disease and pest pressure, perhaps due to seeding depth, poor seed lots, or maladaptation to Corvallis growing conditions.

Even without irrigation, the Sudangrasses all provided over 80% cover by maturity, and the foxtail millet and Sudangrasses produced over 2.5 tons/ac biomass (Table 5, Figure 5). The 'Sweet Forever BMR' sorghum-Sudangrass grew over 4 ft tall and produced an impressive 6 tons DM/ac without irrigation, reaching over 7 ft tall and producing an outrageous 18 tons DM/ac with irrigation (Figures 5 and 6). This variety is photoperiod sensitive and thus had the latest maturity date, producing a quantity of biomass that would be fairly hard to manage for most growers. However, most recommendations are to mow, graze, or terminate

Table 5. Average cover, germination, days to 50% bloom, vigor, disease, and pests for seven warm season grass cover crops in irrigated and dryland plots at the Corvallis Plant Materials Center, 2017.

Crop	Variety	Cover* at 28 DAP[¥]		Germ at 28 DAP		50% Bloom DAP		Cover at 50% Bloom				Vigor[£]		Disease[£]		Pests[£]	
				%		Irrig	Dry	Irrig		Dry							
teff	Excaliber	1.4	d	25	d	61	61	7.0	b	3.0	b	3.4	b	0.3	b	0.9	c
pearl millet	Tifleaf 3	2.4	bcd	50	c	92	92	9.0	ab	6.0	ab	3.5	b	1.6	a	1.8	a
pearl millet	K Graze	1.8	cd	34	d	92	92	8.5	ab	5.5	ab	3.4	b	1.6	a	1.7	a
foxtail millet	Golden German	4.9	ab	91	a	76	92	9.8	ab	6.8	ab	4.2	a	0.4	b	1.0	bc
soghum-Sudangrass	Sweet Forever BMR	4.1	abc	73	b	105	117	10.0	a	8.5	a	4.3	a	1.4	a	1.4	ab
soghum-Sudangrass	Sweet Six Dry Stalk	5.0	ab	76	ab	84	84	10.0	a	8.3	a	4.4	a	1.1	a	1.4	abc
Sudangrass	Piper	6.6	a	89	a	61	61	9.3	a	8.5	a	4.8	a	1.1	a	1.6	a

*Visual estimate of ground cover, where 1=<10% and 10=90 to 100%; [¥]Days after planting; [£]Vigor, disease, and pests rated on a scale from 0 to 5, where 0=low vigor or no pest/disease damage and 5=high vigor or extensive pest/disease damage. Reported values are averages of biweekly ratings from germination to 50% anthesis for each species. [†]Means in columns followed by the same letters are not significantly different at $P<0.05$.

sorghum-Sudangrass when plants reach 3 to 4 feet tall, or before boot stage (Clark, 2007). We allowed the grasses to reach 50% anthesis before terminating in order to compare maturity dates, but growers could avoid this excessive biomass by taking multiple cuttings or terminating earlier.

Another management issue to resolve in the dryland plots is fertilization. We broadcast applied 60 lb N/ac as granular urea in early July, once true leaves had emerged, but without any precipitation or irrigation to water the fertilizer into the dryland plots, the pellets remained on the surface and most of the N likely volatilized as ammonia. The millets and Sudangrasses showed the most obvious growth response to fertilization in the irrigated plots, while dryland plots of these species showed symptoms of nitrogen deficiency (pale green to yellow leaves with tips turning brown), suggesting that their growth may have been stunted by N-deficiency in addition to the lack of soil moisture. We will attempt to remedy this in 2018 by either incorporating the fertilizer prior to planting, or using a urea fertilizer coated with sulfur or a stabilizer such as NBPT (such as in Agrotain[R]) to reduce volatilization (Jones et al., 2013).

