

**EVALUATION OF SUBSTRATES MINERALIZATION BY C-CO₂ FLUX UNDER NITROGEN FERTILIZATION****Víctor Manuel Montoya-Jasso¹✉, Gerardo Sergio Benedicto Valdés¹, Víctor Manuel Ordaz-Chaparro¹, Alejandrina Ruiz-Bello¹, Jesús Manuel Arreola-Tostado² and Ximena Castillo-Valdez¹.**

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KEY WORDS: Organic matter, moisture, minerals, biostability and substrate respiration.

ABSTRACT

The objective was to evaluate the mineralization of two mixtures of substrates with different nitrogen content, moisture, compost and mineral mixture based on zeolite and dolomite. The measured parameters were pH (extract 1:2), electrical conductivity (extract 1:5) by conductimeter; content of organic matter by ignition; organic carbon based on the results of organic matter using the Douglas factor= 0.5; and nitrogen per micro Kjeldahl. The flow of CO₂ was measured with the IRGA gas analyzer. For both moisture content, the compost-free substrates had a higher C/N ratio. Compost substrates, because of their high mineralization, were appropriate with advantages to the supply of nitrogen. Substrates with compost and 15% moisture released higher CO₂ by presenting more easily degradable compounds. Mineralization rates on substrates were higher with 15% humidity due to increased porous space occupied by gases, in addition, the supply of 50% of nitrogen had a low immobilization due to the lower organic matter content and the 40 cm³ L⁻¹ mineral mixture content changed the dilution of carbon to be metabolized by microorganisms. The rate of mineralization was affected by the use of minerals, the quality and the substrate origin.

EVALUACIÓN DE MINERALIZACIÓN DE SUSTRATOS POR FLUJO DE C-CO₂ BAJO FERTILIZACIÓN DE NITRÓGENO**PALABRAS CLAVES**

Materia orgánica, humedad, minerales, bioestabilidad y respiración del sustrato.

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RESUMEN

El objetivo fue evaluar la mineralización de dos mezclas de sustratos con diferente contenido de nitrógeno, humedad, compost y mezcla mineral a base de zeolita y dolomita. Los parámetros medidos fueron pH (extracto 1: 2), conductividad eléctrica (extracto 1: 5) por conductímetro; contenido de materia orgánica por ignición; carbono orgánico basado en los resultados de la materia orgánica usando el factor Douglas = 0.5; y nitrógeno por micro Kjeldahl. El flujo de CO₂ se midió con el analizador de gases IRGA. Para ambos contenidos de humedad, los sustratos sin compost tenían una relación C/N más alta. Los sustratos de compost, debido a su alta mineralización un 15% de humedad debido al aumento del espacio poroso ocupado por los gases, además, el suministro de 50% de nitrógeno tuvo una baja inmovilización debido al menor contenido de materia orgánica y al contenido de la mezcla mineral L-1 de 40 cm³ cambió la dilución de carbono para ser metabolizada por microorganismos. La tasa de mineralización se vio afectada por el uso de minerales, la calidad y el origen del sustrato.

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INTRODUCTION

Currently, fertilization management techniques and crop production are required to prevent, as far as possible, soil degradation and environmental pollution problems (Martín y Rivera, 2004). One procedure is by replacing soil cultivation with substrate cultivation (Abad y Noguera, 1997). When assessing the quality of a substrate, account must be taken of the proportion of the organic fraction since it is an essential constituent, due its properties and constitution, is responsible for most physicochemical and biological processes (Aguilera et al., 1999), especially in total nitrogen content. Nutrients present in organic matter transforms into inorganic forms, which are available to plants (Guerrero-Ortiz et al., 2012), this process is known as mineralization (Steubing et al., 2001) and causes the reduction of the organic fraction during the conversion of nutrients and the CO₂ release that are incorporated into plants, atmosphere and waste from organic complexes (Chapin et al., 2011). The flow of CO₂ its a parameter tied with the potential fertility both soil and substrate.

While a mineral fraction present improves physical conditions by increasing aeration capacity (Gutiérrez-Castorena et al., 2011), which increases moisture retention capacity and promotes the process of decomposing the organic labile fraction (Wilhelm et al., 2004). The use of minerals, such as zeolite, in substrate has not been developed on a large scale (Stamatakis et al., 2001), in Mexico the use of this resource has received little attention; while in other countries it has been widely used for use as a substrate in hydroponic cultures (Steinberg et al., 2000; Stamatakis et al., 2001 y Ostroumov et al., 2005). While the use of dolomite in agriculture has shown that it influences pH correction and nutrient supply as well Ca and Mg (Corpoica, 2005).

