Assessment of leaf analyses of sugarcane under moisture stress conditions

by

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Contents

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Declaration

I hereby declare that the material presented in this thesis is based on my own original work, except where otherwise acknowledged, and that it has not been submitted previously for examination at this or any other university.

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Abstract

Leaf analysis continues to be an important 'tool' used for diagnostic and advisory purposes in a number of world sugar producing industries. This has especially been the case in countries such as South Africa where leaf analysis is routinely used to check on the adequacy of fertiliser recommendations and as a means to assess nutrient trends in the various regions and the sugar industry as a whole. In contrast, following limited use of leaf testing in the Australian industry, there has recently been a resurgence in interest in leaf sampling as a means of facilitating better nutrient management. Despite the level of historical usage, a set of general third leaf critical values that covers most of the essential plant nutrients was developed by various research scientists in the various sugar producing countries over the years, with slight modifications based on local conditions and experience. Whether solely used for diagnostic purposes, or for more advanced interpretation of nutrient trends or interactions, it is known that leaf analysis data can be affected by various factors such as crop age, season, variety and the presence of moisture stress. Guidelines and prerequisites associated with leaf sampling, and an understanding of the effect of these factors on leaf nutrient values, form an essential component of the overall concept of leaf analysis. Despite recognition that plant water relations may markedly influence plant nutrition, little quantitative information is available regarding the effect of moisture stress on the nutrient content of sugarcane.

The work reported in this thesis was aimed at assessing leaf analysis and the macro nutrient content of young sugarcane under conditions of moisture stress, by

i. Reviewing the development and use of leaf analysis with sugarcane
ii. Assessing evidence from the South African sugar industry that moisture stress was affecting leaf analysis data
iii. Investigating the interaction between moisture stress and the macro nutrient content of sugarcane at an age when leaf sampling is normally practiced
iv. Comparing the interaction of moisture stress and the nutrient content of three different sugarcane varieties
v. Establishing a moisture stress indicator for improved interpretation of sugarcane leaf analysis data.

The project consisted of four distinct, but inter-related, phases. The initial phase centred around i) and ii) above. In the case of ii), examples of data were considered where commercial sugarcane fields had been leaf sampled during and subsequent to moisture stress conditions, as were mean third leaf nutrient values pertaining to selected regions over a range of 'normal' and 'drought-affected' seasons. In addition two case studies were conducted to assess the affect of moisture stress on leaf nutrient values on a whole-farm basis.

The second and third phases of the project (aims iii. and iv.) were conducted in semi-controlled conditions (under an automatic rain-shelter or within a glasshouse). In phase two, the interaction between moisture stress, plant growth and plant nitrogen content was assessed in two experiments in which sugarcane was grown in large pots (80 litre) within a 4 x 4 (moisture stress x sampling date) factorial trial in which N was adequately supplied (Trial 1), and in a 2 x 2 x 4 (N application rate x moisture stress treatments X sampling date) randomised pot trial where two rates of N (equivalent of 120 kg N ha^{-1} and 60 kg N ha^{-1}))were considered. In Trial 1, the moisture stress treatments were as follows: unstressed - soil kept at field moisture capacity; stressed (early) - water withheld from day 90 after planting; stressed (late) - water withheld from day 100 after planting; and stress/relief - water withheld from day 90 after planting, but soil rewatered to field capacity on day 110 after planting. The four harvest (complete destructive sampling) dates were separated by 10 days and began on day 100 after planting. In Trial 2, only two moisture stress treatments were considered ie. unstressed (as above) and stress/relief – water was withheld from day 140 after planting, but soil rewatered from day 165 after planting. The four sampling dates were again separated by 10 days that began on day 145 after planting. These trials were also used to assess the interaction between the other leaf macro-nutrients (P and K) and moisture stress.

In the third phase, two concurrent trials were conducted (Trial 1(Qld) and Trial 2 (Qld) to assess the interaction between the macro-nutrients (N, P and K) and moisture stress in three sugarcane varieties (NCo310, Q141 and Q136). In this case, sugarcane was grown in 40 litre pots within the 2 x 2 x 3 (variety x moisture stress x sampling date) randomised pot trials. The two moisture stress treatments were as follows: unstressed (as above) and stress/relief (water was withheld from day 100 after planting, but stress relieved by rewatering from day 110 after planting). Sampling was conducted on three dates beginning on day 120 after planting.

The final phase consisted of an investigation to establish a robust moisture stress indicator that could be used to identify moisture stress at the time of sampling, and provide a means of assessing or interpreting leaf analysis data (particularly N) under such conditions.

The examples and case studies used to assess evidence of a moisture stress effect in the industry showed that drought effects associated with below 'normal' rainfall had indeed influenced the nutrient content of the third leaf samples. The occurrence of abnormally large numbers of low leaf N and P values were the result of moisture stress effects rather than nutrient deficiencies *per se*.