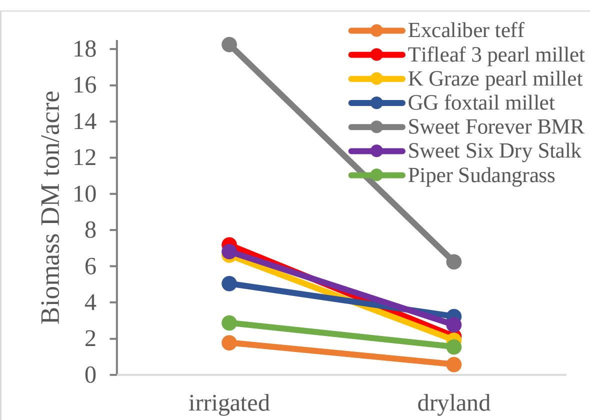


Figure 5. Average biomass of irrigated and dryland warm season grass cover crops at the Corvallis Plant Materials Center in 2017. Critical value for comparison is 4.7 tons DM/ac at α=0.05.

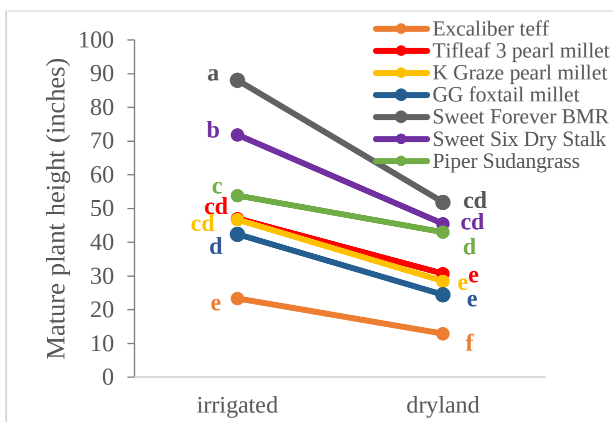


Figure 6. Average plant height at 50% anthesis for irrigated and dryland warm season grass cover crops at the Corvallis PMC, 2017. Means with the same letters are not significantly different at $P<0.05$.

Table 6. Average germination, cover, days to 50% bloom, vigor, disease, and pests for eight leguminous warm season cover crops in irrigated and dryland plots at the Corvallis Plant Materials Center, 2017.

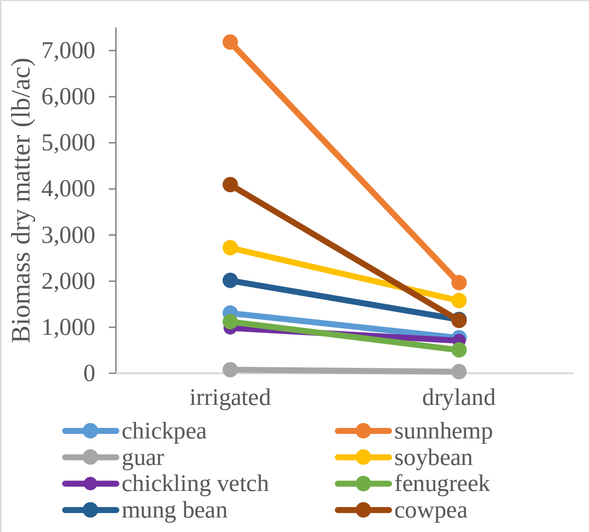
Crop	Variety	Germ at 28 DAP[¥]		Cover* at 28 DAP		Cover at 60 DAP				50% Bloom DAP		Vigor[£]		Disease[£]		Pests[£]	
		%				Irrig		Dry		Irrig	Dry						
chickpea	Desi	54	b†	2.6	ab	7.8	ab	3.5	ab	48	48	4.9	a	0.1	d	0.2	d
sunn hemp	Tillage Sunn	50	b	1.8	bc	6.3	abc	3.5	ab	105	117	3.4	bc	1.3	bc	2.4	a
guar	Kinman	9	c	1.0	c	1.0	c	1.0	b	70	70	1.2	d	1.8	b	2.5	ab
soybean	Viking 2265	54	b	3.0	ab	7.0	abc	5.8	a	70	70	3.9	b	0.7	cd	2.4	a
chickling vetch	AC Greenfix	71	a	4.1	a	8.8	a	5.8	a	44	44	4.9	a	0.1	d	1.2	cd
fenugreek	VNS[§]	79	a	1.8	bc	5.3	bc	3.0	ab	58	58	3.1	bc	0.8	cd	1.5	bc
mung bean	VNS	53	b	1.5	bc	5.5	abc	4.8	ab	82	82	2.8	c	2.2	ab	2.5	a
cowpea	Iron & Clay	74	a	1.9	bc	8.0	ab	5.5	a	117	117	3.3	bc	2.6	a	2.0	ab

[¥]Days after planting; *Visual estimate of ground cover, where 1 = <10% and 10 = 90 to 100%; [£]Vigor, disease, and pests rated on a scale from 0 to 5, where 0=low vigor or no pest/disease damage and 5=high vigor or extensive pest/disease damage. Reported values are averages of biweekly ratings from germination to 50% bloom for each species; [†]Means in columns followed by the same letters are not significantly different at $P<0.05$; [§]Variety not stated.

