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Research Article

Carbon mineralization in soil mixed with leaves and tubers of red beet, red radish and watermelon radish

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Abstract: The objective of the present study was to determine how carbon mineralization of red beet soil (*Beta vulgaris* L. var. *rapacea*, Chenopodiaceae) is affected by the addition of red radish (*Raphanus sativus* L. var. *radicula*, Brassicaceae), watermelon radish (*Raphanus sativus* L., Brassicaceae) and red beet leaf, tuber and their mixtures (containing 2.0% total organic carbon) under the laboratory conditions (60 days at 28°C). Carbon mineralization of all soil-plant mixtures was determined by CO_2 respiration. The ratios of C mineralization (%) in soils added red radish tuber, leaves and tubers of watermelon radish, leaves and tubers of red radish was significantly higher than no added soil at the end of 60 days. C mineralization ratio increased especially in addition of red radish leaves together with tuber. This result show that organic C and N contents and organic matter quality of red radish were more preferred by soil microorganisms than organic matter of the red beet and watermelon radish.
Keywords: Carbon mineralization, Microbial activity, Organic matter additions, Radish, Red beet.

INTRODUCTION

Allelopathy can be defined as chemical interactions between and among both plants and microorganisms via releases of biologically active chemical compounds into the environment [1]. During the past three decades this scientific field has received growing attention from soil scientists, microbiologists, ecologists, plant physiologists, biochemists, botanists, weed scientists, agronomists, and natural product chemists [2].

The allelopathic potential of certain weed and crop species can influence the growth and distribution of associated weed species and the yield of desired plants, and allelopathy has been employed successfully in biocontrol programs focusing on control of problematic weeds and plant diseases [1, 3]. This allelopathic effects to the weeds is an important subject for biological control in the field conditions [4].

The Brassicaceae family is important for allelopathic potential, as its members produce allelopathic substances [5]. The genus *Raphanus* is a member of Brassicaceae family. The allelopathic effects of *Raphanus sativus* L. succesfully controls the *Sorghum halepense* in cotton fields, when grown in rotation with cotton [4].

Soil microbial respiration is an important bioindicator [6] that it has been commonly used to evaluate the effects of management practices on soil biological quality [7]. The aim of this study was to specify how carbon mineralization of red beet (*Beta vulgaris* L. var. *rapacea*, Chenopodiaceae) soil is effected by the addition of red radish (*Raphanus sativus* L. var. *radicula*, Brassicaceae), watermelon radish (*Raphanus sativus* L., Brassicaceae) and red beet leaves, tubers and their mixtures (containing 2.0% their own total organic carbon) under the laboratory conditions (60 days at 28°C) in a district (Kadirli, Osmaniye) of the Eastern Mediterranean region, Turkey.

MATERIALS AND METHODS

Kadirli, a district of Osmaniye, is located in the eastern Mediterranean region of Turkey. Radish is a plant that grows fast and has an increasing share in foreign and domestic markets. The soil, leaf and tuber samples from three different fields were used for this study. First, second and third plants from these fields were selected as red radish (*Raphanus sativus* L. var. *radicula*, Brassicaceae), watermelon radish (*Raphanus sativus* L., Brassicaceae) and red beet (*Beta vulgaris* L. var. *rapacea*, Chenopodiaceae), respectively.

Soil samples from three different fields were collected from the upper 0-20 cm in March 2013. These soils were air-dried, and then sieved with a 2 mm mesh sieve. Red beet soil was used for incubation experiments because of its total carbon content (2.04 ± 0.05 C%). No plant leaf or tuber was added to red beet soil in the first mixture. 100 g of red beet soil was mixed with 3.16 g oven-dried red beet leaves (63.2 ± 2.35 C%), 3.13 g watermelon radish leaves (63.8 ± 2.35 C%), 3.10 g red radish leaves (64.5 ± 1.54 C%), 2.81 g red beet tubers (71.2 ± 2.35 C%), 2.83 g watermelon radish tubers (70.6 ± 2.67 C%), 2.72 g red radish tubers (73.6 ± 1.16 C%), 3.16 g red beet leaves plus 2.81 red beet tubers, 3.13 watermelon radish leaves plus 2.83 g watermelon radish tubers and 3.10 g red radish leaves plus 2.72 g red radish tubers in the second, third, fourth, fifth, sixth, seventh, eighth and ninth mixtures, respectively. Amounts of leaves and tubers added to red beet soil were chosen according to their own total organic carbon contents. Leaves and tubers of three plants always contained 2.0% total organic carbon. Total organic carbon content of red beet leaves (2.0%) plus tubers (2.0%), watermelon radish leaves (2.0%) plus tubers (2.0%), red radish leaves (2.0%) plus tubers (2.0%) was 4%. To measure soil microbial activity in red beet fields, a control soil which was not added plant parts was included. All of soil samples were moistured to 80% of own field capacity [8]. The CO_2 derived from microbial activity was measured according to Benlot [9].

