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Research Article

Carbon Mineralization of *Ceratonia siliqua* L. Soils under Different Temperature and Humidity Conditions

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Abstract: The aim of this study was to determine how carbon (C) mineralization of carob (*Ceratonia siliqua* L., Fabaceae) soils are affected by different temperatures (23 °C and 28 °C) and humidity [field capacity (FC), 80% and 60% of their field capacity] conditions in the laboratory. The carob soils were taken from Çukurova University campus in the eastern Mediterranean region of Turkey. C mineralization of all soils was determined using CO_2 respiration method. The microbial activity increased together with temperature increases. The microbial activity in the soils humidified at the field capacity and 60% of it was statistically lower compared to the soils humidified with 80% of field capacity at both 23 °C and 28 °C ($P < 0.000$). The rate (%) of C mineralization of 80% of field capacity at 28 °C was significantly higher than field capacity ($P = 0.009$) and 60% of field capacity ($P = 0.006$) at 23 °C and 60% of field capacity ($P = 0.009$) at 28 °C. Based on these results, it is possible to conclude that microorganisms in the carob soil show better activities at 80% of field capacity and 28 °C in 30 days.

Key Words: Carbon mineralization, Carob, Humidity, Microbial activity, Temperature

Ceratonia siliqua L. Topraklarının Farklı Sıcaklık ve Nem Koşulları Altında Karbon Mineralizasyonu

Özet: Bu çalışmanın amacı, laboratuvarda farklı sıcaklık (23 °C and 28 °C) ve nem koşullarının [Tarla Kapasitesi (TK) ve tarla kapasitelerinin %60 ve %80'i] keçiboynuzu (*Ceratonia siliqua* L., Fabaceae) topraklarının karbon (C) mineralizasyonunu nasıl etkilendiğini belirlemektir. Keçiboynuzu toprakları Türkiye'nin Doğu Akdeniz Bölgesindeki Çukurova Üniversitesi kampüsünden alınmıştır. Tüm toprakların C mineralizasyonu CO_2 respirasyon yöntemi kullanılarak belirlenmiştir. Mikrobial aktivite sıcaklık artışı ile birlikte artmıştır. Tarla kapasitesinde ve bunun %60'ına nemlendirilmiş topraklarda mikrobial aktivite hem 23 °C and 28 °C'de tarla kapasitesinin %80'ine nemlendirilmiş topraklardan istatistiksel olarak daha düşüktür ($P < 0,000$). 28 °C'deki tarla kapasitesinin %80'inin C mineralizasyon oranı (%) 23 °C'deki tarla kapasitesi ($P = 0,009$) ve bunun %60'ından ($P = 0,006$) ve 28 °C'deki tarla kapasitesinin %60'ından ($P = 0,009$) anlamlı olarak yüksektir. Bu sonuçlara dayanarak keçiboynuzu topraklarındaki mikroorganizmaların 30 gün içinde 28 °C'de ve tarla kapasitesinin %80'inde daha iyi aktivite gösterdikleri sonucuna varmak mümkündür.

Anahtar Sözcükler: Karbon mineralizasyonu, Keçiboynuzu, Nem, Mikrobial aktivite, Sıcaklık

Introduction

Soil respiration is affected in a complex way by temperature, moisture, soil properties, and quality and quantity of decomposing organic substrates (Kirschbaum, 2000; Raich & Tüfekçioğlu, 2000), and predictions of future changes rely on the detailed knowledge on the effects of each of these factors but also on their interaction (Uvarov et al., 2006). Temperature, together with moisture content, is the most important environmental factor affecting microbial growth and activity in soils (Paul & Clark, 1996; Dalias et al., 2001a; Dalias et al., 2001b; Pietikäinen et al., 2005; Uvarov et al., 2006). The importance of the temperature dependence of soil organisms has been further emphasized in recent years due to the global warming issue (Kirschbaum, 1995; Kirschbaum, 2000; Reichstein

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et al., 2000) since microorganisms are the main group producing CO_2 during decomposition of organic material in soil (Pietikäinen et al., 2005).

