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Changes in some physical properties of the soils tread with wheat straw and rice husk under the rotation of white-head cabbage, tomato and wheat

Betül Bayraklı[1]*, Coşkun Gülser[2]

[1]Republic of Turkey Ministry of Agriculture and Forestry, Black Sea Agricultural Research Institute, 55300 Samsun, Türkiye
[2]Department of Soil Science and Plant Nutrition, Faculty of Agriculture, Ondokuz Mayıs University, 55200 Samsun, Türkiye

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***Corresponding Author**
Tel.: +90 362 256 0514
E-mail: bbetul25@gmail.com

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Abstract

This study was carried out silty clay (SiC) textured soil and silty land (SiL) textured soil in order to reveal the changes in some physical properties of the soil in white-head cabbage (WHC), tomato (T) and wheat (W) rotation after the application of wheat straw (WS) and rice husk (RH). Soil organic matter (OM), bulk density (BD), total porosity (F), aggregate stability (AS), mean weight diameter (MWD), field capacity (FC), volumetric water content (ϴ), penetration resistance (PR), relative saturation (RS) and initial infiltration (In) values were determined, after harvest of each plant. As the results of the experiments pointed out, soil OM contents and F values increased, while BD values decreased after WHC, T and W harvest with WS and RH application. With a higher C/N ratio, WS application increased soil OM content more than RH application. The lowest BD, AS, and MWD values were generally obtained after the WHC and T harvest, and the highest BD, AS, PR and in values after the W harvest. Soil OM content showed very significant negative relationships with BD (-0.561**), MWD (-0.680**) and RS (-0.528**) in the silty clay (SiC) textured soils, while it showed very significant negative relationships with BD (-0.809**), AS (-0.543**), MWD (-0.830**), PR (-0.555**) and very significant positive relationships with FC (0.728**), ϴ (0.814**), RS (0.767**) in the silty loam (SiL) textured soils.

Introduction

Improving the physical properties of the soil is important for sustainable plant growth and other living organisms in the soil. Poor soil structure leads to poor water and aeration conditions that restrict root growth, limiting the efficient use of nutrients and water by plants. It also affects the storage of organic carbon in the soil (Blanco-Canqui and Lal, 2004). Soil properties such as bulk density and aggregate stability are affected by the amount of organic C in the soil and the composition of organic matter (Martin, 1971; Dormaar, 1983; Lal, 2009). Organic matter directly absorbs water and increases the formation and stabilization of the structure containing abundant pores that keep the water under medium tension, increasing the water holding capacity of the soil (Magdoff and Weil, 2004; Varela et al., 2013). The longevity of changes in soil properties due to additional waste is related to decomposition rates. The amount, chemical composition and decomposition rate of wastes cause differences in soil properties and soil organic carbon (OC) content (Martens, 2000; Demir and Gülser, 2008; Gülser et al., 2015). However, the maximum amount of soil C is also determined by various factors including climate, parent material in soil, physiography, drainage, land management practices, and soil properties such as clay content, minerals and nutrient reserves (Lal, 2008; Gülser at al., 2020).

Wheat and paddy are the most important agricultural products of the Bafra Plain, where there are large amounts of WS and RH wastes. Continuous tillage is carried out, and intensive chemical fertilizers are utilized as well as intensive agriculture in the Bafra Plain. The usage of organic wastes as soil conditioners helps to improve soil quality and enables economical disposal of these materials (Ic and Gülser, 2008; Gülser et al., 2010; Candemir and Gülser, 2011).

There is a bulk of research on the decomposition of wheat straw; the deterioration process of straw has been reported to be slower in the field conditions compared to greenhouse experiments, and it has been underlined that this difference is caused by different atmosphere, precipitation and physico-chemical properties of the soil, as well as soil cultivation and microorganisms in the soil (Nielsen et al., 2019). Straw mainly contains lignin, cellulose, hemicellulose, N, P and K, and so forth (Wang et al., 2019). Once the straw is returned to the soil, some nutrients are easily converted into CO_2 by the mineralization of microorganisms in the soil. Wang et al. (2020) have revealed that wheat straw components and nutrients are rapidly released in the natural environment under different tillage practices - without additives such as biomass and organic fertilizers- between 0 and 90 days. However, lignin remaining in the straw, cellulose and straw organic carbon in the hemicellulose remain in the soil longer because macromolecules such as lignin cannot be easily assimilated and converted by bacteria in the soil (Yang et al., 2019). Therefore, the remainder of the straw may have unique surface morphology and mechanical properties likely to have a sustained impact on tillage and soil compaction (Holthusen et al., 2018).

