Using Native Plants as Cover Crops

By

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Background:

Partridge pea (*Chamaecrista fasciculata*) is a warm-season annual legume native to most of the eastern United States. It is a pioneer plant that thrives in recently burned areas, then slowly declines in numbers in subsequent years as secondary succession proceeds. Partridge pea has been recommended for planting after other disturbances to prevent erosion and restore soil health, as it rapidly covers the ground yet does not choke out other plant species (Wikipedia, https://en.wikipedia.org/wiki/Chamaecrista_fasciculata). It is also grown as an ornamental and as bee forage for honey production. USDA cites its value as a cover crop with low to moderate water use that fixes N, supports mycorrhizal fungi, and provides wildlife and pollinator habitat (USDA Agricultural Research Service Cover Crop Chart, V 4.0, April 2023, https://www.ars.usda.gov/plains-area/mandan-nd/ngprl/docs/cover-crop-chart/).

In recent years, SARE awardee and permaculturist Patrick Johnson observed wild, self-seeding populations of partridge pea at his forest farm location in Sandston, VA that showed strong potential as a cover crop for the southeast coastal plain, providing rapid ground coverage and substantial biomass and N fixation potential. In the first year of the project, trials were conducted with four cultivars, only one of which – 'Cherokee National Forest' – germinated sufficiently to give good stands; the others were either dormant or of poor seed quality.

Trials were conducted at two sites in 2023 to compare biomass production and weed suppression of Cherokee National Forest partridge pea with a widely grown summer legume cover crop, 'Iron and Clay' southern pea (= cowpea, *Vigna unguiculata*). Fall crucifers (kale, turnip, radish) were planted after cover crop termination to assess cover crop impacts on vegetable production.

Trial locations, farming practices, soil series, and initial soil test results:

Dayspring Farm, 942 Buena Vista Road, Shacklefords, VA.

35 years organic management with cover crops and organic fertilizers.

The site is in a soil map unit of Emporia sandy loam, 2-6% slopes. Emporia is an Ultisol (fine-loamy, siliceous, subactive thermic Typic Hapludults) with a siliceous mineralogy, low-CEC clays, a sandy topsoil (A horizon), a compacted sandy E horizon, and a sandy clay loam Bt horizon (clay-enriched subsoil B horizon). It is very deep and well drained.

When soil moisture levels are adequate, deep rooted cover crops can penetrate the E horizon and help subsequent crops access the moisture and nutrient resources in the Bt. Winter rye and fall-planted radish can open the E and Bt horizons for the next season's production crops.

Emporia is prime farmland with a high crop productivity index (0.826 on a 0.0 – 1.0 scale), land capability class 2e (moderate risk of erosion), a strong tendency toward depletion of soil organic matter (SOM) and good response to biochar which stabilizes SOM.

Cover crops, especially legumes grown in combination with grasses (e.g., partridge pea or cowpea with pearl millet, foxtail millet, or sorghum-sudangrass) can help build and maintain SOM and soil fertility, especially when used in conjunction with compost and/or biochar.

A Mehlich 3 soil test (Waypoint Analytical Labs in Richmond) conducted in spring of 2023 prior to planting cover crops showed:

- Strongly acidic pH of 5.1.
- Low SOM at 1.4% (loss on ignition).
- Low Cation Exchange Capacity (CEC) at 2.7 meq/100 grams.
- Optimal phosphorus (P) at 60 ppm.
- Medium potassium (K) at 87 ppm, 8.3% base saturation.
- Low calcium (Ca) at 217 ppm, 40.2% base saturation.
- Medium magnesium (Mg) at 42 ppm, 13.0% base saturation.
- Very low boron (B) and sulfur (S) levels; low copper (Cu) and zinc (Zn).

Airport Forest Farm, 11 Early Avenue, Sandston, VA 23150

Permaculture and organic practices, composted wood chips + cover crops to build SOM.

