



Evaluation of Warm-Season Cover Crops on the Southern Coastal Plain, 2016-2018

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ABSTRACT

Warm season cover crops have the potential to fill fallow periods between vegetable crops, after field crop harvest, or act as living mulches in cash crop plantings. Substantial research has been conducted on using cool-season cover crops in southeastern crop rotations, but much less work has been completed on the use of warm-season cover crops in this region. The objective of this study was to evaluate the growth characteristics and biomass production of 23 commercially available warm-season cover crop varieties of 15 warm-season species on the coastal plain of the Southeast. Cowpea (*Vigna unguiculata*), sunn hemp (*Crotalaria juncea*), soybean (*Glycine max*), partridge pea (*Chamaecrista fasciculata*), lablab (*Lablab purpureus*), buckwheat (*Fagopyrum esculentum*), sunflower (*Helianthus annuus*), Japanese Millet (*Echinochloa esculenta* and *Echinochloa frumentacea*), pearl millet (*Pennisetum glaucum*), browntop millet (*Urochloa ramosa*), proso millet (*Panicum miliaceum*), sorghum (*Sorghum bicolor* and *Sorghum bicolor x Sorghum bicolor* var. *sudanense*), and teosinte (*Zea mexicana*) were evaluated for field emergence, ground cover, days from planting to first bloom and 50% bloom, disease and insect resistance, and biomass production at the Jimmy Carter Plant Materials Center in Americus, Georgia during 2016, 2017, and 2018. Pearl millet, Japanese Millet, and browntop millet provided the quickest emergence and ground cover and showed variable lengths in their number of days between planting and blooming. Sorghum species performed well but had a substantial issue with insect and disease resistance. Legumes such as cowpea and sunn hemp provided quick emergence and growth and provided the extra benefit of fixing atmospheric nitrogen. Others such as partridge pea, proso millet, and teosinte provided variable performance across the evaluated characteristics and may be better suited in wildlife plantings than as cover crops. Continued research is needed to evaluate additional plant species and commercially available varieties as well as developing up-to-date planting and management recommendations for the plant species evaluated in this project.

INTRODUCTION

Using cover crops in cropping systems has been shown to prevent soil erosion, reduce fertilizer inputs, improve soil health, suppress weeds, attract and harbor beneficial insects, conserves energy, and manage soil carbon sinks (Clark, 2007; Bugg & Dutcher, 1989; Lal, 2004, Reicosky & Forcella, 1998). Warm season cover crops can be used in the southeastern United States between vegetable crops (Creamer & Baldwin, 2000), as a living mulch in cash crops (Pfeiffer, Silva, & Colquhoun, 2016), or after field corn harvest (Mansoor, Reeves, & Wood, 1997). Substantial research has been conducted on cool-season cover crops, but significantly less information exists on the use of warm-season cover crops. Agricultural producers and conservation planners are faced with choosing from many cover crop options, often without knowing the expected growth and performance of those options. The purpose of this study was

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to evaluate the growth characteristics and biomass yield of commercially available warm season cover crops cultivars in the Southern Coastal Plain Major Land Resource Area (MLRA) of the Southeast.

MATERIALS AND METHODS

The study was conducted at the USDA Natural Resources Conservation Service (NRCS) Jimmy Carter Plant Materials Center, Americus, Georgia from 2016-2018. The Jimmy Carter Plant Materials Center is located on the Southern Coastal Plain MLRA of the southeast United States. The 30-year (1981-2010) mean maximum temperature during the growing season for this study is 87.5 °F and 30-year (1981-2010) mean minimum temperature is 65 °F. The 30-year (1981-2010) mean precipitation during the same time period is 20 inches (PRISM Climate Group, Oregon State University, 2019). During the three years of the study, monthly average temperatures seemed to closely match the 30-year monthly minimum and monthly maximum temperatures while monthly precipitation amounts were variable by year (Figure 1). This is likely due to the irregular, intense nature of the rainfall events that occur in the southeastern United States during the summer allowing for high variability in monthly rainfall totals.

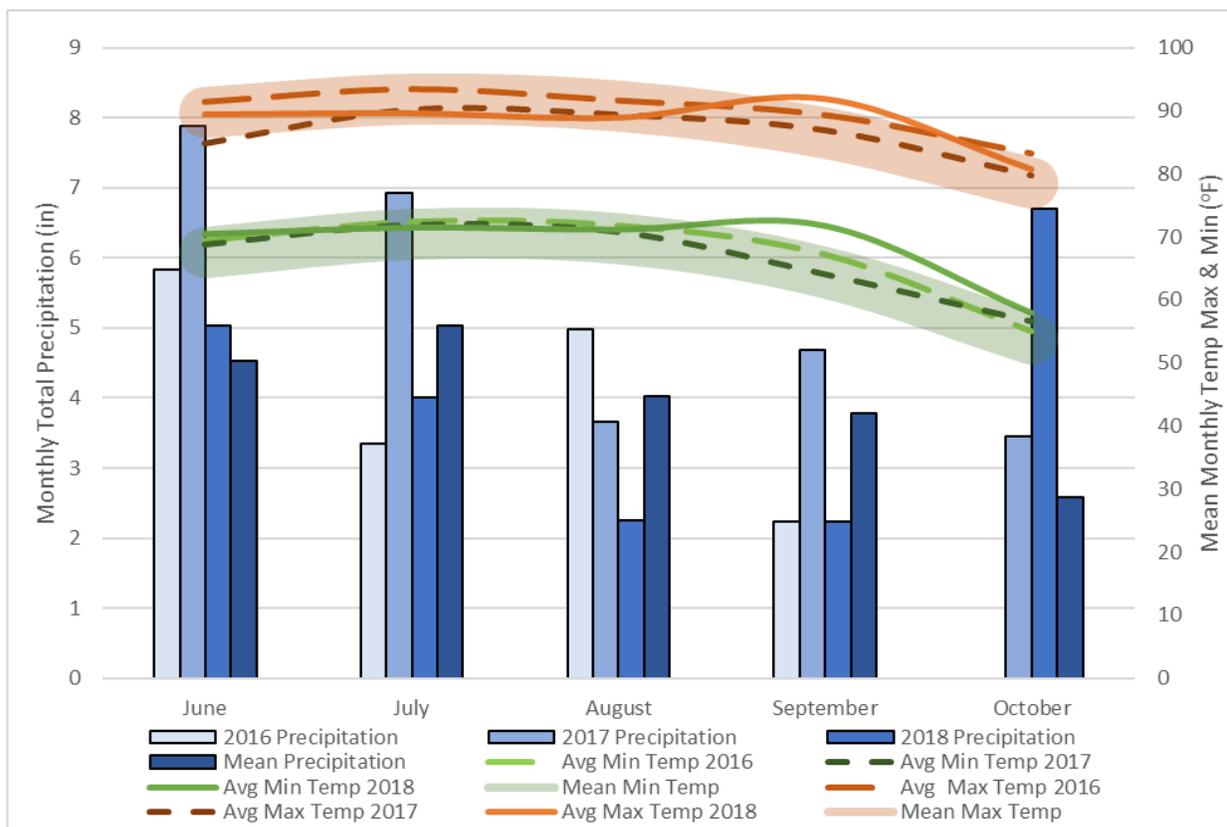


Figure 1. Monthly minimum temperatures, monthly maximum temperatures, and monthly precipitation amounts for 2016, 2017, 2018, and 30-year means (PRISM Climate Group, Oregon State University, 2019)

Commercially available, annual warm season cover crops were planted on 16 June 2016 and 15 June 2017 and 2018 on a bulk seeding rate basis following current recommendations from NRCS and/or other sources (Table 1). Plots were planted using a Kincaid Plot Seed Drill (Kincaid Equipment, Haven KS) with 7.5-inch row spacing on a Red Bay Sandy Loam (fine-loamy, kaolinitic, thermic Rhodic Kandudult) soil (USDA Natural Resources Conservation Service Web Soil Survey, 2019). Plot size was 6 feet x 12 feet.

