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# Comparison of wheat and safflower cultivation areas in terms of total carbon and some soil properties under semi-arid climate conditions

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Abstract

The aim of this study was to compare the soils of the wheat cultivation area (WCA) and the safflower cultivation area (SCA) within semi-arid climate zones in terms of their total carbon, nitrogen, sulphur contents, particle size distribution, aggregate stability, organic matter content, and pH values. This study presents the results from the analyses of 140 soil samples taken at two soil layers (0–10 and 10–20 cm) in the cultivation areas. At the end of the study, it has been established that there were significant differences between the cultivation areas in terms of soil physical properties such as total carbon (TC), total nitrogen (TN), total sulphur (TS) contents and pH, while only the TN content resulted in significantly different between the two soil layers. Moreover significant differences were identified in the cultivation areas in terms of soil physical properties including clay and sand contents, aggregate stability and organic matter content, whereas the only significant difference found among the soil layers was that of their silt content. Since safflower contains higher amounts of biomass than wheat, we found higher amounts of organic matter content and, therefore, higher amounts of TN and TS content in the soils of the SCA. In addition, due to the fact that wheat contains more cellulose – which takes longer to decompose – the TC content of the soil in the WCA were found to be higher than that of the SCA. The results also revealed that the WCA had a higher carbon storage capacity.

1 Introduction

The soil forming process have significant effects on soil properties (Ubalde et al., 2010). One of such processes is the agricultural management practice. It is well known fact that different agricultural management practices such as soil tillage, irrigation, crop design cause changes in physical and chemical properties of soils even though they are formed under same conditions (Özgöz et al., 2012; Reynolds et al., 2007; Valpassos et al., 2001).

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Plants have direct and indirect effects on the soil properties (Schjønning et al., 2004). Plants roots' influence over the physical soil properties such as aggregate formation, compaction and infiltration rate can be described as the direct effects of the plants (Angers and Caron, 1998; Milleret et al., 2009). Having completed their natural life cycles, the plants begin to decompose inside the soil and thereby become one of the main sources of the organic matters, which in turn provide positive contributions to most of the physical, chemical and biological properties of the soils (Karaman et al., 2007; Rowell, 1994; Turgut and Aksakal, 2011).

The crop residues – such as the components dried up or torn from the plants on the ground during the cultivation season or those left underground during the harvest season – along with their roots under the soil constitute a significant portion of the organic materials of the soil (Schjønning et al., 2004). For this reason, the plant types with advanced vegetative components and root distribution contribute more greatly in terms of organic matter contents. In addition the main sources of carbon (C) and nitrogen (N) found in the soil also come from such crop residues (Karaman, 2012). However, since the decomposition of cellulose and lignin – found richly in some types of plants such as wheat – takes longer than other components, it is observed that the soils of such cultivation areas are rich in C content and poor in N content as compared to other cultivation lands (Benbi et al., 2015; Kramer et al., 2002; Srinivasarao et al., 2014; Zhengchao et al., 2013; Kuzyakov and Domanski, 2000).

The total carbon content of soils are highly important due to being both an indicator of the overall soil quality (Rowell, 1994; Schjønning et al., 2004) and relevant to the climate change (Wan et al., 2011; Munoz-Rojas et al., 2012; Parras-Alcantara et al., 2015). Storage of carbon inside the soil involves the processes of carbon intake from the atmosphere by plants and usage of the same in photosynthesis and the transfer of the biomass carbon into the soil in the form of humus (Srinivasarao et al., 2014).

The literature show that there have been many studies investigating the effects of different cropping systems or soil cultivation practices on the total carbon content (Kundu et al., 2007; Nobuhisa et al., 2011; Debasish-Saha et al., 2012; Munos-Rojas

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et al., 2012; Parras-Alcantara et al., 2013; Fialho and Zinn, 2014; Srinivasarao et al., 2014), whereas only a few research has been completed on the comparison of lands formed under the same conditions but allocated to different plant cultivations. This study attempts to compare the soils devoted to wheat and safflower cultivation in the semi-arid climate zones in respect to some of their physical and chemical properties, with particular attention given to their TC content. Since the soil's capacity to store carbon is vitally important in term of climate change and soil fertility, it is believed that the results of this study will be useful in this particular sense.