The objective of the experiment was to evaluate the CO₂ flow of two mixtures of substrates with different nitrogen content, moisture, compost and mineral mixture based on zeolite and dolomite to know the effect to the substrates mineralization.

MATERIALS AND METHODS

The essay was carried out in the Soil Physics Laboratory at Montecillo Campus Colegio de Postgraduados in the State of Mexico, Mexico. Two mixtures of substrates were used: 1) tezontle and sawdust (1:2) and 2) tezontle, sawdust and compost (1:2:2), both with different mineral mixture contents of zeolite and dolomite (0, 40 and 80 cm³ L⁻¹). Two referenced nitrogen concentrations (50 and 100%) were supplied by the Universal Steiner Solution, in addition to two levels of humidity (15 and 30% dry weight basis) resulting in 24 treatments with 3 repetitions. The samples were incubated for 15 days to promote microbial activity and evaluate, each 48 hours, the CO₂ flow for 86 days with support of the IRGA gas analyzer (PP Systems); the samples were moistened based on its dry weight every 7 days until the end of the trial. The measured parameters were pH (extract 1:2), electrical conductivity (extract 1:5) by conductimeter; content of organic matter by ignition; organic carbon based on the results of organic matter using the Douglas factor= 0.5; and nitrogen per micro Kjeldahl. The analysis of the variables was performed using a completely randomized design and the means tests by comparing Tukey with a value of statistical significance $p \leq 0.05$.

RESULTS AND DISCUSSION

Chemical characteristics of substrates

pH. - For the two humidity levels, the most alkaline pH value was obtained by T9 (7.74 and 7.89) while T1 showed the most acidic pH (6.04) with 15% humidity and, with 30% humidity, T5 showed a pH of 6.80. The absolute mineralization rate (AMR) of T9, although it presented significant statistical differences, was only 0.06 g CO₂/g substrate/day higher due to the effect of pH. On the other hand, the AMR was 21% higher when the pH varied 0.21 units between T1 and T5. In most treatments, pH was kept within desirable ranges for substrate production (5.0

– 6.5; Bunt, 1998), changes of 0.15 pH units between humidity levels and mineral mixture content occur because, in the exchange complex, the Ca of the dolomite replacement of H⁺ ions, in addition to the ammonia detachment of organic labile materials (compost) (Soliba, 1998) causing an increase in pH of substrat extract. Alvarado y Fallas (2004) they mention the dolomite as an alternative to reduce acidity.

Electrical conductivity. - Although the EC results obtained did not exceed the recommended ranges for the production of crops in substrates (0 – 1.15 dS m⁻¹; Bunt, 1998), the treatments containing compost the EC was higher compared to those that did not contain compost. With a difference of 0.99 dS m⁻¹, treatments containing compost had average AMR of 1.24 g CO₂/g substrate/day; while the AMR of treatments without compost, and lower EC, was 0.82 g CO₂/g substrate/day. In those treatments where the EC was >2 dS m⁻¹ is attributed to the high decomposition of organic labile materials (R²= 0.82), in addition, Rodríguez et al., (2010) mention that the concentration of salts grows by the loss of mass of the substrates, the product of the mineralization of the OM.

Total nitrogen. - The highest content of nitrogen, for both humidity levels, It was presented by T7 (1.83 and 1.99%), to which 50% of N was supplied, being statistically different from other treatments. While the T7 got the highest content of N was not triggering to achieve the highest AMR, with 1 g CO₂/g substrate/day being less than the T8 which obtained the highest AMR (1.96 g CO₂/g substrate/day) by the effect of supplying N. The low values of total N are related to a high C/N ratio (R²= 0.89) the product of the higher content of non-labile organic materials (sawdust), therefore, the substrates of these treatments showed greater stability and a slow process of mineralization. The use of zeolite, a chemically very active clay, caused the N mineralization process to be slow by competition in microorganisms and the porous mineral, causing a synchronisation between the nourishment absorbed by the plant and the one supplied (Febles et al., 2014).

Table 1. Test of means of the chemical properties of the substrates with 15 and 30% moisture.

