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Effect of Nitrogen Fertilizer on Yield and Quality Parameters of Three Sugarcane Varieties

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ABSTRACT. Information on the response of sugarcane varieties to nitrogen fertilization is limited in Sri Lanka. This study examines interactive effects of nitrogen on the yield and quality of three sugarcane varieties under irrigated conditions in the low country dry zone of Sri Lanka. Three sugarcane varieties (CO775, SL7130 and SL8306) were tested at three nitrogen fertilizer levels in a spilt plot design with four replicates. Total above ground biomass (dry matter) production, partitioning of biomass to millable cane stalks (PBMS), fresh millable stalk yield, brix percent, pol percent and commercial cane sugar content were studied in this field experiment. Application of N fertilizers increased total above ground biomass production and fresh millable cane yield. The highest biomass production (52 Mg/ha) and fresh millable cane yield (108 Mg/ha) were given by 200 kg of N/ha treated plants at 390 days after planting. Fresh millable cane yield has positively correlated with total above ground biomass production. PBMS was highest at 100 kg N/ha and a negative effect was observed at 200 kg N/ha. Luxury consumption of nitrogen reduced brix, pol and commercial cane sugar (CCS) content. Variety SL8306 produced higher total above ground biomass production, PBMS, fresh millable cane yield, brix, pol and commercial cane content compared to CO775 and SL7130 at harvesting. Therefore, SL8306 is a superior variety than CO775 and SL7130 for cultivation under irrigated conditions in the low country dry zone of Sri Lanka. Even though very high level of nitrogen applications increased biomass production and fresh millable cane yield, a significant reduction in partitioning of biomass into millable stalks, brix, pol and CCS content were observed in all three varieties. The most suitable rate of nitrogen is 100 kg/ha under irrigated condition in low country dry zone of Sri Lanka.

INTRODUCTION

Understanding responses to the nutrient levels under which plants are grown is an important factor in efficient crop production. These responses differ considerably among species and cultivars depending on the habitat and genetic determinants and involve changes in growth, water relations and plant carbon, nutrient and hormonal balance.

Nitrogen is the most important nutrient involved in photosynthesis. In a number of species the light-saturated photosynthetic rate has been shown to be a function of leaf N content, which in turn is a function of N availability (Evans, 1989). Reduced photosynthetic rates under N stress are due mainly to low concentrations of photosynthetic enzymes (Chapin, 1991), as N is a major component of soluble and structural proteins involved in

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photosynthesis. Nitrogen stress also causes a decline on stomatal conductance and this could be another factor responsible for reduced photosynthetic rates under N stress (Chapin, 1991). Nevertheless, high intercellular CO_2 concentrations observed inside leaves of plants grown under low N supply suggest that stomatal limitation of photosynthesis is reduced under these conditions and that the CO_2 uptake rate in N-stressed plants is limited primarily by reduced biochemical capacity for photosynthesis (Evans, 1983).

The management of N fertilizer is central to profitable and sustainable sugarcane (*Saccharum officinarum* L.) production. Yield limitations imposed by inadequate N supply can have a negative impact on profitability. Conversely, N application in excess may have potential deleterious off-farm impacts on the environment and can also reduce sugar quality and profitability. Numerous studies have shown that high N application decreases sucrose concentration in fresh millable stalks (Das, 1936; Borden, 1948; Hurney, 1984; Wood, 1990; Stevensen *et al.*, 1992; Chapman, 1994). There is a need to confirm previous responses with modern varieties and production systems. Once a crop is established sugarcane is harvested over a long period of time. The time of harvest is crucial to profitability. This depends on the interaction between environment and the crop in relation to sucrose content or commercial cane sugar content. It also depends on the economics of harvesting, transport and milliling operations. The opportunity exists to use N management to maximize profitability by manipulating the commercial cane sugar content in fresh millable stalks through improving brix and pol percent at different crop ages. However, limited information is available on the determinants of sucrose accumulation over time under variable N supply and with different varieties. Therefore, objectives of this study were to examine (i) the effect of nitrogen on quantity and quality of sugarcane yield; and (ii) the total above ground biomass production and it's partitioning to fresh millable stalks in response to N supply and variety.