Table 1. Species, cultivars, and seeding rates of annual warm season cover crops planted in a 3-year trial at the USDA NRCS Jimmy Carter Plant Materials Center Americus, Georgia, 2016-2018

Common Name	Species	Cultivar	Seeding Rate lb acre ⁻¹
Cowpea	<i>Vigna unguiculata</i>	Red Ripper	60
Cowpea	<i>Vigna unguiculata</i>	Chinese Red	60
Cowpea	<i>Vigna unguiculata</i>	Iron and Clay	60
Sun Hemp	<i>Crotalaria juncea</i>	Tropic Sun	15
Sun Hemp	<i>Crotalaria juncea</i>	AU Golden	15
Sun Hemp	<i>Crotalaria juncea</i>	Common	15
Soybean	<i>Glycine max</i>	Laredo	15
Soybean	<i>Glycine max</i>	Large Lad	40
Partridge Pea ^a	<i>Chamaecrista fasciculata</i>	Lark Selection	6
Partridge Pea ^a	<i>Chamaecrista fasciculata</i>	Comanche	6
Lablab	<i>Lablab purpureus</i>	Rongai	20
Japanese Millet	<i>Echinochloa esculenta</i>	Common	15
Japanese Millet	<i>Echinochloa frumentacea</i>	Chiwapa	15
Proso Millet	<i>Panicum miliaceum</i>	Dove	15
Proso Millet	<i>Panicum miliaceum</i>	Common White	15
Browntop Millet	<i>Urochloa ramosa</i>	Common	20
Pearl Millet ^b	<i>Pennisetum glaucum</i>	Tifleaf 3	20
Sorghum-Sudan	<i>Sorghum bicolor x Sorghum bicolor var. sudanense</i>	Honey Graze BMR	10
Sterile Sorghum	<i>Sorghum bicolor</i>	Common	15
Teosinte	<i>Zea mexicana</i>	Chapingo	15
Teosinte	<i>Zea mexicana</i>	Common	15
Sunflower	<i>Helianthus annuus</i>	Peredovik	15
Buckwheat	<i>Fagopyrum esculentum</i>	Mancan	50

^a dropped in 2018

^b added in 2017

Plots were moved to a new field location each year to avoid contamination by volunteer plants from hard seed planted in previous years. Identical seed lots for each entry were used in 2016 and 2017; however, new seed lots were used in 2018 to avoid skewing the results due to poor seed germination.

Soil pH and soil fertility were adjusted in each year following soil test recommendations. Legumes were inoculated with appropriate rhizobia prior to seeding. Irrigation was applied with overhead sprinklers at a rate of 2 tenths of an inch immediately after planting in each year to facilitate seed germination. No other irrigation was applied in any year. Plots were protected either by electric or woven wire fence each year to control deer browse of the desirable plant species.

Approximately every seven days for the first four weeks after planting, field emergence was estimated for each plot using the following visual rating scale: 0 = poor (<25% germination), 1 = moderate (25-64%

germination), 2 = good (65-85% germination), 3 = excellent (>85% germination). Approximately every 10 days after planting, plant height was determined by measuring the average plant height of the plants on the interior of the plot and ground cover was estimated for each plot using the following visual rating scale: 1= 0-20% ground cover, 2= 21-40% ground cover, 3=41-60% ground cover, 4=61-80% ground cover, 5=81-100% ground cover. Entries were evaluated for disease and insect damage twice during each growing season, once at approximately 28 days after planting and again at 50% bloom (varied by entry) using a 1-5 rating scale where 1=no damage and 5=severe damage. Bloom period was monitored by recording the date that bloom began (first bloom) and the date that 50% of the plants in each plot were blooming (50% bloom). Biomass at 50% bloom was determined by harvesting a random 1.92 ft² area from the interior rows of the plot. This sampling area was selected due to the small size of the plots and the ease of converting sample weights (in grams) to lb acre⁻¹ using a conversion factor of 50 (Pratt & Rasmussen, 2001).

The experimental design was a randomized complete block with 4 replications. For field emergence and ground cover, variation between cultivars was determined using Kruskal-Wallis one-way analysis of variance (ANOVA) procedure and significant ranks separated with Dunn's all-pairwise comparison test ($P<0.05$). Original means were presented for interpretation of results. For biomass, variation between cultivars was determined using ANOVA and significant means separated with Tukey's Honest Significant Difference (HSD) at $P<0.05$. Bloom Period and disease and insect ratings were reported as means. A Log₍₁₀₎ transformation was performed on biomass data when necessary to meet the normal distribution assumption of the ANOVA procedure. All data analysis was performed using Statistix 10 (Analytical Software, 2013).

RESULTS AND DISCUSSION

Cowpea

Cowpea cultivars showed good field emergence at seven days after planting and continued to improve until 14 days after planting. Beyond 14 days after planting, field emergence of cowpea remained steady suggesting that all viable seed had emerged by that time. There were no significant differences observed between cowpea cultivars for field emergence (Table 2). Ground Cover ratings (data not shown) were also similar between cultivars, with all three at or approaching a rating of 5.0 by 30 days after planting. This fast establishment allows for cowpeas to be a good fit for stopping erosion and smothering weeds (Clark, 2007). 'Iron and Clay' cowpea exhibited a later bloom timing than the other two cultivars, reaching first bloom 40 days later than 'Chinese Red' and 38 days later than 'Red Ripper' (Table 3).

Table 2. Field emergence ratings for cowpea cultivars at Jimmy Carter Plant Materials Center 2016-2018

Cultivar	DAP ^a			
	7	14	21	28
Red Ripper	2.3	2.6	2.6	2.6
Chinese Red	2.7	2.8	2.8	2.8
Iron and Clay	2.3	2.6	2.6	2.6
Mean	2.4	2.7	2.7	2.7
SD ^b	0.6	0.5	0.5	0.5

Table 3. Days after planting to first bloom and 50% bloom for cowpea cultivars at Jimmy Carter Plant Materials Center, 2016-2018

Cultivar	First Bloom ^a	50% Bloom ^b
Red Ripper	40	45
Chinese Red	38	44
Iron and Clay	78	83

^a Days from planting until first bloom is fully opened.

^b Days from planting until 50% of the plants in the plot are blooming based on a visual estimate

Note: Germination and emergence ratings were based on a 0-3 scale where 0 = poor (< 25% germination), 1 = moderate (25-64%), 2 = good (65-85%), 3 = excellent (>85%)

^a Days after planting

^b Standard deviation

Mid-season disease and insect damage ratings were very low across the cowpea cultivars. There was a difference in insect and disease damage observed at 50% bloom with ‘Iron and Clay’ exhibiting more insect damage than ‘Red Ripper’ and more disease damage than both cultivars. It is essential to note that the timing of this rating is based on the growth stage of the plant and varied by cultivar. As a result, disease and insect ratings at 50% bloom for ‘Iron and Clay’ were taken over one month later than the other cowpea cultivars. This delay in rating the later cultivar could have allowed for the movement of insect pests into the plots and/or environmental conditions to become more favorable for disease development. Overall, insect and disease ratings were low to moderate throughout the entire growing season, regardless of cultivar (Table 4).

