Comparison of soil tests with plant response to nutrients in selected soils of Vanuatu

Marie Melteras[1], Jane O'Sullivan[2], Colin Asher[2] and Vincent Lebot[1]

[1]Vanuatu Agricultural Research and Training Centre, PO Box 231 Luganville, Espiritu Santo, Vanuatu.
[2]School of Land and Food Sciences, The University of Queensland, Brisbane 4072, Australia Email j.osullivan@uq.edu.au

Abstract

Soils from seven sites in Vanuatu were evaluated by nutrient omission pot trials to identify deficiencies of plant-available nutrients. Results from these trials were compared with relevant soil test results, namely nitrate nitrogen, available phosphorus ($NaHCO_3$ and H_2SO_4 extractants), exchangeable potassium and extractable sulfur. Except for sulfur and H_2SO_4-extractable P, the correlations between soil test value and plant response were poor, and all soil tests incorrectly assigned at least one of the seven soils to the "deficient" or "adequate" categories. In the case of sulfur, increasing the critical value to about 20 mg/kg would have improved the predictive power of the test.

Media summary

Standard soil tests were unreliable predictors of deficiencies of nitrogen, phosphorus, potassium and sulfur in various soils of Vanuatu.

Introduction

Soil tests are commonly used to anticipate the response of crops to fertilization. They are developed empirically to estimate the quantity of each nutrient that is available to the crop, and are calibrated against the actual fertilizer response of a particular plant species on a particular soil. However, the correlation between soil test result and actual nutrient availability may vary considerably across a range of soil types, requiring that the applicability of the test be verified for each combination of soil and species.

A good soil test should be well correlated with plant growth, showing a clear positive relationship between test value and growth or yield of a plant grown in that soil compared with a similar plant supplemented with adequate levels of the nutrient under examination. The test should also be appropriately calibrated, so that critical values accurately separate deficient from adequate soils.

The current study was part of a wider investigation of soil fertility constraints for yam production in Vanuatu. It was undertaken to identify nutritional deficiencies at selected field sites, and to test the usefulness of routine soil tests as predictors of such deficiencies.

Methods

Soils were collected from sites selected for future field experiments. These were at Mele, Teouma and Montmartre on Efate Island, VARTC and Fanafo on Espiritu Santo Island, Naviaru on Malo Island and Lolbuavatu on Pentecost Island.

Quantin (1982) described and analysed soils from throughout Vanuatu, including sites near those selected in this study. His analyses are summarised in Table 1. The Mele soil is a grey sandy loam of mixed alluvial origin. All other soils are reddish-brown clay loams, derived from volcanic ash deposited on limestone plateaux. They are high in iron oxides and strongly phosphorus-fixing. They vary in age and depth of ash, degree of weathering and cropping/land use history. All soils collected in this study had a neutral pH except Montmartre, which was mildly acidic at pH 5.4 (1:5 soil:water). However, liming the Montmartre soil did not improve plant growth in a preliminary pot trial.

Table 1. Characteristics of selected Vanuatu soils (according to Quantin, 1982)

Soil Fraction	Mele	Teouma	Montmartre	VARTC	Fanafo	Naviaru	Lolbuavatu
Organic matter (%)	7.4	8.7-12.8	8.7-12.8	5.4	9.9	5.4	9.6
Clay (%)	16.4	40-66	40-66	47.8	42.9	47.8	30.4
Silt (%)	10.6	16-33	16-33	30.3	25.7	30.3	21.6
Fine Sand (%)	45.8	1.6-19.6	2-20	7.6	10.7	7.6	31
Coarse Sand (%)	16.1	2.3-15.7	2-16	9.0	10.8	9.0	7.4
Organic carbon (%)	4.2	4.4-6.7	4.4-6.7	2.8	5.2	2.8	4.9
Nitrogen (%)	0.38	0.44-0.70	0.45-0.70	0.32	0.72	0.32	0.47
C/N	10.8	9.5-12	9.6-9.8	8.9	7.2	8.8	10.4