Rice husk contains carbon (C), oxygen (O), hydrogen (H), nitrogen (N), sulfur (S), silicon (Si), iron (Fe), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K) and phosphorus (P) (Jenkins et al., 1998), making it a useful source of main nutrients for crops. C (37.8-39.1%) and N (0.5-0.6%) are the two essential nutrients of rice husk (Jenkins et al., 1998; Demir and Gülser, 2021). The ash content of rice husk varies between 16-23% and consists mostly of silica (90-95%) together with other elements (Kapur, 1985; Jenkins et al., 1998; Natarajan et al., 1998). As indicated by these properties, Rice Husk (RH) can potentially be used as a soil conditioner (Verala et al., 2013). Furthermore, RH and its compost can be used as a soil conditioner to improve the physical properties of the soil as reported by some researchers (Jeon et al., 2010; Demir and Gülser, 2021), especially by increasing the soil porosity. Therefore, this study aims to examine the effects of WS and RH applied to silty clay and silty loam textured soils as an organic matter source on some physical properties of the soils in white-head cabbage, tomato, and wheat rotation systems.

Materials and methods

The experiment was carried out on two different lands in the Bafra Plain with silty clay textured soil and on silty loam textured soil. The geology of the research area is formed by the bottom and slope lands. Bottomlands are IV. geological time alluviums. These alluviums are mixtures of sand, silt, clay and some gravel. Sedimentary rocks of the Neogene period (marl, claystone, siltstone and pebbly series) and Eocene flysch (sandstone, claystone, marl and partially limestones) were found on the slopes. The soils in the experimental area have been defined as "Typic Udifluvent" because they display little pedogenetic horizon development and are located in the alluvial flood plains brought by Kızılırmak (Yüksel and Dengiz, 1996). Bafra Plain has a warm and temperate climate. Bafra Plain receives much more precipitation in winter than in summer. It can be classified as CSA (Mediterranean climate) according to the Köppen-Geiger climate classification. The annual average temperature of Bafra district is 13.6°C and its annual average precipitation is 730 mm (Anonymous, 2022). The climate data of the Bafra district between 2007 and 2009, when the experiment was conducted, are given in Figure 1.

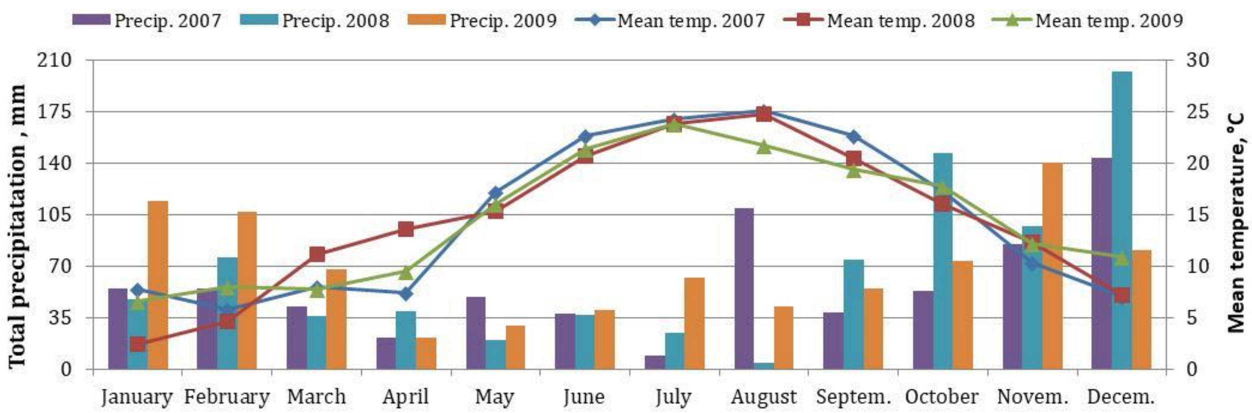

Figure 1. Climatic data of Bafra District (2007-2009)

Trials were carried out in three replications between July 2007 and July 2009 in accordance with the randomized blocks experimental design with the "white head cabbage (WHC) + tomato (T) + wheat (W)" rotation system in both fields where wheat was the previous crop. The WS used in the trials was obtained from the wheat harvested from the field where the experiments were set up, and the RH was obtained from the rice mills in Bafra. Trial subjects have been determined as C: Control, WS: Wheat straw+ Optimum NPK, and RH: Rice husk + Optimum NPK. In the experiments, row spacing and in-row spacing were determined as 100 cm-75 cm (5 rows) for white-head cabbage, 140 cm - 60 cm (4 rows) for tomatoes, and 12 cm (47 rows) for wheat respectively.