The site is in a soil map unit of Coxville silt loam (fine, kaolinitic, thermic Typic Paleaquults), which is very deep but poorly drained, not considered prime farmland, with a moderately low crop productivity index of 0.444. The land capability class is 4W, meaning severe restrictions related to wetness, with the water table within 12 inches of the surface during winter. The A horizons of Coxville soils generally range from loamy sand to loam, though in this locale it is silt loam. The B horizon has a higher clay content, which contributes to slow water infiltration.

In contrast with the Emporia soil, Coxville is not considered responsive to biochar and its wetness could hinder cowpea and partridge pea, which require adequately drained soil to thrive.

The Waypoint soil test showed:

- Moderately acidic pH at 5.8
- Very high SOM of 10.9%, reflecting both the inherently higher SOM retention in a finer textured, poorly drained soil and the history of organic matter inputs.
- High CEC at 14.9 meq/100 grams, likely related to accrual of mineral-associated organic matter (MAOM), formerly known as the "clay-humus complex," which has abundant negative charge (CEC).
- Low P at 17 ppm.

- Adequate levels of K (114 ppm, 2%), Ca (1,964 ppm, 65.9%), and Mg (228 ppm, 12.8%).
- Adequate levels of all micronutrients.

Field trial methods:

Partridge pea (cv. Cherokee National Forest) and cowpea (cv. Iron and Clay) were grown in side-by side plots at each site. Seeds were sown with manually operated push seeders at11 lb/ac for partridge pea and 40 lb/ac for cowpea. Seeding depths were ~ 2 inch. At Dayspring Farm, two types of push seeders were compared (plate seeder and precision seeder).

Cover crops were sown at Dayspring Farm (DF) on May 11-12, at the same locale as the 2022 trials. Because the plate seeder did not work well for the cowpea, resulting in a poor stand, this half of the cowpea plot was replanted with the precision seeder on June 10. At Airport Forest Farm (AFF), an early May seeding failed because of cool, wet soil conditions, and the entire trial was replanted on May 21.

Cover crop biomass samples were taken at DF on September 4, which was 115 days after planting (DAP), except 86 DAP for the replanted half of the cowpea plot. Samples were taken at AFF on September 7, which was 109 DAP. At this time, partridge pea was 4 to 5 feet tall and in full bloom, while the cowpea was still mostly vegetative.

For each plot, five randomly selected, 2 ft X 2 ft quadrats were sampled. All aboveground plant biomass was cut, weighed fresh, and a 1.0 lb (454 gram) subsample was taken using a University of Georgia protocol for subsampling, dried in a crop dryer oven, and weighed to obtain % dry matter. Mean and standard error for fresh and dry biomass were calculated.

Cover crops were terminated during September by mowing followed by tillage.

On September 27, fall cruciferous vegetables were planted after both cover crops including kale (cv,. 'Redbor' and 'Winterbor') and turnips (a white variety and a purple top variety). At DF, each crop variety was planted in a 90-ft bed after each cover crop with two rows per bed, rows 2 ft apart. Kale transplants were set 18 inches apart within row, and turnips thinned to stand 3-4 inches apart. Crops were cultivated three times and were grown under row covers.

At AFF, kale varieties were planted in 20-ft beds with three rows per bed and 12-inch spacing within and between rows. Turnips were planted in a small area, total 10 ft of row per cultivar. spaced 12 inches apart). Crops were cultivated once, and no row covers were used.

At DF, kale was harvested on November 13 and again on December 5 (Redbor only) and December 19 (Winterbor only). Purple top turnips were harvested once on December 19 when the edible roots had attained diameters of 2-3 inches. White turnips did not reach harvest maturity.

At AFF, both kale cultivars were harvested five times between November 17 and December 21. Turnips failed to reach harvest maturity.

Total yields for each crop were converted to lb per 100 ft bed (~0.01 ac).