## 2 Materials and methods

### 2.1 Materials

The study was conducted in two different experimental areas, the wheat cultivation area (WCA) and safflower cultivation area (SCA), located within the province of Eskişehir (Fig. 1). These areas had been maintained with bread wheat (*Triticum aestivum*) – fallow sequence and safflower (*Carthamus tinctorius*) – fallow sequence for more than 20 years. Average wheat yield in the experimental area is  $2.75 \text{ t ha}^{-1}$ , while average safflower yield is  $0.7 \text{ t ha}^{-1}$ . The geographical coordinates of the WCA are  $39^{\circ}46'12.32'' \text{ N}$  and  $30^{\circ}23'53.27'' \text{ E}$ , while the coordinates of the SCA are  $39^{\circ}44'12.88'' \text{ N}$  and  $30^{\circ}09'50.51'' \text{ E}$ . Moreover both areas rely on a precipitation based agricultural system. Total annual precipitation rate in the experimental area is 370 mm, classified as the semi-arid climate zone. While the lowest temperature in the area is  $-0.1^{\circ}\text{C}$  in January, the highest temperature is  $21.7^{\circ}\text{C}$  in July. The soils on the both experimental areas were formed on non-decomposed quaternary material (MRE Earth Science Portal, 2014). Both areas of cultivation are situated on a straight slope, and the elevations from the sea level are 812 and 1018m for the WCA and the SCA, respectively.

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2.2 Methods

2.2.1 Sampling pattern and soil analyses

In order to identify the soil properties of the experimental areas, the WCA and SCA were divided into 10m × 10m grids, and 140 disturbed soil samples were taken from 0–10 and 10–20 cm depths in each 35 points where the grids intersect. Total carbon (TC), total nitrogen (TN) and total sulphur (TS) contents of the soils were identified using an elemental analysis device (elemental analyzer, vario MAKRO cube CHNS, Elementar). Wet combustion method (Sparks et al., 1996), Yoder wet-sieving method (Dane 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 soils, respectively. The pH values of the soils were measured in the 1 : 2.5 soil-water suspension (Conklin, 2005).

2.2.2 Statistical analyses

Descriptive statistics, including average, SD, the minimum and maximum values and coefficient of variation were determined for all the studied soil properties The Shapiro–Wilk W Test was used for determining whether soil properties fit normal distribution Moreover, the analysis of variance was applied in determining the differences between the cultivation areas and the soil layers in terms of the soil properties. JMP 5.0 package software was used in conducting statistical analyses.

3 Results and discussion

3.1 Fundamental characteristics of the soils in the experimental areas

As a result of the elemental analysis, it was established that TC content was the highest in the soil, while TS was the least Analyses showed that the soil texture for the WCA



was clay (Fig. 2a). In addition the organic matter content, the aggregate stability and pH were classified as intermediate, very-good and mid-level alkaline, respectively. As for the SCA, the results revealed that the texture was within the clay and loamy clay (Fig. 2b), and was considered to be “very good” in terms of aggregate stability, high in organic matter content and within the light alkaline in terms of pH. The coefficient of variation (CV) values for studied soil properties were less than 50 %, while the lowest CV was observed for pH and the highest was observed for the TS. Moreover the Shapiro–Wilk W test results indicated that all the observed soil properties were normally distributed (Table 1).

### 3.2 Comparison of the soil properties

#### 3.2.1 Particle size distribution

The results of particle size analysis showed that the clay and silt contents were significantly greater in the WCA, while the sand content was significantly greater in the SCA. As for soil layers, the differences in terms of clay and sand content were not significant, while silt content was significantly greater at the 0–10 cm layer (Table 2). The particle size distribution is regarded as the least affected soil property from agricultural management practices (Karaman et al., 2012). For this reason, it is believed that the difference between the cultivation areas, in term of particle size distribution, was caused by the parent material differences where the soils were originally formed (Table 2).

#### 3.2.2 Organic matter content

The organic matter content was found to be significantly greater in the SCA than the WCA (Table 2). As it is well known that the main source of the organic matter in the soil is the plant and animal residues (Karaman et al., 2012) and any organic substance amount resulting from a plant is directly proportionate to its biomass (Sollins et al.,

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1996; Jaiarree et al., 2011; Novara et al., 2013). The reason for the greater organic matter content in the SCA than the WCA can be explained by the fact that the biomass amount of the safflower (Lenssen et al., 2007; Schillinger et al., 2007) and its residues remaining after the harvest season (Krupinsky et al., 2006) are greater than the wheat.

- 5 No significantly difference was observed among the soil layers in terms of organic matter content (Table 2).

### 3.2.3 Total carbon

Average TC was significantly greater in the WCA compared to the SCA (Table 2). The fact that the wheat contains a higher amount of cellulose (59 %) than safflower (40 %) (Del Río et al., 2012; Schjønning et al., 2004; Smith, 1996), and that the decomposition rate of cellulose is fairly slow (Boswell, 1941) can help explain the higher rates of TC content in the WCA. Another reason for the higher rates of carbon content in the WCA can be associated with a higher rate of C : N ratio for the wheat compared to the safflower. Despite the absence of any study directly comparing the TC contents of both wheat and safflower cultivation areas, the studies comparing the soils of wheat with other crop species also reported greater TC and C : N ratios for wheat (Benbi et al., 2015; Bolinger et al., 1997; Koga et al., 2011). TC content was greater in the top soil layer but this difference was not significant (Table 2).