The texture of soil was estimated by a Bouyoucos hydrometer [10] and field capacity water (%) was determined by a vacuum pump with 1/3 atmospheric pressure [11]. The soil pH was determined in mud saturated (1:2.5 soil-to-water suspension) using pH meter [12]. $CaCO_3$ content (%) of soil was determined by Scheibler calcimeter [13]. The contents of organic carbon and total nitrogen of samples (%) were determined by the Anne and Kjeldahl methods, respectively [14].

Solid phase extraction (SPE) method was used for extraction procedures of pesticide residues in biobed, farm-soil and water [15].

Repeated Measures (General Linear Model) analysis was performed to determine the differences in the carbon mineralization over incubation time among mixtures [16]. Results were given as means and standard errors in tables and the figures. Differences between the data were assumed as significant at P ≤ 0.05 levels. Obtained data from this study were analysed using SPSS v.11.5.

RESULTS AND DISCUSSION

Red beet, red radish and watermelon radish and their field soils had different physical and chemical characteristics (Table 1-2). Pesticide residue did not find in all of red radish, watermelon radish and red beet soils. Red beet soils were used in the all incubation experiments because of its total organic C content (2.04%) and being a member of the different family (Chenopodiaceae).

Table 1: Physical and chemical characteristics (mean ± S.E.; *n*= 3) of red beet, watermelon radish and red radish field soils in Kadirli-Osmaniye

Characteristic	Red beet soil	Watermelon radish soil	Red radish soil
Sand [2–0.02 mm (%)]	77.5 ± 0.78a	69.5 ± 0.50b	79.2 ± 0.89a
Silt [0.02–0.002 mm(%)]	5.60 ± 0.81a	11.3 ± 0.53b	7.96 ± 0.30a
Clay [<0.002 mm (%)]	16.9 ± 0.16a	19.3 ± 0.61b	12.9 ± 0.74c
Texture type	Sandy loam (SL)	Sandy loam (SL)	Sandy loam(SL)
Field capacity (%)	21.9 ± 0.52a	22.7 ± 1.45a	23.2 ± 0.39a
pH	7.45 ± 0.05a	7.77 ± 0.04b	7.59 ± 0.03a
$CaCO_3$ (%)	23.5 ± 0.29ab	22.6 ± 0.30a	24.4 ± 0.30b
C (%)	2.04 ± 0.05a	1.90 ± 0.05a	1.84 ± 0.06a
N (%)	0.11 ± 0.01a	0.20 ± 0.01b	0.23 ± 0.03b
C/N	18.8 ± 1.34a	9.70 ± 0.33b	8.16 ± 0.81b
Pesticide residue (ppm)	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a

Different letters denote significant differences among three field soils (P ≤ 0.05).

Table 2: C and N contents (%; mean ± S.E.; *n*= 3) of red beet, watermelon radish and red radish leaves and tubers growing in Kadirli-Osmaniye.

Analysis		Red beet	Watermelon radish	Red radish
%N	Leaf	0.18 ± 0.009ax	0.42 ± 0.02bx	0.36 ± 0.02bx
	Tuber	0.28 ± 0.017ax	0.31 ± 0.017ax	0.29 ± 0.03ax
%C	Leaf	63.2 ± 2.35ax	63.8 ± 2.35ax	64.5 ± 1.54ax
	Tuber	71.2 ± 2.35ay	70.6 ± 2.67ax	73.6 ± 1.16ay

a and b letters denote significant differences among three plants. x and y letters denote significant differences among different plant parts ($P \leq 0.05$).

