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Distribution of glomalin-related soil protein and soil organic carbon in water-stable aggregate fractions of citrus rhizosphere

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ABSTRACT

Soil organic carbon (SOC) and glomalin-related soil protein (GRSP) play an important role on soil aggregate stability, but few studies to examine distributive characteristics of these soil aggregate binding agents within water-stable aggregate (WSA) fractions. This study examined the distributive characteristics of SOC and GRSPs within five WSA sizes: macroaggregates (2.00–4.00, 1.00–2.00, 0.50–1.00 and 0.25–0.50 mm) and microaggregate (<0.25 mm) isolated from the rhizosphere of 24-year-old citrus trees (*Citrus unshiu* grafted on *Poncirus trifoliata*) in Jingzhou, China. Percentage of $WSA_{2.00–4.00\ mm}$ was the highest and $WSA_{<0.250\ mm}$ was the lowest in the citrus rhizosphere. In general, easily-extractable GRSP (EE-GRSP) and total GRSP (T-GRSP) were significantly higher in $WSA_{0.50–1.00\ mm}$ and lower in $WSA_{1.00–2.00\ mm}$. Difficultly-extractable GRSP (DE-GRSP) increased with the increase of WSA sizes, but SOC increased with the decrease of WSA sizes. Among three GRSP fractions, only T-GRSP was significantly positively correlated with WSA.

KEYWORDS

Bradford-reactive soil protein;
Water-stable aggregate sizes;
Macroaggregate and microaggregate;
Soil organic carbon.

INTRODUCTION

Glomalin, an alkaline-soluble protein produced by spores and hyphae of arbuscular mycorrhizal fungi (AMF)[1,2], releases into soil as glomalin-related soil protein[3]. In general, GRSP contains as high as 25% of soil carbon[4], with a slow turnover which can reach as high as 6–42 years in soil[5]. GRSP also attributes to soil organic carbon sequestration through its function on soil aggregation. It seems that GRSP is one of soil organic carbon pool[3]. Furthermore, GRSP is of importance in improving soil structure, since GRSP was generally considered as aggregate binding agents[6,7], thereby, conferring a significantly positive relationship with soil aggregate stability[8,9].

Although previous studies have demonstrated the important role of GRSP on soil carbon sequestration and soil aggregation[5,9], the studies of contribution of the GRSP to soil aggregate and soil carbon were mainly focused on farmland and aggregate in 1–2 mm size class and less on different aggregate fractions. For example, Wright et al.[10] reported that GRSP varied in aggregate size classes in a farmland. However, the knowledge available on GRSP in aggregate sizes are limited, especially in fruit orchid.

In this study, we monitored the distribution of GRSP fractions and SOC in macroaggregate and microaggregate, but also revealed the relationship between GRSP and SOC in the rhizosphere of *Citrus unshiu*.

MATERIALS AND METHODS

Experimental site and soil sampling

The 24-year-old *Citrus unshiu* grafted on *Poncirus trifoliata* was used as the plant material and was planted in a citrus orchard of Yangtze University (30°362 N, 112°142 E), Jingzhou, Hubei province. The annual mean temperatures of the site are 15.9 to 16.6!, annual rainfall ranges from 1100 mm to 1300 mm and 80% rainfall occurs during march to October.

We collected the soil samples (Xanthi-udic ferralsol) from 0–15 cm depth rhizosphere of four similar trees with random selection in July, 2013. A total of 2 kg soil samples was obtained from each citrus tree. Following that, soils were well mixed, air-dried, ground, and then sieved (4mm) to remove any stones and roots.

Parameter determinations

Determination of percentage of water-stable aggregates (WSA) at the size of 2.00–4.00, 1.00–2.00, 0.50–1.00, 0.25–0.50, and <0.25 mm was followed by the method of Wu et al.[11] based on a soil aggregate analyzer (DM200–IV, Shanghai, China).

