WHEAT ROOTS AND RESIDUE EFFECTS ON SOIL AGGREGATION AND CARBON

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ABSTRACT

Crop residues have been identified for a number of off-field uses. Poor understanding of the role of crop residues in key soil processes limits our ability to predict sustainable crop residue removal rates. A study was conducted to compare aggregate size distribution, aggregate stability, and soil organic carbon fractions in the 0 to 3 inch depth of soils receiving surface residue and roots, surface residue only, roots only, or no residue for five years. Aggregate size distribution was similar among treatments at the beginning of the study in 2002. After five years there was a loss of aggregates from the largest size class and a gain in aggregates in smaller size classes for the roots only and no residue treatments likely resulting from less physical protection from rainfall. Aggregate stability declined in the no residue treatment in 2004 and 2006 probably caused by declining availability of nutrient and energy resources for soil biota. There was trend for lower labile carbon concentration in soils from the root only and no residue treatments likely resulting from limited carbon addition to the soil of these treatments. Crop residue provides energy and nutrients for soil biota and provides physical protection to the surface soil, both contributing to the stabilization of aggregates and distribution of carbon among pools. Roots alone were unable to maintain soil aggregation.

INTRODUCTION

Crop residues are being collected and used for particle board production, animal feed, and as a feedstock for biofuel production. These activities are likely to increase as animal production and ethanol production compete for corn grain, as brewers grain increases in availability as a animal feed, and as cellulosic biofuel production becomes viable (Perlack et al., 2005). Crop residues are known to contain mineral nutrients that can be utilized by subsequent crops following residue decomposition, serve as an energy and nutrient source for soil biota, and provide physical protection against wind and water erosion (Lal, 2004). Although we have good estimates of residue needs to manage runoff and loss of soil from erosion, our ability to estimate sustainable crop residue removal rates is limited by a lack of understanding about the role of aboveground and belowground crop residue in nutrient cycling, carbon sequestration, and aggregation processes. The objective of this study was to compare aggregate size distribution, aggregate stability, and soil carbon fractions in soils with crop residue inputs as surface residue and roots, surface residue only, roots only, or no residue for five years.

MATERIALS AND METHODS

This study was conducted at the Rogers Memorial Research Farm near Lincoln, NE. Soil at the Rogers Farm was an Aksarben (formerly Sharpsburg) silty clay loam (fine smectitic, mesic, Typic Argiudoll). The field had been cropped to rainfed no-tillage grain sorghum (*Sorghum bicolor* (L.) Moench), soybean (*Glycine max* (L.) Merr.), winter wheat (*Triticum aestivum* L.) rotation for several years and was planted to winter wheat the year prior to this study. Four treatments from a larger study comparing physical and biological properties among soils receiving various carbon sources were selected for presentation in this paper. The four treatments were: plots planted to winter wheat with crop residue returned at harvest (roots and residue), plots growing winter wheat with aboveground residue (straw) removed at harvest (roots only), a fallow plot receiving the residue (straw) from the previous treatment (residue only), and a fallow treatment (control). The experimental design was a randomized complete blocks with four replications. Winter wheat was planted in October and harvested in July each year. Treatments were applied from 2002 to 2007. The plots were not tilled during the execution of the study.

At harvest, soil samples were collected with a shovel from a depth of 0 to 3 inches in each plot. Soil clods were gently broken up and air dried. Aggregate size distribution was determined by placing a mass of soil on a nest of sieves and shaking the sieves on a mechanical shaker as described by Kemper and Chepil (1965). Wet aggregate stability was determined for the three largest size classes using the method proposed by Kemper (1965). In 2002, at the initiation of the study, soil was ground and analyzed for labile carbon (Weil et al., 2003), total carbon (Schepers et al., 1989), and particulate organic matter (Cambardella et al., 2001). In subsequent years, soils were analyzed for labile carbon.