Table 4. Insect and disease damage ratings for cowpea cultivars at Jimmy Carter Plant Materials Center, 2016-2018

Cultivar	Mid-Season		50% Bloom	
	Insect	Disease	Insect	Disease
Red Ripper	0.7	0.0	1.3	0.8
Chinese Red	0.8	0.3	1.6	0.9
Iron and Clay	0.5	0.0	2.0	2.1
Mean	0.6	0.1	1.6	1.3
SD ^a	0.5	0.3	0.5	0.9

Note: Damage ratings were based on a 0-5 scale where 0 = no damage and 5 = dead plants

^aStandard deviation

Mean cowpea biomass also varied significantly by cultivar. Here, ‘Iron and Clay’ benefited from the additional growing time that it received due to its later bloom timing. ‘Iron and Clay’ produced the highest 3-year average biomass ($6028 \pm 370 \text{ lb acre}^{-1}$). ‘Chinese Red’ and ‘Red Ripper’ had similar biomass production to each other but less than ‘Iron Clay’ (3778 ± 255 and $3536 \pm 210 \text{ lb acre}^{-1}$ respectively) (Figure 2). The yields observed in this trial were similar to those seen in a study in Nebraska (Power & Koerner, 1994), suggesting that cowpea may have reliable biomass production across a wide range of the United States.

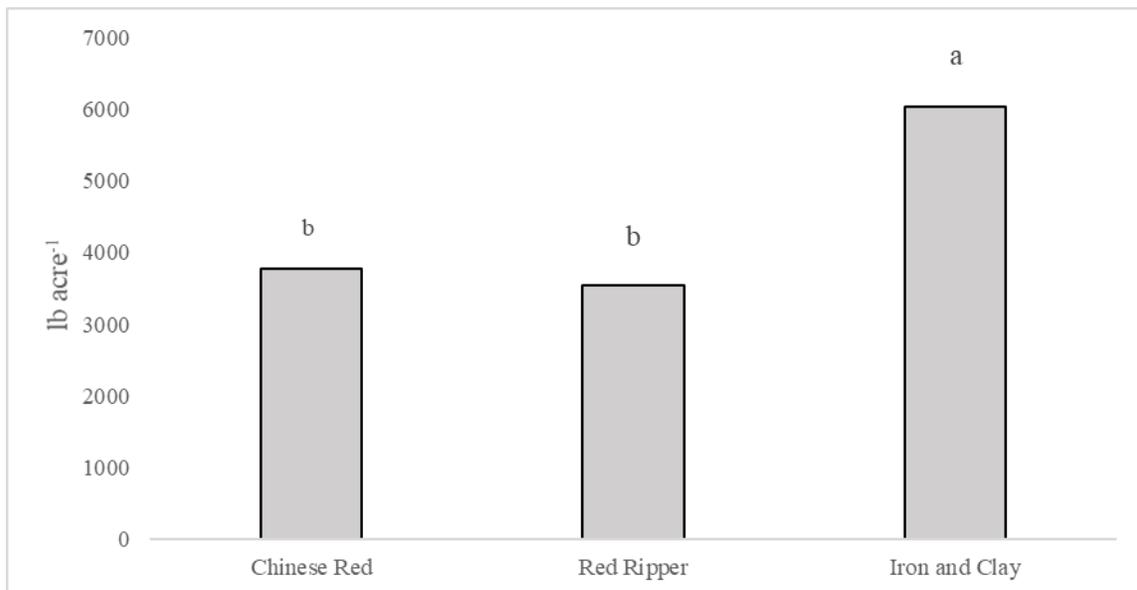


Figure 2. Biomass of cowpea cultivars at Jimmy Carter Plant Materials Center, 2016-2018. Bars labeled with the same letter are not significantly different according to Tukey’s HSD at $P < 0.05$.

Sunn Hemp

Three sunn hemp entries were evaluated each year: ‘Tropic Sun’, ‘AU Golden’, and common sunn hemp. It is important to note that the common sunn hemp used in this trial exhibited different bloom dates between seed lots. For that reason, the common sunn hemp seed lots have been reported separately where appropriate to avoid averaging the results of different performing seed lots.

All sunn hemp entries exhibited good emergence by seven days after planting and only slight improvements in emergence occurred after that point (Table 5). This agrees with Rotar & Joy (1983), who reported high seedling vigor and quick early growth of sunn hemp. Ground cover ratings at 30 days after planting (data not shown) were similar between ‘Tropic Sun’, ‘AU Golden’, and common sunn hemp, at 2.5, 2.7, and 2.6 respectively.

Table 5. Field emergence ratings of sunn hemp cultivars at Jimmy Carter Plant Materials Center, 2016-2018

Cultivar	DAP ^a			
	7	14	21	28
AU Golden	1.9	2.0	2.0	2.0
Common (2016 & 2017)	1.6	1.8	1.8	1.8
Common (2018)	2.0	2.0	2.0	2.0
Tropic Sun	1.8	1.9	2.0	2.0
Mean	1.8	1.9	2.0	2.0
SD ^b	0.4	0.3	0.3	0.3

Note: Germination and emergence ratings were based on a 0-3 scale where 0 = poor (< 25% germination), 1 = moderate (25-64%), 2 = good (65-85%), 3 = excellent (>85%)

^a Days after planting

^b Standard deviation

Bloom period varied widely depending on cultivar and/or entry. ‘AU Golden’ was the earliest to bloom of those evaluated at 38 days after planting. This was expected as ‘AU Golden’ was developed and released as an earlier blooming, seed producing sunn hemp cultivar in the sub-tropical regions of the Southeastern United States (Mosjidis, 2014). This adds an additional management consideration to those who choose to use ‘AU Golden’ as a cover crop because timely termination will be needed to avoid producing seed. ‘Tropic Sun’ was the latest blooming sunn hemp cultivar at 86 days after planting. The common sunn hemp seed lot planted in 2016 and 2017 bloomed at 48 days after planting while the 2018 seed lot bloomed at 87 days after planting (Figure 3).

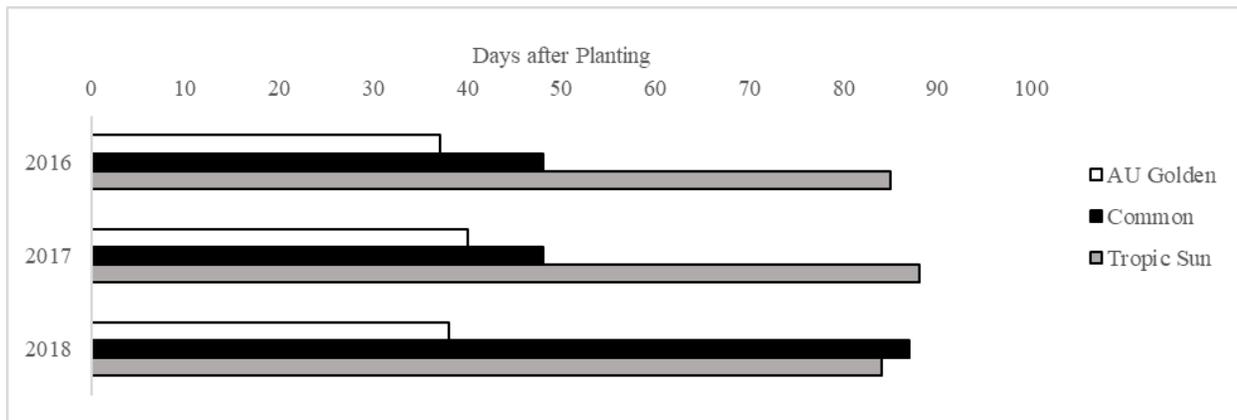


Figure 3. Days after planting to first bloom for 2 sunn hemp cultivars and common sunn hemp at Jimmy Carter Plant Materials Center, 2016-2018.