The carob [evergreen tree (*Ceratonia siliqua* L., Fabaceae)] is described as a plant with a large adaptability to the Mediterranean basin (Lossaint, 1973; Batlle & Tous, 1997) and distributed in the eastern Mediterranean region of Turkey, characterized by semiarid Mediterranean climate conditions (Davis, 1969). The carob tree has an active root system in the top 15-20 cm of the soil, as this soil zone is generally more fertile and better aerated (Batlle & Tous, 1997). CO_2 diffusion resulting from the degradation of organic materials in this fertile soil zone has been considered as a valuable index of microbial activity in the present study. However, there is not much knowledge on which temperatures and humidity effectively activate the microorganisms in this fertile soil zone (Aka & Darıcı, 2005). The range of diurnal temperature fluctuations in litter and topsoil depends on many factors and can reach 25-30 °C (Byzova, 1977).

Our aim was to determine how carbon (C) mineralization of the carob soils are affected by different temperature (23 °C and 28 °C) and humidity [field capacity (FC), 80% and 60% of their field capacity] conditions in the laboratory. Temperature responses of C mineralization rates have been extensively investigated in numerous field and laboratory experiments (Dalias et al., 2001a; Dalias et al., 2001b; Kirschbaum, 1995; Kirschbaum, 2000). The carob soils were taken from Çukurova University campus characterized by the semiarid climate conditions in the eastern Mediterranean region of Turkey. This study was performed to provide further insight on temperature and humidity dependence of C mineralization in the carob soil with own organic matter.

Materials and Methods

This study was conducted at the Çukurova University campus (2200 ha) in Adana, Turkey (mean annual precipitation of 663 mm, mean annual temperature of 18.7 °C) characterized by the semiarid Mediterranean climate conditions in the eastern Mediterranean region of Turkey. The precipitation and temperature data of Adana are based on a 50-year period (Meteoroloji Bülteni, 2001). The soil used for the incubation experiments was classified as Alfisols for Çukurova University campus (Soil Survey Staff, 1998).

To get the carob soil samples, 3 superficial soil samples from the upper 20 cm of carob soil were taken from each 3 corners of this site due to its shape in October 2003. Samples from each corner were mixed, homogenized, and considered as a composite and representative sample of the study site. After removing recognizable plant debris, these composite samples were air-dried and sieved through a 2 mm mesh sieve before analysis.

An aerobic incubation (soil C mineralization) experiment was established using a full factorial design with 2 factors: i) temperature (2 temperature conditions) and ii) humidity (3 humidity conditions). The 2 temperature conditions were 23 °C and 28 °C. The 3 humidity conditions were field capacity, 80% and 60% of their field capacity. Three replicates by each factor level combination were used.

Soils were placed in 750 ml incubation vessels for the carbon mineralization. The final moisture contents of the carob soils for 3 different humidity conditions were adjusted to field capacity (27%), 80% and 60% of their field capacity before the incubation at both 23 °C and 28 °C (Schaefer, 1967). The CO_2 produced from microbial respiration was absorbed periodically in 40 ml saturated $Ba(OH)_2$ solution in small tubes, which were placed on the top of the soil in the incubation vessels. The incubation vessels were closed. Empty vessels were used as blanks. The CO_2 produced as a result of microbial respiration was measured every 3 days by titration with oxalic acid [due to the decrease in CO_2 production, measurement times were delayed 1 or 2 days (Benlot, 1977)]. The incubation was carried out in dark at both 23 °C and 28 °C for 30 days in a temperature-controlled incubator. The rate (%) of carbon mineralization of both soils with their own organic carbon was calculated by dividing the cumulative $C(CO_2)$ produced in 30 days by total organic carbon.

The soil texture was determined by the Bouyoucos hydrometer (Bouyoucos, 1951), and the field capacity water (%) was determined by applying 1/3 atmospheric pressure with a vacuum pump (Demiralay, 1993). The pH was measured in a 1:2.5 soil-to-water suspension with a pH meter (Jackson, 1958). Organic carbon content (%) was determined by the Anne method (Walkley & Black, 1934; Duchaufour, 1970). Organic nitrogen content (%) was determined by Kjeldahl method (Duchaufour, 1970).

