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Biomass evaluation of cool season legumes grown at differing seeding densities with and without a rye cover in the Texas Rolling Red Plains

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Figure 1. Sunrise photo of legume and rye cover crops at the USDA-NRCS James E. "Bud" Smith Plant Materials Center near Knox City, Texas. Photo courtesy of Dustin Wiggans.

ABSTRACT

Current mono-cropping practices facilitate the continual removal of above ground plant material (stover), and in turn, hinder sustainability of the agroecosystem by removing soil carbon and soil organic matter, decreasing soil productivity, decreasing soil moisture content, and increasing the potential for water and wind erosion. One way to maintain sustainability and profit is to offset stover removal by utilizing cover crops. The purpose of this study was to evaluate biomass produced by five cool season legumes grown at differing seeding densities as a monoculture and as a component in a multispecies mix. 'Frosty' berseem clover (*Trifolium alexandrinum*), 'Dixie' crimson clover (*Trifolium incarnatum* L.), VNS common vetch (*Vicia sativa*), 'AU Merit' hairy vetch (*Vicia villosa Roth*), and 'Wyo' winter pea (*Pisum sativum* L.) were sown at planting rates

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of 25, 50, 100, and 150% of the suggested Sustainable Agriculture and Research Education (SARE) planting rates as a monoculture and as a component of a cover crop mix with 'Wrens Abruzzi' cereal rye (*Secale cereal* L.) planted at 30.0 lb·a^{-1}. Data were not statistically different; however, there were some notable observations. Berseem clover (540 lb·a^{-1} versus 334 lb·a^{-1}) and crimson clover (658 lb·a^{-1} versus 503 lb·a^{-1}) produced more biomass (when planted with a rye cover) at the 100% versus 150% planting rate, respectively. Common vetch (CV-1.0) produced 1987 lb·a^{-1} compared to CV-1.5 (1784 lb·a^{-1}) when planted without a rye cover. Additionally, WP-0.25 yielded 1821 lb·a^{-1}, which was greater than WP-0.5 (1601 lb·a^{-1}) when planted without a rye cover. Hairy vetch (HV-1.5, 150%) produced the greatest biomass, with and without a rye cover, of 793 lb·a^{-1} and 3227 lb·a^{-1}; respectively, of all species.

INTRODUCTION

Figure 2. 'Wyo' winter pea sown with cereal rye near Knox City, Texas. Photo courtesy of Brandon Carr.

Using cover crops within current farming practices provides producers an alternative to leaving land fallow. When coupled with current agronomic practices, cover crops provide numerous benefits including reducing soil erosion, increasing soil organic matter, improving soil structure and water infiltration, decreasing water and subsequent amendment runoff, reducing surface temperature and water evaporation, weed suppression, and ultimately increasing soil productivity (Doran et al., 1984; Hall et al., 1984; Hudson, 1994; Atech and Doll, 1996; Unger and Vigil, 1998; Hartwig and Ammon, 2002). Therefore, development of cropping systems that expand biomass production without undermining crop and soil productivity must be pursued if demands for food and fuel continue to increase (Wilhelm et al., 2007). It is imperative to not only evaluate cover crop biomass production, as a single species and part of a cover crop mix, but to also investigate differing seeding rates of the individual cover species.

Johnson et al., (1993) used fall-planted winter rye, fall-planted hairy vetch, and soybean stubble from the previous year, accompanied with tillage, mowing, and herbicide treatments as methods for controlling cover crops. Their results indicated that combining cover crops with management techniques provided better overall corn yields and suppressed weeds the most. Scott et al., (1987) had comparable yields when incorporating intercrops and cover crops, and side-dressing nitrogen at different rates. Sainju et al., (2007) concluded cover crops offer increases in soil carbon fractions and carbon sequestration while improving soil quality in irrigated versus dryland cotton. And lastly, cover crops promote sequestration of soil organic carbon. Available data from the scientific literature suggests that soil organic carbon sequestration with adoption of conservation tillage compared with conventional tillage without a cover crop was 300 $lb\cdot acre^{-1}\cdot yr^{-1}$, while the rate of sequestration with a cover crop was 600 $lb\cdot acre^{-1}\cdot yr^{-1}$. These data indicate that including a cover crop in a conservation tillage system can essentially double the carbon sequestration benefit from using conservation tillage alone (Causarano et al., 2005).

