EFFECTS OF STRAW REMOVAL, CLAY CONTENT, AND STAND AGE ON SOIL HEALTH IN TALL FESCUE SEED PRODUCTION: FINAL REPORT

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Introduction

This report describes our final findings from a soil health project and expands on the dataset first presented in the *2019 Seed Production Research Report* (Verhoeven et al., 2020). The aim of this work was to determine whether straw management and stand age affect soil health outcomes in tall fescue stands. In addition, we looked at the effect of soil clay content on measures of soil health.

Soil health describes a soil's ability to maintain productive yields and provide ecosystem services such as reduced nutrient leaching, improved water retention, and nutrient cycling. Generally, there is consensus among the scientific community 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, and aggregate stability are commonly used to assess the physical condition of a soil, while measurements of pH, macronutrients, and micronutrients are used to assess chemical properties. Measurements of respiration (CO_2 burst test), organic matter (OM), active carbon (C), soil protein, and potentially mineralizable nitrogen (N) can be used to evaluate the biological 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 (Awale et al., 2017). However, it is important to remember that many soil health measurements are also affected by inherent site properties that cannot be changed, such as soil clay content, landscape position, and climate. To evaluate soils across soil types and textures, large datasets are needed to establish expected ranges for the different measures and to aid in interpretation of soil health measurements for our regionally important soils and cropping systems. This work is a first step toward establishing such a dataset for our Willamette Valley grass seed systems.

Maintaining soil OM levels is generally considered critical for preserving soil health and function. To maintain or increase soil OM, the inputs of OM into the crop system must be equal to or greater than the losses of OM in that system. The main practices that reduce OM losses are those that reduce soil erosion and those that reduce the intensity and/or frequency of tillage (Sullivan et al., 2019). Organic matter inputs may originate from a variety of sources, such as manure or compost amendments, crop residues, and increased crop biomass from greater above-ground growth or intercropping.

Returning postharvest residues to the field is one method of achieving higher OM inputs to a system. With the phaseout 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 damage, and generate immediate farm income from straw sales. The straw is a relatively low-quality organic matter, but it does contain around 100 lb K/acre and on average around 2,175 lb C/acre (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. Additional research within western Oregon grass seed production systems is needed to provide producers with reliable information regarding the effects of long-term straw removal on soil health in perennial grass seed production systems and to better understand the effects of soil clay content on measures of soil health.

The objectives of this study were:

- To evaluate soil health measurements under bale versus full-straw chop-back management practices in tall fescue seed crops.
- To explore relationships between soil health measures and soil clay content and stand age in tall fescue seed crops.

Materials and Methods

A total of 34 fields were sampled in either April 2019 (20 fields) or April 2020 (14 fields), resulting in 17 paired fields from 17 locations. Fields were identified prior to sampling and were selected to meet a set of criteria. To evaluate the similarity in soil texture between the paired fields, we compared the mean percentage of clay and sand between the two fields. Sites with greater than 5% difference in clay content were considered unacceptable pairs and were not included in the analysis. Three sites did not meet this criterion. Year 1 results of the study have been previously published (Verhoeven et al., 2020). The final dataset combined over 2 years includes 14 sites with 28 fields, each consisting of three replicate samples for a total of 84 samples.

All tall fescue seed production fields were greater than 4 years in age (one 3-year-old field pair was included to represent the North Valley). Fields with a history of full-straw chop-back ("full-straw") were paired with similarly 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.

Most fields included in the study had more than one soil series. NRCS soil maps were used to identify sample locations within the dominant soil series type within fields and, to the best of our ability, to match paired fields with soil type. The most commonly sampled soil series was Woodburn, followed by Dayton and Amity. Additional soil series included Quatama, Cornelius-Kinton, Huberly, Aloha, Chehalis, McBee, Malabon, Concord, Bashaw, Helvetia, and Laurelwood.

Sampling occurred over 2 years to break up the field work and allow us to sample enough fields at the same time of year. In most cases, paired fields were sampled on the same day. Three W-shaped transects were sampled per field. Each transect was analyzed separately and was considered a within-field replicate. Transects were placed semirandomly in uniform parts of the field that aligned with soil types in the matching paired fields according to soil maps. Ten soil cores per transect were taken to an 8-inch depth and mixed to form a composite sample. Soil bulk density measurements were collected at two points within each transect (six per field). For the remainder of the analyses, samples were stored at 4°C until laboratory analysis was conducted at OSU's Soil Health Laboratory (formerly the OSU Central Analytical Lab).

