

UTILIZING BUCKWHEAT AND SUDANGRASS COVER CROPS AS FEEDSTOCK IN AERATED, STATIC COMPOST PILES



Abstract

Production of cover crops as feedstock for composting has a variety of benefits and applications. While ample information is available on a variety of compost production and use topics, little research is available on growing and using cover crop residue as a composting feedstock. This Extension publication provides preliminary data on growing and using buckwheat and sudangrass as feedstock, including crop productivity, feedstock quality, composting characteristics, and end-use characteristics of finished compost produced from graduated mixtures of cover crop residue and wood shavings. This information is intended for farmers, researchers, technical service providers, and others interested in the utilization of cover crop residue as composting feedstock.

Introduction

Compost can be produced from a variety of feedstock, including crop residue, livestock manure, food residuals, yard wastes, and other materials. Production of cover crops as feedstock for composting has been recommended in popular literature for on-farm nutrient management (Coleman 1995) as well as in the *On-Farm Composting Handbook* (Rynk et al. 1992) as a good to excellent feedstock.

While ample information on general compost production and use is available in research and Extension literature, including production and use for organic systems (Marriott and Zaborski 2015), crop benefits (Collins et al. 2016; Jackson et al. 2013; Zinati 2017), managing for herbicide residue (Greene et al. 2013; Coker 2015), management of particular feedstock such as food residuals and municipal solid waste (Farrell 2004; Flammer 2017), mortality composting (Price et al. 2009), and composting equipment and infrastructure (Farrell-Tucker and Yepsen 2009), little research is available on growing and using cover crop biomass as a composting feedstock.

There are several potential benefits of growing compost feedstock on farms. These include:

- Reduced weed-seed load in cover crop feedstock as compared to potentially weed-infested animal manures and semi-feral hay, which may contribute viable seed to the finished product.
- Lower food safety concerns that may otherwise be associated with improperly managed animal manure-based composts.
- Improved consistency and reliability in feedstock quality compared to many other sources.
- Increased feedstock supply on farms or in regions with limited access to livestock manure or organics supply streams (“organics” refers to organic materials, such as crop residue, wood shavings, or food wastes).
- Improved control over final compost characteristics.
- Reduced import of undesirable materials onto a farm, such as herbicide residue.

In addition to the benefits listed above, composting crop residue may be useful in low-tillage systems, because it provides an alternative to leaving residue on the soil surface. This is due to the difficulty of managing weeds mechanically amid abundant crop residue as well as cooler spring soil temperatures resulting from surface cover that can reduce crop productivity.

This publication begins to address gaps in basic research on growing and using cover crops for composting by identifying areas of research need and reporting data in these areas (Table 1). Data presented focus specifically on yield, feedstock characteristics, and compost performance of buckwheat and sudangrass, two summer cover crops often grown by farmers in western Washington.

Data in this publication are preliminary and not definitive. Results are from one location in one year. They can provide farmers, researchers, and others with a foundation for future work evaluating (1) the reliability of mid-scale composting reactors in feedstock studies and (2) various feedstock that farmers may want to grow for composting and soil health improvements. This work also provides an approach for evaluating cover crop biomass for on-farm composting.

Table 1. Areas of research need and preliminary data presented in this publication.

Feedstock and Compost Evaluation Measures	Compost Process and End-Product Measures
Cover crop yield measurements	Pile temperature data
Conversions of mass per acre yield to volume	Final carbon-to-nitrogen ratios of various mixtures of cover crops and wood shavings
Feedstock moisture content	
Feedstock bulk density	
Compost mix bulk densities	
Carbon and nitrogen contents	

Methodology

Two approximately half-acre fields of unirrigated sudangrass (var. Piper) and buckwheat cover crop were grown for feedstock at the WSU Puyallup Research and Extension Center in Puyallup, WA in summer 2017. Plots were established in the

southern portion of the Puyallup research fields consisting of Briscot silt-loam (coarse-loamy, mixed, superactive, nonacid, mesic Fluvaquentic Endoaquepts). Location of plots in low-lying areas was significant due to possible yield boost from subirrigation (as compared to what may be observed on dryer sites).

