OPPORTUNITIES FOR AND POTENTIAL CONSEQUENCES OF REDUCING NITROUS OXIDE EMISSIONS FROM SUGARCANE CROPS

By

P.J. THORBURN, J.S. BIGGS,
M.E. PROBERT and B.A. KEATING
CSIRO Sustainable Ecosystems, Brisbane
Peter.Thorburn@csiro.au

KEYWORDS: APSIM, Biofuel, Nitrous Oxide Emissions, Nitrogen Fertiliser, Sugarcane.

Abstract

USE OF nitrogen fertiliser is a major cause for increased atmospheric concentrations of nitrous oxide, a potent greenhouse gas. To reduce greenhouse gas emissions from sugarcane production, and so increase the crop's attractiveness as a sustainable biofuel, it will be important to have a better understanding of nitrous oxide emissions and how they can be reduced. However, few measurements of nitrous oxide losses have been reported so far. Thus, our knowledge about nitrous oxide emissions from sugarcane production systems, and how they might vary in response to different environmental and management conditions, is limited. We compared measurements of nitrous oxide emissions with predictions from the cropping system model APSIM. We then simulated whole-of-crop nitrous oxide emissions over a range of environments and management practices in Australia. Predictions of nitrous oxide emissions were consistent with the measurements available, and greater than those from other intensive crops. Nitrous oxide emissions were predicted to vary considerably between regions, and were higher on irrigated soils and increased when trash was retained. Also, as expected, emissions were related to N fertiliser applications. Adoption of recent recommendations for reducing N fertiliser use was, in an example, predicted to reduce emissions by 40%. Further reductions in N applications and emissions, which may occur if emission trading schemes are adopted and fertiliser prices increase, were shown to reduce both emissions and profitability of sugarcane production. However, the economic value of reduced emissions is likely to be considerably less than that of the lost production. Experimental confirmation of these conclusions would be valuable.

Introduction

Concentrations of nitrous oxide, which is a potent greenhouse gas, have increased significantly over the past century as a result of anthropogenic alterations to the global nitrogen cycle (Crutzen *et al.*, 2008; Schlesinger, 2009). Significant nitrous oxide emissions result from application of nitrogen (N) fertiliser to crops (Bouwman *et al.*, 2002), and these emissions reduce the greenhouse gas benefits of biofuels (Crutzen *et al.*, 2008). Hence, understanding nitrous oxide emissions from sugarcane production systems is an essential prerequisite for maximising the benefits of biofuels production, as well as minimising overall environmental impacts.

There are few measurements of nitrous oxide emissions from sugarcane and most have been conducted in Australia (Weier *et al.*, 1996, 1998; Weier, 1999; Denmead *et al.*, 2008; Wang *et al.*, 2008; Allen *et al.*, 2008; Macdonald *et al.*, 2009). Emissions have been higher than expected compared with other cropping systems in Australia (Galbally *et al.*, 2005). To reduce greenhouse gas emissions, it will be valuable to gain additional information on nitrous oxide emissions from sugarcane systems and, if as high as currently indicated, identify management practices to reduce them.

Simulation models are increasingly being employed in addition to experiments to gain information on nitrous oxide emissions from cropping systems (e.g. Del Grosso *et al.*, 2009). APSIM is a farming systems simulator (Keating *et al.*, 2003) with a well developed capacity to simulate N dynamics in sugarcane systems (Thorburn *et al.*, 2005). Recently, the denitrification processes in APSIM have been tested and the capability added for partitioning denitrified N into the different gasses produced by the process, nitrous oxide and dinitrogen (Thorburn *et al.*, 2010a). Thus, APSIM is now a useful tool for exploring potential nitrous oxide emissions from sugarcane production systems in areas and/or for issues where measurements are unavailable.

In this paper, we use APSIM to investigate nitrous oxide emissions from a range of conditions found in sugarcane production in Australia. The simulations support the high nitrous oxide emissions previously measured, and suggest emissions are possibly greater in other sugarcane growing regions in Australia. We also explore some options for reducing nitrous oxide emissions and the impact they may have on sugarcane farming profitability.

