TECHNICAL NOTE

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EVALUATION OF COVER CROPS AND PLANTING DATES FOR DRYLAND ROTATIONS IN EASTERN WASHINGTON

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Over-wintered, fall-planted cover crop plots at the Pullman PMC, May 5, 2014.

This technical note presents findings from the Cover Crop Biomass Study conducted near Pullman, WA, which compared the above-ground biomass of 37 cover crop species, varieties and mixes with two fall and two summer planting dates. The Technical Note contains recommendations for optimal species and planting dates for cover crops in dryland eastern Washington rotations.

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KEY POINTS

- An early planting date (August to mid-September) is key to optimizing biomass production of an over-wintering cover crop in eastern Washington dryland rotations. Cover crops grow very little over the winter, and often resume growth around the same time the cover crop has to be terminated for spring crop planting.
- Some years, early planting of a fall cover crop may not be possible due to lack of precipitation.
- In this study, cover crops planted September 16 produced substantially more biomass at the time of sampling in the spring than cover crops planted 11 days later, on September 27.
- The over-wintering cover crops that produced the most biomass in this study were cereals: winter triticale, winter barley and winter wheat. These are not the best cover crops for diversifying rotations in the Pacific Northwest.
- The non-cereal, over-wintering cover crops that produced the most biomass from the mid-September planting were forage turnip, ‘Nemat’ arugula, ‘Kodiak’ brown oriental mustard, hairy vetch and several Austrian winter pea varieties.
- The non-cereal, over-wintering cover crops that produced the most biomass from the late-September planting were hairy vetch and the Austrian winter pea varieties.
- Summer cover crops that produced the most biomass were warm-season species: sunflower, sorghum, sorghum-sudangrass, proso millet and safflower.
- Summer cover crops planted on May 27 produced approximately three to six times more biomass than those planted on June 30.
- Cover crops planted on June 30 had slow emergence due to a shallow planting depth and little precipitation.
- More research is needed to determine the effects of fall or summer-planted cover crops on soil health and commodity crop production.

INTRODUCTION

Agricultural producers in the Inland Pacific Northwest historically grew green manure cover crops to supplement soil nitrogen prior to the introduction of chemical fertilizers. They also relied on cover crops to control soil erosion and provide forage and hay for livestock. Typical rotations included field pea and legume-grass mixtures plowed in or harvested before planting grain crops. Cover crops are currently being reconsidered in dryland wheat rotations in the Inland Northwest as a way to diversify rotations and improve "soil health". Cover crops have the potential to improve soil nutrient cycling, improve soil organic matter and water holding capacity, neutralize pH, suppress soil-borne diseases, and provide nitrogen and other nutrients, as well as other benefits. The ability of cover crops to perform these functions depends on the cover crop species and cultivars grown, environmental conditions and how well-suited they are for the conditions, and how long they are allowed to grow.

The short growing season and winter-spring rainfall pattern in the Inland Northwest create challenges for incorporating cover crops into typical rotations. Time periods in which cover crops may be grown are between fall harvest and spring planting, or in place of a commodity crop (in higher rainfall zones) or fallow (in lower rainfall zones). Information on cover crops grown within the available time periods is lacking for our region; specifically how cover crops perform as individual species compared to mixes, and how different planting dates affect cover crop biomass production. The objectives of this trial were to:

1) Determine the best performing cover crops based on above-ground biomass production.
2) Compare cover crop biomass production at different planting dates.
3) Compare the biomass production of individual cover crop species with mixes.

We chose above-ground biomass production as the primary measurement in this study because it is an indicator of how well the cover crop is adapted to particular growing conditions. Plants that establish well and are adapted to the environment accumulate more biomass (carbon) as they perform photosynthesis. Adding more carbon to the agroecosystem may be a way to improve "soil health" because the carbon provides food for microorganisms and improves soil structure and water-holding capacity. Cover crops that produce large amounts of biomass are also more likely to out-compete weeds, and may provide more economic return to justify seed and operational costs.

However, above-ground biomass production may not be the best or only measure for selecting a cover crop. Cover crops that produce large amounts of biomass may also use substantial amounts of water, which may result in a moisture deficit and negatively affect commodity crop yields. Also, plants that produce large amounts of biomass may not provide benefits such as the interruption of a disease cycle, attraction of beneficial insects, or suppression of soil-borne pathogens which may be provided by other cover crops.