The cumulative C(CO_2) values of soil added watermelon radish leaves were significantly different from soil added red beet leaves at the end of 60 days (p = 0.007, Figure 1).

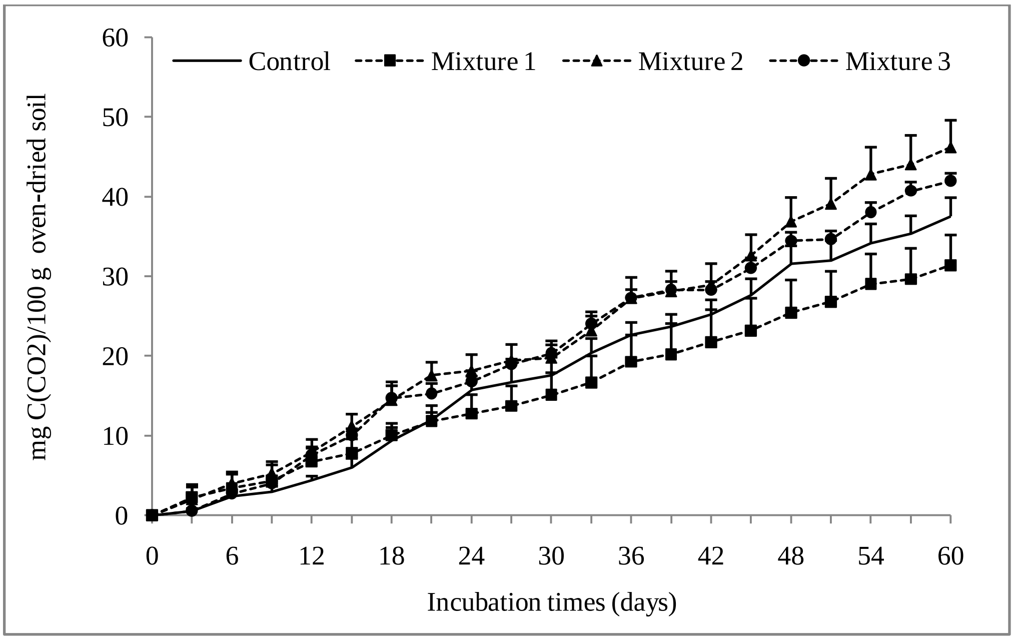

Fig 1: Cumulative C mineralized (mean ± S.E.; *n* = 3) in no added (Control), soils added red beet (Mixture 1), watermelon radish (Mixture 2) and red radish leaves (Mixture 3) of Kadirli-Osmaniye, at different days.

In the light of the results obtained, it can be said that watermelon radish leaves are more suitable organic substance to be used as C source by microorganisms. Soil texture and organic matter are significantly affected by microbial biomass and activity [17, 18]. Mineralization kinetics of organic matter is directly related to the quality (such as humification degree) of the organic matter [19]. Leaf N content (0.42%) of watermelon radish is significantly higher than red beet leaves (0.18%). This value can explain why watermelon radish leaves is more mineralized than red beet leaves. It has been reported that N contents of the soils is a very significant parameter for soil microorganism activity and mineralization [20, 21].

There was only one difference between no added soil and soil mixed with red radish tuber (p = 0.020, Figure 2). When C and N values (%) of the red radish tuber were examined, there was no significant difference among three plant tubers. This result gives an idea that red radish tuber is an organic substance source more easily decomposed by microorganisms than the others.