Treatment	15% h						30% h					
	pH	EC (dS m ⁻¹)	N	OC (%)	OM	C/N	pH	EC (dS m ⁻¹)	N	OC (%)	OM	C/N
1	6.04 d	0.91 e	0.192 d	15.66 a	31.66 a	82.5 e	6.87 c	1.07 d	0.087 c	17.00 a	34.66 a	196.5 a
2	7.00 b	1.05 d	0.175 d	19.00 a	37.33 a	106.5 c	7.14 b	1.03 d	0.175 c	12.33 a	25.00 a	71.5 e
3	7.36 a	0.99 e	0.122 d	11.33 b	23.00 b	93.5 d	7.41 b	1.06 d	0.140 c	14.33 a	29.33 a	103.5 c
4	7.04 b	0.66 e	0.157 d	17.66 a	35.33 a	110.5 b	7.15 b	0.76 e	0.105 c	18.33 a	36.00 a	170.5 b
5	6.21 c	0.82 e	0.227 d	13.00 b	26.66 a	57.5 f	6.80 c	0.97 d	0.227 c	13.33 a	26.66 a	59.5 f
6	6.61 c	0.65 e	0.140 d	12.00 b	24.00 b	114.5 a	7.09 b	0.92 d	0.140 c	11.00 a	22.33 a	78.5 d
7	6.96 b	1.31 d	1.837 a	13.33 a	28.33 a	7.5 g	7.28 b	1.49 c	1.995 a	12.33 a	24.00 a	6.5 h
8	6.71 b	2.12 b	1.592 b	10.66 b	21.33 b	8.0 g	7.02 b	1.90 a	1.470 b	11.33 a	23.00 a	8.5 g
9	7.74 a	2.21 b	1.137 c	8.66 b	17.33 b	7.0 h	7.89 a	1.65 b	1.540 b	10.66 a	21.33 a	6.5 h
10	7.47 a	1.67 c	1.330 c	14.66 a	28.33 a	10.5 g	7.38 b	2.15 a	1.610 b	14.00 a	27.66 a	10.5 g
11	7.61 a	1.54 c	1.225 c	11.33 b	22.66 b	9.5 g	7.38 b	2.06 a	1.890 a	13.00 a	25.66 a	7.5 h
12	6.90 b	2.86 a	1.540 b	11.66 b	23.33 b	7.5 h	7.40 b	1.82 b	1.347 b	12.00 a	23.66 a	8.5 g
LSD (p≤0.05)	0.54	0.46	0.239	5.94	11.50	3.03	0.29	0.31	0.264	10.42	20.26	2.80

Where: pH. – Hydrogen potential, EC. – Electrical conductivity, N.- Total nitrogen, OC.- Organic carbon, OC. – Organic matter, C/N.- C/N ratio and h.- Humidity. **LSD (p≤0.05).** – Low stadistical diference with a statistical probability of 5%. Treatments with diferents letters have different statistical significance (p≤0.05).

Organic matter. – Usually, the treatments with compost showed the lowest OM content result of greater mineralization. The relative rate of mineralization (RRM) showed a difference of 68% mineralization between T8 (1.96 g CO₂/g substrate/day) with compost and T6 (0.626 g CO₂/g substrate/day) without compost. OM values found in those treatments that contained mineral mixture it is attributed, according to Rodríguez et al., (2010) to the addition and/or presence of non-combustible materials in incineration and organic materials rich in lignins.

Organic carbon. – The treatments with 15% moisture showed significant statistical differences at the OC content T9 being the lowest with 8.66% and T12, with 19%. For both moisture content, and with an average difference of 14.16% OC, the RRM was 0.17 g CO₂/g substrate/day per effect of the OC content. Substrates with compost, containing higher OC, they corresponded; according to T to a high mineralization resulting from the higher availability of labile carbon of the OM.

