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Contribution of Net Assimilation Rate to Yield and Its Components in Sugarcane

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ABSTRACT

Growth analysis of eight sugarcane varieties comprising of local and exotic clones were studied under field conditions. Singnificant differences were obtained between varieties in respect of net assimilation rate (NAR), leaf number, longevity of leaves and leaf dry weight (LDW). There were, however, no significant differences between varieties in respect of leaf fresh weight (LFW), phyllochron, leaf area index (LAI), stalk height and brix. The difference in leaf blade/joint weight ratio between the varieties were also not significant. However, when this character was multiplied by longevity, significant varietal differences were obtained. NAR was negatively correlated with leaf blade/joint weight ratio multiplied by longevity suggesting that the higher the leaf weight per unit weight of cane the lower the assimilation rate. The significant contribution of NAR to some sugar yield and its components are discussed. It is suggested that some of these characters can be used in the selection of parent materials in the breeding programme for varietal improvement.

INTRODUCTION

In recent years, much has been learnt about the biochemistry of sugar storage and also the effects of environmental factors on sugar storage in the sugarcane. The factors which determine the differential sugar storage by different sugarcane varieties and clones are, however, less understood and yet these factors appear to be of major interest to the sugarcane breeder. It is apparent that the main reason for the lack of understanding of these factors is that, large number of such factors are involved and requiring in depth study.

One of such factors is the contribution of NAR to yield and its components. The amount of sugar storage will depend on the size and efficiency of the photosynthetic system, the ability of the cane to translocate and size of storage tissues, and also partition of the photosynthates for growth and storage. These factors may be affected by many physiological, morphological and even anatomical factors. Several studies in the past showed differences in photosynthesis among sugarcane varieties (George, 1965; Hartt and Burr, 1965; Irvine, 1967). Studies of Rosario and Musgrave (1972) on net carbon exchange (NCE) of 14 sugarcane varieties, using the leaf chamber technique also reported similar results. Furthermore, the authors found that NCE was significantly associated with some physiological and morphological characteristics of the top visible dewlap (TVD) leaf.

Gregory (1950) assume that there is little hope in increasing the efficiency of the photosynthetic process by selection or breeding. The work of Watson (1947), Blackman and Wilson (1951), however, later showed that there are differences in NAR between species growing in comparable conditions. The differences in NAR between progenies of individual plants of a cultivated species have also been reported (Goodall, 1950).

These results suggest that some genetic variation in NAR exist and selection and/or breeding might operate to improve yield through increasing NAR, and/or to combine high NAR with other desirable characters. In other crops, differences in yield have also been studied in relation to differences in rates of photosynthesis or in leaf angle and the efficiency of the radiant energy interception. But there has been little success in increasing yields by selecting plants with apparently desirable physiological and morphological characteristics (Moss and Musgrave, 1971). Bull (1970) postulated that the rate of leaf area development during early growth, tolerance to high temperature and an extended growing season were probably more important than high rate of CO_2 assimilation per unit leaf area in determining rapid growth rate in sugarcane. An attempt has been made to identify some morphological and physiological characters for breeding and selection purposes.

MATERIALS AND METHODS

Eight sugarcane verieties consisting of four exotics viz. CP47/15, Co440, Co1001 and BJ 6431 and four locals LS1-026, LS1-028, LS1-033 and LS1-025 were used in the present experiment. The experiment was laid out following randomised block design and replicated four times. Two budded setts were planted continuously in the furrow, and furrow to furrow distance was 1.5 m. The plot size was 6m × 6m. The following morphological and physiological parameters were studied:

1. Leaf fresh weight (LFW),
2. Leaf dry weight (LDW),
3. Leaf sheath dry weight,
4. Stalk fresh weight,
5. Stalk dry weight,
6. Tiller number,
7. Stalk height,
8. Leaf number,
9. Leaf area,
10. Leaf area index (LAI),
11. Net assimilation rate (NAR),
12. Rate of leaf appearance (Phyllochron),
13. Longevity of leaves,
14. Leaf blade/Joint weight ratio,
15. Leaf blade/Joint weight ratio multiplied by longevity,
16. Brix,
17. Crop growth rate (CGR)

