Building and strengthening connections and relationships between actors for better soil management in Tonga

Compiled By Siosiua Halavatau

Introduction

This is the report of the contract (Agreement: 2020102729) between the consultant Siosiua Moala Halavatau and CSIRO Pacific Soils Project. The contractor identified and connected with key stakeholders from farmers to policymakers to politicians and the Pacific Soils Project team and facilitated the knowledge transfer process for the new or novel knowledge produced by the project around soil fertility and recommendations for enhanced production practices in Tonga by:

- Organising and facilitating workshops in partnership with Ministry of Agriculture Food and Forests (MAFF) for farmers, knowledge and advisory service actors, researchers and other key actors to share and transfer results of field trials in Tongatapu.
- Facilitating knowledge sharing of results from Tongatapu field trials with key national stakeholders and other actors of interest, e.g. Development projects, etc.
- Supporting the integration of soil knowledge and technology created by the project into existing platforms.
- Sharing insights and feedback from local conditions and user challenges, e.g. using technology or knowledge with the project team to build or enhance trust between researchers, agricultural knowledge and advisory network, farmers and policy makers.

To achieve these the contractor:

- Organised and conducted 3 interactive workshops on nutrient management, diagnosis of pests and disease and nutritional disorders at or near the trial sites with knowledge and advisory service actors, agribusiness and farmers and farmer groups in Tongatapu,
- Organised and facilitated at least 3 rapid soil testing events for farmers to test their soil and discuss what the results mean and how to develop fertilizer recommendations based on soil test results,
- Convened National workshops on Sustainable Soil Health and Fertiliser practice with knowledge and advisory services actors, agribusiness representatives, NGOs, policy makers, politicians, youths, etc, and other relevant innovation system actors to discuss the implications and potential responses to under fertilisation, and declining soil fertility from the farm level through to the national level,
- Brokered agreements with a few online platforms to include results from the Pacific Soils project on its portal for sharing with its users / farmers, exporters, etc.

Training in Nutrient Management, Diagnosis of Pests and Diseases and Nutritional Disorders

Prior discussions with stakeholders identified that apart from nutrient management, diagnosing nutritional problems and pests and diseases are also priority problems. Stakeholders agreed that it is vital for farmers as well as MAFF staff to diagnose problems in

the field correctly. Training was then structured to gather for nutrient management and diagnosis of pests and diseases and nutritional disorders.

This training was conducted for two farmer groups – Nishi Trading and the Eastern District watermelon growers, and MAFF Research and Extension staff. One of the farmer groups – Nishi Trading asked that a separate training on nutrient management be conducted for their famers since they were into planting watermelons for export. A separate training for diagnostic skills was also conducted for the Nishi Trading group. Table 1 below shows the 3 groups of stakeholders and the numbers that attended the training on nutrient management, diagnosis of pests and diseases and nutritional disorders. About 10% of the participants were women.

Table 1. Stakeholders and number of people attended the training. (Participants lists in Appendix 1)

Stakeholders	Training Workshop	Participants
Nishi Trading	Nutrient management	41
Nishi Trading	Diagnosis of pests and diseases and nutritional disorders	30
MAFF	Nutrient management, diagnosis of pests and diseases and nutritional disorders	31
Eastern District farmers	Nutrient management, diagnosis of pests and diseases and nutritional disorders	26
Total Number attended		**128**

These trainings were conducted by a team of Mr. Vunivesi Minoneti of the ACIAR CSIRO Pacific Soils Project delivering the nutrient management part, Mr. Tevita Tukunga from MAFF Extension and MAFF leader in Plant Health Clinic and watermelon trainer for MAFF delivering the diagnosis of pests and diseases and Siosiua Halavatau, the consultant trainer conducted the sessions on diagnosis of nutritional disorders for watermelon.

Training Objectives and Activities

The trainings were aimed at building the capacity of Agriculture sector key stakeholders – farmers (both commercial and subsistence) , youths, NGO staff, and MAFF Research and Extension staff in:

- Nutrient budget and management;
- diagnosing pests and diseases of watermelons;
- and identification of nutritional disorders in watermelon and some of the cucurbits like cucumbers and squash.