Legumes

The fenugreek, chickling vetch, and cowpea had the best germination and establishment of the legumes at over 70%, and the chickling vetch, soybean, and chickpea had among the highest cover at 28 DAP (Table 6). By 60 DAP, only the chickling vetch, soybean, and cowpea had reached over 50% cover in the dryland plots, while the chickling vetch, cowpea, and chickpea had attained over 75% cover by that same date in the irrigated plots. Overall, chickling vetch and chickpea had the highest vigor and lowest pest and disease problems, and were the quickest to reach 50% bloom at less than 50 DAP. Establishment of both species was a bit patchy, however, so higher cover and biomass may be attained with seeding rates closer to the high end of the recommended range for each species (Table 1). Disease was highest in the cowpea and mung bean, and those same species, along with the guar, sunn hemp, and soybean, suffered the most insect damage. Guar had very poor germination, low vigor, provided little cover, and had high incidence of pests and disease, likely due to inadequate soil temperatures for germination and optimal growth in Corvallis; guar is reported to germinate best at soil temperatures of 70 to 86°F, and optimum temperature for root development is 77 to 95°F (Undersander et al., 1991). Mung bean had only moderate germination and cover, and fairly low vigor throughout the growing season; germination and growth requirements for mung bean are reported to be similar to soybean (Oplinger et al., 1990), so perhaps there is a different variety that would perform better in our region. An early June hail storm appeared to cause varying degrees of damage to the sesame, okra, ‘K Graze’ pearl millet, and all of the legumes except the chickling vetch, chickpeas, and fenugreek, but most plants seemed to recover by a couple weeks later.

Sunn hemp produced the most aboveground dry matter biomass, total nitrogen, and plant available nitrogen (PAN) with irrigation, but in the dryland plots its biomass was no higher than the soybean, cowpea, or mung bean, and it produced almost no PAN as the stems became more woody and the C:N ratio increased (Figures 7 through 10). ‘AC Greenfix’ chickling vetch biomass had the highest nitrogen content at 3.8 and 3.1% N for irrigated and dryland plots, respectively, while nitrogen content of the other legumes ranged from 1.1 to 2.9% N (data not shown). The higher N content meant that dryland chickling vetch produced an estimated 9 lb



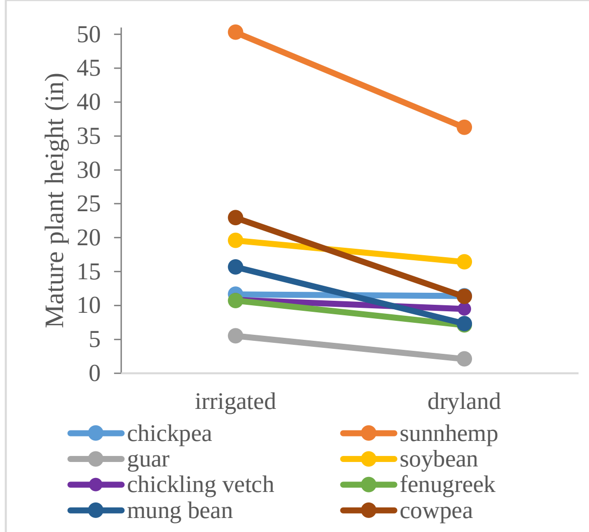
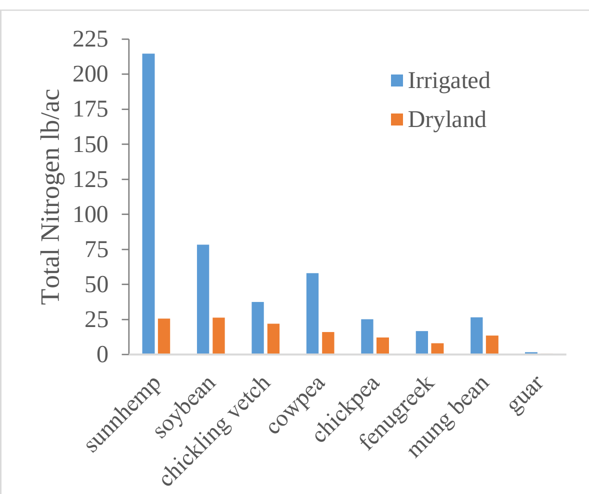