### 3.2.4 Total nitrogen

20 The TN content was found to be greater in the soils of the SCA than the WCA (Table 2), most probably due to the higher soil organic matter content recorded in the former site as organic nitrogen is converted into mineral nitrogen as a result of the decomposition of the organic materials (Rowell, 1993). Previous studies under different climate conditions and management practices also reported similar findings of positive correlation between organic matter and total nitrogen in soils. (Barrett and Burke, 2000; Filep and Rékási, 2011; Parras-Alcantara et al., 2013; Hu et al., 2014; Parras-Alcantara

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and Lozano-Garcia, 2014). In respect to the soil layers, the analyses revealed that the TN content was significantly greater in the topsoil (Table 2), which is similar to the previous studies (Parras-Alcantara et al., 2013; Yu and Jia, 2014). The fundamental reason for this difference can be related to the rate of decomposition being faster on the top surface due to better ventilation conditions.

3.2.5 Total sulphur

In similar to the TN content, the TS content in the SCA was significantly greater than that of the WCA (Table 2). Literature show that a significant portion of the sulphur component in the soil consists of the organic sulphur resulting from the organic matter decomposition (Karaman, 2012; Janzen and Ellert, 1998), and for this reason it is anticipated that the SCA with rich organic matter content should also yield a higher TS content. Moreover, it was established that there was no significant differences among the soil layers in terms of TS content (Table 2).

3.2.6 Aggregate stability

It was determined that the aggregate stability values of the SCA were significantly higher than the WCA (Table 2). Low aggregate stability can generally be related with deterioration in the structural properties of the soil generally caused by some agricultural practices including use of heavy machinery and tillage under unsuitable soil moisture conditions in agricultural fields (Dilkova et al., 2002). In order to promote the aggregate stability in such areas it is suggested that the organic substance content in the soil be increased by way of fertilization and scattering of plant residues in the field (Lal, 1998; Swindale, 1998). As explained above, the SCA had greater organic matter content than the WCA, considered as one of the factors for the higher aggregate stability. Moreover, literature shows that the safflower cultivation improves the physical properties of the soil (Jayawardane and Chan, 1994) through its deep roots (Wachsmann et al., 2008) and high organic residues, yielding higher aggregate stability





values the SCA. In addition, Nichols and Toro (2011) reported that when safflower is used in crop rotation sequences, higher aggregate stability values were found over the wheat-fallowing crop rotation sequence). No significant difference was detected among the soil layers in terms of aggregate stability (Table 2).

### 3.2.7 pH

It was established that the pH values of the SCA was significantly lower than the WCA (Table 2). The reasons for this low pH in the SCA may be associated with two processes including the decomposition of organic matter emerging organic acids and carbonic acids produced by dissolving of CO<sub>2</sub> in soil solution following root and microbial respiration (Karaman et al., 2013; Rowell, 1993). These reasons are parallel to our findings since the analyses revealed higher organic matter content in the SCA, a main factor lowering pH compared to the WCA. No significantly difference was observed among the soil layers in terms of pH values (Table 2).

## 4 Conclusions

This study was initiated to examine the soil properties of the wheat and safflower cultivation areas formed under the similar parent material and climate conditions. The results revealed that the organic matter content of the soils has a determining effect on the TN, TS, pH and aggregate stability. Due to the higher ratio of organic matter content in the SCA, we found that the TN, TS and aggregate stability values were all significantly greater in the SCA than the WCA while the pH was significantly lower in the SCA. As for the amount of TC content, however, it was found that the quality of the organic matter was more important than its quantity. The fact that the wheat has higher ratios of lignin and cellulose content results in slower decomposition rate and higher TC content in the WCA as compared to the SCA. Moreover, while the silt and

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TN contents of the soils were found to be significantly greater in the bottom soil layer the rest of the soil properties were measured to be similar among the soil layers.

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## Comparison of cultivation areas in terms of soil properties

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**Table 1.** Descriptive statistics of the soil properties.

