USE OF CHLOROPHYLL METERS TO MONITOR NITROGEN STATUS OF SUGAR CANE

By

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Abstract

As leaf greenness can now be measured instantaneously by the chlorophyll meter, the latter technology, if applicable to sugar cane, would not only enable a sugar cane field to be sampled quickly and easily but would also provide the opportunity to fine-tune its fertiliser nitrogen (N) management at short notice during the growth period in response to changing weather conditions in Mauritius. The results obtained in Mauritius showed that, as is the case for leaf N concentration, sites as well as variety and age of sugar cane affected chlorophyll meter readings. Furthermore, the correlation between leaf N concentrations and chlorophyll meter readings was so poor that the latter could not serve as surrogate for leaf N levels. Though the chlorophyll meter readings increased with rates of N applied, the narrow ranges of values did not clearly separate adequately fertilised from N-deficient sugar cane. Nevertheless, the fact that sugar cane leaf greenness attained a plateau when its yield response to N fertilisers reached a maximum indicated that the chlorophyll meter has a potential for the prediction of yield. To achieve that potential, further research is required to calibrate the meter readings over the wide range of soil and climate conditions existing in Mauritius.

Introduction

Foliar diagnosis is a valuable tool for checking the nutrient status and correcting impending nutrient deficiencies in sugar cane in Mauritius and elsewhere (see e.g. El Wali and Gascho, 1984; Humbert, 1968). Though current technology for determining nutrient concentrations, including N, in plant tissue is straightforward, it is time consuming and requires costly laboratory facilities. The time delay between leaf sampling and obtaining results prevents timely in-season producer response to N deficiencies and serves more as a post-mortem of past N fertiliser practices rather than as a true management tool to improve fertiliser N efficiencies.

Nutrient requirements of sugar cane, like other crops, are dependent on climate, particularly solar radiation and rainfall (Ng Kee Kwong et al., 1988; Wood and Meyer, 1986) and on fertiliser management. Research in plant nutrition has shown that much of the leaf N is present in enzymes associated with chlorophyll. Therefore, leaf chlorophyll concentration can be correlated with leaf N concentration and can serve as a surrogate for leaf N concentration in the prediction of N requirements of crops (Chapman and Barreto, 1997; Lopez-Cantarero et al., 1994).

With lightweight, hand-held and battery-powered chlorophyll meters now available, estimates of chlorophyll levels can be made instantaneously and done without destructive leaf sampling. If chlorophyll levels in sugar cane leaves can be correlated with the plant N status, this meter may offer the capability of sampling an area easily with results immediately available in the field. This would allow fertiliser N management to be fine-tuned during the growing season by reacting to changing weather conditions. While the use of the hand-held chlorophyll meters as a tool for quickly identifying N deficiencies in crops such as rice, corn and barley has been widely reported (e.g. Chapman and Barreto, 1997; Vidal et al., 1999; Wienhold and Krupinsky, 1999), there have been no published reports relating chlorophyll meter measurements to the N status of sugar cane. This study was therefore initiated to determine the feasibility of using a hand-held chlorophyll meter to monitor the N status of sugar cane and ultimately to use the meter to correct in-season N deficiencies of sugar cane.

Materials and methods

The study was conducted during the 1996–1997 and 1997–1998 sugar cane growing seasons in field trials laid down in 1994 by the sugar estates to determine the yield responses of sugar cane varieties, M3035/66, M1658/78 and R570 to N fertilisers. Treatments were arranged in a split plot design with four main N treatments (0, 70, 140 and 210 kg N/ha) replicated four times in a randomised complete block design. The three varieties made up the subplots whose size varied from 270 m² to 405 m² depending upon the field layout on the sugar estates. All the subplots were adequately fertilised with phosphorus (P) and potassium (K), the P rates being dependent on soil tests while the dosage of K (as muriate of potash) varied from 145 to 175 kg K₂O/ha. While the P was applied in the furrows at planting, the N as calcium ammonium nitrate and K were either banded in the furrows at planting or surface banded along the sugar cane rows approximately eight weeks after planting or after harvest of the plant cane or ratoon.

