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Greenhouse Gas Emission Levels of a Conventional Vineyard in a Mediterranean Climate

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Abstract: In this study, the emission levels of the three greenhouse gases of importance in agriculture, carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) in a vineyard of the DOCa Rioja are evaluated. The magnitude of the flows of these gases is studied in relation to conventional soil management under the influence of Mediterranean climatic conditions (precipitation and temperature). The selected plant material is a commercial Vitis vinifera L. cv. Tempranillo blanco vineyard from the DOCa. Rioja, growing in a Typic Haploxerepts soil, subgroup of the Inceptisols Order. The experimental design consisted of the selection of 3 homogeneous subplots in 2018. Simultaneous identification and quantification of CO_2, N_2O and CH_4 was conducted using a new methodology combining gas chromatography with a mass detector and an electron microcapture detector (GC/MS/ECD). Analysis of the results shows that emissions depend on climatic variations, especially in the wetter seasons. Differences in GHG fluxes were also detected between alleys and rows, associated with the different agricultural practices applied, such as tillage and irrigation.

Key words: greenhouse gas (GHG), vineyard, chromatography, tillage, precipitation

1. Introduction

Tilled soils can emit more CO_2 compared to non-tilled soils, as this practice favors the decomposition of organic residues by the soil microorganisms [1]. Furthermore, the use of mulching and the addition of compost, in combination with fluctuations in soil water content from rainfall and irrigation, influence soil carbon dynamics [2]. With regard to N_2O, this is an abundant greenhouse gas (GHG) emitted by nitrification-denitrification processes and is responsible for the destruction of the ozone layer and the increase in global warming [3]. This gas, together with CH_4, has increased as a result of changes in land use and intensive farming [4].

2. Material and Methods

2.1 Description of Vineyard Parcel

The study was carried out in a commercial vineyard of 1.11 ha. in the Rioja Alta subzone of the DOCa Rioja, on a plot of the Vitis vinifera L. cv. Tempranillo blanco variety grafted on Richter-110 (R-110) with a bilateral Royat cordon training system. The orientation of the rows was northwest-southeast, with a planting density of 3,030 plants per ha^{-1}. In addition, the plot was characterized by a soil of the Inceptisols Order, Subgroup "Typic Haploxerepts", according to the USDA soil classification system [5]. The effective depth of the soil profile was 138 cm, of which the first two horizons have a loamy texture, while the last horizon is characterized by being sandy loam.

With regard to climatic conditions, the 2018 growing year presented abundant rainfall (668 l m^{-2}), distributed mainly in the months of January (13.4%), July (20.4%) and September (14.3%). The average annual temperature was 13.9°C, with February being the coldest month with a monthly average of 4.9°C and August the warmest with 23.1°C (Fig. 1).