The common sunn hemp seed lots exhibited differences in the mid-season insect ratings though the differences observed are overall very small and likely irrelevant. ‘AU Golden’ displayed less disease damage than either ‘Tropic Sun’ or the 2018 seed lot of the common sunn hemp at 50% bloom (Table 6). This was again likely due to the increased number of days that the later maturing cultivars were exposed to variable environmental conditions suitable for disease development.

Table 6. Insect and disease ratings for sunn hemp cultivars at Jimmy Carter Plant Materials Center, 2016-2018.

Cultivar	Mid-Season		50% Bloom	
	Insect	Disease	Insect	Disease
AU Golden	0.5	0.0	0.7	0.3
Common (2016 & 2017)	0.0	0.0	1.0	0.9
Common (2018)	1.0	0.0	1.0	2.0
Tropic Sun	0.3	0.0	0.9	1.2
Mean	0.4	0.0	0.9	0.9
SD ^a	0.5	0.0	0.4	0.7

Note: Damage ratings were based on a 0-5 scale where 0 = no damage and 5 = dead plants

^a Standard deviation

Biomass was variable by cultivar as well with ‘Tropic Sun’ being the highest biomass producer (21 633 ± 2521 lb acre⁻¹). ‘AU Golden’ was the lowest biomass producer (6297 ± 489 lb acre⁻¹), but its growth period only allowed for less than half the days of growing time than that of its longer maturing counterparts. The 2016/2017 common sunn hemp and the 2018 common sunn hemp produced 13030 ± 712 lb acre⁻¹ and 13 407 ± 2857 lb acre⁻¹ respectively (Figure 4).

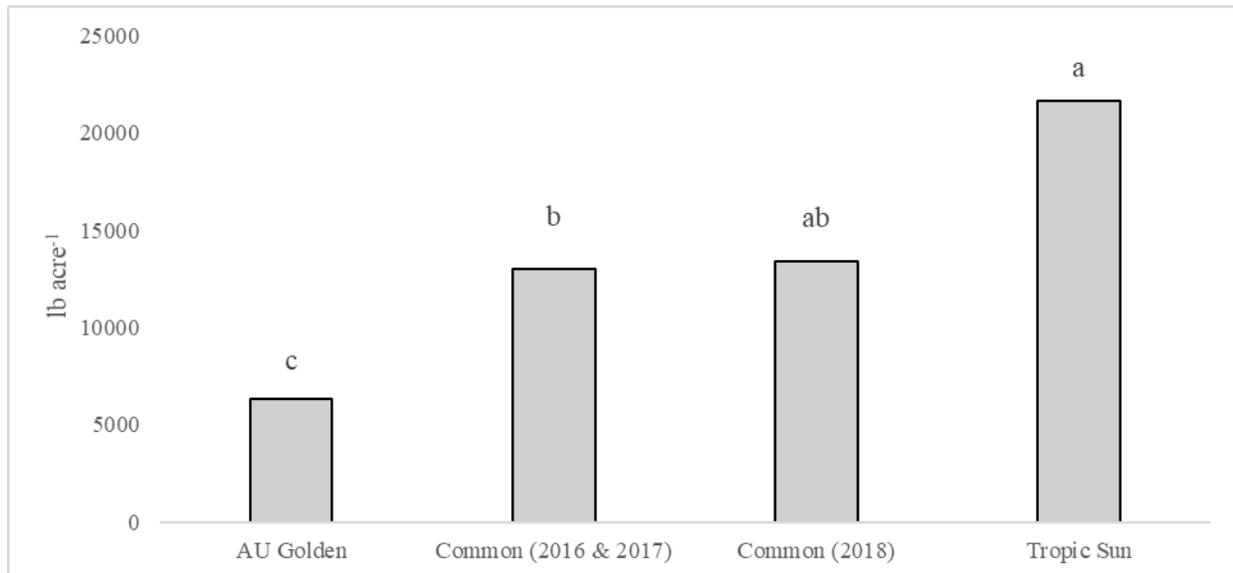


Figure 4. Biomass of sunn hemp cultivars at 50% bloom at Jimmy Carter Plant Materials Center, 2016-2018. Bars labeled with the same letter are not significantly different according to Tukey’s HSD at $P < 0.05$.

Common sunn hemp seed lots showed differences in insect and disease ratings (Table 6) and bloom period (Figure 3). This shows common sunn hemp seed lots from different sources or grown at different times could likely not provide repeatable, predictable results. For that reason, producers would be better served to select named cultivars of sunn hemp that will provide the standardized, predictable growth characteristics that meet their specific needs.

Other Legumes

Field emergence in this grouping was variable and unpredictable throughout the 3-year study (Table 7). The soybean cultivars performed as expected in 2016 and 2017 but showed much less emergence in 2018 with the use of a new seed lot. Lark selection partridge pea was not evaluated in 2016 or 2017 as a stand representative of the cultivar was rarely achieved in either year. ‘Comanche’ partridge pea was not evaluated in 2016 and 2017 and the data for that cultivar is included in this grouping’s dataset. New seed lots were not obtained for either partridge pea cultivar in 2018, therefore they were dropped from the study in that year. Lablab provided acceptable emergence every year. Due to its inability to achieve a replicated, representative stand in any year, Lark selection partridge pea is not included in the data analysis for this group. In addition, since most of the grouping had either seed stand or seed procurement issues in 2018, only data from 2016 and 2017 was included in the data analysis.

Table 7. Field emergence ratings for 3 legume species at Jimmy Carter Plant Materials Center, 2016-2018.

Species	Cultivar	Year	DAP ^a			
			7	14	21	28
Soybean	Laredo	2016	1.0	1.0	1.0	1.0
		2017	1.0	2.0	2.0	2.0
		2018	0.5	0.5	0.5	0.5
	Large Lad	2016	1.3	1.3	1.3	1.3
		2017	1.3	2.0	2.0	2.0
		2018	0.0	0.8	0.0	0.0
Partridge Pea	Comanche	2016	0.0	0.0	0.0	0.3
		2017	1.0	1.0	0.8	0.8
		2018 ^b	--	--	--	--
	Lark selection	2016	0.0	0.0	0.0	0.0
		2017	0.0	0.0	0.0	0.0
		2018 ^b	--	--	--	--
Lablab	Rongai	2016	1.3	1.3	2.0	2.0
		2017	2.0	2.0	2.0	2.0
		2018	1.0	2.0	2.0	2.0

Note: Germination and emergence ratings were based on a 0-3 scale where 0 = poor (< 25% germination), 1 = moderate (25-64%), 2 = good (65-85%), 3 = excellent (>85%)

^a Days after planting

^b Partridge pea was not included in 2018

Ground cover ratings were similar at 20 days after planting among all cultivars. By 30 days after planting however, ‘Large Lad’ soybean significantly provided higher ground cover ratings than ‘Laredo’ soybean or ‘Comanche’ partridge pea (Table 8). Though some differences were observed among cultivars at 30 days after planting, they were small and likely irrelevant when comparing the ground cover ratings of this species grouping to other groupings in the study.

Bloom period varied by species in this group. The partridge pea began blooming 4 days later and reached 50% bloom 2 days later than the soybean cultivars. The lablab did not bloom during the trial in any year (Table 9). Lablab is unlike any plant species in this study as it requires warm temperatures but a short photoperiod to bloom. These conditions are found at the lower latitudes of the tropical regions. Lablab would not bloom until very late in the growing season at higher latitudes (Keatinge, Qi, Wheeler, Ellis, & Summerfield, 1998), such as the sub-tropical Southeastern United States.