In addition, above-ground biomass may not always be directly correlated with below-ground biomass, and root exudates of some cover crops may be better for supporting beneficial soil microbes than others. Unfortunately, research on these subjects is very difficult to conduct and there is little evidence to support any information for specific crops. Until more research can be conducted on these subjects, tangible factors such as above-ground biomass production and measurable agronomic benefits are our best criteria for selecting cover crops.

MATERIALS AND METHODS

This study was conducted at the NRCS Pullman Plant Materials Center near Pullman, WA. The area receives an average of 20 inches of annual precipitation and has an average of 5653 growing degree days (GDD) (base temperature 32°F). During the time of this study (September 1, 2013 to August 12, 2014) the Pullman PMC received approximately 15.61 inches of precipitation. The number of GDDs and average maximum and minimum temperatures for the periods of cover crop growth are listed in Table 1. There were two extremely cold episodes during the winter months, one in December and one in February, with low temperatures at or below 0°F, high temperatures not exceeding 20°F, and gusty winds. The cover crops were protected by snow cover during these episodes.

Table 1. Number of calendar days, growing degree days (GDD), and average maximum and minimum temperatures during the periods of growth for the fall- and summer-planted cover crops.

Fall	Calendar Days	GDD (base 32°F)	Ave Max Temp (°F)	Ave Min Temp (°F)
9/16/13 - 5/15/14	241	2026	46.6	30.2
9/27/13 - 5/16/14	231	1819	45.9	29.7
Summer				
5/27/14 - 8/12/14	77	2488	80.0	47.9
6/30/14 - 8/12/14	43	1661	88.0	51.4

Cover crop species were selected for this study based on their availability and low cost. Cultivars were selected based on what the seed companies had on hand. The NRCS Irrigated Mix and the NRCS Dryland Mix were developed by Washington NRCS technical staff for previous cover crop guidelines. The Diana's Cool and Warm 9 Species Mix was developed by Diana Roberts, WSU Extension Specialist in Spokane County, in cooperation with a landowner. She has evaluated this mix in other trials. The other mixes were developed to compare various number of species, and cool season, warm season, or cool and warm season mixes.

The following table (Table 2) lists the cover crops planted, the timing of planting (fall/summer), seeds per pound and pure live seed (PLS) seeding rates. Most individual species plots were seeded at rates of 10 to 60 PLS per sq ft, depending on seed size, and mixes were seeded at rates of 20 to 30 total PLS per sq ft, depending on species components.

Table 2. Cover crops, varieties and mixes planted in this study with indication of fall or spring planting and seeding rate.