To determine NAR, CGR and LAR, the following formulae were used:

$$NAR = \frac{(W_2 - W_1)\ (Log_e\ LA_2 - Log_e\ LA_1)}{(t_2 - t_1)\ (LA_2 - LA_1)}$$

$$\text{Average leaf area over the period } t_2\text{-}t_1 \text{ (LA)} = \frac{LA_2\text{-}LA_1}{(\text{Log}_e\ LA_2\text{-Log}_e\ LA_1)}$$

$$\text{Average leaf area index (LAI)} = \frac{LA}{\text{Ground area}}$$

$$\text{Crop growth rate (CGR)} = \frac{\text{Log}_e\ W_2\text{-Log}_e\ W_1}{t_2\text{-}t_1}$$

$$\text{Leaf area ratio (LAR)} = \frac{LA\ (\text{Log}_e e\ W_2\text{-Log}_e\ W_1)}{(W_2\text{-}W_1)}$$

Where W_1 and W_2 were the dry weights of stem tissue and LA_1 and LA_2 were the single surface leaf area of plants at the time t_1 and t_2 respectively.

Preliminary tests showed that, the leaf area calculated by using Mongelard's formula (1968) : A = 3/4 BW x L, where A = leaf area, BW = the greatest width of the leaf, L = the length of the leaf, was highly correlated with the method used in calculating leaf area from the NAR formula given above. The correlation coefficient was 0.73*. Growth analysis characters were calculated on individual plant basis.

The number of days between the appearance of successive leaf primordia on the apex is termed the phyllochron, and since in sugarcane there is no build up of leaf primordia on the apex, the phyllochron is the same as the number of days between the appearance of successive leaves. To record the rate of leaf appearance (phyllochron), a red spot was placed on the topmost unrolling leaf of thirty canes at random at each plot immediately after each sampling date. On the following sampling date the number of leaves that had appeared since marking were counted on ten of the marked canes at random. Phyllochron is then calculated as :

$$\frac{\text{Number of days between the planting and sampling date}}{\text{Number of leaves that appeared during the painting and sampling date.}}$$

The leaf blade/joint weight ratio was calculated for each individual cane sampled by dividing the fresh weight of the topmost fully expanded leaf blade by the weight per joint of the five topmost fully expanded joints or at the first two samplings dates by the mean weight per joint of all the joints of the cane.

The leaf blade/joint weight ratio is one factor determining the amount of leaf per unit weight of cane. Longevity was calculated by multiplying the number of days between the appearance of successive leaves (phyllochron) by the number of leaves at the end of the period.

RESULTS AND DISCUSSION

The results of NAR and other morphological and physiological parameters are shown in Tables 1 and 2. There were found significant differences in NAR between the varieties. The highest NAR was obtained from the local variety LS1-028, while the lowest NAR was also obtained in the local variety LS1-026. No significant differences between varieties in respect of LFW, phyllochron, leaf area, LAI, stalk height and brix.

There were also no significant differences in leaf blade/joint weight ratio between the varieties. However, when this leaf blade/joint weight ratio was multiplied by longevity, significant varietal differences were obtained (Table 3).

Figure 1 shows the relationship between NAR and leaf blade/joint weight ratio multiplied by longevity. There was found a negative correlation between the two characters, suggesting that higher the leaf weight per unit cane, lower the assimilation rate. The largest positive and negative deviations from the regression equation were recorded in the local varieties LS1-028 and LS1-026 respectively.

Table 1. Mean morphological and physiological characteristics measured in eight sugarcane varieties under field conditions.

Varieties	NAR g/cm²/day	Leaf No.	LFW (g)	LDW (g)	Phyllo-chron (d)	Longe-vity of leaves (d)	Leaf Area (cm²)
LS1-026	2.1	9	13.4	9.7	14.1	131.4	574.6
CP47/15	3.4	8	12.5	8.8	12.5	107.0	565.1
LS1-028	8.3	10	12.5	9.1	15.4	153.5	609.3
Co440	2.5	10	13.2	8.9	14.4	136.2	597.2
LS1-025	4.4	10	8.6	5.9	12.0	122.0	544.9
Co 1001	2.8	10	13.3	8.5	16.3	159.6	528.6
LS1-033	3.6	9	10.5	6.9	15.6	146.0	570.3
BJ 6431	5.3	10	9.3	6.5	12.5	125.0	579.6
LSD (0.05)	2.5	0.76	NS	3.3	NS	33.6	NS

NAR- Net assimilation rate, LFW-Leaf Fresh weight, LDW-Leaf dry weight.