It should be emphasised that in research and extension, successful diagnosis of the problems a crop is facing is half the battle won and only the right cure is left but if one cannot identify the problem then the battle is lost before the war even begins.

Nutrient Management

The training was aimed at making stakeholders understand the concept of mass nutrient balance and how to manage the key nutrients applied as fertilizers. The training was conducted using PowerPoint presentations and discussions. We used the Pacific Soils Project watermelon data from the site with Fahefa soil to illustrate nutrient budgeting. The diagram

(Fig 1) below was used to explain to growers the nutrient inputs - the native soil fertility, how much nutrients are removed in the harvest, how much returned in the non-harvested biomass, and the potential losses. We discussed the logic behind the amount of fertilizers applied using yield targets and their nutrient uptakes, the amount in the soil from soil analysis, and phenomena like P-fixation for phosphorus and N use efficiency. We discussed the 4R approach of right source (NPK or single nutrient fertilizers), right rate (determined from soil test results), right time to apply and right place (broadcast/side dress or band placed).

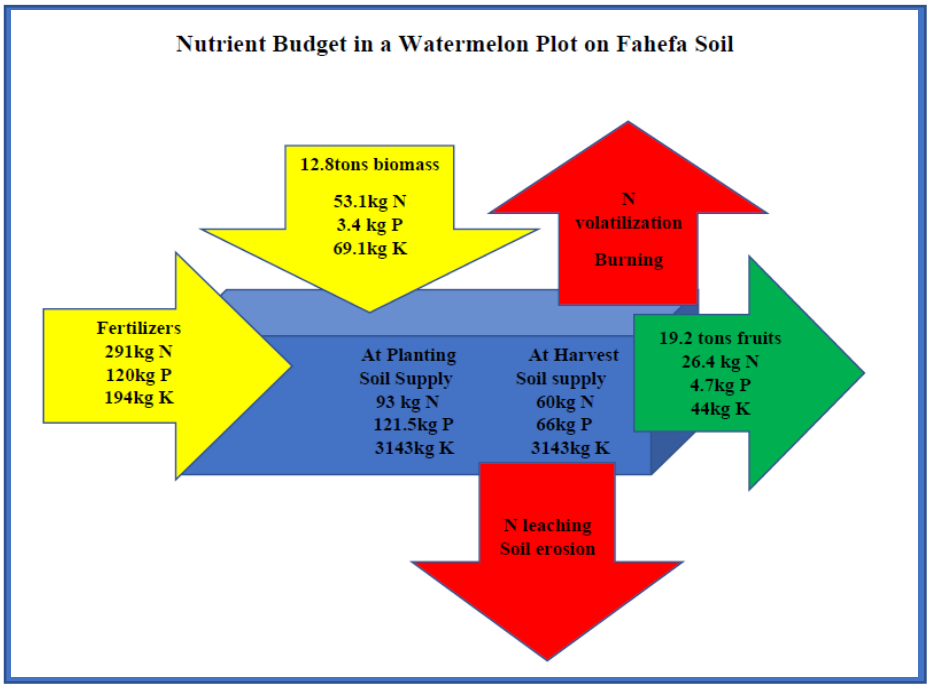


Fig 1. Nutrient balance sheet for watermelon grown on a Fahefa soil.

The nutrient balance sheet showed a few things that must be taken into consideration in improving nutrient management.

- Nitrogen inputs = 291 (fertilizer) + 93 (soil) = 384kg for the hectare
- Phosphorus inputs = 120 (fertilizer) + 121 (soil) = 241kg for the hectare
- K inputs = 194kg (fertilizer) + 3143kg (soil) = 3337kg for the hectare
- N removal = 26.4 (fruits) + 53.1 (non-harvest biomass) = 79.5kg
- P removal = 4.7 (fruits) + 3.4 (non-harvest biomass) = 8.1kg
- K removal = 44kg (fruits) + 69.1kg (non-harvest biomass) = 113.1kg

Soil test at harvest:
N = 60kg
P = 66kg
K = 3143kg

From the data above for:

- N = 384kg at planting and only 79.5kg was taken up by the crop. This means 304.5kg is the balance but the soil test at harvest is only 60kg left in the soil. Could the rest have been lost in leaching and volatilization – that is a big possibility. If the data can be used to work out an N use efficiency – it is only about 20%.

