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A survey of Sigatoka leaf disease (*Mycosphaerella musicola* Leach) of banana and soil calcium levels in North Queensland

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Abstract. Annual averages of lesion development of yellow Sigatoka caused by *Mycosphaerella musicola* were calculated from surveys conducted at 14-day intervals for 57 banana sites in the North Queensland production region situated in the wet tropics between Cardwell and Innisfail. Soil up to 250 mm depth was sampled from sites between March 2000 and September 2001. Soil parameters were compared with 12 months of leaf disease data averaged centrally about the time the soil sample was taken. The 4 different formulas for calcium expression tested all proved to be significant predictors of disease levels. The strongest relationship ($r^2 = 0.229$) between soil calcium levels and disease levels was obtained from a formula based on an Albrecht interpretation of the soil test data, which includes a pH-derived estimation of exchangeable hydrogen in the denominator. A Chi square analysis on a model incorporating calcium and soil boron was statistically significant ($P<0.001$). The model combining calcium and boron levels explained more variation in disease levels than calcium alone. Variation in other factors influencing disease such as fungicide program, weather conditions, soil moisture conditions and crop stage may account for variation in disease levels at low calcium sites.

Introduction

Yellow Sigatoka is considered endemic to the North Queensland banana industry. Control of the disease relies upon protectant and systemic fungicides (generally applied on a 14-day schedule) as well as cultural methods, however the influence of soil calcium levels has not previously been investigated. The significance of calcium in disease control in other crops has been reported. Engelhard (1989) stated that it has been known for nearly 100 years that amending the soil with lime would provide a significant measure of disease control of club root in crucifiers. Zimmer (2000) also noted that boron is required for calcium uptake, meaning plant availability may be restricted where boron is deficient. A calcium–boron interaction was found in sand culture trials of turnip where Palm (1963) found that increasing levels of calcium and boron together reduced club root infection more strongly than increasing calcium concentrations alone. In a study of fusarium wilt on flax, Keane and Sackston (1970) found high calcium levels supplied continuously, or after inoculation only, significantly reduced disease when boron supply to the plants was adequate or excessive. A fusarium wilt–calcium–boron interaction in tomato was also described by Edgington and Walker (1958), who stated that the influence of boron on disease was dependant upon the calcium supply. The findings of these 3 papers, Edgington and Walker (1958), Palm (1963) and Keane and Sackston (1970) all suggest increases in calcium supply may enhance the binding of pectic materials in the host cell walls increasing their resistance to maceration by fungal enzymes.

Few studies of banana plant disease report soil nutrient levels. Most published studies determining optimum soil nutrient levels in banana focus primarily on yield. Johns and Vimpany (1999) found maximum banana yield at pH 5 ($CaCl_2$) and questioned the validity of pH targets higher than this. Moody and Daniells (2002) suggested a similar target pH of 5.5 (1:5, soil:water), as banana is tolerant of acidity. Proportions of cations relative to each other may be more important than absolute levels (Hazelton and Murphy 1992; Zimmer 2000). There are however, a number of different methods to calculate these cation proportions. Desirable cation levels on the soils exchange complex can be expressed as a percentage of the exchangeable bases present, or as a percentage of the total exchange capacity (TEC). Workers such as Zimmer (2000), who state the importance of cation balance to plant health, use the percentage of the total exchange method that is commonly referred to as the Albrecht method. The Albrecht method includes a pH-derived estimation of exchangeable hydrogen in the denominator of cation percentage calculations. The effect of this is summed up by Walters and Fenzau (1996) when they state, in eco-agriculture, an acid soil is viewed as a deficient soil. In such a model, calcium percentage and pH are inseparable as pH affects the calculated calcium percentage. In the present study, the relationships between Sigatoka disease in bananas and calcium and boron levels in the soil are investigated.

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Materials and methods

The presence of Sigatoka leaf spot on banana leaves was recorded in surveys conducted on a 14-day schedule at 57 sites between Cardwell and Innisfail. Disease surveys used a modification of the method described by Ganry (1986) which records the stages of early lesion development on leaves 2–7 of non-flowering plants. Stages of disease development are described in Table 1.