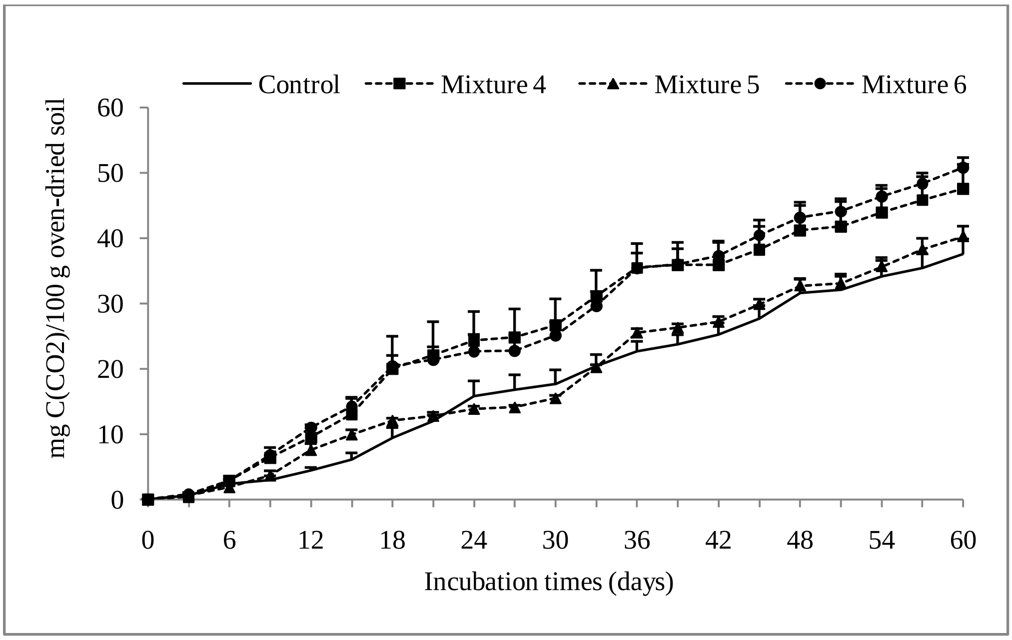

Fig 2: Cumulative C mineralized (mean ± S.E.; *n* = 3) in no added (Control), soils added red beet (Mixture 4), watermelon radish (Mixture 5) and red radish tubers (Mixture 6) of Kadirli-Osmaniye, at different days.

For the soils mixed together with leaf and tuber (Figure 3), C mineralizations of watermelon radish and red radish were significantly higher than no added soil ($p = 0.014$ and $p = 0.000$, respectively). When soils added leaf and tuber were gathered according to total C and N contents (%) of two parts of each plant (leaf + tuber C, leaf + tuber N), total N content can be ordered as watermelon radish (0.73%), red radish (0.65%) and red beet (0.46%), respectively. C contents of plant parts were similar in the total. Difference between two plants (watermelon radish and red radish) and no added soil can be connected with total N contents of two parts of plants.

