

# EVIDENCE FOR DIFFERENT NITROGEN USE EFFICIENCIES OF SELECTED SUGARCANE VARIETIES

AW SCHUMANN, JH MEYER AND S NAIR

*South African Sugar Association Experiment Station, Private Bag X02, Mount Edgecombe, 4300*

## Abstract

There is increasing interest in improving the nitrogen (N) use efficiency of cultivated crops, due to the high cost of synthetic N fertiliser. Since existing differences in N use efficiency between sugarcane varieties could be exploited to improve N fertilisation, a hydroponic pot experiment was conducted to test the performance of seven commercial South African varieties (NCo376, N12, N14, N16, N19, N24, N25) at three N concentrations (30, 60, 90 mg N/L). At the first N increment, significant varietal differences in internal N use efficiency (g sucrose/g accumulated N) were recorded in the ratoon cane. High N use efficiencies for N12 and N19 were 65 and 63% respectively, above the 'reference' variety NCo376. In contrast, N14 was 19% less efficient than NCo376, which is in agreement with results from field trials. These data suggest that substantial benefits may be derived from variety specific N fertiliser recommendations for sugarcane, rather than a single recommendation based on NCo376. Based on field trial data, fertiliser recommendations for N14 have recently been increased by 30 kg N/ha. The hydroponic technique should be useful for initial screening of the many commercial and new sugarcane varieties before final field testing and amendments to fertiliser recommendations.

*Keywords:* fertiliser, nitrogen, N use efficiency, *Saccharum* spp., screening, varieties

## Introduction

There is increasing interest in improving the nitrogen (N) use efficiency of cultivated crops, due to the high cost (energy requirement) of synthetic N fertiliser. Grass crops such as sugarcane (*Saccharum* spp.) have a particularly high N requirement that normally exceeds the inherent capacity of soils to supply N by mineralisation of organic matter. However, long term N fertilisation also contributes to artificial acidification of soil, especially topsoil (van Antwerpen and Meyer, 1996), while high N applications are undesirable from an immediate environmental perspective (nitrate leaching to ground water, eutrophication of surface waters). Historically, N fertiliser recommendations for sugarcane in South Africa have been based on the requirements of the variety NCo376 and the N mineralising potential of four soil categories (Inman-Bamber, 1984; Meyer *et al.*, 1986). Recent experiences with the rapidly increasing range of new varieties in South Africa and elsewhere have indicated that there may be exploitable genotypic differences in N use efficiency (Gascho *et al.*, 1986; Stevenson *et al.*, 1992) and that foliar N norms may require revision for different varieties (Hellmann, 1975).

A rapid screening (hydroponic) and field testing programme of existing and new varieties for relative plant N requirements may be used to further optimise the N fertiliser recommendations for each variety. In this study, a hydroponic sand culture study was initiated to establish the N use efficiencies of seven commercial South African sugarcane varieties, and the results from the ratoon crop are presented.

## Materials and methods

Seven currently used South African sugarcane varieties (NCo376, N12, N14, N16, N19, N24, N25) were established in an outdoor hydroponic sand culture trial using three concentrations of N nutrient solution (N<sub>1</sub>= low; N<sub>2</sub>= moderate; N<sub>3</sub>= high). Plants were established from disease free single budded setts planted directly into 20 L drained black plastic pots filled with washed coarse Umgeni river sand. Nutrients and tap water were supplied from a continuous bath of nutrient solution in 50 L galvanised steel trays, into which the pots were placed. The height of this nutrient solution 'water table' was kept at ~5 to 10 cm, and each tray contained five pots of the same variety (single replication factorial design). Solutions were replaced weekly with fresh tap water and basal nutrients from 'Hygrotech Seedling' fertiliser (30,00 N, 8,57 P, 40,22 K, 31,65 Ca, 8,57 Mg, 14,51 S, 0,989 Mn, 0,079 Fe, 0,089 Zn, 0,016 Cu, 0,330 B, 0,330 Mo [mg/L]), KCl (165 mg K/L) and additional N (44, 57 mg N/L) treatment from reagent grade (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>. In the summer months, concentrations of Hygrotech Seedling and (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> fertiliser were doubled to compensate for the additional nutrient requirements of the crop.

