

Short communication

Glomalin in aggregate size classes from three different farming systems

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Abstract

Glomalin was measured in soil from farming systems managed for 8 years by chisel tillage (CT), more intensive tillage for organic (ORG) production, and no tillage (NT) on Acrisols (FAO Soil Units) in the Mid-Atlantic region of the U.S. Whole soil and aggregate size classes of >2.00, 0.50–2.00 and 0.21–0.50 mm (macroaggregates), 0.05–0.21 mm (microaggregates), and <0.05 mm (fine material) were examined. Glomalin-related soil protein (GRSP) was extracted from 1-g samples (four plots per treatment) with 100 mM sodium pyrophosphate, pH 9.0, at 121 °C in three extraction cycles. Extracts were pooled and quantified by using the Bradford protein assay. Concentrations of GRSP and total carbon (C) in aggregates were linearly related across aggregate size classes for all treatments ($\text{GRSP} = 0.101\text{C} + 0.56$, $r^2 = 0.95$). No tillage had significantly greater whole soil GRSP than did CT or ORG ($P = 0.01$). Mean values for GRSP in aggregates of NT were higher than for CT or ORG aggregates by 0.53 and 0.66 mg g⁻¹ aggregates, respectively. There were no differences among treatments in GRSP concentrations in fine material. In NT the concentration of GRSP increased as aggregate size increased in contrast to the disturbed treatments, CT or ORG, where there were no differences in GRSP concentration across aggregate size fractions. Larger proportions of GRSP were distributed in macroaggregates of NT compared to CT and ORG in contrast to larger proportions in microaggregates of CT and ORG than in NT. Although soil disturbance in ORG farming is greater than for CT farming, both treatments had similar GRSP concentrations and distributions.

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1. Introduction

Arbuscular mycorrhizal (AM) fungi produce copious amounts of an insoluble glue-like substance, glomalin, on hyphae (Driver et al., 2005; Wright et al., 1996; Wright, 2000). Glomalin is an abundant component of

soil organic matter and has been linked to aggregate stability (Wright and Upadhyaya, 1996, 1998; Nichols and Wright, 2005). Tillage is detrimental to soil structure and greatly influences the production of glomalin as shown by a significant increase in glomalin concentration and in stability of 1–2 mm size aggregates after 3 years of NT management compared with plow-tillage (Wright et al., 1999).

The need to quantify relationships between microbial processes and aggregation is challenged by the complexities of obtaining such measurements in a

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dynamic and multidimensional system (Six et al., 2004). Studies and concepts that link microorganisms and soil structure date from the early 1900s to the present and were reviewed by Six et al. (2004). Six et al. (2004) also discussed and diagramed a conceptual model of microaggregate formation within macroaggregates and postulated that particulate organic matter (POM) is the major source of carbon for glues produced by microorganisms.

Green et al. (2005) examined aggregate size distribution and total C in aggregates in the 0–5 cm depth from three management systems [no till (NT), chisel tillage (CT) and an intensively disturbed organically managed system (ORG)] to relate management, aggregates and erosion. The current study examined aggregates from the study by Green et al. (2005) to: (1) compare glomalin concentration to total C concentration in aggregates, (2) define treatment-related differences in glomalin concentration for aggregate size classes and (3) characterize treatment-related size class distribution of glomalin.

2. Materials and methods

2.1. Study site

The site, climate, crop rotations and cultural practices were described by Green et al. (2005). Briefly, the experiment was performed on Ultisols (Acrisols in FAO Soil Units) in the Mid-Atlantic area of the U.S. and had been under NT management more than 10 years before CT and ORG treatments were superimposed 7 years before sampling in 2003. Conventional management (CT) was chisel-tillage (~15 cm depth), disking with a tandem disk, and field cultivation, or only field cultivation before planting. The ORG treatment was minimally tilled for a number of years but was moldboard plowed the year samples were taken. Chemical herbicides were applied to NT and CT plots, and weed control for ORG was primary tillage, rotary hoeing, and cultivating. The NT and CT treatments were fertilized with mineral fertilizer. The ORG treatment had 5.1 Mg ha⁻¹ (dry weight) poultry (*Gallus gallus domesticus*) litter applied every 3 years, and the last application was in 2001, 2 years before sampling for this study. Cropping for CT and NT was a 3-year rotation of corn-soybean [*Glycine max* (L.) Merr.]-wheat (*Triticum aestivum* L.)/soybean, and ORG cropping was a 3-year rotation of corn-soybean-wheat/hairy vetch (*Vicia villosa* Roth.). A rye (*Secale cereale* L.) cover crop was included after corn in all cropping systems.