Results

Table 1 shows the outcome of second year (2023) trials with 'Cherokee National Forest' partridge pea (*Chamaecrista fasciculata*) and 'Iron and Clay' cowpea (*Vigna unguiculata*) at two locations with contrasting soil types. Partridge pea generated at least as much biomass at both sites as cowpea, with both crops exceeding 3 tons/ac in 109-115 days and reaching 1.7 tons/ac within 86 days for the late planting of cowpea at DF (Table 1). While biomass totals and daily accruals are numerically higher for partridge pea than for cowpea, high variability (large SEM values for partridge pea at DF and cowpea at AFF) renders this trend statistically non-significant.

The nitrogen content of the cover crops at the time of sampling and termination was not determined. Partridge pea was in full to late bloom at termination. Annual legumes at this stage normally contain ~2 – 2.5% N, equivalent to about 130-165 lb total N/ac for this cover crop. Cowpea was mostly vegetative with sporadic early blooms at termination, a stage at which annual legumes normally contain 2.5-3.5% N. Thus, the cowpea biomass is estimated to contain 85-120 lb N/ac at DF and 170-240 lb N/ac at AFF.

Table 1. Estimated fresh weight, percent dry matter, dry weight, standard error of the mean (SEM) for dry weight, and daily biomass accrual per acre for partridge pea and cowpea at two sites during 2023. Statistics are based on five randomly selected 2.0 ft by 2.0 ft quadrats for each cover crop at each site.

Location and cover crop species	Mean fresh weight, t/ac	% dry matter	Mean dry weight, t/ac	SEM dry weight, t/ac	Sample DAP	Biomass accrual, lb/ac-day
DF, partridge pea	12.72	25.6	3.26	1.03	115	57
DF, cowpea	10.05	16.9	1.70	0.11	86[a]	40
AFF, partridge pea	12.47	29.3	3.65	0.22	109	67
AFF, cowpea	11.50	30.0	3.45	0.58	109	63

[a] Four of the five randomly selected quadrats were taken from the part of the DF cowpea plot that was replanted in June because of poor functioning of the plate seeder; therefore the data were considered most representative of the late planting date and shorter growth period.

Soil samples were taken at the time of cover crop termination to determine whether the two cover crops differed in their impacts on soil health and fertility (Table 2). SOM and soil organic N appeared higher after partridge pea than after cowpea. However, pre-plant soil cores were collected from the entire area (both plots) at each site to obtain a single soil sample, while cover crop plots were sampled separately after termination. Thus, the apparent differences between cover crops likely represented pre-existing differences between the two plots or random error (unavoidable variation among samples).

Table 2. Soil test parameters measured before cover crop planting and after termination of partridge pea (PP) or cowpea (CP) cover crops at two locations.

Soil test parameter	DF, Cologne, VA			AFF, Sandston, VA		
	Before cover crop	After PP	After CP	Before cover crop	After PP	After CP
Acidity (pH)	5.1	5.1	5.1	5.8	5.7	5.7
SOM (%)	1.4	1.6	1.1	10.9	13.3	10.7
CEC (meq/100 g)	2.7	3.2	2.2	14.9	12.9	13.5
Nitrate-N, ppm	nd[a]	15	6	nd	3	5
Soil organic N, ppm	nd	630	490	nd	3,370	2,980
Estimated soil C:N[b]		12.7	11.2		19.7	18.0
Phosphorus, ppm	60	68	54	17	8	25
Potassium, ppm	87	82	50	114	43	48
Magnesium, ppm	42	49	32	228	192	201
Calcium, ppm	217	267	200	1,964	1,689	1,772

[a] nd = not determined

[b] calculated by dividing SOM% by 2 to estimate soil organic carbon (SOC), converting to ppm (= % X 10,000) and dividing by soil organic N (Kjeldahl N on soil test).

