Genotypic response of sugarcane to enhanced efficiency fertilisers (EEF)

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Abstract

Efficient nitrogen (N) use in crop production systems is critical for sustainable sugarcane production. This can be achieved through improved N supply to match crop demand, improved cultivars, and management practices that minimise N loss. The effect of enhanced efficiency fertiliser (EEF; polymer-coated urea: nitrification inhibitor, 80 kg N ha^{-1}) and standard urea application (80, 200 kg N ha^{-1}) on plant and first ratoon crop yield of 12 sugarcane genotypes were compared. Yield response to fertiliser varied with crop class and genotype, and a significant genotype by N supply interaction effect was observed in the ratoon crop. The results indicate a genotype-dependent yield response with EEF.

Key Words: Genotype performance, Yield, crop class

Introduction

Global targets for improved nitrogen (N) use efficiency aim to reduce N inputs and minimise N losses that contribute to greenhouse gas emissions and water pollution while maintaining agricultural productivity and economic viability (Foley et al. 2011; United Nations 2019). The Australian sugar industry, situated primarily within the Great Barrier Reef catchment, has prioritised N fertiliser management to reduce dissolved inorganic N input (Brodie and Landos 2019; Thorburn 2013). Current industry fertiliser management is centred on broad regional yield potential with soil testing, however, avenues for further refinement of N management have been identified including; climate-based yield forecasting, cultivar improvement and 'enhanced efficiency fertiliser' (EEF) product development (Thorburn et al. 2017; Bell et al. 2015)

Developing EEF for sugarcane cropping, which aims to synchronise N release and crop N uptake, has followed that in other cropping industries (Dimkpa et al. 2020), with the majority of available products delaying N release or stabilising N in urea with polymer coating, and urease or nitrification inhibitors (Vilas et al. 2019). Responses of crop yields and nitrous oxide emissions to EEF have been varied (Soares et al. 2015; Wang et al. 2016) and modelling crops using Agricultural Production Systems Simulator (APSIM) have identified early season rainfall and later starting ratoon crops as most likely to benefit from EEF compared to standard urea (Verburg et al. 2019). Sugarcane cultivars have varied biomass and N accumulation dynamics (Robertson et al. 1996; van Heerden et al. 2010; Wood et al. 1996), and morphological and physiological traits linked to N response will impact fertiliser use efficiency (Robinson et al. 2015). However, there has been limited evaluation of the impact of cultivar on EEF efficacy. This study aimed to determine the genotypic variation in yield response to EEF compared to standard urea fertiliser to evaluate the EEF efficacy and the potential for integrated fertiliser and cultivar development.

Methodology

Field experiment

Twelve sugarcane genotypes including Australian commercial cultivars (SRA7, SRA8, Q229, MQ239), parental lines (QN04-1643, QC91-580, QS95-6004), foreign varieties (H87-4094, N14), *S. spontaneum* introgression backcrosses (KQB07-33647, QBYC05-20853), *Erianthus sp.* introgression backcross (QBYN04-10061) were evaluated with varied N supply in the field in the Burdekin region (19°35'59" S, 147°18'02"E), Queensland, Australia. The site, previously used for sugarcane production, was depleted of N with a 6-month maize crop grown without fertiliser application and total above-ground

biomass removal at harvest. The trial was planted in June 2017 and plant and ratoon crops were harvested on 18 June 2018 and 26 July 2019, respectively. The soil was classified as light to medium clay, brown eutrophic melanic dermosol, with organic carbon content averaging 0.85%.
The trial was a split-plot design with three replicates; the main plot factor was four levels of N fertiliser application and the subplot factor was 12 sugarcane genotypes comprised of 4 rows of 10m length with a row spacing of 1.52m. The four N application treatments were 0N, 80N (80 kg N ha^{-1}), the industry-recommended rate for the region (200 kg N ha^{-1}) applied as standard urea, and 80N EEF kg ha^{-1}. The 80N EEF was a 60:40 mix of Agromaster® (Polymer-coated slow-release urea, Impact Fertiliser): ENTEC® (urea with a nitrification inhibitor, Incitec Pivot). Phosphorus and potassium were applied to all plots at 30 kg ha^{-1} and 100 kg ha^{-1}, respectively. Fertiliser treatments were applied on 8 September 2017 in the plant crop (PC) and 28 September 2018 in the ratoon crop (1R). The trial was established and managed following the industry best management practices.