C/N ratio. - In both moisture levels, treatments without compost showed the highest C/N ratio with values 57.5 – 196.5, while treatments with compost showed the lowest values (<10.5). The treatments RRM with compost, and a low C/N ratio, was 1.34 g CO₂/g substrate/day higher compared to those treatments without compost and high C/N ratio. Substrates C/N ratio from 5 to 20 indicates that they are mature (Terés, 2001) and offer greater

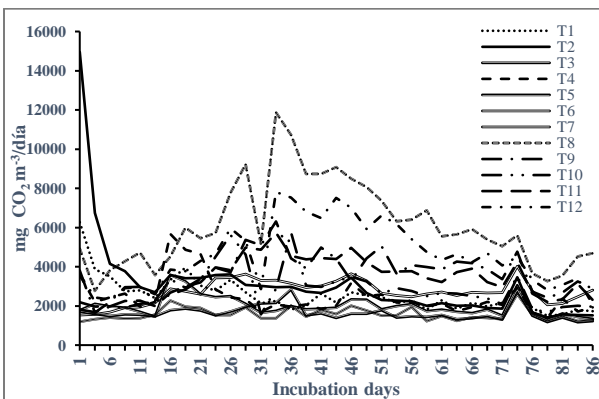
inorganically available nutrients, treatments that did not contain compost were C/N ratio >57 due to the increased presence of materials which were not decomposed (Lemaire, 1997) because they have high lignin content, substrates of these treatments are the most appropriate for the production of long-cycle crops.

CO₂ flow in substrates with different moisture content

During the first 7 days of incubation and under 15 humidity, CO₂ exhibited variations, mainly in treatments that did not contain compost. The maximum values of CO₂ were presented from days 33 to 36, obtaining the highest emission of T8 and T12 with 11,871 and 7,911 mg CO₂ m⁻³/day, respectively. After 14 days of incubation, and when the substrates contained 30% moisture, the detached CO₂ was higher in treatments containing compost. The maximum values of CO₂ were presented from days 26 to 38, obtaining the highest emission of T8 (9,245 mg CO₂ m⁻³/day) and T9 (6,435 mg CO₂ m⁻³/day).

The rate of CO₂ emissions for substrates with compost and under the two humidity levels, it relates to Velasco and De Mingo (1981) who point out that mineralization is approximately 80% higher in media containing easily degrading OM. In substrates containing sawdust, the organic fraction is stable because labile material is available in a smaller proportion, which slows the degradation of OM (Acosta et al., 2006).

a)



b)

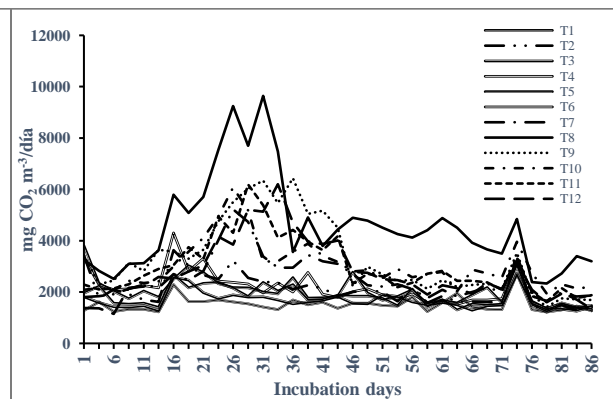


Figure 1. a) CO₂ evolution in substrates with 15% moisture and b) CO₂ evolution in substrates with 30% moisture, both in 86 incubation days.

CO₂ accumulative in substrates with different moisture content

T8 and T12, with 15% moisture, desped out major CO₂ after 30 days of incubation (99,253 y 69,678 mg CO₂/g substrate, respectively) by the presence of compost. With 30% moisture content, the treatments that got the greatest accumulation of CO₂ at the end of the experiment were T8 with 82,373 mg CO₂/g substrate and T9 (59,773 mg CO₂/g substrate). The tended to release higher CO₂ when the humidity present is lower is attributed to the smaller space

occupied by total porous space (Or and Weaigt, 2000) because the substrates increase their capacity for gravimetric moisture retention by increasing the percentage of total porosity. The content of moisture 15 and 30%, in both susbtrate mixture, caused detachment of concentrations greater than 2,000 ppm of CO₂/day. Lorenzo (2012) mentions that to achieve the highest photosynthetic rate in pepper cultivation you should have a concentration of 1,000 ppm, which is commonly applied by CO₂ injectors being an expensive method (Antón et al., 2011).

