SIDE-DRESS APPLIED ESN REDUCES N_2O COMPARED WITH SINGLE UREA APPLICATION FOR IRRIGATED CORN

S.J. Del Grosso, J.A. Delgado, and C.E. Stewart
USDA ARS Soil Management and Sugar Beet Research Unit, Fort Collins, CO
steve.delgrosso@ars.usda.gov (970) 492-7281

ABSTRACT

Enhanced efficiency fertilizers (e.g., ESN poly coated urea), may reduce soil nitrous oxide (N_2O) emissions while maintaining or increasing crop yields. However, further increases in N fertilizer efficiency may be attainable with a starter fertilizer application followed by side dressed ESN. We monitored soil N_2O using surface chambers from three N treatments (202 kg N ha^{-1} single application of urea, 34 kg N ha^{-1} starter urea combined with 168 kg N ha^{-1} side-dressed ESN, and a 0 N control) to determine their effects on per unit area and yield scaled emissions from a no-tilled clay loam soil under irrigated, continuous corn production for three years. Average annual cumulative emissions were 1.4 kg N ha^{-1} yr^{-1} for the urea treatment, 0.8 kg N ha^{-1} yr^{-1} for starter urea with side-dressed ESN, and 0.3 kg N ha^{-1} yr^{-1} for the control. Interannual variability was large for the urea treatment, ranging from 0.8 to 2.0 kg N ha^{-1} yr^{-1}, and minimal for starter urea with side-dressed ESN (0.7 to 0.9 kg N ha^{-1} yr^{-1}), and the control (0.27 – 0.3 kg N ha^{-1} yr^{-1}). Average annual yield scaled emissions were 0.13 kg N Mg^{-1} yr^{-1} for the urea treatment, 0.08 kg N Mg^{-1} yr^{-1} for starter urea with side-dressed ESN, and 0.05 kg N Mg^{-1} yr^{-1} for the control. Yield scaled emissions showed similar inter-annual variability patterns as observed for unit area. These results provide evidence that side-dressed ESN combined with starter urea application is a reliable way to decrease area and yield scaled N_2O emissions from irrigated no till corn.

INTRODUCTION

Nitrogen (N) fertilizers are typically applied to corn to maintain optimal yields. However, N fertilizers also contribute to adverse environmental impacts including increased atmospheric N_2O concentrations, NO_x and NH_3 emissions which compromise air quality, and nitrate leaching into aquatic systems which enhances eutrophication. In this paper we concentrate on N_2O emissions because N_2O is a powerful greenhouse gas that also contributes to stratospheric ozone depletion. In addition, agricultural soils are the major anthropogenic source of N_2O, and corn is responsible for more N_2O than any other crop grown in the US.

Compared to standard urea (the most common N fertilizer used in the US), enhanced efficiency fertilizers are designed to improve synchrony between N availability in soil and crop N uptake. The polymer-coated urea known as ESN (Nutrien Ltd.) attempts to accomplish this by gradually releasing N as the polymer coating breaks down in response to favorable soil water content and temperature conditions. Meta-analyses suggest that ESN and similar slow release fertilizers reduce N_2O by about 24% on average (Zhang et al. 2019), but results are not consistent, and studies often show no reductions (e.g., An et al. 2021). In theory, ESN should increase crop yields or allow reduced rates without a yield penalty, and recent meta-analysis for maize showed an average increase of about 5% (Zhang et al. 2019).

Previous research in Colorado has shown that broadcast ESN reduced N_2O emissions by about 42% on average from no till and strip till irrigated corn (Halvorson et al., 2014), but did not increase yields compared to urea (Halvorson and Del Grosso 2013). Side-dress applications of a slow-release fertilizer with a starter N application could more closely match plant N demand, increasing yields under no-tillage while at the same time reducing N_2O emissions compared to urea. Combined yield boosts with reduced N_2O emissions could lead to improved yield-scaled N_2O emissions, a critical metric for environmental impact. The objective of this study was to compare N_2O emissions and corn grain yields from a single application of urea with starter urea combined with side-dressed ESN for a no till irrigated system in Colorado over three years.