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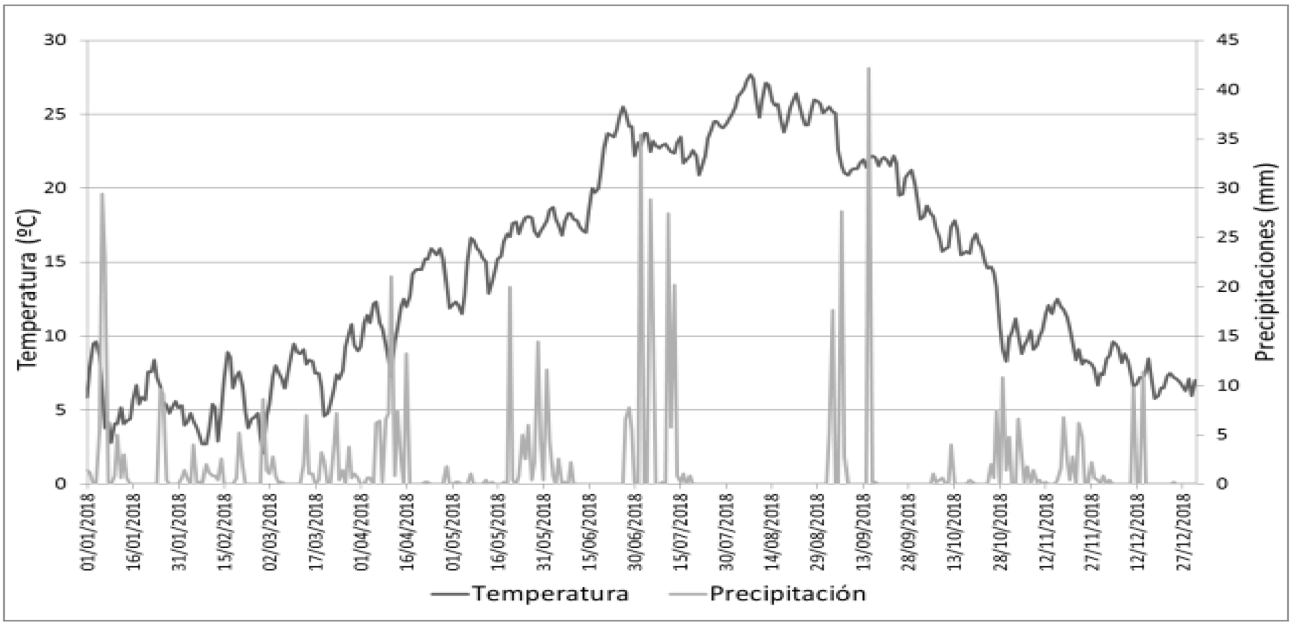

Fig. 1 Temperature and rainfall records for 2018.

2.2 Experimental Design

In order to carry out the experiment, three non-adjacent sub-plots were selected, using 3 rows and 3 alleys, as replicates. For the collection of gaseous samples emitted by the soil, the closed chamber gas flow capture system was selected [6]. The PVC rings used (Ø = 31.5 cm and h = 16 cm) were inserted 5 cm into the soil [7]. After placing the chamber lid and sealing it, samples were taken through a septum placed at the top of the chamber. Using a syringe, 20 ml of sample was withdrawn and transferred to 12 ml inert vials [8].

The chambers were set up early in the morning, coinciding with the collection of the first sample (t = 0) and subsequent samples were taken every 20 min (t = 20, t = 40, t = 60 min), following the method employed by Yu et al. (2019) [9]. For the quantification of the concentrations of each gas, Agilent 7890A equipment was used, with two independent columns, and two detectors, a mass spectrometer (MS), with which CO_2 and CH_4 were analyzed, and an electron microcapture detector (ECD), used for the determination of N_2O. The chromatographic separation of the GHGs was carried out isothermally (Tª = 35°C), working in split mode using helium as a carrier gas.

Once the calibration line was obtained using mixtures of standard gases, the GHG concentrations of the samples were determined (ppm). To calculate the concentrations of CO_2 (kg ha^{-1} day^{-1}), N_2O and CH_4 (g ha^{-1} day^{-1}), the measurements t = 0 and t = 60 were taken into account, according to the procedure described by Fangueiro et al. (2017) [10].

3. Results and Discussion

With regard to CO_2, it was observed that when the accumulated rainfall is of the order of 40-50 l m^{-2} in 2-3 days, and coincides with temperatures above 20°C, emissions can double or even triple (Fig. 2). This is verified in advanced stages of the biological cycle of the grapevine, where very significant increases in CO_2 levels were quantified both in the alleys (300 kg ha^{-1} day^{-1}) and in the rows (270 kg ha^{-1} day^{-1}). These increases are due to both root respiration and soil microbial activity.

In the case of tillage, slight increases in CO_2 fluxes are generated by allowing soil aeration [11], as shown in Fig. 2, where CO_2 fluxes obtained in the months of March and May increase when tillage with a cultivator is carried out in the days prior to gaseous sampling.