Methodology

Contrasting sugarcane production systems were analysed using long term (40–60 years) simulations to investigate how nitrous oxide emissions varied (full details are given by Thorburn *et al.*, 2010a). The systems were based on soils, climate and crop management information from previous studies of sugarcane production in four regions. These spanned a wide range of environments, including the super-humid tropics (Tully; ~17.9S, 145.9E), dry tropics (Burdekin River Irrigation Area; ~19.8S, 145.9E), humid tropics (Mackay, two soils; ~21.2S, 149.0E) and dry sub-tropics (Maryborough; ~25.5S, 152.7E).

Nitrous oxide emissions have previously been measured in the Mackay region, at Eton (Weier *et al.*, 1998) and Te Kowai (Denmead *et al.*, 2008; Macdonald *et al.*, 2009). Hence, this study provided the first insights into potential nitrous oxide emissions in the other regions.

A range of management practices and soils were represented in the simulations. In Australia, there is a wide range of potential planting times, both within and between regions and this variation is represented in the systems simulated. The planting time influences the length of fallow before planting, and a range of fallow lengths is represented in the systems simulated. Irrigation management varied, with sugarcane fully irrigated in the Burdekin simulations, grown under supplementary irrigation in Maryborough simulations and not irrigated in the other systems. Simulations for the two soils in Mackay each had two different trash managements (retention and removal).

The amount of N applied in the simulations reflected common practice in the regions, ranging from over 200 kg/ha (averaged across all crops and fallows) in the Burdekin region to less than 130 kg/ha in the Tully and Maryborough regions (Figure 1). Soils ranged from clays in the Burdekin and the Eton site in Mackay, to sandy-clay-loams at the Te Kowai site in Mackay. Average cane yields in the simulations ranged from 74 t/ha (averaged across all crops), at Maryborough, to 80–84 t/ha for the loamy soils at Tully and Mackay (Te Kowai), to 87–91 t/ha in the clay soils of Mackay (Eton) and the Burdekin.

For the Te Kowai site in Mackay, cane yield, nitrous oxide emissions and partial gross margin (PGM) to farmers of sugarcane production were also simulated for a wide range of N application rates (35–200 kg/ha), keeping all other management factors the same as in the previous simulations. The PGM was calculated from the income from sugarcane (assuming a sugar price of AU$400/t and CCS of 13.5) less the cost of N fertiliser. The N application rate corresponding to the highest PGM was identified over a range of fertiliser prices to explore the possible sensitivity of nitrous oxide emissions, which are a function of N rate, to N price.

Results and discussion

Extent of emissions

Simulated long-term nitrous oxide emissions varied from 4–6 kg N/ha at the rainfed sites (Mackay and Tully) to 5–11 kg N/ha for the irrigated sites (Burdekin and Maryborough). The simulated emissions are consistent with previous measurements of emissions from rainfed sugarcane (Denmead *et al.*, 2008; Allen *et al.*, 2008; Wang *et al.*, 2008; Macdonald *et al.*, 2009). In particular, at Te Kowai near Mackay, nitrous oxide emissions of 4.1–4.7 kg N/ha were measured from a crop in 2006–07 (Denmead *et al.*, 2008) and over the first 60 days of a crop in 2007–08 (Macdonald *et al.*, 2009), similar to average long-term simulated values of 3.2–4.2 kg N/ha. Our simulations suggest these results are representative of longer time frames.

Nitrous oxide emissions were equivalent to 2–5% of N fertiliser applied (Figure 1) in the simulations. These relative emissions were consistent with the processes known to drive nitrous oxide emissions. At the Mackay sites, for example, emissions were higher from the clay soil at Eton than the more loamy soil at Te Kowai. Also, retaining trash on these soils increased simulated denitrification and nitrous oxide emissions, as expected from experimental results (Weier *et al.*, 1998). Emissions were simulated to be high at the Burdekin site, reflecting the heavy clay nature of the soil combined with the high number (16) of irrigations in the simulation.

