ASPECTS OF TARO PRODUCTION ON THE SHALLOW CALCAREOUS SOILS OF NIUE

R.J. Lucas*, B. Punu** & W.J. Cable***

SUMMARY

Methods of subsistence taro growing on the Pacific island of Niue (19°S) are described. Also described in outline is a package of practices based on research that can substantially increase yields. The 'package' includes use of a siratrotaro rotation with siratro being undersown in taro and taro hulis being planted in siratro stubble killed by herbicides. Trials with responses to N, K and Zn are reviewed. Soil pH increases between 6.7 and 8.2 with percent coral sand and taro weight decreases linearly as pH rises, unless induced deficiencies are remedied. Foliar analysis confirms, and can be used to measure K and Zn deficiency. Iron may also be deficient at high pH.

RESUME

Les méthodes de la culture du taro de subsistance dans 1'île pacifique de Niué (19° S) on été exposées. De méme un paquet technologique permettant d'accroître sensiblement le rendement a été exposé dans ses grandes lignes. Le "paquet" comprend une rotation siratro-taro; 1'opération consiste à semer le siratro au bas du taro et á planter les hulis du taro sur le chaume du siratro détruit par des herbicides. Des essais de réponses a N, K et Zn ont été passés en revue. Le pH du sol accroît entre 6, 7 et 8.2 pour cent quand il s'agit du sable coralligène, et le poids du taro décroît de facon linéaire quand pH monte, à moins de pallier aux défaillances provoquées. L'analyse foliaire confirme et peut étre utilisée pour mesurer le manque de K et de Zn. Le fer fait aussi probablement défaut quand pH est élevé.

RESUMEN

Se describen métodos de cultivo (de subsistencia) de malanga en la Isla del Pacĩfico de Niue (19°). Se reseña también un paquete de prácticas, basadas en investigacion, que pueden incrementar substancialmente los rendimientos. El "paquete" incluye el empleo de una rotación siratro malanga con el siratro sembrado antes de malanga para despues sembrar las "estacas" (hulis) de la malanga sobre el rastrojo del siratro, eliminado con herbicidas. Se revizan ensayos sobre respuesta a N, K y Zn. El pH del suelo se incrementa de 6.7-8.2 a medida que aumenta el porcentaje de arena coralĩfera y el peso de la malanga decrece linealmente a medida que el pH se eleva, a menos que las deficiencias inducidas se subsanen. El análisis foliar confirma y puede ser usado para medir deficiencias de K y Zn. El Hierro puede ser deficiente a pH elevados.

INTRODUCTION

The Pacific island of Niue is an isolated coral atoll of 26,300 ha which lies south of Samoa and east of Tonga at 19°S and 170°W. The Niuean people are Polynesians who have close cultural relationships with their Tongan and Samoan neighbours. Taro is the staple food, and on ceremonial occasions the number and size of taros presented by a family or village are a measure of vigour and status.

The humid tropical trade wind climate is favourable for crop growth. Mean annual rainfall is 2000 mm with about 60% falling during the warmer wetter season from December to April.

The principal soil parent material is volcanic in origin. Soil depths vary considerably over very short distances because of the irregularity of the underlying former lagoon and reef formations. Crop growth and natural vegetation reflect variations in soil depth. On substantial areas mechanical cultivation is impossible because of limestone outcrops, while in other places where the absence of rock allows the use of machinery, the mantle of soil over the underlying makasea (coral sand) is often so shallow that cultivation can result in mixing this sand with top soil. The consequent increases in calcium carbonate and pH aggravates trace element deficiencies.

