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Direct N_2O emissions following transition from conventional till to no-till in a cover cropped Mediterranean vineyard (*Vitis vinifera*)

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ABSTRACT

Knowing underlying practices for current greenhouse gas (GHG) emissions is a necessary precursor for developing best management practices aimed at reducing N_2O emissions. The effect of no-till management on nitrous oxide (N_2O), a potent greenhouse gas, remains largely unclear, especially in perennial agroecosystems. The objective of this study was to compare direct N_2O emissions associated with management events in a cover-cropped Mediterranean vineyard under conventional tillage (CT) versus no-till (NT) practices. This study took place in a wine grape vineyard over one full growing season, with a focus on the seven to ten days following vineyard floor management and precipitation events. Cumulative N_2O emissions in the NT system were greater under both the vine and the tractor row compared to CT, with 0.15 ± 0.026 kg N_2O–N ha^{-1} growing season^{-1} emitted from the CT vine compared to 0.22 ± 0.032 kg N_2O–N ha^{-1} growing season^{-1} emitted from the NT vine and 0.13 ± 0.048 kg N_2O–N ha^{-1} growing season^{-1} emitted from the CT row compared to 0.19 ± 0.019 kg N_2O–N ha^{-1} growing season^{-1} from the NT row. Yet these variations were not significant, indicating no differences in seasonal N_2O emissions following conversion from CT to NT compared to long-term CT management. Individual management events such as fertilization and cover cropping, however, had a major impact on seasonal emissions, indicating that management events play a critical role in N_2O emission patterns.

1. Introduction

With the current trend of increasing greenhouse gas (GHG) emissions and associated global change, there is a pressing need to quantify N_2O emissions in perennial systems under different management practices. No-till or conservation tillage have been adopted as methods to increase soil and water quality, increase water use efficiency, decrease surface water runoff (Mitchell et al., 2007) and increase soil organic C, thus reducing GHG emissions by C sequestration (Paustian et al., 2000). However, the effect of these practices on N_2O emissions remains inconclusive. Kong et al. (2009) found that after one year minimum-till management increased N_2O emissions compared to conventionally tilled systems in a fine textured soil in a Mediterranean climate. Furthermore, Six et al. (2004) predicted that initial N_2O emissions will increase under newly converted NT systems but might eventually level out and/or decrease after adequate soil aggregation and aeration is reached. Conversely, Del Grosso et al. (2002) predicted an increase in N_2O emissions with time after NT adoption using the DAYCENT model. These studies indicate that the effect of no-till on N_2O emissions is not only difficult to predict, but is highly dependent on soil texture, climate, and the duration of practice. More importantly, these studies do not provide insight into how perennial systems may respond to changes in tillage.

In the Mediterranean climate of California, vineyard management generally involves the practice of combining no-till with leguminous cover crops as a way to decrease soil erosion on hillslopes, increase C sequestration, and reduce the use of synthetic fertilizers without affecting crop yield or quality (Baumgartner et al., 2008). While it is known that cover crops affect both the C and water balance of vineyard systems, their effect on GHG emissions remains largely unknown. Although Steenwerth and Belina (2008) measured increased N_2O emissions in cover cropped compared to non-cover cropped vineyards, very few studies exist, making generalizations difficult to support. In fact, many models and inventories fail to include data on GHG emissions from vineyards and other perennial systems due to a lack of measurements (IPCC, 2006). Since vineyards cover a large area of California, knowing the current GHG emissions and developing best management practices has the potential to greatly impact regional current and future estimates of N_2O emissions.

In this study we measured emissions immediately before and for several days following each management event in order to

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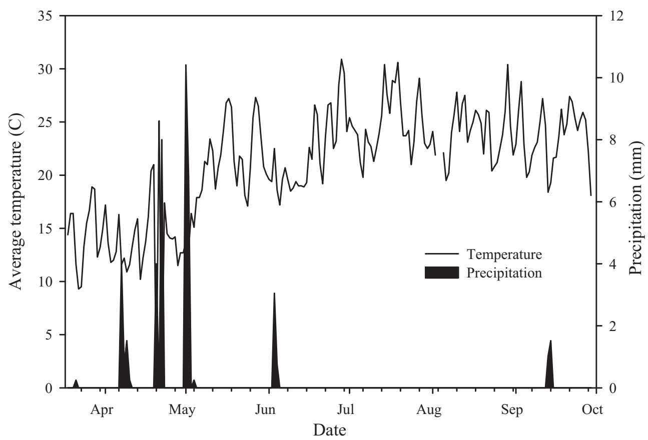

Fig. 1. Temperature and precipitation data from 18 March 2009–29 September 2009 measured from a UC IPM weather station in Arbuckle, CA.