MATERIALS AND METHODS

The experiment was conducted at the Sugarcane Research Institute (SRI) at Udawalawe during 2000 and 2001. The selected site is located in the low country dry zone (DL1) of Sri Lanka, where the annual average rainfall is 1450 mm with a distinctly bi-modal distribution (Panabokke, 1996). The maximum and minimum temperature during the experimental period was 29-34°C (day) and 24-28°C (night), respectively. The soil in which the experiment was carried out was sandy clay loam, which belongs to the great group Reddish Brown Earth (RBE) soils with pH of 6.7 (1:2.5 soil water). The initial total soil nitrogen level was 0.12% ±0.02.

Three nitrogen treatments (N_0, N_{100} and N_{200}) *i.e.*, 0, 100 and 200 kg/ha of N and three varieties of sugarcane; CO775, SL7130 and SL8306 were used in a factorial experiment with nine treatment combinations. These treatments were tested in a split plot design, with nitrogen treatment in main plots and varieties in sub plots with four replicates. The individual plot size was 10×8.22 m (six rows) and the spacing between rows was 1.37 m. A space of three meters was maintained between plots. As planting materials, eight months old three budded stem cuttings were used and 210 cuttings were planted in a plot. Urea was used as nitrogen source. Other than urea all the plots were fertilized with triple super phosphate (TSP) and murate of potash (MOP) at the rate of 40 and 100 kg/ha, respectively, as recommended by SRI. One third of nitrogen, 1/3 of potassium and full amount of phosphorus were applied, as basal dressing and other 2/3 of nitrogen and potassium were applied 90 days after planting. Irrigation was done once in 10 days until 11 months after planting using furrow irrigation. Other field practices were maintained similarly for all plots. The growth period of the sugarcane was divided in to four physiological stages; germination to emergence (0–1 month), tillering to canopy establishment (2–3 months), grand growth (4–9 months) and maturation or ripening (10–12 months).

Randomly selected plants over a two metre length along a row were cut at ground level to estimate total above ground biomass production (Mg/ha). These were separated in to dead plant parts (trash), green leaves, immature top parts (cabbage) and stem (stalk) and were oven dried at 80°C to estimate biomass production. PBMS was calculated using the following equation:

$$PBMS = \frac{Stalk\ dry\ matter}{Total\ above\ ground\ biomass} \times 100$$

Fresh millable cane yield (Mg/ha) was estimated by harvesting 10 m^2 area of each plot (all the stalks in 10 m^2 area was cut at ground level, all the trash and cabage was removed and weighed). Randomly selected 15 sugarcane stalks were used to extract juice to measure brix and pol%. These parameters were measured at 90, 150, 210, 270, 330 and 390 days after planting. Brix value in stalk juice was measured directly by using brix hydrometer (Model RFM 80) (Jamees, 1984). Pol% was calculated using the readings measured by a polarimeter (Model AA-100) (Jamees, 1984) and the pol factor was taken from a standard chart (Jamees, 1984). Pol% and CCS were calculated using the following equations:

$$Pol\% = \frac{Pol\ metre\ reading}{Pol\ factor}$$

$$CCS = 0.82\ [Pol - 0.4\ (brix - pol)]$$

Analysis of variance (ANOVA) of the measured data was carried out using the SAS statistical package.

RESULTS AND DISCUSSION

No significant interactions (P>0.05) were observed between nitrogen and varieties on measured parameters. However, main effects of nitrogen and variety were significantly different at P<0.05 for all parameters.