Wright and van Westerndorp[1] presented a comprehensive account of the soils and agriculture of Niue, but this was before Widdowson's important work on zinc deficiency. In general the soils are classified as latosols of high base status with large amounts of aluminum and iron oxide clays. Silica content is low and mineral reserves of potassium are extremely low. Exchangeable potassium is also low on account of high

* Agriculture Department, Niue, South Pacific.
** East-West Centre Grantee, University of Hawaii.
***East-West Centre Grantee, Department of Botany, University of Hawaii, Honolulu, Hawaii 96822.

levels of exchangeable calcium and magnesium. Both total and available phosphorus values are high, but sulphur is considered to be marginally deficient. Widdowson demonstrated the presence of marked zinc deficiency in most crops growing on the shallower soils[2,4], and in a soil with pH 8 and 41% calcium carbonate he showed that *Crotalaria anagyroides* responded to iron.[3] Leaf analyses have shown that manganese and copper are sometimes below optimum in some crops, and molybdenum is currently being investigated. Molybdenum levels in legume leaves were unexpectedly low for plants growing in soil with such high pH. Responses to fertilizer nitrogen are usually obtained but the magnitude of the response depends on growing conditions and previous land use. Table 1 presents some chemical analyses of a shallow and deep soil to show the range encountered within one soil type. Most topsoils have pH values between 6.8 and 7.4.

SUBSISTENCE TARO GROWING

Shifting cultivation has enabled a population of up to 5000 to maintain themselves on their infertile island. Bush fallows of at least ten year duration after a single taro crop are necessary to maintain soil fertility. Taro yields in general are low and depend on the length of the preceding bush fallow, rainfall, the depth of soil to rock or coral sand, amount of coral sand in soil (pH), the cultivar planted and the thoroughness of weeding. Fresh corms in an average to good crop weigh about 400 g (500 kg corms/ha) but the yield range is wide.

Land clearing and burning, planting, weeding, and harvesting are the main operations of which the three or four hand weedings are by far the most laborious. Practices such as mulching are not normally considered; irrigation is impossible because there is no surface water and fertilizer is rarely used in crops grown in the traditional way. The average taro garden is about 0.1 ha and, as taros are planted successively at about two week intervals, a balanced age range results and harvests for domestic consumption can be taken throughout the year.

Over 30 taro cultivars are recognised and at least seven of these are commonly grown. The most popular 'talo fase' matures from seven to nine months and accounts for approximately 70 percent of all taro planted. Talo fase is favoured for its sweet taste and moderate size, for while large, later-maturing cultivars may bring status to the grower, the smaller corms are generally considered more palatable.

EARLY FERTILIZER TRIALS ON TARO

Since its establishment in 1954 the Niue Agriculture Department has made efforts to assist subsistence taro production as well as cash cropping. Initial fertilizer trials were conducted using taro as the test crop, as it was considered that the use of fertilizer for all crops would be adopted more readily if yield increases could be demonstrated in the main subsistence crop.

Sulphate of ammonia, superphosphate and muriate of potash were used in various combinations and rates of application in a series of field trials[1]. Results were often statistically inclusive because of poor conditions for experimentation, but N and K gave varying responses depending on rainfall, time of planting, the length of the previous bush fallow, and cropping history of the land. Phosphate however did not appear to increase yields in any of the trials.

ZINC DEFICIENCY

After Widdowson's visit to Niue in 1964 and his subsequent pot trials in New Zealand confirming general conditions of zinc deficiency in Niue's shallow calcareous soils, the application of Zn to cash crops such as passionfruit and limes became normal practice. However, the use of Zn for subsistence taro crops has not yet been adopted.

Despite some outstanding responses to soil-applied Zn in several trials it was unsuccessful. Reasons for failure to obtain statistically significant responses to Zn in field trials were again related to soil variability and hence poor local control in experiments.

Taro is not well adapted to the calcareous high pH soils but, as it is the favoured staple, efforts must be made to overcome all deficiencies. The apparent inability of taro to take up trace elements from these soils in comparison with the apparent responsiveness of weeds is a problem, and nutrient placement will be important.

Methods which have been tried in recent trials have included: placement of Zn compounds in the base and sides of the hole before the huli (planting material or sett) is planted; placement of Zn in the side of the hole after the huli is planted but before consolidation with the koho (planting stick); soaking huli overnight in 1% zinc sulphate solutions before planting; and placement of Zn solutions in the taro leaf. The current recommendation is for 2 or 3 g of zinc oxide or 5 g of zinc sulphate to be placed on the soil surface at the planting hole site. Normal use of the planting stick in making the hole then ensures that the Zn is mixed throughout the soil immediately surrounding the newly planted huli.