Sections of plantations which had the same soil type, planting date, soil amendment, fertiliser and chemical treatment were termed sites. Site size varied between 2 and 20 ha. Disease survey points were flagged and revisited on each sampling occasion. Sample point number varied from 2 to 10 per site with larger sites having more sample points. The percentage of large non-flowering plants with one or more leaves visibly spotted by the disease (PS) was also recorded in each survey using the method described by Stover (1974). Soil samples were also collected from disease survey points between 7 March 2000 and 15 September 2001. Between 2 and 10 samples were taken from each point depending upon the number of points at the site, resulting in 20 samples at each site. Samples were taken to a depth of 250 mm using a stainless steel 15 mm diameter hollow tube core extractor constructed by Incitec Queensland. Samples were packaged in overnight express post satchels and sent to 1 of 2 laboratories depending upon grower preference. Analyses were carried out by Incitec Laboratory, Murarrie, Queensland or Caso Agrifood laboratories, Toowoomba, Queensland. Soils were sampled for general agronomic purposes.

Laboratory analysis

Samples were analysed using standard soil tests at the NATA certified commercial laboratories mentioned above. pH was measured in a 1:5 soil to water solution. Exchangeable calcium, magnesium, potassium and sodium were extracted using the neutral normal ammonium acetate method (15D1 in Rayment and Higginson 1992). Where soil samples had a pH reading below 5.5, exchangeable aluminium was extracted with potassium chloride. Boron was extracted using the hot $CaCl_2$ method (12C2 in Rayment and Higginson 1992). All extractant analyses were carried out using an inductively coupled plasma emission spectrophotometer.

Data analysis

Leaf disease data were converted to a numerical disease score using a modified Ganry (1986) method. Disease score (DS) points were allocated depending upon the stage of lesion development and the age of infected leaves as described in Table 2. Rapid disease development indicated by late stage lesions that had developed on young leaves produced high disease scores. Individual plant disease scores were averaged across sites.

Twelve-month averages for disease parameters (DS, PS), were calculated for each site, combining data 6 months before and after the date of the soil sample. This was done to account for variations in weather conditions through the seasons and the subsequent effect on disease levels. Each DS and PS is then an average of 26 surveys at the site.

Four formulas were developed for expressing soil exchangeable calcium level. Formula 1 refers to absolute calcium levels in mg/kg, independent of other cations and cation exchange capacity. Formula 2 expresses calcium as a percentage of the exchangeable cations measured calculated in cmol(+)/kg. Formula 3 includes an estimate of exchangeable hydrogen in the denominator of the percentage calcium expression. This was calculated from the pH using the equation: %H = –0.2041pH + 1.4173 up to pH 7 (Albrecht 1975). Formula 4 removes aluminium from the estimate of exchangeable hydrogen used in formula 3. Formula 4 also has the underlying assumption that aluminium ions, being acidic, are included in the pH-derived estimation. Formula 4 was suggested by Fernando Mendez del Hoyo of Tenerife, Spain (personal communication). The equations for calculation of formulas 2–4 are as follows:

$$\text{Ca\%} = \text{Ca cmol(+)/kg/(Ca + Mg + K + Na + Al) cmol(+)/kg} \quad (2)$$

$$\text{Ca\%} = \text{Ca cmol(+)/kg/(Ca + Mg + K + Na + Al + H) cmol(+)/kg} \quad (3)$$

$$\text{Ca\%} = \text{Ca cmol(+)/kg/(Ca + Mg + K + Na + \{H – Al\}) cmol(+)/kg.} \quad (4)$$

Statistical analyses

Statistical analyses were carried out by Datasense of Townsville. Exploratory graphics and statistical analyses were performed using the statistical package SPSS Ver. 9.0.1 for Windows (SPSS Inc. 2001) and Microsoft Excel. Multiple linear regression tests were used to determine the predictive values of various measures of soil calcium and soil pH (the independent variables) against plant disease (the dependant variable) measured as DS and PS. Calcium correlated significantly (P<0.001) with measures of DS and PS in all 4 formulas with regression coefficients for formula 4>3>2>1 (Fig. 1).