RESULTS AND DISCUSSION

Aggregation

In 2002, all treatments had a similar aggregate size distribution with most of the soil mass contained in the largest aggregate size class (Fig. 1). A similar aggregate size distribution among the treatments at the initiation of the study was expected as the plots were part of a field that had been uniformly cropped for several years. From 2002 to 2006 the aggregate size distribution changed in all treatments with a decrease in mass of soil present in the largest aggregate size class and an increase in mass of soil present in the smaller aggregate size classes. The loss of aggregates from the largest size class was greatest for the control treatment where the mass of soil present in the largest size class in 2006 was one-sixth that at the beginning of the study (Fig. 1). In the two treatments receiving surface residue the aggregate size distribution was similar from 2002 to 2005 and than declined in 2006. The physical protection provided by the surface residue maintained aggregate structure in these two treatments. The reason for the decline in large aggregates in 2006 is not apparent. In the roots only treatment, the mass of soil present in the largest aggregate size class was less than that for the two treatments receiving residue in all years after 2002 (Fig. 1). Plant crowns and roots remaining after residue removal provided less physical protection for the soil.

Wet Aggregate Stability

There were few treatment effects on aggregate stability. Aggregate stability was lower in the control treatment in the largest aggregate class in 2004 and 2006 and in the two largest size classes in 2005 (Fig. 2). Declining aggregate stability in the control treatment is likely due to a decline in readily available energy (residue) for soil microorganisms involved in aggregation.

Soil Carbon

At the beginning of this experiment total organic carbon (2.14%), particulate organic matter (10.2 ppm), and labile carbon (Fig. 3) was similar in all treatments. This is expected since all plots were within a field that was uniformly cropped prior to this study. Total organic carbon and particulate organic carbon will be measured again at the conclusion of the study to determine treatment differences over the five years. Labile carbon was measured every year as it was thought to represent a more dynamic pool of soil carbon (Weil et al., 2003). While there is year-to-year variation in measured labile carbon, there is a trend for lower values in the root only and control treatments (Fig. 3). We attribute higher labile carbon amounts in the residue and root and residue only treatments to movement of carbon from the applied residue into the surface soil.

Soil aggregates are considered dynamic with macroaggregates breaking down and reforming periodically over time (Six et al., 2000). Macroaggregates are thought to form around fresh residue and are the site for microaggregate formation. Microaggregates are more stable and afford chemical and physical protection of soil carbon. This process is dependent on the input of organic matter into the soil. Some minimum amount of residue is required to sustain the microorganisms involved in the aggregation process (Wilhelm et al., 2007). Our results show that root and crown residue alone is not sufficient to maintain aggregation. Other studies are quantifying the amount of surface residue required to maintain soil aggregation and other critical soil functions.

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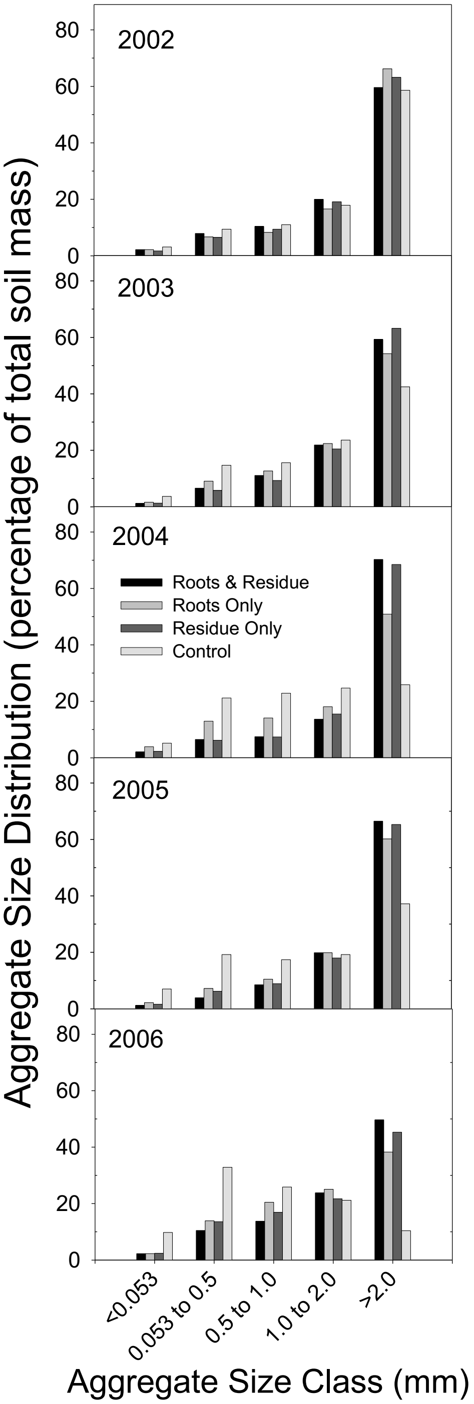