MATERIALS AND METHODS

The study was located on a Fort Collins clay loam soil (fine-loamy, mixed, mesic Aridic Haplustalfs) at the Agricultural Research Development and Education Center (ARDEC) (lat. 40° 39'6" N, long. 104° 59'57" W; 1535 m above sea level) northeast of Fort Collins, CO. The soil chemical and physical properties of the 0- to 7.6-cm soil depth were: pH, 7.6; SOC, 11.6 g kg^{-1}; TSN, 1.5 g N kg^{-1}; electrical conductivity (1:1 water/soil ratio), 0.34 mS cm^{-1}; bulk density, 1.46 g cm^{-3}; \$0 %sand and 33% clay (Halvorson et al., 2010; Halvorson and Del Grosso, 2012). The experimental design was a split-plot randomized complete block with three replications. Main plot size was10.7 by 21.3 m.

The study was initiated in 2015 in plots that were cropped with no till corn. Corn was directly planted into the previous year's corn residue followed by application of herbicides for weed control. For the business as usual treatment, urea fertilizer was broadcast applied at 180 kg N ha^{-1} after planting. For improved N management, urea fertilizer was broadcast applied at 30 kg N ha^{-1} after planting followed by a side-dress application of ESN at 150 kg N h^{-1} 30 days after planting. No N fertilizer was applied for the control treatment. A linear-move sprinkler irrigation system was used to apply water as needed during the growing season.

Measurements of the soil–atmosphere exchange of N_2O began in 2015 following procedures reported by Mosier et al. (2006), Halvorson and Del Grosso (2013), and Parkin and Venterea (2010). Measurements were generally made two to three times per week during most of the growing (end of May through August). Sampling frequency was reduced to around twice per week for the end of the growing season (until around the end of the September), and then reduced further to once or twice per month during the non-growing season. This is justified because previous work showed that high N_2O pulses in this system occur only after the application of fertilizer and that emissions return to background levels by the end of September, regardless of the type or amount of fertilizer applied (Halvorson et al. 2016; Liu et al. 2005). The general gas sampling schedule during the time when large pulses occur (June-August) was to collect gas samples on Monday before the scheduled weekly irrigation event (the plots only had opportunity to irrigate on Mondays), Wednesday, and Friday. A vented non-steady-state closed chamber (rectangular aluminum, 78.6 cm x 39.3 cm x 10 cm height, with anchor) was used (Mosier et al., 2006). Anchors were set perpendicular to the corn row so that the corn row and inter-row area were contained within each chamber, and corn plants cut off at about V-6 growth stage to facilitate air tight chamber placement (Halvorson and Del Grosso 2012). Two chambers were placed within each plot for a total of six gas measurements per treatment per sampling date. Air samples from inside the chambers were collected by syringe at 0, 15, and 30 minutes. The samples were transported to the laboratory where the 25-mL air samples were injected into 12-mL evacuated tubes sealed with butyl rubber septa (Exetainer vial from Labco Limited, High Wycombe, Buckinghamshire, UK). The gas chromatograph (Varian model 3800, Varian Inc., Palo Alto, CA) was equipped with an electron capture detector to quantify N_2O concentrations.

Samples were collected mid-morning (time when average daily temperatures typically occur) and were scaled up to calculate daily N_2O fluxes. Daily emissions for non-sampling days were obtained using linear interpolation between adjacent sampling dates and cumulative emissions were derived by summing daily emissions. Emission factors (EF) were calculated by subtracting cumulative annual emissions for the fertilized treatments from the control treatment and dividing by the amount of fertilizer applied (180 kg N ha^{-1}). Nitrous oxide emissions were also calculated on per unit grain yield and per unit grain N bases by dividing cumulative annual emissions by dry matter yields and N in harvested grain, respectively.

Soil water content (0- to 10-cm depth) and soil temperature (5 to 7 cm depth) were monitored at each gas sampling event using 3 soil moisture and temperature probes (EC-TM model, Decagon Devices Inc., Pullman, WA) located ~20 cm from the corn row in each replication. Water-filled pore space (WFPS) was calculated according to the soil bulk density (measured by core method) at 0- to 10-cm depth following crop harvest and an assumed particle density of 2.65 Mg m^{-3} (Linn and Doran, 1984).