Variety	Common Name	Scientific Name		Fall		Summer	Season	Seeds/lb	PLS lb/ac
Nemat	arugula	*Eruca sativa*	1	x	1	x	cool	280,000	5
	spring barley	*Hordeum vulgare*			2	x	cool	14,000	93
Wintmalt	winter barley	*Hordeum vulgare*	2	x			cool	14,000	93
Koto	buckwheat	*Fagopyrum esculentum*			3	x	warm	20,000	65
Balady	berseem clover	*Trifolium alexandrinum*	3	x			cool	206,880	6
	spring chickpea	*Cicer arietinum*			4	x	cool	2,300	189
	crimson clover	*Trifolium incarnatum*	4	x			cool	150,000	9
	white Dutch clover	*Trifolium repens*	5	x			cool	712,000	4
	red clover	*Trifolium pratense*	6	x			cool	272,000	5
	sweet clover	*Melilotus officinalis*	7	x	5	x	cool	260,000	5
small seed	faba bean	*Vicia faba*	8	x	6	x	cool	2,000	22
	blue flax	*Linum perrene*	9	x	7	x	cool	88,000	15
	spring lentil	*Lens culinaris*			8	x	cool	10,000	44
Red Chief	winter lentil	*Lens culinaris*	10	x			cool	10,000	44
German	foxtail millet	*Setaria italica*			9	x	warm	216,000	6
White Huntsman	proso millet	*Panicum miliaceum*			10	x	warm	84,800	15
Kodiak	brown oriental mustard	*Brassica juncea*	11	x	11	x	cool	160,000	8
Caliente	oriental mustard	*B. juncea* + *S. alba*	12	x	12	x	cool	180,000	7
Pacific Gold	yellow oriental mustard	*Brassica juncea*	13	x	13	x	cool	160,000	8
Ida-Gold	yellow mustard	*Sinapis alba*	14	x	14	x	cool	160,000	8
Martigena	yellow mustard	*Sinapis alba*	15	x	15	x	cool	140,000	8
Monida	oat	*Avena sativa*	16	x	16	x	cool	19,400	67
Fenn	Rebecca's pea 1	*Pisum sativum*	17	x			cool	3,800	115
Granger	Rebecca's pea 2	*Pisum sativum*	18	x			cool	3,800	115
Melrose	Rebecca's pea 3	*Pisum sativum*	19	x			cool	3,800	115
Specter	Rebecca's pea 4	*Pisum sativum*	20	x			cool	3,800	115
F210	Rebecca's pea 5	*Pisum sativum*	21	x			cool	3,800	115
1269	Rebecca's pea 6	*Pisum sativum*	22	x			cool	3,800	115
VNS	Austrian winter pea	*Pisum sativum*	23	x			cool	3,800	115
Banner	spring pea	*Pisum sativum*			17	x	cool	2,000	218
daikon type	oil seed radish	*Raphanus sativus*	24	x	18	x	cool	39,200	33
	spring rapeseed	*Brassica napus*			19	x	cool	157,000	8
Winfred	winter rapeseed	*Brassica napus*	25	x			cool	157,000	8
	safflower	*Carthamus tinctorius*			20	x	warm	44,000	30
Longtail Delight	sorghum	*Sorghum bicolor*			21	x	warm	27,300	48
MS9000	sorghum-sudangrass	*S. bicolor* x *S. bicolor*			22	x	warm	21,000	62
	sunflower	*Helianthus annuus*			23	x	warm	47,000	28
	teff	*Eragrostis tef*			24	x	warm	1,300,000	1
Trical102	winter triticale	x *Triticosecale*	26	x			cool	12,000	109
	spring triticale	x *Triticosecale*			25	x	cool	12,000	109
	forage turnip	*Brassica rapa* ssp. *rapa*	27	x	26	x	cool	220,000	6
	spring wheat	*Triticum aestivum*			27	x	cool	12,000	109
Norwest553	winter wheat	*Triticum aestivum*	28	x			cool	12,000	109
	common vetch	*Vicia sativa*	29	x	28	x	cool	40,000	33
	hairy vetch	*Vicia villosa*	30	x	29	x	cool	16,300	80
	Mix 1 NRCS Dryland Mix		31	x	30	x	cool		
	Mix 2 NRCS Irrigated Mix		32	x	31	x	cool		
	Mix 3 Winter Hardy Mix		33	x			cool		
	Mix 4 Warm Season Mix				32	x	warm		
	Mix 5 Cool Season 2 Species		34	x	33	x	cool		
	Mix 6 Cool Season 3 Species		35	x	34	x	cool		
	Mix 7 Cool and Warm Season 6 Species		36	x	35	x	c & w		
	Mix 8 Diana's Cool and Warm 9 Species		37	x	36	x	c & w		

Mixes were composed of the following species, each represented equally on a percentage basis.

Mix 1: NRCS Spring Dryland Mix	
Variety	**Common Name**
	spring barley
VNS	sweetclover
	spring rapeseed
Banner	spring pea

Mix 2: NRCS Spring Irrigated Mix	
Variety	**Common Name**
VNS	spring triticale
VNS	sweetclover
Martigena	yellow mustard
daikon type	oil seed radish
Koto	buckwheat
Banner	spring pea

Mix 3: Winter Hardy Mix	
Variety	**Common Name**
VNS	Austrian winter pea
Red Chief	winter lentil
Norwest553	winter wheat
Trical102	winter triticale
Winfred	winter rapeseed

Mix 4: Warm Season Mix	
Variety	**Common Name**
Koto	buckwheat
White Huntsman	proso millet
VNS	safflower
VNS	sunflower
MS9000	sorghum-sudangrass

Mix 5: Cool Season 2 species Mix	
Variety	**Common Name**
Monida	oat
Banner	spring pea

Mix 6: Cool Season 3 species Mix	
Variety	**Common Name**
Monida	oat
Banner	spring pea
VNS	hairy vetch