The wheat planted in November 2006 in both fields was harvested in the first week of July 2007. All of the WS obtained from this harvest (225 kg da^{-1} silty loam textured soil, and 300 kg da^{-1} clay textured soil) and RH, which was transported from the factory site equivalent to this amount of straw, were applied to the soil using goble discs on July 09, 2007, according to the trial subjects. Organic materials were applied to the field with their original dimensions. Sowing, planting and harvesting processes were carried out between the dates of August-November 2007 for white-head cabbage, May-September 2008 for tomatoes, and November 2008-July 2009 for wheat plants. According to the soil analysis results, all of the phosphorus and potassium fertilizers were applied at once before planting and half of the nitrogen fertilizer was applied before planting wheat, white cabbage and tomatoes. The second nitrogen application was done in the middle of tillering in wheat, on the first hoe in white head cabbage, and between the rows when the fruits began to appear in tomatoes (Deniz and Özdemir, 1980; Özdemir and Güner, 1983a and 1983b). Ammonium sulfate (21%) was used as nitrogen fertilizer, diammonium phosphate (18-46%) as phosphorus fertilizer and in Ağıllar location potassium sulfate (50%) fertilizer was used as potassium fertilizer needed. Sprinkler irrigation was used to provide germination in wheat and White head cabbage. The first irrigation water was applied to the opened furrows with middle breaking in tomatoes. Other irrigations were made according to the observations made on the soil and plants. Irrigation was done in the form of row irrigation and care was taken to give equal water to the parcel in each irrigation. After the harvest of each rotation plant, measurements were made at 0-20 cm depth in each plot in the trial areas, and analyses were made on disturbed and undisturbed soil samples taken from the plots.

The organic carbon (OC) value of organic wastes was determined by the dry-ashing method (Nelson and Sommers, 1982), total N was determined by the Kjeldahl method (Bremner and Mulvaney, 1982), and pH and electrical conductivity (EC) were determined by the suspension obtained by shaking the samples diluted with 1:10 (weight:volume) pure water in a mechanical shaker for 1 hour (Kacar, 1984). General soil properties such as; texture was determined by the hydrometer method (Demiralay, 1993); soil reaction (pH) was determined by pH meter in saturation paste; electrical conductivity ($EC_{25°C}$) was determined by EC meter in the same paste; and organic carbon (OC) content was determined using the modified Walkley-Black method (Kacar, 1994). Bulk density, total porosity, gravimetric and volumetric moisture contents and relative saturation values in the soil samples taken from the field with an undisturbed sampling cylinder were determined according to Demiralay (1993). Aggregate stability values of the soil samples were determined by the “wet sieving” method (Kemper and Rosenau, 1986). The initial infiltration values, which refer to the entry of water into the soil from the soil surface, were determined according to the single cylinder infiltrometer method (Soil Quality Ins. Staff., 1999). Field capacity and wilting point values of the disturbed soil samples were determined after the soil samples reached the hydraulic equilibrium state under 1/3 atm and 15 atm pressures in the pressure table instrument (Black, 1965). Penetration values were determined by Cone Penetration Testing using Eijkelkamp penetrometer with a surface area of 2 cm^2. Air-dried soil samples were sieved from different sieve apertures, and the mean weight diameter values were calculated by using the amount and percentage of aggregates remaining on each sieve (Demiralay, 1993).

Statistical analysis was carried out according to randomized blocks experimental design by using 3 subjects, 3 replications and 3 alternation plants in the JMP statistical program and the significant ones were grouped with the LSD test (Yurtsever, 1984).

Results and discussion

Some physical and chemical properties of the experiment soils are given in Table 1. Silty Clay soil contains 6.73% sand, 51.94% clay and 41.33% silt, while silty loam soil contains 30.50% sand, 7.20% clay and 60.30% silt. Both trial fields were found to be neutral in terms of soil reaction and salt-free, and poor in organic matter content (Soil Survey Staff, 1993). Some features of WS and RH used in the experiment are shown in Table 2. The C/N ratios in the experiment materials were determined as 105.46 for WS and 83.22 for RH, and the pH values as 6.93 and 7.73.