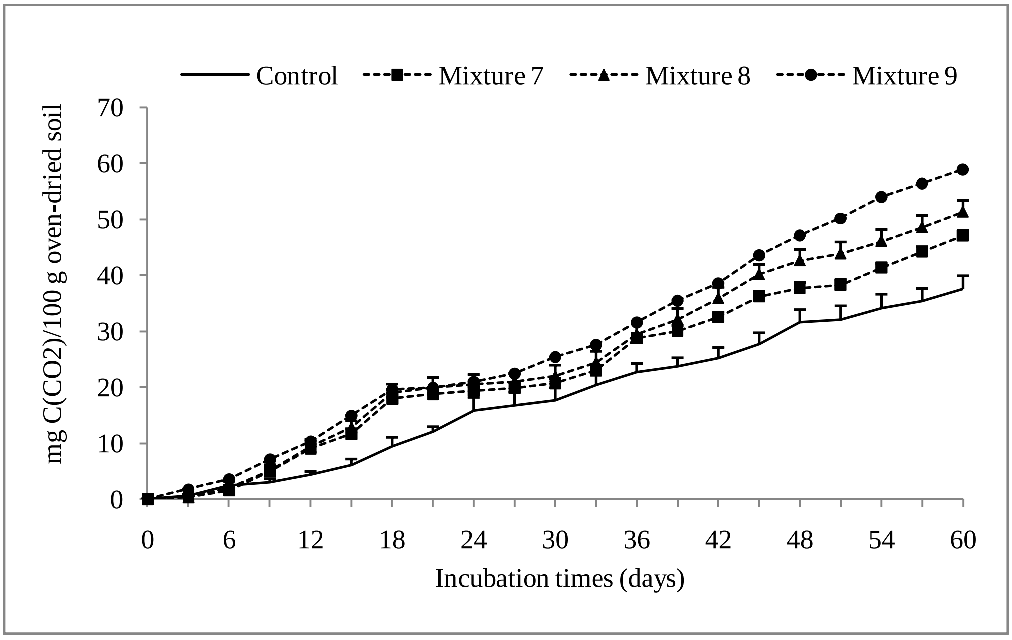

Fig 3: Cumulative C mineralized (mean ± S.E.; *n* = 3) in no added (Control), soils added red beet (Mixture 7), watermelon radish (Mixture 8) and red radish leaves plus tubers (Mixture 9) of Kadirli-Osmaniye, at different days.

C mineralization ratio (%) of soil added red radish tuber, leaves and tubers of watermelon radish, leaves and tubers of red radish was significantly higher than no added soil at the end of 60 days (Figure 4). While the lowest C mineralization ratio was in soil added red beet leaves the highest ratio was found soil mixed together with leaves and tubers of red radish.

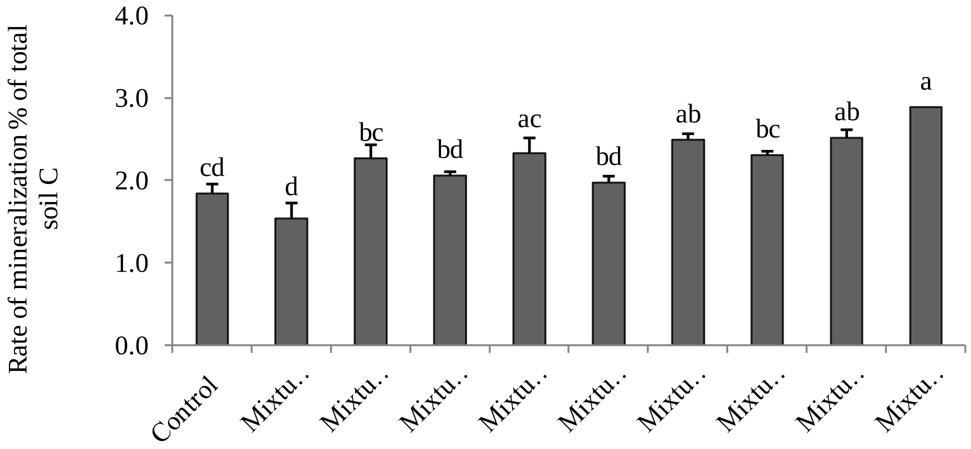

Fig 4: Ratios of mineralization of organic carbon (Rm) of no added (Control) and all additions in Kadirli-Osmaniye (mean ± S.E.; *n* = 3), at the end of the incubation period (60 days). Different letters denote significant differences among no added and the other mixtures at P ≤ 0.05 level [soils added red beet leaves (Mixture 1), watermelon radish leaves (Mixture 2), red radish leaves (Mixture 3), red beet tubers (Mixture 4), watermelon radish tubers (Mixture 5), red radish tubers (Mixture 6), red beet leaves plus tubers (Mixture 7), watermelon radish leaves plus tubers (Mixture 8) and red radish leaves plus tubers (Mixture 9)].

These results showed that especially red radish leaves and tubers additions to the soils increased the microbial activities of this soil. The results from our study suggest that microorganisms in this soil might be capable of usage to the added organic matter (especially red radish) by C mineralization. Aggangan et al. [22] found that rates of microbial respiration and biomass concentration were significantly influenced by the amount of eucalypt leaf litter added in both native forest and pasture soils.

CONCLUSION

Our results suggest that red beet, watermelon radish and red radish leave or/and tuber additions increased C mineralization. C mineralization increased especially by addition of red radish leaves together with tuber. This result show that organic C and N contents and organic matter quality of red radish were more preferred by soil microorganisms than organic matter of the red beet and watermelon radish. It might be said that selected plants in this study have no allelopathic effects on C mineralization of soil microorganisms.

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