In addition to soil health properties (Table 1), soil samples were analyzed for texture (% sand/silt/clay). Soil health analysis followed the methods outlined by Cornell University in the Comprehensive Assessment of Soil Health (CASH, https://soilhealth.cals.cornell.edu/). Soil test potassium (K), phosphorus (P), calcium (Ca), and magnesium (Mg) levels were determined by Mehlich-3 extraction. Soil OM was calculated from total C analysis. Other biological soil health indicators included soil respiration and potentially mineralizable N. Both analyses were performed at 23°C on air-dried soil that was rewetted to 50% water-filled pore space. Respiration was measured by CO_2 accumulation at 24 and 96 hours. Potentially mineralizable N was determined using a 28-day aerobic respiration and measuring the accumulation of NO_3^-.

Data were analyzed using a linear mixed-effects model, with residue management and stand age as independent variables and soil clay content as a covariate. Correlation analysis with stand age and soil clay content was conducted on each management group and across the entire dataset.

Results and Discussion

Effects of straw management

Results of key soil health parameters are shown in Figure 1. There was no impact of straw management on soil physical properties (bulk density, water-stable aggregates). Among the soil chemical properties, straw management significantly affected soil test K levels, which were higher under full-straw management practices ($P = 0.002$). This result is not surprising given that the straw contains high amounts of K. Growers typically apply higher rates of potash fertilizer on fields that are baled on a consistent basis. Results from this study suggest that soil K levels are not adequately maintained with potash fertilizer applications in systems with complete straw removal by baling. In addition

Table 1. Soil health parameters measured in this study.

Chemical/nutrient	Physical	Biological
pH	Bulk density	Soil respiration (24- and 96-hour)
Electrical conductivity (EC)	Water-stable aggregates (WSA)	Total C%, total N%
Mehlich-3 extractable P, K, Ca, Mg		Active C (permanganate oxidizable C)
Cation exchange capacity (CEC)		Potentially mineralizable nitrogen (PMN)

to higher soil K in full-straw fields, soil P levels were elevated in full-straw fields ($P = 0.066$). Other soil chemical parameters were not affected by straw management.

Among the biological soil properties measured, we observed elevated respiration in the full-straw fields (96-hour test) ($P = 0.051$). 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, and higher activity may be the result of higher microbial populations and/or increased activity reflective of increased availability of food, such as C from the straw.

Overall, total and active C in soil were not affected by straw management. The lack of straw management effect on soil C may be due to the large size of the soil C pool and/or to more dominant factors that affect total C and OM, such as tillage and below-ground inputs. The soil total C pool is large, and it often takes a long time and significant management changes to detect changes in this pool. We hypothesized that depth stratification may also play a role, as straw C in these systems may be more concentrated in the surface layers. To help address this question, in 2020 we took subsamples from the 0- to 3-inch depth for analysis of soil C, OM, and active C. However, we still did not see an effect of straw management on soil C. Active C is a subcomponent of total soil C and is thought to be more digestible and utilized quickly by the microbial community. Active C has been reported to be more responsive to management practices (Awale et al., 2017). However, in this study no differences in active C were observed between straw management practices.

Effect of stand age and clay content on soil health measures

Both stand age and soil clay content were expected to influence soil health measures. The impact of stand age is attributed to the passing of time since the last soil disturbance (e.g., tillage). When soil is disturbed, decomposition of organic matter is accelerated, and soil C is typically lost. Therefore, in the absence of disturbance, soil C levels and microbial communities, especially soil fungi, are more likely to build up. Soil C content often increases with clay content because of the large and negatively charged surface area of clay particles, which absorb OM. In our study, stand age