The purpose of this study was to evaluate biomass produced by five cool season legumes grown at differing seeding densities as a monoculture and as a component in a multispecies mix. Frosty berseem clover (*Trifolium alexandrinum*), Dixie crimson clover (*Trifolium incarnatum* L.), VNS common vetch (*Vicia sativa*), AU Merit hairy vetch (*Vicia villosa Roth*), and Wyo winter pea (*Pisum sativum* L.) were sown at 25, 50, 100, and 150% of the Sustainable Agriculture and Research Education (SARE) planting rates in both monoculture and as a component in a mix with Wrens Abruzzi cereal rye (*Secale cereal* L.)

MATERIALS AND METHODS

Experimental layout was a split-plot design with two replicates of legumes without a rye cover and two replicates of legumes with a rye cover evaluating five individual legume species at four differing planting rates planted in the fall and harvested in the spring: five species x four rates = 20 main plots per replicate, x two replicates for legumes without a rye cover and two replicates with a rye cover for a total of 80 plots (Table 1 and Figure 6). Individual plots were 5.0 ft wide by 20 ft long, prepped by chisel plow and tandem disked before planting. No additional soil nutrients were added, and plots were maintained weed-free by hand-rouging as needed.

Figure 3. Vetch sown as a single cover crop near Knox City, Texas. Photo courtesy of Brandon Carr.

All plots were seeded using a Wintersteiger Plotseed XL Planter (Wintersteiger, Salt Lake City, Utah) during the fall in six-inch rows. Legumes and Wrens Abruzzi cereal rye were planted into weed-free fields on 15 Nov 2020, 08 Nov 2021, and 25 Oct 2022; and harvested 21 Apr 2020, 19 Apr 2021, and 19 May 2022, respectively. Wrens Abruzzi cereal rye was planted at rate of 30.0 $lb\cdot a^{-1}$ (Table 1). A 5.0 ft^2 subsection was hand-harvested in the spring approximately two weeks before planting of the regionally appropriate commodity crop, to determine rye, legume, and weed biomass. All species were separated, dried at 130°F in a forced air oven until constant, and weighed to the nearest 0.01 pounds to determine final biomass weight. Additionally, each species growth stage was recorded at harvest. Legume growth stages were determined using procedures by Plumblee and Harrelson (2022), and rye growth stages were determined using procedures by Gerber (2021).

Visual assessments of both disease and insect resistance were collected every 30-days from planting to harvest following procedures set forth by Sarratonio (1991). A derived scale of 1 to 5: 1 = severe damage, 3 = moderate damage, and 5 = no damage, was used to determine each species susceptibility to withstand disease and insect pressure.

Legume seeding rates planted with and without cereal rye were analyzed as separate experiments using the analysis of variance procedure in Statistix 10 (Analytical Software; Tallahassee, Florida) for a randomized complete block design. Means which differed at $P < 0.05$ were separated with the Least Significant Difference (LSD) pairwise comparison test.

RESULTS AND DISCUSSION

Weeds, insects, and disease data were non-significant for any species planted as a monoculture or as a component of a mix with cereal rye (data not shown).

Wrens Abruzzi rye produced the largest biomass yield when planted with WP-0.25 (2976 $lb \cdot a^{-1}$) and the lowest yield when planted with WP-1.0 (2222 $lb \cdot a^{-1}$, Table 2 and Figure 8).

Average yearly temperature for 2020, 2021, 2022 for the northcentral Texas Rolling Red Plains was 64.6, 64.2, and 65.5 °F; respectively, and total annual precipitation was 23.1, 25.1, and 10.1 inches for the same three-year period. Weather data included temperature and rainfall information up to 31 Jul 2022 (Table 3).

Figure 4. Crimson clover near Knox City, Texas. Photo courtesy of Brandon Carr.