As expected, plant extension rate, leaf area index (LAI) and dry matter production were all negatively affected by the imposition of moisture stress over the sampling periods in all of the trials. Significant increases in these parameters occurred with stress relief. In relation to plant N, it was found that there was a significant interaction between moisture stress treatment and sampling date. Compared to the unstressed sugarcane, the total plant N declined markedly with imposition of moisture stress (when N was adequately applied), but improved considerably with stress relief, resulting in no significant differences between the unstressed and stress/relief sugarcane on the last sampling date. These differences in plant N, due to moisture stress effects, were also generally apparent when the harvested plants were partitioned into their component parts (spindle, leaf and sheath number and trash). In particular, it was found that the moisture stress treatments and date of sampling had a significant effect on third leaf N content. However, when N was limiting, little recovery in total and third leaf N was apparent once stress was relieved.

In partitioning the plants, it was found that like N, the plant P and K concentrations declined with increasing leaf and sheath numbers. Generally, total and third leaf P value were less sensitive than plant N to moisture stress effects. Plant K was generally found to be insensitive to moisture stress. In terms of the third leaf nutrient values (N, P and K) there was no evidence of varietal differences between the three varieties

(NCo310, Q141 and Q136) under either unstressed or stress/relief conditions. Trends in leaf N, P and K grown in sub-optimal (yet balanced) nutrient conditions were similar to those observed when nutrients were adequately supplied.

It was found that the dry mass of the top sections of the third leaf laminae (between the 200mm section (used for chemical analysis) and the leaf tip) expressed as a percentage of their wet mass (D%W(L3T)) used in combination with the dry mass of a sample of spindles (from the same plants) expressed as a percentage of their wet mass (D%W (Sp)), provided a useful indicator of moisture stress in sugarcane at the time of leaf sampling. D%W (L3T) values of less that 32% in combination with D%W (Sp) values less than 22% would indicate unstressed conditions in sugarcane at the time of sampling. D%W (L3T) values greater than 32% in combination with D%W (Sp) values above 22% would indicate stressed conditions. D%W (L3T) values above 32% in combination with D%W (Sp) less than 22% would indicate stress-relieved conditions but with inadequate recovery of the third leaves (moisture and nutrients). In cases where D%W (L3T) indicated moisture stress conditions, estimation of 'unstressed' third leaf N values corresponding to third leaf N values affected by moisture stress (as quantified by a D%W (L3T) value) was found to be possible, using a regression equation (r^2=0.656) that linked relative third leaf N values (actual third leaf N values expressed as a percentage of baseline values) to D%W(L3T). Although the estimation of 'unstressed' third leaf P values corresponding to third leaf P values affected by moisture stress was also found to be possible, the appropriate regression equation was weaker than that associated with the third leaf N values.

In general, it was concluded that total and third leaf N, P and K values are differentially affected by moisture stress and stress/relief conditions. The decline and recovery in plant N values with time when water was withheld and then re-applied confirmed the interaction between water availability and the N content of sugarcane. However, due to the work reported in this thesis, this interaction has now been quantified and is more fully understood. The proposed use of D%W (L3T) and D%W (Sp), together with the regression equations relating D%W (L3T) to relative third leaf nutrient values provides a useful remedy for dealing with moisture stress conditions during leaf sampling. The substantially eased constraints on leaf sampling will hopefully encourage renewed, and possibly greater, use of leaf analysis for better nutrient management in sugarcane production.

General introduction

Leaf analysis is a nutritional 'tool' that is successfully used in a number of agricultural industries around the world. In particular, the sugar industries of countries such as South Africa, Brazil and Mauritius have recognised the value of foliar testing as a means of better managing and targeting nutrient inputs. Growers in the South African sugar industry, for instance, are encouraged to regularly leaf sample their ratoon sugarcane crops, as a means of checking on the adequacy of fertiliser recommendations based on soil samples collected prior to the establishment of plant cane. In other countries, such as Australia, there has been a resurgence in interest in leaf analysis as a means of managing and/or monitoring nutrients in sugarcane, particularly due to a perceived over-application of N and P, and possible under-application of K. Irrespective of the level of utilisation of leaf analysis in the different sugar industries, much effort has over the years been directed towards establishing, developing and/or confirming suitable critical (or threshold) values for use with sugarcane.

However, one specific aspect of leaf analysis that has consistently been problematic is the effect of drought stress on nutrient concentrations in plant tissue. Although it has long been recognised that moisture stress affects the nutrient content of sugarcane leaves, there is no evidence to suggest that this effect has been comprehensively investigated under controlled conditions. As such, little quantitative data is available on which to base interpretation guidelines for dealing with leaf analysis data affected by moisture stress, although some attempts have been made to use surrogates, such as nutrient ratios, for this purpose. In addition, the absence of a simple yet robust moisture stress index for use with leaf analysis in sugarcane has continued to hamper the meaningful interpretation of leaf analysis data.

In view of the above, this investigation was aimed at assessing leaf analysis as a tool for continued use in sugarcane production and then to assess the major nutrient content of sugarcane under moisture stress conditions. This would ultimately enable the development of suitable guidelines and a moisture stress indicator to ensure better interpretation of leaf analysis data that may be affected by moisture stress.