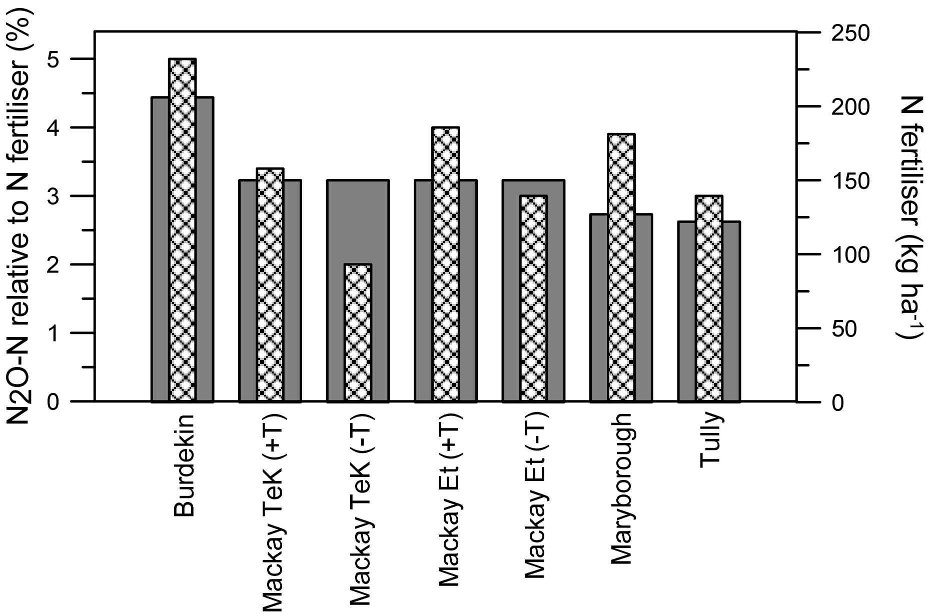

Fig. 1—Simulated, long-term average nitrous oxide emissions (hatched bars) N fertiliser applications (grey bars) at five sites. For Mackay, sites were at Te Kowai (TeK) and Eton (Et) and either had trash retained (+T) or removed (-T) in the simulations.

Our results (Figure 1) support the conclusions from several previous experiments (Denmead *et al.*, 2008; Allen *et al.*, 2008; Wang *et al.*, 2008; Macdonald *et al.*, 2009) that nitrous oxide emissions from Australian sugarcane crops are substantially greater than expected for the level of N fertiliser use and experience in other crops (Galbally *et al.*, 2005), and suggest the cause is the relatively warm and moist climate and the availability of carbon in the soils.

Additionally, we provide the first estimates of emissions for fully irrigated production in Australia's dry tropics (Burdekin), partly irrigated production in the sub-tropics (Maryborough) and rainfed production in the wet tropics (Tully). It will be valuable to experimentally confirm our predictions for these regions. However, we suggest that nitrous oxide total emissions in Australian sugarcane production may generally be equivalent to 3 to 5% of N fertiliser. While very high emissions (~20% N fertiliser) have been measured from sugarcane growing on organic soils with shallow water tables (Denmead *et al.*, 2008; Wang *et al.*, 2008), these areas are relatively small in Australia and are unlikely to represent the general situation.

Global warming potential of nitrous oxide emissions from Australian sugarcane production has been estimated at 1.3 Mt CO_2-e/year (Weier, 1998), compared to total nitrous oxide emissions from agricultural soils in Australia of 15 Mt CO_2-e/y (NGGI, 2007). Our predicted nitrous oxide emissions are equivalent to 2.2–3.8 Mt CO_2–e/year for the amount of N traditionally applied to sugarcane in Australia (~80 Mt/year; Fertiliser Industry Federation of Australia, pers. comm.). Thus, we suggest that global warming potential of sugarcane in Australia is substantially greater than the previous estimate.