- P = 241kg at planting and only 8.1kg was taken up by the crop. This means 232.9kg is the balance but the soil test at harvest is only 66kg left. Could the rest have been fixed by the soil which has a P fixation capacity of more than 60%.
- K is not a real issue with so much K and the soil test at harvest did not differ from at planting.

This complete nutrient balance sheet is probably the first in Tonga and it shows us the inefficiency of our nutrient management strategy.

Using Nutrient Uptakes During the Growth Cycle to Guide Fertilizer Management

Currently the fertilizer management for watermelon in Tonga is at planting apply about 150g NPK (13-13-21) and at running apply about 100g Urea. Fig 2 below was used to show the uptake of N, P and K during the growth of a 90 to 105 days watermelon crop. It is very clear that at about 45 days N and K uptake increase sharply. The P uptake is relatively low throughout. With the low N use efficiency in Fig. 1 and the uptake pattern for N

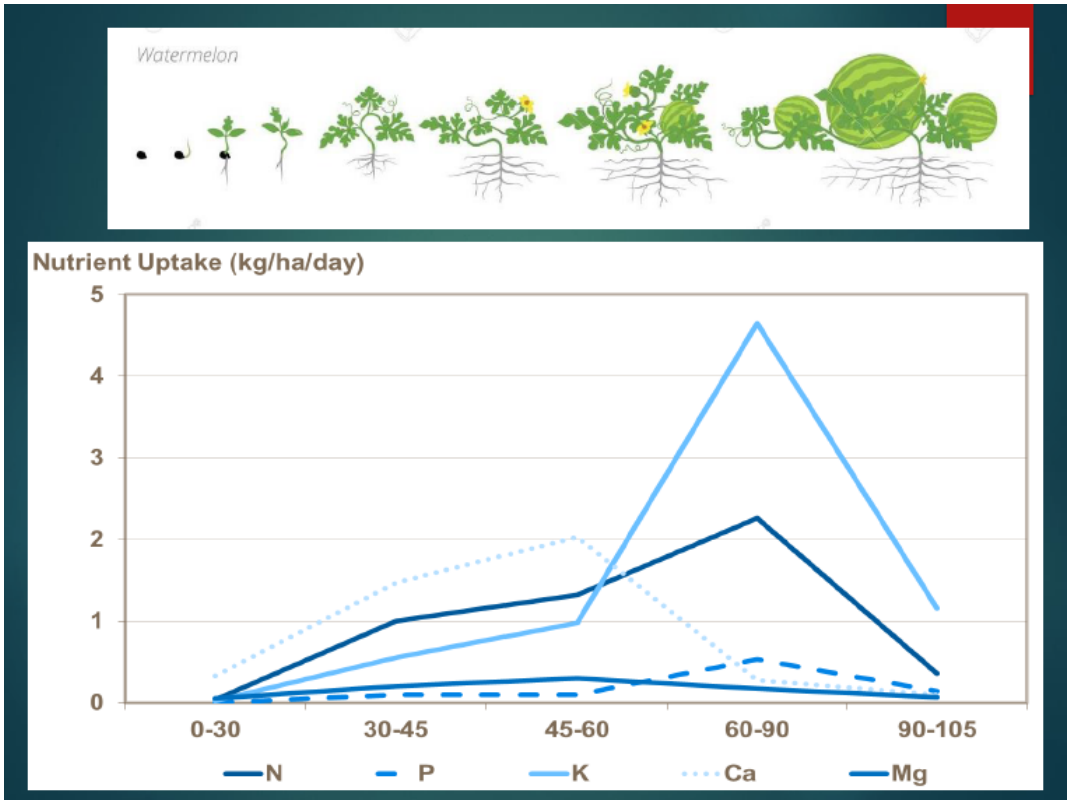


Fig 2. Nutrient uptakes of macronutrients by watermelon. (Adopted from Quattruci, 2000)

and K in Fig 2, we need to apply N and K at around 45th to 60th day to carry the fruits to harvest as well as the need to have K available for fruit quality. There was agreement to test this strategy against the traditional practice during this growing season.

