EFFECTS OF STRAW REMOVAL ON SOIL HEALTH IN TALL FESCUE SEED PRODUCTION (YEAR 1)

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Introduction

Soil health describes a soil's ability to maintain productive yields and provide ecosystem services such as reduced nutrient leaching, good water retention, and nutrient cycling. Soil health test packages are available from commercial and university laboratories, but there is no standardized set of measurements for these test packages. Generally, there is consensus that soil health test packages should include measurements of the physical, chemical, and biologic status of a soil. For example, measurements of penetration resistance, water-holding capacity, or aggregate stability are commonly used to assess the physical condition of a soil, while measurements of pH and macro- and micronutrients are used to assess the chemical condition. Measurements of respiration (often called a CO_2 burst test), organic matter (OM), active carbon (C), soil protein content, and potentially mineralizable nitrogen (N) rates can be used to evaluate the biologic status of a soil.

Management practices, such as the frequency and intensity of tillage, crop residue management, rotation sequence, and cover cropping, have been shown to influence soil health properties (Nunes et al., 2018; Awale et al., 2017). However, it is important to remember that many measures of soil health are also affected by inherent soil or site properties that cannot be changed, such as clay content, landscape position, or climate. To evaluate soils across soil types and textures, large datasets are likely needed to develop regional scoring calibrations for different texture classes (Fine et al., 2017).

Maintaining soil OM levels is generally considered to be critical to preserve soil health and function. To maintain or increase soil OM, growers must implement practices that decrease OM losses and increase inputs. The main practices that reduce OM losses are practices that reduce soil erosion and reduce the intensity and/or frequency of tillage (Sullivan et al., 2019). Organic matter inputs can come from a variety of sources, such as manure or compost amendments, crop residues, and increased crop biomass from enhanced growth or intercropping. Returning postharvest residues to the field is one method of achieving higher OM inputs to a system.

With the phase-out of field burning, most tall fescue seed crop growers have had success with baling and removing straw after harvest. Removing straw can increase the efficacy of soil-active preemergent herbicides, potentially reduce slug and vole pressure, and generate immediate farm income from straw sales. The straw is a relatively low-quality organic matter, with negligible amounts of most macro- and micronutrients, but it does contain around 100 lb/acre of potassium (K) and on average around 2,175 lb/acre of carbon (5,000 lb/acre biomass x 43.5% C) (Hart et al., 2012). Growers are aware of the need to replace K with potash fertilizer, but the effects of removing C and OM on overall soil health properties are less known. Data from Oregon systems are needed to help better inform producers of possible trade-offs associated with long-term straw removal. Data need to be collected in a way that allows us to begin differentiating the effects of management versus soil type on measures of soil health.

The objectives of this study are to:

- Evaluate soil health measurements under bale versus full-straw chop-back management practices in tall fescue seed crops.
- Explore relationships between soil health measures and key soil/site properties (e.g., texture) in tall fescue seed crops

Materials and Methods

This is a 2-year study, with data from 22 fields sampled in year 1 (2019) reported here. In 2020, an additional 20 fields will be sampled, doubling the dataset. Fields sampled in 2019 will not be resampled in 2020.

We identified paired tall fescue seed fields that were 4 years or older throughout the Willamette Valley (one 4-year-old perennial ryegrass pair was included) (Figure 1). Fields with a history of full-straw chop-back ("full-straw") were paired with similar-aged stands on the same or related soil series in a nearby field (less than 10 miles away) that had a history of continuous straw removal ("baled"). To be considered full-straw management, the field had to have been managed under the full-straw practice for 75% of stand years.

The fields sampled almost always had more than one soil series. We used Natural Resources Conservation Service (NRCS) soil maps to sample from portions of the field corresponding to dominant soil types and soil types matching the paired field. The most commonly sampled soil series was Woodburn, followed by Dayton and Amity. Other soil series sampled included Quantama, Cornelius-Kinton, Huberly, Aloha, Chehalis, McBee, Nekia, and Jory.

All fields were soil sampled between April 10 and May 2, 2019. In most cases, paired fields were sampled on the same day. Three zigzag transects per field were sampled and analyzed separately. Transects were placed semirandomly in uniform parts of the field and in portions of the field aligned with soil types in the matching paired field. Ten soil cores per transect were taken to an 8-inch depth and mixed to form a composite sample. Penetration resistance and bulk density measurements were conducted in the field. Samples for laboratory analysis were stored at 4°C until laboratory analysis was conducted at OSU's Central Analytical Lab.