Applying our results to global sugarcane production for the area occupied by the crop (FAO, 2007) and average N application rates (Roy *et al.*, 2006) suggests the global warming potential of nitrous oxide emitted from all sugarcane production may be equivalent to 60–100 Mt CO_2–e/year. This is 2–3% of the global warming potential previously attributed to nitrous oxide emissions from all fertilised croplands (Stehfest and Bouwman, 2006). This result, together with the fact that nitrous oxide emissions account for more than half the greenhouse gasses emitted during sugarcane production (Thorburn *et al.*, 2009), suggests that reducing nitrous oxide from sugarcane is likely to be a higher priority than may have been previously thought for increasing the sustainability of sugarcane production both in Australia and globally.

Reducing emissions

As expected (Bouwman *et al.*, 2002), nitrous oxide emissions increase with increasing N fertiliser application (Figure 2a). Thus, emissions can be reduced by reducing N applications. This may come about in two ways:

Firstly, improved N recommendations have shown there is considerable scope for reducing N rates in Australian sugarcane production without significantly reducing productivity (Schroeder *et al.*, 2006; Thorburn *et al.*, 2010b). Thus, at Te Kowai for example (Figure 2a), reducing N application from 170 kg/ha (the recent average in that region) to 120 kg/ha would reduce nitrous oxide-N emissions by ~40%. This reduction in emissions would not be associated with a loss of income as yields are likely to be maintained at these N application rates (Thorburn *et al.*, 2010b).

Secondly, nitrogen applications may also be reduced if the price of N fertiliser increases. Price increases are likely if emissions trading schemes are introduced, because the cost of energy used in the manufacture and distribution of fertiliser will rise, and the possibility of an emissions levy on fertiliser.

As N fertiliser prices increase, maximum profitability occurs at lower N application rates (Figure 2b). So farmers **may** respond to price increases by reducing N applications, which would result in lower nitrous oxide emissions. However, with increased N price, not only is the N rate at which maximum profitability reduced, the maximum profit itself also decreases.

Thus, higher N prices could result in both lower nitrous oxide emissions and lower farm profitability if farmers respond by reducing N applications. In the simulations for Te Kowai, the trade off between nitrous oxide emissions and farm profitability can be illustrated for varying N prices by taking the N rate at which maximum PGM occurs (i.e. the dots on the curves in Figure 2b) and calculating the corresponding nitrous oxide emissions and PGM values over a range of N prices (Figure 3).

In this example, nitrous oxide emissions decrease by ~0.46 kg N_2O-N/ha for each unit (i.e. AU$1) increase in N price. If the price of carbon is AU$20/t CO_2-e the value of the reduced nitrous oxide emissions is ~AU$4.25. The corresponding decrease in PGM is ~AU$98 per unit increase in N price, or more than 20 times the value of nitrous oxide emissions.

The economic impact of increased N prices will be even greater if price increases are such that they drive N applications low enough so that cane yields and sucrose concentrations are reduced. In this situation, the reduced cane and sugar supply would potentially reduce mill profitability. This analysis illustrates the point that decreases in N fertiliser rate below recommended rates as a response to higher N prices could have substantial negative net economic effects.