Mix 7: Cool and Warm Season 6 species Mix	
Variety	**Common Name**
Monida	oat
Banner	spring pea
VNS	hairy vetch
Martigena	yellow mustard
White Huntsman	proso millet
Koto	buckwheat

Mix 8: Diana Robert's Cool and Warm 9 sp	
Variety	**Common Name**
Monida	oat
Banner	spring pea
VNS	crimson clover
VNS	hairy vetch
VNS	forage turnip
VNS	safflower
VNS	sunflower
Martigena	yellow mustard
MS9000	sorghum-sudangrass

The field with fall-planted cover crops has Palouse Silt Loam soil and the field with summer-planted cover crops has Caldwell silt loam soil. We prepared the seedbeds with conventional techniques: disking, rototilling and roller-packing. We planted fall cover crops on September 16 and September 27, 2013, and summer cover crops on May 27 and June 30, 2014. We planted all plots at a depth of 0.75" with a double disk drill and we inoculated all legume species with the appropriate *Rhizobium* bacteria. The experimental design is a randomized complete block with three replications of each plot. The plots received no supplemental water or fertilizer.

Biomass was sampled in the fall and spring by cutting all plant material in a 0.5 m^2 frame to a height of 2 inches with a battery- or gas-powered hedge trimmer. The biomass was weighed, weeds were removed and the biomass was weighed again. A sub sample was taken from the material, weighed, dried, and weighed again to calculate percent dry matter. Percent dry matter was multiplied by cover crop biomass to calculate a dry matter (DM) lb/ac value. Other data collected include percent establishment 6 weeks after planting, percent cover of the over-wintering plots in early spring, and height at the time of biomass sampling.

RESULTS AND DISCUSSION

Fall Planted Cover Crops

By the end of October 2013, most cover crops had excellent establishment, however they were only about 2 inches tall. They produced very little biomass, which was surprising considering the warm sunny days we had throughout September and October, and the timely rains. From September 1 to October 30, we received 2.23 inches of precipitation. The plots planted on September 16 had an accumulation of 706 Growing Degree Days (GDD) and the plots planted on September 27 had 426 GDD (base temperature 32°F). Factors that diminished plant growth besides temperature were day length and sun angle. By September 21, day length was less than 12 hours, and the sun angle was low. These factors reduce the amount of solar radiation the plants receive, which decreases their photosynthetic activity. The plants were too short to sample biomass in late fall 2013, so we waited until spring to sample.

Cover crop mix planted on September 16, 2013 after 40 days of growth. October 25, 2013

Fall Cover Crop Overwintering and Total Biomass Production

Twenty-eight of the 37 cover crop entries overwintered from both fall planting dates. At the time of biomass sampling on May 15, 2014, the September 16-planted plots were generally taller and produced more biomass than the September 27-planted plots (Figure 1 and Table 1). The plots with the most biomass from both plantings were the winter cereals: winter triticale, winter barley and winter wheat. A few of the mixes, the Mix 3: Winter Hardy Mix, and Mix 2: NRCS Irrigated Mix also produced large amounts of biomass, however they were primarily composed of cereals. The overwintering species in the Winter Hardy Mix were the winter triticale and winter wheat. Winter rapeseed, Austrian winter pea and winter lentil also overwintered but were present in very small quantities. In the NRCS Irrigated Mix, the primary overwintering species was spring triticale.

The non-cereal cover crops from the September 16 planting with the most biomass production were forage turnip, 'Nemat' arugula, '1269' Austrian winter pea, 'Kodiak' brown oriental mustard, 'Fenn' Austrian winter pea, and hairy vetch, followed by other Austrian winter pea varieties. The non-cereal cover crops from the September 27 planting with the most biomass were hairy vetch and the Austrian winter pea varieties. Mix 8: Diana Robert's Cool and Warm 9 Species Mix was primarily composed of forage turnip and hairy vetch; and Mix 6: Cool Season 3 Species Mix and Mix 7: Cool and Warm 6 Species mix were primarily composed of hairy vetch.

Table 3. Comparison of biomass production and height of over-wintering cover crops planted on September 16 and 27, 2013 near Pullman, WA, at the time of sampling on May 15, 2014.

