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Effects of Aggregate Size and Compaction Level on CO_2-C Fluxes and Microbial Populations

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Abstract: The aim of this study is to identify the effects of aggregate size and intra-row compaction levels on soil carbon di oxide-carbon (CO2-C) fluxes, bacterial and fungal populations during wheat growing period. A horizontal axis rotary tiller was used to obtain two different mean weight diameters (MWD) by changing tractor forward speeds. Tractor forward speeds were 1.8 and 4.5 km h-1, and intra-row compaction levels were: control, 30 kPa and 60 kPa. The fluxes of CO2-C, microbial inhabitants and penetration resistance (PR) were statistically significant different for both MWD and intra-row compaction levels. Maximum CO2-C fluxes, bacteria and fungi inhabitants were obtained with 12.75 mm MWD and control whereas the minimum rates were assigned at the plot which 17.87 mm MWD and 60 kPa intra-row compaction. Increasing the intra-row compaction lowered the soil CO2-C fluxes and microbial population, but increased the penetration resistance.

Key words: Rotary tiller, Tractor forward speed, Mean weight diameter (MWD), Growing season, Wheat, Intra-row compaction

Agregat büyüklüğü ve sıkıştırma düzeylerinin CO_2 yayılımı ve mikrobiyal popülasyona etkileri

Özet: Bu araştırmanın amacı, agregat büyüklüğü ve sıra üzeri sıkıştırma düzeylerinin buğday bitkisinin gelişim periyodu boyunca CO_2 yayılımı, bakteri ve mantar popülasyonlarına olan etkilerini belirlemektir. Araştırmada, iki farklı ortalama ağırlık çap grubu elde edebilmek amacıyla yatay rotorlu toprak frezesi farklı traktör ilerleme hızlarında kullanılmıştır. Traktör ilerleme hızları olarak 1.8 ve 4.5 km h^{-1}, sıra üzeri sıkıştırma düzeyleri olarak ise 0.30 ve 60 kPa sıkıştırma düzeylerinden yararlanılmıştır. Araştırma sonuçlarına göre, CO_2 yayılımı, mikrobiyal popülasyon ve penetrasyon direnci üzerine hem ortalama ağırlıklı çap değerlerinin hem de sıra üzeri sıkıştırma düzeylerinin etkileri önemli bulunmuştur. Tüm ölçüm periyotlarında en yüksek CO_2 yayılımı ile bakteri ve mantar popülasyonları; 12.75 mm ortalama ağırlıklı çap grubu ile sıkıştırmanın uygulanmadığı parsellerde gözlenirken, en düşük değerler; 17.87 mm ortalama ağırlıklı çap grubu ve 60 kPa sıkıştırma düzeyinin uygulandığı parsellerde elde edilmiştir. Sıra üzeri sıkıştırma düzeyindeki artış CO_2 yayılımını ve mikrobiyal popülasyonu azaltmış, penetrasyon direncini ise artırmıştır.

Anahtar Kelimeler: Toprak frezesi, Traktör ilerleme hızı, Ortalama ağırlıklı çap (MWD), Gelişim periyodu, Buğday, Sıra üzeri sıkıştırma

1. Introduction

Soil organic matter (SOM) is a natural resource for soil life and there is a forceful connection between the plentifulness of soil organisms and the contents of SOM (Nakamoto and Tsukamoto, 2006). Soil tillage account for develop of microbial inhabitant.However conservation practices which plant residues on the soil surface encourage fungal development (Pankhurst et al 2002). According to Frey et al 1999 and Beare et al 1997 reduced tillage and no–tillage practices increases microbial population.

Macropore volumes of soil decreases with compaction which affects soil physical properties and aggregate size distribution, and this situation changed waters and air rates of soil and favorable effects on plant growth (Ruser et al 2006, Beylich et al 2010).

Compaction may also was chanced soil C mineralization and affect soil biological processes (De Neve and Hofman, 2000) in addition to these reduced in C mineralization (Tan and Chang 2007), reduced bacteria population and C–N ratio (Li et al 2004).

Soil compaction may change the microhabitats of soil microorganisms because changes position in soil aggregate size distribution and this situation affects soil function and soil microbial community (Grigal 2000).

Bilen et al (2010) reported that, CO_2-C fluxes, bacteria populations and total porosity values more at the plot with tilled conventional tillage practices than compare to reduced tillage.