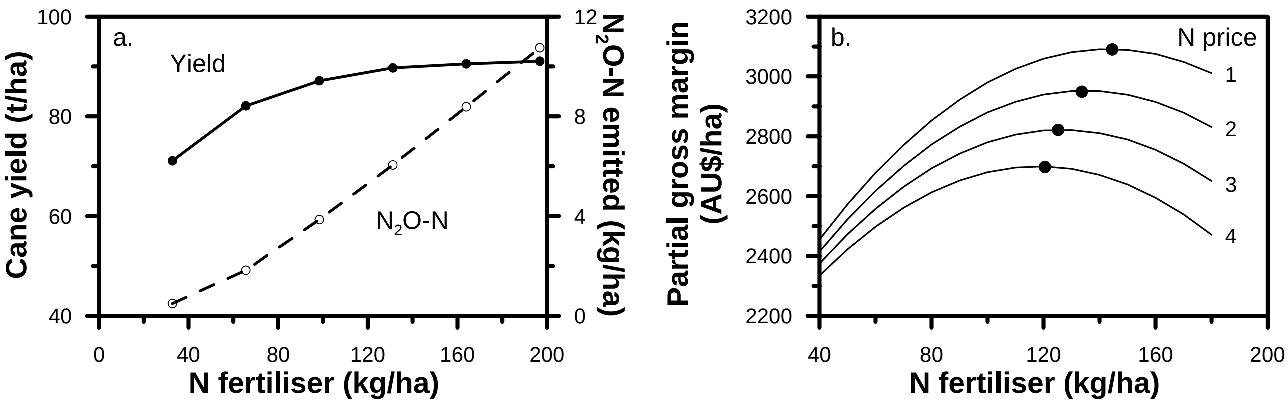

Fig. 2—Simulated, long-term average response of (a) cane yields, nitrous oxide emissions and (b) partial gross margin to increasing application of N fertiliser for the Te Kowai site. The sensitivity of partial gross margin to four fertiliser prices (AU$/ kg N) is shown in (b), and the N rate of maximum partial gross margin indentified by the dots.

The nitrous oxide emissions are enhanced by high concentrations of nitrate and carbon in the soils and anaerobic soil conditions. Thus, as well as reducing N fertiliser applications, other management practices affect nitrous oxide emissions. In our simulations, as expected, the highest relative emissions occurred in the two irrigated production systems, Burdekin and Maryborough (Figure 1). In irrigated production systems, minimising water logging following irrigation will help reduce nitrous oxide emissions. Also, as expected, retaining crop trash also increased emissions (Figure 1).

Given the advantages of this widely-adopted practice in Australian sugarcane production (Weier *et al.* 1998; Robertson and Thorburn, 2007), other methods to reduce emissions will need to be employed. Practices such as splitting N fertiliser applications may help (Weier 1999; Allen *et al.*, 2008), as might slow release fertilisers or nitrification inhibitors (Wang *et al.*, 2008), although the benefits of these practices have not been consistent.

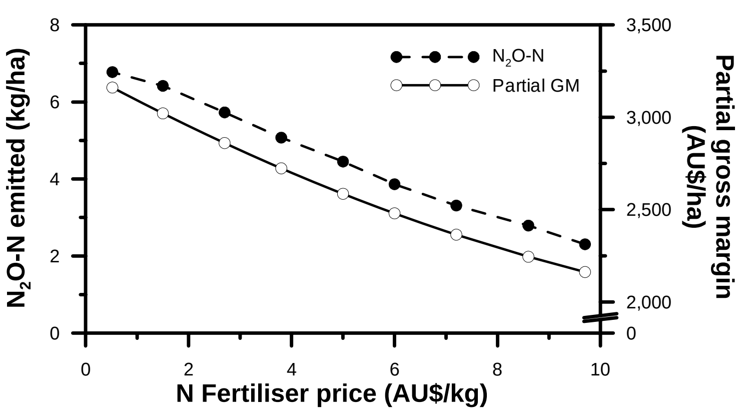

Fig. 3—Simulated change in nitrous oxide emissions and maximum partial gross margin to increasing N fertiliser price for the Te Kowai site, assuming N fertiliser is applied at the rate corresponding to the maximum partial gross margin (e.g. Figure 2b).

Conclusions

Our study supports the proposition that nitrous oxide emissions from Australian sugarcane production are considerably greater than expected compared with measurements in other intensive crops, and so reducing emissions will be important for increasing sustainability of the industry. Adoption of contemporary recommendations for reducing N fertiliser use is a likely pathway to significantly reducing emissions.