Figure 1. Aggregate size distribution from 2002 to 2006 for soils growing winter wheat and having residue returned at harvest (roots & residue), having residue removed (roots only), fallow with residue added (residue only), or fallow (control).

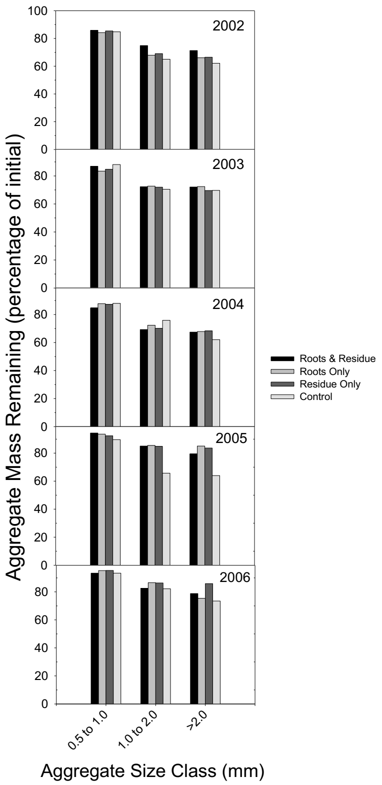

Figure 2. Aggregate stability from 2002 to 2006 for soils growing winter wheat and having residue returned at harvest (roots & residue), having residue removed (roots only), fallow with residue added (residue only), or fallow (control).

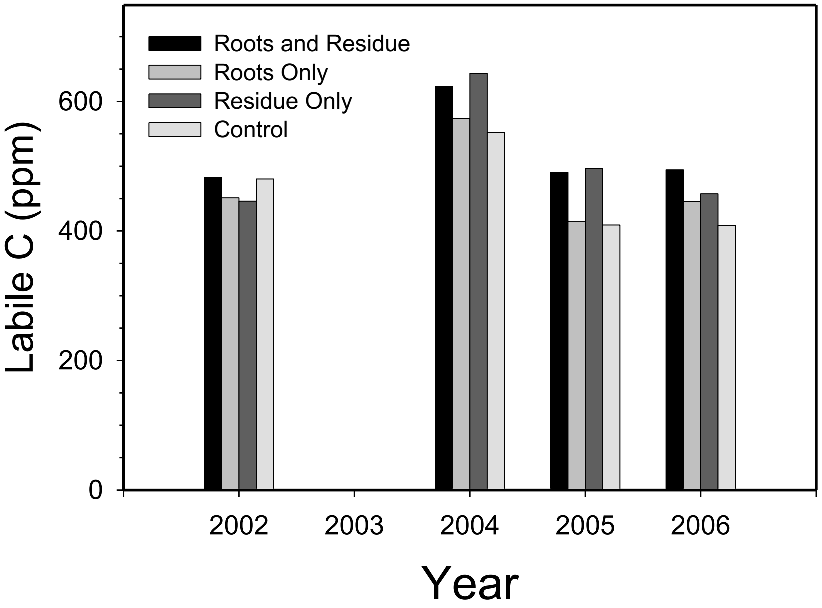

Figure 3. Labile carbon concentration from 2002 to 2006 for soils growing winter wheat and having residue returned at harvest (roots & residue), having residue removed (roots only), fallow with residue added (residue only), or fallow (control).