The plant crop was grown for 543 days, harvested, and the ratooning stools were allowed to regrow for a further 399 days before final harvest and termination of the experiment. Stalk height and number was determined at monthly intervals to provide an estimate of growth rates during the course of the experiment. Leaves (third expanded leaf from top) from the plant crop were sampled at 54, 85, 117, 148 and 253 days for determination of N, P and K concentrations by Kjeldahl digestion and subsequent steam distillation (N), colorimetry (P), and atomic absorption spectrophotometry (K). Similar analyses as well as Ca and Mg (atomic absorption spectrophotometry) determinations were performed on the ratoon crop at 135, 162 and 235 days.

Harvested plants were partitioned into tops, stalks and roots for analysis. Dry mass, stalk numbers, and concentrations of N, P, K, Ca, Mg, SiO<sub>2</sub> and ash were analysed in these components. The weighed millable stalks were put through a

DHP disintegrator and the juice extracted in an Ultra Turrex blender for the determination of brix (refractometer), pol (polarimeter), and calculation of sucrose yield.

Data were processed by parallel curve analysis to conduct F-tests (Genstat 5 Committee, 1993). The arithmetic means of shoot biomass and sucrose yield were used together with the mean accumulated N to divide these measured variates into four quadrants (Figures 6 and 7). In a graphical plot of plant performance (biomass or sucrose) versus N accumulation, the top left quadrant (A) represents varieties which are efficient responders to N and the bottom right quadrant (B) inefficient non-responders, while the top right quadrant (C) represents inefficient responders. The remaining quadrant constitutes variety performance of intermediate value. An internal N use efficiency index was also calculated for the above-ground portion (stalks + tops) of the ratoon crop as sucrose yield (g/pot)/N accumulated at harvest (g/pot).

### Results and discussion

Nitrogen concentration in the third leaf, which is a diagnostic tool used for checking on N fertiliser recommendations in sugarcane, was significantly different for the seven varieties and three N fertility treatments (Figure 1). Nitrogen concentrations increased linearly with applied N fertiliser, with the exception of NCo376, which showed no further increases at the highest N level (Figure 1). The slopes of the average responses over all N levels were highest for N14 and lowest for N12, N16, and N19 (Figure 1). Although leaf N concentrations in these hydroponically grown plants were all below the threshold of 1.6% used to determine N sufficiency in the field, these results imply that adjusted thresholds for different varieties would be beneficial to the growers.

Total N accumulation in the sugarcane shoots was for the most part linearly related to applied N, with negligible varietal differences, except for variety N14, which accumulated

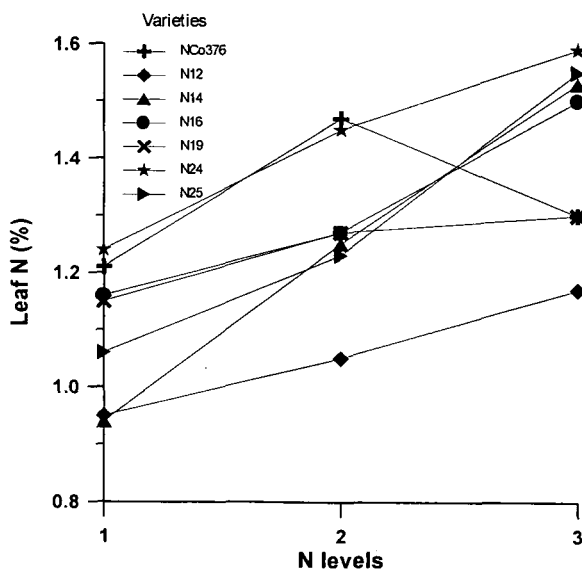


Figure 1. Variation in leaf N concentration at 162 days with increasing N fertility levels in seven ratooned sugarcane varieties.

significantly more N at the highest N treatment (Figure 2). There were significant N x variety interactions for total root mass accumulation in the ratoon crop (Figure 3), with N25 and N14 showing the most vigorous stimulation of root growth by N fertilisation. These results suggest that, at a high level of N nutrition, varieties N25 and N14 may exploit a larger soil volume for nutrients and water than a less responsive variety such as N24 (Figure 3). Leaf K concentrations were generally inversely related to N fertility levels due to the dilution of tissue K caused by increasing biomass (Figure 4). The most vigorously responding varieties (N14, N25) showed the greatest reduction in K concentrations, and therefore a significant N x variety interaction was recorded.