Further reductions in N applications, which may occur if emission trading schemes are adopted and fertiliser prices increase, may not only reduce emissions, but profitability of sugarcane production. The economic value of lost production is likely to be much greater than the value of reduced greenhouse gas emissions. Experimental confirmation of these conclusions would be valuable. Simulating the relative efficacy of these different management practices may guide experimentation in that area. APSIM's ability to represent such management options in detail (Keating *et al.*, 2003; Thorburn *et al.*, 2005) will make it a useful tool for these investigations.

Acknowledgements

We would like to acknowledge valuable feedback on the manuscript provided by Bernard Milford, CANEGROWERS.

REFERENCES

Allen, D., Kingston, G., Rennenberg, H., Dalal, R. and Schmidt, S. (2008). Nitrous oxide emissions from sugarcane soils as influenced by waterlogging and split N fertiliser application. Proc. Aust. Soc. Sugar Cane Technol., 30: 95–104.

Bouwman, A.F., Boumans, L.J.M. and Batjes, N.H. (2002). Emissions of N_2O and NO from fertilised fields-summary of available measurement data. Glob. Biogeochem. Cycl., 16: 1058, doi:10.1029/2001GB001811.

Crutzen, P.J., Mosier, A.R., Smith, K.A., and Winiwarter, W. (2008). N_2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels. Atmos. Chem. Phys., 8: 389–395.

Del Grosso S.J., Ojima D.S., Parton W.J., Stehfest, E., Heistemann, M., DeAngelo, B. and Rose, S. (2009). Global scale DAYCENT model analysis of greenhouse gas emissions and mitigation strategies for cropped soils. Glob. Planet. Change, 67: 44–50.

Denmead, O.T., Macdonald, B.C.T., Naylor, T., Wang W., Salter, B., White, I., Wilson, S., Griffith, D.W.T. and Moody, P. (2008). Whole-of-season greenhouse gas emissions from Australian sugarcane soils. Proc. Aust. Soc. Sugar Cane Technol., 30: 105–114.

FAO (2007). FertiStat – Fertiliser Use Statistics. FAO Plant Production and Protection Division, http://www.fao.org/ag/agl/fertistat/index_en.htm.

Galbally, I., Meyer, M., Bentley, S., Weeks, I., Leuning, R., Kelly, K., Phillips, F., Barker-Reid, F., Gates, W., Baigent, R., Eckard, R. and Grace, P. (2005). A study of environmental and management drivers of non-CO_2 greenhouse gas emissions in Australian agro-ecosystems. Environ. Sci., 2: 133–142.

Keating, B.A., Carberry, P.S., Hammer, G.L., Probert, M.E., Robertson, M.J., Holzworth, D., Huth, N.I., Hargreaves, J.N.G., Meinke, H., Hochman, Z., McLean, G., Verburg, K., Snow, V., Dimes, J.P., Silburn, M.D., Wang, E., Brown, S., Bristow, K.L., Asseng, S., Chapman, S., McCown, R.L., Freebairn, D.M. and Smith, C.J. (2003). An overview of APSIM, a model designed for farming systems simulation. Eur. J. Agron., 18: 267–288.

Macdonald, B.C.T., Denmead, O.T., White, I., Naylor, T., Salter, B., Wilson, S. and Griffith, D.W.T. (2009). Emissions of nitrogen gases from sugarcane soils. Proc. Aust. Soc. Sugar Cane Technol., 31: 85–92.

NGGI (2007). National Greenhouse Gas Inventory 2005. Department of the Environment and Heritage. Australian Greenhouse Office, Canberra.

Robertson, F.A. and Thorburn, P.J. (2007). Management of sugarcane harvest residues: consequences for soil carbon and nitrogen. Aust. J. Soil Res., 45: 13–23.

Roy R.N, Finck A., Blair G.J. and Tandon, H.L.S. (2006). Plant nutrition for food security: A guide for integrated nutrient management. FAO Fertiliser and Plant Nutrition Bulletin 16, FAO, Rome.

Schlesinger, W.H. (2009). On the fate of anthropogenic nitrogen. PNAS, 106: 203–208.