Table 8. Ground cover ratings at 20 and 30 days after planting for 3 legume species at Jimmy Carter Plant Materials Center, 2016-2017.

Species	Cultivar	DAP ^a	
		20	30
Soybean	Laredo	1.0	1.1 b*
	Large Lad	1.1	2.0 a
Partridge Pea	Comanche	1.0	1.0 b
Lablab	Rongai	1.0	1.6 ab
	Mean	1.0	1.4
	SD ^b	0.2	0.6

Note: Ground cover ratings were based on a 1-5 scale where 1= 0-20%, 2= 21-40%, 3=41-60%, 4=61-80%, 5=81-100%.

^a Days after planting

^b Standard deviation

* Means in columns followed by the same letter are not significantly different according to Dunn's all pairwise comparison test ($P < 0.05$).

Table 9. Days after planting to first bloom and 50% Bloom for 3 legume species at Jimmy Carter Plant Materials Center, 2016-2017.

Species	Cultivar	First Bloom ^a	50% Bloom ^b
		Soybean	Laredo
	Large Lad	54	67
Partridge Pea	Comanche	58	69
Lablab	Rongai	-- ^c	-- ^c

^a Days from planting until first bloom is fully opened.

^b Days from planting until 50% of the plants in the plot are blooming based on a visual estimate

^c Lablab did not bloom before termination

Disease and insect damage ratings were low and irrelevant for all cultivars at the mid-season rating. At 50% bloom however, differences were observed with the partridge pea having less insect damage than either of the two soybean cultivars or the lablab cultivar. Partridge pea showed less disease damage than 'Rongai' lablab at 50% bloom as well (Table 10).

Table 10. Insect and disease ratings for 3 legume species at Jimmy Carter Plant Materials Center, 2016-2017

Species	Cultivar	Mid-Season		50% Bloom	
		Insect	Disease	Insect	Disease
Soybean	Laredo	0.3	0.0	2.0	1.0
	Large Lad	0.4	0.0	2.1	0.5
Partridge Pea	Comanche	0.0	0.0	0.5	0.0
Lablab	Rongai	0.1	0.0	2.0	1.1
	Mean	0.2	0.0	1.7	0.7
	SD ^a	0.4		0.9	0.7

Note: Damage ratings were based on a 0-5 scale where 0 = no damage and 5 = dead plants.

^a Standard deviation

Biomass production was highest by 'Large Lad' soybean and 'Rongai' Lablab at 8680 ± 603 lb acre⁻¹ and 8230 ± 609 lb acre⁻¹, respectively. Both cultivars produced significantly more biomass than 'Comanche' partridge pea which yielded 3930 ± 1103 lb acre⁻¹ (Figure 5). Though partridge pea was the poorest performer in this species grouping, (Dietz, Jr., Whiting, Jr., & Koerth, 2006) reported the importance of partridge pea to the diets of Northern Bobwhite Quail, while (Houck & Row, 2019) noted its importance as food and cover for multiple wildlife species, as a honey plant, and as a restoration plant for disturbed areas. This suggests partridge pea should still be considered an important part of plantings aimed at promoting wildlife habitat and land restoration.

Non-Legume Broadleaf Species

In addition to the legume species, two other non-legume broadleaf plant species, 'Mancan' buckwheat and 'Peredovik' sunflower were evaluated as a part of this study. The buckwheat showed good field emergence, a 2.0 rating, at 7 days after planting and showed some improvement beyond that rating at 14

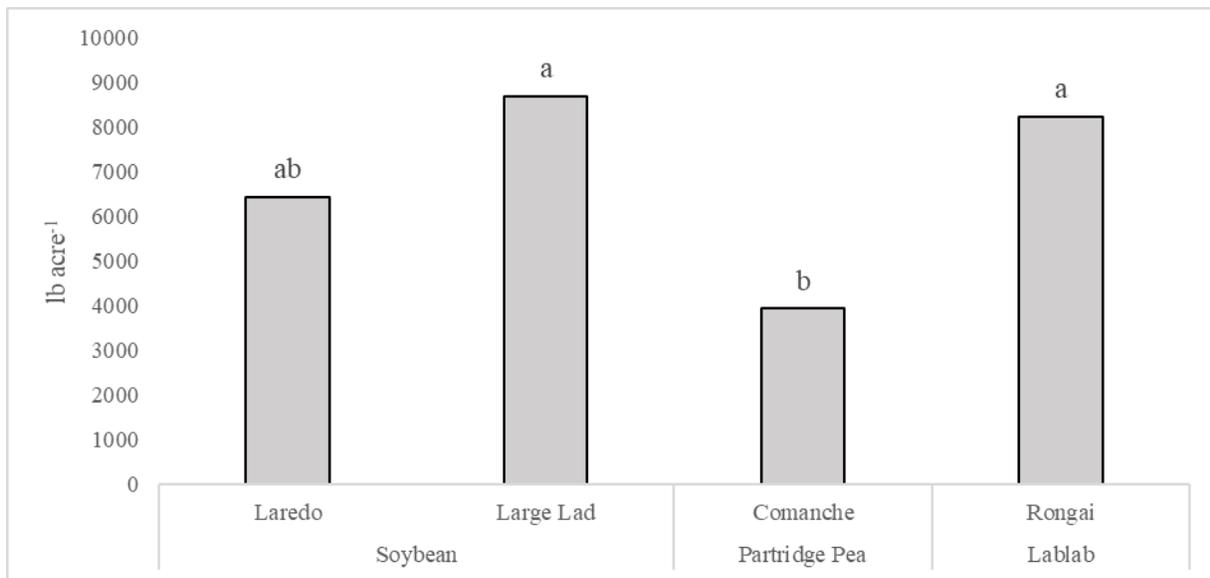


Figure 5. Mean Biomass Production for 3 legume species at Jimmy Carter Plant Materials Center, 2016-2017. Bars labeled with the same letter are not significantly different according to Tukey's HSD at $P < 0.05$

days after planting. It did not exhibit any further increases in field emergence beyond 14 days after planting. 'Peredovik' sunflower showed lower field emergence ratings overall, only reaching 0.9 by 7 days after planting and improving to a 1.7 rating by 14 days after planting. Like buckwheat, the sunflower saw no improvements in its field emergence ratings beyond 14 days after planting (Table 11). Ground cover ratings were low for both species at 10 days after planting. 'Mancan' buckwheat had more than doubled its ground cover rating by 20 days after planting, but it remained low compared to other species in the study. 'Peredovik' sunflower produced low ground cover ratings at 20 and 30 days after planting (Table 12).