According to the results obtained from both experimental areas, it was found that WS and RH applications to the soils increased the organic matter content of the soils compared to the control application at the end of different rotation periods (Figure 2). Applying organic waste to the soils increased the organic matter content in silty loam soil more than in the control application. Many researchers have stated that different organic wastes and compost applications from wastes

Table 1. Some physical properties of the experiment soils

	Sand, %	Clay, %	Silty, %	Texture class	pH(1:1)	EC,dS.m^{-1}	OM, %
Silty Clay	6.73	51.94	41.33	SiC	7.55	0.58	0.62
Silty Loam	30.50	7.20	62.30	SiL	7.65	0.56	0.41

Table 2. Some properties of the experiment materials

Material	C, %	OM, %	N, %	C/N	pH	EC, dS.m^{-1}
Wheat straw	44.19	88.61	0.419	105.46	6.93	7.54
rice husk	40.78	81.56	0.490	83.22	7.43	1.20

increase the OM content of soils (Candemir and Gülser, 2011; Barus, 2016; Abdallah et.al., 2019; Gülser et al., 2017; Cercioğlu, 2017; Demir and Gülser, 2021). The fact that the WS application caused a marked increase in the OM contents of the soils in all rotation periods compared to the RH application in both experiment sites can be attributable to the fact that the WS (105.46) is wider than the RH (83.22) in terms of C/N ratio. Candemir and Gülser (2011) reported in their study that as the C/N ratio of different organic materials added to the soil widened, the mineralization rates in the soil slowed down, and the increased OM content of the soil was more durable. Cultivation of tomato plants by tillage following white-head cabbage and the application of additional tillage such as hoeing and middle breaking during plant development led to an increase in mineralization in the soil and a decrease in the amount of OM in all applications. Gülser et al. (2020) reported that organic carbon had been retained in the soil with reduced tillage, and the total amount of OM was approximately 10% to 30% higher than conventional tillage.

The effects of organic waste applications on some physical properties of soil in the trial areas in different

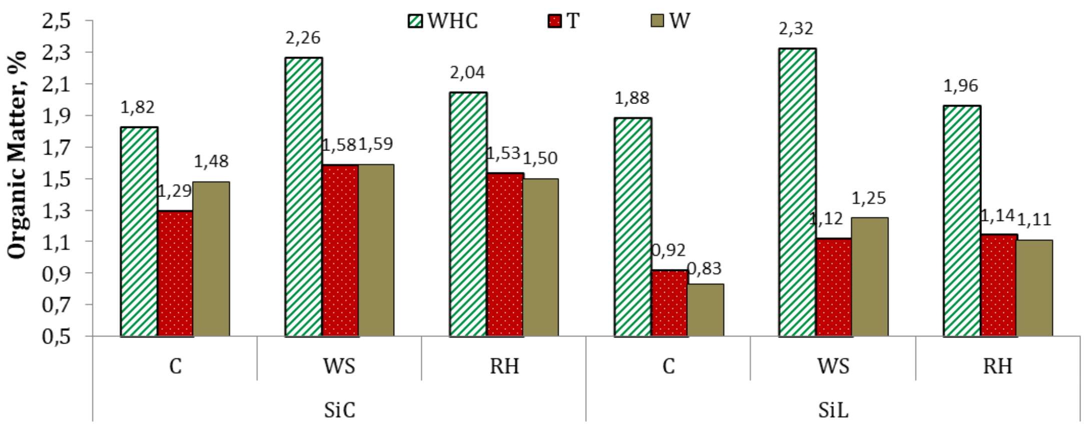

Figure 2. The effect of wheat straw (WS) and rice husk (RH) treatments on organic matter content of the soils compared to control (C) at the end of the rotation periods (WHC: White head cabbage; T: Tomato; W: Wheat)

alternation periods are given in Tables 3 and 4. A statistical difference was determined between organic waste applications according to the variance analysis values performed with BD (P<0.01) and in (P<0.01) in silty clay soil. According to the analysis of variance performed with PR (P<0.05), In (P<0.01) and MWD(P<0.01) values in silty loamy soil, a statistical difference was found between waste treatments (Table 3). A statistical difference was determined between the harvest periods of alternation plants in all parameters (except FC in silty clay soil) in both silty clay and silty loam soils (P<0.01) (Table 4). As shown in Table 5, there were significant negative relationships between OM contents and BD (-0.561** in SiC; -0.809** in SiL) values of soils with different textures, and significant positive relationships between OM contents and F (0.560** in SiC; 0.810** in SiL) values. WS and RH applications decreased the BD values of the soils compared to the control in both applications. The BD values of the soils were found lower in the WS application compared to the RH application (Table 3). Given the BD values according to the rotation periods, the lowest values of bulk density in both soils were obtained after the WHC harvest. In contrast, the BD values increased during the tomato and wheat harvest periods (Figure 3). The highest BD values in both soils were obtained from the control application during the wheat harvest period. Parallel to the decreases in the BD values of the soils, the F values of the soils also increased (Figure 3). Many studies have found that the addition of organic matter to the soil