Estimated sucrose concentrations in the harvested ratoon crop were significantly lower at higher N fertility levels, except for variety N19 at the first N increment, and variety N14 at the

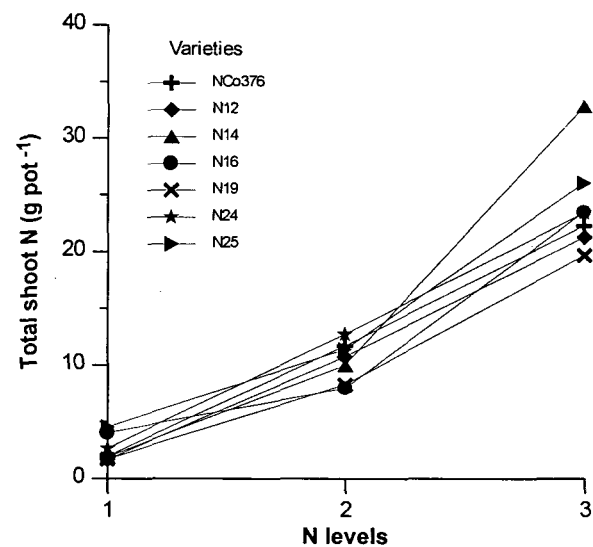


Figure 2. Nitrogen accumulation in harvested above-ground portions of seven ratooned sugarcane varieties with increasing N supply.

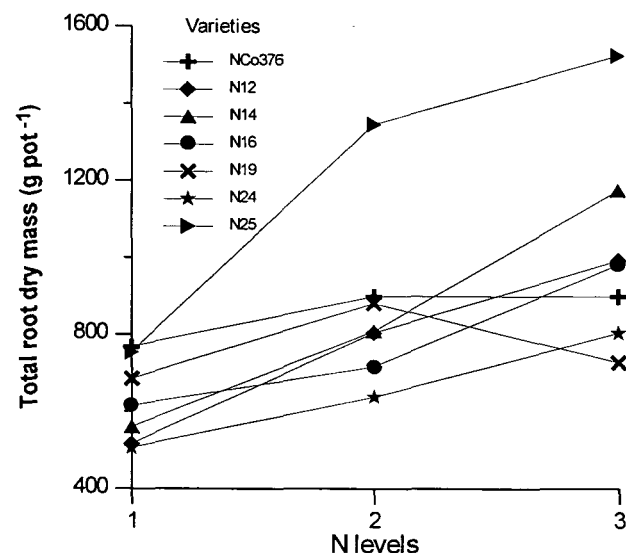


Figure 3. Variation in total root mass with increasing N fertility levels in seven ratooned sugarcane varieties.

second N increment (Figure 5). This was attributed to lower sucrose purity at higher N application rates. The total above-ground harvested biomass responses to N accumulation indicated that N12, N25, N19 and NCo376 were the most efficient responders at the medium N fertility level and that all varieties were inefficient responders at the highest N level (Figure 6). Two varieties (N14 and N16) were inefficient non-responders at the first and second N levels, suggesting that these genotypes would benefit the most from higher N fertilisation.

Sucrose yield analysis confirmed that varieties N14 and N16 should benefit the most from higher N nutrition, and that N12

and N19 were the most efficient performers at moderate N nutrition (Figure 7). These data also suggest that the sucrose yield of N12, N19 and NCo376 may be reduced significantly by excessive N fertility (Figure 7). The greatest varietal differences in sucrose yield were recorded at intermediate N fertility (N12 ~500 g/pot; N14 ~150 g/pot), which suggests that moderate fertility levels would be most effective for screening N efficient varieties in pot or field experiments. The superior sucrose yields of varieties N24 and N25 at high N fertility can be largely attributed to their higher total accumulation of N in the shoots, and greater stalk mass, rather than increased stalk numbers.