No fertilizer or soil amendments were applied prior to seeding, reflecting typical practices for cover crop production between cash crops. Cropping history at the site consisted of summer no-till kale and winter rye-vetch cover crop between 2015 and 2017. Field preparation consisted of primary and secondary tillage in a single pass with a rotary spader (Imants Spader, Reusel, Netherlands). Cover crops were seeded with a minimum-till drill (Land Pride 3P500, Salina, KS) in mid-July (Table 2).

Prior to cover crop harvest, three 10 ft long by 36 in wide swaths within each plot were harvested with a John Deere 935 plot harvester and weighed to obtain yield measurements. Biomass was harvested between late August and early September (Figure 1) and transported to a concrete composting pad. Prior to composting, approximately 0.67 ft³ cover crop biomass subsamples were collected to measure bulk density and porosity (WSU Puyallup[c], n.d.) and analyzed for total carbon and nitrogen at Soil Test Farm Consultants in Moses Lake, WA.

Understanding the Basics of Carbon-to-Nitrogen Ratios, Bulk Density, and Bulking Agents

Basic understandings of carbon-to-nitrogen ratios, bulk density, and bulking agents are important to successfully using crop residue as compost feedstock. The carbon-to-nitrogen ratio (C:N) of feedstocks is determined by the total carbon and total nitrogen in the materials. Total C and N estimates for feedstock are available from book values, such as those found in the *Compost Mixture Calculator* (WSU Puyallup[a], n.d.), *On-Farm Composting Handbook* (Rynk et al. 1992), or by laboratory analysis (WSU Puyallup[b], n.d.). Bulk density is determined by calculating the weight per cubic yard of feedstock.

Altogether, the bulk density, C:N, and moisture content of individual feedstocks determine the characteristics of the starting mix as a whole, which ideally has a C:N between 20:1 and 40:1, and a pile moisture content between 40% and 65%. Calculators to complete these estimations as well as protocol for determining bulk density and other parameters are available online (WSU Puyallup[c], n.d.; Walters 2016; Vermont Agency of Natural Resources, n.d.; Keener et al. 2008).

Lastly, bulking agents, such as wood shavings, straw, or chipped trees, are used to raise the starting C:N of compost mixes, increase porosity, and facilitate aeration during composting.

Some useful concepts for interpreting and applying information in this publication are as follows:

- Bulking agent materials, while important in providing aeration, should be used at lower rates when composting crop residues with wider C:N values (40:1 or greater). This will avoid boosting the starting mix C:N beyond the target range.
- Crop residues with narrower C:N values (25:1 or less) may require more bulking agent to achieve the target mix C:N range, and adequate aeration.
- Feedstock with narrower C:N values typically have higher bulk density due to moisture associated with nitrogen and high-energy carbon compounds in these often-green materials (Cogger et al. 2017).
- Feedstock with higher bulk density tend to require more bulking agent to achieve target pile porosity (ideally, 35–60% free air space).
- Feedstock with lower bulk density may require less to no bulking agent and still be able to achieve a target pile porosity value.
- Initial feedstock bulk density estimations are used, as noted above, to calculate the C:N and percent moisture content in a starting blend, while final pile bulk density numbers can indicate suitable or unsuitable uses for the compost (such as a seedling mix ingredient).
- Finished composts with C:N values lower than 15:1 reliably contribute available N during the season applied, while materials with a C:N around 20:1 or greater can either provide available N or temporarily tie up available nitrogen (i.e., immobilize nitrogen; Gale et al. 2006).

Table 2. Seeding parameters and yield of two cover crops grown for composting.

Cover Crop	Seeding Rate (lb/acre)	Planting Date	Harvest Date*
Sudangrass	35	July 14, 2017	Sept 7, 2017
Buckwheat	70	July 12, 2017	Aug 31, 2017

*Harvest date for the two cover crops differed for no other reason than logistical limitations and, as such, is a source of potential treatment bias.

Compost recipes were made by mixing the two cover crops with varying amounts of Douglas fir (*Pseudotsuga menziesii*) wood shavings, which were approximately 0.4 in² by 0.08 inches thick. Compost recipes were blended by layering feedstock into a manure spreader and dispensing the contents onto a concrete pad (Figure 2). Water was added while the materials were in the manure spreader to moisten the feedstock to approximately 65 percent moisture content, evaluated utilizing a hand squeeze method (Washington Organic Recycling Council, n.d.). Each cover crop was mixed in crop-to-shaving volume ratios of 2:1, 3:1, 4:1, and 5:1, resulting in eight separate mixtures.