Tentative conclusions that can be drawn from the soil test data include:

- Summer legume cover crops had little effect on soil pH.
- Soil test K showed a sharp downward trend in three of the four plots, possibly related to crop uptake. Crop tissue K levels can range from 2 to 4 percent; thus, the cover crop may have taken up 100-200 lb K per acre, temporarily depleting soil K reserves. Since cover crop residues are returned to this soil, soil test K may recover after termination.
- There is a trend toward lower soil C:N ratio after cowpea than after partridge pea, possibly reflecting a higher tissue N concentration and a more rapid decomposition and N release from cowpea (mostly vegetative, succulent) than from partridge pea (full bloom, tall, thick stems).
- There is no consistent trend in other soil test parameters, so the apparent changes in individual plots are likely due to random error.

Cover crops generally dominated over weeds. At DF, the partridge pea was virtually weed-free, whereas the cowpea had some weeds growing with it. Some partridge pea plants growing near the edges of the plot flowered three to four weeks earlier than the main stand, suggesting that these early bloomers may have emerged from seed left by the 2022 planting. Several cultivars were planted at this site in 2022, of which only one – Cherokee National Forest – established a good stand; other cultivars may have required a year of weathering in the soil to break dormancy. Partridge pea is known to require cold stratification or seed coat scarification to overcome dormancy.

At AFF, weeds, especially bracken fern, were present in higher numbers in cowpea than in partridge pea. In addition, a few of the native wild population of partridge pea emerged in the cowpea, and likely also in the Cherokee National Forest partridge pea, from which it would be more difficult to distinguish.

Yields of fall brassica vegetable crops planted after cover crop termination showed no consistent difference between cowpea and partridge pea (Table 3). AT DF, the large apparent differences in yields of Redbor kale (higher for cowpea) and purple top turnip (higher for partridge pea) may be attributed to random error, especially since the trials were unreplicated. Yields were generally low, and trended higher for Winterbor than Redbor, and substantially higher at AFF than at DF.

Table 3. Yields of fall kale and turnip planted on September 27, 2023 after termination of partridge pea and cowpea cover crops.

	DF, Cologne, VA		AFF, Sandston, VA	
	Partridge pea	Cowpea	Partridge pea	Cowpea
Crop and cultivar	------------------- Pounds per 100-ft bed --------------------			
‘Redbor’ kale	7.2	12.2	24.0	21.0
‘Winterbor’ kale	16.0	14.8	43.2	45.3
Purple top turnip	18.4	7.2	-[a]	-[a]

[a] Not harvested – did not reach maturity.

Possible yield-limiting factors for the fall brassica crops include:

- Later than optimum planting dates.
- Low (acidic) soil pH, especially at DF, where yields were lowest.
- Without row cover, turnips were apparently unable to reach maturity at AFF.

Discussion

In this study, partridge pea cv. ‘Cherokee National Forest’ has shown strong potential as a vigorous, weed-competitive, N-fixing summer annual cover crop in the southeastern US coastal plain. Although native populations of partridge pea are described as reaching about two feet in height (Wikipedia, USDA Cover Crop Chart), this cultivar attained heights of 4-5 feet and generated more than three tons per acre of aboveground dry weight within 109-115 days after a May planting. This biomass is within the range considered sufficient to provide a weed-suppressive mulch if terminated by roller-crimper for no-till fall vegetable planting.

Partridge pea biomass was at least commensurate with that of ‘Iron and Clay’ cowpea, the “go-to” summer annual legume for N fixation, biomass, and weed suppression in this region. Notably, partridge pea performed equally well in widely divergent soil types and conditions:

- Sandy, well-drained, strongly acidic, and very low in SOM, CEC, Ca, and some micronutrients (DF).

- Silt-loam, poorly drained, moderately acidic, very high in SOM and CEC as a result of organic amendments, and adequate levels of cations and micronutrients. Although an early planting failed owing to wetness, both crops thrived when replanted later in May after water table levels had subsided.