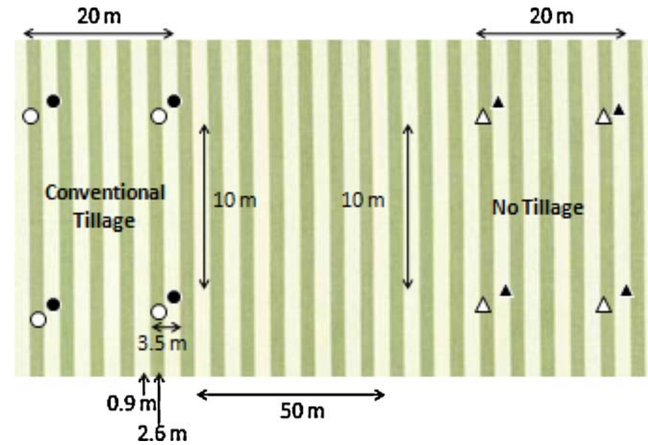

Fig. 2. Experimental setup. Circles indicate CT management while triangles indicate NT management. White symbols indicate the vine row while black symbols indicate the tractor row.

accurately gauge the emissions directly related to each management practice. The objectives of this study were thus to (1) quantify N_2O emissions from a wine grape vineyard over one full growing season and (2) compare the effect of no-till versus conventional tillage on cumulative emissions in order to better understand the climatic and management factors influencing N_2O emissions in Mediterranean vineyards.

2. Materials and methods

2.1. Site description

This study was conducted in a wine grape vineyard (*Vitisv inifera*, var. Zinfandel) in Arbuckle, CA (39°3.13′N; 121°58.753′W) spanning one full growing season from 18 March through 29 September 2009. The average temperature was 20.9 °C and annual precipitation was 42.7 mm during this time period (Fig. 1). The soil was a Willows silty clay with a bulk density of 1.3 g cm^{-3}, pH of 7.2 and C:N ratio of 11.2. The vineyard was established in 1989 and a leguminous cover crop mix was planted in the tractor rows beginning in 1991, which was incorporated into the soil via conventional tillage each spring. During the study, the vineyard was irrigated a total of 16 cm ha^{-1} through the surface drip irrigation system, which was applied to the vines in small doses every other day. Fertilization occurred once at a rate of 5 kg N ha^{-1}as urea-ammonium nitrate (32% N), which was applied through the irrigation system in early August. Tillage occurred in the conventionally tilled tractor rows three times throughout the season by disking to a depth of 15 cm. Beginning in September 2008 the no-till tractor rows were not tilled at all; however, the cover crop was mowed once in late March and again in early May and the residues were left on the soil surface, providing 47 kg organic N ha^{-1} in the tractor rows. This value represents the total N accumulated by the cover crop and was calculated by multiplying the total N content of the cover crop with the total biomass added to the soil after mowing.

In this study, the vineyard was divided into two rows each of no-till and conventional till, with each measurement row further divided into two functional locations: the vines and the tractor rows, with four pseudo-replications of each location and treatment (Fig. 2). In the tractor rows, measurements were taken in the center of the cover cropped area in order to capture cover crop management and tillage events. Under the vines, measurements were taken underneath the drip irrigation lines in order to capture fertilization and irrigation events.

2.2. N_2O flux measurements

In situ soil-surface N_2O fluxes were measured using a vented-closed-flux chamber method (Hutchinson and Mosier, 1981). At sampling time, the chambers were sealed onto bottom collars and samples were taken through a rubber septum at regular intervals (0, 60, and 120 min). Gas samples were taken using a 20 mL air-tight polypropylene syringe and pressurized into pre-evacuated 12 mL vials. Samples were taken once per day for a period of 7 days following irrigation, fertilization, and precipitation events and 10 days following tillage events and harvest. Background N_2O fluxes were measured every 14 days in between management events. Soil temperature at a depth of 15 cm and air temperature within the chamber were measured using a thermocouple.

Nitrous oxide concentrations were analyzed within one week of sampling date by electron capture gas chromatography (GC-2014 Shimdazu Gas Chromatograph). Gas concentrations were tested for linearity (Hutchison and Mosier, 1981) to determine the best flux and finally converted to μg N_2O–N m^{-2} min^{-1}using the Ideal Gas Law. The seasonal cumulative N_2O emissions per tillage regime and functional location were calculated by interpolating the emissions between each sampling day. Total emissions within CT and NT were calculated by weighing the cumulative N_2O production with the relative vine and tractor row widths of each location across the vineyard.

2.3. Soil analyses

Three replicate soil samples to a depth of 15 cm were bulked within 30 cm of each chamber during each sampling period using a 2 cm diameter auger. Soil moisture content was measured gravimetrically by drying the subsamples at 105 °C for 24 h. Ammonium and nitrate concentrations were measured by extracting 5 g field moist soil with 50 mL of 2 M KCl (Zhong et al., 2009) and colorimetrically determined (Shimadzu UV PharmaSpec 1700). The pH was measured using a 1:1 ratio of deionized water to finely ground air-dried soil. Total C and N content were measured by dry combustion (Costech Instruments ECS 4010). Water-filled pore space (WFPS) was calculated using the bulk density and assuming a mineral particle density of 2.65 g cm^{-3}(Robertson and Groffman, 2007).

2.4. Statistical analysis

Differences in growing season N_2O emissions between the vines and tractor rows as well as between the conventionally tilled and