Feedstock ratios were selected using the WSU Compost Calculator (WSU Puyallup[a], n.d.). The calculator produces starting compost recipe carbon-to-nitrogen ratios based on feedstock moisture content, total carbon and nitrogen, and bulk density, as obtained from a laboratory analysis. The range of 5:1 to 1:1 mix ratios were selected to bracket a wide range of starting carbon-to-nitrogen ratios (Table 3). The recommended initial carbon-to-nitrogen ratio in a compost pile, identified in the National Organic Program compost recommendations, is 25:1 to 40:1.

After mixing, blended feedstock was placed into custom two-yard capacity, static, aerated composting reactors (Figure 3), based on the “Compost Micro Bin” concept (O2Compost 2020). These free-standing, aerated bins are recommended for small livestock operations, and education and research projects, among other applications.

The reactor bins were 4 ft by 4 ft by 4 ft in dimension, made from 5/8-inch exterior-grade plywood, constructed on a pallet, and fitted with a removable tarp and wood-framed lid. Two courses of 2 in by 4 in dimensional lumber bracing, bolted at the ends, provided lateral support at roughly 1.5 and 2.5 ft from the base (Figure 4). Mixes were composted for approximately six weeks, with aeration provided via PVC manifolds and one-half hp blowers.

The piles containing buckwheat and sudangrass were built on August 31, 2017, and September 8th, 2017, respectively. Reactor temperature data were collected with a compost thermometer daily for the first seven days, then approximately every third day through day 40 and day 49 for sudangrass- and buckwheat-containing piles, respectively. Temperatures were taken at the top, middle, and bottom of the composting material. Forced aeration was provided via the 4 in aeration manifold and set to cycle on for twenty seconds and off for sixty seconds.



Figure 1. Harvesting cover crop with a John Deere 935 plot harvester. Harvesting and transporting large quantities of cover crop biomass efficiently is likely to be a challenge when using this feedstock. Haying equipment is one option, provided moist baled biomass is used immediately to avoid unwanted combustion of compressed, decomposing feedstock.



Figure 2. Mixing buckwheat and wood shavings with a manure spreader.



Figure 3. Compost reactor with aeration manifold.

Table 3. Starting carbon-to-nitrogen ratios of compost mixes.*

Feedstock Ratio	Buckwheat C:N	Sudangrass C:N
5:1	41:1	48:1
4:1	43:1	51:1
3:1	46:1	56:1
2:1	53:1	66:1
1:1	70:1	90:1

*Starting carbon-to-nitrogen ratios calculated using the WSU Compost Calculator (WSU Puyallup[a], n.d.).

Timing intervals were selected based on best estimations of aeration dynamics in these particular reactors, with the goal of providing sufficient oxygenation to support microbial decomposition while not suppressing temperatures by over-aerating the compost. Buckwheat-containing piles were aerated from days 5 to 25, and sudangrass-containing piles from days 4 to 17. The same approximate start date for aeration was targeted for each feedstock. Active aeration was terminated for all mixes when temperatures declined (when the thermophilic composting phase appeared to be ending), combined with observations that aeration may have been suppressing compost temperatures.



Figure 4. Filled compost reactor.

Results and Discussion

Data from this work provide preliminary information on the composting performance of buckwheat and sudangrass as composting feedstock. Due to limitations on the number of compost reactors available, replication was not practical and, as a result, measures of variance are not available.

Yield

Regarding yield, buckwheat and sudangrass did not produce apparently different amounts of dry biomass or volume as measured in yards per acre on an as-is basis (i.e., from the field and not dried; Table 4). Yields, in comparison with available regional data (Chris Benedict, unpublished data), indicate that buckwheat and sudangrass at this site were average to high (3,723 lb per acre compared to 3,683 lb per acre for buckwheat, and 3,883 lb per acre compared to 3,051 lb per acre for sudangrass).

Table 4. Yield of sudangrass and buckwheat on a mass and volume basis.

	Dry wt (lb/acre)	Yd/acre (as is*)
Buckwheat	3,723	48
Sudangrass	3,683	54

*As is refers to the volume of samples as harvested directly from the field and not dried.

No apparent differences were observed in cover crop production (by volume or biomass) when strip harvested triplicate subsamples were analyzed for variance using a Tukey pairwise comparison test ($p \leq 0.05$). Cover crop fields were not replicated in this trial.