Exchangeable soil inorganic N was sampled at intervals throughout the crop season from 4 plots in each of the replicate blocks for all N supply treatments. The soil was sampled from 0-20 and 20-60 cm depths and extracted with 2 M KCl (1:5) after stirring for 1 hr, then centrifuged at 4500 rpm for 10 minutes. The supernatant was analysed for nitrate (Miranda et al. 2001) and ammonium (Kempers, 1974) content and using a conversion derived from a sub-sample dried for 3 days at 105^{O}C. Cane yield was evaluated after ~12 months of crop growth, using plot weight, after mechanically harvesting the two middle rows using a commercial harvester and weigh the truck. The yield response ratio of each genotype was calculated by comparing yield at 0N treatment.

Statistical Analysis

Analyses of variance (ANOVAs) for a split-plot design were conducted for each crop class (PC, 1R) to test the genotype, N treatment, and genotype × N treatment interaction effects within the experiment using GenStat version 20 (www.genstat.com; VSN International Ltd) where genotypes and N rates were regarded as random effects and replicate as a fixed effect. ANOVAs of both crop classes where two factors were involved in the total variances was conducted using the following model (Miller et al. 1963).

$$Yij\mathrm{k} = \mu + tj + bk\mathrm{j} + g\mathrm{i} + (gt)\mathrm{ij} + (gb)\mathrm{ijk}$$

Where, Y_{ijk}=observed trait of the i^{th} genotype in the j^{th} treatment in the k^{th} block; μ=mean of all observations; tj=effect of the j^{th} treatment; j=1, 2, or 3; bkj=effect of the k^{th} block within the j^{th} treatment; k=1, 2 (error 1); gi=effect of the i^{th} genotype; i=1–12 ; (gt)ij=interaction effect between the i^{th} genotype and the j^{th} treatment; and (gb)ijk=interaction effect between the i^{th} genotype and the k^{th} block within the j^{th} treatment (error 2).

Results

Genotypic variation in yield response

Yield response to standard urea fertiliser and EEF varied with crop class and genotype (Table 1, Figure 1) with the impact of N supply increasing in the ratoon crop. A significant genotype by N supply interaction effect was observed in the ratoon crop.

Table 1. Variance ratio for genotype, N treatment, and genotype× N treatment interaction effects on yield (T ha^{-1}) of plant and ratoon crops.

Crop	N supply	Genotype	N x Genotype
Plant	6.02*	24.89*	0.95
Ratoon	22.67*	17.9*	2.22*

In the ratoon crop, the yield ratio (fertilised/unfertilised) of genotypes when supplied with 80 kg EEF N ha^{-1} ranged from 1.3 to 1.9 (Figure 1C). Overall, EEF-supplied crops performed poorly compared to standard urea with only four genotypes (KQB07-33647, N14, Q229, QBYC05-20853) having significantly increased yield compared to the unfertilised plots compared with 10 genotypes when supplied with standard urea. Genotype QC91-580 had a significantly (p<0.05) lower yield when supplied with 80 kg N EEF ha^{-1} compared with 80 kg N standard urea ha^{-1}.

