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Improvements in aggregate stability of recently deposited sediments supplemented with tea waste and farmyard manure

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Abstract

Organic matter supplement is well-known to influence soil aggregate stability (AS), but the corresponding change in recently deposited fine sediment is not documented well. In this study, improvements in aggregate stability of recently deposited sediment supplemented with the farmyard manure (FYM) and tea waste (TW) during 18-week incubation under controlled conditions. The FYM and TW were applied to recently deposited sediment at different doses (0, 2.5, 5, 7.5, 10, 12.5, and 15 % on weight base). The AS was determined at different times after adding organic matter (2nd, 4th, 6th, 8th, 10th, 14th, and 18th weeks) using wet sieving methods. The results showed that aggregate stability of deposited sediment treated with TW was statistically significantly higher than these of samples treated with FYM. Aggregate stability increased with increasing doses of both FYM and TW. In the FYM applied samples, AS reached the highest value at the end of second week, and declined within the following incubation period. However, in the samples treated with TW, AS reached the highest value at the end of eighth week. The results of this study were clearly indicated that tea waste and farmyard manure applications noticeably increased aggregate stability of recently deposited sediment, therefore it is suggested that TW and FYM could be used for structural stabilization of sediments.

1 Introduction

The stability of structure refers to the resistance that the soil aggregates offer to the disintegrating influences of water and mechanical manipulation (Jury and Horton, 2004). The aggregate stability is one of the most important factors of soil resistance against degradation (Jozefaciuk and Czachor, 2014). Aggregate stability influences the macro scale physical behavior of soils including erosion, infiltration, and permeability, thus aggregate stability is a useful indicator of the suitability of the soil structural condition for favorable crop production (Lal, 2006). Colazo and Buschiazzo (2010) revealed that, the size and stability of soil aggregates are the main factors affecting sensitivity of the soil against wind erosion. Similarly, Shin et al. (2010) reported that the characterizations of soil aggregation relate to appropriate indicator of sensitivity of soil against interrill erosion.

Organic matter is the most important component of soil aggregate stability, because soil organic carbon acts as a binding agent and as a nucleus in the formation of aggregates (Bronick and Lal, 2005). The addition of organic matter can increase the resistance of aggregates to the dispersive and dissolution actions of water through the formation of relatively strong intra-aggregate bonds (Paré et al., 1999). In respect to these remarks, the addition of organic matter has been used in the restoration of degraded soils for a long time. Wiesmeier et al. (2015) reported that, green manure application to the soil significantly increased macro and micro aggregate rates. Additionally, Bandyopadhyay et al. (2010) also reported that the application of farmyard manure increased aggregate stability in soils. In consequence of the differences in the composition of organic material, the variability of effects on aggregate stability emerges as an expected result. Knowledge of the application rates that reach aggregate stability to the maximum level is essential to organic matter recommendation rates. Moreover, determination of the application periods depends on the effective time that emerges as a result of application of organic materials.

Recent studies conducted in the field and greenhouse conditions indicated the fact that differences among organic matter sources (Alagöz and Yilmaz, 2009; Turgut and Aksakal, 2011; Karami et al., 2012; Hueso-González et al., 2014), application dozes (Mbagwu, 1989; Paré et al., 1999; Nyamangara et al., 2001; Jozefaciuk and Czachor, 2014) and incubation times (Bravo-Garza et al., 2010) led to variability of aggregate stability. In these studies farmyard manure, green manure, composts and other organic wastes have been used as organic matter sources. However, the effects on the soil properties of tea waste that obtained at the end of tea production process has not been studied before.

Sediment is described as solid particles generated by the disintegration process of organic and inorganic materials (Bortone, 2006). These particles, found in various shapes and sizes, can be transported by water, wind, glaciers and other natural causes (Montgomery et al., 2000). Sediment from large erosion plots and a small watershed is frequently enriched in fines, that is, the fraction of clay and silt particles is greater in the sediment than in situ soil (Foster et al., 1985). The sediment deposited in the dam reservoir is the material detached and transported by rainfall and runoff (Ellison, 1947). Thus the sediment lacks sufficient organic matter and inorganic soil constituents such as Fe and/or Al oxides and hydroxides to cause aggregation. The recently sediments accumulated in the dam reservoir areas is suitable for plant growth in terms of texture (Turgut et al., 2015), but they lost productivity because of deterioration in their physical and chemical properties, so sediments are a good example for degraded soils.

