General Impact Factor (GIF): 0.875
Scientific Journal Impact Factor: 1.205

e- ISSN: 2394-5532
p- ISSN: 2394-823X

International Journal of Applied And Pure Science and Agriculture
www.ijapsa.com

Studies on relationship between total glomalin and soil aggregates in perennial fruit crop orchards

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Abstract

Glomalin is a glycoprotein produced by Arbuscular Mycorrrhizal (AM) fungi, which play an important role in soil aggregation. The presence of total glomalin was studied in different fruit crop orchards viz., Anona (Anona spuamosa), Guava (Psidium guajava), Mango (Mangifera indica) and Sapota (Manilkara achras (Mill) Forsberg) to understand the total glomalin in relation to soil aggregation in perennial fruit crop orchards. Soil samples were collected from inside and outside drip circle of plants and then graded into different aggregates by using various sieves viz., 2.0, 3.0 and 4.0 mm. All the samples were analysed for total glomalin content and AM fungal spores by adopting standard methods. The results indicated that the soils from outside drip circle had significantly higher total glomalin (6.20 - 9.42 mg g^{-1} soil) compared to the soils from inside drip circle (5.60 - 7.10 mg g^{-1} soil) in all the fruit crops orchards. This observation clearly indicated that the undisturbed fruit crop orchard soils contain 9.60% - 24.6 % higher total glomalin compared to inside drip circle of guava, mango and anona orchards. Among the different soil aggregates, the 3-4 mm size aggregates had significantly higher total glomalin compared to 2.0 mm soil aggregates, which clearly indicates the role of glomalin in soil aggregation process. The total AM fungal spores were observed to be significantly varies between different aggregates, but not much proportinate variation among different size of aggregates.

Keywords: Glomalin, soil aggregation, Arbuscular mycorrhizal fungi, drip circle, fruit orchards

I. INTRODUCTION

Soil structure plays an important role on the functioning of soil, which supports plant and animal life, controlling environmental quality, nutrient and gas fluxes and water quality [1]. Soil structure is expressed as the degree of stability of aggregates, which is one of the critical factors and moderates physical, chemical, and biological processes in soil [2]. In soil, a combination of primary mineral particles with organic and inorganic materials forms aggregates. In general, formation of soil aggregation is complex, during the process of soil aggregation the microaggregates formed from organic molecules tied to clay and cations, which in turn linked with other microaggregates and forms macroaggregates [1]. In brief, soil aggregation is the result of rearrangement, flocculation and cementation of soil particles wherein soil organic carbon, polycations, clay minerals and, especially microorganisms play a key role [1] in this process. Among the various group of microbes, the aggregating power of soil microrganisms were classified in the following order *viz*., fungi and a few gum forming bacteria > actinomycetes > yeasts > most bacteria [3, 4]. Among the various factor, the soil aggeregation property is considered as one of the important factors for maintaining soil health.

Soil aggregation is a complex process which is mainly dependent upon secretion of microbial polysaccharides or gummy substances that hold soil particles together. There are number of microbes are reported to be involved in soil aggregation, however Arbuscular Mycorrhizal (AM) fungi are considered to be primary soil aggregators. Glomalin, a brown to red-brown colored glycoprotein produced by AM fungi and is a important component of soil organic matter [5], which act as cementing agent for aggregation of soil particles [6]. AM fungi are ubiquitous root-symbiotic fungi in the phylum Glomeromycota [7] and it forms generally mutualistic association with roots of the majority of higher plants and play a potential role in plant nutrition [8, 9].

In soil, AM fungi are reported to produce glomalin [5] and it contains around 30–40% C [10]. Normally, the glomalin enters into soil after the death of extraradical hyphae and is commonly called as Glomalin Related Soil Protein (GRSP) [10]. The GRSP is very good source for soil organic carbon since it accounted for 4 to 5% of total C and nitrogen (N) source and this contribution was higher than the contribution of microbial biomass C in Hawaiian soils [10]. Hence maintaining the level of GRSP is very important for soil fertility [11] management. Some of the scientific evidences clearly documented the strong positive correlation between GRSP and Soil organic carbon [12, 13] and which indicates the AM fungi importance on the soil C cycle.

The carbon within the glomalin molecule may resist decomposition for up to 100 years. It permeates organic matter, binding it to silt, sand and clay particles, forming clumps. This type of soil structure is more stable enough to resist wind and water erosion, but porous enough to allow air, water and roots move through it [14]. In general, AM fungi takes carbon from plant for their growth and then produce glomalin, [15]which is highly positively correlated with soil aggregate stability [5].There are many reports available on AM fungi and their interaction on different crop plants, but no much information on glomalin in relation to different soil aggregates in perennial fruit crop orchard in India. In view of above, the present study was initiated with main aim to understand the occurrence of glomalin in relation to different soil aggregates in prenial fruit crop orchards.