Legume Seeding Rates with Cereal Rye

Increasing the seeding rate of the legumes with a cereal rye cover did not significantly increase overall biomass. Berseem clover (BC-0.25) and BC-0.5 did not produce harvestable yields in any year as a component of a cover crop mix. Berseem clover (BC-1.0) produced a greater yield (540 $lb \cdot a^{-1}$) compared to the increased planting rate of BC-1.5 (334 $lb \cdot a^{-1}$), but the increase in yield was not significant. Similar results were noted among the other legume species when planted with a cereal rye as part of a cover crop mix. For example, CC-0.25 produced 532 $lb \cdot a^{-1}$ versus CC-1.5 which produced 503 $lb \cdot a^{-1}$. Common vetch (CV-1.0) had the lowest yield of 144 $lb \cdot a^{-1}$ while CV-0.25 produced the highest (311 $lb \cdot a^{-1}$). Wyo winter pea (WP-1.5) produced the highest biomass yield (579 $lb \cdot a^{-1}$) and WP-0.5 the lowest at 311 $lb \cdot a^{-1}$. Hairy vetch (HV-1.5) produced the greatest legume biomass (793 $lb \cdot a^{-1}$) of all species when planted with a rye cover (Table 2 and Figure 7).

Legume Seeding Rates without Cereal Rye

Biomass yields varied within legume species and seeding rates when planted as a single species versus as a component of a cover crop mix. Common vetch (CV-1.0) produced 1987 $lb \cdot a^{-1}$ and was higher than CV-0.25 (1357 $lb \cdot a^{-1}$) and CV-0.5 (1404 $lb \cdot a^{-1}$) albeit, nonsignificant ($p = 0.0836$). Wyo winter pea (WP-1.5) yielded 2306 $lb \cdot a^{-1}$ and WP-0.25 yielded 1821 $lb \cdot a^{-1}$ though, non-significant ($p = 0.2513$, Table 2 and Figure 7). These data suggest lower planting rates of these particular legumes are as successful as 1.0x or 1.5x times the SARE suggested planting rates when used as a single-species cover crop.

Figure 5. Picture of winter pea, vetch, and crimson clover surrounded by cereal rye at the USDA-NRCS James E. "Bud" Smith Plant Materials Center near Knox City, Texas. Photo courtesy of Brandon Carr.

CONCLUSION

Increasing the seeding rate of the annual legumes evaluated in this study did not significantly increase biomass when planted with and without cereal rye. Cereal rye produced the most consistent biomass regardless of the legume species or legume seeding rate. These data suggest lower planting rates were as productive as full planting rates for these annual specific cool season cover crop species. Additional testing on different soils and under different climatic conditions in northwest Texas and southern Oklahoma are needed to verify these findings.

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Table 1. Species identification, legume name, variety, rate difference, percent of rate change, and planting rate for different legume species, and a single rye species, planted as cover crops at the USDA-NRCS James E. "Bud" Smith Plant Materials Center near Knox City, Texas, in 2020, 2021, and 2022.

ID	**Legume**	**Variety**	**Rate**	**% Rate Δ**	**PLS ($lb \cdot a^{-1}$)[¥]**
BC-0.25	Berseem Clover	Frosty	Lowest	0.25	3.0
BC-0.5	Berseem Clover	Frosty	Low	0.5	6.0
BC-1.0	Berseem Clover	Frosty	Full	1.0	12.0
BC-1.5	Berseem Clover	Frosty	High	1.5	18.0
CC-0.25	Crimson Clover	Dixie	Lowest	0.25	5.0
CC-0.5	Crimson Clover	Dixie	Low	0.5	10.0
CC-1.0	Crimson Clover	Dixie	Full	1.0	20.0
CC-1.5	Crimson Clover	Dixie	High	1.5	30.0
CV-0.25	Common Vetch	VNS[±]	Lowest	0.25	5.0
CV-0.5	Common Vetch	VNS[±]	Low	0.5	10.0
CV-1.0	Common Vetch	VNS[±]	Full	1.0	20.0
CV-1.5	Common Vetch	VNS[±]	High	1.5	30.0
HV-0.25	Hairy Vetch	AU Merit	Lowest	0.25	5.0
HV-0.5	Hairy Vetch	AU Merit	Low	0.5	10.0
HV-1.0	Hairy Vetch	AU Merit	Full	1.0	20.0
HV-1.5	Hairy Vetch	AU Merit	High	1.5	30.0
WP-0.25	Winter Pea	Wyo	Lowest	0.25	20.0
WP-0.5	Winter Pea	Wyo	Low	0.5	40.0
WP-1.0	Winter Pea	Wyo	Full	1.0	80.0
WP-1.5	Winter Pea	Wyo	High	1.5	120.0

¥ Pure Live Seed (PLS)
± Variety Not Stated (VNS)
Wrens Abruzzi cereal rye planted at 30.0 $lb \cdot a^{-1}$.
All species planted: 15 Nov 2020, 08 Nov 2021, and 25 Oct 2022.
All species harvested: 21 Apr 2000, 19 Apr 2021, and 19 May 2022.
Row spacing for all species = 6.0 inches.