		Planting Date			
		9/16/13		9/27/13	
Variety	Common Name	Height (in)	Biomass (DM lb/ac)	Height (in)	Biomass (DM lb/ac)
Trical102	winter triticale	19	5629 a[1/]	12	4361 a
	Mix 3 Winter Hardy Mix	16	5269 a	12	3532 ab
Wintmalt	winter barley	13	4924 a	9	2479 bc
Norwest553	winter wheat	14	4281 ab	13	3762 a
	Mix 2 NRCS Irrigated Mix	16	3663 abc	9	1521 cd
	Mix 8 Diana's Cool and Warm 9 Species	16	2066 bcd	7	205 e
	forage turnip	20	1832 bcd	9	30 e
Nemat	arugula	10	1553 cd	8	246 e
1269	Austrian winter pea	9	1544 cd	7	696 de
Kodiak	oriental mustard	11	1459 cd	4	33 e
Fenn	Austrian winter pea	7	1432 cd	6	898 de
	hairy vetch	9	1349 cd	5	987 de
Specter	Austrian winter pea	10	1311 cd	6	875 de
F210	Austrian winter pea	8	1294 cd	6	560 de
Melrose	Austrian winter pea	9	1178 cd	6	913 de
Granger	Austrian winter pea	10	1147 cd	7	675 de
	Mix 6 Cool Season 3 Species	7	1069 d	7	411 de
Caliente	oriental mustard	3	1049 d	3	60 e
VNS	Austrian winter pea	7	987 d	6	956 de
Winfred	winter rapeseed	8	944 d	1	31 e
Pacific Gold	yellow oriental mustard	10	829 d	3	39 e
	Mix 1 NRCS Dryland Mix	11	753 d	8	676 de
	common vetch	7	682 d	5	308 e
	Mix 7 Cool and Warm Season 6 Species	6	608 d	5	185 e
	crimson clover	3	427 d	3	57 e
Red Chief	winter lentil	4	374 d	4	304 e
	faba bean	3	193 d	2	7 e
Monida	oat	3	42 d	3	20 e
	Mix 5 Cool Season 2 Species	3	29 d	5	34 e

1/ Means within the same column followed by the same letter are not significantly different with Tukey HSD means comparisons at $\alpha = 0.05$.

