United States Department of Agriculture

FINAL STUDY REPORT (9/2023)
A multi-location study including the Booneville Plant Materials Center (Booneville, Arkansas), Jimmy Carter Plant Materials Center (Americus, Georgia), Norman A. Berg National Plant Materials Center (Beltsville, Maryland), James E. "Bud" Smith Plant Materials Center (Knox City, Texas), and East Texas Plant Materials Center (Nacogdoches, Texas)

Seeding Rates of Annual Cool Season Legume Cover Crops in the Southern and Eastern U.S.

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ABSTRACT

The amount of biomass a cover crop produces influences how effective it will be for suppressing weeds and improving soil quality in a production agriculture cropping system. These and other ecosystem services provided by cover crops are affected by planting density. The objective of this study was to evaluate the effect of seeding rate on cover crop biomass production and weed suppression of common cool season legumes including berseem clover (*Trifolium alexandrinum* L.), common vetch (*Vicia sativa* L.), crimson clover (*Trifolium incarnatum* L.), hairy vetch (*Vicia villosa* Roth.), and winter pea (*Pisum sativum* L.) planted as monocultures and in a mix with cereal rye (*Secale cereale* L.) in the Southeast, Southern Plains, and Mid-Atlantic regions of the United States. Plant Materials Centers (PMC) in Texas, Arkansas, Georgia, and Maryland planted the legumes at 25, 50, 100 and 150% of the Sustainable Agriculture Research and Education drilled planting rate for monoculture plantings and in a mixture with 30 pure live seed (PLS) lb/acre of cereal rye. Cover crop biomass production was determined at termination dates that coincide with crop rotations and cash crops commonly grown in the region where the PMC is located. Cover crop biomass varied among seeding rates when analyzed over locations. Lower seeding rates produced statistically similar biomass as higher seeding rates. Hairy vetch and crimson clover were the most productive legumes when planted as a monoculture. Mixing 30 PLS lb/acre of cereal rye with the legumes and varying seeding rates reduced weeds and increased total biomass production but there were no statistical differences between seeding rates. Crimson clover and hairy vetch planted with cereal rye produced the most biomass regardless of the legume seeding rate. Lower seeding rates were found to produce the most biomass yield/lb of seed and the greatest return on seed investment.

INTRODUCTION

Cover crop biomass production is an important characteristic for enhancing ecosystem services (Bybee-Finley et al., 2017; Finney et al., 2016). Biomass mitigates soil erosion by reducing rain drop impacts and increasing soil structure (Blanco-Canqui et al., 2015). One of the keys to maximum biomass production is planting the cover crop at densities that optimize plant growth and productivity while still meeting the goal(s) of the cover crop planting such as weed suppression, increased organic matter, or nitrogen fixation for the subsequent cash crop. High seeding rates increase seed costs, reduce profit margins, and may lead to excessive inter and intraspecies competition, which limits overall growth and production. Conversely, low seeding rates may reduce biomass production due to low plant densities and increased weed competition with the cover crop for water, nutrients, and sunlight (Craine and Dybzinski, 2013). The objective of this study was to determine the effect of seeding rates on biomass production and weed suppression of the cool season leguminous cover crops including berseem clover, common vetch, crimson clover, hairy vetch, and winter pea planted as monocultures or in a mix with cereal rye in the Southeast, Southern Plains, and Mid-Atlantic regions of the United States.

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MATERIALS AND METHODS

The study was conducted at the USDA-Natural Resources Conservation Service's PMCs in Texas, Arkansas, Georgia, and Maryland (Table 1). Annual cool season legumes were planted at 25, 50, 100 and 150% of the Sustainable Agriculture Research and Education (SARE) recommended seeding rate in *Managing Cover Crops Profitably* (Table 3B Planting; Clark, 2007). Plots were established in October-November as a single species or in a mix with cereal rye planted at 30 lb/acre (Table 2). A strip plot experimental design with 2 replications was used. Plot size was ~6-ft x 20-ft. Seed was drilled into a prepared seedbed using an experimental drill equipped with a cone seeder to accurately plant the seed according to the recommended SARE planting rate. In locations with multiple years of evaluation (Table 1), plots were planted in a different location each year to avoid contamination from the previous year's trial. Plots received no fertilizer or supplemental water during the duration of the study.