The set of analyses outlined in Table 1 follows the framework and protocols outlined by Cornell University in the Comprehensive Assessment of Soil Health (CASH, https://soilhealth.cals.cornell.edu/). In addition to the soil health properties listed in Table 1, soil samples were analyzed for texture (% sand/silt/clay). Soil OM was calculated from total C analysis, but we report only OM.

Methods can vary among labs for biological tests such as respiration and potentially mineralizable N, and changes to the procedure, such as the order of soil wetting, incubation moisture, or temperature, can affect results. It is therefore essential to compare only results analyzed at the same lab and to ask the lab to share their procedure if you are unsure. The full protocol for

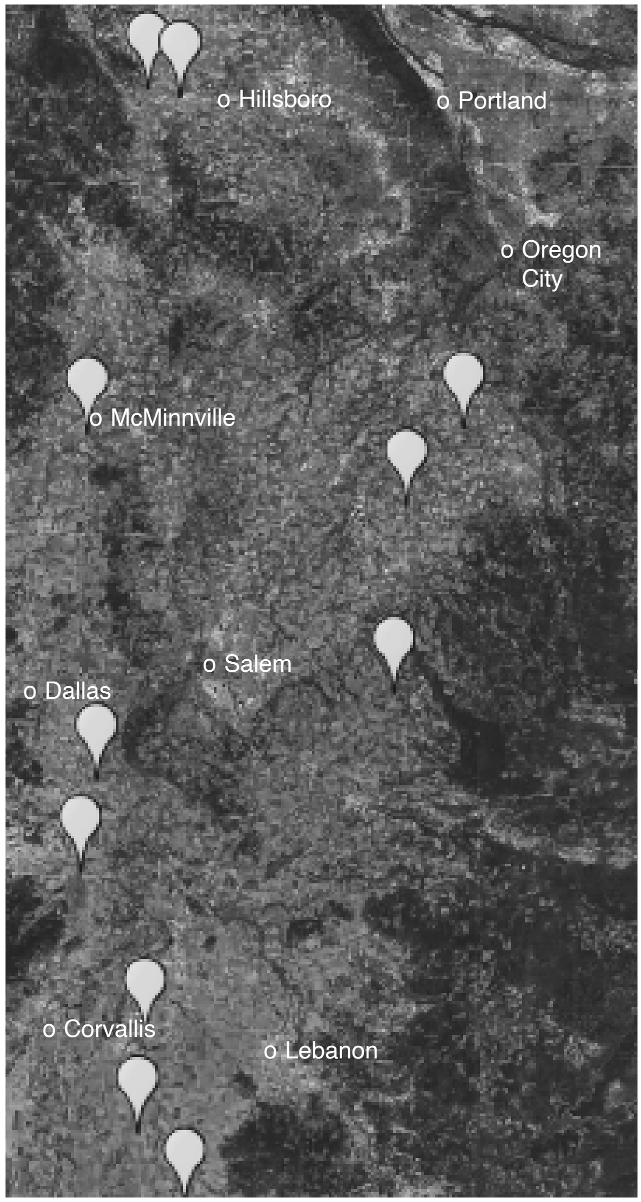

Figure 1. Map of the Willamette Valley showing the general location of the 11 sites (one full-straw and one baled field at each) sampled in 2019.

Table 1. List of chemical, physical, and biologic properties measured to assess soil health.

Chemical/nutrient	Physical	Biologic
pH	Bulk density	24- and 96-hour respiration
Mehlich-3 P, K, Mg, Ca	Penetration resistance	Organic matter % (from total C)
Electrical conductivity (EC)	Wet aggregate stability	Active carbon[1]
Cation exchange capacity		Potentially mineralizable nitrogen

[1]Often referred to as permanganate oxidizable carbon in other texts.

respiration and potentially mineralizable N analysis can be obtained from the Central Analytical Laboratory at OSU (https://cropandsoil.oregonstate.edu/cal). In brief, both analyses were performed at 23°C on air-dried soil, rewetted to 50% water-filled pore space. Respiration was measured by CO_2 accumulation at 24 and 96 hours. Potentially mineralizable N was analyzed using a 28-day aerobic respiration and measuring the accumulation of NO_3^-.

