ASSOCIATION BETWEEN NUTRIENTS AND RUST IN SUGARCANE IN KWAZULU-NATAL

P CADET[1,2], SA McFARLANE[2] and JH MEYER[2]

[1]*Institute of Research for Development*
[2]*South African Sugar Association Experiment Station, P/Bag X02, Mount Edgecombe, 4300, South Africa*

Abstract

Brown (common) rust has recently been prevalent in the South African sugar industry, particularly on N29, a sugarcane variety that is often severely affected by the disease. Cool, moist conditions have favoured the development of rust, but there has been a tendency for more severe infections to be associated with well grown sugarcane. To investigate this observation, two parallel rows, one with higher rust levels than the other, were selected in a field of N29. Soil and leaf samples were taken at 3 m intervals along each row and analysed for nutrients, and the leaves were assessed for the severity of rust infection. The data were subjected to principle component analysis. The results indicated that rust strongly interfered with the physiology of the plant. The presence of rust appeared to favour the uptake of K, to the detriment of Ca, Mg and Si. It is hypothesised that early application of Ca, before rust infection, may reduce levels of infection by limiting the uptake of K. The results also suggested that the application of Si might offer some protection against the fungus. Nematodes did not influence rust severity.

Keywords: sugarcane, sugarcane diseases, rust, *Puccinia melanocephala*, nutrition

Introduction

Brown (common) rust, caused by *Puccinia melanocephala* H. and P. Sydow. has been prevalent in the South African sugar industry over the past three years, with conditions being ideal for rust development. Although many varieties have been affected by the disease, N29 was found to be particularly susceptible to infection. The disease has had a severe effect on growth in a number of fields and although N29 has many other good traits, growers have been dissuaded from planting the variety in some extension areas.

Age of the crop and weather conditions, particularly temperature and humidity, play an important role in the severity of rust infection (Comstock and Ferreira, 1986). Observations in many parts of the industry indicated also that rust infections are often more severe in well grown sugarcane. Similar observations were reported in sugarcane in Florida, USA, and in other crops (Anderson and Dean, 1986). They reported that the association between nutrition and rust severity is complex and, in most cases, would appear to be influenced by specific combinations of plant nutrients.

The analysis and interpretation of results is difficult and has led to conflicting assumptions in the literature (Anderson and Dean, 1986). This communication describes a method of analysing data from soil and leaf samples taken from a field exhibiting different levels of rust, and provides hypotheses on the relationships between nutrients and rust and, derived from these hypotheses, possible methods of control.

Materials and Methods

A field of 4-month old plant cane of variety N29 near Eston in the KwaZulu-Natal Midlands was used in this study. Rust severity increased down the slope in the field, and was particularly severe near the bottom of the field. Two parallel rows, about 15 m from the bottom of the slope and spaced 4 m apart, were selected for the study. Although both rows were infected with rust, the row further down the slope, henceforth referred to as the 'rust row', had more rust than the row above, which will be referred to as the 'control row'. Soil and leaf samples were taken, and stalk heights were measured at 3 m intervals along the length of each 75 m row. These samples were analysed for nutrients and the leaves were assessed for rust severity based on the approximate percentage leaf area affected.

In the soil, the physico-chemical analysis included pH, P, K, S, Ca, Mg, Na, Al, Mn and Fe content (ppm) and relative proportions (%) of clay, silt, fine, medium and coarse sand. In the leaves, N, P, K, S, Ca, Mg, Zn, Si, Mn, Cu and Fe content (ppm), as well as the N/S ratio, were analysed.

Two tables were compiled from the results of soil and leaf analyses, with columns representing the different soil and leaf parameters, and 50 rows representing 25 points along each of the two rows. Values were obtained using principal component analysis (PCA) and coinertia analysis (Thioulouse *et al*., 1997). When the normed actual values ($(x - \text{average } x)/\sigma$) or the factorial values were projected on the rows, circles represented values above average (positives) and squares represented values below average (negatives).