Soil aggregates alter microbial structure, manage oxygen diffusion, regulate water flow and reduce run-off and erosion (Barthes and Roose 2002). These processes changes on SOM dynamics and nutrient cycling (Six et al 2004). Jastrow et al (2007) reported that soil aggregate distribution is an important factor for microbial decomposition.

The aim of this study is to determinate effects of different aggregate size and intra-row compaction level on penetration resistance, CO_2-C fluxes and bacterial and fungal populations of wheat.

2. Materials and Methods

Experimental Site

The study was carried on the research farm of Ataturk University. Soil experimental sites were classified as an Ustorthents according to the USDA soil taxonomy (Soil Survey Staff 1999). Some climatic data related to the experimental site were given in Table 1.

Experimental Design

Experimental plots were ordered in a randomized complete block design with three replications. A horizontal rotary tiller, for obtained various soil aggregate size, was used at two different tractor forward speeds such as 1.8 and 4.5 km h^{-1}, and these values were used to calculate for mean weight diameters (MWD)[AS (1) = 12.75 mm MWD; AS (2)= 17.87 mm MWD]. A speed radar (DJRVS II) and speed control monitor (DJCMS 100) was used to control at the variation of the tractor forward speed.

In the research three different intra-row compaction levels were examined as C0 (0 kPa), C30 (30 kPa) and C60 (60 kPa). Press wheels, with different extra iron flange weights connected to each unit of a seed drill to compact seed intra-rows (Figure 1).

Tillage was carrying on May 2010. After the seedbed preparation, all plots were sown using seed drill, commonly used in wheat planting in Turkey. Diammonium phosphate fertilizer (18% N, 46% P_2O_5) was applied while sowing with 100 kg ha^{-1}. The winter wheat seed (Cv:Kırik) was sowed in the second week of May with 120 kg ha^{-1}.

Table 1. *Monthly precipitation and average temperature at the study site (Anonim 2010)*

	Monthly average rainfall (kgm^{-2})											
Months	1	2	3	4	5	6	7	8	9	10	11	12
Values	14.3	90	33.7	36	121.7	40.7	2.4	1.3	6.0	27.4	43.6	8.2
	Monthly average temperature (°C)											
Months	1	2	3	4	5	6	7	8	9	10	11	12
Values	-9.8	-8.7	-1.7	4.06	9.7	14.5	17.9	19.6	13.8	7.9	1	-3

Figure 1. *Seed drill used in the experiment with rubber press wheels*

Soil Physical Properties and Laboratory Analysis Techniques

To identify aggregate size rate, soil samples were fortuitously taken from tilled soil without delay after tillage, with three replications, from 0-10 cm soil depth and these samples were dried at the laboratory. Soil samples were sieved with set of sieves (from 63 to 1 mm mesh openings) and mean weigh diameter (MWD) was calculated (Altikat and Celik, 2011).

After tillage soil penetration resistance was determined with an Eijkelkamp analog penetrometer (Eijkelkamp Agrisearch Equipment, Giesbeek, The Netherlands) in a depth of 0–10 cm and 5 cm increments all of the experimental periods (Korucu ve Yurdagül, 2013).

Soil organic C, cation exchange capacity, field water capacity, and electrical conductivity (EC) were determined by the the Smith-Weldon method (Tiessen and Moir, 1993), atomic absorption spectrophotometer after the method of Handershot et al (1993), tensiometer method (Topp et al 1993), an EC meter according to the method of Janzen (1993), respectively. Soil physical and chemical properties were given in Table 2. Soil samples were taken from soil at the sowing, flowering and harvesting periods, respectively. Average colony forming unit (CFU) per gram of oven-dried soil was calculated for each soil sample (Canbolat et al 2006; Madigon and Martingo 2006) and results were reported in Table 2.

Table 2. *Some initial chemical, physical and microbiological properties of experiment site*

Soil properties	**Value**
Bulk density, Mg m^{-3}	1.06
Porosity, vol. %	60.06
Sand, %	48.44
Silt, %	39.50
Clay, %	12.06
Texture	Loam
pH	7
Cation exchange capacity, cmol kg^{-1}	32
Electrical conductivity, dS m^{-1}	0.62×10^3
Salt, %	0.015
Field capacity at 1/3 atm, g kg^{-1}	25.3
Wilting capacity at 15 atm, g kg^{-1}	14.7
Number of bacteria, CFU* g^{-1} soil	2.57×10^7
Number of fungi, CFU g^{-1} soil	2.39×10^5
Total C respired as CO_2, mg m^{-2} h^{-1} (CO_2-C)	3.2 (0.27 Mg C ha^{-1} y^{-1})

Basal respiration (BR) was determined by using in vitro static incubation of unamended field-moist soil (Islam et al 2000). The BR rate was calculated as below:

BR rates (mg CO_2/kg soil)=(CO_2soil - CO_2air)/20 days.(1)

Statistical Analysis

Analysis of variance (ANOVA) was used to evaluate significance of each treatment. Comparison of means was performed using LSD.