Table 2. Mean morphological and physiological characteristics measured in eight sugarcane varieties under field conditions.

Varieties	LAI	Leaf sheath DW (g)	Stalk No. 1000/ha	Stalk height (m)	Stalk F.W. (tch)	Stalk DW (g)	TC/TS	Brix	C.G.R.* % day
BS1-026	16.0	7.7	37.3	1.62	13.1	70.0	1.3	17.0	0.19
CP47/15	15.7	6.1	80.8	1.52	33.0	82.2	3.3	17.2	0.23
LS1-028	16.9	6.0	58.1	1.61	15.6	53.5	1.6	17.2	0.10
CO440	16.1	7.0	67.6	1.66	28.9	89.3	2.9	17.3	0.07
LS1-025	15.1	4.9	72.4	1.83	24.6	72.6	2.5	15.4	0.18
CO. 1001	14.7	5.1	46.7	1.76	50.5	217.0	5.1	16.9	0.05
LS1-033	15.8	4.6	46.1	1.70	33.3	142.9	3.3	17.0	0.08
BJ 6431	16.1	4.9	60.9	1.67	17.2	57.0	1.7	16.2	0.38
LSD (0.05)	NS	2.3	8.1	NS	12.9	22.6	-	NS	0.17

LAI - Leaf area index,DW - dry weight, tch - tonnes cane/ha, TC/TS - tonnes cane/tonnes sugar ratio
FW - fresh weight, CGR - Crop growth rate.

* LSD (p = 0.05) on % CGR was calculated from the angular's transformed data.

Table 3. Leaf blade/joint weight ratio and leaf blade/joint ratio multiplied by longevity.

Variety	Leaf blade/Joint Wt. ratio	Leaf blade/Joint Wt. ratio X Longevity
LS1-026	0.011	1.44
CP47/15	0.009	0.71
LS1-028	0.011	0.90
Co440	0.011	1.06
LS1-026	0.011	0.93
Co1001	0.009	0.87
LS1-033	0.006	0.56
BJ 6431	0.007	0.63
LSD (0.05)	NS	0.45