Table 2. Legume biomass and rye biomass production (lb·a^{-1}) of five different legume species at four differing planting rates when planted with and without a rye cover at the USDA-NRCS James E. "Bud" Smith Plant Materials Center near Knox City, Texas.

			Cereal rye (with legume cover)		Legume (without cereal rye)		Legume (with cereal rye)	
Field ID	**Rate**	**Pure Live Seed (lb·a^{-1})**	**Cereal Rye Biomass (lb·a^{-1})**	**P-Value ($p < 0.05$)**	**Legume Biomass (lb·a^{-1})**	**P-Value ($p < 0.05$)**	**Legume Biomass (lb·a^{-1})**	**P-Value ($p < 0.05$)**
BC-0.25	Lowest	3.0	2930	0.6338	765	0.6486	0¥	0.6558
BC-0.5	Low	6.0	2552		770		0¥	
BC-1.0	Full	12.0	2800		950		540	
BC-1.5	High	18.0	2373		1256		334	
CC-0.25	Lowest	5.0	2941	0.9602	1201	0.7191	532	0.5928
CC-0.5	Low	10.0	2975		1406		451	
CC-1.0	Full	20.0	2690		1481		658	
CC-1.5	High	30.0	2752		1732		503	
CV-0.25	Lowest	5.0	2677	0.9647	1357	0.0836	311	0.6680
CV-0.5	Low	10.0	2619		1404		261	
CV-1.0	Full	20.0	2772		1987		144	
CV-1.5	High	30.0	2460		1784		181	
HV-0.25	Lowest	5.0	2584	0.8293	1827	0.3903	319	0.3877
HV-0.5	Low	10.0	2448		2514		337	
HV-1.0	Full	20.0	2840		2674		343	
HV-1.5	High	30.0	2677		3227		793	
WP-0.25	Lowest	20.0	2976	0.3079	1821	0.2513	315	0.3253
WP-0.5	Low	40.0	2736		1601		311	
WP-1.0	Full	80.0	2222		1950		436	
WP-1.5	High	120.0	2336		2306		579	

¥No yield produced or collected.

Table 3. Five-year weather data at the USDA-NRCS James E. "Bud" Smith Plant Materials Center near Knox City, Texas.

5-year average				
Year	**Avg. High Temp (F)**	**Avg. Low Temp (F)**	**Avg. Temp (F)**	**Total Precipitation (inches)**
2017	79.3	52.3	65.8	17.2
2018	78.1	51.3	65.0	32.0
2019	77.0	51.3	60.1	22.8
2020	78.1	51.0	64.6	23.1
2021	77.5	51.1	64.2	25.1
2022*	81.0	49.8	65.5	10.1

All data collected from West Texas Mesonet; Knox County: https://www.mesonet.ttu.edu/site-local
*Last full month of data collected 31 July 2022.

Figure 6. Plot map for five legume species at differing planting densities, with and without a rye cover, grown at the USDA-NRCS James E. “Bud” Smith Plant Materials Center near Knox City, Texas.

North

Replicate	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Replicate
4	WP-0.25	CC-0.5	BC-0.25	CV-0.25	BC-1	CC-0.25	HV-1.5	CC-1.5	CV-1.5	CV-1	HV-0.25	HV-1	CC-1	WP-0.5	CV-0.5	BC-1.5	HV-0.5	WP-1.5	WP-1	BC-0.5	4
3	WP-0.25	CC-0.5	BC-0.25	CV-0.25	BC-1	CC-0.25	HV-1.5	CC-1.5	CV-1.5	CV-1	HV-0.25	HV-1	CC-1	WP-0.5	CV-0.5	BC-1.5	HV-0.5	WP-1.5	WP-1	BC-0.5	3
2	CC-1.5	HV-1	WP-0.25	CC-0.25	CV-0.5	BC-1.5	CC-1	HV-1.5	CV-1.5	CC-0.5	BC-0.5	BC-1	BC-0.25	CV-1	WP-0.5	CV-0.25	WP-1.5	HV-0.5	WP-1	HV-0.25	2
1	CC-1.5	HV-1	WP-0.25	CC-0.25	CV-0.5	BC-1.5	CC-1	HV-1.5	CV-1.5	CC-0.5	BC-0.5	BC-1	BC-0.25	CV-1	WP-0.5	CV-0.25	WP-1.5	HV-0.5	WP-1	HV-0.25	1
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	