N_2O emission levels are mainly affected by soil moisture and temperature, leading to increased emissions [9]. N_2O concentrations were low throughout the cycle, not exceeding 7.07 g ha^{-1} day^{-1} except at specific times when high emission peaks occurred. These peaks corresponded to episodes of abundant rainfall, in months where the temperature exceeded 15°C. In addition, practices such as the application of mineral fertilizer N-P-K 15-15-15 (300 kg ha^{-1}) led to an increase in emission levels, reaching 54 g ha^{-1} day^{-1} in the vineyard rows in April (Fig. 3).

It should be noted that the CO_2 and N_2 fluxes obtained are similar to those obtained by Marques et al. [11] and Yu et al. [9].

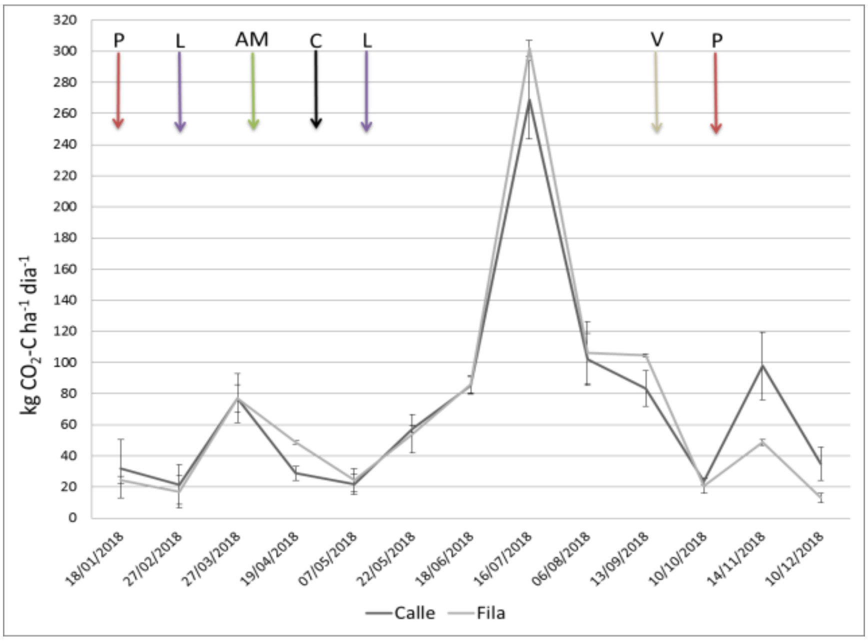

Fig. 2 Evolution of CO_2 emissions (kg ha^{-1} day^{-1}) (P = Pruning; L = Tilling; AM = Mineral fertilization; C = Digging rows; V = Harvesting).

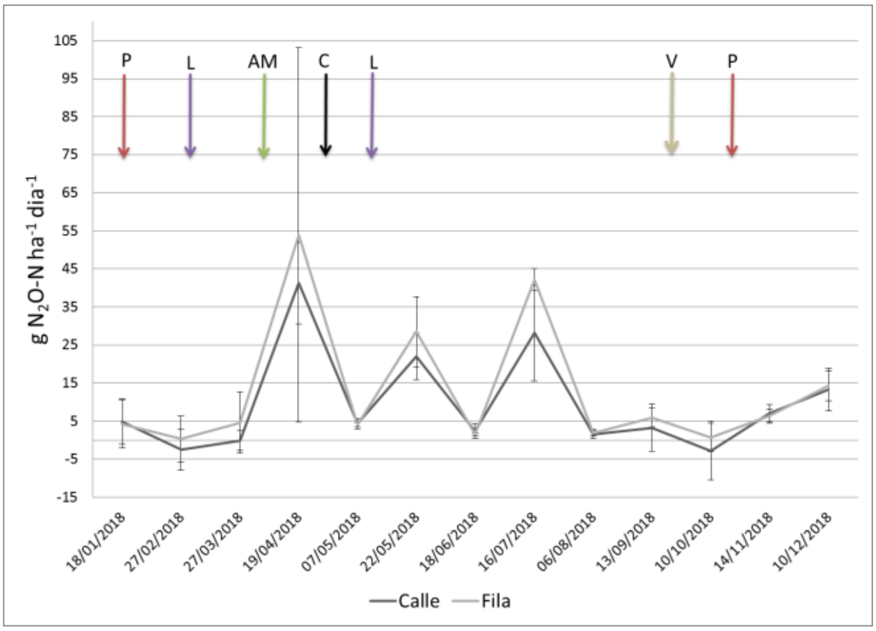

Fig. 3 Evolution of N_2O emissions (g ha^{-1} day^{-1}) (P= Pruning; L= Tilling; AM= Mineral fertilization; C= Digging rows; V= Harvesting).