Results

Distribution of rust

The normed percentage of rust for the 50 samples projected on the map of the two rows showed that sugarcane in both rows was infected with *P. melanocephala*, mainly on the extremities of each row. The sugarcane in the rust row was nevertheless more frequently and more severely infected than the control row (Figure 1). The stalks were taller on the right half than on the left half in each row. Rust levels and plant heights were not correlated.

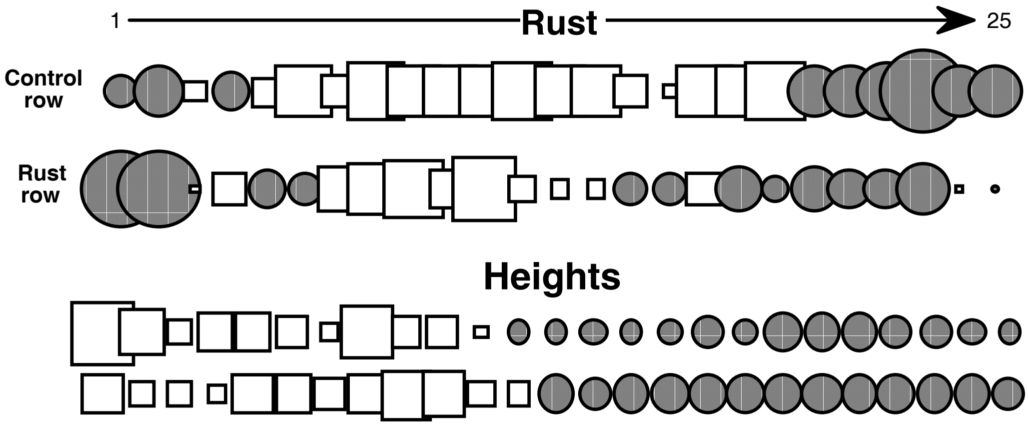

Figure 1. Rust levels and stalk heights at the 25 sampling points along the two rows. Normed values; circles represent values above average, and squares represent values below average. The size of the symbol is proportional to the distance to the average.

Distribution of nematodes

The first two factors of the PCA described 47% of the total variability of the nematode data. A size effect is evident in the first factorial plan, as almost all variables appeared in the same positive half of the factorial plan, with positive F1 values (Figure 2A). The only exception was the number of nematodes per gram of roots, which had a very low F1 value and was strongly correlated with the positive part of F2. When the level of rust was plotted against the F1 factorial values, which described the greatest variability within the nematode community, the regression was not significant (Figure 2B).