During the logarithmic growth period of the second and third ratoon cane (January to April 1997...
and 1998), 30 top visible dewlap (TVD) leaves were randomly collected from each subplot. A chlorophyll meter SPAD 502, Soil Plant Analysis Development Section (SPAD), Minolta Camera Co Ltd, Japan was used to obtain SPAD readings from the middle 10 cm section (free of midrib) of the TVD leaves. The meter reads in dimensionless units called SPADs after measuring the transmittance of the leaf in the red and near infrared wavelengths. The SPAD value is in fact a relative measure of leaf greenness rather than leaf chlorophyll concentration. A reference standard provided with the 502 model assures reliability. Two meter readings were taken from each leaf section so that the readings for each subplot are reported as the average of 60 readings. Preliminary studies have shown that when the midrib was avoided, there was no significant difference in SPAD readings of the sections before and after detaching the TVD leaves from the sugar cane plant. Since only the usefulness of the meter for predicting the leaf N status was tested, no analyses were made of how SPAD readings were related to the traditional method of determining chlorophyll in sugar cane leaves.

After the SPAD measurements, the 10 cm sections of the TVD leaves were dried to constant weight at 90 °C in a forced air oven and ground in a Wiley mill to pass through a 0.5 mm sieve. The N content (on a dry weight basis) in the TVD leaf samples was read directly on a calibrated Near Infrared Reflectance (NIR) spectrophotometer. Determination of area of the TVD leaf was carried out as outlined by Mongelard (1968) and its specific leaf weight (SLW) was calculated as the ratio of its dry weight to its area. At harvest, the cane stalks were weighed to obtain cane yield and sampled for determination of sucrose using an automatic saccharimeter.

Results and discussion

Relationship between leaf N and chlorophyll meter readings

Existing literature, e.g. Schepers et al. (1992), generally shows a strong positive correlation between leaf N concentrations and chlorophyll meter readings. The data obtained in this study showed that a strong correlation between leaf N and SPAD values did not exist in sugar cane in Mauritius. The relationship between leaf N and SPAD values based on data pooled together irrespective of age of sugar cane, location and variety was very poor with a correlation coefficient (r) less than 0.30 (Table 1). Such a poor relationship between leaf N and SPAD values was expected because while, in general, leaf N concentration in sugar cane was higher during the early stage of growth and gradually declined with age of the crop, the SPAD values did not always follow the same pattern (Figure 1). Since the SPAD values of the most recently expanded TVD leaf did not gradually decline with age of the sugar cane, there was no reason for SPAD values and leaf N content to be highly correlated.

It has been reported that the displayed value of the chlorophyll meter is subject to wide variations due to factors other than N status (Johnkutty and Polanippan, 1996). Similar to leaf N, SPAD readings are affected, for instance, by stage of growth, variety differences and location (Schepers et al., 1992; Piekielek et al., 1995). The influence of these three parameters on the SPAD values of sugar cane TVD leaf is illustrated in Figure 1. As shown in Table 1 even when these factors were standardised or considered separately, the correlation between leaf N and the SPAD values remained poor.

Cultivar effects on SPAD readings in rice have been found to be due to differences in leaf thickness of the cultivars (Turner and Jund, 1994). Peng et al. (1993, 1996) reported that the effects of cultivars and growth stage of rice on SPAD readings can be overcome simply by dividing the SPAD value by the specific leaf weight (SLW) of the sampled leaf as the SLW is associated with leaf thickness. Determination of SLW is destructive and would deprive the chlorophyll meter of some of its advantages particularly its simplicity though, for sugar cane, leaf area can be accurately estimated as a function of leaf length and width (Mongelard, 1968). Nevertheless, even after the adjustment of SPAD values by division with SLW, there was no improvement in the correlation between leaf N and the corrected SPAD reading (Table 1). The present study demonstrates that chlorophyll meter readings cannot be used as surrogates for leaf N concentrations in sugar cane.