Feedstock Carbon-to-Nitrogen Ratios and Bulk Density

Nitrogen content and carbon-to-nitrogen ratios of buckwheat and sudangrass feedstock did not appear to differ appreciably (Table 5). As a bulking agent, wood shavings exhibited low N content and lower bulk density than the cover crop materials. The carbon-to-nitrogen content of both feedstocks were most comparable to published values for non-leguminous hay (15:1–32:1) and higher than those for grass clippings (9:1–25:1; Rynk et al. 1992).

Bulk density of sudangrass feedstock was apparently lower (315 lb per yard) than for buckwheat (432 lb per yard), indicating its potential use as a stand-alone feedstock with little or no bulking agent. Generally, cover crop bulk density values were comparable with published bulk density values for grass clippings (300–400 lb per cubic yard; Rynk et al. 1992).

Pile Temperatures

Compost piles exceeded the temperature required for pathogen reduction (131°F) within two days at all pile monitoring locations in both cover crops (Figure 5). Temperatures remained above 131°F through day nine in buckwheat-containing piles and through day six in sudangrass-containing piles. Buckwheat compost at 5:1 showed apparent temperature separation (was warmer) in the latter phase of composting at all three positions in the reactor (low, middle, high) as compared to the lower ratios of buckwheat to wood shavings.

The termination of active aeration corresponded generally to an increase in pile temperatures (Figure 5). However the increase occurred a few days after termination in buckwheat, and a few days prior in sudangrass, indicating other factors may have been involved. Daily average and maximum air temperatures (Figure 6) markedly increased between September 20th and 28th, approximately the same time frame that pile temperatures increased (September 22–25 and day 22–25 in buckwheat, and September 19–22 and day 13–16 in sudangrass). A combined influence of aeration and ambient air temperature possibly explains the rise in pile temperature.

Table 5. Physical and chemical properties of feedstock and initial compost mixtures.

Feedstock	Bulk Density* (lb/yd)	Moisture %	% N	C:N
Sudangrass	315	79.6	1.2	35
Buckwheat	432	76.9	1.3	33
Wood shavings	142	9.8	0.2	299

*The standard deviation of three feedstock bulk density subsamples was 108 lb per yard and 23 lb per yard for buckwheat and sudangrass, respectively. Replicated laboratory data for % N and C:N for feedstock were not available.

Finished Compost C:N and Bulk Density

Composts built with a starting ratio of 5:1 crop-to-shavings yielded finished composts with the lowest apparent C:N (Figure 7). Buckwheat-containing compost with a 5:1 crop-to-shavings starting ratio had a final compost C:N of 21:1.

Bulk density measurements in buckwheat tended to increase with decreasing wood shavings (Figure 8), and this could have detrimental effects (due to decreased aeration for microbes) if wood shavings were further reduced in the starting material. Sudangrass could likely be composted well with less to no wood shavings in the initial mixture, and this would generate a final compost with a lower C:N.

Conclusions

Results in this publication provide initial data and a foundation for future trials using compost micro bin reactors to evaluate a range of potential on-farm feedstock for composting and soil health improvements.

Sudangrass and buckwheat proved to be effective compost feedstock, producing reasonable yield, no deleterious characteristics in the composting process, and finished product with a C:N that could be utilized for a range of composting applications. Previous Washington State University Extension cover crop trials indicate that sudangrass and buckwheat yields reported here are comparable to unpublished results observed elsewhere.

Finished compost C:N values close to 20:1 were achieved in the 5:1 mixture of buckwheat-wood shavings, while the same mixture with sudangrass yielded a C:N of 32. The 5:1 buckwheat-wood shavings mix, and the sudangrass mix with less (to no) wood shavings, showed potential to yield a finished compost capable of supplying slow release nitrogen for a growing crop in the season of application.