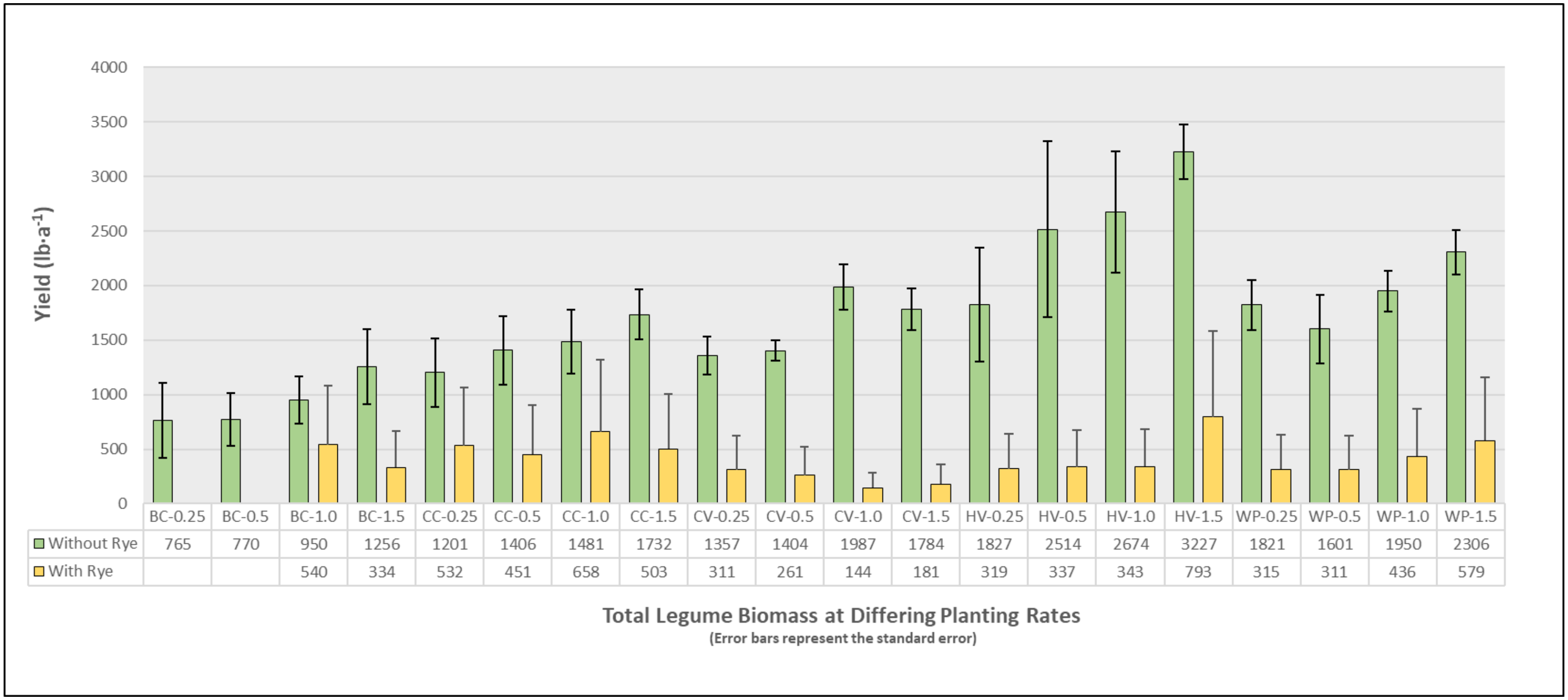
Plots Numbers

Plant ID	
BC	Berseem Clover
CC	Crimson Clover
CV	Common Vetch
HV	Hairy Vetch
WP	Winter Pea

Planting Rates	
0.25	Planting Rate
0.5	Planting Rate
1.0	Planting Rate
1.5	Planting Rate

