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NO-TILLAGE REDUCES YIELD-SCALED NITROUS OXIDE EMISSIONS IN RAINFED MEDITERRANEAN CONDITIONS: A LONG-TERM FIELD AND MODELLING APPROACH

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INTRODUCTION

Nitrogen fertilization is of a paramount importance for crop production. However, the application of excessive N leads to losses of reactive N such as the emission of nitrous oxide (N_2O) from soils to the atmosphere, contributing to global warming. In Mediterranean rainfed agroecosystems, crop productivity and crop N use are strongly limited by soil water. Consequently, the adoption of water conserving techniques such no-tillage can increase crop yields but also soil N_2O emissions. We present a combined approach of long-term field data and modelling to analyze the impact of tillage and N rates on yield-scaled N_2O emissions (YSNE), a joint indicator of productivity and GHG emission, in a site representative of rainfed Mediterranean conditions.

MATERIAL AND METHODS

A field experiment was run from 1996 to 2014 in Agramunt, NE Spain (41°48′ 36′′ N, 1°07′ 06′′ E, 330 m asl) comparing two tillage types (CT, conventional intensive tillage; NT, no-tillage) with three mineral N rates (0, 60 and 120 kg N ha^{-1}) in a barley monoculture. The area presents mean annual precipitation of 401 mm, PET of 855 mm, and average air temperature of 14.1 ºC. The experimental layout consisted of a randomized complete block design with three replications. Soil was classified as Typic Xerofluvent, and presented a pH (H_2O, 1:2.5) of 8.5 and a loam soil texture (0-30 cm depth). The CT treatment consisted of one moldboard plough pass (25-30 cm depth) plus one or two cultivator passes (15 cm depth) before sowing, while herbicide weed control was used in NT. A third of the N rate was applied before sowing and the rest as top-dressing at the beginning of the tillering stage using ammonium nitrate (33.5% N). The grain was harvested using a commercial combine. Observed soil N_2O emissions and ancillary variables (soil moisture, temperature, and ammonium and nitrate nitrogen at 0-5 cm depth) reported in Plaza-Bonilla et al. (2014) were used to independently calibrate and evaluate the STICS model (Brisson et al., 2008). Soil N_2O emissions were quantified during the 2011-2012 cropping season with the use of static chambers and a gas chromatography system equipped with an ECD detector. Crop growth and productivity was calibrated and evaluated with a second dataset comprising soil water and mineral N content (0-90 cm depth) and crop biomass and yield data of the eighteen years covered by the experiment. Soil parameters (from analysis), climatic variables (from the nearest weather station) and management practices were provided as inputs for the simulation. The performance of the model was evaluated with different statistical criteria. After evaluation, soil N_2O emissions and emission factor (FE) of the 18 experimental years were simulated for each tillage and N rate combination. Finally, the annual YSNE were estimated with the simulated cumulative soil N_2O emissions and the grain yield measured in the field experiment. An analysis of variance was performed for grain yield with tillage, N fertilization, year and their interaction as sources of variation with the JMP 12 statistical package (SAS Institute Inc, 2015).

RESULTS AND DISCUSSION

Barley grain yield was significantly affected by the tillage x nitrogen x year interaction ($p = 0.004$). In the first two years of experiment CT led to greater grain yields than NT, while opposite results (NT > CT) were observed in 13 subsequent cropping seasons. In general, crop yield response to N application (i.e. 60 vs 0 kg N ha^{-1}) was only observed under NT (in 11 years) (Table 1). That aspect highlights the key role played by soil water conservation on crop performance.

Model efficiency was greater than 0.5 for all ancillary variables with the exception of soil nitrate at soil surface (0-5 cm), which was better simulated at the plough layer (0-30 cm depth). STICS performed reasonably well when simulating the dynamics of soil moisture with some overestimation in CT values. Surface soil (5 cm) temperature was well simulated by the model, independently of the treatment. The model adequately responded to the application of fertilizer with an increase in soil ammonium (0-5 cm) levels similar than the observed. The comparison between observed and simulated cumulative N_2O emission during the 2011-2012 barley growing season led to a model efficiency of 0.83. According to the model simulations cumulative N_2O emissions would be greatly affected by the irregularity of precipitations and N rate, with a minor impact of tillage systems (Table 1). In this line, Plaza-Bonilla et al. (2017) showed the ability of the STICS model to cope with the effects of interannual climatic variability on soil N_2O emissions under temperate conditions of SW France. Simulated mean N_2O EF was similar between tillage treatments, and only exceeded the IPCC default value of 1% in the NT-60 and NT-120 treatments in three and 1 out of 18 years, respectively. The mean YSNE would be 3 times greater under CT compared to NT, and would increase when increasing the N fertilizer rate (Table 1).

Table 1. Barley grain yield, simulated cumulative N_2O emissions and yield-scaled N_2O emissions as affected by tillage (CT, conventional tillage; NT, no-tillage) and N fertilization rate (0, 60 and 120 kg N ha^{-1}) in a rainfed semiarid Mediterranean location. Values are means of 18 years. Values between brackets correspond to the standard deviation.

Variable	Treatments					
	CT-0	CT-60	CT-120	NT-0	NT-60	NT-120
Grain yield (kg DM ha^{-1})	1455 (1232)	1532 (1243)	1590 (1228)	1601 (782)	2248 (894)	2426 (878)
Cumulative N_2O emission (kg N_2O-N ha^{-1} yr^{-1})	0.50 (0.4)	0.82 (0.4)	1.09 (0.6)	0.53 (0.5)	0.92 (0.6)	1.19 (0.7)
Yield-scaled N_2O emissions (g N_2O-N kg^{-1} grain)	1.25 (2.4)	1.58 (2.4)	2.11 (3.7)	0.45 (0.5)	0.56 (0.6)	0.63 (0.5)

CONCLUSION

Lower yield-scaled nitrous oxide emissions under no-tillage represents a win-win strategy for the relationship between agricultural productivity and environmental sustainability of rainfed Mediterranean agroecosystems.

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