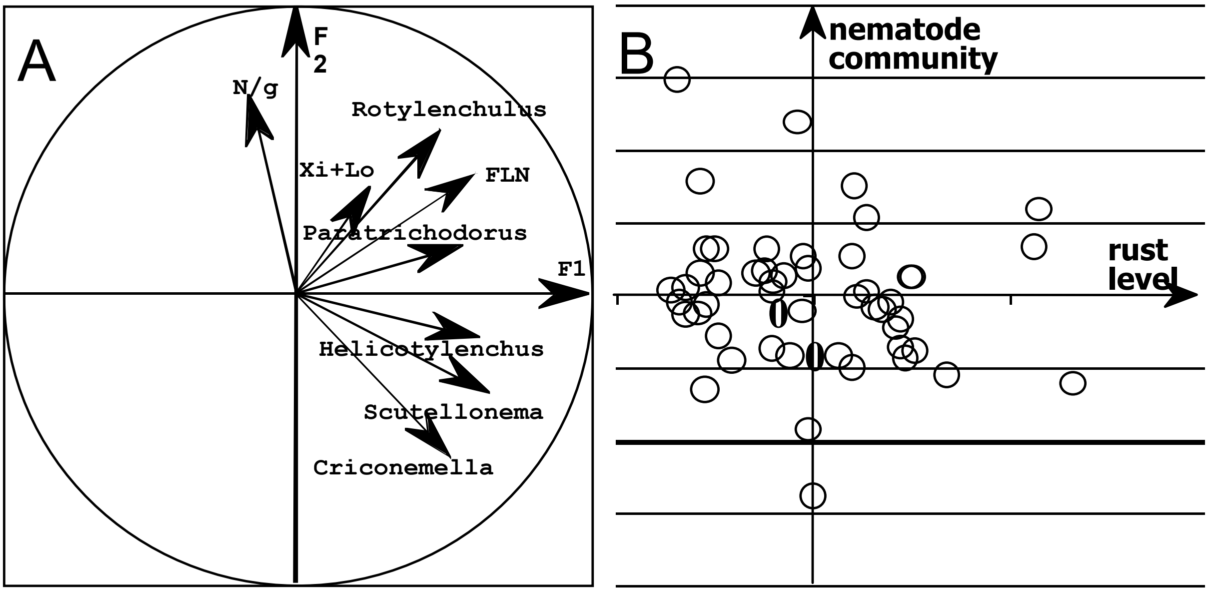

Figure 2A. Factorial map of the PCA of the nematode abundance (No/200 cm^3 of soil and No/g of dry roots) (FLN: free-living nematodes; Xi+Lo: Xiphinema + Longidorus). 2B.Relationship between the first factorial values of the nematode PCA and the rust level at each sampling point.

Soil analysis

As with the nematode data, the analysis of the soil physico-chemical factors did not show strong structures. The first four factors described 20.7, 16, 12.8 and 11.4% of the total variability. Only the third factor was significantly correlated with the rust level (Figure 3A). The determining soil factors for the third factor of the PCA were sulphur content and percentage of medium and coarse sand. These sand fractions increased significantly with the percentage of rust (Figure 3B). However, the regression curve for sulphur was not significant. When the F3 factorial values were projected on the two rows, both extremities of the rust row and the right extremity of the control row had negative factorial values, corresponding to positive values for rust level. Only the left extremity of the control row showed different symbols. This situation explained the significant regression observed between the level of rust and F3 factorial values.

Leaf analysis

No strong similarities in the severity of rust were evident when the first two factorial values of the leaf content PCA were projected on the row map. However, F2 values were significantly correlated with the rust level (Figure 4A). The greatest negative values of F2 were, in most instances, located at the ends of both rows, where rust severity was greatest. Among the most important leaf factors for the second PCA factor were K and Ca, with the rust level increasing significantly with the K content of the leaves (Figure 4B) and declining with the Ca content. The regression was not significant for Mg.

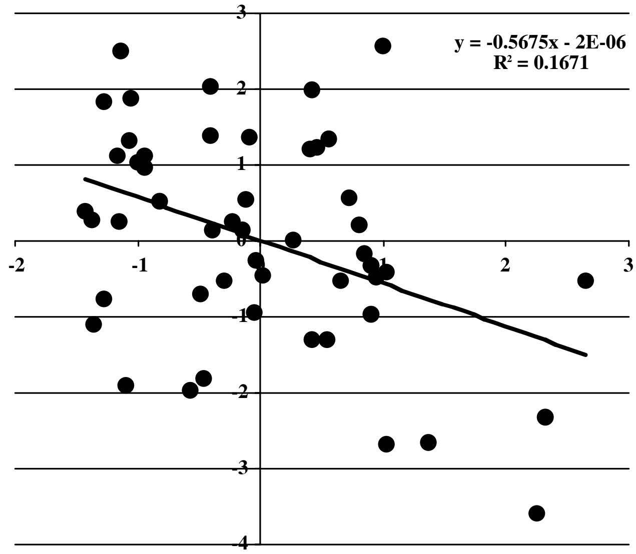

Figure 3a). Relationship between the third factorial values of the soil PCA and the rust level at each sampling point (normed values).