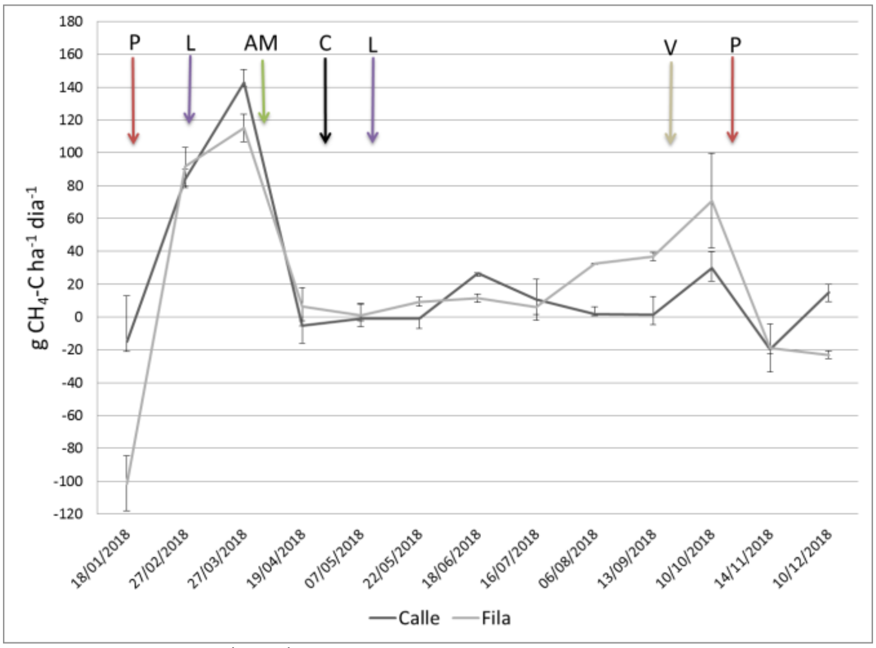

Fig. 4 Evolution of CH_4 emissions (kg ha^{-1} day^{-1}) (P = Pruning; L = Tilling; AM = Mineral fertilization; C = Digging rows; V = Harvesting).

Finally, CH_4 is mainly influenced by the contribution of semi-composted and buried cow dung in the month of November 2017, which may have favored the proliferation of microbial processes [12]. This caused the month of March to reach the maximum CH_4 concentration where the emissions from the lane (142.98 g ha^{-1} day^{-1}) were higher than those from the row (115.14 g ha^{-1} day^{-1}). This difference may have been caused by tillage prior to sample collection, releasing higher amounts of CH_4 [13] in the alley than in the row. In relation to the effect of soil moisture, CH_4 emissions behaved differently from those of CO_2 and N_2O, with the highest fluxes observed in months with lower precipitation [14], as was the case in August (0 l m^{-2}), October (33.8 l m^{-2}) and December (22.6 l m^{-2}).

4. Conclusion

The study of GHG emissions from a vineyard soil has shown that climatic variations are very important, conditioning CO_2, N_2O and CH_4 fluxes in the grapevine cycle. Precipitation was somewhat more significant than the thermal profile, increasing CO_2 and N_2O fluxes and decreasing CH_4 fluxes. Regarding the latter, the most important flux variations are related to the application of cow manure. On the other hand, the differences between GHG emissions in the alley and in the rows of the vineyard are in turn affected by the different agronomic practices carried out in each of these areas, with no significant differences between the two.

Acknowledgements

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