To evaluate the fit of pairing between fields, we compared the mean percent clay and sand between the two fields. Sites with greater than 5% difference in clay or sand content were considered unacceptable pairs and were not included in t-test means comparisons between the management practices. This reduced the number of sites from 11 to 7. To evaluate the relationship between soil health measures and clay or stand age, we performed regression analysis across all sites. We excluded one site from this analysis. This site was located on a Jory/Nekia soil with more than double the OM and total N than that of other sites at both fields.

Results and Discussion

Effects of straw management

Results of four key soil health measures are shown in Figure 2. Among the soil physical properties—bulk density, penetration resistance, and wet aggregate stability—we observed no differences between the management practices. Among soil chemical properties, we found higher K under full-straw management ($P = 0.03$), which is not surprising given that the straw contains high amounts of K (Figure 2). However, these results indicate that in general K removal from baling is not adequately being replaced by potash fertilizer applications. Among the biologic soil properties measured, we observed a trend of higher respiration in the 96-hour measurement in the full-straw fields (Figure 2, $P = 0.073$). The 24-hour respiration rate, which is the measure most similar to the commercially available Solvita "burst" test, tended to be higher in the full-straw fields, but differences were not significant. Respiration rates reflect microbial activity but also availability of a food source for microbes, in this case likely C from the straw.

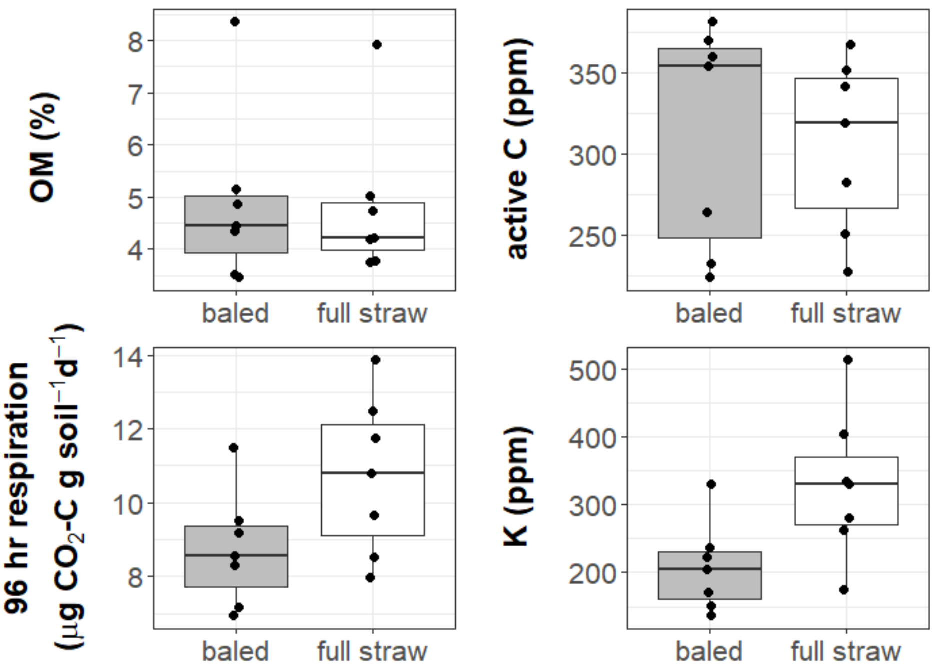

Figure 2. Box plots of key soil health properties in the baled and full-straw fields (n = 7). Each point represents a field and is the average of the three transects. The top of each box represents the 25th percentile, while the lower end of the box represents the 75th percentile (i.e., 25% of observations were above and below the boxed area). Solid bold lines indicate the mean for each management, respectively.

We did not observe any difference in OM or active C between the management practices (Figure 2). We had hypothesized an increase in OM and active C in the full-straw fields. The lack of straw management effect on soil OM could be attributed to the large size of the OM pool in these soils (mean soil OM > 4% for both practices) and/or to more dominant factors that affect OM, such as tillage and below-ground inputs. The soil OM pool is large, and it often takes a long time and significant management changes to detect changes in this pool. Depth stratification may also play a role; straw C in these systems may be more concentrated in the surface layers, but that was not visible when we sampled at 0–8 inches. In 2020, subsamples from the 0- to 3-inch depth will be analyzed for total C, OM, and active C. Active C is a smaller pool of C that is thought to be more digestible and used relatively quickly by the microbial community; it has been observed to be more responsive to management practices (Awale et al., 2017). However, we found no differences in active C between the management practices.