3. Results and Discussion

Penetration Resistance

The penetration resistance was increased when increasing the soil depth and intra- row compaction levels for all of the sample periods. However, effect of the aggregate size distribution on the penetration resistance wasn't statistically significant. All of the sample periods (sowing, flowering and harvesting), maximum penetration resistance values were determined at the 60 kPa (C60) intra-row compaction level while minimum value were observed as 0 kPA (C0) (Figure 2). Results of penetration resistance were indicated at the Figure 2. In addition to this, penetration resistance values below 2-3MPa which accepted critical level by Busscher and Sojka, 1987; Hakansson and Lipiec, 2000. Root growth is slowing above this level (Vepraskas 1994, Shafiq et al 1994).

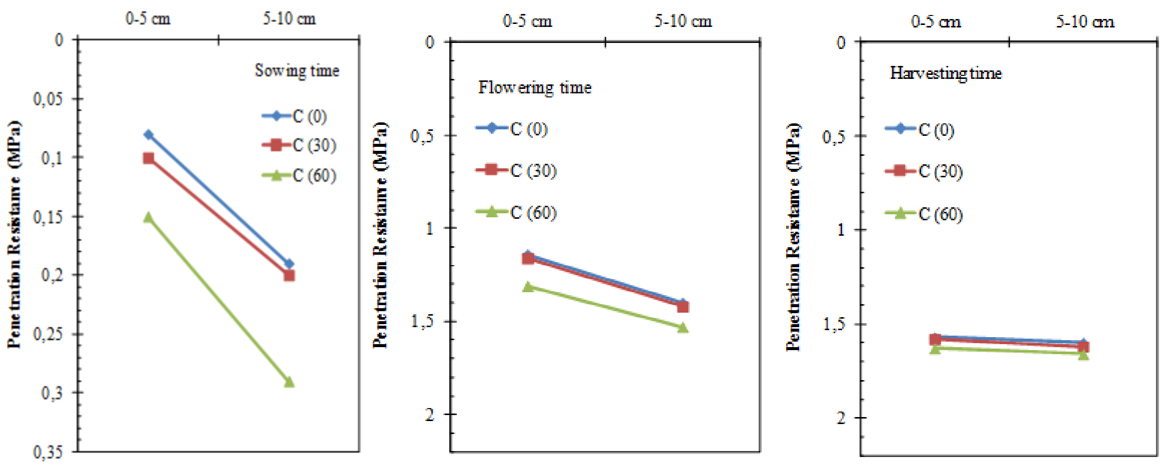

Figure 2. The effects of intra-row compaction on the penetration resistance

Bacterial and fungal population

Average bacteria numbers were affected statistically significant ($p<0.01$) from aggregate size (AS) and intra-row compaction levels all of the sample periods (Table 3). The highest bacterial numbers were observed from AS1 at the sowing, flowering and harvesting periods with 2.33, 2.42 and 2.5 CFU g^{-1} dry soil, respectively. However, increasing the intra-row compaction levels were decreased the bacteria populations (Table 3). The similar results were observed at the fungal population (Table 4).

Compaction may increase soil strength, reduce drainage and water movement, and restrict soil aeration (Lipiec and Stepniewski 1995). These effects nutrient loses and decrease crop nutrient availability (Motavalli et al 2003). However, compaction affects soil microbiological properties (Mapfumo et al 1998). A decrease in macropore continuity in compacted soil may create less favorable conditions for soil microorganisms and microbial activity (Jensen et al 1996). Intensely compaction may also negatively effects soil microbial activity.