Growth stages of the legumes and cereal rye were recorded prior to collection of biomass production data (Table 3). Biomass was harvested from the center of the plot in mid to late April to coincide with planting windows of a cash crop (Table 1). Biomass was partitioned into legume, cereal rye, and weeds categories; weighed separately, dried, and a dry matter yield determined for each vegetative component. Biomass production from cereal rye and legume mixes was combined and reported as total biomass yield. Only Arkansas and Maryland reported weed suppression as a percentage of total biomass.

Economic parameters were determined using current seed costs of legumes and cereal rye. Only hairy vetch was used in the economic analysis at the Beltsville location due to poor survival of the other legumes.

Table 1. Location of Plant Materials Center, soil type, study years, month and year of planting and harvest.

Plant Materials Center	Latitude, Longitude	Soil type	# of Years Study was Conducted	Planted	Harvested
Americus, GA	32° 6' 1.8756" N 84° 15' 34.9632" W	Orangeburg loamy sand	1	10/24/2019	4/14/2020
Beltsville, MD	39° 1' 5.16" N 76° 51' 16.344" W	Christiana-Downer complex	1	10/10/2019	4/29/2020
Booneville, AR	35° 5' 16.08" N 93° 59' 36.528" W	Leadvale silt loam	2	10/19/2019 10/19/2022	4/30/2020 4/28/2023
Knox City, TX	33°26'42.8"N 99°51'56.6"W	Miles fine sandy loam	3	11/15/2019 11/08/2020 10/25/2021	4/21/2020 4/19/2021 5/19/2022
Nacogdoches, TX	31°30'07.6"N 94°45'49.1"W	Woden fine sandy loam	2	10/15/2020 10/15/2021	4/15/2021 4/08/2022

Table 2. Seeding rates of annual legumes and cereal rye based on SARE recommended drilled rate of 100% for the legumes and ½ rate for cereal rye (Clark, 2007).

Common Name	Scientific name	Variety	SARE drilled rate	25%	50%	100%	150%
				--------------PLS lb/acre-------------			
Berseem clover	*Trifolium alexandrinum* L.	Frosty	8-12	3	6	12	18
Common vetch	*Vicia sativa* L.	VNS[2/]	15-20	5	10	20	30
Crimson clover	*Trifolium incarnatum* L.	Dixie	15-20	5	10	20	30
Hairy vetch	*Vicia villosa* Roth.	AU Merit	15-20	5	10	20	30
Winter pea	*Pisum sativum* L.	Wyo	50-80	20	40	80	120
Cereal rye	*Secale cereale* L.	Wrens Abruz			30		

[1/]Variety not stated.

Statistical Analysis

Kruskal Wallis one way analysis of variance (ANOVA) in Statistix 10 (Analytical Software, Tallahassee, FL) revealed no significant differences in seeding rate for total cover crop biomass at Knox City, and Nacogdoches, Texas, Arkansas, and Maryland but biomass production of all treatments was greater in Georgia (P<0.05). Due to similar trends in total biomass response to seeding rate, data for seeding treatments was pooled for all locations for final analysis. Only the hairy vetch data was included in the pooled data for the Maryland location. Analysis of variance procedure in Statistix 10 was used to analyze the effect of seeding rates on biomass production of legumes planted as a monoculture and cereal rye/legume mixes, respectively at P<0.05. Percent weeds in the total biomass of the legume monoculture and legume and cereal rye mixes, respectively, in Arkansas and Maryland were analyzed using ANOVA procedure at P<0.05.

Table 3. Average growth stage of cool-season annual legumes and cereal rye by location at harvest.

Cover crop	Americus, GA	Beltsville, MD	Booneville, AR	Knox City, TX	Nacogdoches, TX
berseem clover	early bloom	late veg	---[1/]	late veg	early seed fill
common vetch	early bloom	late veg	---	early bloom	early seed fill
crimson clover	early seed fill	full bloom	---	mid-bloom	early seed fill
hairy vetch	full bloom	late veg	---	early bloom	early seed fill
winter pea	full bloom	late veg	---	late veg	early seed fill
cereal rye	ripening	flowering	---	flowering	flowering

[1/] Not determined.