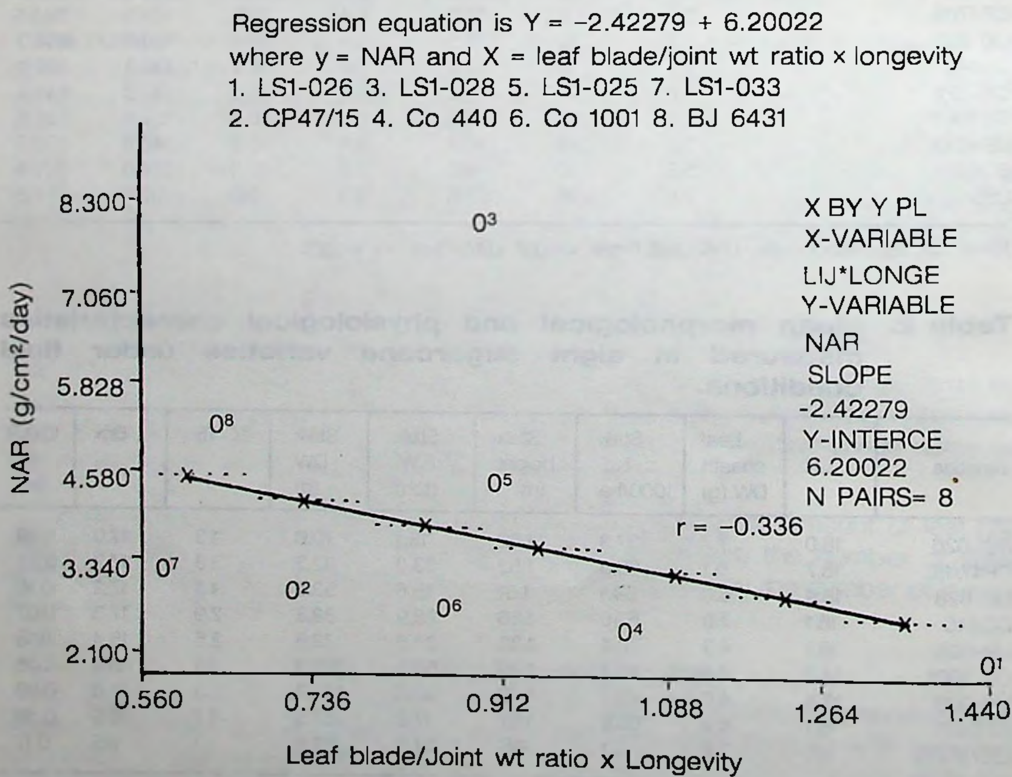

Figure 1. Relationship between net assimilation rate (NAR) and leaf blade/joint weight ratio multiptied by longevity.

Table 4. Correlation matrix between NAR and certain morphological and physiological characters.

Parameters	Leaf No.	Leaf FW	Leaf DW	Phyllo-chron	Longe-vity	Leaf area	LAI	LAR
NAR	0.349	-0.308	-0.168	-0.003	-0.201	0.475	0.573	0.701
Leaf No.	—	-0.222	-0.277	0.198	0.530	0.070	0.00	0.179
Leaf FW	—	—	-0.959**	0.564	0.335	0.185	0.142	-0.171
Leaf DW	—	—	—	0.421	0.207	0.347	0.337	0.084
Phyllochron	—	—	—	—	0.924	0.047	0.033	-0.407
Longevity	—	—	—	—	—	0.030	0.022	-0.252
Leaf Area	—	—	—	—	—	—	0.972	0.706*
LAI	—	—	—	—	—	—	—	0.799*
LAR	—	—	—	—	—	—	—	—
Leaf Sheath DW	—	—	—	—	—	—	—	—
Stalk No.	—	—	—	—	—	—	—	—
Stalk Length	—	—	—	—	—	—	—	—
Stalk FW	—	—	—	—	—	—	—	—
Stalk DW.	—	—	—	—	—	—	—	—
TC/TS	—	—	—	—	—	—	—	—
Brix	—	—	—	—	—	—	—	—
CGR	—	—	—	—	—	—	—	—

The sign denotes the nature of correlation and the asterisks refer to the level of significance (* -0.05 and **-0.01).

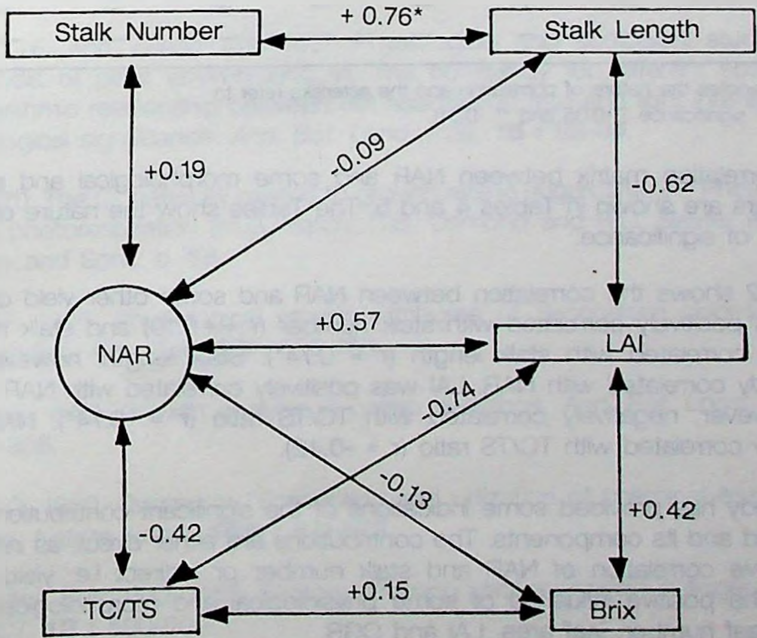

Figure 2. Correlation of net assimilation rate (NAR) and some yield components (field experiment)

Table 5. Correlation matrix between NAR and certain morphological and physiological characters.