II. MATERIAL AND METHODS

Soil samples were collected from the inside and outside drip circle of 8-12 years old different tropical fruit crops *viz,* Anona (*Anona squamosa*), Guava (*Psidium guajava* L*),* Mango (*Mangifera indica),* Sapota *(Manikara sapota*) orchard at Research Farm of ICAR- Indian Institute of Hortcultural Research, Bengaluru, Kranataka, India. In each fruit crop orchard, the composite 1000 g soil samples were collected separately at 0-20 cm depth within 2 m radius (inside drip circle) of tree canopy and between trees (out side drip circle). Random soil samples from 10 trees were mixed as one composite sample, like these five samples were collected from each orchard. The data generated from four different orchards were pooled and presented in this study.

The soil samples collected from different fruit crops were grouped into four categories *viz*., <2.0 mm, 2.0 mm, 3.0 mm and 4.0 mm size aggregate by using standard sieves and then all the samples were air-dried, ground, and sieved for the analysis of total glomalin. The soil total glomalin estimation was done as described by Wright and Upadhyaya (1996). The soil containing AM fungal spore was estimated by using wet sieving and decanting method [16]. The data were analyzed using Web Agri Stat Package version WASP1.0, Graphpad Prism 5 software and subjected to one way analysis of variance (ANOVA). Treatment difference were evaluated using least significant difference (LSD) at $p<0.05$.

III.RESULTS AND DISCUSSION

The soil samples collected from inside drip circle of anona, guava, mango and sapota were analysed for total glomalin (TG) content and results are given in table 1. In all the fruit crop orchards, < 2mm soils recorded significantly higher TG (6.8 -9.4 mg g^{-1} soil) compared to other soil aggregates. Among the different fruit crops, the TG content was found higher in mango (9.4 mg g^{-1} soil) orchard followed by sapota (8.7 mg g^{-1} soil) and guava (8.6 mg g^{-1} soil). The average content of TG from different fruit crop orchards indicated that soils of < 2mm size had significantly higher (8.38 mg g^{-1} soil) compared to other soil aggregates (4.79 -7.01 mg g^{-1} soil). Among different macro aggregates (2.0, 3.0 and 4.0 mm size), the TG content was found to be increased with increasing size of aggregates in all the fruit crop orchards. However, the TG was found significantly higher in 4.0 mm size soil aggregate (5.7 – 8.2 mg g^{-1} soil) compared to 3.0 mm (5.2-5.8 mg g^{-1} soil) and 2.0 mm (4.4 -5.0 mg g^{-1} soil) aggregates. The overall results of TG content in different fruit crop orchards indicated that around 42.8 % higher TG was recorded in 4.0 mm size soil aggregate compared to 2.0 mm size soil aggregate. This finding clearly showed the importance of TG on soil aggregation process in perennial fruit crop orchards.

Table 1. Total glomalin (mg g^{-1} soil) content of soils collected from inside drip circle of different fruit crop orchards

Different soil aggregates	Anona	Guava	Mango	Sapota	Average
2mm	5.0	4.4	5.2	4.6	4.79
3mm	5.2	5.6	5.5	5.8	5.54
4mm	5.7	6.3	8.2	7.8	7.01
<2mm	6.8	8.6	9.4	8.7	8.38
SEM	0.030	0.045	0.058	0.053	
CD(p=0.05)	0.066	0.099	0.125	0.116	

Values are mean of five replications SEM – Standard error means CD (p=0.05) - Critical difference at 5 % level

The TG content in outside drip circle of anona, guava, mango and sapota are presented in table 2. Similar to inside drip circle, the TG was found significantly higher (7.3 -10.0 mg g^{-1} soil) in < 2mm soils of all the orchards compared to other macro aggregates. In all the orchards, the 4.0 mm size aggregates had significantly higher TG (6.5 - 8.1 mg g^{-1} soil) compared to 3 mm and 2 mm size aggregates. The average TG content from different fruit crop orchards indicated that 4.0 mm size aggregate had 31.1 % higher TG compared to 2.0 mm size aggregate. The TG content either from inside or outside drip circles from different orchards indicated that the fine soils (< 2mm size) had significantly higher TG compared to all other aggregates. This might be due to the fine soils (< 2mm size) were the collective fraction of all other maco aggregates (2.0, 3.0 and 4.0 mm). Similarly in 2009, Bedini and his co-workers reported that there was significant variation in total glomalin content in different macro aggregates.