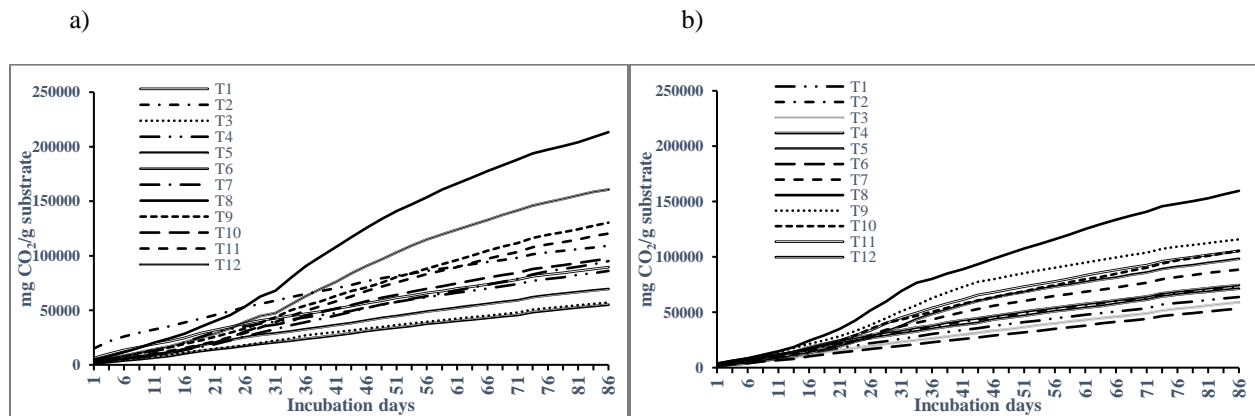


Figure 4. a) CO₂ accumulation in substrates with 15% moisture and b) CO₂ accumulation in subtrates with 30% moisture, both in 86 incubation days.

Absolute and relative mineralization rate

AMR fluctuation of substrates con 15% moisture was 0.63 g CO₂/g substrate/day in the T6 and 2.24 g CO₂/g substrate/day at T8. With regard to the substrate with 30% moisture, the AMR followed the same trend as with the 15% moisture, T6 showed the AMR lowest with 0.61 g CO₂/g substrate/day and T8 the higher AMR with 1.68 g CO₂/g substrate/day. Occupied moisture is easily released by the presence of macropores and packaging pores (Hillel, 1998), so in treatments with higher moisture content porous space was smaller and therefore the amount of CO₂ released was smaller.

AMR of treatments 7 to 12, with compost, showed the highest CO₂ flow for both N levels with fluctuations of 0.96 to 1.96 g CO₂/g substrate/day. In treatments with the supply of 50% N values with the highest emission range (0.66 to 1.96 g CO₂/g substrate/day), while in those that were supplied the 100% of N that range decreased by a 50%. When the content of N was 100% there was biotic immobilization of the nutrient, Ritter et al., (2005) mentions that microorganisms immobilize N for consumption in conjunction with OM N-NH₄⁺ reaction and clay fraction composed by zeolite.