Table 11. Field emergence ratings of 2 broadleaf species at Jimmy Carter Plant Materials Center, 2016-2018

Species	Cultivar	DAP ^a			
		7	14	21	28
Buckwheat	Mancan	2.0	2.6	2.6	-- ^b
Sunflower	Peredovik	0.9	1.7	1.7	1.7

Note: Germination and emergence ratings were based on a 0-3 scale where 0 = poor (< 25% germination), 1 = moderate (25-64%), 2 = good (65-85%), 3 = excellent (>85%)

^a Days after planting

^b Buckwheat was terminated before it reached 28 days after planting

'Mancan' Buckwheat was very quick to bloom, showing its first bloom at 22 days after planting. It reached 50% bloom at 27 days after planting. 'Peredovik' sunflower was slower to bloom, showing its first open bloom at 47 days after planting and reaching 50% bloom at 53 days after planting (Table 13). Disease and insect ratings were very low for 'Mancan' with the highest disease rating of 0.1 at 50% bloom. 'Peredovik' sunflower showed lower insect and disease ratings as well with ratings of 1.3 for both categories at 50% bloom (data not shown). Biomass production was variable between the two species with the sunflower producing more biomass than buckwheat. 'Mancan' buckwheat produced 1219 ± 161 lb acre⁻¹ during its short growth period. 'Peredovik' sunflower produced 5225 ± 1096 lb acre⁻¹, but took advantage of nearly twice as many growing days (Figure 6)

Table 12. Ground cover ratings of 2 broadleaf species at Jimmy Carter Plant Materials Center, 2016-2018

Species	Cultivar	DAP ^a		
		10	20	30
Buckwheat	Mancan	1.0	2.3	-- ^b
Sunflower	Peredovik	1.0	1.0	1.2

Note: Ground cover ratings were based on a 1-5 scale where 1= 0-20%, 2= 21-40%, 3=41-60%, 4=61-80%, 5=81-100%.

^a Days after planting

^b Buckwheat was terminated before it reached 30 days after planting

Table 13. Days after planting to first bloom and 50% bloom for 2 broadleaf species at Jimmy Carter Plant Materials Center, 2016-2018

Species	Cultivar	First	50%
		Bloom ^a	Bloom ^b
Buckwheat	Mancan	22	27
Sunflower	Peredovik	47	53

^a Days from planting until first bloom is fully opened.

^b Days from planting until 50% of the plants in the plot are blooming based on a visual estimate

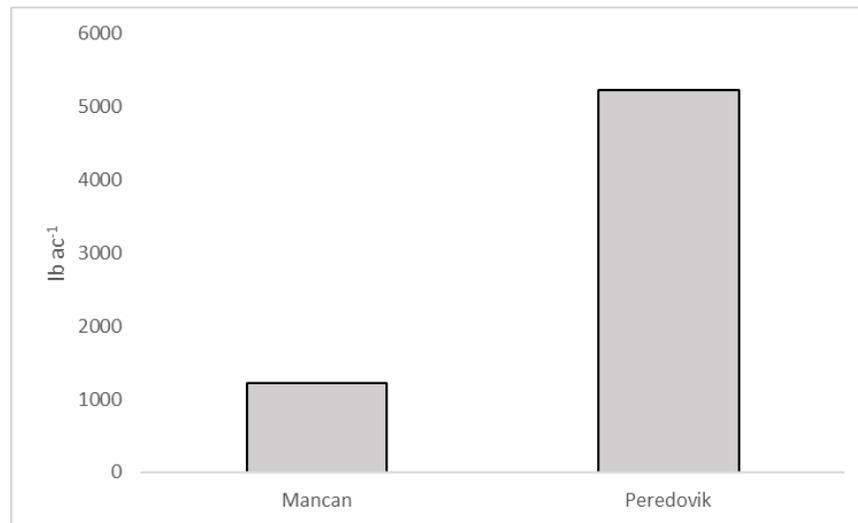


Figure 6. Mean biomass production of two broadleaf species at the Jimmy Carter Plant Materials Center, 2016-2018.

Buckwheat did not produce as much ground cover and biomass yield as was reported by Creamer & Baldwin (2000). Clark (2007) also reported buckwheat to have quick smothering ground cover and higher biomass yields than were observed in this study. Both authors also noted the intolerance of buckwheat to drought and high temperatures; however, and Clark, (2007) noted that “Buckwheat thrives in cool, moist conditions”. The environmental conditions in this study were not conducive for buckwheat and the sandy soil did not allow for an abundance of soil moisture. Buckwheat may perform much differently if planted where cooler temperatures and higher soil moisture conditions exist.

Millets

The millet species examined in this study, except for common white proso millet, exhibited good to excellent field emergence. All entries had nearly maximized their field emergence ratings by 7 days after planting and saw only small improvements in their ratings with subsequent rating times. This illustrates the quick germination and high vigor of the millet species as a group. The common white proso millet did have significantly lower ratings than the other entries in the group though it followed the same trend

of nearly maximizing its ratings by 7 days after planting (Table 14). This points to the lower ratings of the common white proso millet being due to low seed germination rather than slower seedling emergence.

Ground cover ratings for the millet group varied significantly by entry. At 10 days after planting, common browntop millet had significantly higher ground cover ratings than any other millet species. By 20 and 30 days after planting, ‘Chiwapa’ Japanese millet, ‘Tifleaf 3’ Pearl millet, and common browntop

Table 14. Field emergence ratings of millet species at Jimmy Carter Plant Materials Center, 2016-2018.

Species	Cultivar	DAP ^a			
		7	14	21	28
Browntop Millet	Common	3.0 a*	3.0 a	3.0 a	3.0 a
Japanese Millet	Chiwapa	2.8 a	3.0 a	3.0 a	3.0 a
	Common	2.8 a	3.0 a	3.0 a	3.0 a
Pearl Millet ^b	Tifleaf 3	2.6 a	3.0 a	3.0 a	3.0 a
Proso Millet	Common White	1.2 b	1.5 b	1.3 b	1.5 b
	Dove	2.5 a	3.0 a	3.0 a	3.0 a
	Mean	2.4	2.7	2.7	2.7
	SD ^c	0.8	0.7	0.8	0.7

Note: Germination and emergence ratings were based on a 0-3 scale where 0 = poor (<25% germination), 1 = moderate (25-64%), 2 = good (65-85%), 3 = excellent (>85%)

^a Days after planting

^b Pearl Millet was not included in 2016

^c Standard deviation

* Means in columns followed by the same letter are not significantly different according Dunn’s all pairwise comparison test ($P < 0.05$).

Table 15. Ground cover ratings of millet species at Jimmy Carter Plant Materials Center, 2016-2018.

Species	Cultivar	DAP ^a		
		10	20	30
Browntop Millet	Common	2.0 a*	4.7 a	5.0 a
Japanese Millet	Chiwapa	1.1 b	4.3 a	5.0 a
	Common	1.0 b	4.0 ab	4.7 ab
Pearl Millet ^b	Tifleaf 3	1.3 b	4.5 a	5.0 a
Proso Millet	Common White	1.0 b	1.4 c	1.6 c
	Dove	1.1 b	2.7 bc	3.8 bc
	Mean	1.2	3.5	4.1
	SD ^c	0.4	1.4	1.3

Note: Ground cover ratings were based on a 1-5 scale where 1= 0-20%, 2= 21-40%, 3=41-60%, 4=61-80%, 5=81-100%.

^a Days after planting

^b Pearl Millet was not included in 2016

^c Standard deviation

* Means in columns followed by the same letter are not significantly different according Dunn’s all pairwise comparison test ($P < 0.05$).

Table 16. Days after planting to first bloom and 50% Bloom for millet species at Jimmy Carter Plant Materials Center, 2016-2018.

Species	Cultivar	First Bloom ^a	50% Bloom ^b
		Browntop Millet	Common
Japanese Millet	Chiwapa	61	75
	Common	34	42
Pearl Millet ^c	Tifleaf 3	46	61
Proso Millet	Common White	30	39
	Dove	38	44

^a Days from planting until first bloom is fully opened.

^b Days from planting until 50% of the plants in the plot are blooming based on a visual estimate

^c Pearl Millet was not included in 2016

millet had similar ground cover ratings that were significantly higher than either proso millet entry. The common Japanese millet was also near the top with significantly higher ground cover ratings than the common white proso millet (Table 15).