Table 3. Changes in some physical properties of the soils according to the organic waste treatments

	BD, g.cm^{-3}	PR, Mpa	In, cm.h^{-1}	AS, %	MWD, mm	FC, %
Silty Clay						
Control	1.42 A	1.75	22.88 B	54.18	0.98	36.55
Wheat straw	1.36 B	1.79	55.36 A	55.00	1.00	36.16
Rice husk	1.38 B	1.74	53.56 A	57.98	0.98	35.44
LSD$_{(*0.05;\ **0,01)}$	0.030**	ns	2.77**	ns	ns	ns
Silty Loam						
Control	1.42	1.58 B	22.04 B	11.30	0.55 A	18.59
Wheat straw	1.40	1.84 A	39.14 A	9.65	0.55 A	19.38
Rice husk	1.41	1.61 B	33.75 A	10.65	0.52 B	18.63
LSD$_{(*0.05;\ **0,01)}$	ns	0.119*	6.32**	ns	0.034**	ns

ns = not significantly different, * Significant at P< 0.05, ** Significant at P <0.01.

Table 4. Changes in some physical properties of the soils according to the harvest periods of the rotation crops (WHC: White head cabbage T: Tomato W: Wheat)

	BD, g.cm^{-3}	PR, MPa	In, cm.h^{-1}	AS, %	MWD, mm	FC, %
Silty Clay						
WHC (5.7mo.)	1.29 C	1.39 B	40.61 B	52.25 BC	0.94 B	35.66
T (14.06 mo.)	1.33 B	0.84 C	54.96 A	50.54 C	1.00 A	36.87
W (23.9 mo.)	1.54 A	3.05 A	39.76 B	64.42 A	0.87 C	35.61
LSD$_{(*0.05,\ **0,01)}$	0.033**	0.065**	6.55**	2.23**	0.047**	ns
Silty Loam						
WHC (5.7 mo.)	1.29 C	1.00 C	22.11 B	3.48 B	0.47 D	20.10 A
T (14.06 mo.)	1.41 B	1.29 B	18.84 BC	4.95 BC	0.60 AB	19.00 AB
W (23.9 mo.)	1.55 A	2.74 A	53.97 A	23.17 A	0.54 C	17.50 BC
LSD$_{(*0.05,\ **0,01)}$	0.07**	0.16**	3.61**	3.97**	0.035**	1.58**

ns = not significantly different, * Significant at P< 0.05, ** Significant at P <0.01.

reduces the BD value and increases the total porosity (Candemir and Gülser, 2011; Barus, 2016; Abdallah et al., 2019; Gülser et al., 2017; Cercioğlu, 2017; Demir and Gülser, 2021).

Organic waste applications did not have a statistically significant effect on the AS and MWD values of the soils (Table 3). However, the application of RH, compared with WS, resulted in higher AS in silty clay soil than the control. Factors affecting aggregate stability can be grouped as abiotic (clay minerals, sesquioxides, exchangeable cations), biotic (soil organic matter, activities of plant roots, soil fauna and microorganisms) and environmental (soil temperature and humidity) (Chen et al., 1998). As many studies have pointed out that, there is a positive relationship between the organic carbon content of the soils and the aggregate stability; therefore, the addition of organic matter to the soil increases the aggregate stability (Tisdall and Oades, 1982; Rasiah et al., 1993; Cercioglu et al., 2014; Gülser et al., 2015). In silty loam soil, AS values increased with WS and RH applications in WHC rotation period compared to control but decreased in T and W rotation periods. The MWD values of the soils increased in the W rotation period when compared to the WHC rotation