Effects of soil clay content and stand age

We used regression analysis to examine how soil clay content and stand age affected the measured soil health properties. The older a stand, the more time had passed since it was disturbed by tillage. Stand age ranged from 4 to 14 years, with an average of 7.5 years. Clay content ranged from 15.4 to 47.8%, with an average of 24.7%. Using field averages, we observed that as clay increased, OM, active C, water-stable aggregates, total N (data not shown), and K increased (Figure 3) ($P < 0.05$). Measures of biological activity did not show a correlation with clay content. With respect to stand age, we observed a positive relationship between stand age and OM and total N ($P < 0.05$). Respiration and active C tended to increase with stand age as well ($P < 0.1$) (Figure 4).

Conclusion

In summary, under full-straw management we observed increased K and respiration relative to the baled fields. We did not observe differences in OM or active C between the management practices. Percent OM and total N increased with stand age. This result suggests that C storage in these systems is related to the lack of disturbance (i.e., time since tillage) and is probably also impacted by below-ground root inputs during the life of the stand. For many of the soil health measures examined, we observed a strong effect of soil clay content. It is therefore critical that soil texture be analyzed and taken into account when interpreting soil health measurements. At this time, we strongly caution against using soil analyses to compare fields. Rather, these analyses should be used as relative measures to observe changes over time within a field.