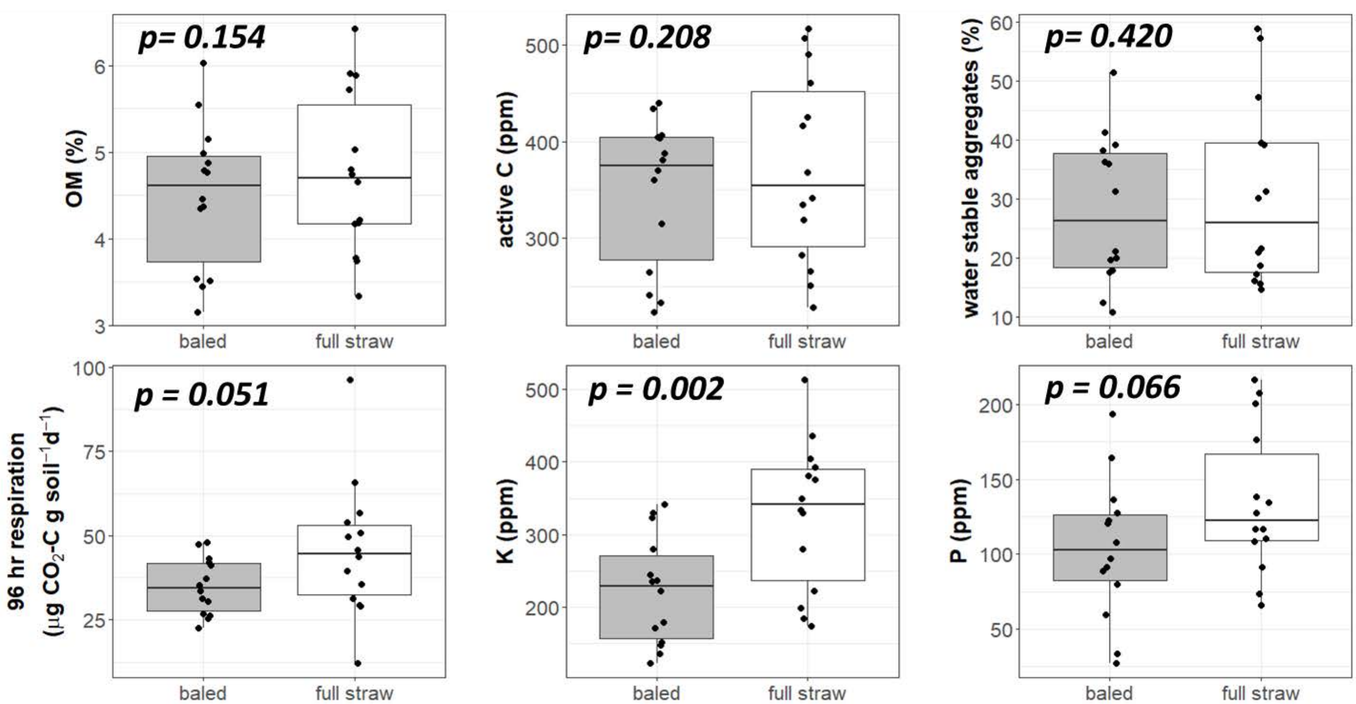

Figure 1. Box plots of key soil health properties in the baled and full-straw fields (n = 14) measured in 0- to 8-inch samples. Each point represents a field and is the average of the three transects sampled within a field. The top of each box represents the 25th percentile, while the lower end of the box represents the 75th percentile (i.e., 25% of observations were above, and 25% were below, the boxed area). Solid bold lines indicate the mean for each management, respectively.

ranged from 3 to 18 years, with an average of 8 years. Clay content ranged from 15.4 to 47.8%, with an average of 25.7%.

In this study, total soil N and C were significantly affected by stand age (*P* = 0.018 and *P* = 0.026, respectively, Figure 2). In the case of soil C, this relationship was likely driven by a correlation between soil C and stand age in the full-straw fields (*P* = 0.047), as this relationship was not observed in baled-straw fields (*P* = 0.523). These results demonstrate that with time, straw C additions can contribute to higher soil C.

Soil clay content had a significant effect on most soil health parameters. The only parameters not affected by clay content were K (Figure 2), pH, bulk density, and potentially mineralizable N. Active C, respiration (Figure 2), and Ca were positively correlated with clay content only in full-straw fields. These results indicate an interaction between clay content and straw residue, which improved these soil health parameters. Similarly, P levels declined with increasing clay content, but more so in baled-straw fields.

Conclusion

These data show that soil clay content is a powerful driver of many soil health outcomes and that it should be taken into account when analyzing soil health data from Willamette Valley soils. Comparisons between fields are valid only for soils with similar clay content and should be made with caution. Given the strong interaction between soil clay content and soil health parameters, we recommend using soil health parameters to track changes over time within a field rather than to compare fields.