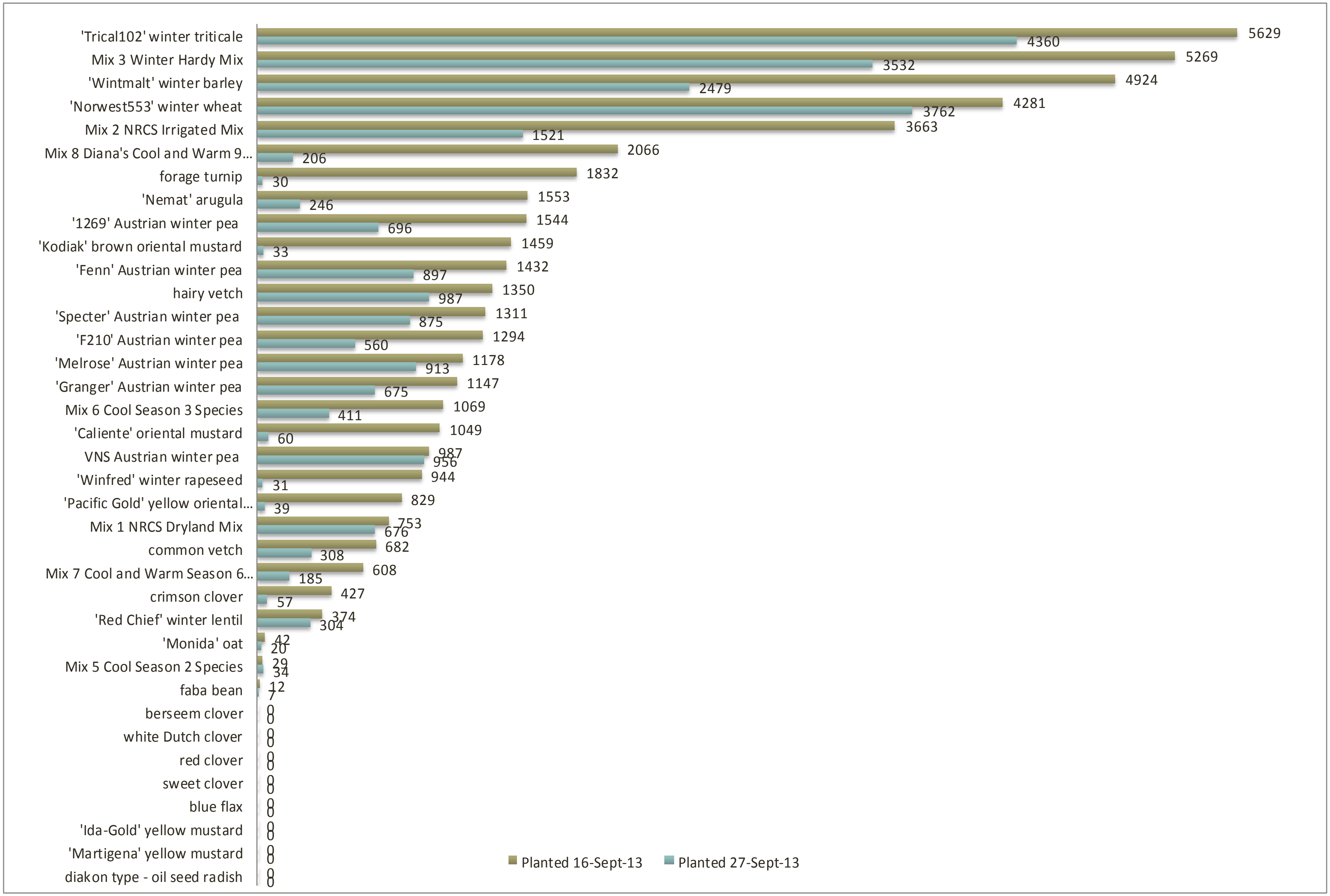

Figure 1. Comparison of biomass (DM lb/ac) produced by all cover crops planted on September 16 and September 27, 2013 near Pullman, WA. Biomass was sampled on May 15, 2014.

Summer Cover Crop Biomass Production

The cover crops that produced the most above ground biomass in the summer plantings were in general warm-season species. The top-producing cover crops in the May 27 planting were sunflower, 'Longtail Delight' sorghum, Mix 4: Warm Season Mix, 'MS9000' sorghum-sudangrass, safflower and Mix 2: NRCS Irrigated Mix (Table 3). The NRCS Irrigated Mix was comprised of warm- and cool-season species, and the species were equally represented. The cover crops that produced the most above ground biomass in the June 30 planting were sunflower, 'White Huntsman' proso millet, Mix 4: Warm Season Mix, 'Longtail Delight' sorghum, and safflower.

Cover crops planted on May 27 produced approximately three to six times the amount of biomass than cover crops planted on June 30 (Table 3 and Figure 2). This was not only a factor of a longer growth period, but also moisture amount and timing. The Pullman PMC received 1.53 inches of precipitation during the May 27 to August 12 growth period, and 0.51 inches during the June 30 to August 12 growth period. Stored soil moisture likely declined from May 27 to June 30 due to high air temperatures and extra cultivation for seed bed preparation.

June 30 was the beginning of a hot, dry period and we re-learned the importance of proper seeding depth. After two days of rain (which delayed our planting date) our seedbed was more firm than it appeared and we did not achieve proper seeding depth for the first replication. We adjusted the seeding depth for the second and third replications. The seedlings in these replications emerged sooner than the first replication, however emergence was still delayed due to the lack of moisture. We counted most of the plots in the first replication of the June 30 planting as "missing" because they were just beginning to emerge at the time of biomass sampling. We were not able to perform any statistical analysis on the June 30 plots since we had only two replications.

The arugula, oil seed radish, mustard varieties planted on May 27 in this study were bolting at the time of biomass sampling, however the forage turnip was not. (The mustard varieties were sampled early, on July 22, because there were senescing and dropping seed. The arugula, oil seed radish and forage turnip were harvested at the normal sampling date, August 12.) None of the mustard or mustard-related species planted on June 30 were bolting at the time of sampling. Mustard species tend to bolt when day length is increasing, such as before the summer solstice. Bolting should be avoided when growing a cover crop because the plants quickly transition to the reproductive phase and produce minimal biomass. A later planting date (after the summer solstice) or selection of a non-bolting variety are ways to avoid bolting if mustards and mustard-related species are included in summer cover crop mixes.