CURRENT TARO FIELD TRIALS

Efforts are being made to define the relationships between soil properties and taro yield so that treatment responses can be assessed with more precision. Soil depth and pH are the most easily measured soil characteristics, and these have been recorded for each individual taro plant at harvest time in experiments on methods of Zn application.

A fairly close linear relationship between soil pH and taro weight has been demonstrated in the data from the Zn application trials. Taro yield per plant decreased from about 400 g where the soil pH was less than 7.0 to 200 g at 7.6 and 100 g at 7.8. Soil depth did not have a strong influence in this highly calcareous soil, but some of the deviation from the soil pH — taro weight relationship appears to be partially explained by soil depth variation.

A further problem encountered in field trials on such variable soils is the wide range in rate of taro maturity. The taro must either be harvested at some arbitrary time when most have matured but before appreciable corm deterioration occurs, or individual taros must be harvested as they mature. This second alternative is more realistic in relation to the subsistence garden situation, but it creates experimental and statistical difficulties which might be overcome by expressing yield in terms of production per unit time. Under Niuean conditions the harvest period for a single planting date could extend from seventh to ninth month in a crop of the 'talo fase' cultivar. Table 2 illustrates the situation when a trial of rates of zinc sulphate was harvested seven months after planting.

The top/root ratio is a useful index of 'maturity'. Thus control taro plants were mainly mature at seven months, but Zn treated taro was still in a state of vigorous leaf growth. Mature corm weights for the Zn-treated plants would have been considerably greater if they had been allowed a longer growth period than the weights of the immature corms harvested at the date considered appropriate for the untreated control plants.

DEFICIENCY SYMPTOMS AND FOLIAR ANALYSES

Because of the rather variable and sometimes inconclusive results obtained in field trials and the need for numerous soil depth and pH measurements, less laborious and expensive approaches to plant nutrition problems are being sought. Visual assessment (qualitative assessment) of crop nutrient deficiencies can be helpful in understanding some of the apparent anomalies encountered with conventional field trials. Foliar analysis is likely to provide a quantitative dimension.

Three month old, third leaves of the cultivar 'talo fase' with symptoms which were assumed to indicate K and/or Zn deficiency were collected, sorted into groups, dried at 80°C and analysed in Hawaii. Potash deficiency was assumed initially to be indicated by marginal chlorosis followed by necrosis which extended from the leaf margins into the interveinal areas in older leaves. Interveinal chlorosis without the marginal necrosis and spreading necrosis was considered to be characteristic of Zn deficiency.

Assumed zinc deficient leaves were sorted into four groups for analysis. Results are presented in Table 3. The field diagnosis of K deficiency was confirmed. The level of K decreased with increasing severity of marginal chlorosis and necrosis. Calcium, Mg and P levels were all very high, while N was deficient. Sulphate, Mn, and Cu all appeared to be adequate, but nitrate had accumulated in the most extreme K and Zn deficiency groups. Iron and Zn were both in the deficient range in all samples, and while their values did not decrease much with increasing severity of chlorosis, it was notable that P, Ca and Mg levels all increased considerably from high to excessive values in the most K-and Zn-deficient samples.

Comparison of results in Table 3 with Hawaii tentative standard values for dryland taro leaves confirmed that present fertilizer recommendations are along the correct lines, with the exception that N, K and Zn applications may have to be supplemented with Fe if optimum growth is to be achieved. Trials will be initiated to test the need for Fe in taro.

INCREASING THE EFFICIENCY OF SUBSISTENCE TARO PRODUCTION

Labour in the active age group is increasingly scarce through migration to New Zealand, so there is a need in Niue to reduce the amount of time required to produce taro for domestic use. Also, labour released from taro production can be diverted to cash cropping, such as the provision of an adequate and regular supply of fruit to the recently completed food processing factory.