2.2. Samples

Samples were from four replicate plots under NT, CT or ORG management. Separation of soil size fractions was described in Green et al. (2005). Briefly, soils were collected from 0 to 5 cm depth of non-wheel traffic inter-rows at four sites in each plot and combined, air dried, and pre-sieved to retain material <6 mm. A 30-g sub-sample from each plot was wet-sieved into the following size classes: 2.00–6.00, 0.50–2.00, 0.21–0.50, 0.05–0.21 and <0.05 mm. Fractions larger than 0.21 mm were considered macroaggregates, the 0.05–0.21 mm fraction was microaggregates, and material <0.05 mm was fine material made up of silt and clay sized microaggregates and primary silt and clay particles. Non-sieved whole soil samples from each plot also were tested.

2.3. Extraction and quantification of glomalin

Extractions were performed on 1-g samples by addition of 8 ml of 100 mM sodium pyrophosphate, pH 9.0 and autoclaving at 121 °C for 1 h (Wright et al., in press). The supernatant was removed and two additional sequential 1-h extractions were performed. All supernatants from a sample were combined, the volume was measured, an aliquot was centrifuged at 10,000 × g and glomalin-related soil protein (GRSP) was measured by the Bradford protein assay (Wright et al., 1996; Rillig, 2004). Values reported represent the means of two replicate Bradford assays.

2.4. Total soil carbon

Total carbon was measured by dry combustion as described by Green et al. (2005).

2.5. Statistical analysis

Differences among the treatments and within treatments were tested by one-way analysis of variance, after Bartlett's test of equal variances was satisfied, using Statistix (Analytical Software, Tallahassee, FL). Results were considered significantly different at the $P < 0.05$ level. Pair-wise comparisons were by LSD ($\alpha = 0.05$).

3. Results and discussion

3.1. Carbon and GRSP in soil size-fractions

Total C in all size-fractions (data from Green et al., 2005) across treatments was significantly linearly

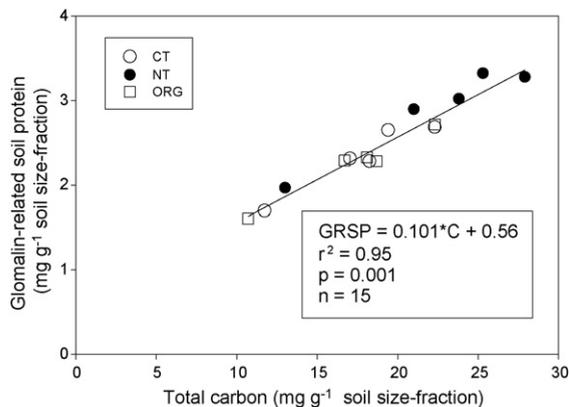


Fig. 1. Relationship between organic carbon in wet-sieved soil size fractions and glomalin-related soil protein (GRSP), measured by the Bradford protein assay, from plots managed by no tillage (NT), chisel tillage (CT), or organically with moldboard and disk tillage (ORG). Mean values for four replicate plots are shown.

related to GRSP (Fig. 1). Because glomalin is a glycoprotein (Wright et al., 1996), soil organic C generally is related to GRSP concentration (Wright et al., 1996; Nichols and Wright, 2005). At this site GRSP and total C were tightly correlated.

3.2. Treatment effects on whole soil concentrations of GRSP

Mean values and standard deviation (S.D.) for whole soil GRSP were: NT = 2.86 ± 0.15 , CT = 2.27 ± 0.28 , and ORG = 2.09 ± 0.33 mg g⁻¹ soil. Significant differences were detected in GRSP concentrations among treatments ($P = 0.01$). No-till had significantly greater GRSP than did CT or ORG, and CT was equivalent to ORG. Concentrations of GRSP in these soils was within the low range of 2.5–15 mg g⁻¹ GRSP in 1–2 mm aggregates for 11 undisturbed soils in the Mid-Atlantic States geographic area (Wright and Upadhyaya, 1998).

3.3. Treatment effects on GRSP concentration in soil size-fractions

Concentrations of GRSP were different among treatments in three of the five fractions examined (Fig. 2). In fractions where GRSP concentration varied significantly due to treatment, concentrations in NT fractions were consistently high.

Within treatments NT aggregates showed significant differences in GRSP concentration among size class fractions ($P < 0.001$) (Fig. 2) and showed an increase in GRSP as aggregate size increased. Concentration comparisons of GRSP within CT or ORG size classes