RESULTS AND DISCUSSION

Biomass Yield

Legumes Planted as Monoculture

There were no effects of seeding rate or legume by seeding rate interaction for cover crop biomass production when averaged over locations and years (Appendix A; P>0.05). When averaged over all legumes and years there were no significant differences in biomass production between the seeding rates. Planting at 150% of the normal seeding rate versus 25% only showed a 30% increase in biomass. Seeding rates at 50% and 100% produced similar biomass (Fig. 1). Plant competition for moisture, nutrients and light may explain the similarity in cover crop biomass across seeding rates (Craine and Dybzinski, 2013). Lower seeding rates likely produced fewer but larger plants due to less competition among established plants. In contrast higher seeding rates likely produced more but smaller plants due to increased competition for moisture, nutrient, and light. Crimson clover compensates for low plant density by branching and with a high plant density, it initiates quicker flowering (Knight, 1959). In similar studies in Arkansas, researchers found no differences in cover crop biomass of berseem clover, common vetch, crimson clover, hairy vetch, or winter pea planted as monocultures at seeding rates of 25, 50, 100 and 150% of SARE recommended rates (Univ. of Arkansas). These results were similar to work in North Carolina where Vann et al. (2018) reported no differences in cover crop biomass production, N content, or corn (*Zea mays* L.) yield with crimson clover seeding rates from 20 to 80 lb/acre. Additionally, interseeding hairy vetch into corn and soybean [*Glycine max* (L.) Merr.] from 40 to 80 lb/acre in Nebraska did not increase hairy vetch cover crop biomass (Koehler-Cole et al., 2022).

Legume and Cereal Rye Mix

Adding cereal rye to the incremental legume seeding rates produced more total biomass than legumes planted alone (Fig. 2), but legume seeding rate in the mixture did not affect cover crop biomass production when averaged over locations and years (P>0.05). These results agree with others who reported higher biomass production when cereal rye was included with cool season legume cover crops (Poffenbarger et al., 2015; Hayden et al., 2012). Research indicates that in addition to bolstering biomass production and nutrient scavenging (Shipley et al., 1992), cereal rye may enhance the cold tolerance of winter pea in the mid-Atlantic region when planted as cover crop mix for row crop production (Vann et al., 2019). Crimson clover and hairy vetch, mixed with cereal rye, produced the most cover crop biomass of all planted annual legumes.

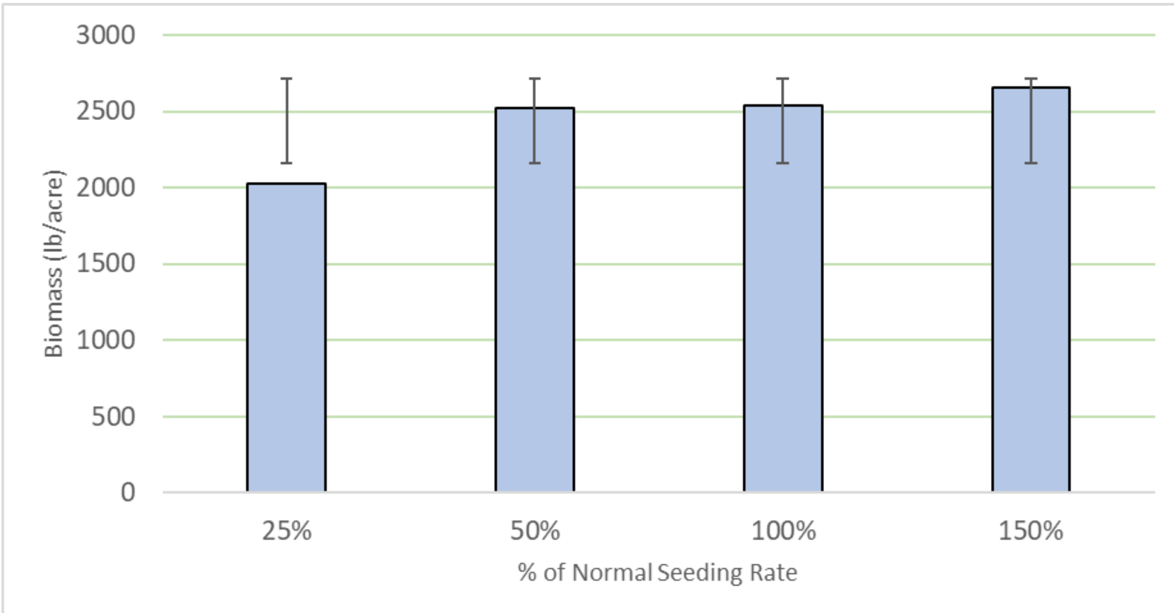

Fig 1. Biomass of all legume species as percent of the normal seeding rate averaged over locations and years.