Relationship between chlorophyll meter readings and sugar cane yield

Since leaf greenness was expected to rise with increases in soil N availability, the chlorophyll meter therefore invariably registered an increase in SPAD value after N application (Figure 2). The range of SPAD value increases with N rates was, however, a narrow one. Indeed, as fertiliser N rates were increased to 140 and then to 210 kg N/ha, chlorophyll meter readings tended to plateau in contrast to leaf N content which often continued to rise with increasing N rates as a result of luxury consumption of N. This trend of rising SPAD values with increasing fertiliser N rates was in fact in synchrony with the yield response of the sugar cane to N fertilisers and indicated that leaf chlorophyll content or leaf greenness as measured by the SPAD-502 chlorophyll meter may be used to provide an estimate of potential yield as does leaf N concentration. This is supported by the fact that the correlation coefficients (r) between cane yields and SPAD readings were in general just as high as the r values obtained between cane yields and leaf N concentrations (Table 2). As indicated by Shapiro (1999), chlorophyll meter reading can then be used to determine the point between N needed for optimum yield and N applied in excess of that point.

The use of a chlorophyll meter to indicate N needed for optimum yield would represent an advantage over the adoption of an optimum leaf N concentration for the same purpose. The data collected in the course of the study showed that the time of day when the reading is made had no influence on the magnitude of the SPAD reading. The fact that the SPAD value at
midday is not different from that recorded before sunrise would, therefore, remove one of the major constraints in the current practice of foliar diagnosis which requires that leaf sampling be undertaken early in the morning and be completed before eight o’clock (Halais, 1962). However, the variation in SPAD readings among sugar cane plants within a field (coefficient of variation being of the order of 17%) still demands multiple leaf measurements for an accurate and representative estimate of leaf greenness.

As discussed in the preceding section, the usefulness of the chlorophyll meter on predictions of sugar cane yield will be hampered by the variation in SPAD readings caused by factors such as differences in variety and age of the crop. To overcome these uncertainties, Schepers et al. (1992) proposed normalising each field with a reference strip that was well fertilized with N. Corn, for instance, was found to require a side dressing of N if the chlorophyll meter readings were 95% or less of those recorded in the well-fertilised strip (Schepers et al., 1992). Though normalised chlorophyll meter readings have potential for N management in sugar cane, a necessary component of the procedure is that one must always have strips of sugar cane fields fertilised adequately with N for optimum yield.

Table 1—Linear correlation coefficients (r) between chlorophyll meter readings and sugar cane top visible dewlap leaf nitrogen concentrations (% d.m) for varieties M 3035/66, M 1658/78 and R 570 at different locations in Mauritius.

<table>
<thead>
<tr>
<th>Sites and soil families*</th>
<th>Number (n) and year of paired observations</th>
<th>Varieties</th>
<th>r value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Britannia (F1)</td>
<td></td>
<td>M 3035/66 &amp; M 1658/78</td>
<td>0.24</td>
</tr>
<tr>
<td>Mon Desert Alma (B1)</td>
<td></td>
<td>M 3035/66 &amp; M 1658/78</td>
<td>0.23</td>
</tr>
<tr>
<td>Riche en Eau (F1)</td>
<td>4 sites pooled together</td>
<td>M 3035/66</td>
<td>0.30</td>
</tr>
<tr>
<td>Gros Bois (B1)</td>
<td></td>
<td>M 3035/66</td>
<td>0.34</td>
</tr>
<tr>
<td>Britannia (F1)</td>
<td>1997, n = 36</td>
<td>M 3035/66</td>
<td>0.55</td>
</tr>
<tr>
<td>Mon Desert Alma (B1)</td>
<td>1997, n = 36</td>
<td>M 1658/78</td>
<td>0.70</td>
</tr>
<tr>
<td>Mon Desert Alma (B1)</td>
<td>1997, n = 36</td>
<td>M 1658/78</td>
<td>0.12**</td>
</tr>
<tr>
<td>Mon Desert Alma (B1)</td>
<td>1997, n = 36</td>
<td>M 3035/66</td>
<td>0.32**</td>
</tr>
<tr>
<td>Belle Vue (P2)</td>
<td>1997, n = 72</td>
<td>R 570</td>
<td>0.50</td>
</tr>
<tr>
<td>Belle Vue (P2)</td>
<td></td>
<td>R 570</td>
<td>0.31</td>
</tr>
<tr>
<td>Belle Vue (P2)</td>
<td></td>
<td>R 570</td>
<td>0.31**</td>
</tr>
<tr>
<td>Belle Vue (P2)</td>
<td></td>
<td>R 570</td>
<td>0.31**</td>
</tr>
</tbody>
</table>