Micronutrient Uptakes and Implication on Micronutrient Management

It was emphasised to the farmers that macronutrients like N, P and K are needed in larger quantities (kg/ha) whereas micronutrients (Fig 3) are needed in minute quantities (g/ha). It

was also emphasised that micronutrients are better applied as foliar application rather than soil applied because of the danger to run from deficient conditions to toxic levels. We also discussed the potential to negotiate with fertiliser manufacturers in New Zealand and Australia to fortify NPKs with some of the micronutrients.

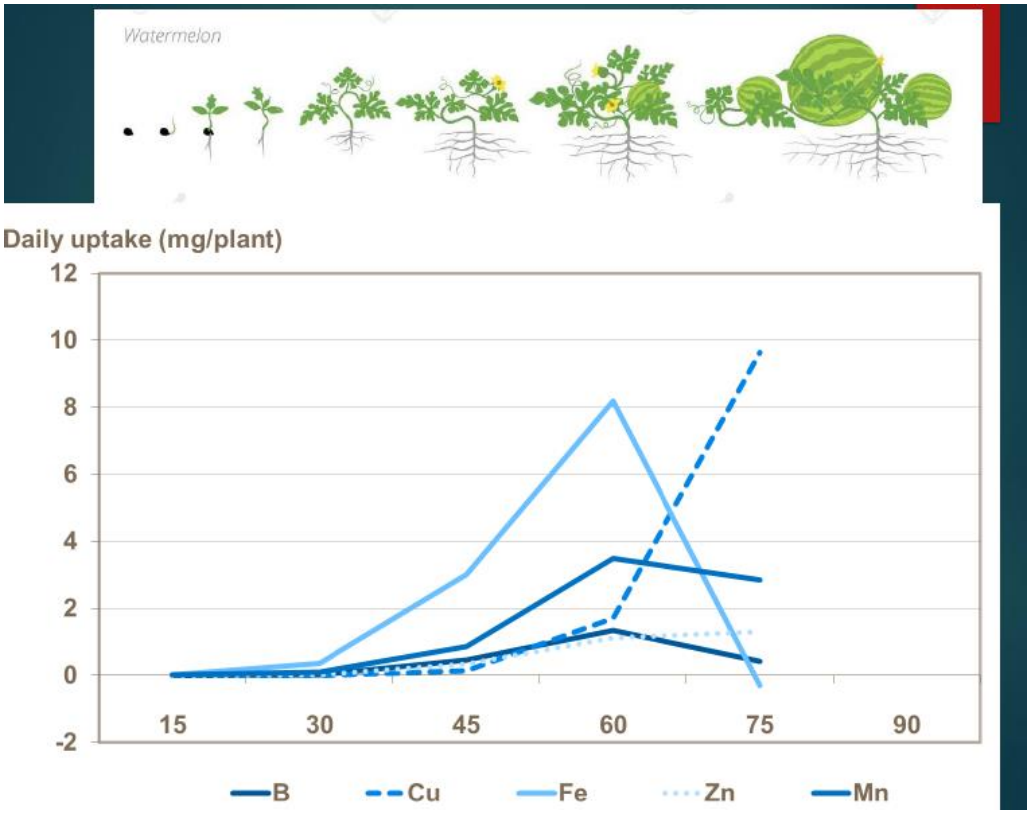


Fig. 3 Micronutrient uptakes of watermelon. (Adopted from Quattruci, 2000)

The growers were also advised to be cautious with applying too much P as it may antagonise availability of Zn in marginal areas and cause Zn deficiencies. Also where possible apply foliar micronutrient sprays 2 or 3 times in the growing cycle.

Responses and Impacts

The farmers were appreciative of the training and admitted their willingness to work together to improve nutrient management.

There was realization that having the alternatives of single nutrient fertilizers like Urea, CAN, Muriate of Potash and Single and Triple Super Phosphate apart from NPKs will help them greatly to improve their nutrient management based on soil test results.