RESULTS AND DISCUSSION

Environmental Factors

Soil temperatures (5-7 cm depth) were cooler during May and early June compared with later in the growing season with crop canopy closure when soil temperatures rose to around 22°C, then declined during the latter part of the growing season. Water-filled pore space was generally between 50 and 60% during the growing season each year. Yearly precipitation in 2012 was 159 mm lower than the 126 yr average at Fort Collins, CO, 2013 was 81 mm lower than the long-term average, and 2014 was 59 mm lower than long-term average.

Area Scaled Nitrous Oxide Fluxes and Emission Factors

Annual cumulative N_2O-N fluxes were significantly greater for the fertilized treatments compared to the control during all three years (Figure 1). Cumulative emissions were significantly lower for the starter urea combined with side-dressed ESN compared to single application urea during 2015 and 2017. Averaged across years, cumulative annual N_2O-N fluxes were significantly greater for single application urea (1.37 kg N ha^{-1}) compared to starter urea combined with side-dressed ESN (0.75 kg N ha^{-1}) and both were significantly greater than the control (0.27 g N ha^{-1}). Emission factors for single application urea ranged from 0.28 to 0.83% (mean = 0.55%) and were higher than those for starter urea combined with side-dressed ESN which ranged from 0.2 to 0.3% (mean = 0.24%).