Biomass production and partitioning of biomass to millable stalk (PBMS)

Effect of nitrogen on biomass production and PBMS

Application of nitrogen significantly increased (P<0.05) biomass production at all the sampling dates (Fig. 1a). Application of 200 kg N/ha increased the biomass production approximately by 14 and 33%, at 270 days after planting (DAP) and 16 and 34% at 390 DAP over 100 kg N/ha and control, respectively. The highest biomass production in N_{200} plants at 390 DAP (52.31 Mg/ha). There was no significant difference between 100 and 200 kg N/ha fertilizer levels until 210 DAP. Two hundred kg N/ha increased biomass production approximately by 14, 15 and 16% over 100 kg N/ha at 270, 330 and 390 DAP, respectively. Biomass production of the control treatment was significantly (P<0.05) low at all sampling dates. The lower biomass production of control may be associated with the lower leaf area index and radiation use efficiency due to lower leaf chlorophyll content and production of lower photosynthetic enzymes (Subasinghe, 1994). Nitrogen is a major component of Ribulose 1,5 bisposphate carboxylase oxygenase (Rubisco) and phosphoenole phyruvate carboxylase (PEPC), which are involved in C4 photosynthesis. Thus the stress of low nitrogen will affect the above two enzymes due to which photosynthesis may reduce significantly (Davidson, 1953; Yadav and Sharma, 1980; Gascho *et al.*, 1986). These results confirmed previous observations (Muchow, 1988; Subasinghe, 1994; Wood *et al.*, 1996) showing nitrogen has a marked influence on leaf area development and dry matter production.

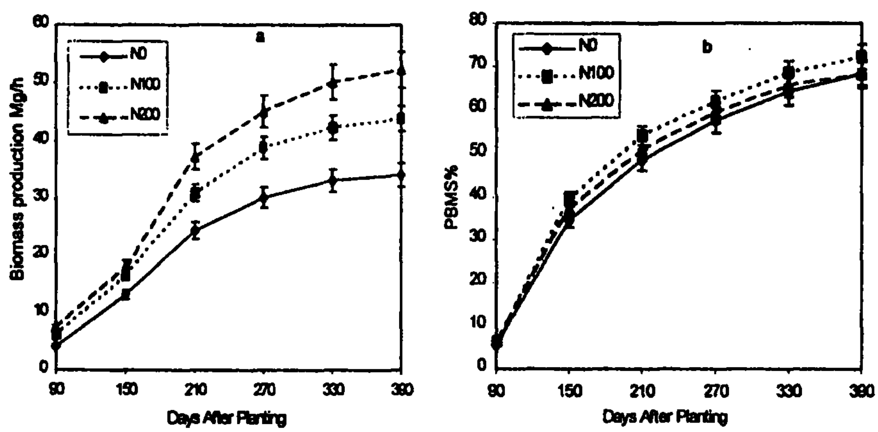

Fig. 1. Variations of (a) total above ground biomass production and (b) partitioning of above ground biomass into millable stalks (PBMS) in response to nitrogen.

[Note: These graphs were plotted using mean values of the three sugarcane varieties (CO775, SL7130 and SL8306)].

PBMS values were significantly different (P<0.05) after 150 DAP (Fig. 1b). The control treatment had significantly lower (P<0.05) PBMS values than the 100 kg N/ha treatment and the rate of decrease was approximately 13%, 11%, 8%, 6% and 5% at 150, 210, 270, 330 and 390 DAP, respectively. Application of 200 kg N/ha gave comparatively lower values of PBMS than 100 kg N/ha in all sampling dates except at 390 DAP. The highest PBMS percentage was given by N_{100} at 390 DAP, which was a 5% increment than that of N_0 and N_{200} plants at 390 DAP.

With the increase of nitrogen fertilizer application, total biomass production increased significantly (P<0.05). However PBMS reached a maximum at 100 kg N/ha and negative effects were observed with further increment in N. This may be due to large part of dry matter remaining in other plant parts such as trash, green leaves and cabbage. Partitioning of biomass to stalk of sugarcane is reduced with excess amount of nitrogen application (Robertson *et al.*, 1996).