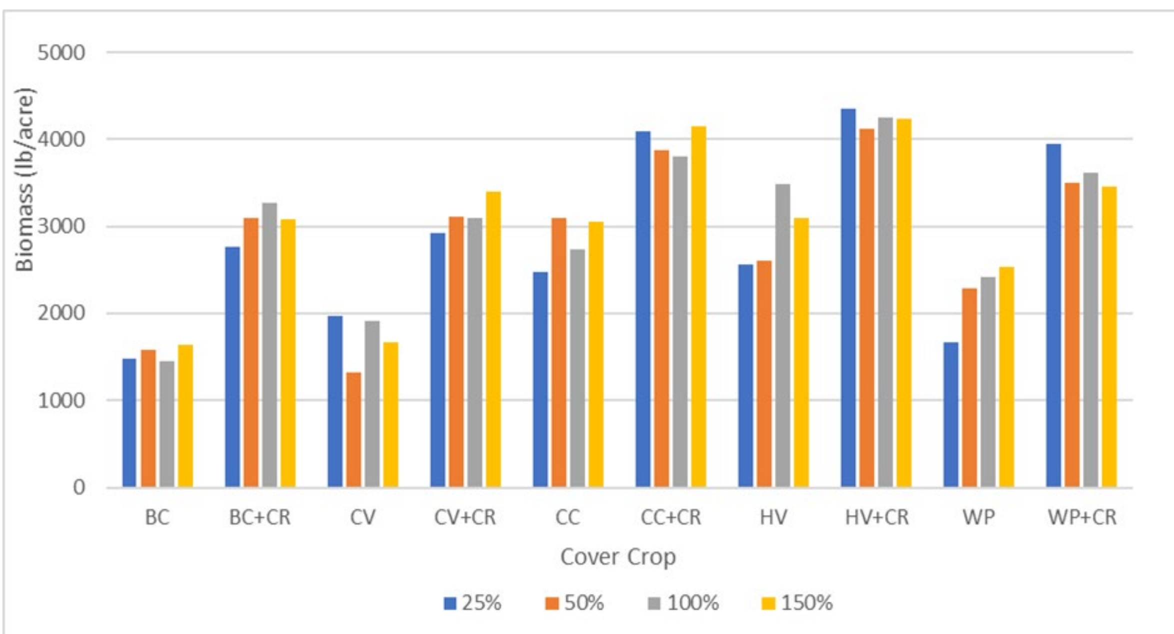

Fig. 2. Biomass of legumes planted as a monoculture or in a mix with cereal rye at 25, 50, 100 and 150% of the normal seeding rate averaged over locations and years (berseem clover (BC), BC and cereal rye (CR) (BC+CR), common vetch (CV) and CV+CR, crimson clover (CC), CC and CC+CR, hairy vetch (HV), and HV+CR, and winter pea (WP) and WP+CR).

Weed Suppression

Planting cereal rye with the legumes reduced the percentage of weeds in total biomass production for all legumes mixtures in Arkansas and for the hairy vetch mixture in Maryland (Fig. 3 and 4), but there were no significant differences in percent weeds in the total biomass due to legume seeding rates with or without cereal rye (P>0.05). Adding cereal rye to low biomass producing common vetch and winter pea in Arkansas, resulted in substantial weed suppression (Fig. 3). Crimson clover and hairy vetch, mixed with cereal rye, produced the most cover crop biomass of all planted annual legumes.