The bloom period of the entries in this grouping varied widely showing the versatility of millet species to fit into a wide range of agronomic cropping rotations. The proso millets, common browntop millet, and common Japanese millet were among the earliest to bloom with all of them reaching 50% bloom between 39 and 44 days after planting. ‘Tifleaf 3’ pearl millet was the next to reach 50% bloom at 61 days after planting and ‘Chiwapa’ Japanese millet was the latest in this grouping, reaching 50% bloom at 75 days after planting (Table 16).

Insect ratings were low and irrelevant among all the cultivars at both rating timings. Disease ratings showed some differences in cultivars with ‘Tifleaf 3’ pearl millet having moderate disease ratings at the mid-season timing while the other cultivars in the grouping exhibited low disease ratings. At the 50% bloom rating, ‘Tifleaf 3’ pearl millet exhibited moderate disease ratings, followed by ‘Chiwapa’ Japanese millet, and common white proso millet. The other entries in the grouping exhibited low and irrelevant ratings at 50% bloom (Table 17).

Table 17. Insect and disease ratings for millet species at Jimmy Carter Plant Materials Center, 2016-2018.

Species	Cultivar	Mid-Season		50% Bloom	
		Insect	Disease	Insect	Disease
Browntop Millet	Common	0.3	0.0	0.0	0.2
Japanese Millet	Chiwapa	0.0	0.3	0.3	1.3
	Common	0.0	0.3	0.0	0.2
Pearl Millet ^a	Tifleaf 3	0.0	2.0	0.5	2.0
Proso Millet	Common White	0.0	0.4	0.0	1.2
	Dove	0.1	0.3	0.3	0.3
	Mean	0.1	0.2	0.5	0.8
	SD ^b	0.2	0.7	0.4	0.8

Note: Damage Ratings were based on a 0-5 scale where 0 = no damage and 5 = dead plants

^a Pearl Millet was not included in 2016

^b Standard deviation

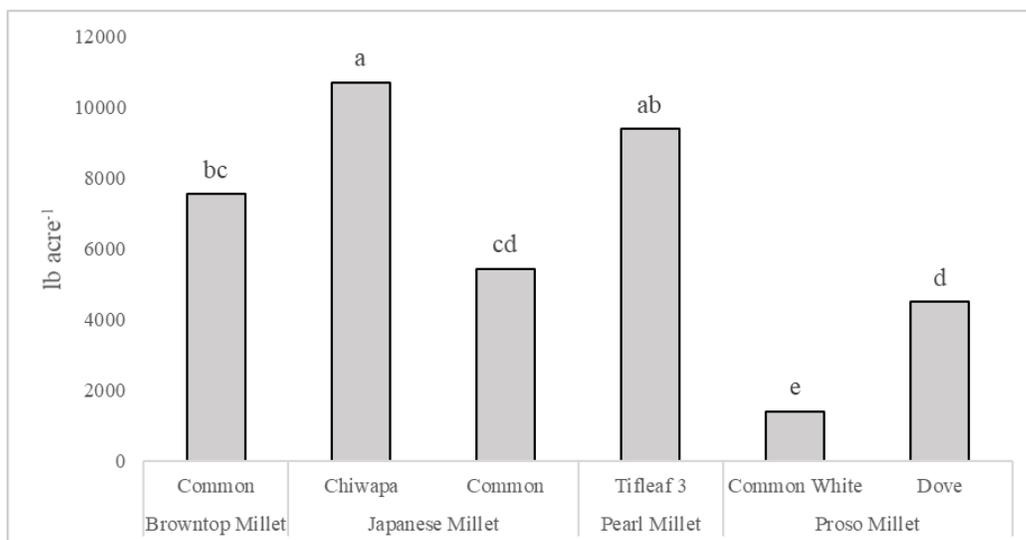


Figure 7. Mean biomass production for millet species at Jimmy Carter Plant Materials Center, 2016-2018. Bars labeled with the same letter are not significantly different according to Tukey’s HSD at $P < 0.05$.

Biomass production varied significantly among the entries in this grouping with the later maturing cultivars, such as ‘Chiwapa’ Japanese millet and ‘Tifleaf 3’ pearl millet, producing more biomass than the earlier cultivars in the grouping. ‘Chiwapa’ produced $10\,708 \pm 574$ lb acre⁻¹ while ‘Tifleaf 3’ produced 9386 ± 1309 lb acre⁻¹. Common browntop millet and common Japanese millet produced less biomass than the highest yielding cultivar, but still exhibited high biomass production at 7545 ± 458 lb acre⁻¹ and 5429 ± 333 lb acre⁻¹ respectively, especially considering the shortened maturity windows of these entries. Proso millet entries produced the least amount of biomass in the groupings with ‘Dove’ producing 4492 ± 249 lb acre⁻¹ and the common white producing 1391 ± 482 lb acre⁻¹ (Figure 7). Performance of the proso millets in this grouping combined with the reporting of ‘Dove’ proso millet is used primarily as a food source for mourning doves (Release Brochure for ‘Dove’ Proso Millet (*Panicum miliaceum* L.), 2012), which suggests proso millet cultivars are better suited for other uses than as cover crop.

Sorghum

Two sorghum cultivars were evaluated in this study. One of them, ‘Honey Graze BMR’, is a sorghum-sudangrass hybrid, while the common cultivar is a sterile, forage sorghum variant. Field emergence ratings were similar between the two cultivars at 7 days after planting, but the common sorghum had significantly higher field emergence ratings at 14, 21 and 28 days after planting. Field emergence ratings did increase substantially between 7 and 14 days after planting suggesting that more plants emerged during that time, but the ratings only increased slightly beyond 14 days after planting (Table 18). Ground cover ratings were similar between the cultivars at 10 days after planting, but the common sorghum had significantly higher ground cover ratings at 20 and 30 days after planting (Table 19).

Table 18. Field emergence ratings for sorghum cultivars at Jimmy Carter Plant Materials Center 2016-2018.

Cultivar	DAP ^a			
	7	14	21	28
Honey Graze BMR	1.9	2.2 b*	2.2 b	2.2 b
Common sterile	2.0	2.6 a	2.7 a	2.7 a
Mean	1.96	2.4	2.4	2.4
SD ^b	0.2	0.5	0.5	0.5

Note: Germination and emergence ratings were based on a 0-3 scale where 0 = poor (< 25% germination), 1 = moderate (25-64%), 2 = good (65-85%), 3 = excellent (>85)

^a Days after planting

^b Standard deviation

* Means in columns followed by the same letter are not significantly different according to Dunn’s all pairwise comparison test ($P < 0.05$).

Table 19. Ground cover ratings of sorghum cultivars at Jimmy Carter Plant Materials Center, 2016-2018.

Cultivar	DAP ^a		
	10	20	30
Honey Graze BMR	1.0	2.3 b*	3.2 b
Common sterile	1.0	3.0 a	3.8 a
Mean	1.0	2.7	3.5
SD ^b	0.0	0.8	0.6

Note: Ground cover ratings were based on a 1-5 scale where 1= 0-20%, 2= 21-40%, 3=41-60%, 4=61-80%, 5=81-100%.

^a Days after planting

^b Standard deviation

* Means in columns followed by the same letter are not significantly different according to Dunn’s all pairwise comparison test ($P < 0.05$).