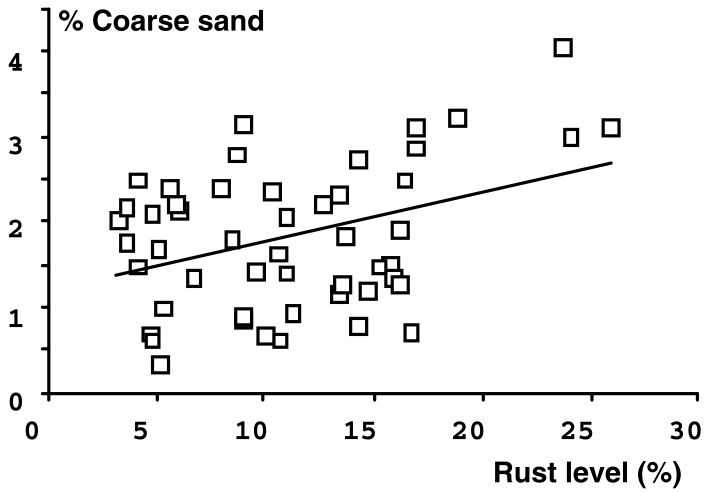

Figure 3b). Change in rust severity according to the percentage of coarse sand.

Effect of rust on plant physiology

To study the effect of rust on the physiology of the plant, the samples were classified according to rust severity and not restricted to the rust row or control row. Two tables were compiled with soil and leaf characteristics for 20 low and 20 high rust samples, excluding the 10 median samples. The 20 samples with low rust had an average rust level of 5.8%, compared with 16.8% for the 20 samples with high rust. The coinertia analysis performed on the low rust samples, to study the relationship between soil and leaf characteristics, was not significant. Of the row permutations, 14.6% gave a better result than that obtained with the original row order. However, the relationship between soil and leaf characteristics was highly significant for the high rust plants (P=0.002).

In the plants with low rust, the Ca, Mg and Si content in the leaves was positively correlated with the levels of Ca, Mg and Fe in the soil (Figure 5). However, the regression was not significant for Fe. In plants with high rust, the levels of Ca and Mg in the leaves were negatively correlated with the levels of these elements in the soil. Potassium content in the leaves of low rust plants was negatively correlated with levels of Ca, Mg and Fe in the soil (Figure 5). In contrast, this relationship was positive in the high rust plants, although the regression was not significant for Ca.

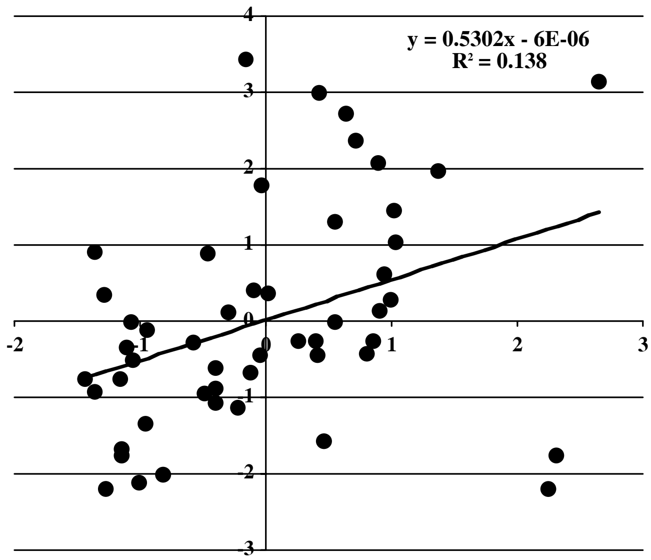

Figure 4a). Relationship between the second factorial values of the leaf PCA and the rust level at each sampling point.