Determination of GRSP fractions from different size WSAs was carried out following Koide and Peoples[12]. Here, fraction 1 was defined as easily-extractable GRSP (EE-GRSP), and fraction 2 was called as difficultly-extractable GRSP (DE-GRSP). Total GRSP (T-GRSP) is the sum of EE-GRSP and DE-GRSP.

Soil organic carbon (SOC) content in aggregates was measured using the dichromate oxidation spectrophotometric method[13].

Statistical analysis

The data were statistically analyzed by one-way variance (ANOVA) with SAS software. The significant differences were compared with the Least Significant Differences (LSD) at the 5% level.

RESULTS AND DISCUSSION

Percentage of water-stable aggregate of citrus rhizosphere

Figure 1 showed that in citrus rhizosphere, percentage of WSA at different sizes ranked as $\mathrm{WSA}_{2.00–4.00\ \mathrm{mm}} > \mathrm{WSA}_{1.00–2.00\ \mathrm{mm}}$ H” $\mathrm{WSA}_{0.50–1.00\ \mathrm{mm}}$ H” $\mathrm{WSA}_{0.25–0.50\ \mathrm{mm}} > \mathrm{WSA}_{<0.25\ \mathrm{mm}}$.

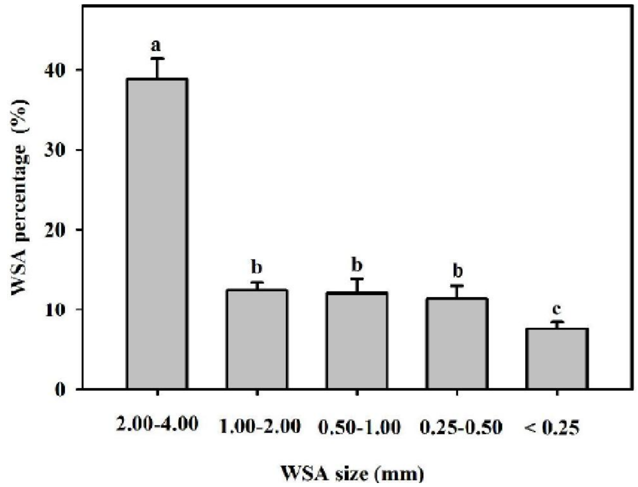

Figure 1 : Percentage of water-stable aggregate in the citrus rhizosphere. Date (means ± SE, n = 3) above the bars followed by different letters show significant differences at P < 0.05

Glomalin-related soil protein within water-stable aggregate fractions

In the present work, average value of T-GRSP concentration in different WSA fractions was 6.73 mg/g dry soil (TABLE1), which was significantly lower than that in tropical rain forest[14], permanent forest[15] and grassland[6,16]. This inconsistency may attribute to different concentration of humic substances and different AMF communities in the citrus rhizosphere. Humic substances are more abundant in those areas and could co-extracted with glomalin[17,18], consequently resulting in higher value of T-GRSP in soils[19,20]. On the other hand, citrus rhizosphere soils were dominated by *Glomus* species[21] and those AMF species tend to produce less glomalin[22]. However, T-GRSP concentration in our study was significantly higher than that in a citrus orchard[23]. This may due to different sampling seasons and sampling years, since glomalin had a temporal destruction in a year[24] and glomalin could accumulate in the soil along with time[5].

TABLE 1 : GRSP and SOC concentrations within different water-stable aggregate fractions

Water-stable aggregate size (mm)	GRSP concentration(mg/g dry soil)			SOC concentration (mg/g dry soil)
	EE-GRSP	DE-GRSP	T-GRSP	
2.00–4.00	3.03±0.16b	3.86±0.13a	6.89±0.18b	11.41±0.16b
1.00–2.00	2.40±0.35c	3.81±0.14a	6.21±0.23c	11.64±0.19a
0.50–1.00	3.53±0.22a	3.76±0.06a	7.29±0.26a	11.74±0.23a
0.25–0.50	2.84±0.22b	3.60±0.08b	6.44±0.26c	11.86±0.19a
< 0.25	3.02±0.25b	3.44±0.10b	6.46±0.33c	12.06±0.20a