Results

The soils in the region are highly weathered and generally acidic with pH measurements ranging from 4.1 to 7. Measured cation exchange capacities were low and varied from 1.6 cmol(+)/kg to 14.6 cmol(+)/kg. The inclusion of an estimate of exchangeable hydrogen gave TEC values ranging between 2.6 cmol(+)/kg and 17.7 cmol(+)/kg. Soil boron readings ranged from 2.5 mg/kg to 0.2 mg/kg. Leaf disease data calculated as annual averages of 26 surveys ranged from ranged from 4489 to 13 for DS, and 56.6% to 0% for PS.

Soil boron data were available for 50 of the blocks sampled. A Chi square analysis was used to examine the relationship between disease levels and levels of calcium and boron in the soil. Following the suggestions of Zimmer (2000) ‘favourable’ soil criteria were set as having calcium at >60% of TEC and boron >1 mg/L. Disease criteria were set for DS at less than 400 and PS at less than 1.1% of plants. The Chi square analysis of the association between disease and favourable soil criteria was highly significant (P<0.001) for both disease parameters. Figures 2 and 3 show the

Table 1. *Mycosphaerella musicola* (Leach), stages of disease development used for recording

Lesion stage	Color of lesion	Length of lesion	Shape of lesion	Restricted by lamina veins
1	Yellow	<1 mm	Speck	Yes
2	Yellow	<8 mm	Streak	Yes
3	Rusty	>8 mm	Spot	No
4	Black	>10 mm	Spot	No
5	White centre	>10 mm	Spot	No

Table 2. Disease score points allocated for various stages of lesion development and ages of infected leaves

Lesion stage	Leaf number 2	3	4	5	6	7
1	1200	1000	800	600	400	200
2	1400	1200	1000	800	600	400
3	2600	2400	2200	2000	1800	1600
4	2800	2600	2400	2200	2000	1800
5	3000	2800	2600	2400	2200	2000

interaction of calcium and boron on DS and PS, respectively. As calcium levels increase, the disease parameters, represented by the width of the bubbles, decrease. The highest concentration of small bubbles is where both calcium and boron criteria are met, defined by the area above 1.05 mg/L on the boron axis and to the right of 60% of the TEC on the calcium axis.

Discussion

Calcium alone is a statistically significant predictor of disease levels. There is, however, much variation between sites with low calcium levels. This is expected as there are obviously other factors such as crop management practices, fungicide programs, crop stage, weather conditions and inoculum levels which may affect disease level. The calcium–boron interaction as seen in Figures 2 and 3 accounts for variation within sites which meet the <60% of TEC calcium criteria. Of the 10 sites which met the calcium criteria of >60% of TEC and boron criteria of >1 mg/L, 9 sites had low levels of disease, while of the 40 sites which did not meet the calcium and/or boron criteria, 34 had average disease scores above 400 for CS (Fig. 2) and 1.1%