Schroeder, B.L., Wood, A.W., Moody, P.W., Panitz, J.H., Agnew, J.R., Sluggett, R.J. and Salter, B. (2006). Delivering nutrient management guidelines to growers in the central region of the Australian sugar industry. Proc. Aust. Soc. Sugar Cane Technol., 28: 142–154.

Stehfest, E. and Bouwman, L. (2006). N_2O and NO emission from agricultural fields and soils under natural vegetation: summarising available measurement data and modeling of global annual emissions. Nutri. Cycl. Agroecosys., 74: 207–228.

Thorburn, P.J, Biggs, J.S., Collins, K. and Probert, M.E. (2010a). Nitrous oxide emissions from Australian sugarcane production systems – are they greater than from other cropping systems? Agric. Ecosys. Environ., in press.

Thorburn, P.J., Meier, E.A. and Probert, M.E., (2005). Modelling nitrogen dynamics in sugarcane systems: Recent advances and applications. Field Crop. Res., 92: 337–352.

Thorburn, P., O'Connell, D. and Grant, T. (2009). Enhancing the assessment of biofuels feedstock production through more realistic representation of farming systems. In: Van Ittersum, M.K., Wolf , J. and Van Laar, H.H. (Eds), Proc. Conf. Integrated Assessment of Agriculture and Sustainable Development: Setting the Agenda for Science and Policy. Egmond aan Zee, The Netherlands, 10–12 March 2009. Wageningen University and Research Centre, Wageningen, pp 388–389

Thorburn, P.J., Webster, A.J., Biggs, J.S. and Biggs, I.M. (2010b). Evaluating an ecologically-based system for sustainable management of nitrogen fertiliser management. Proc. Int. Soc. Sugar Cane Technol., this issue.

Wang, W.J., Moody, P.W., Reeves, S.H., Salter, B. and Dalal, R.C. (2008). Nitrous oxide emissions from sugarcane soils: Effects of urea forms and application rate. Proc. Aust. Soc. Sugar Cane Technol., 30: 87–94.

Weier, K.L. (1999). N_2O and CH_4 emission and CH_4 consumption in a sugarcane soil after variation in nitrogen and water application. Soil Biol. Biochem., 31: 1931–1941.

Weier, K.L., McEwan, C.W., Vallis, I., Catchpoole, V.R. and Myers, R.J.K. (1996). Potential for biological denitrification of fertiliser nitrogen in sugarcane soils. Aust. J. Agric. Res., 47: 67–79.

Weier, K.L., Rolston, D.E. and Thorburn, P.J. (1998). The potential for N losses via denitrification beneath a green cane trash blanket. Proc. Aust. Soc. Sugar Cane Technol., 20, 169–175.

PERSPECTIVES ET CONSÉQUENCES POTENTIELLES DES RÉDUCTIONS D'EMISSIONS DE PROTOXYDE D'AZOTE EN CULTURE DE CANNE À SUCRE

Por

P.J. THORBURN, J.S. BIGGS et M.E. PROBERT
CSIRO Sustainable Ecosystems, Brisbane
Peter.Thorburn@csiro.au

MOTS-CLÉS: APSIM, Biocarburants, Émissions de Gaz à Effet de Serre, Émissions de Protoxyde D'azote, Engrais d'Azote, Canne à Sucre.