Repeated Measures (General Linear Model) analysis was performed to determine the differences in carbon mineralization over incubation time between temperature conditions (23 °C and 28 °C) and humidity conditions [field capacity, 80% and 60% of their field capacity (Kleinbaum, 1998)]. The means of the 3 replicates were used for each combined soil for comparisons. Results were given as mean ± standard error (S.E.) in the tables and figures. The values of $P \leq 0.05$, 0.01, and 0.001 were accepted as significant.

Results and Discussion

The carob soils are loam textured. Field capacity, pH, and $CaCO_3$ are 27.0 %, 7.71%, and 18.1%, respectively. Soil organic carbon content is 2.85%, whereas soil nitrogen content is 0.26%. C/N ratio of this soil is 10.8 (Table 1).

Our results showed that cumulative $C(CO_2)$ respired of all carob soils at the field capacity, 80% and 60% of their field capacity clearly increased with incubation time in both 23 °C and 28 °C incubation conditions (Figure 1 and 2). It is clear that soil respiration responds positively to temperature in the present study. Similar results were also observed in semiarid soils (Cotant et al., 2004). Within all water potentials (-0.03, -0.50, -1.00, and -1.50 MPa), respiration rates always increased with an increase in temperature (5, 15, 25 and 35 °C) in the present study. Temperature is just one of the variables that influences soil respiration (Davidson et al., 2000; Dalias et al., 2001a; Dalias et al., 2001b; Uvarov et al., 2006). However, it may explain up to 72%-96% of the variation in soil respiration in temperate forests (Rey et al., 2002; Subke et al., 2003). Interactions between incubation time and temperature and incubation time and humidity were significant at $P < 0.001$ level in the microbial respiration.

Table 1. Some physical and chemical properties (mean ± S.E.; n = 3) of the carob soils (FC: field capacity).

Characteristic	
Clay [<0.002 mm (%)]	9.41 ± 0.65
Silt [0.02-0.002 mm (%)]	41.7 ± 2.36
Sand [2-0.02 mm (%)]	48.8 ± 2.07
Texture Type	Loam (L)
FC (%)	27.0 ± 0.27
pH	7.71 ± 0.04
$CaCO_3$ (%)	18.1 ± 1.68
C (%)	2.85 ± 0.39
N (%)	0.26 ± 0.08
C/N ratio	10.8 ± 1.29

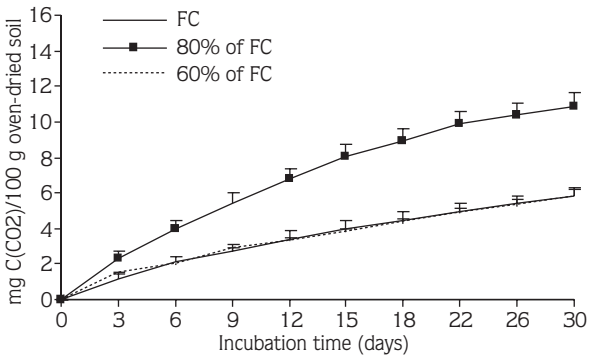

Figure 1. Cumulative C mineralized (mean ± S.E.; n = 3) in different humidity conditions [FC (field capacity), 80% and 60% of their FC] of carob soils, at 23 °C and in different durations.

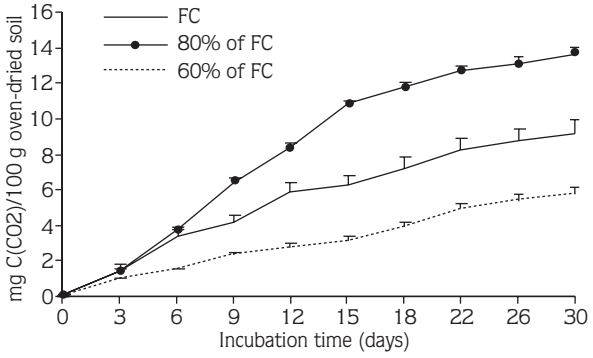

Figure 2. Cumulative C mineralized (mean ± S.E.; *n* = 3) in different humidity conditions [FC (field capacity), 80% and 60% of their FC] of carob soils, at 28 °C and in different durations.