Although aggregate stability is improved mainly through the application of farmyard manure, no information is available on the effect of tea waste on aggregate stability. Thus, our hypothesizes were that (i) the aggregate stability would be improved by application of the tea waste, (ii) the effect of tea waste and farmyard manure on aggregate stability would be different, (iii) the aggregate stability would be influenced by the application dozes and (iv) elapsed time after organic material application of both farmyard manure and tea waste would change the aggregate stability. It is expected that increased aggregate stability after tea waste application on sediments can improve the physical properties of degraded soils.

2 Materials and methods

2.1 Material

In this study, the recently accumulated sediments in Borçka Dam reservoir were used. Since its completion in 2006, large amount of sediments have been accumulated in the reservoir of the Borçka Dam. One of the sediment deposition area formed in the reservoir was identified as the sampling area. Soil samples were taken from 15 points on that deposition area (Fig. 1) and analyzed for some physical and chemical properties given in Table 1. Two different types of organic material were used in the study. One of them was production waste referred to as tea waste (TW) taken from a tea factory and the other was farmyard manure (FYM) taken from a cattle-raising farm. The study was conducted in a fully-controlled greenhouse condition.

2.2 Methods

The sediments obtained from reservoir site were air-dried in the laboratory, clods were broken, and mixed until obtaining a homogenous mixture. The TW and FYM were dried, pulverized in a blender and passed through a 2 mm sieve. The statistical design of the study was split-split plot in randomized completed block with two replications (Table 2). Main plot was organic material sources and subplot was application dozes. The sediments were mixed with TW and FYM to make up a total of 2000 g of mixtures for each application dozes. The percentages of TW and FYM used in the mixture were as fallow: 0, 2.5, 5, 7.5, 10, 12.5, and 15 %. To prevent the intermingling of the application, an apparatus consisting of 28 compartments with each 40 × 25 cm in size was created (Fig. 2). Each mixture was placed in this apparatus with two replications. During an 18-week incubation period following the addition of TW and FYM, temperature of the greenhouse was maintained in the range of 25 to 28 °C while the moisture of the mixtures was kept at 23 % all the time. Aggregate stability was determined at the ends of 2, 4, 6, 8, 10, 14 and 18 weeks for each treatment. In these periods, the six subsamples were taken from each replication and aggregate stability analysis was performed on them. Wet combustion method (Sparks et al., 1996), Yoder wet-sieving method (Jacob et al., 2002) and hydrometer method (Gee et al., 1986) were used for identifying the organic matter content, aggregate stability (1–2 mm aggregates) and particle size distribution of the sediments, respectively. The pH values of the sediments were measured in the 1 : 2.5 soil-water suspensions (Conklin, 2014). The JMP 5.0 software was employed for all of the statistical tests (JMP, 2007). Differences of aggregate

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stability between TW and FYM applications and their dozes were examined by one-way ANOVA. Student's t test at 5 % level probability was used to test the differences between means of individual treatments.

3 Results and discussion

Results showed that both TW and FYM application increased aggregate stability of sediments (Fig. 3). Moreover, it was revealed that TW application improved the aggregate stability significantly better than FYM application ($F = 3.91$; $p<0.05$). Despite the absence of any study directly comparing the effect of both TW and FYM on aggregate stability, the studies comparing the aggregate stability of soils supplemented with green manure and FYM reported that FYM increased aggregate stability dramatically shortly after the addition of organic matter (Karami et al., 2012). However, in long-term studies, green manures were reported to be more effective on water stable aggregates (Annabi et al., 2011; Turgut and Aksakal, 2011).

Since the effect of TW and FYM on aggregate stability was significantly different, differences among the application dozes were examined separately for TW and FYM. The aggregate stability determined as 5.66 % before organic material application showed a tendency to increase depending on rate of application. In case of 2.5 % application doze, the FYM showed greater effect on increasing aggregate stability than the TW, but when the doze was increase to 5 %, TW application resulted in better improvement for aggregate stability than FYM.

In TW treated samples, the rates of increase in aggregate stability were similar with the dozes of 7.5 and 10 %. However, aggregate stability tended to increase with increasing doses and reached the highest value at 15 % level (Fig. 4). As for the FYM treated samples, the aggregate stability stayed similar at 2.5, 5, and 7.5 % application dozes. However, the aggregate stability values increased again with an application rate of 10 %, while they reached the highest values and stayed almost similar at application rates of 12.5 and 15 % (Fig. 4). The differences among the application dozes were statistically significant with TW ($F = 21.44$; $p<0.01$) and FYM ($F = 17.82$; $p<0.01$) applications in terms of aggregate stability.