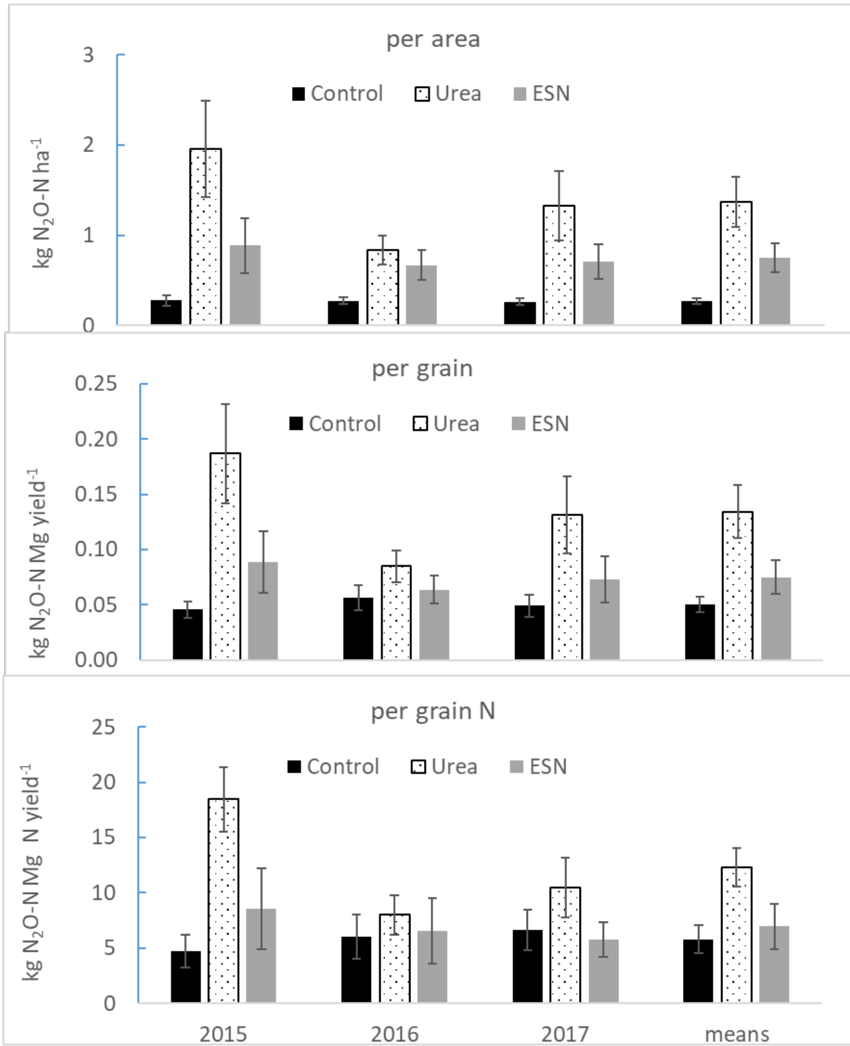

Figure 1. Comparison of nitrous oxide emissions from irrigated corn on area, grain yield, and grain N bases from 0 N addition control plots, business as usual plots amended with180 kg N ha^{-1} after planting, and improved N management plots receiving 30 kg N ha^{-1} urea after planting followed by a side-dress application of ESN at 150 kg N h^{-1} 30 days after planting.

Yield scaled N_2O Emissions

Nitrous oxide emissions per unit of grain yield showed similar patterns of area scaled emissions and when averaged over years were greater for single application urea (0.13 kg N_2O-N per Mg grain) compared to starter urea combined with side-dressed ESN (0.08 kg N_2O-N per Mg grain) and both were significantly greater than the control (0.05 kg N_2O-N per Mg grain). (Figure 1). The individual years showed the same patterns and differences were significant for all years. Patterns were similar for grain N scaled emissions and when averaged over years were greater for single application urea (17 kg

N_2O-N per Mg grain N) compared to starter urea combined with side-dressed ESN (0.08 kg N_2O- N per Mg grain N) and both were significantly greater than the control (0.05 kg N_2O-N per Mg grain N). (Figure 1). The individual years showed the same patterns and differences were significant for all years.

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REFERENCES

An, H., Owens, J., Beres, B., Li, Y. and Hao, X., 2021. Nitrous oxide emissions with enhanced efficiency and conventional urea fertilizers in winter wheat. Nutrient Cycling in Agroecosystems, 119, pp.307-322.

Halvorson, A.D., S.J. Del Grosso, and F. Alluvione, 2010. Tillage and inorganic nitrogen source effects on nitrous oxide emissions from irrigated cropping systems. Soil Sci. Soc. Am. J. 74:436-445.

Halvorson, A.D. and S.J. Del Grosso, 2013. Nitrogen placement and source effects on nitrous oxide emissions and yields of irrigated corn. J. Envir. Qual. 42: 312-322. doi:10.2134/jeq2012.0315.

Halvorson, A.D., C. Snyder, A. Blaylock, and S.J. Del Grosso, 2014. Enhanced-efficiency nitrogen fertilizers: Potential role in N_2O emission mitigation. Agron. J. 106:715-722. doi:10.2134/agronj2013.0081.

Halvorson, A.D., Stewart, C.E. and Del Grosso, S.J., 2016. Manure and inorganic nitrogen affect irrigated corn yields and soil properties. Agronomy Journal, 108(2), pp.519-531.

Linn, D.M., and J.W. Doran, 1984. Effect of water-filled pore space on carbon dioxide and nitrous oxide production in tilled and non-tilled soils. Soil Sci. Soc. Am. J. 48:1267-1272.

Liu, X.J., Mosier, A.R., Halvorson, A.D. and Zhang, F.S., 2005. Tillage and nitrogen application effects on nitrous and nitric oxide emissions from irrigated corn fields. Plant and Soil, 276(1-2), pp.235-249.

Mosier, A.R., A.D. Halvorson, C.A. Reule, and X.J. Liu, 2006. Net global warming potential and greenhouse gas intensity in irrigated cropping systems in northeastern Colorado. J. Environ. Qual. 35:1584-1598.

Parkin, T. and R. Venterea, 2010. Chamber-based trace gas flux measurements. In: R.F. Follett, editor, GRACEnet sampling protocols. p. 3-1-3-9.

Zhang, W., Liang, Z., He, X., Wang, X., Shi, X., Zou, C. and Chen, X., 2019. The effects of controlled release urea on maize productivity and reactive nitrogen losses: A meta-analysis. Environmental Pollution, 246, pp.559-565.