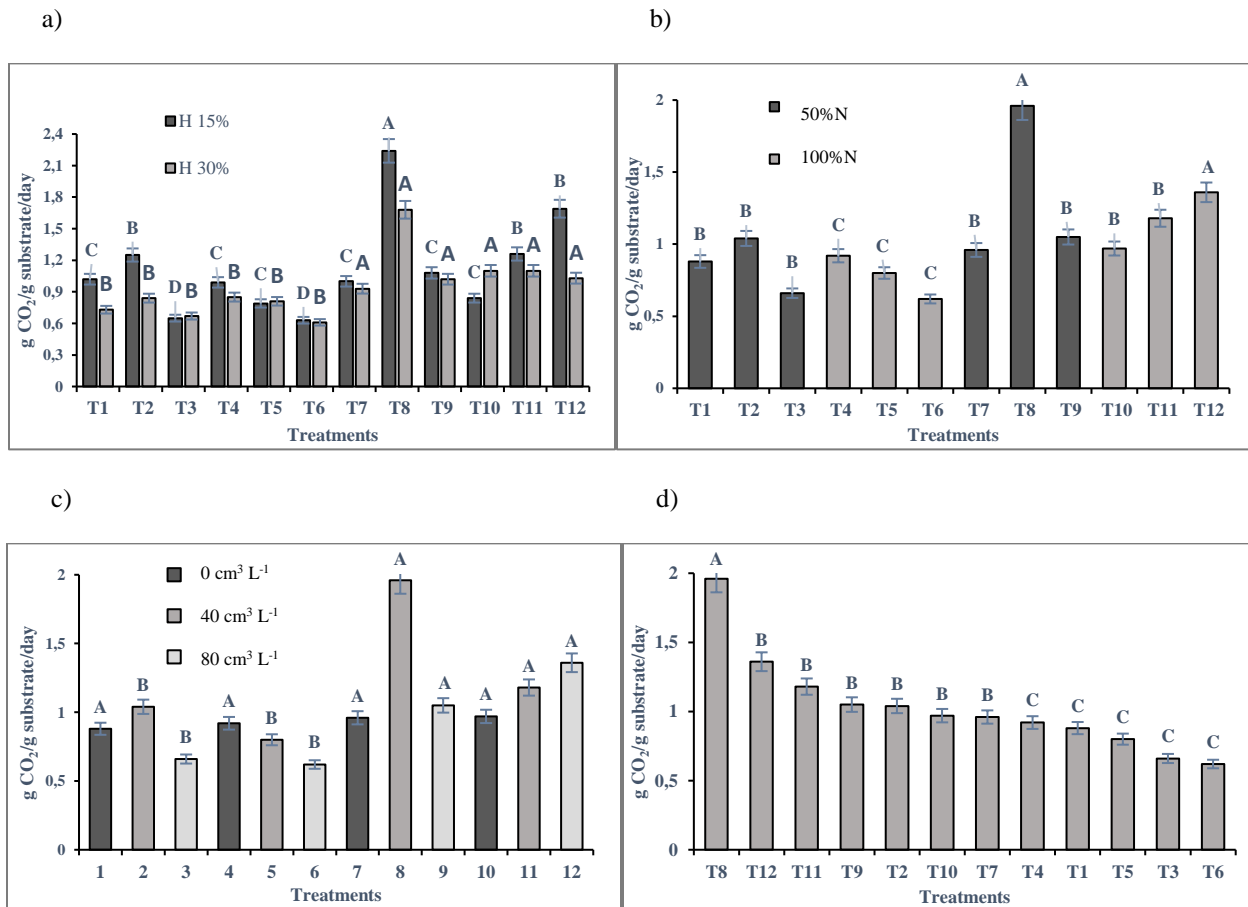


Figure 5. a) Absolute rate of mineralization of substrates with two moisture levels, b) Absolute rate of mineralization of substrates with two nitrogen levels, c) Absolute rate of mineralization of substrates with three mineral mixture levels and d) Relative rate of mineralization of the substrates; at 86 incubation days.

In T2, T5, T8 and T11, treatments with 40 cm^3 of MM L^{-1} of substrate, the largest AMR was observed with values ranging from 0.80 to 1.96 $\text{g CO}_2/\text{g substrate/day}$. When compost was applied and 80 $\text{cm}^3 \text{L}^{-1}$ MM content (T9 and T12), an average AMR of 1.20 $\text{g CO}_2/\text{g substrate/day}$ was presented, when compost it was not applied emissions reduced by a 39% with the same MM content. In this regard it has been found, Scott et al., (1996), mineralization to occur in a stable manner they must first be waste should be metabolized by microbial action and then stabilized by mineral colloids. Treatments with 80 $\text{cm}^3 \text{L}^{-1}$ of MM with the presence of compost presented a dilution effect of C with the clay fraction, which means that OM is evenly distributed in the mineral matrix (Matus et al., 1998).

It was observed that the T presented the highest AMR with 1.96 $\text{g CO}_2/\text{g substrate/day}$ due to compost content, beating 0.60 $\text{g CO}_2/\text{g substrate/day}$ of T12. The higher content of high C/N ratio in T6 was reflected to emit 1.34 $\text{g CO}_2/\text{g substrate/day}$ less than T8, which caused T6 to be treated with the lowest AMR. According to Acosta et al., (2006), biological activity is very active by the presence of labile organic materials, that means that when CO_2 emission is increased by use of compost, more C is released into environment and reduced depending on the amount of minerals supplied.

CONCLUSIONS

In substrates it does not follow the logic that the higher moisture is present in the soil, the greater the

mineralization of organic matter. Using compost-free substrates, 80 cm³ of mineral mixture L-1 of substrate and 15% humidity delayed the mineralization of organic matter and the CO₂ flow emitted was lower, showing favorable emissions for plant utilization and increased photosynthetic rate, which complements the contribution of CO₂ to intensive production systems. Substrates with compost and 15% humidity they delayed their initial

mineralization, but also led to greater CO₂ liberation and an increase in the chemical fertility of the substrate.

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