Figure 7. Average dry matter biomass production by eight leguminous warm season cover crops in irrigated and dryland plots at the Corvallis Plant Materials Center, 2017. Critical value for comparison is 1,797 pounds DM/ac at α=0.05.

Figure 8. Average plant height at 50% bloom for eight leguminous warm season cover crops in irrigated and dryland plots at the Corvallis Plant Materials Center, 2017. Critical value for comparison is 4 inches at α=0.05.

PAN/ac, while estimated PAN for subsequent crops was negligible from all other species under dryland conditions (Figure 10).

When we dug up a few plants in each of the legume plots in late August to make visual observations of nodulation on the roots, the chickling vetch and chickpeas appeared to have good nodulation, but nodulation was patchy on the soybean, cowpea, and sunn hemp, and fairly poor on the fenugreek and mung bean (although many plants were starting to senesce by this point so it was difficult to tell). Plants in the dryland plots generally had less nodulation than in the irrigated plots, and most nodules appeared dried out and inactive. The plants in the dryland plots also generally had less extensive or branched root systems, but deeper tap roots.



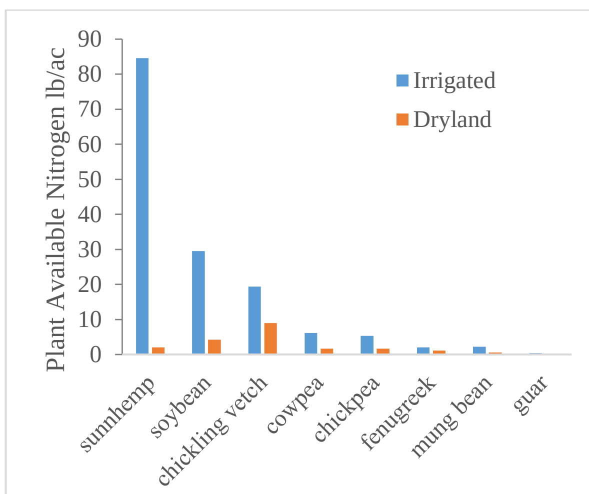


Figure 9. Total nitrogen in aboveground biomass of eight leguminous warm season cover crops in irrigated and dryland plots at the Corvallis Plant Materials Center, 2017.

Figure 10. Estimated plant available nitrogen in aboveground biomass of eight leguminous warm season cover crops in irrigated and dryland plots at the Corvallis Plant Materials Center, 2017.

Chickling vetch is an indeterminate bloomer, and the pretty little blue, purple, pink, and white pea-type flowers attracted many bumble bees, honey bees, hover flies, and other pollinators over a relatively long bloom period from early July to early August, particularly in irrigated plots (Figure 1). Chickpea had a similar bloom period, but the small pink flowers did not appear as attractive to pollinators. Very few or no pollinators were observed visiting the fairly inconspicuous flowers of the fenugreek, guar, soybean, mung bean, and cowpea.

CONCLUSION

Preliminary results suggest that there are a number of warm season cover crops that might be viable options for either irrigated or dryland production in western Oregon. So far, the following crops appear promising for use in dryland settings: Sudangrass and sorghum-Sudangrass hybrids, Golden German foxtail millet, safflower, sunflower, buckwheat, chickling vetch, soybean, cowpea, and chickpea. For short windows, buckwheat, phacelia, chickling vetch, chickpea, and Piper Sudangrass appear promising, both with and without irrigation. For providing forage for bees and other beneficial insects, buckwheat, phacelia, sunflower, safflower, and chickling vetch are good candidates. And for producing copious amounts of biomass as residue to smother weeds or to add organic matter to the soil, Sweet Forever BMR sorghum-Sudangrass is a good pick.

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