The finding of this study was agreed with the results reported in literature. Paré et al. (1999), Curtin and Mullen (2007), Turgut and Aksakal (2011) and Karami et al. (2012) reported that the percentage of stable aggregates increased depending on the supplement levels of FYM and various green wastes. It is well known that organic matter increased the stability of macro-aggregates (> 0.25 mm) through the binding of the soil mineral particles by polysaccharides (Tisdall and Oades, 1982; Oades, 1984). Thus, the improvement in aggregate stability of this study can also be associated with the increase in the percentage of bonding materials (polysaccharides, humic acid and humin) available in the organic materials enabling binding soil particles to each other.

In respect to the elapsed time after organic matter application, both TW and FYM treatments showed differences on increasing rate of aggregate stability. In the case of TW application, aggregate stability increased from the second week and continued until the eighth week. However, after this point, a non-regular change occurred in the aggregate stability as shown in Fig. 5. Statistical analyses revealed that these differences among the elapsed times were not significant ($F = 1.12$; $p>0.05$). Similar to the TW, in the case of FYM addition, the aggregate stability tended to increase from the second week, but, unlike TW, it reached its highest value on the fourth week. However, the rate of water stable aggregate started to decrease after the fourth week (Fig. 5). These differences among the elapsed time after the application were found to be statistically significant ($F = 3.97$; $p<0.01$).

Similar studies stated that the time when aggregate stability reaches its highest value varies depending on the type of organic material and study conditions. Abiven et al. (2009) found that aggregate stability reached the highest value in 30–100 days after addition of plant-based organic wastes while it was between 14–60 days in the case of FYM application under similar greenhouse conditions.

Researchers suggested that the rate of decomposition of FYM in soil is higher than plant-based organic wastes (Mohanty et al., 2011; Saikia et al., 2015). This might explain why the aggregate stability reached the highest value in a shorter time and tended to decrease depending on the elapsed time for the FYM application in our study. In addition, in the case of TW application, it takes longer for the aggregate stability to reach the highest value and it is not tend to decrease in the period of elapsed time, which may be associated with lower decomposition rate of the TW.

4 Conclusions

The results of this study clearly indicated that; (i) TW is more efficient than FYM in terms of aggregate stability, (ii) addition of TW and FYM resulted in significant improvement for the aggregate stability of sediments, (iii) aggregate stability increased depending on application dozes of both TW and FYM, and (iv) FYM increased aggregate stability to the highest value in shorter time while it took longer time to reach the highest value in the tea waste treatment. We conclude that both TW and FYM applications increased aggregate stability of sediments, indicating that the physical properties of degraded soils can be improved with such treatments.

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Table 1. The some properties of the sediment used in this study.

	Min	Max	Mean	SD	CV
Clay (%)	24.68	28.80	26.63	0.81	3.04
Silt (%)	37.68	43.93	40.43	1.51	3.73
Sand (%)	31.34	35.63	32.93	1.33	4.04
Organic matter (%)	1.23	1.35	1.28	0.03	2.34
pH	8.32	8.73	8.60	0.11	1.28
Aggregate stability (%)	4.52	6.32	5.66	0.68	12.01

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Table 2. The experimental design.

Tea waste	10 % doze 1st replication	7.5 % doze 2th replication	5 % doze 1st replication	7.5 % doze 1st replication	2.5 % doze 1st replication	15 % doze 2th replication	0 % doze 1st replication
	0 % doze 2th replication	2.5 % doze 2th replication	15 % doze 1st replication	12.5 % doze 1st replication	10 % doze 2th replication	12.5 % doze 2th replication	5 % doze 2th replication
Farmyard manure	7.5 % doze 2th replication	0 % doze 2th replication	15 % doze 2th replication	7.5 % doze 1st replication	10 % doze 1st replication	12.5 % doze 1st replication	2.5 % doze 2th replication
	15 % doze 1st replication	12.5 % doze 2th replication	5 % doze 2th replication	0 % doze 1st replication	10 % doze 2th replication	2.5 % doze 1st replication	5 % doze 1st replication

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Figure 1. Photos from the sediment deposition area.

Figure 2. The apparatus used in the study.

