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# Dynamics of $^{14}$C-labelled Glucose and $NH_4^+$ in a Regularly Flooded Extremely Alkaline Saline Soil

Luc DENDOOVEN*, Eustacio RAMÍREZ-FUENTES, Rocio ALCÁNTARA-HERNÁNDEZ, Cesar VALENZUELA-ENCINAS, Katia Berenice SÁNCHEZ-LÓPEZ, Marco LUNA-GUIDO and Victor Manuel RUÍZ-VALDIVIEZO

*Laboratory of Soil Ecology, ABACUS, Cinvestav, Avenida Instituto Politecnico Nacional 2508, CP 07360, Mexico (Mexico)*

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## ABSTRACT

Flooding an extremely alkaline (pH 10.6) saline soil of the former Lake Texcoco to reduce salinity will affect the soil carbon (C) and nitrogen (N) dynamics. A laboratory incubation experiment was done to investigate how decreasing soil salt content affected dynamics of C and N in an extremely alkaline saline soil. Sieved soil with electrical conductivity (EC) of 59.2 dS m$^{-1}$ was packed in columns, and then flooded with tap water, drained freely and conditioned aerobically at 50% water holding capacity for a month. This process of flooding-drainage-conditioning was repeated eight times. The original soil and the soil that had undergone one, two, four and eight flooding-drainage-conditioning cycles were amended with 1 000 mg glucose-$^{14}$C kg$^{-1}$ soil and 200 mg $NH_4^+$-N kg$^{-1}$ soil, and then incubated for 28 d. The $CO_2$ emissions, soil microbial biomass, and soil ammonium ($NH_4^+$), nitrite ($NO_2^-$) and nitrate ($NO_3^-$) were monitored in the aerobic incubation of 28 d. The soil EC decreased from 59.2 to 1.0 dS m$^{-1}$ after eight floodings, and soil pH decreased from 10.6 to 9.6. Of the added $^{14}$C-labelled glucose, only 8% was mineralized in the original soil, while 24% in the soil flooded eight times during the 28-d incubation. The priming effect was on average 278 mg C kg$^{-1}$ soil after the 28-d incubation. Soil microbial biomass C (mean 66 mg C kg$^{-1}$ soil) did not change with flooding times in the unamended soil, and increased 1.4 times in the glucose-$NH_4^+$-amended soil. Ammonium immobilization and $NO_2^-$ concentration in the aerobically incubated soil decreased with increasing flooding times, while $NO_3^-$ concentration increased. It was found that flooding the Texcoco soil decreased the EC sharply, increased mineralization of glucose, stimulated nitrification, and reduced immobilization of inorganic N, but did not affect soil microbial biomass C.

*Key Words*: C mineralization, $CO_2$ emission, microbial biomass C, mineral N, nitrification

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Characteristics of soil of the former Lake Texcoco, located to the east of Mexico City, Mexico, are highly variable with pH ranging from 8 to 10.5 and electrical conductivity (EC) ranging from 1 to 150 dS m$^{-1}$ (Dendooven *et al.*, 2010). The highly variable characteristics of the soils are due to their intrinsic variability and that the soils have been drained for different periods and effluents have been used in some parts. The bare soil is easily eroded by wind, resulting in dust pollution over Mexico City. Drainage systems have been installed to lower the water table since the beginning of the 1990s, and the tertiary treated sewage effluent is used for irrigation to remove salts and improve aeration in the root zone. Vegetating the soil will require the application of nutrients as the soil is known to have a low N content (Dendooven *et al.*, 2010).

An investigation into the effect of drainage and irrigation with effluent on soil characteristics showed that after 8-year flooding, soil characteristics had changed (Luna-Guido *et al.*, 2000). The soil EC had decreased from 79.9 to 2.6 dS m$^{-1}$ and pH from 10.2 to 8.3 after 8-year flooding. Mineralization of added organic carbon (C) was also affected by flooding. In a first study, the amount of $^{14}$C-labelled glucose mineralized after 97 d was 601 mg C kg$^{-1}$ soil in the soil with EC of 2.6 dS m$^{-1}$, but only 360 mg C kg$^{-1}$ soil in the soil with EC of 79.9 dS m$^{-1}$ (Luna-Guido and Dendooven, 2001). In a second study, the amount of $^{14}$C-labelled maize mineralized after 98 d was > 500 mg C kg$^{-1}$ soil in the soils with EC $\leq$ 24.6 dS m$^{-1}$, but only 257 mg C kg$^{-1}$ soil in the soil with EC of 32.7 dS m$^{-1}$ (Luna-Guido *et al.*, 2003). Nitrogen (N) dynamics were also affected. In the soil with EC of 79.9 dS m$^{-1}$ amended with 200 mg $(NH_4)_2SO_4$-N kg$^{-1}$, 24 mg $NO_3^-$-N kg$^{-1}$

*Corresponding autor. E-mail: dendooven@me.com.

was formed after 97 d. However, in the soil with EC of 2.6 dS $m^{-1}$ 118 mg $NO_3^-$-N $kg^{-1}$ was formed.