Approximately 200 kg of soil from the top 15 cm was collected at each site and shipped to the Vanuatu Agricultural Research and Training Centre (VARTC) for pot experiments. Subsamples were chemically analysed at Incitec Laboratories, Brisbane, or at the School of Land and Food Sciences, University of Queensland. Both laboratories followed standard methods of the Australian Soil and Plant Analysis Council (ASPAC) and used ASPAC standard soils as checks in all tests. The tests reported here are those relating to deficiencies detected in the pot trials, namely nitrate (1:5 soil:water), phosphorus (Colwell test: bicarbonate-extract, and BSES test: sulfuric acid extract), potassium (ammonium acetate extract), and sulfur (calcium hydrogen phosphate extract). These followed methods 7B1, 9B1, 9G1, 15D3 and 10B3 respectively, in Rayment and Higginson (1992).

Each soil was subjected to a nutrient omission pot trial, after Asher et al. (2002), using maize as the test plant. In these experiments, the control consisted of pots supplied with all essential nutrient elements at estimated adequate levels. Appropriate nutrient levels were selected on the basis of a preliminary trial with each soil. For each test treatment, all nutrients were added except one. Plants grown in the latter pots depended on the soil for supply of the missing nutrient only. Hence growth which was less than in the “all nutrients” control indicated a deficiency in the soil of the omitted nutrient. Four replications of each treatment were used, except in the control treatment where there were 8 replicates. Pots were lined with plastic bags to prevent nutrient leaching, and filled with 1.5 kg of air-dried soil. To apply nutrients, the soil from each pot was spread in a thin layer on a plastic sheet, measured amounts of stock nutrient solutions were applied and the soil was mixed thoroughly before returning to the pot and wetting to field capacity. Maize seeds of standardized weight were germinated prior to planting and three seeds per pot were sown; plants were thinned to two per pot after one week. Pots were watered daily to weight to maintain soil moisture at approximately field capacity throughout the growing period. After 22 days, the trials were harvested, the plant tops were dried at 65?C and weighed. The data were subjected to Student's t test to determine the probability of a difference between each omission treatment and the control. Results from the pot trials and soil tests were compared to evaluate the predictive ability of each soil test.

Results and Discussion

Nutrient omission pot trials revealed deficiencies of phosphorus in all soils tested, of nitrogen in four soils, of potassium in two soils and of sulfur in two soils (Table 2). No other nutrient deficiencies were detected.

Table 2. Summary of results of nutrient omission trials on seven soils.

Soil No.	Island	Site	Relative top dry weight (% of control)			
		Treatment:	All-N	All-P	All-K	All-S
1	Efate	Mele	54.4 *[1]	54.5 *	102.0 ns	81.4 *
2	,,	Teouma	61.7 *	38.3 *	78.7 *	93.0 ns
3	,,	Montmartre	98.0 ns	32.6 *	73.9 *	93.4 ns
4	Espiritu Santo	VARTC	78.3 *	23.9 *	108.0 ns	84.4 *
5	,,	Fanafo	97.4 ns	18.4 *	88.9 ns	97.9 ns
6	Malo	Naviaru	102.6 ns	37.1 *	97.1 ns	104.5 ns
7	Pentecost	Lolbuatu	81.9 *	28.7 *	87.9 ns	92.8 ns

[1]Relative dry weights which were significantly lower than the control “All nutrients” treatment, at P=0.05 or less according to Student’s t-test, are marked *.

Relative yields for each nutrient recorded as deficient were plotted against the soil test result for that nutrient (Figure 1). Previously reported critical ranges for these tests were obtained from Peverill et al. (1999) and used to assign each soil as deficient or adequate for the tested nutrient.