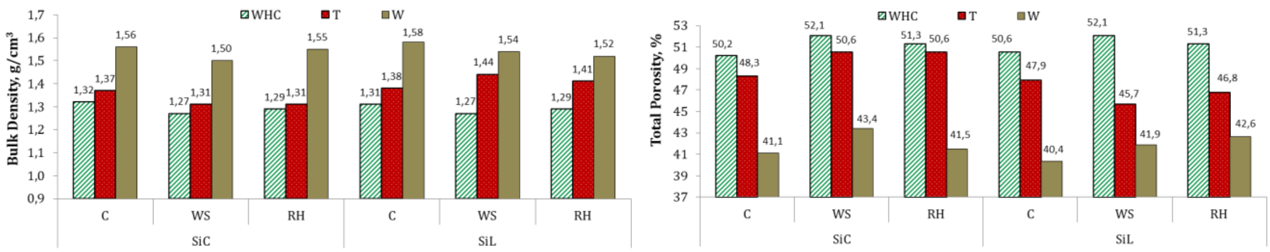

Figure 3. Effects of wheat straw (WS) and rice husk (RH) treatments on bulk density and total porosity of the soils compared to the control (C) at the end of the rotation periods (WHC: White head cabbage; T: Tomato; W: Wheat)

period (Figure 3). MWD values of the soils generally decreased in parallel with the AS values with the addition of organic matter. Significant negative relationships were found between the OM contents of the soils and the AS (-0.208** in SiC; -0.543** in SiL) and MWD (-0.680** in SiC; -0.830** in SiL) values (Table 5). This decrease may be due to the increase in microbial activity after the application of organic materials in addition to tillage during the rotation periods, the inability to meet the increasing nutritional need due to this increase, and the fact that the use of some organic compounds that provide aggregation as nutrients by microorganisms. Aşkın et al. (2000) reported that the increase in the microbial activity of soils reduced AS, and they explained the reason for this, suggesting that microorganisms, previously producing the products that enable aggregation, consumed these products. Considering the sampling times, the highest AS values

Table 5. Relationships between identified properties of silty clay (SiC) and silty loam textured soils (SiL) (n= 27)

	Texture	BD	F	AS	MWD	FC	Θ	PR	RS	In
OM	SiC	-0.561**	0.560**	-0.208	-0.680**	-0.362	0.016	-0.156	-0.528**	0.187
	SiL	-0.809**	0.810**	-0.543**	-0.830**	0.728**	0.814**	-0.555**	0.767**	-0.246
BD	SiC		-1.000**	0.865**	0.666**	-0.151	-0.746**	0.893**	-0.111	-0.301
	SiL		-1.000**	0.887**	0.532**	-0.833**	-0.937**	0.929**	-0.880**	0.738**
F	SiC			-0.865**	-0.667**	0.152	0.745**	-0.893**	0.111	0.303
	SiL			-0.888**	-0.531**	0.835**	0.937**	-0.929**	0.880**	-0.738**
AS	SiC				0.560**	-0.595**	-0.943**	0.942**	-0.539**	0.009
	SiL				0.166	-0.838**	-0.753**	0.941**	-0.685**	0.840**
MWD	SiC					0.011	-0.478**	0.497**	-0.045	0.106
	SiL					-0.329	-0.632**	0.232	-0.624**	-0.041
FC	SiC						0.606**	-0.473**	0.745**	-0.238
	SiL						0.817**	-0.755**	0.775**	-0.586**
Θ	SiC							-0.917**	0.745**	-0.169
	SiL							-0.835**	0.990**	-0.676**
PR	SiC								-0.471**	-0.210
	SiL								-0.784**	0.915**
RS	SiC									-0.566**
	SiL									-0.668**

were obtained in the third sampling period, coinciding with the summer period, in both soils. As pointed out in some other studies, AS values are generally higher in summer than in winter (Özdemir, 1994; Layton et al., 1993; Erel et al., 2010). Blackman (1992) suggested that aggregate stability also changes seasonally depending on soil moisture content. Some researchers have found that macroaggregate stability decreases with increasing soil water content (Rasiah et al., 1992; Caron and Kay, 1992; Chan et al., 1994). This study found the moisture content of both soils was also lower in the third sampling period, when the highest AS values were obtained, compared to the moisture contents of the other periods.