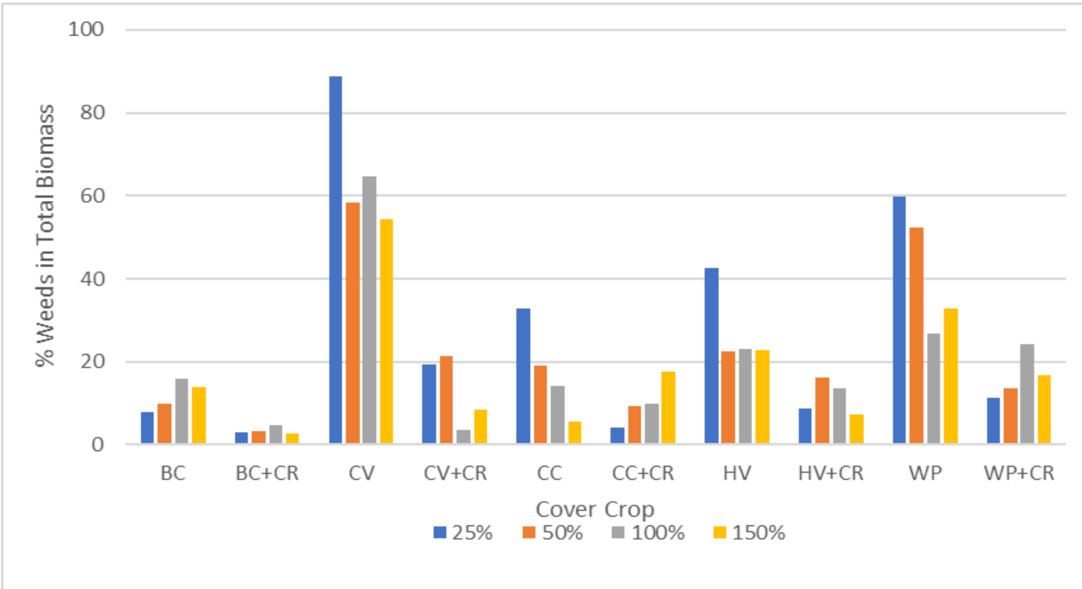

Fig. 3. Percent weeds in the total biomass of single legume species and legume and cereal rye mix at 25, 50, 100 and 150% of the normal seeding rate in Arkansas. (berseem clover (BC), BC and cereal rye (CR) (BC+CR), common vetch (CV) and CV+CR, crimson clover (CC), CC and CC+CR, hairy vetch (HV), and HV+CR, and winter pea (WP) and WP+CR).

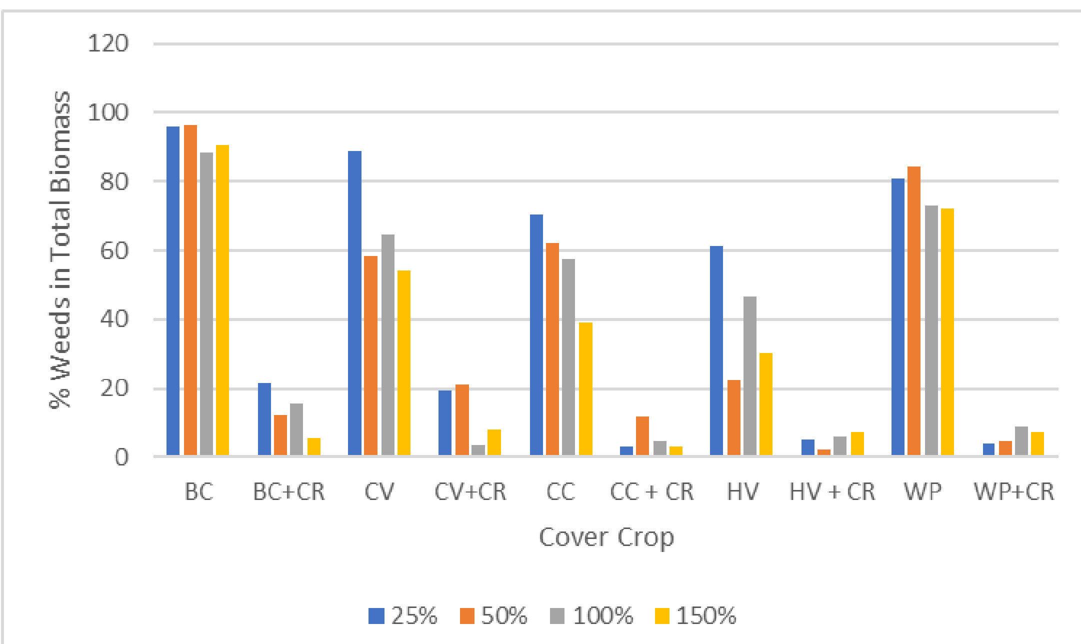

Fig. 4. Percent weeds in the total biomass of single legume species and legume and cereal mix at 25, 50, 100 and 150% of the normal seeding rate in Maryland. (berseem clover (BC), BC and cereal rye (CR) (BC+CR), common vetch (CV) and CV+CR, crimson clover (CC), CC and CC+CR, hairy vetch (HV), and HV+CR, and winter pea (WP) and WP+CR).

The effectiveness of the cereal rye in suppressing weeds was most evident in Maryland where the percentage of weeds in the total biomass were reduced by >60% because of poor legume performance (Fig. 4). The value of cereal rye for weed suppression is known (Clark, 2007). Results from this study and other studies support the effectiveness of cereal rye for weed suppression when planted alone or in a mix with annual legumes (Ficks et al., 2022; Pittman et al., 2019; Hayden et al., 2012).