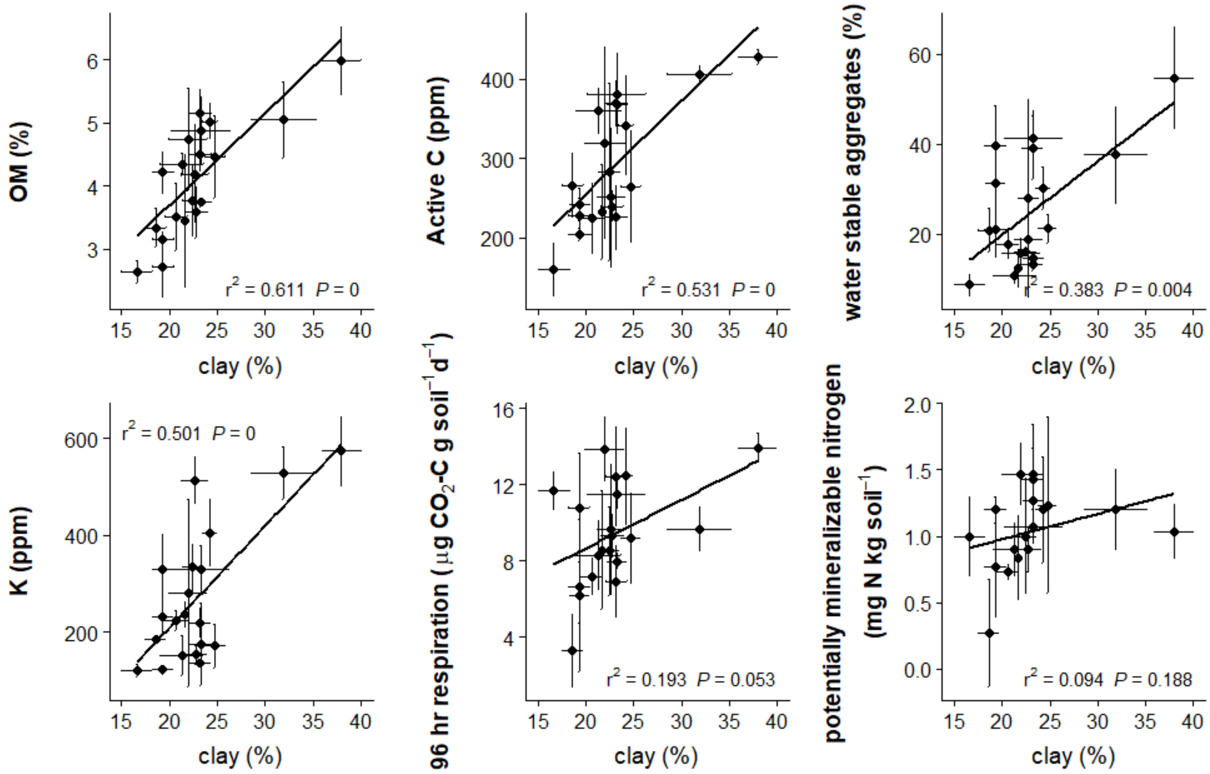

Figure 3. Relationship between soil clay content and select soil health properties across both management practices at ten sites. Each point represents a field and is the average of the three transects.

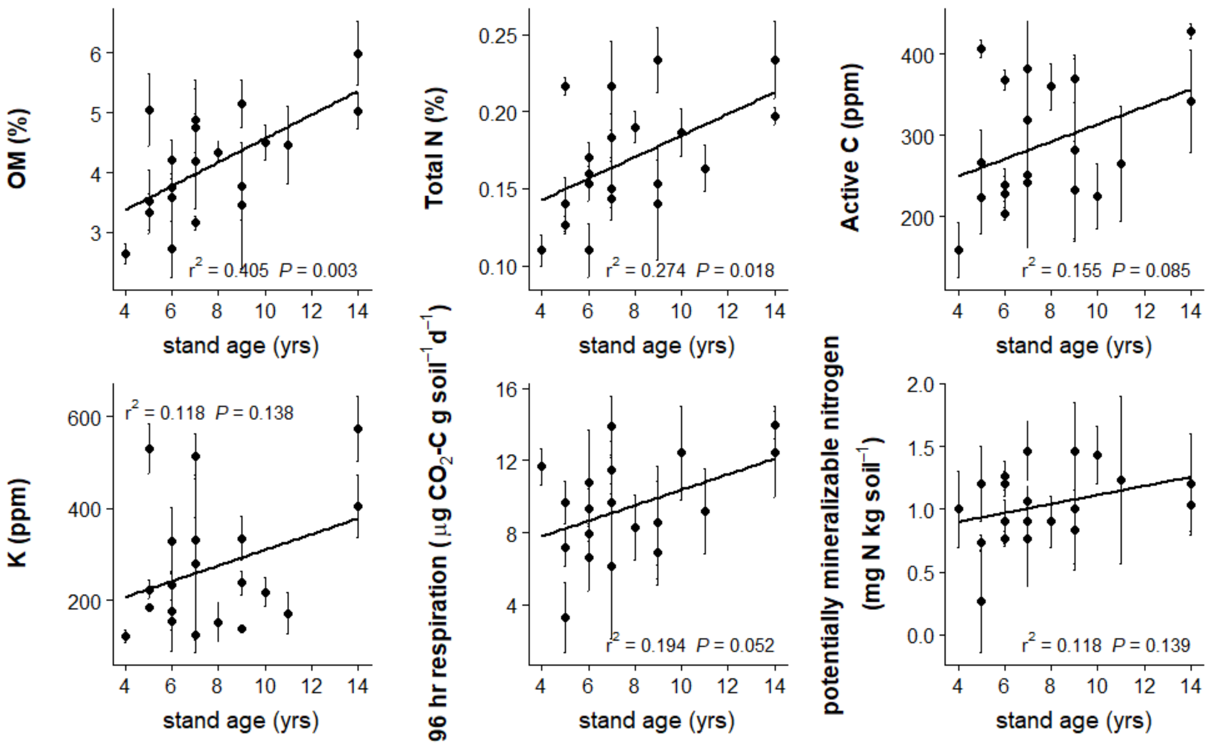

Figure 4. Relationship between stand age and select soil health properties across both management practices at ten fields. Each point represents a field and is the average of the three transects.

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Acknowledgments

The authors thank the participating growers for allowing us to sample their fields and for providing background management information. The fieldwork for this project was greatly aided by the help of Eliza Smith and Brian Donovan. We greatly appreciate the accommodating and cooperative spirit of the OSU Central Analytical Lab for their work on the analyses. Lastly, we thank Claire Phillips and Kristin Trippe of the USDA-ARS Forage Seed and Cereal Research Unit for their input and interest in discussing these data with us.