At the end of the incubation period, there were significant differences in mineralized C between 80% and 60% of field capacity, field capacity and 80% of field capacity at 23 °C ($P < 0.001$, multiple comparisons by Tukey's HSD test), but it did not statistically change between field capacity and 60% of field capacity ($P > 0.05$). At 28 °C, differences between 80% and 60% of field capacity, field capacity and 80% of field capacity, field capacity and 60% of field capacity were significant ($P < 0.001$, multiple comparisons by Tukey's HSD test). As a summary, it is found that the microbial activity in the soils humidified at the field capacity and 60% of it was statistically lower compared to the soils humidified with

80% of field capacity at both 23 °C and 28 °C ($P < 0.001$). This result shows that soil moisture is a limiting factor in the soils with low and high moisture contents. CO_2 outlet from this soil is also lower because of this limiting situation. Soil moisture can limit soil respiration by limiting microbial contact with available substrate and dormancy and/or death of microorganisms at low soil water potentials (Orchard & Cook, 1983).

Soil humidified at the field capacity at 28 °C was significantly different from both field capacity and 60% of field capacity at 23 °C at the end of the incubation period ($P = 0.001$). 80% of field capacity at 28 °C was also significantly different from both field capacity and 60% of field capacity at 23 °C ($P < 0.001$). 80% of field capacity at 23 °C was statistically different from both 80% and 60% of their field capacity at 28 °C ($P = 0.007$ and $P < 0.001$, respectively). 60% of field capacity at 28 °C was not statistically different from field capacity and 60% of field capacity at 23 °C ($P = 1.000$). There was no significant difference between field capacity at 28 °C and 80% of field capacity at 23 °C ($P = 0.159$). Interaction among incubation time, temperature, and humidity was significant at $P = 0.002$ level for mineralized C. This result showed that soil microbial activity was affected from varying temperature and humidity conditions within 30 days.

The rate (%) of carbon mineralization of 80% field capacity at 28 °C was significantly higher than field capacity ($P = 0.009$) and 60% of field capacity ($P = 0.006$) at 23 °C and 60% of field capacity ($P = 0.009$) at 28 °C (Figure 3). All these results might be explained with the fact that 28 °C is more suitable temperature than 23 °C for microbial activity. We know that temperature is also an important factor regulating microbial activity and shaping the soil microbial community (Pietikäinen et al., 2005).

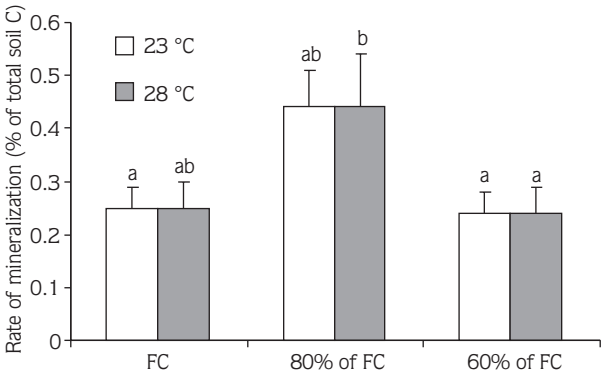

Figure 3. Rate of mineralization (R_m, mean ± S.E.; $n = 3$) of the organic carbon in 3 different humidity conditions [FC (field capacity), 80% and 60% of FC] and 2 different temperature conditions (23 °C and 28 °C) of carob soils at the end of incubation period (30 days). Different letters denote significant differences between different humidity and temperature conditions at $P \leq 0.05$ level.

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References

Aka H & Darıcı C (2005). Carbon and nitrogen mineralization in carob soils with Kermes oak and Aleppo pine leaf litter. *Eur J Soil Biol* 41: 31-38.

Batlle I & Tous J (1997). *Carob tree (Ceratonia siliqua L.), Promoting the conservation and use of underutilized and neglected crops 17*. Rome: IPGRI Press.

Benlot C (1977). *Recherches sur les activites biochimiques dans les successions de sols derives de cendres volcaniques sous climat tropical humide (Zaire-Indonesie)*. ENS Lab., De Zoologie, Paris.

Bouyoucos GS (1951). A recalibration of the hydrometer for mohing mechanical analysis of soil. *Agron J* 43: 434-438.

Byzova JB (1977). Temperature conditions of dwelling and respiration intensity in soil invertebrates. In: Ghilarov MS (ed.) *Adaptation of Soil Animals to Environmental Conditions*, pp. 3-44. Moscow: Nauka Publication House.

