SHORT COMMUNICATION

INVESTIGATION INTO THE EFFECT OF NUTRITION ON BROWN RUST DEVELOPMENT IN SUGARCANE

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Abstract

Severe and widespread brown rust infections in sugarcane, caused by *Puccinia melanocephala*, result in substantial yield losses and limit the planting of otherwise good varieties. The severity of brown rust is often variable within a field. This has been linked to differences in levels and proportions of certain plant nutrients, which in turn affect the nutrient balance within the plant, potentially promoting rust development. The aim of this study was to identify the nutrients (or nutrient interactions) that influence the development of brown rust by undertaking transect studies in fields showing variable rust severity at two locations. Severe rust infections were associated with high soil levels of a number of nutrients including K, Ca, Mg and Mn, and lower levels of Fe at both locations. Manganese levels were lower in leaves with severe rust, but Si levels were higher. The results suggest that excessive amounts of nutrients in the soil may increase the likelihood of severe rust infections and that nutrient antagonisms, particularly to Mn uptake, are implicated in infection by brown rust.

Keywords: sugarcane, brown rust, *Puccinia melanocephala*, nutrition, disease management

Introduction

Research on a wide range of crops has shown that nutrition may either increase or decrease a particular disease by effecting changes in plant growth, morphology, anatomy and chemical composition, and may also directly affect the pathogen (Marschner, 1986). However, the effects are often variable from one study to another and are generally poorly understood. As a result, the potential of nutrition management as a form of disease control has not been fully realised (Walters and Bingham, 2007).

Sugarcane brown rust, caused by *Puccinia melanocephala* H. Syd. and P. Syd. has, until recently, been successfully managed through varietal resistance in the South African sugarcane industry. An apparent genetic shift in populations of *P. melanocephala* resulted in varieties that had previously shown acceptable resistance to the pathogen, becoming severely infected on occasion (Pillay *et al*., 2005). The severity of brown rust infection is dependent on variety, plant age, climatic conditions and the strain of *P. melanocephala* that is present. It is also reported to be affected by the physical and chemical properties of the soil (Anderson and Dean, 1986; Anderson *et al.*, 1990; Cadet *et al*., 2003; Johnson *et al*., 2007). In a study done by Anderson *et al.* (1990), the relationship between nutrition and brown rust in sugarcane proved to be complex, and most often associated with nutrient imbalances. Variability in rust severity has been observed within a number of fields in the rust-prone areas of the South African sugar industry. A research project was undertaken to identify the nutrients (or nutrient interactions) that influence the development of brown rust by doing transect studies in fields showing variable rust levels at two locations. The results of these studies are discussed.

Experiment procedure

Sample collection and analysis

Fields of variety N29 showing varying degrees of rust infection were identified at Eshowe and Compensation (North Coast). At Eshowe, two rows were selected, each 90 m long. One of these rows ran along a contour and showed severe rust infection, whereas the other row, with slight rust, was located further up the slope. At Compensation, 45 m sections of four rows, each separated by one row, were selected for the transect study. Rust levels were variable along each row, ranging from stools with no rust to stools with 80% leaf area affected. The rows were divided up into 3 m sections, and one soil sample (0 to 200 mm depth) and 20 leaf samples (top visible dewlap) were collected from each section when the cane was four months old. These samples were analysed for nutrients by the Fertiliser Advisory Service at the South African Sugarcane Research Institute (SASRI), and the leaves were assessed for rust severity based on the estimated percentage leaf area affected.

Statistical analysis

Simple correlation analysis was performed between rust severity and soil/leaf analysis at each location using GraphPad Prism 4 software. Correlation results were considered significant where the probability was significant at $P<0.05$.

Results

Significant correlations ($P<0.0001$) were obtained between rust severity and all the parameters measured in the soil samples collected at Eshowe. Although most of these were positive, Fe (-0.70***) and clay content (-0.47***) were negatively associated with rust severity (Table 1). The mean pH of the soils in the high and low rust areas at Eshowe were 6.7 and 4.9, respectively. Fewer significant correlations were obtained from the soil samples at Compensation but highly significant correlations were again obtained for rust and Mn (0.61***), Ca (0.60***) and Fe (-0.68***). While P was positively associated with rust severity at Eshowe (0.72***), a negative correlation was obtained at Compensation (-0.58***). The mean pH of the soils in the high and low rust areas at Compensation were 5.1 and 4.9, respectively.