Table 4. Comparison of biomass production and height of cover crops planted on May 27 and June 30, 2014 near Pullman, WA at the time of sampling on August 12, 2014 (Mustards were sampled on July 22, 2014).

		Planting Date			
		5/27/14		6/30/14	
Variety	Common Name	Height (in)	Biomass (DM lb/ac)	Height (in)	Biomass (DM lb/ac)
	sunflower	48	14530 a[1/]	26	4789
Longtail Delight	sorghum	23	10498 ab	16	2592
	Mix 4 Warm Season Mix	33	9540 abc	18	2757
MS9000	sorghum-sudangrass	36	9301 abcd	24	1365
	safflower	21	8686 abcde	14	2097
	Mix 2 NRCS Irrigated Mix	20	6062 abcde	8	756
Koto	buckwheat	30	5423 bcde	11	1300
	spring wheat	22	5298 bcde	12	1712
Monida	oat	20	5226 bcde	8	801
German	foxtail millet	22	5131 bcde	10	1395
White Huntsman	proso millet	20	4871 bcde	15	3204
	Mix 1 NRCS Dryland Mix	16	4755 bcde	8	396
	Mix 8 Diana's Cool and Warm 9 Species	22	4399 bcde	13	1457
Martigena	yellow mustard	27	4383 bcde	7	363
Nemat	arugula	17	4201 bcde	6	400
	Mix 7 Cool and Warm 6 Species	22	3944 bcde	11	1359
	Mix 6 Cool Season 3 Species	18	3827 bcde	7	447
Ida-Gold	yellow mustard	24	3597 bcde	9	911
	Mix 5 Cool Season 2 Species	19	3511 bcde	7	515
	teff	18	3297 bcde	8	411
Kodiak	brown oriental mustard	28	3277 bcde	12	810
	spring barley	19	3072 bcde	7	424
Pacific Gold	yellow oriental mustard	22	3000 bcde	10	669
Caliente	oriental mustard	24	2949 bcde	11	1210
	flax	18	2944 bcde	11	472
Daikon type	oil seed radish	12	2202 bcde	5	.
	forage turnip	5	1777 cde	4	.
	sweetclover	16	1681 cde	4	.
	common vetch	12	1215 cde	5	.
	spring lentil	7	778 de	4	.
	spring triticale	6	762 de	6	168
	spring rapeseed	11	674 de	3	.
	hairy vetch	9	631 e	5	.
	spring chickpea	11	561 e	9	256
Banner	spring pea	9	560 e	7	608
	faba bean	14	395 e	6	205

1/ Means within the same column followed by the same letter are not significantly different with Tukey HSD means comparisons at α = 0.05. (Biomass means from the June 30 planting could not be analyzed statistically due to the number of missing plots.)