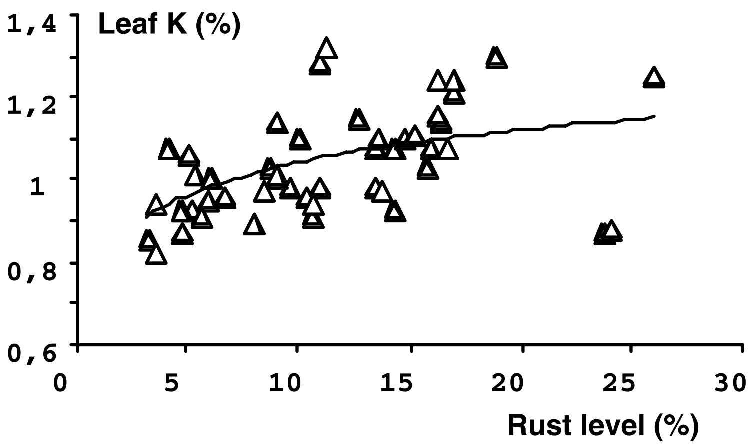

Figure 4b). Change in rust level according to the percentage of K.

Discussion

Ca and Mg are in balance with K uptake in plants (Marschner, 1986). In the present study, the nutritional status of the soil was very similar in the rust row and the control row. This was shown by the relationship between the soil and leaves from the low rust plants, which was characterised by the uptake of Ca, Mg and Si, while the uptake of K was depressed. This is normal, although the relationship was not very strong. Conversely, leaf infection by *P. melanocephala* strengthened, but reversed, the relationships between soil and leaf elements compared with less infected plants in the same row. In the high rust plants the level of a particular element in the soil was not related to its level in the leaves. The presence of rust appeared to favour the uptake of K, to the detriment of Ca, Mg and Si. These results suggest that rust strongly interfered with the physiology of the plant.