	Leaf Sheath DW	Stalk No.	Stalk Length	Stalk FW	Stalk DW	TC/TS	Brix	CGR
NAR	0.315	0.190	-0.086	-0.426	-0.436	-0.416	-0.129	0.153
Leaf No.	0.228	-0.129	0.646	-0.066	0.051	-0.053	-0.377	-0.155
Leaf FW	0.713*	-0.291	-0.513	0.218	0.274	0.220	0.847	-0.505
Leaf DW	0.023	-0.247	-0.650	-0.043	0.015	-0.039	0.820*	-0.552
Phyllochron	0.010	-0.664	0.061	0.416	0.655	0.418	0.601	-0.779*
Lengevity	-0.145	-0.652	0.320	0.300	0.570	0.306	0.313	-0.693
Leaf area	0.444	0.068	-0.569	-0.667	-0.662	0.669	0.453	0.056
LAI	0.393	-0.003	-0.617	-0.737*	-0.695	-0.739*	0.419	0.153
LAR	0.276	0.226	-0.375	-0.885**	-0.898	-0.879**	-0.112	0.512
Leaf sheath DW	-	-0.124	-0.547	-0.392	-0.356	-0.390	0.523	-0.899**
Stalk No.	—	—	0.759*	0.038	-0.398	0.034	-0.230	0.284
Stalk length	—	—	—	0.291	0.393	-0.298	-0.709*	-0.227
Stalk FW	—	—	—	—	0.906	1.000**	0.158	-0.505
Stalk DW	—	—	—	—	—	0.905**	0.185	-0.577
TC/TS	—	—	—	—	—	—	0.153	-0.512
Brix	—	—	—	—	—	—	—	-0.442
CGR	—	—	—	—	—	—	—	—

The sign denotes the nature of correlation and the asterisks refer to the level of significance (*-0.05 and ** -0.01)

The correlation matrix between NAR and some morphological and physiological parameters are shown in Tables 4 and 5. The Tables show the nature of correlation and level of significance.

Figure 2 shows the correlation between NAR and some other yield components. NAR was positively correlated with stalk number ($r = +0.19$) and stalk number was positively correlated with stalk length ($r = 0.74^*$). Stalk length, however, was not significantly correlated with NAR. LAI was positively correlated with NAR ($r = +0.57$), and, however, negatively correlated with TC/TS ratio ($r = -0.74^*$). NAR was also negatively correlated with TC/TS ratio ($r = -0.42$).

The study has provided some indications of the significant contribution of NAR to sugar yield and its components. The contributions are either direct, as in the case of the positive correlation of NAR and stalk number or indirect i.e. yield is affected through the positive influence of some physiological and morphological characters such as leaf number, leaf area, LAI and CGR.

It appears that the varieties having high NAR, the chances of survival of tillers will be enhanced as evidenced by the positive correlation between NAR and stalk number. This may be due to two factors, (1) tiller survival is promoted due to the capacity to partition and translocate photosynthates for tiller development and (2) the smothering effect of shading is reduced in high NAR varieties due to thick narrow and erect leaf habit. This narrow and erect leaf habit allows better light penetration through the canopy and the late tillers are afforded enough time to produce photosynthate and become established and compete with early tillers. It is also felt that with high NAR varieties, tonnage can be increased directly by increasing population density in a unit area (Black *et.al.* 1969). The significant variation in yield among the varieties shows the potential for selecting high tonnage canes. Furthermore, the lack of variation in brix among the varieties could be due to the fact that these varieties have already achieved its maximum genetic potentiality. It can also be that enough attention has not yet been paid in the breeding programme to improve this character.

Therefore, it is hoped that the results would help the breeder to choose suitable characters to incorporate in the breeding programme that can further improve sugar yield and tonnage.

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