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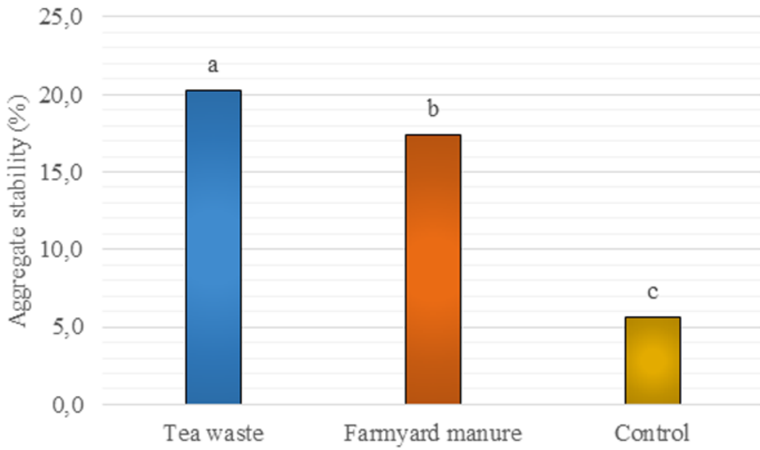

Figure 3. Aggregate stability of sediments treated with tea waste and farmyard manure. The means with different letters indicate significant differences ($p<0.05$).

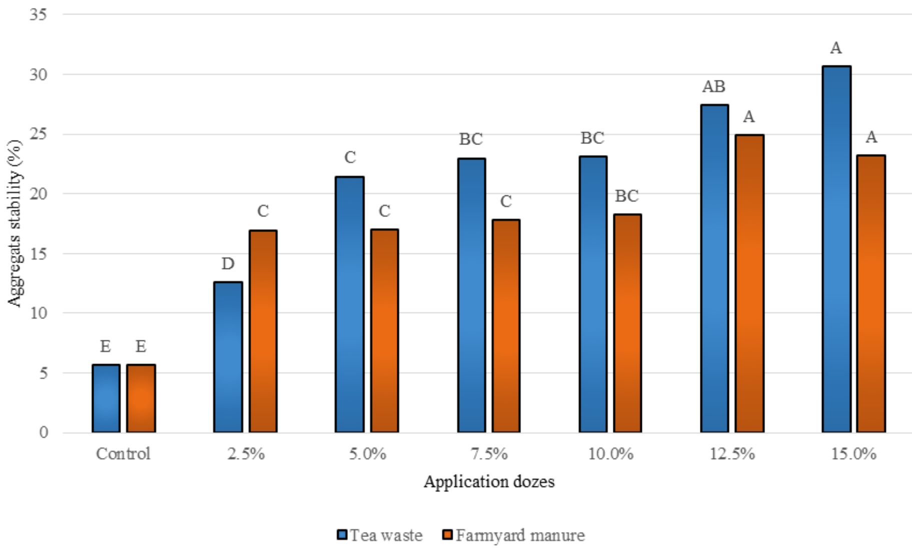

Figure 4. Changes in aggregate stability depending on application levels of tea waste and farmyard manure. The means with different letters indicate significant differences among dozes (p<0.01).

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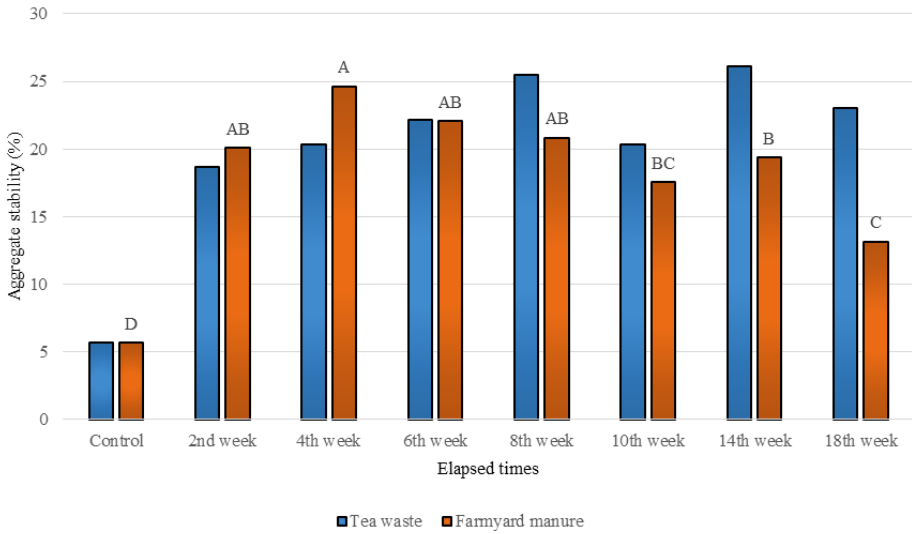

Figure 5. Changes in aggregate stability depending on elapsed times after application. The means with different letters indicate significant differences among elapsed times ($p<0.01$).

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