The percentage of weeds in total biomass was generally higher in lower seeding rates and usually decreased as seeding rates increased; however, the reduction in weeds due to higher seeding rates was not significant (Fig. 3 and 4) (P>0.05). Although legume differences were not an objective of this study, berseem clover, crimson clover and hairy vetch appeared to be more effective in suppressing weeds than common vetch or winter pea in Arkansas (Fig. 3). Crimson clover biomass had the smallest percentage of weeds as seeding rates increased from 25-150%. Common vetch provided minimal weed suppression despite its similarities in growth habit and plant morphology to hairy vetch (Ball et al., 2002), which was effective in suppressing weeds in Arkansas. Common vetch lacked the biomass production to be effective in suppressing weeds (<500 lb/acre) (Appendix A). The low biomass production of this common vetch source may be due to poor adaptation to west-central Arkansas. In a non-related field study at the Univ. of Arkansas Experiment Station near Kibler, AR, about 50 miles north of Booneville, Arkansas, common vetch also was the least productive of the cool season legumes in the evaluation. Unlike other legumes planted in this study, common vetch did not have a variety name, so its origin, range of adaptation and production potential are unknown (Table 2). Planting materials of unknown origin or variety not stated (VNS) can result in inconsistent plant performance and productivity from year to year.

In Maryland, apart from hairy vetch planted at 50-150% seeding rates (Fig. 4), none of the legumes planted as a monoculture were effective in suppressing weeds as indicated by the high percentage of weeds in the total biomass. Poor variety adaptation to the location may explain the low productivity and high percentage of weeds found with some of the legumes.

Economic Analysis

Economic parameters were determined using published seed cost data to calculate seeding costs and the biomass yield per lb of seed at different seeding rates of both the legumes and legume plus cereal rye mix (Table 5). Additionally, biomass yield per seed cost per acre was also calculated for each legume and legume plus cereal rye seed rate (Table 5).

Increasing legume seeding rate above the 25% recommended rate essentially had no effect on biomass production of any of the legumes or legume plus cereal rye combinations (Fig. 2 and Table 5). The hairy vetch results support the Mirsky et al. (2017) research which concluded that the optimum seeding rate for maximizing cover crop biomass production of hairy vetch depends on the latitude where the hairy vetch is grown. Mirsky et al. (2017) stated that seeding rates at or above the SARE recommended rates were required for latitudes above Maryland (> 40º N), but about 25-50% of the normal SARE recommendation was optimal for locations south of Maryland because of a longer production period and potentially higher yield associated with lower latitudes. All locations in this study were below 40º latitude with several locations significantly further south than that latitude (Table 1). These results suggest that, because no consistent trends were identified by legume type or location (Appendix A and B), a reduction in SARE recommended seeding rate for the southern US is warranted, at least for the legumes tested.

Although there was no consistent advantage in terms of biomass yield per seed cost per acre (Table 5), total biomass production per acre was 40 to 90% higher with the addition of 30 lb PLS/acre of cereal rye. For those producers needing higher biomass amounts for erosion or weed control, adding a cereal rye would be more cost effective than increasing legume seeding rate.

With inconsistent returns to seeding rate increases above 25% recommended and with the addition of a grass to the mix, we were unable to identify or confirm an advantage to use higher seeding rates or the addition of grasses to produce a return on seed investment in this study. In several cases, highest production and economic return was seeding a legume at 25% of recommended seeding rate with or without cereal rye. There may be additional agronomic considerations in selecting a seeding rate that are not reflected in this analysis.

CONCLUSIONS

Choosing the wrong cover crop species or variety jeopardizes the purpose of the cover crop planting (e.g., erosion control, weed suppression, organic matter, N fertility) and is a waste of time, money, and other resources required to establish cover crops as part of a cropping system as found in Maryland. An extreme example of this problem can come from using variety not stated (VNS) seed, which at best can represent a single local type and at worst different types from year to year. A good practice is to avoid planting VNS unless the origin can be verified and there is sufficient evidence to confirm the plant's adaptation to the targeted area. Contact the local USDA-Natural Resources Conservation Service (NRCS) or extension service for assistance with the recommended cover crop varieties for your area or refer to Cover Crop Performance and Adaptation Trials at PMCs | Natural Resources Conservation Service (usda.gov) and other resources developed by the NRCS Plant Materials Program for making informed decisions on cover crop varieties and other topics related to cover cropping.