Sorghum cultivars showed some differences in their first bloom time with common sorghum blooming 9 days earlier than ‘Honey Graze’. Difference in bloom between the cultivars had closed at the 50% bloom time; however, with the common sorghum reaching bloom 3 days earlier than ‘Honey Graze’ (Table 21). Disease and insect ratings were similar between the sorghum cultivars. Disease and insect ratings were much higher for the sorghum grouping than for any other grouping in the study (Table 20). In each year, sugarcane aphid (*Melanaphis sacchari*), an invasive species, and a secondary infection of black sooty mold caused by the aphids’ honeydew secretions were the cause of these higher ratings. This insect and related disease pest have been reported to cause biomass yield losses on sugarcane (*Saccharum officinarum*) and sorghum species such as forage sorghum, sudangrass, and Johnsongrass (Haar et al., 2019).

Table 20. Insect and disease ratings for sorghum cultivars at Jimmy Carter Plant Materials Center, 2016-2018

Cultivar	Mid-Season		50% Bloom	
	Insect	Disease	Insect	Disease
Honey Graze BMR	0.7	0.4	2.6	3.3
Common sterile	0.5	0.3	2.5	3.3
Mean	0.6	0.3	2.5	3.3
SD ^a	0.5	0.6	1.1	0.6

Note: Damage ratings were based on a 0-5 scale where 0 = no damage and 5 = dead plants.

^a Standard deviation

Table 21. Days after planting to first bloom and 50% bloom for sorghum cultivars at Jimmy Carter Plant Materials Center, 2016-2018

Cultivar	First Bloom ^a	50% Bloom ^b
Honey Graze BMR	62	74
Common sterile	53	71

^a Days from planting until first bloom is fully opened.

^b Days from planting until 50% of the plants in the plot are blooming based on a visual estimate

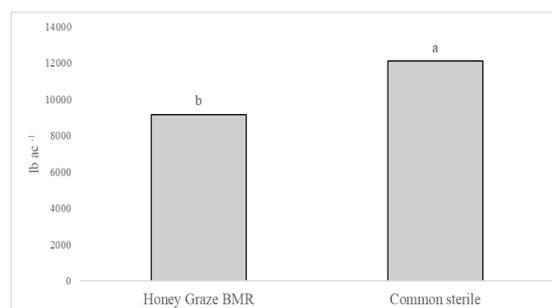


Figure 8. Mean biomass production for sorghum cultivars at Jimmy Carter Plant Materials Center, 2016-2018. Columns labeled with the same letter are not significantly different according to Tukey's HSD at $P < 0.05$.

Biomass production was significantly different between the two sorghum cultivars. The common forage sorghum produced 12100 ± 794 lb acre⁻¹ while 'Honey Graze' produced 9162 ± 954 lb acre⁻¹ (Figure 8). These results agree with Clark (2007) who reported a sorghum-sudangrass yield of 8000-10,000 lb acre⁻¹ and with Undersander (2003) who reported yields of 3-11 tons acre⁻¹ for forage sorghums and a trend for forage sorghums to yield more than sorghum-sudangrass hybrids.

Teosinte

'Chapingo' and common teosinte exhibited very similar performance throughout all the study parameters. Both cultivars had field emergence ratings of 1.8 at 7 days after planting, increasing to 2.0 by 14 days after planting and remaining consistent for 21 and 28 days after planting (data not shown). The ground cover ratings followed a similar trend with both cultivars having very low ratings at 10, 20, and 30 days after planting (Table 22).

The bloom timings for both cultivars were similar as well with 'Chapingo' reaching first bloom only three days later than the common teosinte. 'Chapingo' also held the same three day later trend for the 50% bloom rating (Table 23). Disease and insect ratings were low and irrelevant throughout the season and showed no difference between the cultivars (data not shown).

Like noted in (Release Brochure for 'Chapingo' Mexican teosinte [*Zea mexicana* (Schrad.) Kuntze], 2018), initial growth of teosinte was slow, but growth and vigor increased once the plants were established. Biomass production was high, though no significant difference was observed between teosinte sources. 'Chapingo' produced $15\,014 \pm 2301$ lb acre⁻¹ of biomass while common produced

Table 22. Ground cover ratings of teosinte cultivars at Jimmy Carter Plant Materials Center, 2016-2018

Cultivar	DAP ^a		
	10	20	30
Chapingo	1.0	1.1	1.2
Common	1.0	1.0	1.2
Mean	1.0	1.04	1.2
SD ^b	0.0	0.2	0.5

Note: Ground cover ratings were based on a 1-5 scale where 1= 0-20%, 2= 21-40%, 3=41-60%, 4=61-80%, 5=81-100%.

^a Days after Planting

^b Standard deviation

Table 23. Mean values for days after planting to first bloom and 50% bloom for teosinte cultivars at Jimmy Carter Plant Materials Center, 2016-2018

Cultivar	First Bloom ^a	50% Bloom ^b
Chapingo	102	108
Common	99	105

^a Days from planting until first bloom is fully opened.

^b Days from planting until 50% of the plants in the plot are blooming based on a visual estimate

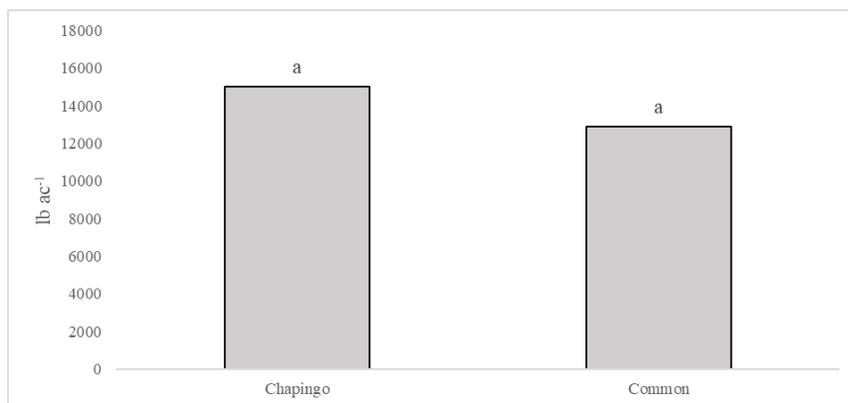


Figure 9. Mean biomass production for teosinte cultivars at Jimmy Carter Plant Materials Center, 2016-2018. Columns labeled with the same letter are not significantly different according to Tukey's HSD at $P < 0.05$.

$12\ 890 \pm 2003$ lb acre⁻¹ (Figure 9). Teosinte produced more biomass than any other grass species in the study but had low ground cover ratings during the early portion of the growing season.

CONCLUSION

Most of the cover crops options examined in this study were well adapted to the Southern Coastal Plain MLRA of the Southeast. Buckwheat did not perform well in the sandy soil commonplace across the coastal plain when planted in June but may perform better if planted in cooler time of year such as early spring. Other entries, like proso millet, partridge pea, and teosinte, are likely better suited for use in wildlife plantings than as cover crops. The millet grouping likely performed the best when considering its quick emergence and ground cover, low insect and disease damage, and high biomass yields. The sorghum species showed moderate emergence and biomass yields but had a significant problem with insect and disease damage due to an invasive aphid pest. Legumes, such as cowpea and sunn hemp, showed good early growth and moderate biomass yields with the added benefit of capturing atmospheric nitrogen. Some species, that did not perform well in all attributes tested, may have a place as a cover crop as a component of a cover crop mixture. Producers and conservation planners that wish to use warm season cover crops as part of their overall land management plan have several viable options to choose for cover cropping. More research is needed on warm season cover crops in the southeastern coastal plain as there are many other possible cultivars and additional plant species that may be well suited for this use. Additionally, research needs to continue on topics such as seeding rates, planting dates, and optimum cover crop/cash crop rotations to provide the best cover crop information to land managers.

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