Both Cherokee National Forest partridge pea and Iron and Clay cowpea generated more than three tons per acre of aboveground biomass within 109-115 days after planting, which is considered sufficient to provide weed-suppressive mulch when terminated by roller-crimper. Both crops clearly show a capacity to perform well strongly acidic soils with low SOM and nutrient levels, and thus can contribute to restoration of soil health during organic transition in coastal plains Ultisols and other lower-fertility soils.

The capacity of cover crop residues to release plant available nitrogen (PAN) directly to the following crop is inversely related to the carbon to nitrogen (C:N) ratio of the residues. Little or no N is released from residues with less than 1.5% N (C:N ~30), while half of the residue N content may be mineralized within 10 weeks after incorporation of cover crops with 3-4% N (C:N ~10-15) (Purdue University, 2016, *Cover Crops for Soil Nitrogen Cycling*, https://ag.purdue.edu/department/agry/agry-extension/_docs/cover-crops/covercropsnitrogen.pdf; D.M. Sullivan, N. Andrews and L.J. Brewer, 2020, Pacific Northwest Extension Bulletin 636, *Estimating Plant-Available Nitrogen Release From Cover Crops*, https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/pnw636.pdf). However, any cover crop nitrogen that is not immediately available to the next crop becomes integrated into the soil organic N pool, and is thus not "lost" bot serves the vital function of replenishing the soil's capacity to provide N to crops via mineralization of active SOM. Conversely some of the N released from a very low C:N cover crop might be lost to leaching or denitrification if it is mineralized more quickly than the subsequent production crop can use it.

The soil N and C:N data in Table 2 suggest that cowpea residues may release a larger percentage of their N as PAN during the 10 weeks after termination than partridge pea residues. Indeed, the stemmy texture of partridge pea at termination (when it was flowering profusely) suggests a higher C:N ratio than the succulent, vegetative cowpea at termination. Additional research including replicated trials and cover crop tissue N analysis is needed to verify this hypothesis.

Another interesting observation is that the large pool of SOM at AFF has a higher C:N ratio (18:1-20:1) than the limited pool of SOM at DF (11:1-13:1), and that nitrate-N levels were higher at DF than at AFF, especially after partridge pea (Table 2). While the silt loam soil at AFF receives regular and generous additions of composted woody materials that might contribute to SOM with a higher C:N ratio, soil fertility at DF is primarily maintained through cover crops and the use of more concentrated organic fertilizers such as pelleted poultry litter and feather meal, which may contribute to the lower C:N ratio of the SOM.

Although yields of brassica crops planted after termination of summer legume cover crops were low, the harvest data showed no evidence that either cover crop supported better yields than the other. In other words, there is no evidence in this experiment that substituting partridge pea for the region's "workhorse" summer legume cover – cowpea – entails any yield cost.

Additional research into soil C and N dynamics in cropping systems that use partridge pea versus cowpea, in conjunction with different organic amendments (composted woody materials, biochar, manure compost, etc) and on different soil types can provide valuable information to help organic producers optimize soil health, crop N nutrition, and yield.

In addition to providing biomass, carbon sequestration, plant-available nitrogen, and weed suppression, partridge pea is an excellent bee forage plant for honey production as well as providing food and habitat for pollinators and other beneficial insects including natural enemies of crop pests.

Wild partridge pea is native to nearly all of the eastern United States, which suggests that improved, regionally adapted cultivars may be available or could be developed for other parts of the eastern US from New York and the Great Lakes region to Florida and the Gulf Coast.

One possible disadvantage of partridge pea is its strong tendency to self-seed and to produce dormant seed. Because this plant species flowers over an extended period, it may set and shed some viable seeds before the producer is ready to terminate the cover crop. In addition, seeds for planting may need to be scarified (partially disrupting the seed coat) and/or cold-stratified both to ensure good stands and to minimize the number of dormant seeds in the soil that might emerge in a future year during vegetable or grain crop production. These traits might become advantageous in natural areas and conservation buffer plantings, where partridge pea can provide nourishing seed for wildlife as well as pollen and nectar for beneficial insects.