Hairy vetch and crimson clover were the most productive legumes, regardless of seeding rate, when planted as a monoculture or in mixture with cereal rye. Lower legume seeding rates (25-50%) produced statistically similar biomass as higher legume seeding rates (100-150%). Adding 30 PLS lb/acre of cereal rye to the legumes reduced weeds and increased total biomass production. Because there was no effect of legume seeding rate on total biomass yield of a monoculture legume or legume plus cereal rye mixtures, lower seeding rates produced the highest biomass yield per lb of seed and the greatest return on seed investment.

The results of this study suggest that legume cover crop seeding rates could be reduced by 50% of the normal seeding rate in the southern U.S. when planted as a monoculture or when planted with 30 PLS lb/acre of cereal rye. However, additional field testing is needed to verify this recommendation. Additionally, more studies are needed in different geographical regions/latitudes on planting dates, seeding rates, and termination times to optimize production of the best adapted cool season legumes and cereal rye varieties for cover cropping.

Additional Reports on the Results of this Study at Individual Locations

Arkansas – Chintala, R., S. Haller, A. Pettit, B. Holleman. 2022. Impacts of seeding rate, cereal rye mixture, and termination time on biomass. Final Study Report 12/2022 p. 1-13.

Texas – Wiggans, D. 2022. Biomass evaluation of cool season legumes grown at differing seeding densities with and without a rye cover in the Texas Rolling Red Plains. Final Study Report 10/2022 p. 1-7.

Table 5. Seed cost calculations of legumes and legume + cereal rye mix at different seeding rates.

	Legume				Legume + Cereal Rye[1/]			
Seeding rate (PLS lb/acre)	Mean biomass yield (lb/acre)	Biomass yield/lb of seed	Seed cost/acre	Biomass yield/$ of seed/acre	Mean biomass yield (lb/acre)	Biomass yield/lb of seed	Seed cost/acre	Biomass yield/$ of seed/acre
	Berseem Clover				**Berseem Clover + Cereal Rye[1/]**			
3	1483	494	7.50	198	2763	85	23.70	117
6	1578	263	15	105	3090	86	31.20	99
12	1457	121	30	49	3269	78	46.20	71
18	1638	91	45	36	3076	64	61.20	50
	Common Vetch				**Common Vetch + Cereal Rye**			
5	1968	394	7.30	270	2916	83	23.50	124
10	1324	132	14.60	91	3106	78	30.80	101
20	1915	96	29.20	66	3094	62	45.40	68
30	1670	56	43.80	38	3405	57	60.00	57
	Crimson Clover				**Crimson Clover + Cereal Rye**			
5	2479	496	14.50	171	4090	117	30.70	133
10	3100	310	29	107	3878	97	45.20	86
20	2741	137	58	47	3809	76	74.20	51
30	3055	102	87	35	4148	69	103.20	40
	Hairy Vetch				**Hairy Vetch + Cereal Rye**			
5	2556	511	13.45	190	4350	124	29.65	147
10	2610	261	26.9	97	4113	103	43.10	95
20	3482	174	53.8	65	4242	85	70	61
30	3093	103	81	38	4239	71	96.90	44
	Winter Pea				**Winter Pea + Cereal Rye**			
20	1660	83	17.60	94	3952	79	34	117
40	2282	57	35.20	65	3497	39	51	68
80	2419	30	70.40	34	3618	33	87	42
120	2535	21	105.60	24	3455	23	122	28

[1/] Cereal rye was planted at 30 PLS lb/acre.