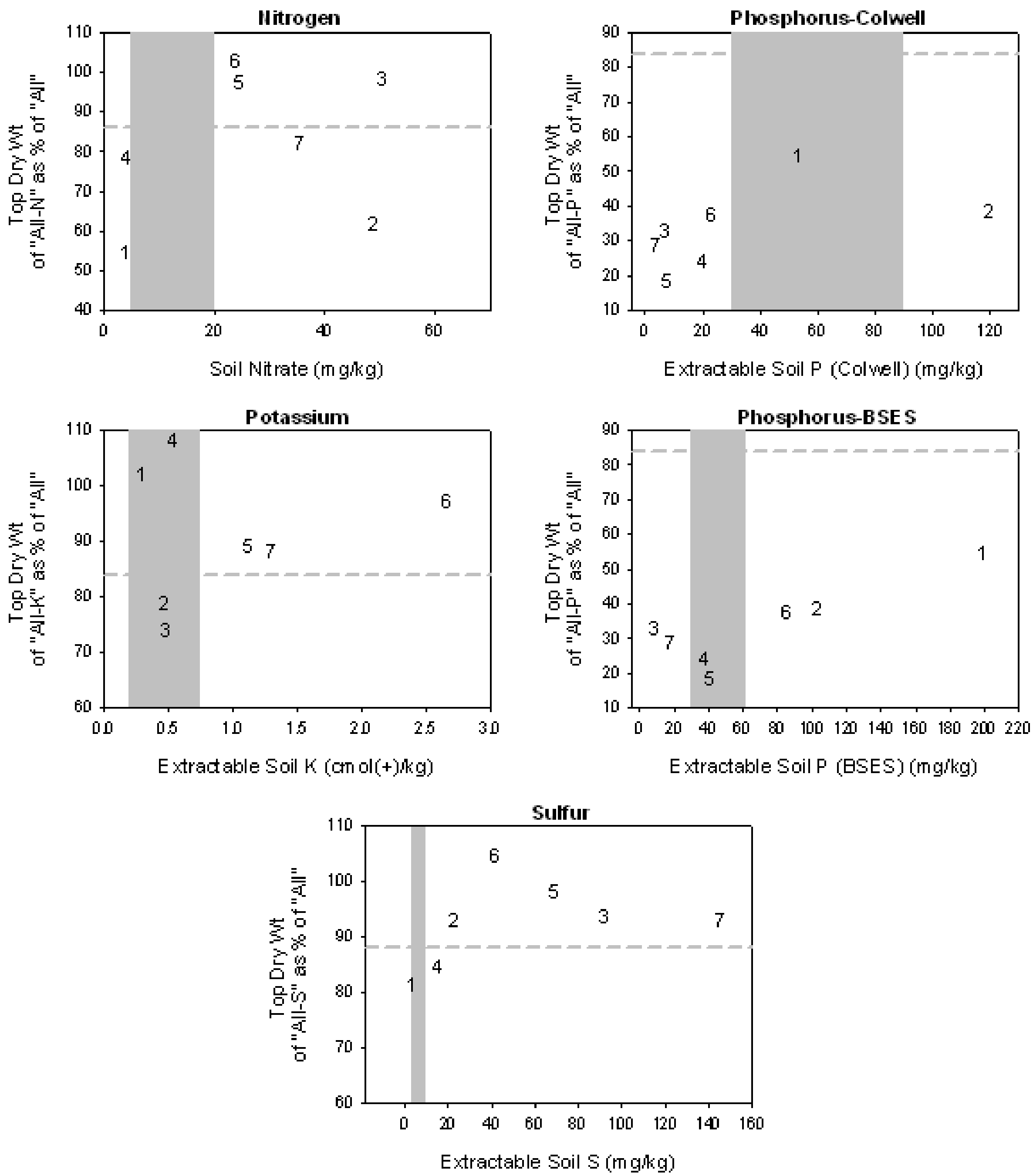

Figure 1. Relationships between soil test result and nutrient response of maize in nutrient omission pot trials for selected Vanuatu soils. Data points are numbered corresponding to the soil numbers in Table 2. Vertical shaded areas represent approximate critical range for various crops and soils (Peverill et al, 1999). Horizontal dashed lines separate deficient from adequate yields according to Student's t-test ($P<0.05$).