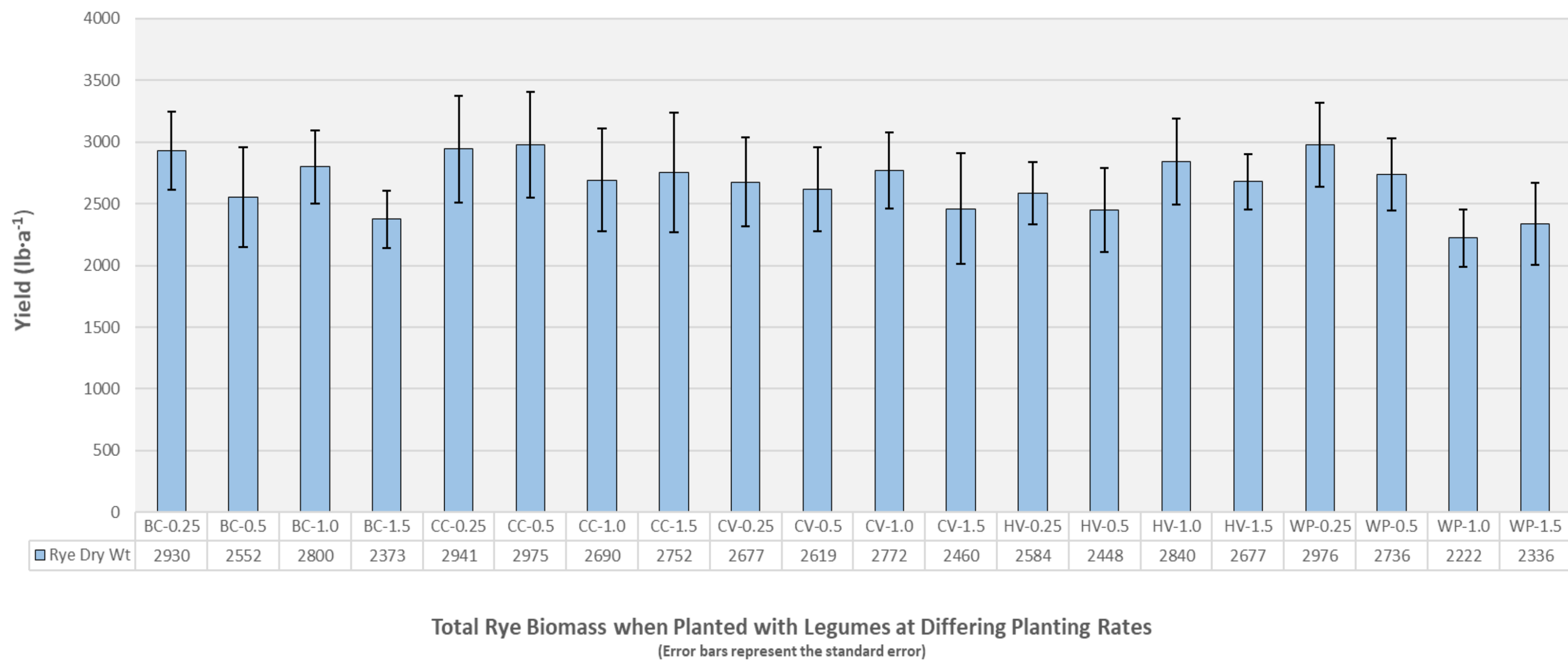
Rep Difference	
Rep 1	Without rye
Rep 2	Cereal rye
Rep 3	Without rye
Rep 4	Cereal rye

Figure 7. Graph showing biomass production (lb·a^{-1}) of five legume species at differing planting rates, with and without a rye cover, grown at the USDA- NRCS James E. "Bud" Smith Plant Materials Center near Knox City, Texas.



	BC-0.25	BC-0.5	BC-1.0	BC-1.5	CC-0.25	CC-0.5	CC-1.0	CC-1.5	CV-0.25	CV-0.5	CV-1.0	CV-1.5	HV-0.25	HV-0.5	HV-1.0	HV-1.5	WP-0.25	WP-0.5	WP-1.0	WP-1.5
Without Rye	765	770	950	1256	1201	1406	1481	1732	1357	1404	1987	1784	1827	2514	2674	3227	1821	1601	1950	2306
With Rye			540	334	532	451	658	503	311	261	144	181	319	337	343	793	315	311	436	579

Figure 8. Graph showing rye biomass production (lb·a^{-1}) when planted with different legume species at differing planting rates as part of a cover crop mix at the USDA-NRCS James E. "Bud" Smith Plant Materials Center near Knox City, Texas.



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