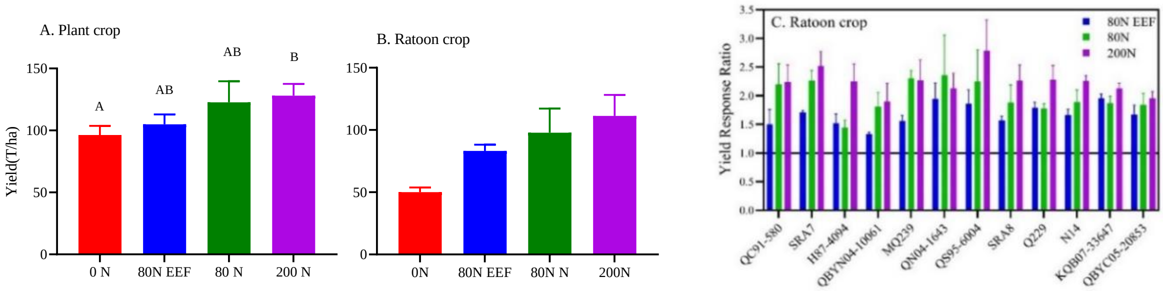

Figure 1. Average cane yield (T ha^{-1}) of the plant (A) and ratoon (B) crops supplied with varied N rates;0 kg N ha^{-1}(red), 80 kg N ha^{-1}(green), 200 kg N ha^{-1} (purple) as standard urea, and 80 kg N ha^{-1} EEF (blue). Mean values + standard error (n = 36) are shown and different letters indicate significant difference following Tukey's post hoc test (P<0.05) for each crop class. (C) Yield response ratio in the ratoon for genotypes fertilised with 80 kg EEF N ha^{-1} (blue), 80 kg N ha^{-1} (green), 200 kg N ha^{-1} (purple) compared to no fertiliser application. (Least Significant Difference) for genotypes, treatments, and genotype by treatment interaction (0.16, 0.39 and 0.55) from Tukey's post hoc (P<0.05).

Soil N availability

The exchangeable soil inorganic N pool (0- 20 cm) varied with type and rate of fertiliser application (Figure 2); similar trends were also observed in deeper (20-60 cm) soil profile (data are not shown). The measured N pool was dominated by nitrate and was elevated in fertilised plots for 50 days after fertiliser addition in the plant crop (Figure 2). In the plant crop, similar soil N patterns were observed for the 80N EEF and standard urea treatments. The first sampling time for the ratoon crop was 90 days after fertiliser addition at which time elevated nitrate and ammonium were observed only in the 80 N EEF kg ha^{-1} plots (Figure 2).

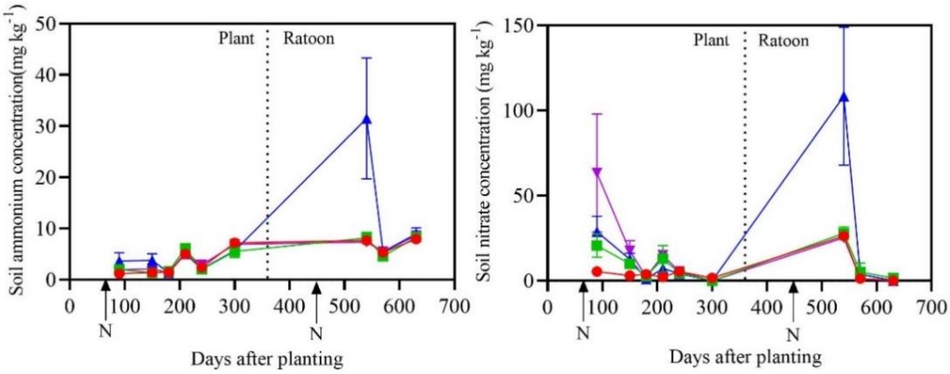

Figure 2. Soil ammonium and nitrate concentration (mg kg^{-1} DW) at 0-20 cm depth throughout the crop cycle. Crops were supplied with varied N rates; 0 kg N ha^{-1} (red circle), 80 kg N ha^{-1} (green square), 200 kg N ha^{-1}(purple triangle) standard urea and 80 EEF (blue triangle). Error bars indicate the standard error of means (n= 9). The timing of fertiliser is indicated by arrows.

Conclusion

For the ratoon crop, there was a genotypic effect on EEF efficacy and overall use of EEF compared to standard urea did not provide a yield benefit. This study evaluated only yield and did not quantify N losses, which may also be impacted by crop genotype.

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