Cotant RT, Dalla-Betta P, Klopatek CC & Klopatek JM (2004). Controls on soil respiration in semiarid soils. *Soil Biol Biochem* 36: 945-951.

Dalias P, Anderson JM, Bottner P & Coûteaux MM (2001a). Long-term effects of temperature on carbon mineralisation processes. *Soil Biol Biochem* 33: 1049-1057.

Dalias P, Anderson JM, Bottner P & Coûteaux MM (2001b). Temperature responses of carbon mineralization in conifer forest soils from different regional climates incubated under standard laboratory conditions. *Global Change Biol* 6: 181-192.

Davidson EA, Trumbore SE & Amundson R (2000). Soil warming and organic carbon content. *Nature* 408: 789-790.

Davis PH (1969). *Flora of Turkey and the East Aegean Islands*. Edinburgh: Edinburg Press.

Demiralay İ (1993). *Toprak Fiziksel Analizleri*. Erzurum: Atatürk Üniversitesi Ziraat Fakültesi Yayınları 143.

Duchaufour P (1970). *Precis de Pedologie*. Paris: Masson et C[1e].

Jackson ML (1958). *Soil Chemical Analysis*. New Jersey: Prentice-Hall Inc.

Kirschbaum MUF (1995). The temperature dependence of soil organic matter decomposition, and the effect of global warming on soil organic C storage. *Soil Biol Biochem* 27: 753-760.

Kirschbaum MUF (2000). Will changes in soil organic carbon act as a positive or negative feedback on global warming?. *Biogeochem* 27: 753-760.

Kleinbaum DG, Kupper LL, Muller KE & Nizam A (1998). *Applied Regression Analysis and Other Multivariable Methods*. California: Duxbury Press.

Lossaint P (1973). Soil-vegetation relationships in Mediterranean ecosystems of southern France. In: Castri F & Mooney HA (eds.), *Mediterranean type ecosystems origin and structure*, pp. 199-210. New York: Heidelberg Press.

Meteoroloji Bülteni (2001). *Ortalama ve ekstrem kıymetler*. Ankara: Meteoroloji Müdürlüğü Yayını.

Orchard VA & Cook FJ (1983). Relationship between soil respiration and soil moisture. *Soil Biol Biochem* 15: 447-453.

Paul EA & Clark FE (1996). *Soil Microbiology and Biochemistry*. USA: Academic Press.

Pietikäinen J, Pettersson M & Baath E (2005). Comparison of temperature effects on soil respiration and bacterial and fungal growth rates. *FEMS Microbiol Ecol* 52: 49-58.

Raich J & Tüfekçioğlu A (2000). Vegetation and soil respiration: correlation and controls. *Biogeochem* 48: 71-90.

Reichstein M, Bednorz F, Broll G & Kätterer T (2000). Temperature dependence of carbon mineralisation: conclusions from a long-term incubation of subalpine soil samples. *Soil Biol Biochem* 32: 947-958.

Rey A, Pegoraro E, Tedeschi V, De Parri I, Jarvis PG & Valentini R (2002). Annual variation in soil respiration and its components in a coppice oak forest in Central Italy. *Global Change Biol* 8: 851-866.

Schaefer R (1967). Characteres et evolution des activites microbiennes dans une chaine de sols hidromorphes mesotrophiques de la plaine d'Alsace. *Rev Ecol Biol Sol* 4: 567-592.

Soil Survey Staff (1998). *Keys to Soil Taxonomy*. Washington: USDA-NRCS.

Subke JA, Reichstein M & Tenhunen JD (2003). Explaining temporal variation in soil CO_2 efflux in a mature spruce forest in Southern Germany. *Soil Biol Biochem* 35: 1467-1483.

Uvarov AV, Tiunov AV & Scheu S (2006). Long-term effects of seasonal and diurnal temperature fluctions on carbon dioxide efflux from a forest soil. *Soil Biol Biochem* 38: 3387-3397.

Walkley A & Black IA (1934). An examination of the Degtjareff method for determining siol organic matter and a proposed modification of the chromic acid titration method. *Soil Sci* 37: 29-38.