Widespread adoption of chemical weed control could lead to large increases in taro production per unit of labour. Mixtures of contact and pre-emergence herbicides show great promise. Paraquat mixed with prometryne is the best combination tested so far.

Herbicides can also play a role in assisting the growing of siratro (*Macroptilium atropurpureum*) as rotational cover crops in place of a bush fallow between taro crops. A continuous four year rotation between these would be attractive. It has been demonstrated that taro can be planted directly into siratro which had been killed with either 2,4-D or a mixture of 2,4-D and picloram. Taro growth was not affected by residues at any of the herbicide rates used, but all rates killed the siratro. Accessible, easily worked land could therefore be cropped much more intensively than usual without any deterioration in soil fertility, if siratro seed was undersown in the maturing taro crop ahead of the usual pre-harvest weed invasion. Then, after about three years of soil rejuvenation and application of 2,4-D, the area could be replanted in taro by using the planting stick to make planting holes through the mulch of dead legume stems and leaves.

Increased fertilizer use on taros results in increased yields. Closer spacing than the traditional 90 cm x 90 cm in good soil pockets should prevent corm size from becoming undesirably large. N and K fertilizer is recommended in at least two applications after weeding during the first four months. Zinc should be incorporated with the soil when the planting hole is made.

Considerable increases in subsistence taro production are easily attainable if the presently available technology is adopted. Unfortunately, traditional subsistence agricultural methods are often extremely slow to change, but hopes are held that increasing material aspirations may provide the incentive for greater use of herbicides, fertilizers and cover crops.

REFERENCES

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3. — — — — — (1966) Chlorosis in seedling *Crotalaria anagyroides* on a calcareous soil. *New Zealand J. Agric. Res.* 9, 261-7.

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TABLE 1

Chemical analyses of soils
(from Widdowson 1966a)

Fonuakula silty clay loam	Depth horizon (cm)	pH	Truog P (mg%)	Cation exchange properties							$CaCO_3$
				CEC	TEB	Base satn (%)	Ca	Mg	K	Na	
							(me.%)				(%)
Shallow site	0-10A	7.7	7	27.0	Free lime	-	-	3.5	0.38	0.2	8
Deep site	0-13A	6.2	8	29.4	25.3	86	19.1	5.7	0.30	0.2	0
	13-20AB	5.9	4	8.7	3.8	44	2.9	0.6	0.07	0.2	0
	20-43B	6.0	5	7.0	2.8	40	2.3	0.5	0.03	0.0	0

TABLE 2

Top/root ratios at harvest in relation to Zn weight applied

Treatment kg/ha $ZnSO_4.7H_2O$	Top/root ratio	Mean corm (g)
0	44	210
25	32	300
50	30	370
100	31	330

TABLE 3

Foliar analyses of taro leaves showing chlorotic symptoms (3rd leaves from 3 month unfertilized taro crop)

Deficiency symptoms: degree of severity	Major elements %					Trace elements ppm				NO_3	SO_4
	N	P	K	Ca	Mg	Mn	Fe	Cu	Zn	ppm	ppm
Zn_3Moderate	2.95	.69	1.79	4.08	.92	200	34	7.6	11.2	210	510
Zn_2Present	3.07	.53	1.66	3.52	.69	140	39	7.1	12.2	90	560
Zn_1Slight	3.17	.59	1.62	3.4	.65	186	42	8.1	12.4	96	530
Zn_0Faint	3.12	.54	2.1	3.0	.47	175	40	7.2	13.4	88	440
K_3 Obvious	2.60	.63	0.78	4.52	1.15	165	34	7.0	11.8	140	350
K_2 Moderate	2.50	.57	0.66	4.35	1.02	207	37	7.2	12.8	88	360
K_1 Slight	3.07	.65	1.51	4.00	.82	203	39	7.2	11.0	88	435
Above normal range		.56									
Normal				1.27	0.19	24	58	5	26		
Critical level	4.5	.40	6.2								
Sub normal	3.6	.20	3.2								
Deficient	1.8		1.5	0.55	0.09		45	2	14		50