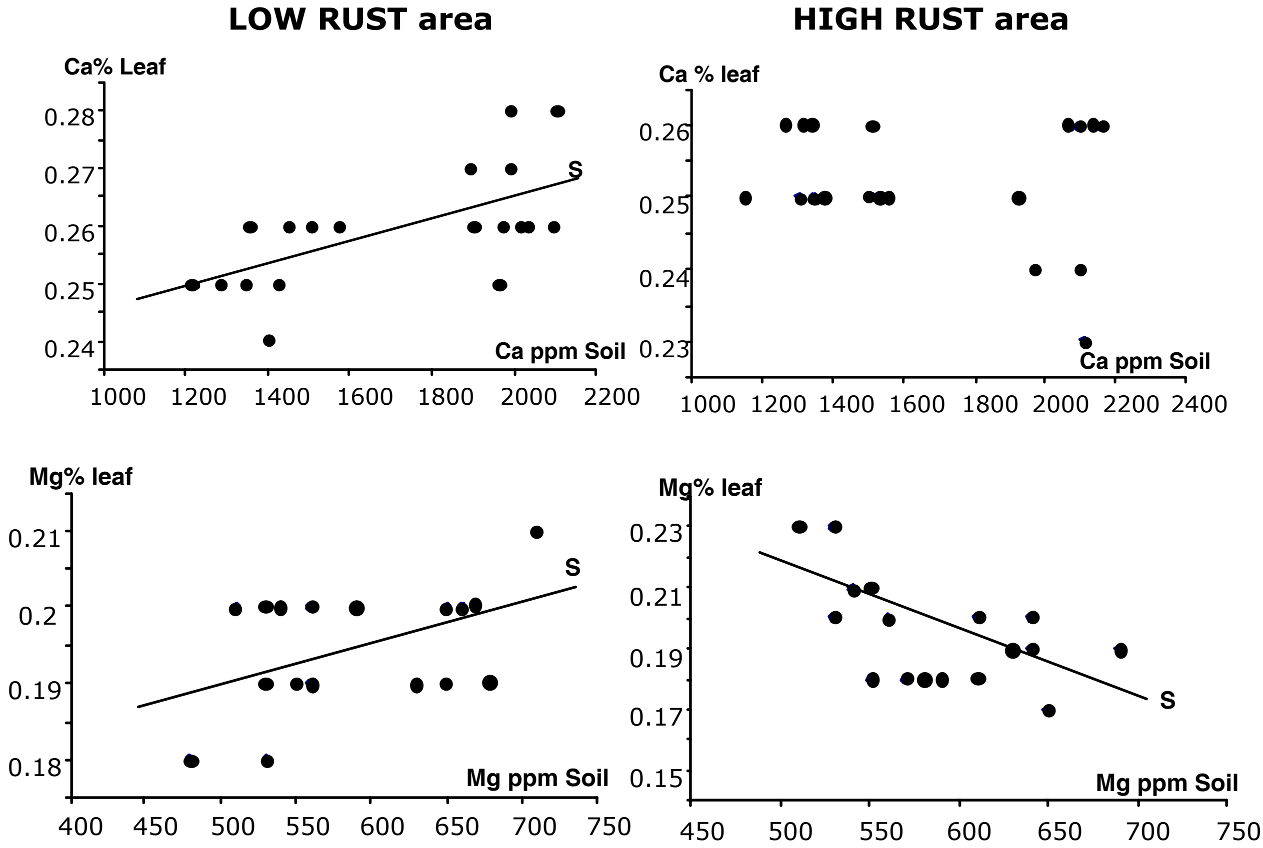

Figure 5. Relationship between the main elements in soil and leaf for the 'high rust' and 'low rust' plants.

Rust is an obligate parasite that directly modifies the physiology of its host to promote its development (Marschner, 1986). The fungus is able to do this by reducing the plant's uptake of Si, an element known to induce resistance to a number of fungal diseases, as well as reducing the uptake of K. However, this is not supported by the observations in the present study that suggest that high levels of K in the leaves are related to *susceptibility* to rust.

During its development, the fungus destroys many of the epidermal cells on the leaves, a process likely to cause a reduction in photosynthetic activity. K is important in the photosynthetic processes in sugarcane (Hartt and Burr, 1965). Damage to the epidermis may therefore result in an increase in the uptake of K. This preferential uptake would be antagonistic to that of Ca and Mg, as shown by the relationship between the nutrient status of the soil and leaf samples taken from the most infected plants. In this case, the rust appeared to interfere indirectly with plant physiology through necrosis of portions of the leaf. A similar indirect consequence of parasite damage on plant physiology is observed with nematodes, which do not directly kill the sugarcane tillers. By partly destroying the roots, they simply slow down tiller elongation and the tillers are thereafter eliminated by the natural physiological process of competition for light by better developed, neighbouring tillers.

Conclusions

In terms of control methods for rust, the consequences of the assumptions below are highly contrasted:

- *Direct physiological interference*
  It is possible that increased application of Ca before the infection of the plant could limit the uptake of K and confer resistance to later infection. However, applying Ca after infection would be ineffective, as the results suggested that the preferential uptake of K and the blockage of Ca were independent of the relative levels of these elements in the soil.
- *Indirect effect on plant physiology*
  Application of Ca will not have any effect, as the plant will naturally promote the uptake of K to compensate for reduced photosynthetic capability. However, the application of Si to increase its content in the leaves could reduce infection, as this element is known to induce resistance to many fungal diseases and is important in the development of healthy sugarcane.

Other control measures would be the destruction of the fungus with a fungicide or the use of a resistant variety.

REFERENCES

Anderson DL and Dean JL (1986). Relationship of rust severity and plant nutrients in sugarcane. *Phytopath* 76: 581-585.

Comstock JC and Ferreira SA (1986). *Sugarcane rust: Factors affecting infection and symptom development.* Proc int Soc Sug Cane Technol *19: 402-410.*

Hartt CE and Burr GO (1965). Factors affecting photosynthesis in sugarcane. *Proc int Soc Sug Cane Technol* 12: 590-609.

Kiraly Z (1976). Plant disease resistance as influenced by biochemical effects of nutrients in fertilizers. *Proc 12th Colloq Int Potash Inst Bern*, 33-46.

Marschner H (1986). Relationship between mineral nutrition and plant diseases and pests. pp 369-390 In: *Mineral Nutrition in Higher Plants*. Academic Press, London, UK.

Thioulouse J, Chessel D, Dolédec S and Olivier JM (1997). ADE-4: a multivariate analysis and graphical display software. *Statistics and Computing* 7: 75-83.