When interactions between soil clay content, stand age, and residue are considered, we saw that total C, microbial activity, and soil K and P increased in fields with full straw loads. As clay content increased, we saw increases in microbial activity (measured by respiration) and active C in the full-straw fields. Soil K, and to a lesser degree soil P, and respiration also increased in full-straw fields regardless of soil clay content. Overall, the results from this study establish important baseline data for typical soils under tall fescue seed production and should help producers, agronomists, and researchers interpret soil health measures in future studies.

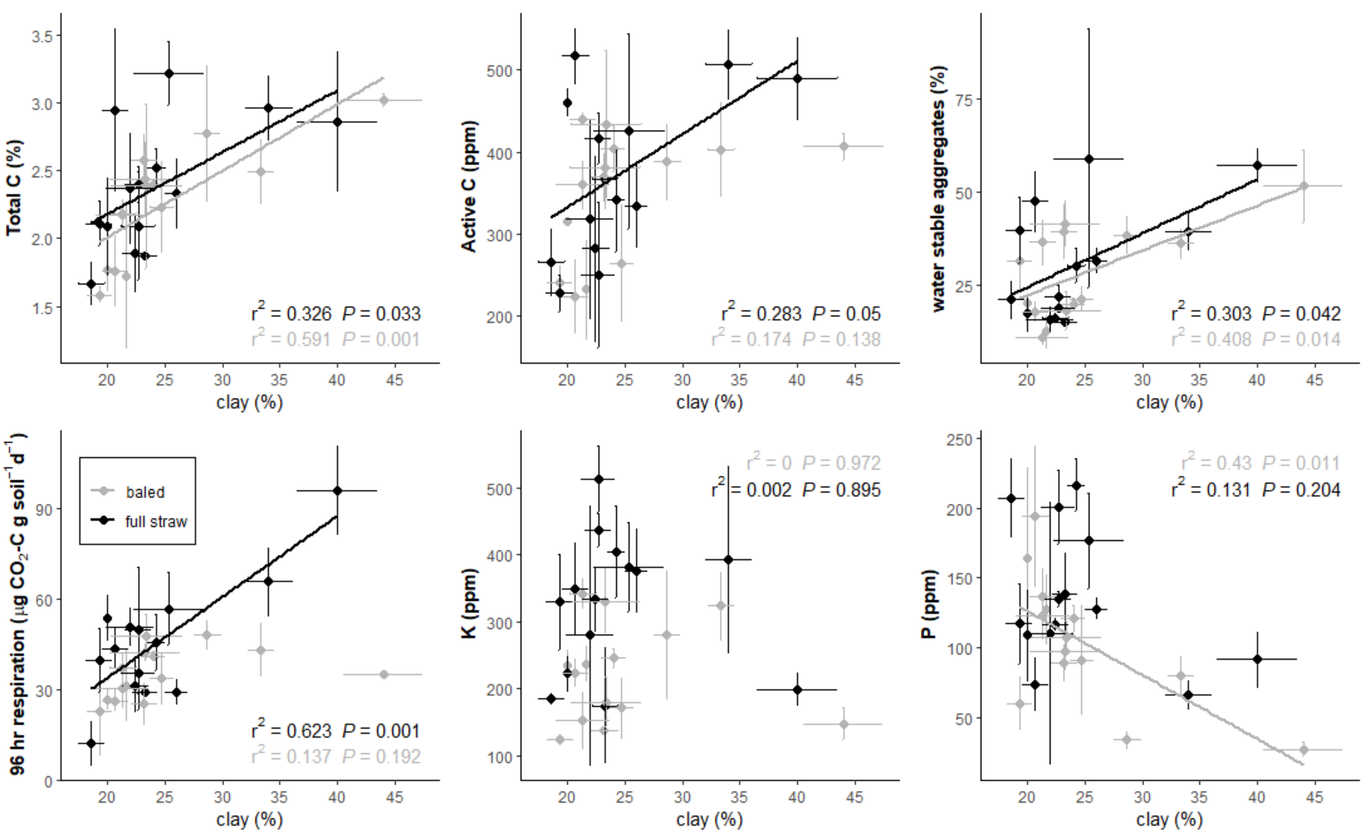

Figure 2. Relationships between soil clay content and select soil health properties for full-straw (black) and baled (gray) fields measured in soil samples from 0 to 8 inches. Each point represents a field and is the average of the three transects. A regression line is shown only when the regression was significant at *P* < 0.05.

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