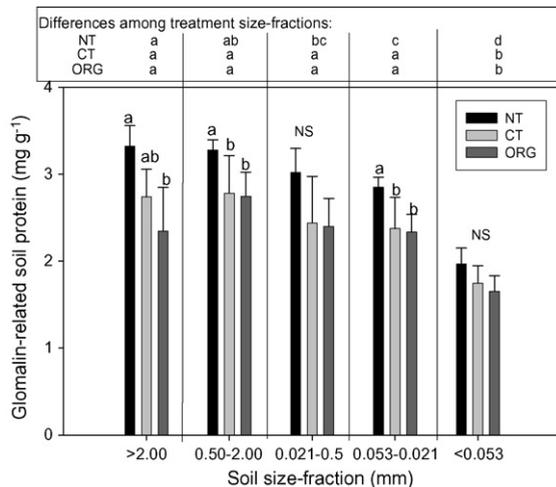


Fig. 2. Concentration of glomalin-related soil protein, measured by the Bradford protein assay, in wet-sieved soil size classes from plots managed by no tillage (NT), chisel tillage (CT), or organically with moldboard and disk tillage (ORG). Bars within a group that have different letters above them are different ($P < 0.05$, LSD $\alpha = 0.05$). NS = no differences in treatments was detected. In the box above the graph differences are indicated among size fractions within each treatment ($P < 0.03$, LSD $\alpha = 0.05$).

showed significant differences ($P = 0.02$ and 0.004 , respectively), but all of the aggregated size fractions were equal and the fine material had significantly less GRSP than the aggregated material.

Mean GRSP values for aggregates were used to compare losses due to tillage. The GRSP under NT was 0.53 and 0.66 mg g⁻¹ of aggregates greater than values for CT and ORG, respectively, or 0.07 and 0.08 mg g⁻¹ aggregates years⁻¹ over the 8 years that CT and ORG had been superimposed on the NT treatment. The difference between CT and ORG GRSP concentration was slight even though ORG management with moldboard and disk plowing was harsher than chisel tillage for the CT treatment. It is possible that an additional vetch cover crop every third year in ORG plots (Green et al., 2005) supported greater activity of AM fungi compared with CT plots and overcame the effects of the additional disturbance for weed control in ORG plots. Further work is needed to define specific factors that may mitigate disturbance effects on AM fungal activity in CT and ORG management systems.

3.4. Distribution of GRSP in soil size-fraction on a whole soil basis

Distribution of GRSP in size-fractions on a whole soil basis was different for NT compared with CT and ORG (Fig. 3). Distributions of GRSP in CT and ORG

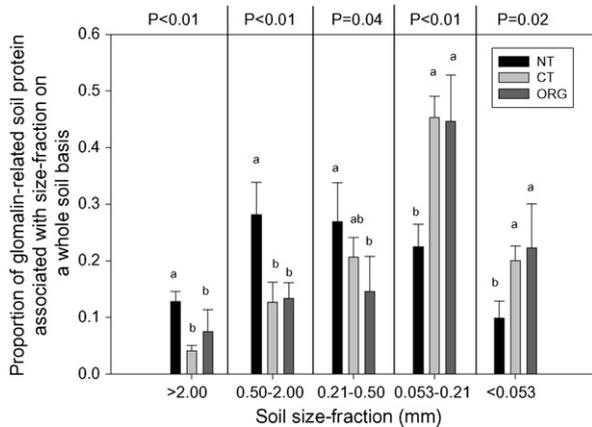


Fig. 3. Distribution of glomalin-related soil protein, measured by the Bradford protein assay, in wet-sieved soil size classes of plots managed by no tillage (NT), chisel tillage (CT), or organically with moldboard and disk tillage (ORG). One-way analysis of variance significance for each size class is shown above the size class, means separations (LSD $\alpha = 0.05$) are indicated by different letters above bars within a size class.

treatments showed similar patterns. Distribution of GRSP followed the same pattern as C and N, and the controlling factor was aggregate size-fraction distribution for treatments (Green et al., 2005). The NT treatment had a significantly larger proportion of GRSP in macroaggregate size-fractions than the CT or ORG treatments. The CT and ORG systems had a greater proportion of GRSP in microaggregate than NT. High values for GRSP in fine material (<0.053 mm) from CT and ORG indicated that ca 20% of glomalin was not incorporated into aggregates.

3.5. Formation of aggregates

We propose that glomalin be considered as a microbial glue in aggregate formation in addition to POM-derived glues. All treatments in this study had statistically equivalent concentrations of GRSP in the fine fraction (Fig. 2). However, across aggregate size fractions of treatments there were two patterns. In NT the concentration of GRSP increased as aggregate size increased. In the disturbed treatments, CT or ORG, there were no differences in GRSP concentration across aggregate size fractions. Significant increases in GRSP as aggregate size increased for NT (Fig. 2) and the greater proportion of aggregates in NT on a whole soil basis (Fig. 3 and Green

et al., 2005) may reflect the glue-like nature of glomalin within and among microaggregates. Further work will be necessary to compare aggregate size classes over a broad range of soil types to compare tillage treatment effects on C and glomalin, particularly among soils that accumulate large or small amounts of glomalin.

3.6. Summary

These results show differences in GRSP concentration and distribution in different soil size-fractions due to soil management. Concentrations and distributions of GRSP were different between NT and CT or ORG and were similar for CT and ORG. Glomalin may contribute to binding within microaggregates and macroaggregates.

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