Table 2. Total glomalin (mg g^{-1} soil) content of soils collected from outside drip circle of different fruit crop orchards

Different soil aggregates	Anona	Guava	Mango	Sapota	Average
2mm	5.3	5.8	4.7	4.8	5.15
3mm	5.7	5.9	6.3	6.1	6.00
4mm	6.5	7.6	7.7	8.1	7.48
<2mm	7.3	9.4	10.0	9.4	9.03
SEM	0.034	0.049	0.058	0.057	
CD(p=0.05)	0.075	0.106	0.126	0.123	

Values are mean of five replications SEM – Standard error means CD (p=0.05) - Critical difference at 5 % level

The occurrence of AM fungal spores were analysed in different soil aggregates and the results are given in table 3 and 4. In general, outside drip circle (2.2- 4.8 number per gram soil) had slightly higher AM fungal spores as compared to inside drip circle (2.2 – 4.2 number per gram soil). Out of four different fruit orchards, sapota and mango soils recorded slightly higher AM fungal spores compared to anona and guava orchards. It might be due to the variation of age of the plant, the sapota and mango orchard was more than 12 years old, where as the guava and anona was 7- 8 years old.

Table 3. AM fungal spore population in soils collected from inside drip circle of different fruit crop orchards

Different soil aggregates	AM fungal spores (number per gram soil)			
	Anona	Guava	Mango	Sapota
2mm	2.2	2.4	3.2	3.2
3mm	2.4	2.0	2.2	2.8
4mm	2.5	2.2	2.4	3.0
<2mm	3.2	2.8	3.6	4.2
SEM	0.01	0.01	0.02	0.02
CD(p=0.05)	0.03	0.03	0.04	0.04

Values are mean of five replications SEM – Standard error means CD (p=0.05) - Critical difference at 5 % level

Table 4. AM fungal spore population in soils from outside drip circle of different fruit crop orchards

Different fruits	AM fungal spores (number per gram soil)			
	Anona	Guava	Mango	Sapota
2mm	3.2	3.0	3.4	3.0
3mm	2.2	2.6	3.0	3.2
4mm	2.6	2.8	3.2	2.6
<2mm	3.6	3.2	4.4	4.8
SEM	0.02	0.01	0.02	0.02
CD(p=0.05)	0.04	0.03	0.04	0.05

Values are mean of five replications SEM – Standard error means CD (p=0.05) - Critical difference at 5 % level

The total glomalin content from guava, mango, and anona orchards clearly indicated that the undisrupted soil (outside drip circle) had higher TG (6.2 -9.42 mg g^{-1} soil) content than soils from inside drip circle (5.6 – 7.1 mg g^{-1} soil). Similar to TG content, the AM fungal spore population was slightly higher in outside drip circle. The above finding clearly indicates that the frequent disturbance of soil may hinder the microbial properties in fruit crop orchard. So the agronomic practices like zero or minimum tillage may improve TG content as well as AM fungal spore proliferation in perennial fruit crop orchards. Some earlier studies clearly proved the positive relationship between AM fungi and glomalin content in soil. The elimination of AM fungal growth by incubating soil without host plants found decrease the GRSP concentrations [17]. Similarly, in long-term grassland plots, the elimination of AM fungi by fungicide treatment found drastically decreased the GRSP concentrations [10].

In soil, the aggregate stability as an index of soil structure and it is responsible for water-holding capacity and SOC storage [18] Many studies proved that AM fungi producing GRSP is positively correlated with soil aggregate stability in different type of soils [5].Similarly, in citrus rhizosphere, TGRSP and EE-GRSP were positively correlated with water stable aggregate and it clearly shows the importance of GRSP role on stabilizing soil aggregates in rhizosphere[10, 19]. In general, macroaggregates are formed and stabilized by root, fungal hyphae and GRSP [20]Some findings clearly documented the role of AM fungal hyphae and GRSP on soil aggregate stability of different size fractions [5, 21]. The present findings amply proved that the undisrupted soils of different fruit crop orchards had higher total glomalin than frequently disturbed soil (inside drip circle). Hence, the good management practices like zero or minimum tillage may improve soil aggregate properties in perennial fruit crop orchards.

IV. ACKNOWLEDGEMENTS

The authors gratefully thank Director and Head, Division of Soil Science, ICAR-Indian Institute of Horticultural Research, Bengaluru for the support and infrastructural facilities.

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