Varietal effect on biomass production and PBMS

Total above ground biomass production of the three varieties (CO775, SL7130 and SL8306) were similar at the early stages of growth (up to 150 DAP). However, significant differences ($P<0.05$) were observed at 270 DAP and thereafter (Table 1). The highest above ground biomass production was in variety SL8306 at 390 DAP. This was 44.24 Mg/ha and was a 6% and 11% increment over varieties CO775 and SL7130, respectively. The rate of increase in biomass production of all three varieties was high during the first seven months of growth and decreased gradually up to the ninth month. After nine months the rate of biomass production declined rapidly (Table 1). Since sugarcane is a determinate crop it produced its biomass rapidly during the vegetative growth (1-7 months) and during maturity increase in biomass increased at a decreasing rate and crop growth rate.

Table 1. Varietal effects on total above ground biomass production and partitioning of biomass into millable stalks (PBMS).

Parameter	Variety	Sampling days					
		90	150	210	270	330	390
	CO775	5.85 ns	16.76 ns	30.80 a	38.82.b	41.18.b	42.57b
Total biomass	SL7130	6.77	16.20	29.48 b	34.73.c	37.57 c	39.30c
production	SL8306	5.43	14.68	31.28.a	40.67 a	43.18 a	44.78a
(Mg/ha)	CV%	11.75	13.63	10.10	14.62	9.54	11.62
	CO775	5.66 b	36.02 b	52.75 ab	60.27 a	65.13 b	68.57b
PBMS%	SL7130	5.39 b	35.65.b	50.22 b	57.24 b	63.16 c	65.21c
	SL8306	7.70 a	38.72.a	53.82 a	61.42 a	68.93 a	72.87a
	CV%	14.63	17.23	11.41	9.36	12.74	8.44

These values are means of 12 observations. Means with the same letter along a column within a parameter are not significantly different at $P>0.05$. ns = not significant ($P>0.05$).

Robertson *et al.* (1996) show that before millable stalk was present in measurable quantities in the above ground biomass, 50-60% of the biomass was present in the green leaf component and about 40% in the cabage component, with the trash component forming a negligible proportion. As biomass increased, the fraction as millable stalks increased while the fraction as green leaf and cabage declined exponentially (Robertson *et al.*, 1996; Wood *et al.*, 1996). Similar results were obtained in this study in biomass partitioning to millable stalk (Table 1). Variety SL8306 had the highest PBMS percentage (73%) at 390 DAP. This was 7 and 11% higher than that of CO775 and SL7130, respectively (Table 1). These results are in agreement with the South African studies on biomass partitioning to the stalk of plant and ratoon-crop of sugarcane under irrigated conditions (Thompson, 1978).

Responses of brix and pol percentage to nitrogen

Nitrogen fertilizer application significantly decreased ($P<0.05$) brix and pol% after 210 days of planting. Plants that received 200 kg N/ha had lower brix value; approximately 8, 10, 9 and 9% at 210, 270, 330 and 390 DAP, respectively than control. N_{100} plants showed relatively lower brix% value compared to N_0 plants throughout the sampling series (Fig. 2a). The highest brix% was 19.78, and this was 3 and 9% increase over the N_{100} and N_{200} plants, respectively, at 390 DAP.

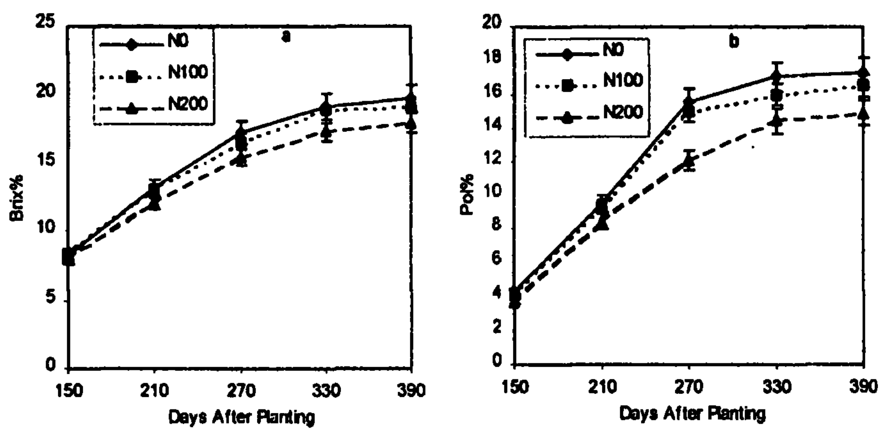

Fig. 2. Variations of (a) brix and (b) pol percentage in juice of millable stalks of sugarcane in response to nitrogen fertilization.