Note: Date (means ± SE, *n* = 3) within a column followed by different letters show significant

GRSP concentrations varied in different WSA size fractions (TABLE 1). EE-GRSP and T-GRSP concentrations were always significantly higher in WSA$_{0.500\ mm}$, and significantly lower in WSA$_{1.00–2.00\ mm}$. EE-GRSP concentrations within WSA fractions ranked as WSA$_{1.00–2.00\ mm}$ < WSA$_{0.25–0.50\ mm}$ ≈ WSA$_{<0.25\ mm}$ ≈ WSA$_{2.00–4.00\ mm}$ < WSA$_{0.50–1.00\ mm}$, DE-GRSP as WSA$_{<0.25\ mm}$ ≈ WSA$_{0.25–0.50\ mm}$ < WSA$_{0.50–1.00\ mm}$ ≈ WSA$_{1.00–2.00\ mm}$ ≈ WSA$_{2.00–4.00\ mm}$, and T-BRSP as WSA$_{1.00–2.00\ mm}$ ≈ WSA$_{0.25–0.50\ mm}$ ≈ WSA$_{<0.25\ mm}$ < WSA$_{2.00–4.00\ mm}$ < WSA$_{0.50–1.00\ mm}$. Those results are partly in agreement with the findings of Wright et al.[10] and Wu et al.[23], which reported that GRSP concentrations increased with the increase of WSA sizes in farmland soil and citrus soil, respectively.

Soil organic carbon within water-stable aggregate fractions

Previous studies have demonstrated that SOC was more abundant in macroaggregate than in microaggregate under no-till soil management conditions[25-27]. In the present work, however, SOC contents increased with the decrease of WSA size (TABLE 1). This result is consistent with the observations of Zhang et al.[28], who reported that SOC contents increased with the decrease of WSA size under both no tillage and ridge tillage practice conditions. Six et al.[29] also reported that microaggregate protect SOC more effectively than macroaggregates.

TABLE 2 : Correlation coefficients among three fractions of GRSP, SOC and WSA

	EE-GRSP	DE-GRSP	T-GRSP	SOC	WSA
EE-GRSP	1.00	-0.09	0.95**	0.04	0.31
DE-GRSP		1.00	0.21	0.20	0.41
T-GRSP			1.00	0.10	0.49*
SOC				1.00	-0.06
WSA					1.00

Note: *and ** indicate significant differences at *P* < 0.05 and *P* < 0.01, respectively

Correlation analysis

SOC is generally of great importance on aggregate stability and affect WSA[30]. However, no positive correlations between SOC and WSA were found in this study (TABLE 2). In fact, SOC was slightly negatively correlated with WSA, which is consistent with the findings of Huang et al.[31]. EE-GRSP significantly positively correlated with T-GRSP (TABLE 2), suggesting that EE-GRSP was the main part of T-GRSP in citrus rhizosphere. On the other hand, SOC did not significantly correlated with any GRSP fractions, implying that GRSP fractions did not give the key contribution to SOC pools. In GRSP and SOC, we only found the significantly positive correlation of T-GRSP with WSA(TABLE 2), suggesting that in citrus rhizosphere aggregate stability was highly correlated with T-GRSP but not other soil binding agents, and confirming the key role of T-GRSP on soil aggregation[7].

CONCLUSIONS

GRSP and SOC exhibited distributive characteristics within WSA fractions of the citrus rhizosphere. EE-GRSP and T-BRSP always significantly higher in WSA$_{0.50–1.00\ mm}$, and significantly lower in WSA$_{1.00–2.00\ mm}$. DE-GRSP increased with the increase of WSA sizes, but SOC increased with the decrease of WSA size. T-GRSP was positively correlated with WSA rather than other GRSP fractions and SOC, suggesting that T-GRSP may be more important in soil aggregation than other soil aggregate binding agents (SOC, EE-GRSP, and DE-GRSP), at least in citrus rhizosphere.

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