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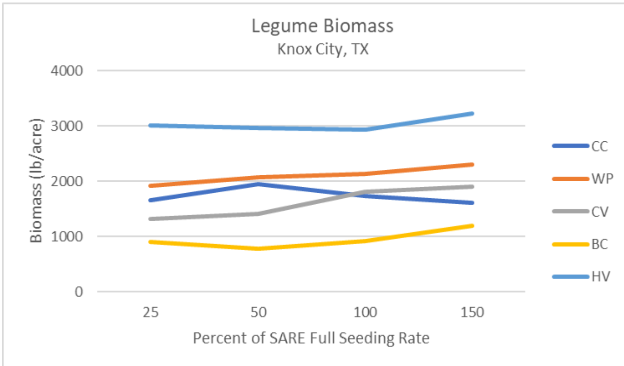
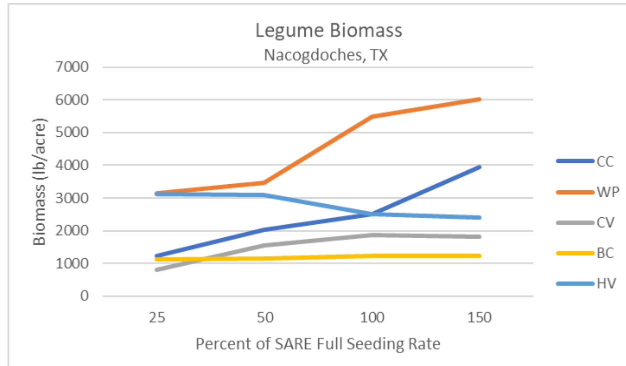
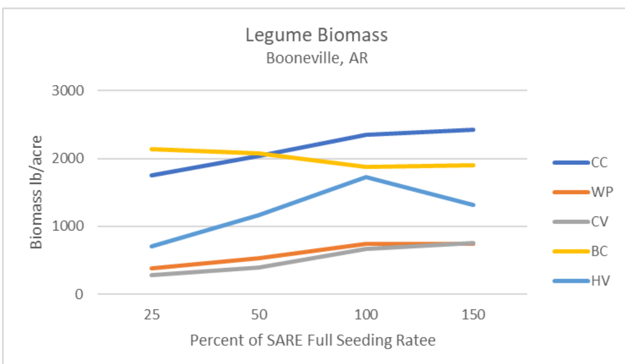
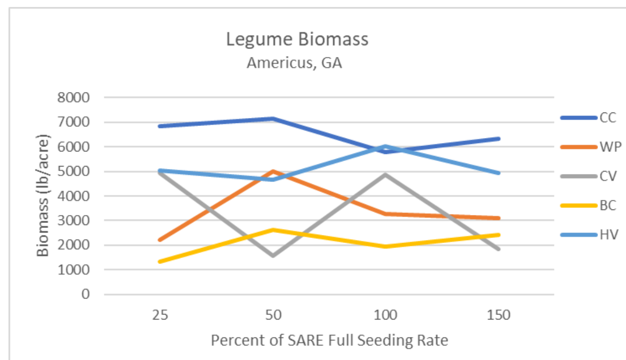
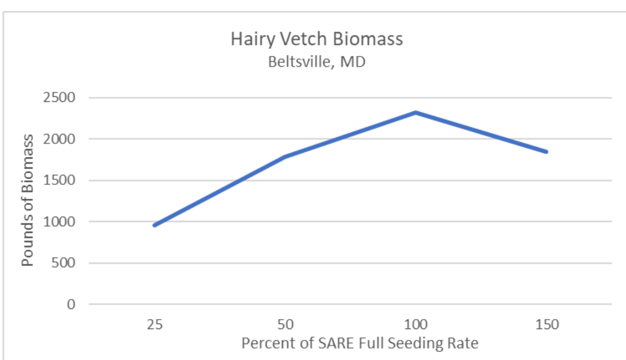
Appendix A: Biomass yield of legumes by percent of the SARE (Sustainable Agriculture Research and Education) full seeding rate for berseem clover (BC), crimson clover (cc), common vetch (CV), hairy vetch (HV) and winter pea (WP) at each location and the total legume biomass averaged over locations.

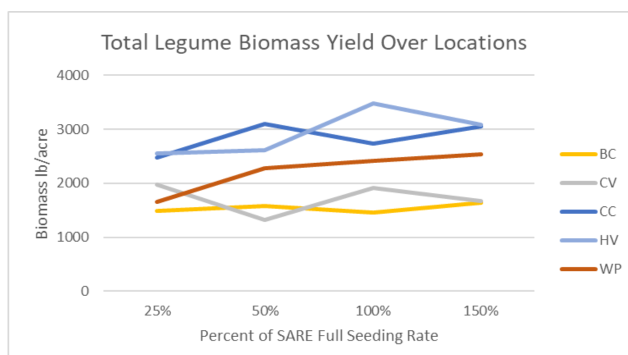












Appendix B: Biomass yield of legumes by percent of the SARE (Sustainable Agriculture Research and Education) full seeding rate for berseem clover (BC), crimson clover (cc), common vetch (CV), hairy vetch (HV) and winter pea (WP) rate with 30 lb/acre cereal rye (CR) at each location and the total biomass of legume and CR mix averaged over locations.