[Note. These graphs were plotted using mean values of the three sugarcane varieties (CO775, SL7130 and SL8306)].

No significant difference ($P>0.05$) in pol% could be observed among nitrogen treatments before the 210 DAP. However, N_{200} plants significantly decreased ($P<0.05$) pol% by approximately 11, 22, 15 and 14% than that of N_0 plants at 210, 270, 330 and 390 DAP, respectively (Fig. 2b). N_{100} plants had relatively a lower pol% than N_0 plants at all sampling dates. These results confirm those of Robert and Wiedenfeld (1995), who reported that nitrogen application have negative effect on juice purity (brix and pol%). They also found that in the first ratoon crop of sugarcane, juice purity and sugar content declined with increasing nitrogen application. High nitrogen application promotes luxury nitrogen uptake, and as a result, nitrogen use efficiency in biomass and sucrose production decreases (Wiedenfeld, 1995; Müchow *et al.*, 1996). Gascho *et al.* (1986) observed a similar decrease in sucrose, nitrogen ratio with increasing nitrogen application.

Responses of brix and pol% to variety

Brix and pol% varied in the deferent varieties (Table 2). SL8306 maintained comparatively higher brix and pol% than CO775 and SL7130 thorough the growth period. SL8306 had the highest value for brix percentage (19.54%) at 390 DAP, which was a 8 and 9% increment ($P<0.05$) than that of CO775 and SL7130, respectively (Table 2). The highest pol% value (16.93) was in SL8306 and was a 7 and 8% increment ($P<0.05$) compared to CO775 and SL7130, respectively at 390 DAP (Table 2). Muchow *et al.* (1996) observed slight difference of juice purity, brix and pol% among cultivars. Similar results have been observed by Robertson *et al.* (1996). Though maximum values of brix and pol% was observed at 390 DAP, there was no significant difference ($P>0.05$) in both brix and pol value between 330 and 390 DAP (Table 2). These two parameters, therefore, suggest that the variety SL8306 matured at 330 DAP compared to the other two varieties (CO775 and SL7130).

Table 2. Varietial effects on brix and pol percentage of sugarcane juice.

Parameter	Variety	Sampling days				
		150	210	270	330	390
	CO775	7.80b	12.83b	16.91b	18.27ab	18.71ab
	SL7130	7.81b	12.90b	16.63b	17.71b	18.35b
Brix%	SL8306	8.87a	13.68a	17.96a	118.99a	19.54a
	CV%	7.61	10.34	13.19	9.36	14.63
	CO775	3.72b	9.02b	13.91b	14.77b	15.31b
	SL7130	3.65b	9.03b	13.39b	15.32b	15.52b
Pol%	SL8306	4.75a	10.20a	15.14a	16.61a	16.93a
	CV%	7.84	10.81	12.65	9.44	13.89

These values are means of 12 observations. Means with the same letter along a column within a parameter are not significantly different at $P>0.05$.

Response of millable cane yield and commercial cane sugar (CCS%) to applied nitrogen

Nitrogen fertilizer application increased the fresh millable cane yield significantly ($P<0.05$). The highest fresh cane yield (108 Mg/ha) was observed at N_{200} at 390 DAP. The increases in the fresh millable cane yield of N_{200} plants over the N_0 and N_{100} plants were 34 and 11%, respectively at the harvesting stage (at 390 DAP) (Fig. 3a). In this study, a positive correlation was observed between biomass production and fresh millable cane yield (Fig. 4). Increased application of nitrogen fertilizer increased both biomass production and millable cane yield. In sugarcane cultivation, the most important factor is weight of fresh millable cane yield and or percentage of commercial cane sugar in millable cane stalks. On the other hand, farmers prefer to have more millable stalk fresh weight from their field as they are paid according to the fresh weight of millable cane stalk by the factory in Sri Lanka. However, the percentage of CCS is more important in sugar processing, because the sugar recovery rate basically depends on the CCS% of fresh millable cane stalks.