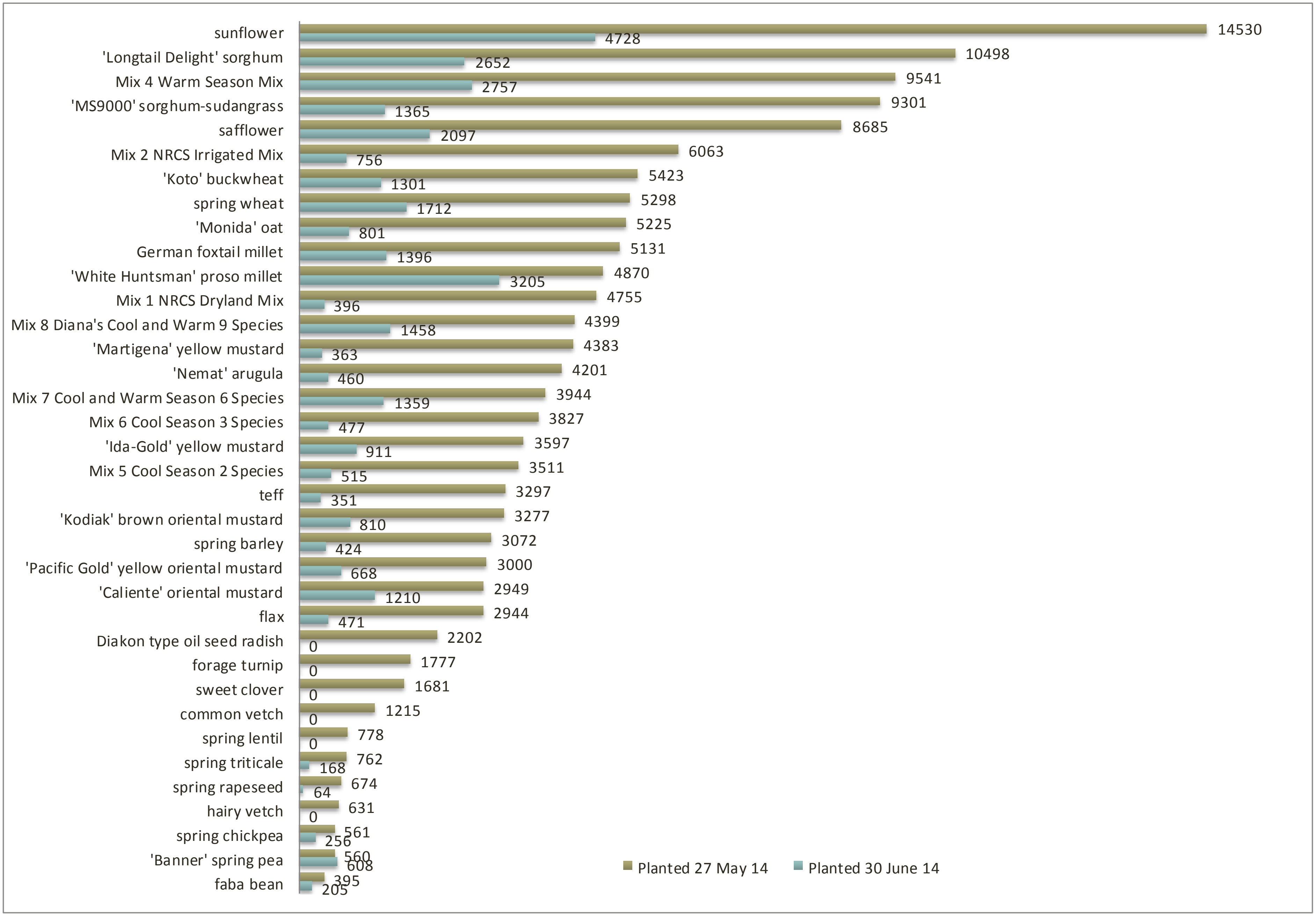

Figure 2. Comparison of biomass (DM lb/ac) produced by all cover crops planted on May 27 and June 30, 2014 near Pullman, WA. Biomass was sampled on August 12, 2014.

CONCLUSIONS

This study demonstrates the necessity for planting cover crops as early in the fall as possible in order to maximize biomass production. Cover crops grow very little over the winter, and often resume growth around the same time the cover crop has to be terminated for spring crop planting. In the fall of 2013, it was possible for growers to plant a cover crop immediately following harvest in August and establish a stand due to the precipitation we received in August and September. However the previous fall, the fall of 2012, this would not have been possible because we did not receive any rain from late June until mid-October. A grower planning to plant an overwintering cover crop needs to be flexible. A late planting date may result in little to no economic return or soil health benefit.

Because cereals dominate Pacific Northwest dryland rotations, a non-cereal cover crop may provide the most effective agronomic results. A mix that includes forage turnip, 'Nemat' arugula, Austrian winter pea, and 'Kodiak' oriental mustard planted as early in the fall as possible may be a good place to start when experimenting with over-wintering cover crops in our region.

In addition, this study demonstrates the risk of waiting too late to plant a summer cover crop. An earlier planting date involves less risk because rain during the period of establishment is more likely, however the date cannot be too early if the cover crop includes warm season species. Many warm season crops will not germinate until the soil temperature is at least 55 degrees. If they are planted before this time, weeds may occupy their space before they have a chance to emerge. The risk of planting cover crops late in the season can be mitigated with proper seed depth.

The best cover crops for the summer growth period, according to results from this study, are the warm season species: sunflower, sorghum, sorghum-sudangrass, safflower, proso millet and buckwheat. These species may provide good diversity for rotations in eastern Washington and adjacent areas.

More studies are needed to determine the effect of fall-planted and summer-planted cover crops on soil health and commodity crop yield, especially in areas where moisture is limited.

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