***Table 3.** Effects of aggregate size and Intra-row compaction on the bacteria population (CFU g^{-1}dry soil)*

Analyses of variance				
Treatments		**Sowing**	**Flowering**	**Harvesting**
Intra-row compaction (C)		0.009**	0.021*	0.007**
Aggregate size (AS)		0.001**	0.001**	0.001**
C x AS		0.578 ns	0.589 ns	0.505 ns
Aggregate Size		**Sowing**	**Flowering**	**Harvesting**
AS (1)		2.33 a √	2.42 a	2.50 a
AS (2)		1.93 b	2.04 b	2.17 b
Level of compaction		**Sowing**	**Flowering**	**Harvesting**
C (0)		2.23 a	2.31 a	2.41 a
C (30)		2.11 b	2.22 b	2.31 b
C (60)		2.07 b	2.17 b	2.28 c
SEM		0.054	0.051	0.044
AS (1)	12.75 mm MWD		**	P<0.01
AS (2)	17.87 mm MWD		*	P<0.05
C (0)	No compaction		ns:	Non significant
C (30)	30 kPa intra-row compaction		SEM	Standard error of means
C (60)	60 kPa intra-row compaction			
√:	Means within the same column followed by the same letter are not significantly different			

Table 4. Effects of aggregate size and Intra-row compaction on the fungi population (CFU g^{-1}dry soil)

Analyses of variance				
Treatments		**Sowing**	**Flowering**	**Harvesting**
Intra-row compaction (C)		0.020*	0.040*	0.007**
Aggregate size (AS)		0.001**	0.001**	0.001**
C x AS		0.991 ns	0.918 ns	0.936 ns
Aggregate Size		**Sowing**	**Flowering**	**Harvesting**
AS(1)		1.96 a √	2.06 a	2.15 a
AS(2)		1.42 b	1.59 b	1.75 b
Level of compaction		**Sowing**	**Flowering**	**Harvesting**
C(0)		1.80 a	1.910 a	2.04 a
C (30)		1.69 ab	1.823 ab	1.96 ab
C (60)		1.58 b	1.737 b	1.86 b
SEM		0.072	0.063	0.054
AS (1)	12.75 mm MWD		**	P<0.01
AS (2)	17.87 mm MWD		*	P<0.05
C(0)	No compaction		ns:	Non significant
C(30)	30 kPa intra-row compaction		SEM	Standard error of means
C (60)	60 kPa intra-row compaction			
√:	Means within the same column followed by the same letter are not significantly different			

Several studies have reported that soil microbial activity was decreased with an increase of soil bulk density (Lee et al 1996, De Neve and Hofman, 2000). Li et al (2003) indicated that, compaction might also have reduced soil bacteria production, because it created anaerobic conditions by increasing soil moisture. Similar results were observed at this study.

CO_2 - C Fluxes

The effects of aggregate size (AS) and intra-row compaction levels on the CO_2-C fluxes values were statistically significant. In the research increasing aggregate size and compaction level were decreased CO_2-C fluxes.

The CO_2-C fluxes at the plot with AS(1) was determined as 8.48, 10.09 and 11.49 MgC ha^{-1} y^{-1} at the sowing, flowering and harvesting periods, respectively. These values were decreased at the plot with AS (2) (5.27, 7.56 and 9.78 MgC ha^{-1} y^{-1}) at the sowing, flowering and harvesting periods, respectively.

Increasing the intra-row compaction levels were decreased the CO_2-C fluxes from soil to air. The minimum CO_2-C flues values were observed at the plot with no compaction and the highest values were determined at the C (60) kPa intra-row compaction level all of the sampling periods.

The highest CO_2-C fluxes were obtained at the harvesting period and the minimum fluxes were obtained at the sowing period. At the harvesting period, plant root growth, soil biomass and soil microbial activity had increased and these increases contribute to increased CO_2-C fluxes.

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4. Conclusion

It was investigated the effects of different aggregate size distribution and intra-row compaction levels on penetration resistance, CO_2-C fluxes and bacterial and fungal populations in wheat. In the research, penetration resistance was increased by increasing soil depth for all of the treatments. However, penetration resistance values in all treatments were below the 2–3 MPa critical compaction level. According to obtained results, increasing in the compaction levels and aggregate size level were decreased CO_2-C flux, bacteria and fungi population. The maximum CO_2-C fluxes values were observed at the AS (1) and no compaction plot and minimum values were determined at the AS (2) and C (60) intra-row compaction level all of the sampling periods. In addition to these maximum bacteria and fungi population values were observed at the plot with AS (1) and no compaction for sowing, flowering and harvesting periods.

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