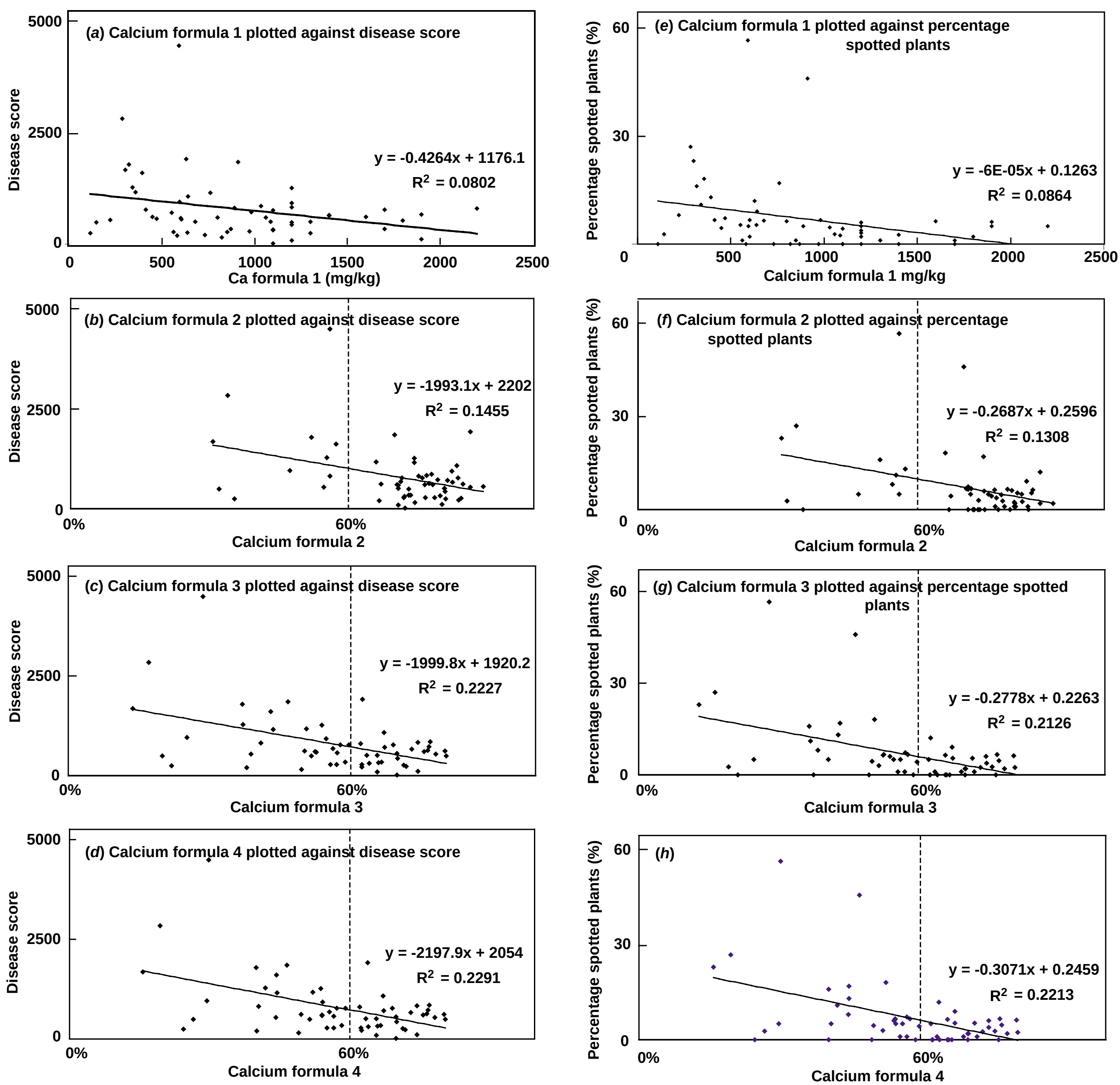

Figure 1. Relationships between calcium formulas 1–4 and disease parameters.