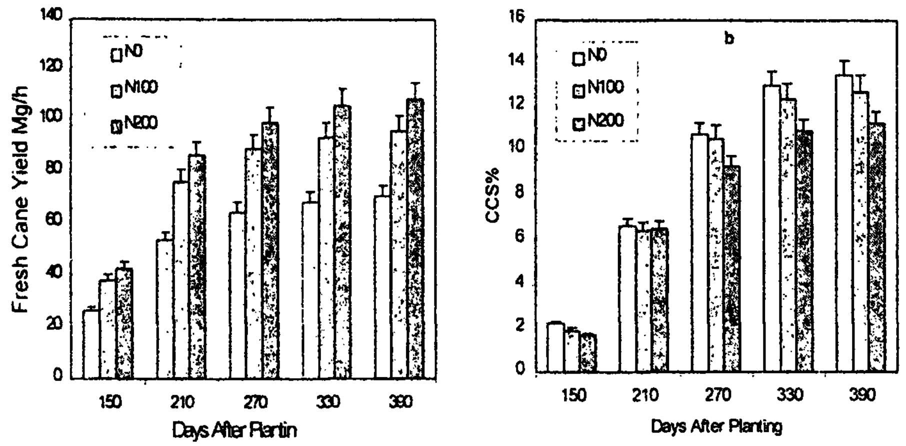

Fig. 3. Variations of (a) fresh millable cane yield and (b) commercial cane sugar content in response to nitrogen.
[Note: These graphs were plotted using mean values of the three sugarcane varieties (CO775, SL7130 and SL8306)].

Although, increased nitrogen fertilizer applications positively respond by increasing biomass production and fresh millable cane yield, it decreases CCS% significantly in fresh millable cane stalks.

Plants supplied at 200 kg of N/ha had lower CCS% during all sampling stages and it was significantly ($P<0.05$) lower than the N_0 and N_{100} plants at 270 DAP. Therefore, percentage CCS in N_{200} plants decreased approximately by 13, 16 and 16% ($P<0.05$) compared to N_0 plants at 270, 330 and 390 DAP, respectively (Fig. 3b). There was no significant difference ($P>0.05$) of CCS% between N_0 and N_{100} plants, however N_{100} plants had relatively lower values of CCS% throughout the sampling series (Fig. 3b). Sucrose production in sugarcane will decrease with high N applications (Gascho *et al.*, 1986; Muchow *et al.*, 1996). Other studies also have shown that high nitrogen application decreased sucrose concentration (CCS%) in fresh millable cane stalks (Wood, 1990; Stevensen *et al.*, 1992; Chapman, 1994).

Responses of millable cane yield and CCS% to variety

There was a significant difference ($P<0.05$) in fresh millable cane yield among the three varieties (CO775, SL7130 and SL8306) of sugarcane. The highest fresh millable cane yield (98 Mg/ha) was in SL8306 at 390 DAP. This was a 7 and 20% increase over CO775 and SL7130, respectively (Fig. 5a). Variety SL8306 had the highest CCS value (13%) at 390 DAP. These were 7 and 10% ($P<0.05$) higher values than that of CO775 and SL7130, respectively. SL8306 maintained higher fresh millable cane yield and higher CCS than the other two varieties at all sampling dates (Fig. 5a and 5b). Biomass production, partitioning of biomass into millable stalk, fresh millable stalk yield, brix, pol% and CCS% were always higher with the variety SL8306 compared to varieties CO775 and SL7130. Earlier studies have also shown that the rates of photosynthesis and radiation use efficiency were higher in SL8306 than CO775 and SL7130 (Kumara and Bandara, 2001). Therefore, SL8306 is a potential variety for cultivation under irrigated conditions in the low country dry zone of Sri Lanka.