Table 1. Correlations between brown rust ratings and nutrient levels in soil and leaf samples collected within fields showing variable rust severity at Eshowe and Compensation.

SOIL ANALYSIS

ESHOWE	pH	P	K	Ca	Mg	Fe	Clay	Zn	Mn	Na
Spearman r	0.73	0.72	0.81	0.82	0.74	-0.70	-0.47	0.86	0.61	0.40
P value (two-tailed)	P<0.0001	P<0.0001	P<0.0001	P<0.0001	P<0.0001	P<0.0001	0.0001	P<0.0001	P<0.0001	0.0017
P value summary	***	***	***	***	***	***	***	***	***	**
COMPENSATION										
Spearman r	0.10	-0.58	0.43	0.60	0.49	-0.58	0.34	0.16	0.68	-0.1887
P value (two-tailed)	0.5709	0.0005	0.0143	0.0003	0.0046	0.0005	0.0589	0.3871	P<0.0001	0.3010
P value summary	ns	***	*	***	**	***	ns	ns	***	ns

LEAF ANALYSIS

ESHOWE	P	K	Ca	Mg	Fe	Si	Zn	Mn	S
Spearman r	0.54	0.79	0.25	0.36	-0.16	0.69	-0.09	-0.75	0.44
P value (two-tailed)	P<0.0001	P<0.0001	0.0536	0.0042	0.2195	P<0.0001	0.49	P<0.0001	0.0005
P value summary	***	***	ns	**	ns	***	ns	***	***
COMPENSATION									
Spearman r	0.19	0.16	0.57	0.19	0.29	0.59	0.19	-0.35	0.16
P value (two-tailed)	0.2960	0.3966	0.0007	0.2928	0.1034	0.0004	0.3038	0.0497	0.3888
P value summary	ns	ns	***	ns	ns	***	ns	*	ns

Highly significant positive correlations were obtained between rust severity and P, K and Si in leaves collected from Eshowe, while rust was negatively associated with Mn (-0.75***) and Cu (-0.40**). At Compensation, only Si (0.59***) and Ca (0.57***) showed significant positive associations with rust severity. Mn (-0.35*) was again negatively correlated with rust levels.

Large amounts of Ca were present in the soil in the high rust areas at both locations, along with high levels of K and Mg (Figure 1); it is noteworthy that levels of these nutrients were generally well above the threshold values for sugarcane production. Conversely, Fe levels were high in the low rust areas.