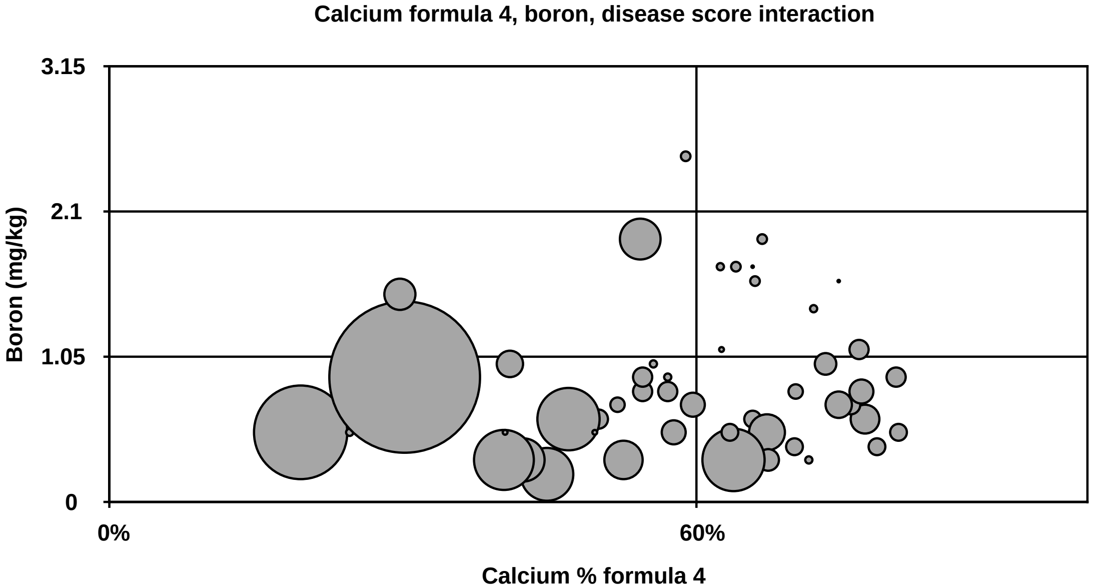

Figure 2. Calcium percentage formula 4, boron and DS interaction; DS is represented by the width of bubbles.

for PS (Fig. 3). These 2 elements alone would seem to be useful disease predictors. Palm (1963) suggests the primary effects of calcium and boron in reducing infection and subsequent development of club root in turnip are on the resistance of the epidermal cell to invasion, rather than on the persistence of the pathogen. If this is the case, then the same mechanism may well apply to air-borne pathogens such as Sigatoka of banana. That only 10 of the 50 sites had above 60% calcium calculated in formula 4 and 1 mg/kg boron suggests adjustments of many of the soils in the study may reduce reliance upon fungicides. Only 13 of the 50 sites tested for boron levels had boron concentrations above 1 mg/kg. The potential for disease development could feasibly increase in a logarithmic manner as soil calcium/boron levels are lowered. Measured disease levels would then vary below this potential depending upon the other disease control factors. Further suggested work includes testing various soil calcium and boron levels in small plot trials where other factors affecting disease are constant across treatments. Future trials should include calcium and boron leaf tissue analysis. It should be noted that the leaf disease data were collected as part of commercial

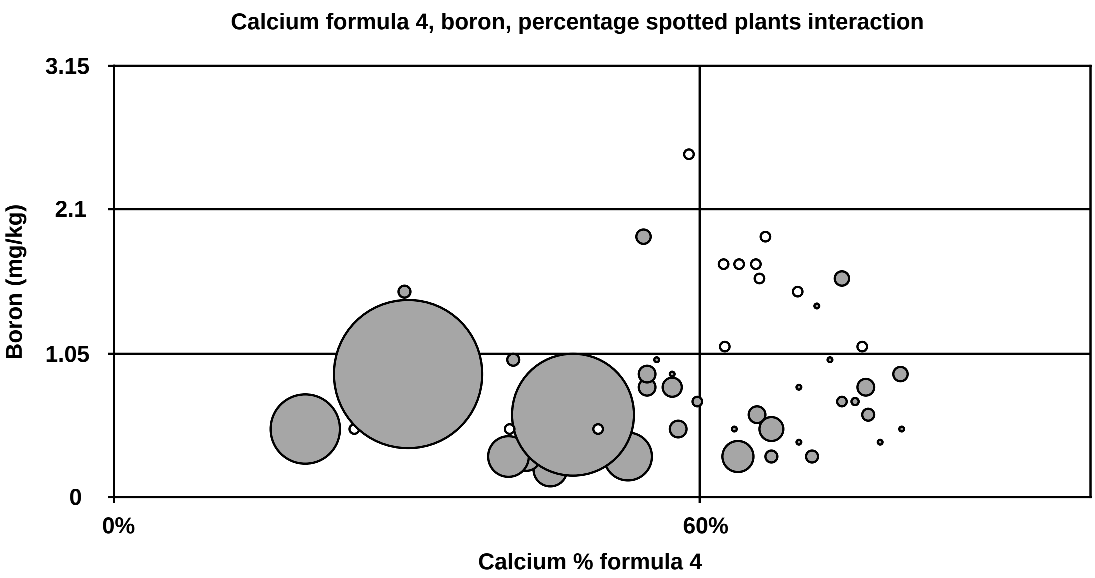

Figure 3. Calcium percentage formula 4, boron and PS interaction; PS is represented by the width of bubbles; hollow bubbles represent zero PS values.

disease monitoring. Fungicides were selected and scheduled depending upon DS. Cultural control practices such as removal of diseased leaves were recommended depending upon measured PS. This meant higher scoring sites received additional applications of fungicides and a higher proportion of systemic rather than protectant fungicides as well as a higher level of cultural control measures. Fungicide application interval varied from 7 to 28 days. Sites with high disease scores received up to 31 fungicide applications in the survey period while low disease scoring sites received as few as 21.