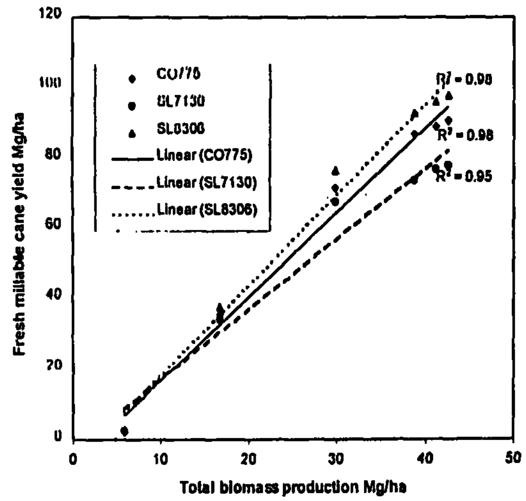

Fig. 4. Relationship between above ground biomass production and fresh millable cane yield
[Note: These graphs were plotted using mean values of 12 observations].

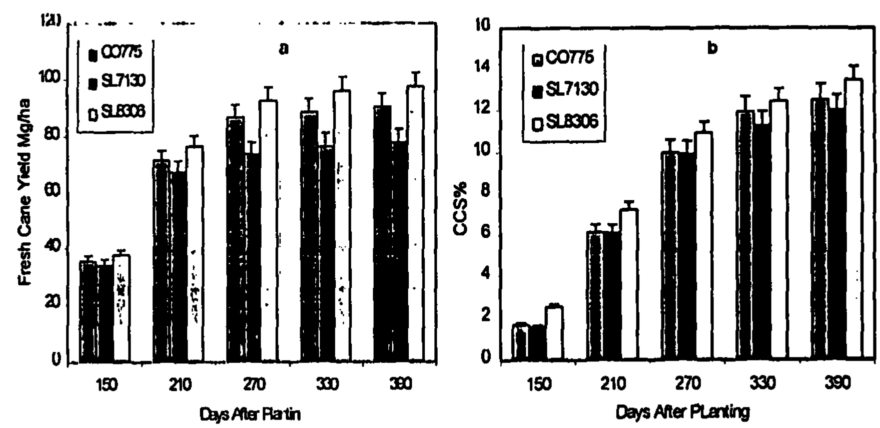

Fig. 5. Variations of (a) fresh millable cane yield and (b) commercial cane sugar content in three sugarcane varieties.
[Note: These graphs were plotted using mean values of 12 observations].

Increased N fertilizer application increases both biomass production and fresh millable cane yield. However, very high level of N application had a negative effect on partitioning of biomass in to millable cane, brix, pol% and commercial cane sugar. Therefore, when fertilizing sugarcane both the quantity and quality of cane yield needs to be considered. According to the results of this experiment, the best application is 100 kg of nitrogen per hectare (N_{100}).

CONCLUSIONS

This study showed that the luxury consumption of N increased biomass production and fresh millable cane yield, however decreased partitioning of biomass to millable cane yield, juice quality (brix and pol%) and commercial cane sugar percentage. The most appropriate rate of application of N is 100 kg N/ha for sugarcane under irrigated conditions in the experimental site of the low country dry zone of Sri Lanka. Variety SL8306 is superior to the other two varieties and can be recommended for cultivation under irrigated conditions in the low country dry zone of Sri Lanka with similar environmental condition to experimental site.

REFERENCES

Borden, R.J. (1948). Nitrogen effects upon the yield and composition of sugarcane. Haw. Planters Rec. 48: 27-306.

Chapin, F.S. (1991). Integrated responses of plants to stress: a centralized system of physiological responses. Bio. Sci. 41: 29-36.

Chapman, L.S. (1994). Fertilizer N management in Australia. Proc. Aust. Soc. Sugarcane Technol. 1994 Conf. pp. 83-92.

Clements, H.F. (1980). Sugarcane Crop Logging and Crop Control, Principles and Practice, Pitman Publishing Limited, London.