Résumé

L'UTILISATION de l'engrais azoté est une cause majeure de l'accroissement des concentrations atmosphériques en protoxyde d'azote, un gaz à effet de serre potentiel. Pour réduire les émissions de gaz à effet de serre provenant de la production de canne à sucre, et augmenter ainsi l'intérêt de cette plante comme biocarburant durable, il serait important d'avoir une meilleure connaissance des émissions de protoxyde d'azote et des façons de les réduire. Cependant, peu de mesures de pertes en protoxyde d'azote ont été relatées jusqu'ici. Ainsi, notre connaissance sur les émissions de protoxyde d'azote des systèmes de production de canne à sucre, et leur variabilité selon les conditions environnementales et les pratiques culturales, est limitée. Nous avons comparé des mesures d'émissions de protoxyde d'azote aux prévisions du modèle de croissance APSIM. Nous avons ainsi simulé des émissions de protoxyde d'azote de parcelles sur une gamme d'environnements et de pratiques culturales en Australie. Les prévisions des émissions de protoxyde d'azote furent conformes aux mesures disponibles, et supérieures à celles d'autres cultures. Les émissions de protoxyde d'azote ont été simulées pour des régions très variées, et furent plus élevées sur sols irrigués et accrues quand les résidus de récolte étaient restitués. En outre, comme prévu, les émissions furent liées aux applications d'engrais azoté. L'adoption des recommandations récentes pour réduire l'utilisation d'engrais azoté, dans un exemple, réduisit les émissions de 40%. D'autres réductions des applications d'azote et des émissions, qui peuvent se produire si les plans de taxation des émissions sont adoptés et si les prix d'engrais augmentent, ont montré une réduction à la fois des émissions et de la rentabilité de la production de canne à sucre. Cependant, la valeur économique des émissions réduites est vraisemblablement plus faible que celle due à la réduction de production. Une confirmation expérimentale de ces conclusions serait très utile.

OPORTUNIDADES Y CONSECUENCIAS POTENCIALES DE LA REDUCCIÓN DE LAS EMISIONES DE OXIDO NITROSO EN CULTIVO DE CAÑA DE AZÚCAR

Par

P.J. THORBURN, J.S. BIGGS y M.E. PROBERT
CSIRO Sustainable Ecosystems, Brisbane
Peter.Thorburn@csiro.au

PALABRAS CLAVES: APSIM, Los Biocarburantes, Gases de Efecto Invernadero, Emisiones de Óxido Nitroso, Fertilizantes de Nitrógeno, Caña de Azúcar.

Resumen

EL USO de los fertilizantes nitrogenados es la principal causa de incremento de las concentraciones atmosféricas de óxido nitroso, un potente gas de efecto invernadero. Para reducir las emisiones de gas de efecto invernadero en la producción de caña de azúcar, y para incrementar la atractividad del cultivo como un biocombustible sostenible, será importante tener un mejor entendimiento de las emisiones de óxido nitroso y de cómo pueden reducirse. Sin embargo, pocas mediciones de pérdidas de óxido nitroso han sido reportadas hasta el momento. Por lo tanto, nuestro conocimiento es limitado sobre las emisiones de óxido nitroso desde los sistemas de producción de caña de azúcar, y de cómo podrían variar en respuesta a las diferentes condiciones ambientales y de manejo. Hemos comparado mediciones de emisiones de óxido nitroso con predicciones hechas a partir del modelo de sistemas de cultivo APSIM. Luego, hemos simulado las emisiones de óxido nitroso del cultivo completo sobre un rango de ambientes y prácticas de manejo en Australia. Las predicciones de las emisiones de óxido nitroso fueron consistentes con las mediciones disponibles, y mayores que aquellas provenientes de otros cultivos. Se predijo que las emisiones de óxido nitroso varían considerablemente entre regiones, y fueron más altas en los suelos irrigados e incrementadas cuando se mantuvo el residuo de la cosecha. También, como se esperaba, las emisiones estuvieron relacionadas a las aplicaciones de fertilizantes nitrogenados. En un ejemplo, la adopción de las recomendaciones recientes para la reducción del uso de fertilizantes nitrogenados, predijo la reducción de las emisiones en un 40%. Además, las reducciones en las aplicaciones de nitrógeno y en las emisiones, que pueden ocurrir si se adoptan los planes propuestos en los protocolos, y el precio de los fertilizantes aumenta, demostramos que se reducen tanto las emisiones como la rentabilidad de la producción de caña de azúcar. Sin embargo, el valor económico de las emisiones reducidas es probablemente considerablemente menor que el de las pérdidas de producción. La confirmación experimental de esas conclusiones debería ser evaluada.