Organic waste applications were found not to have a significant effect on the field capacity values of the soils (Table 3). This may be due to the large particle size of the wastes, resulting in an increase in macroporosity in the soil. Haynes and Naidu (1998) reported that both field capacity and wilting point of

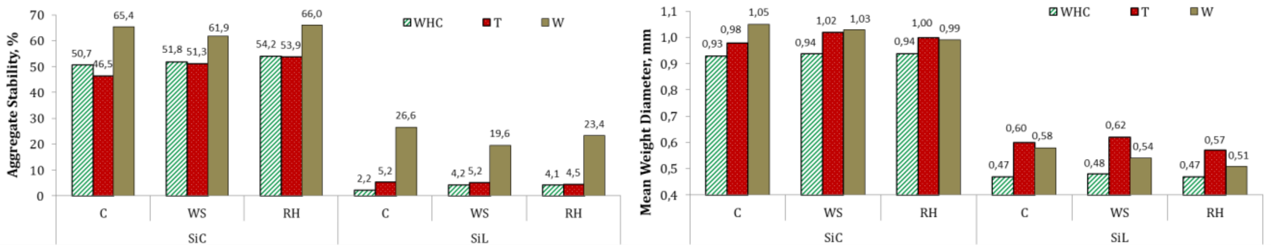

Figure 4. Effects of wheat straw (WS) and rice husk (RH) treatments on aggregate stability and mean weight diameter of the soils compared to control (C) at the end of the rotation periods (WHC: White head cabbage; T: Tomato; W: Wheat)

soils increased with the addition of organic waste, but the available water holding capacity generally did not change significantly. Considering the rotation periods, FC values did not show a significant difference in silty clay soil, while FC (P<0.01) values in silty loam soil decreased significantly from WHC to W harvest (Table 4). The volumetric water content of the soils generally decreased with WS and RH applications compared to the control application in both soils (Figure 5). This can be explained by the decrease in BD values and the increase in the total pore amount as a result of waste applications.

While the penetration resistance (PR) values in silty clay soil were not affected by organic waste applications, significant differences were found between the applications in silty loam soil (Table 3). The decrease in the bulk density of the soils and the increase in the total porosity with organic waste applications caused a decrease in the PR values. OM content in silty loam soil showed a strong negative correlation (-0.561** in SiC; -0.809** in SiL) with PR (Table 5). In both plots, the PR values measured from the first sampling WHC harvest to the third sampling W harvest showed statistically significant increases (Figure 4). PR values above 1.7 MPa, which is the critical level for plant growth in the soil, were determined in the measurements after the W harvest, which coincides with the summer period, when the volumetric water content of the soils was the lowest. Many researchers have found negative relationships between soil PR and moisture content (Gülser et al., 2011; Şeker, 1997; Turgut et al., 2010). The PR values of the soils showed significant positive relationships with BD values and significant negative relationships with volumetric water content and F values (Table 5). Studies have reported that the addition of organic material may cause lower PR values due to low bulk density, high porosity and higher water content (Getahun et al., 2018; Castioni et al., 2018; Unger and Jones, 1998; Vaz et al., 2001).

The increase in the total porosity and the decrease in the volumetric water content in both soils caused a decrease in the RS values compared to the control (Figure 6). Relative saturation values generally showed significant negative relationships with AS (-0.539** in SiC; -0.685** in SiL), OM (-528** in SiC; 0.767** in SiL), and BD (-0.111** in SiC; -0.880** in SiL) (Table 5). The decrease in BD and the increase in AS with the application of waste in the soil caused an increase in macroporosity and a decrease in the RS value as a result. Gülser et al. (2015) reported that they found higher moisture content in the soil in compost and hazelnut husk application, and yet these applications had lower RS values compared to the control.

Waste applications, depending on the decrease in the relative saturation value, also caused an increase in the in values of the soils (Figure 6). The value of both soils was higher in the WS application. In silty clay soil, the initial infiltration increased by 52% with WS application compared to the control, while it increased by 47% with RH application. Similarly, in silty loam soils, there was a 51% increase in WS and a 46% increase in RH. In silty clay soil, the highest in value was obtained after T harvest (Figure 6). This may result from the increase in macroporosity by tilling the soils because of middle breaking of tomatoes. On the other hand, in silty loam soil, the highest in values were determined after

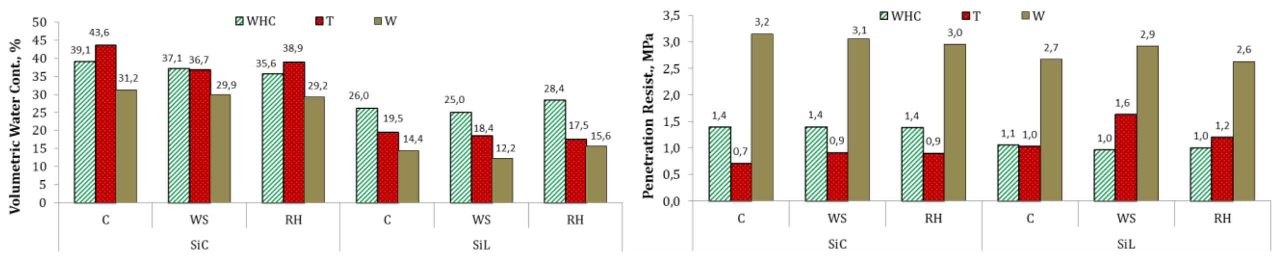

Figure 5. Effects of wheat straw (WS) and rice husk (RH) treatments on volumetric water content and penetration resistance of the soils compared to control (C) at the end of the rotation periods (WHC: White head cabbage; T: Tomato; W: Wheat)