Variables	Mean	Min	Max	Coefficient of variations (%)	Shapiro–Wilk W Test
Total carbon %	2.10 ± 0.41	1.48	2.73	19.50	0.984 ns
Total nitrogen %	0.15 ± 0.04	0.09	0.22	26.67	0.976 ns
Total sulphur %	0.017 ± 0.008	0.003	0.038	47.05	0.977 ns
Organic matter content %	3.58 ± 0.89	2.21	5.86	24.86	0.978 ns
pH	7.92 ± 0.36	7.34	8.41	4.55	0.998 ns
Aggregat stability %	67.52 ± 15.67	29.60	92.98	23.20	0.975 ns
Clay content %	43.61 ± 6.74	28.40	54.94	15.46	0.981 ns
Silt content %	32.01 ± 3.09	22.94	38.90	9.65	0.987 ns
Sand content %	24.29 ± 7.03	11.92	38.43	28.94	0.992 ns

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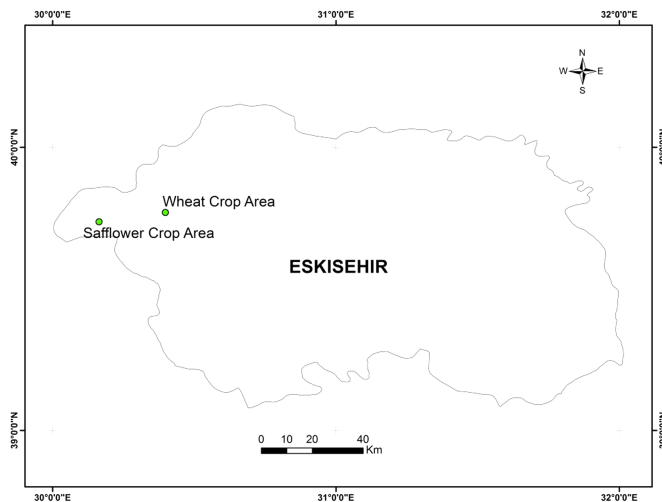


**Table 2.** Summary of ANOVA for soil properties.

Soil properties	Cultivation area		<i>F</i> values	Soil Layers		<i>F</i> values
	WCA	SCA		0–10 cm	10–20 cm	
Sand content (%)	18.30 B	30.64 A	363.4**	24.47	24.48	0.01 ns
Silt content (%)	32.50 a	31.27 b	6.02*	32.56 A	31.22 B	7.15**
Clay content (%)	49.20 A	38.08 B	214.3**	42.97	44.31	3.12 ns
Organic matter (%)	2.74 B	4.43 A	1470.8**	3.59	3.59	0.01 ns
TC (%)	2.491 A	1.704 B	2617.2**	2.104	2.091	0.49 ns
TN (%)	0.117 B	0.183 A	705.0**	0.153 a	0.147 b	6.50*
TS (%)	0.010 B	0.024 A	251.9**	0.016	0.017	1.71 ns
Aggregate stability (%)	62.82 B	73.62 A	18.33**	70.16	73.62	2.38 ns
pH	8.24 A	7.57 B	1991.9**	7.89	7.91	2.92 ns

\* 0.05 significant level; \*\*: 0.01 significant level; ns: non-significant. The means with different capital and small letters indicate significant differences.

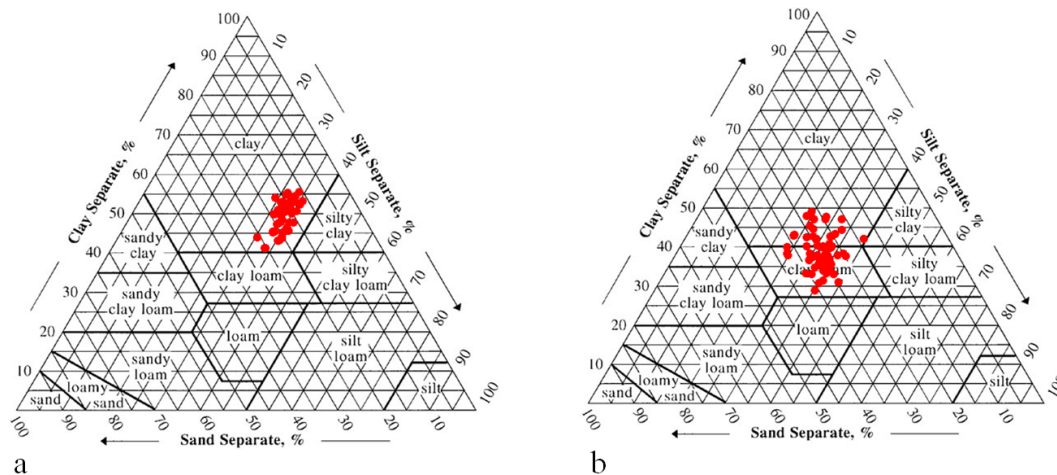




**Figure 1.** The locations of studied areas.

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**Figure 2.** The particle size distribution of soil samples in the wheat (a) and safflower (b) cultivation areas.

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