*For description, see Parish and Feillafé (1965).

**Chlorophyll meter readings were corrected for specific leaf weight before determining r.
Fig. 2—Increases in chlorophyll, leaf readings, leaf visible dewar, leaf nitrogen concentrations and cane yields of varieties in 3055.

M 1969/78 and A 570 as a function of rates of fertilizer nitrogen.

Leaf N

Fertilizer N rates (kg/ha)

1997 Yield

1999 Yield

Leaf N (% of field)

Cane yield (t/ha)

M 1969/78 (Amo Detant Ama - B soil)

M 305568 (Rhode-Eau - F soil)

M 570 (Rhode-Eau - P soil)
Table 2—Correlation of yield (tonnes cane/ha) with chlorophyll meter readings and with N concentration in the top visible dewlap leaf of sugar cane varieties R570 and M303566.

<table>
<thead>
<tr>
<th>Location and soil family*</th>
<th>Variety</th>
<th>Linear correlation coefficient (r)</th>
<th>1997</th>
<th>1998</th>
<th>1997</th>
<th>1998</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Yield vs leaf N (% d.m.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constance (L2)</td>
<td>R 570</td>
<td>0.80</td>
<td>0.21</td>
<td>0.71</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>Union (L2)</td>
<td>R 570</td>
<td>0.65</td>
<td>0.14</td>
<td>0.16</td>
<td>0.55</td>
<td></td>
</tr>
<tr>
<td>FUEL (L4)</td>
<td>R 570</td>
<td>0.36</td>
<td>0.95</td>
<td>0.96</td>
<td>0.83</td>
<td></td>
</tr>
<tr>
<td>Belle Vue (P2)</td>
<td>R 570</td>
<td>0.91</td>
<td>0.30</td>
<td>0.93</td>
<td>0.98</td>
<td></td>
</tr>
<tr>
<td>Beau Plan (L1)</td>
<td>R 570</td>
<td>0.04</td>
<td>0.32</td>
<td>0.52</td>
<td>0.86</td>
<td></td>
</tr>
<tr>
<td>Mon Désert Alma (B1)</td>
<td>M 303566</td>
<td>0.98</td>
<td>0.15</td>
<td>0.98</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>Riche en Eau (F1)</td>
<td>M 303566</td>
<td>0.68</td>
<td>0.48</td>
<td>0.85</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>Gros Bois (B1)</td>
<td>M 303566</td>
<td>0.94</td>
<td>0.39</td>
<td>0.90</td>
<td>0.86</td>
<td></td>
</tr>
<tr>
<td>Britannia (F1)</td>
<td>M 303566</td>
<td>0.09</td>
<td>n.d.</td>
<td>0.60</td>
<td>n.d.</td>
<td></td>
</tr>
</tbody>
</table>

* For a description of soil family, see Parish and Feillafé (1965).

Conclusions

Foliar diagnosis as a N management tool will gain prominence as producers further scrutinise their fertilisation programs to enhance the productivity of their sugar cane lands. As such, producers will be searching for tools that are rapid, reliable and cost effective to eliminate over application of fertiliser N and to correct in-season N deficiencies.