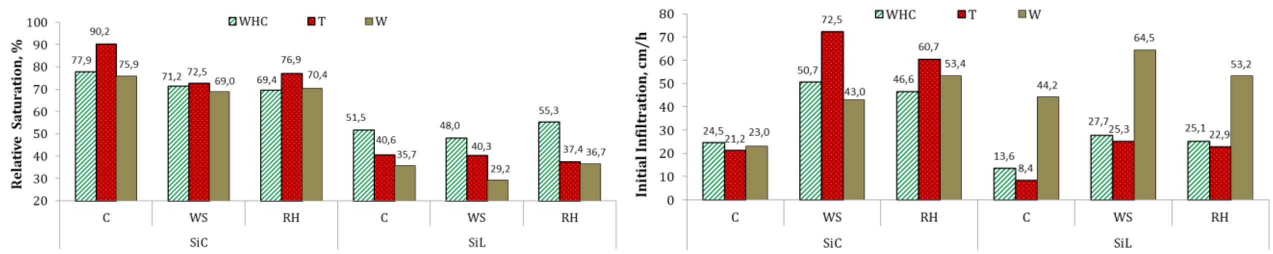

Figure 6. Effects of wheat straw (WS) and rice husk (RH) treatments on the relative saturation and initial infiltration rate of the soils compared to control (C) at the end of the rotation periods (WHC: White head cabbage; T: Tomato; W: Wheat).

the W harvest, which was the last sample with the lowest RH and ϴ contents.

Conclusion

This study was conducted in silty clay and silty loam textured soils in Bafra Plain to find out the effects of WS and RH applications on physical soil properties in whitehead cabbage + tomato + wheat rotation system. In both experiment sites with WS and RH application, OM contents and F values of soils increased after WHC, T and W harvest, while BD values decreased. OM content of soil had greater increase with WS application, which has a wider C/N ratio, compared to RH application, and it decreased in both fields from WHC harvest to W harvest. The lowest BD, AS, and MWD values were generally obtained after the WHC and T harvest with more tillage during the growing season, while the highest BD, AS, PR and the values were obtained after the W harvest without tillage during the growing season. The high in value in this period was due to the soil moisture content and therefore the low RS value. Soil OM content showed very significant negative relationships with BD, MWD and RS in silty clay textured soil (SiC), while it showed very significant negative relationships with BD, AS, MWD, and PR and very significant positive relationships with TK, ϴ, RS in silty loam textured soil (SiL). Measured PR values showed very significant positive relationships with BD and AS, and very significant negative relationships with F, TK, ϴ, and RS. The values of the soils increased with WS and RH applications and showed very significant negative correlations with RS values. The highest in values in the experiment were determined in WS application due to the macroporosity increased after the T harvest in the soils with SiC texture, and because of the low RS in the soil after W harvest in the soils with SiL texture. In this study, it was found that the organic waste with a high C:N ratio increased the OM content of the soil more, the OM content of the soils decreased due to tillage in the multi-rotation system, and the soils contained more OM compared to the control despite these decreases. The effects of different organic wastes on the physical properties of the soil in the rotation system also differed according to the soil texture. With waste applications, AS and MWD values generally increased in silty loam, while they decreased in the soils with silty clay content. The application of WS and RH, residuals after the harvest in the region, to the soil provided positive improvements in the physical properties of the soils within a period of rotation.

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that might apper to influence the work reported in this paper.

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Author Contributions

BB: Conceptualization, investigation, methodology, validation, software, validation, formal analysis, investigation, resources, data curation, writing-original draft preparation, writing-review and editing, visualization, supervision, statistical analysis, project administration; **CG:** Conceptualization, investigation, methodology, validation, software, validation, formal analysis, investigation, resources, data curation, writing-original draft preparation, writing-review and editing, visualization, supervision, statistical analysis, project administration.

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