Das, U.K. (1936). Nitrogen nutrition of sugarcane. Plant Physol. 11: 251-317.

Davidson, L.G. (1953). Comparative effects of selected fertilizer treatments on yields of different varieties of sugarcane. ISSCT. 8: 190-195.

Evans, J.R. (1983). Nitrogen and photosynthesis in the flag leaf of wheat (*Triticum aestrium*). Plant Physiol. 72: 297-302.

Evans, J.R. (1989). Photosynthesis and nitrogen relationship in leaves of C3 plants. Oecologia. 78: 157-170.

Gascho, G.J., Anderson, D.L. and Ozaki, H.Y. (1986). Cultivar dependent sugarcane response to nitrogen. Agron. J. 78: 963-970.

Hurney, A.P. (1984). Excess nitrogen is detrimental to crop yields. BSES Bult. 8: 18-19.

Inman-Bamber, N.G. and Thompson, G.D. (1989). Models of dry matter accumulation by sugarcane. Proc. S. Afr. Sugar Technol. Assoc. 63: 212-216.

Jamees, C.P.C. (1984). Cane sugar hand book . 11th Edition, A Wiley-Interscience Publication John Wiley and Sons, New York. pp.689-717.

Kumara, A.D.S. and Bandara, D.C (2001). Influence of nitrogen application and varietial differences on selected physiological parameters of sugarcane. Trop. Agric. Res. J. 13: 220-230.

Muchow, R.C. (1988). Effect of nitrogen supply on the comparative productivityof maize and sorghum in a semi-arid tropical environment. i. Leaf growth and leaf nitrogen. Field Crop Res. 18: 1-16.

Muchow, R.C., Robertson, M.J. and Wood, A.W. (1996). Growth of sugarcane under high input conditions in tropical Australia. ii. sucrose accumulation and commercial yield. J. Field Crops Res. 48(1): 11-25.

Panabokke, C.R. (1996). Soils and Agro-ecological Environments of Sri Lanka. Natural Resources. Energy and Science Authority of Sri Lanka, 47/5 Maintland Place, Colombo, Sri Lanka. pp. 73-100.

Rathi, K.S. and Singh, R.A. (1982). Net income and quality of juice of cane ratoon as affected by increasing doses of nitrogen. Indian Sugar. 33: 11-13.

Robert, P. and Wiedenfeld, R.P. (1995). Effects of irrigation and nitrogen fertilizer application on sugarcane yield and quality. J. Field Crops Res. 43: 101-108.

Robertson, M.J., Wood, A.W. and Muchow, R.C. (1996). Growth of sugarcane under high input conditions in tropical Australia. i. Radiation use, biomass accumulation andpartitioning. J. Field Crops Res. 48: 11-25.

Stevensen, D.W.A., Van der Merwe, A., Benniniga, W. and Allison, J.C.S. (1992). Response of different sugarcane varieties greater than normal applications of nitrogen. Proc. South African Sugar Technol. Assoc. pp. 50-53.

Subasinghe, R.A. (1994). Physiological responses of sugarcane to nitrogen and potassium. Ph.D theses, University of Hawaii.

Thompson, G.D. (1978). Production of biomass by sugarcane. Proc. South African Sugar Technol. Assoc. 52: 180-187.

Wiedenfeld, R.P. (1995). Effects of irrigation and nitrogen fertilizer application on sugarcane yield and quality. J. Field Crop Res. 43: 101-108.

Wood, R.A. (1990). The role of nitrogen, phosphorus and potassium in the production of sugarcane in South Africa. Fertilizer Res. 26: 89-98.

Wood, A.W., Muchow, R.C. and Robertson, M.J. (1996). Growth of sugarcane under high input conditions in tropical Australia. iii. Accumulation, partitioning and use of nitrogen. J. Field Crops Res. 48: 30-40.

Yadav, R L. and Sharma, R.K. (1980). Dry matter and nitrogen accumulation pattern of early, mid-late, and late varieties of sugarcane as influenced by rate of nitrogen. Indian J. Agron. 25: 201-208.