Though chlorophyll meter readings can be done quickly and reliably as opposed to the substantial time and equipment required to analyse for plant tissue N, our results show that chlorophyll meter readings cannot serve as surrogates for sugar cane leaf N levels, but they can potentially be adapted to determine the N needs of sugar cane. Meter readings mean little by themselves and need to be calibrated for each field, soil, variety and environment. This means that if the chlorophyll meter is to be adopted for the N management of sugar cane, further research over a wide range of soil and climate conditions will need to be conducted to determine the simplest and yet most reliable way of applying this technology to sugar cane. In this context, because chlorophyll meters provide a unitless indication of leaf greenness, utilisation of this technology may require normalising the data relative to an adequately fertilised area of the field. Furthermore, the simplicity and ease of use of this new tool may need to be combined with other simple measurements such as dry matter or leaf area to develop an improved and reliable method for predicting N fertiliser requirements of sugar cane in Mauritius.

Acknowledgment

The collaboration of managers and agronomists of sugar estates is gratefully acknowledged. The authors also thank the Director and colleagues at MSIRI for their support and help.

REFERENCES


L’ÉVALUATION DE L’ÉTAT NUTRITIONNEL DE LA CANNE EN AZOTE PAR LE CHLOROPHYLLE-MÈTRE PORTATIF

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Résumé
La mise au point des chlorophylle-mètres portatifs a permis d’évaluer sur place et avec succès l’état nutritionnel azoté des cultures tel que le riz, le maïs et le blé à partir d’une mesure de l’intensité de la verdure des feuilles. Si ces instruments se révélaient fiables pour la canne à sucre, ils permettraient un diagnostic rapide et peu onéreux d’un champ afin de procéder également à un ajustement rapide de la fumure azotée en réponse aux conditions climatiques variables. Les résultats obtenus à Maurice ont démontré que tout comme la teneur en N de la feuille, les mesures du chlorophylle-mètre sont aussi influencées par l’âge, la variété de la canne et par le site expérimental. La faible corrélation reliant le niveau de N dans la feuille et la lecture du chlorophylle-mètre indique que les relevés du chlorophylle-mètre ne peuvent se substituer aux valeurs réelles de N dans la feuille. Même si les données du chlorophylle-mètre augmentaient avec le taux d’azote, le faible écart entre les relevés ne permet pas de distinguer un champ carencé d’un autre bien pourvu en N. Néanmoins le fait que l’intensité de la verdure des feuilles suit de près la réponse de la canne à la fumure azotée, montre que le chlorophylle-mètre pourrait être utile dans l’estimation du rendement d’un champ. Cependant, pour exploiter ce potentiel, la recherche devra s’orienter vers l’étalonnage du chlorophylle-mètre pour les différents types de sols et conditions climatiques rencontrés à Maurice.

USO DEL CLOROFILÔMETRO PARA SEGUIMIENTO DEL NITRÓGENO EN CAÑA DE AZÚCAR

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Resumen
En la medida en que se puede medir el color verde de las hojas de manera instantánea con el clorofilómetro y, al usarlo en los campos comerciales de caña de azúcar se pueden tomar muestras rápidas que proporcionan la oportunidad para corregir oportunamente las deficiencias de nitrógeno que ocurren durante el período de crecimiento, debido a cambios en las condiciones del clima en la isla de Mauricio. Los resultados obtenidos muestran que las lecturas del clorofilómetro son afectadas por el contenido de clorofila en la hoja, por el sitio y por la variedad de caña. Además, las correlaciones entre el contenido de nitrógeno y las lecturas del clorofilómetro fueron tan pobres que no pudieron ser usadas para juzgar los niveles de nitrógeno en la hoja. Aunque, las lecturas de clorofila aumentaron con las dosis de N aplicadas, el rango de las lecturas no fue lo suficientemente amplio para diferenciar los campos con y sin deficiencias de nitrógeno. Sin embargo, el hecho de que el color de las hojas de la caña alcancen un valor constante cuando la respuesta en producción al nitrógeno es máxima, indica que las lecturas del clorofilómetro tienen un potencial para la predicción de la producción. Para alcanzar el potencial, se debe investigar más en la calibración de las lecturas del clorofilómetro en un rango amplio de condiciones de suelo y de clima en la isla de Mauricio.