Minoru Nishi, the owner of the Nishi Trading also has an agricultural input supply store, will now order the straight fertilizers as well. There is also the opportunity to also have some micronutrient sources available.

Many of the MAFF staff saw the inefficiency of the nutrient use and ask how to improve nutrient use. We discussed the 4R approach: Right source – at the moment we are constrained with use of NPKs but one of the input suppliers agreed to import single nutrient fertilizers like Muriate of Potash and single and triple superphosphate.

Right amount – soil tests will be used more to guide fertilizer recommendations.

Right time – from the nutrient balance and use efficiency – split applications of N and K sources were agreed on but on-farm trials should be established.

Right place – band placing P sources should be promoted and broadcasted N should be applied and buried.

The farmers and MAFF staff were looking forward to the soil test training to further discuss some of these issues.

The way forward will be the group, MAFF and the consultant will look at opportunities to run some on farm trials comparing their current nutrient management practices and those suggested in the training.

Diagnosis of Pests and Diseases

Someone who has a plant problem will ask two questions: What is the problem, and how do I correct it? These are hard questions for beginners and experts alike. Diagnosis is the process of determining the cause of a problem. It can be a long or short process depending on one's ability, experience, and the nature of the problem. Once the cause is known, an appropriate management strategy can be developed.

The presentation was well received by the farmers and MAFF staff. Farmers and Extension agents and Research scientists were encouraged to download the app Pacific Pests from internet and use the factsheets to identify pests and diseases.

Fig 4. Some of the most common insect pests of watermelons and photos for diagnosis.

Leaf miner

Melon worm

Thrips

Aphids

Squash beetle

Broad mite

Fig 5. Some of the most common diseases



Fusarium wilt Downy mildew Anthracnose


Gummy stem blight Powdery mildew


Papaya ringspot in watermelon.

The papaya ring spot was highlighted as a disease of concern for watermelon export to New Zealand.

One of the discussing points was chemical use. Table 2 gives the list chemicals that can be used on watermelon, the pests and disease they control and instruction on rates for mixing in knapsack or mist blowers.

Table 2. Chemicals for control of pests and diseases of watermelon

Pesticide	***Pesticides that can be used as well***	***Pests and diseases***	***Mix per knapsack***	***Mix per mist blower***

Manzate	Mancozeb (Contact & Systemic Properties)	Fungal Diseases	90ml	120ml
	Suncozeb (Contact & Systemic Properties)	Fungal Diseases	90ml	120m
	Kotek (Contact & Systemic Properties)	Fungal Diseases	90ml	120m
	Tilt (Contact & Systemic Properties)	Fungal and Bacterial Diseases	90ml	120m
Copper	Copper Hydroxide (Contact & Systemic Properties)	Fungal and Bacterial Diseases	45ml	120m
	Kocide (Contact & Systemic Properties)	Fungal and Bacterial Diseases	60ml	150ml
	Cusol (Contact & Systemic Properties)	Fungal and Bacterial Diseases	75ml	180ml
Benlate	Benomyl (Systemic)	Fungal Diseases	30ml	60ml
	Sunomyl (Systemic)	Fungal Diseases	30ml	60ml
Systhane	Microbutanil (Protectant)	Fungal Diseases	5ml	15ml
	Sunbutanil (Protectant)	Fungal Diseases	5ml	15ml
	Prostar (Protectant)	Fungal Diseases	5ml	15ml
Punch	Flusilazol	Fungal Diseases	5ml	30ml
Perfekthion	Rogor (Systemic)	Biting/ rasping & sucking insect	5ml	45ml
	Dimethoate (Repellent)	Biting/ rasping & sucking insect	5ml	45ml
Orthene	Acephate (Systemic)	Biting & sucking insect	5ml	15ml 1
Confidor	Suncloprid (Systemic)	Green peach aphid, silver leaf whitefly, woolly aphid, grey cabbage aphid and turnip aphid on an extensive range of vegetables, plus various other insect pests in ornamentals.	5ml	15ml 1
	Imidacloprid (Systemic)		5ml	15ml 1
Lannate	Methomyl	Ticks, spiders/ Lepidopterous pest as an ovicide, larvicide and adulticide	5ml	15ml 1
Avid	Agrimec (Contact)	Adult and immature mites/ phytophagous insects and mites	5ml	15ml 1
	Abamectine (Contact)	phytophagous insects and mites	5ml	15ml 1
	Multigard (Contact)	Snail/ Slug & mites	5ml	15ml 1
	Hortigard (Contact)	Snail/ Slug & mites	5ml	15ml 1