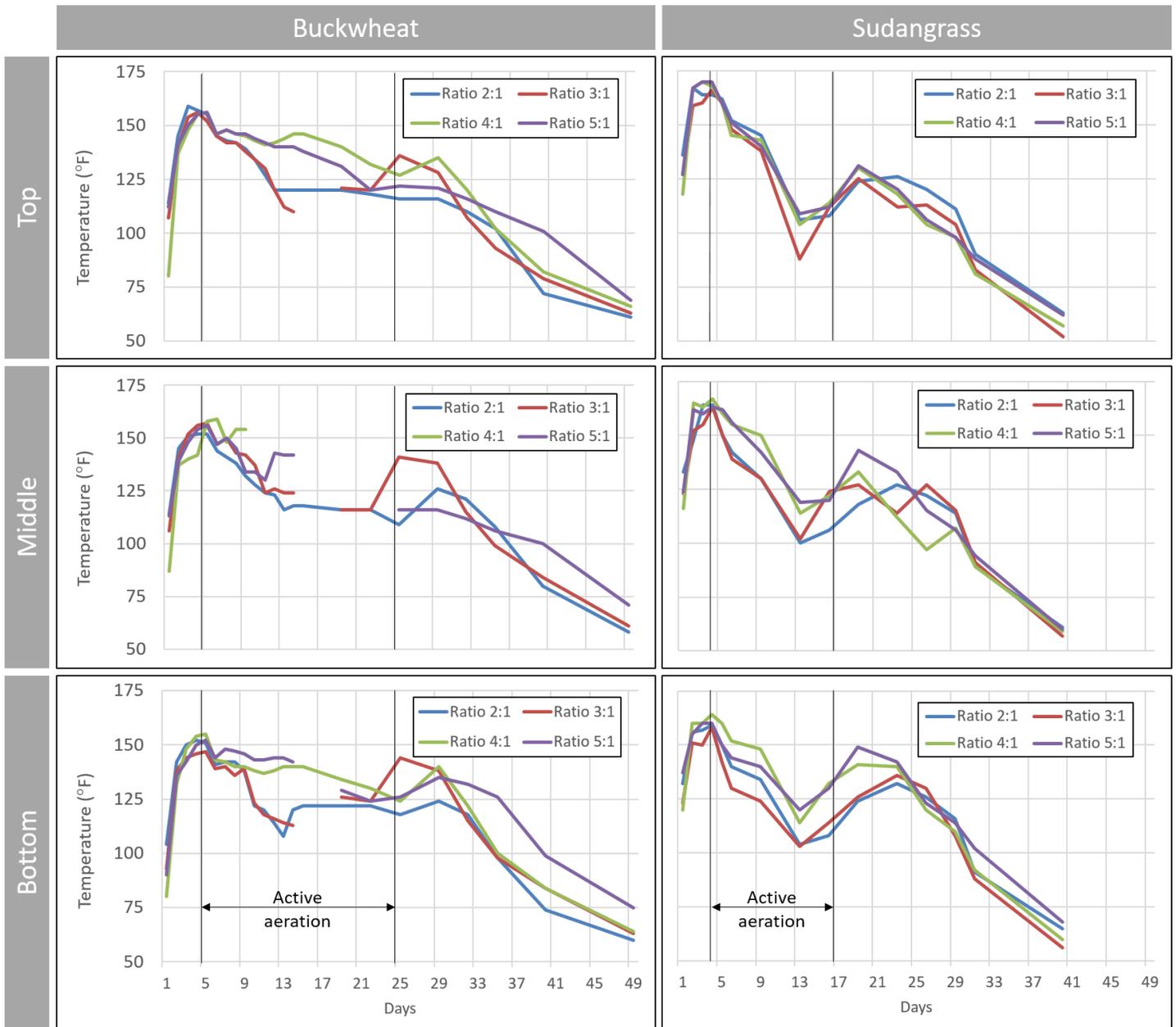


Figure 5. Compost pile temperatures during the thermophilic composting stage. Ratio is the ratio of cover crop to wood shavings; vertical lines indicate the period of active aeration.

Higher than desired starting C:N (41:1 to 70:1 in buckwheat, and 48:1 to 90:1 in sudangrass) indicate these cover crop residues should be composted with as little bulking agent as possible, while still maintaining adequate porosity.

Both buckwheat and sudangrass had similar percent N in their tissue but, because of the apparently higher bulk density of the buckwheat and the fact that materials were mixed by volume, more cover crop tissue was contributed in the composts with buckwheat than sudangrass. The lower bulk density of the sudangrass indicates that this material, in particular, could be composted with little to no bulking agent.

Bulk density measurements of feedstock proved to be variable, though less so for sudangrass. Bulk density variability generally can complicate conversions from mass to yards per acre, which

is a measure with practical importance in developing and calculating predictable compost feedstock recipes. Among those interested in using cover crop feedstock for composting, protocol for bulk density should be implemented with attention to uniformity in methodology within and between feedstock crops. These regional measurements of cover crop feedstock bulk densities are comparable with bulk density book values for grass clippings.