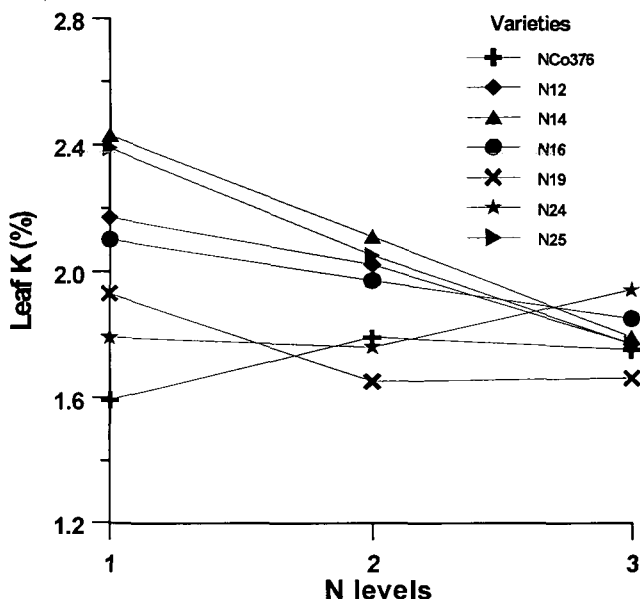


Figure 4. Variation in leaf K concentrations after 135 days with increasing N fertility levels in seven ratooned sugarcane varieties.

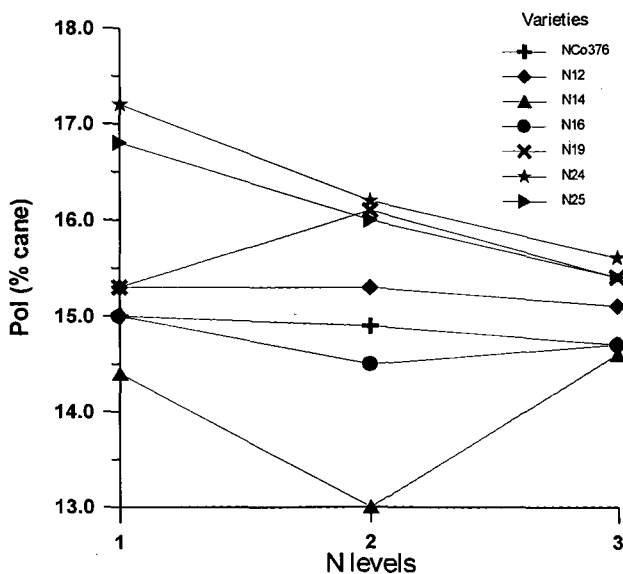


Figure 5. Variation in Pol % cane with increasing N fertility levels in seven ratooned sugarcane varieties.

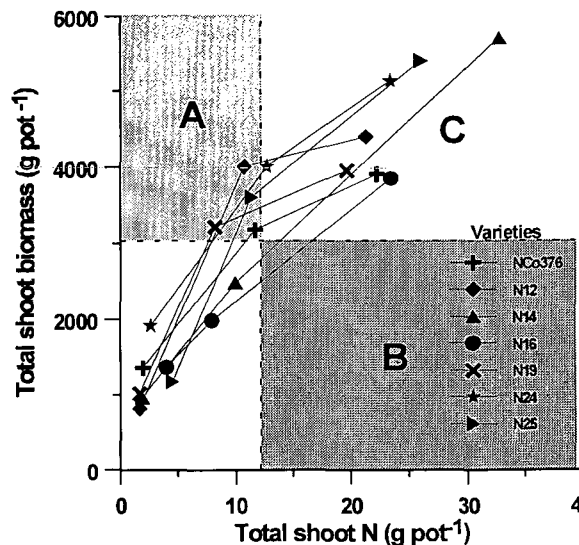


Figure 6. Above ground harvested biomass (DM) and N accumulation of seven ratooned sugarcane varieties at three different N fertility levels. A = efficient responders; B = inefficient non-responders; C = inefficient responders.