Responses from Stakeholders

Many of the growers are experienced farmers and some quite knowledgeable about diagnosis of pests and diseases and their control. After the presentations the following were responses from the farmers:

- The farmers need follow up on diagnosis of pests and diseases and their control. They were advised to download Pacific Pests app and use to help their diagnosis.
- The farmers also need training in safe use of pesticides covering from reading labels, to mixing pesticides, to pesticide sprayer calibration, safety gears, LD_{50}, withholding periods, and half-life of chemicals.
- There was also concern that the 4 spray recommendations program by MAFF may not be enough to protect the watermelon crop. The farmers will work with MAFF on developing spray program for all cucurbits.

There were some discussions on the number of sprays per watermelon crop. When conditions are good only 4 sprays are required but weather and environmental conditions should determine the actual number of sprays. Link to the number of sprays is the half-life of chemicals. We must not respray a chemical unless less than its half-life otherwise chemicals will build up in the soil.

A caution was made that when alternate spraying chemicals, they must be from different family or types. For example Mancozeb and Zineb should not be alternated.

Importance of reading the labels was also raised to guide the mixing rates and safety especially the withholding periods.

Importance of calibration of chemicals for knapsack and mist blowers was discussed. This is prerequisite to determining the optimum rates and rates can change with walking speed of the person doing the spraying.

Questions of potential soil and water pollution from chemical use was also raised and a training covering behaviour of chemicals should be conducted in the near future.

Diagnosis of Nutritional Disorders

The capacity of MAFF research and extension staff is about average with most extension staff being diploma holders and research staff with very few experienced research scientists (most just joined the Division with very limited research experience). With this capacity – the basic diagnostic field experiences in diagnosis of nutrient deficiency symptoms is quite low.

The sessions started with explanation of the concepts of essentiality of nutrients as a lead up towards why nutrient deficiencies show specific symptoms that can be used to identify which nutrient is limiting. The criteria for essentiality of nutrients are:

- It has a role in the nutrition (metabolism) of the plants.
- If deficient the plant will not complete its life cycle.
- If deficient it will show characteristic symptoms.
- Symptoms can only be corrected by application of the element deficient.

It was emphasised that when a nutrient is deficient the deficiencies can be any combinations of the followings:

- Stunting – nutrients involved in stem elongation, photosynthesis, and protein production
- Chlorosis – deficient nutrients necessary for photosynthesis and/or chlorophyll production
  - entire plants or leaf or localize
  - interveinal
- Purplish – red coloring
  Low P cause accumulation of sugars that favors synthesis of anthocyanin.
- Necrosis – happens in later stages of deficiencies causing plant part to brown and die.

To help diagnose nutrient deficiency symptoms – it is also important to understand the concepts of mobile and immobile nutrients. Mobile nutrients are nutrients that move freely in the plants and when deficient they move to younger leaves and deficiencies are shown on older leaves. These include N, P, K and Mg and Mo. Immobile nutrients they are locked in the older leaves when nutrients are limiting and deficiencies appear on younger leaves – these include Ca, B, S, Fe, Mn and Cu. Zn is the exception when limiting deficiencies appear in both young and old leaves.

Demonstrations of flow charts for both mobile (Fig. 5) and immobile nutrients (Fig 6.) were done and A3 posters of mobile and immobile nutrient deficiency symptoms were also printed out and distributed.