In this experiment, more aeration than was necessary to promote efficient and rapid decomposition (on for twenty seconds and off for sixty seconds, from, approximately, day 4 to 20) may have been provided. However, a concurrent spike in ambient air temperatures indicated environmental factors should be monitored for their effect on compost temperature dynamics.

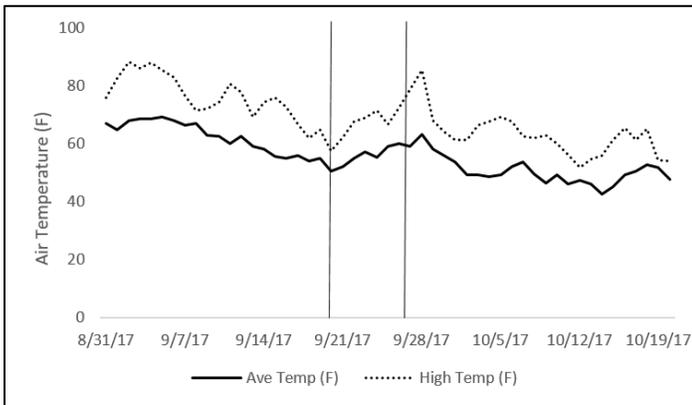


Figure 6. Daily average and high ambient air temperatures (°F) as measured at the WSU Puyallup Research and Extension Center, Puyallup, WA. The lines indicate the approximate period of time during which the piles underwent a temperature surge.

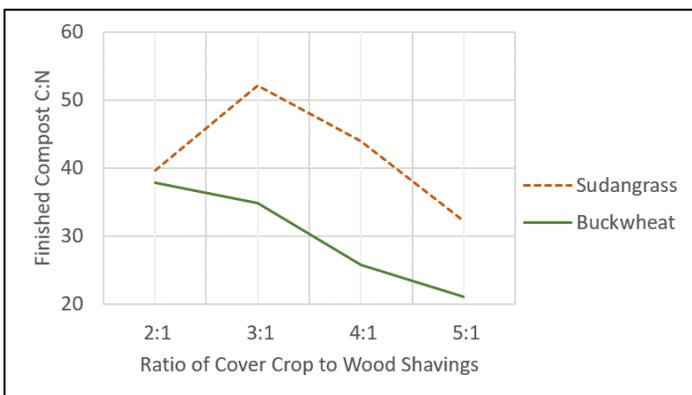


Figure 7. Carbon-to-nitrogen ratio of finished composts.

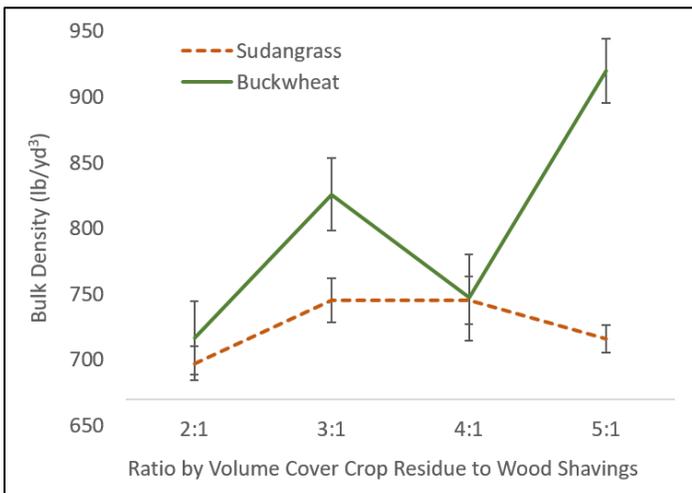


Figure 8. Bulk density of finished composts. Mean bulk density differences in finished compost between recipes for each feedstock, based on three subsamples, are denoted with non-overlapping letters using Tukey pairwise comparisons ($p \leq 0.05$).

Finally, crop residue can apparently contribute more porosity as a bulking agent than may be anticipated, a conclusion in agreement with composting resources that suggest crop residues have very good structure (Rynk et al. 1992). As a result, less airflow (by volume, or through longer intervals between

aeration) may be sufficient in piles utilizing large amounts of buckwheat, sudangrass, or other crop residue.

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