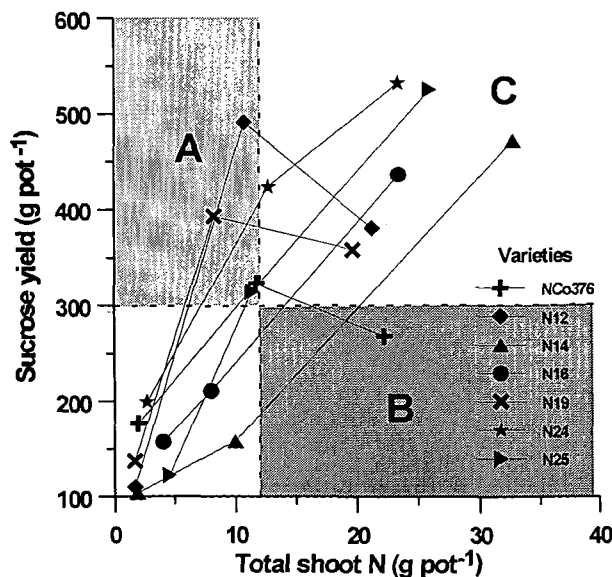


Figure 7. Sucrose yield and N accumulation of seven ratooned sugarcane varieties at three different N fertility levels. A = efficient responders; B = inefficient non-responders; C = inefficient responders.

Although root growth of variety N24 showed little response to applied N (Figure 3), both above-ground shoot mass and sucrose yield were high for this variety at the highest N fertility level (Figures 6 and 7). In contrast, the high sucrose and shoot biomass yields of varieties N14 and N25 had matching root growth at the highest level of N (Figures 3, 6 and 7). Nitrogen use efficiencies calculated over the first N increment for these varieties confirmed that N12 and N19 were most efficient, while N14 and NCo376 were least efficient (Figure 8). The relative ranking of varieties would be:

N12>N19>N25>N24>N16>NCo376>N14.

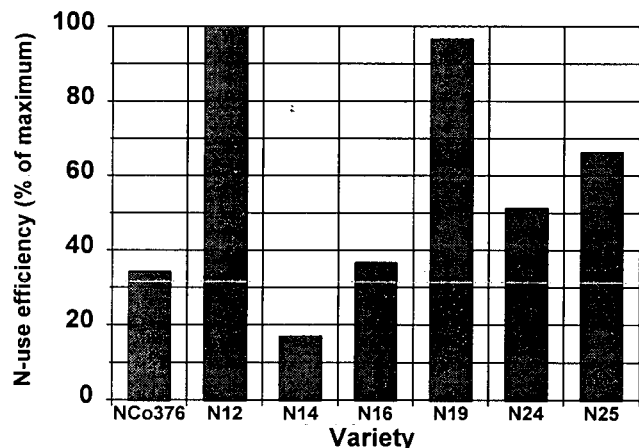


Figure 8. Internal N use efficiency of seven ratooned sugarcane varieties over the first increment of N supplied ( $N_2-N_1$ ).

### Conclusions

The study revealed that N use efficiency of the seven varieties in relation to sucrose yield varied markedly under the specified hydroponic culture conditions. Current fertiliser recommendations for N14 grown under irrigated conditions have recently been increased by 30 kg N/ha, based on field trial data obtained from Pongola.

A field trial comparing the N requirement of four cane varieties is currently in progress in Mpumalanga. Provisional results confirm the need for increasing the N recommendation for N14 by 30 kg/ha, whereas for other N efficient varieties (N12 and N19), the N recommendation may be revised downwards. It is also likely that the threshold concentration for leaf N in variety N12 may have to be reduced by ~0,3% when compared with the variety NCo376. The hydroponic technique should be useful for initial screening of the many commercial and new sugarcane varieties before final field testing and amendments to fertiliser recommendations.

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