Although there were clear indications that changes in EC and pH were responsible for differences in mineralization of added organic material and changes in N dynamics, they were not conclusive, as other characteristics, most importantly clay content, differed between the soils (Luna-Guido *et al.*, 2003). Total clay content, specific surface area of clay, and the nature of clay mineral are known to affect the decomposition of organic material (Müller and Höper, 2004; Kölbl *et al.*, 2006; Tye *et al.*, 2009).

Therefore, in this study, incubations were done with the soil whose salinity had been manipulated. The aim was to investigate how decreasing the salt content of an extremely alkaline saline soil affected dynamics of C and N.

## MATERIALS AND METHODS

### *Soil sampling site*

The soil samples were taken from the former Lake Texcoco bed, which is located in the valley of Mexico City, Mexico, at an altitude of 2 240 m a.s.l. with a mean annual temperature of 16 °C and an annual precipitation of 705 mm. Details of the soil characteristics, vegetation and the drainage system installed can be found in Luna-Guido *et al.* (2000).

The soil was sampled randomly with a stony soil auger of 7 cm in diameter (Eijkelkamp, Giesbeek, the Netherlands) by augering the 0–15 cm layer 40 times in each of the three different sampling plots with a size of *ca.* 400 $m^2$. As such, approximately 50 kg soil was collected from each plot. The soil from each plot was pooled, and thus three soil samples were obtained and taken to the laboratory. This field-based replication was maintained in the laboratory experiment.

### *Incubation of soil columns and treatments*

The soil from each plot ($n = 3$) was passed through a 5-mm sieve, adjusted to 40% water holding capacity (WHC) and pre-incubated in 70-L drums for 7 d. Each drum contained 10 kg soil and was closed airtight. The drums contained a beaker with 500 mL distilled $H_2O$ to avoid desiccation and a beaker with 1 000 mL 1 mol $L^{-1}$ NaOH solution to trap $CO_2$ evolved. The drums were opened once every day for 10 min to avoid anaerobic conditions in the soil.

After 7 d of pre-incubation, 18 sub-samples of the 2-kg soil from each plot ($n = 3$) were separately packed into PVC columns of diameter 10 cm and length 50 cm, to a bulk density of 0.95 g $cm^{-3}$, which is the mean bulk density found in this soil (Beltrán-Hernández, 2001). Each column was fitted at the bottom with a thin plastic plate with holes evenly distributed over its surface. A polyethylene filter disc (nominal pore size 0.5 μm) was placed on top of the plastic plate and covered with a layer of acid washed sand (0.16 kg) to prevent loss of soil particles during leaching (Bellini *et al.*, 1996).

The experimental treatments are given in Table I. Three soil columns from each plot ($n = 3$) were selected at random, and the soil was removed, characterized (Table II) and used in an aerobic experiment to investigate the dynamics of $^{14}$C-labelled glucose and inorganic N ($NH_4^+$, $NO_2^-$ and $NO_3^-$). As such, nine soil samples were used in the aerobic incubation experiment (i.e., three columns from three plots). The original soil (never flooded) was denominated M0.

Each of the remaining soil columns was flooded with 2 L tap water and drained freely until approximately 50% WHC ($\leq$ 3 d). The top of the columns was fitted with Parafilm® to avoid drying of the soil, but to allow aeration. The soil was then conditioned aerobically and at constant water content (approximately 50% WHC) for one month. This process of flooding-draining-conditioning was repeated eight times. After one (M1), two (M2), four (M4) and eight flooding-draining-conditioning cycles (M8), three columns were selected again at random from each plot ($n = 3$) (a total of nine columns were thus used for each flooding treatment). The soil was removed from these columns,

TABLE I

Description of experimental treatments in the incubation of soil columns

| Treatment code | Description |
|---|---|
| M0 | Original soil, never flooded |
| M1 | Soil column receiving one flooding-drainage-conditioning cycle[a)] |
| M2 | Soil column receiving two flooding-drainage-conditioning cycles |
| M4 | Soil column receiving four flooding-drainage-conditioning cycles |
| M8 | Soil column receiving eight flooding-drainage-conditioning cycles |

[a)]The process of flooding the soil, draining the soil freely until *ca.* 50% water holding capacity, covering the column with Parafilm® and conditioning the soil for a month.