The formula used to calculate the calcium percentage has a large impact on the disease–calcium relationship. This is demonstrated by the variation in the regression coefficients in Figure 1 and also shown in the numbers of sites with soil calcium percentages above 60%. Analyses using formula 2 resulted in 46 of the 57 sites with soil calcium levels above 60% while calculations with formulas 3 and 4 both resulted in 28 out of 57 sites. Formula 2 is widely used commercially and this may explain why the disease–calcium interaction has not been detected in earlier studies. Previous studies by Johns and Vimpany (1999) and by Moody and Daniells (2002) have demonstrated that optimum yield in banana can be obtained at pH 5.5. At pH 5.5 about 29% of the TEC is estimated to be occupied by hydrogen ions (Albrecht 1975). This makes 71% of the TEC available for calcium, magnesium and potassium, meaning a calcium percentage greater than 60% is unlikely at pH 5.5 using this formula. The pH and calcium required for optimum plant health in banana may be higher than that required for optimum yield.

Conclusion

In our study of banana sites in Far North Queensland, we have found evidence to support the disease–calcium interaction, predicted by the principle of cation balance as developed by Albrecht (1975). The strength of the relationship between calcium saturation and disease activity is highly dependant upon the method of calculation used. The interaction of boron in the calcium saturation disease relationship is a significant finding. Palm (1963), Keane and Sackston (1970), and Edgington and Walker (1958) had similar findings with other hosts and diseases. This suggests these results may be repeated in other crops.

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References

Albrecht WA (1975) ‘The Albrecht papers.’ (Acres USA: Metairie, LA)

Edgington LV and Walker JC (1958) Influence of calcium and boron nutrition on development of fusarium wilt of tomato. *Phytopathology* **48**, 324–326.

Engelhard AW (1989) ‘Soilborne plant pathogens: management of diseases with macro- and microelements.’ (APS Press: St Paul MN)

Ganry J (1986) Basic principals of a forecasting system for regulated control of Sigatoka disease in banana when using a systemic oil fungicide. In ‘Proceedings improving citrus and banana production in the Caribbean through phytosanitation’. St Lucia, 2–5 December.

Hazelton PA and Murphy BM (1992) ‘What do all the numbers mean? A guide for the interpretation of soil test results.’ NSW Department of Conservation and Land Management, Sydney, NSW.

Johns GG and Vimpany IA (1999) Interaction of pH amendment and potassium fertiliser on soil chemistry and banana plant growth. *Australian Journal of Agricultural Research* **50**, 199–210.

Keane EM and Sackston WE (1970) Effects of boron and calcium nutrition on flax on fusarium wilt. *Canadian Journal of Plant Science* **50**, 415–422.

Moody P and Daniells J (2002) Managing soil acidity in banana production. *Good Fruit and Vegetables* **12**, 33–34.

Palm ET (1963) Effect of mineral nutrition on the invasion and response of turnip tissue to *Plasmodiophora brassicae* wor. *Contributions from Boyce Thompson Institute* **22** 91–112.

Rayment GE, Higginson FR (1992) ‘Australian laboratory handbook of soil and water chemical methods.’ (Inkata Press: Melbourne)

SPSS Inc. (2001) ‘SPSS Base 10.0 for Windows user’s guide.’ (SPSS Inc.: Chicago, IL)

Stover RH (1974) Effect of measured levels of Sigatoka disease of bananas on fruit quality and leaf senescence. *Tropical Agriculture* (Trinidad) **51**, 531–542.

Walters C and Fenzau CJ (1996) ‘Eco-farm.’ (Acres USA: Metairie, LA)

Zimmer GF (2000) ‘The biological farmer.’ (Acres USA: Metairie, LA)

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