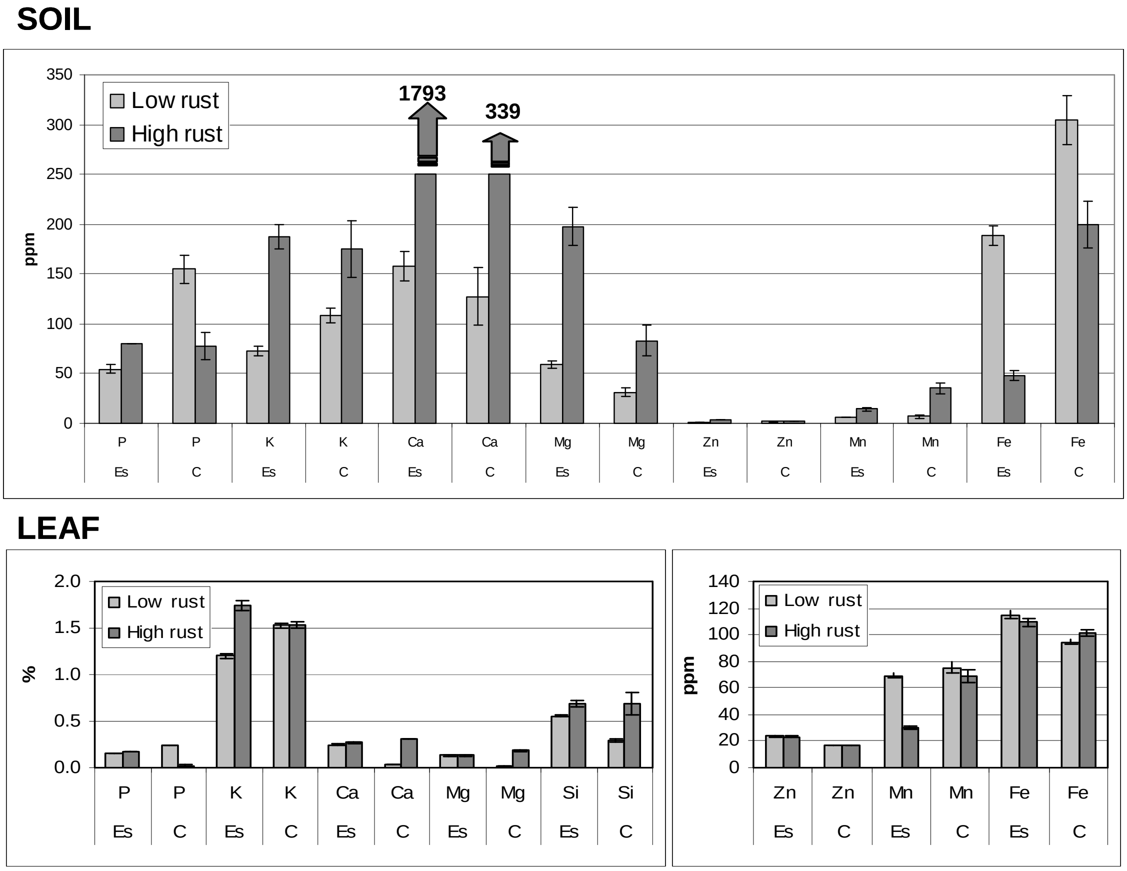

Figure 1. Mean nutrient levels in soil and leaf samples taken from high and low rust areas within fields at Eshowe (Es) and Compensation (C).

Nutrient levels in the leaves did not always reflect those in the soil and in most cases were satisfactory, not excessive. High rust was associated with high Mn levels in the soil and lower Mn levels in the leaves at both sites. Si levels were higher in leaves collected from the high rust areas.

Discussion

Certain nutrients are known to influence the uptake of others, some of which may have a protective function against plant pathogens. It is possible that these processes influenced rust severity in the fields selected for this study. High levels of nutrients in the soil (K, Ca, Mg, Mn) tended to be associated with increased rust severity; however, variations in leaf nutrient concentrations between high and low rust areas were less marked (Figure 1). The most noteworthy outcomes of this study were that rust was positively correlated with soil Mn but negatively correlated with Mn in the leaf, that high levels of Fe in the soil were associated with low rust and that levels of Si were higher in severely infected plants. These relationships were significant at both sites and need to be investigated further. In particular, the role of the well-documented Mn-Fe antagonism (Marschner, 1986) in the development of rust warrants further study.

Normally Ca would increase resistance to microbial enzymes by stabilising cell walls and membranes and inhibiting the effects of pectolytic enzymes produced by fungi and bacteria (Conway *et al*., 1991). However, excessive amounts of Ca, such as those observed in this study, can interfere with the uptake of a number of nutrients, including Mn. Manganese is reported to reduce the incidence of bacterial and fungal diseases by inhibiting the development of the pathogen through the production of phenolics and phytoalexins, and by improving the physical defences of the plant through lignification and callus formation (Thompson and Huber, 2007). Environmental factors such as high soil pH and high nitrate levels are also reported to reduce the availability of Mn, often resulting in increased disease levels (Huber and McCay-Buis, 1993). A survey of the micronutrient status throughout the South African sugar industry showed that Mn levels were adequate in most fields tested (Meyer *et al*., 1999). However, by ensuring that the environment is suitable for Mn uptake by the plant, rust levels may be reduced. This will be tested in future trials.

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