All soil tests appeared to have some correlation with plant response, although the few data points did not allow statistically significant models to be fitted. However, no test successfully predicted the deficiency or adequacy of nutrient supply in all soils. Critical ranges appeared to be appropriate for nitrate and potassium, but the nitrate test wrongly determined two deficient soils as adequate, while the potassium test found two soils deficient which appeared not to be so.

Phosphorus was severely limiting to plant growth in all the soils tested, although both P tests found one or more soils to have high P levels. It is noted that critical ranges quoted in Landon (1984) (p136) are considerably lower, at 5-15 mg/kg for Colwell P and 20-40 mg/kg for dilute H_2SO_4-extractable P. Phosphorus sorption indices (method 9I1 in Rayment and Higginson, 1992) for these soils were in the range 50-60 (moderately high) except for Mele (soil 1), where the PSI was 29, regarded as very low (Peverill et al, 1999). For this soil, the lower end of the critical range should apply, yet both tests gave considerably higher readings. In the case of the BSES test, the overestimation may be indicative of significant calcium phosphate levels in this soil. Since none of the tested soils supplied adequate P, an appropriate critical level cannot be suggested. It is not possible to say whether the high readings are due to poor correlation or inappropriate calibration.

For sulfur, recalibration with a critical level of approximately 20 mg/kg would achieve successful assignment of these soils. However, it should be noted that the sulfur deficiency indicated in these pot trials, using topsoil only, have not been corroborated in the field, where subsoil sulfur may have supplied crop needs. A deeper sampling regime may be more appropriate for sulfur.

Table 3 summarizes the predictive success of the soil tests in assigning soils as either deficient or adequate for the tested nutrient.

Table 3. The number of soils successfully predicted or not predicted as either deficient or adequate by each soil test applied.

Test	Extractant	Deficient Soils		Adequate Soils	
		Predicted	Not Predicted	Predicted	Not Predicted
Nitrate	Water	2	2	3	0
P (Colwell)	0.5M $NaHCO_3$	5	2	0	0
P (BSES)	0.005 M H_2SO_4	4	3	0	0
K	1M NH_4OAc	2	0	3	2
S	0.01M $Ca(H_2PO_4)_2$	1	1	5	0

Conclusions

This study examined a small range of soils, and measured short-term plant growth in pot experiments. Such studies are not as reliable as field trials for the calibration of soil tests. However, the data have highlighted the limited reliability of soil analyses in predicting plant responses to fertilization. For nitrate and exchangeable potassium, some soils did not follow the general correlation and were wrongly assigned as a result. For available sulfur, the previously published critical range was not appropriate for the range of soils tested. As no soils were non-deficient in phosphorus, it was not possible to assess to what extent calibration or correlation contributed to wrong assignments. Nevertheless, the majority of soils were correctly assigned as either deficient or non-deficient by each test.

Acknowledgement

The research described was funded by the Australian Centre for International Agricultural Research, under the project Diagnosis and Correction of Nutritional Disorders of Yam.

References

Asher C, Grundon N and Menzies N (2002) How to unravel and solve soil fertility problems. ACIAR Monograph No. 83, 139p.

Landon JR ed (1991) Booker tropical soil manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Harlow, UK, Longman Scientific and Technical, 474p.

Peverill KI, Sparrow LA and Reuter DJ eds (1999) Soil analysis – an interpretation manual. CSIRO Publishing, Australia, 369p.

Quantin P (1982) Vanuatu agronomic potential and land use map. Explanatory notes. ORSTOM, Paris.

Rayment GE and Higginson FR (1992) Australian laboratory handbook of soil and water chemical methods. Inkata Press, Melbourne, 330p.