Fig 5. Deficiency symptoms of mobile nutrient

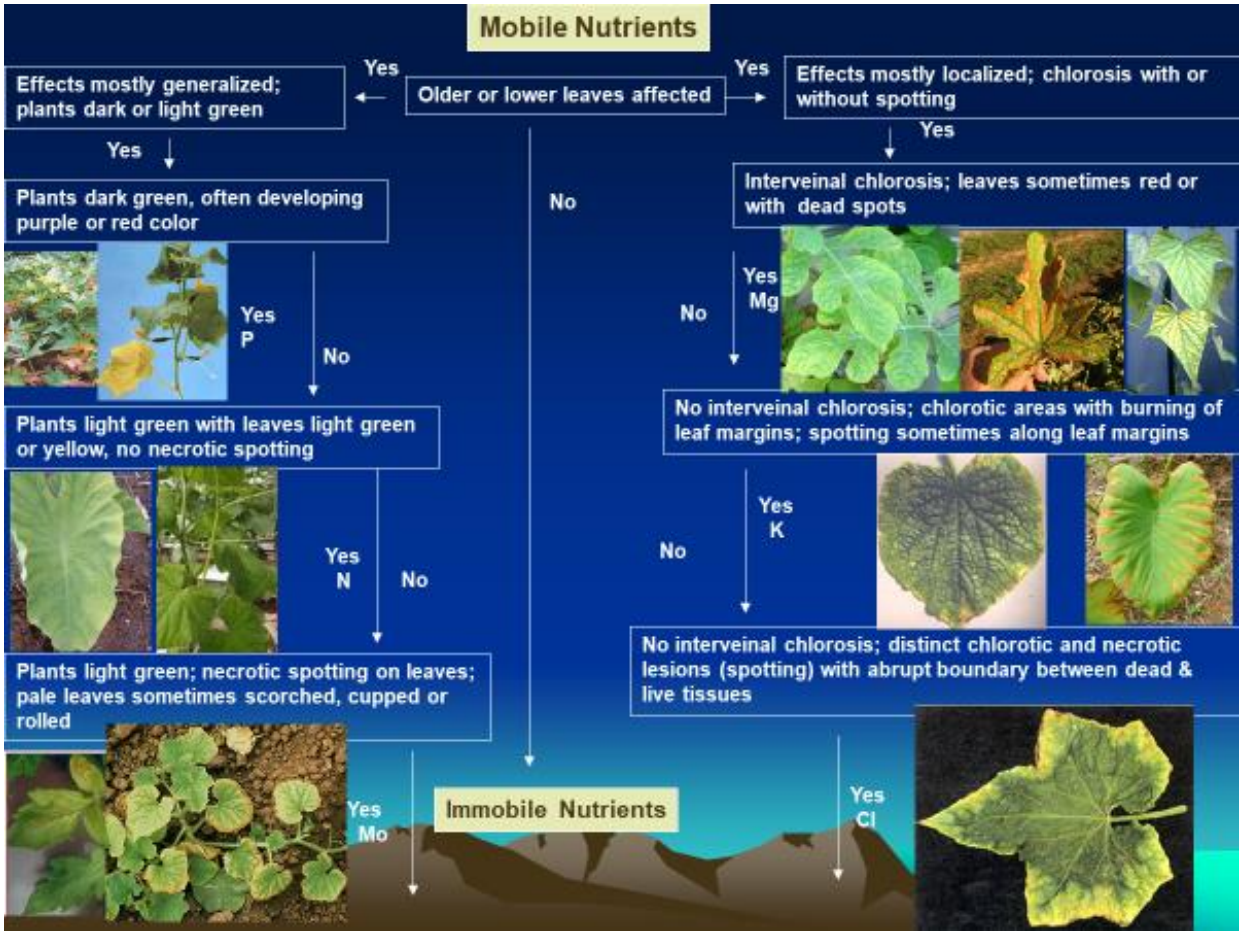
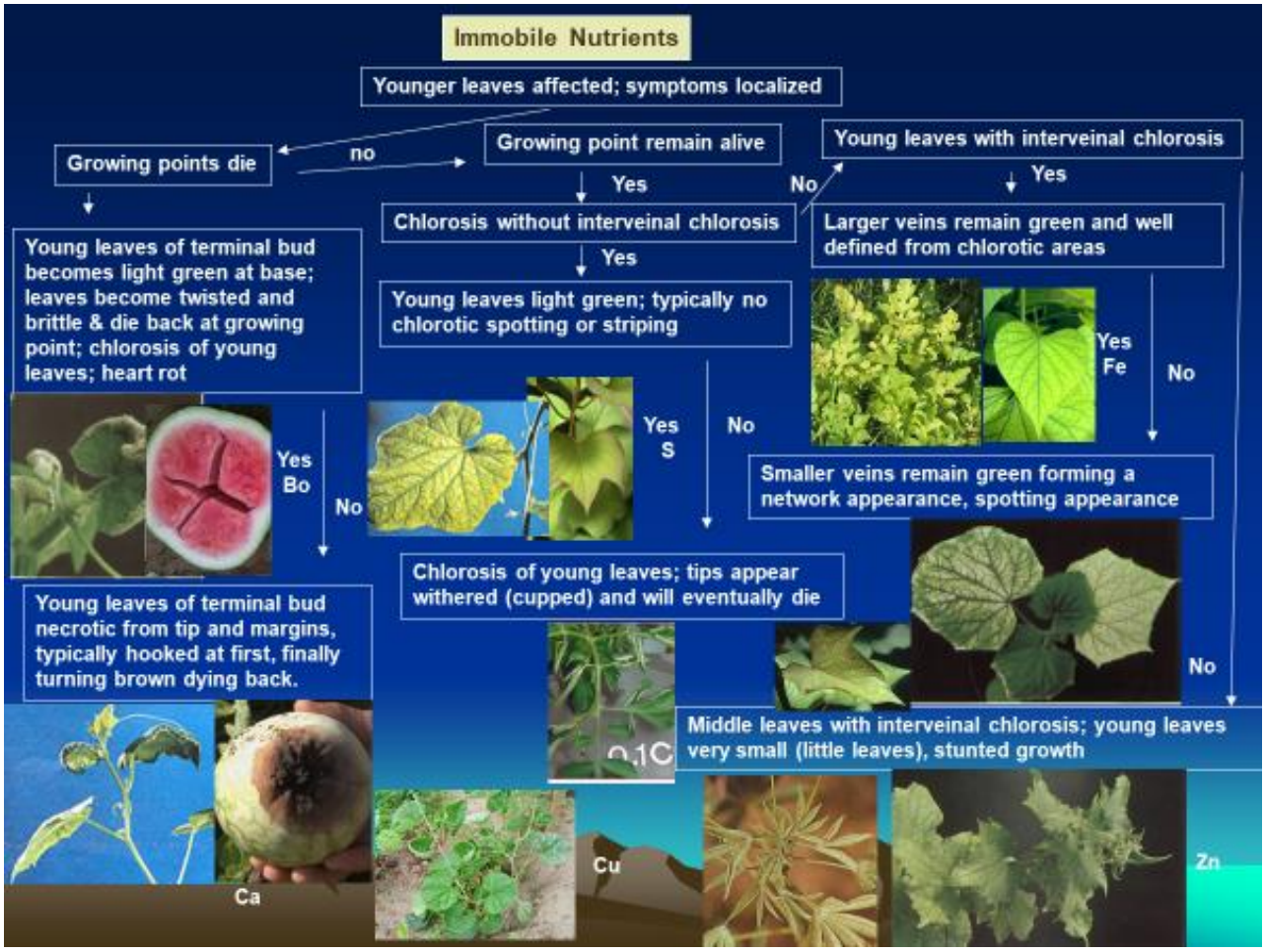


Fig 6. Deficiency symptoms of immobile nutrients



Confusions

In diagnosis, we need to be cautious of potential to make wrong diagnosis because of confusing symptoms like Zn deficiency and little leaf disease in sweet potato. To know which is the symptom – a low concentration of Zn is use to spray one half of a leaf and if it is Zn deficiency – it will recover in about 4 days as below (Fig 7).

Fig 7. Zn and little leaf virus symptoms same and result of low Zn concentration leaf painting

Other Confusing Symptoms

Virus symptoms like leaf curl of the cucumber mosaic virus; chlorine injuries also appear like nutritional leaf margin scorching; herbicide injuries; and blossom end rot can be confused with diseases (Fig 8).

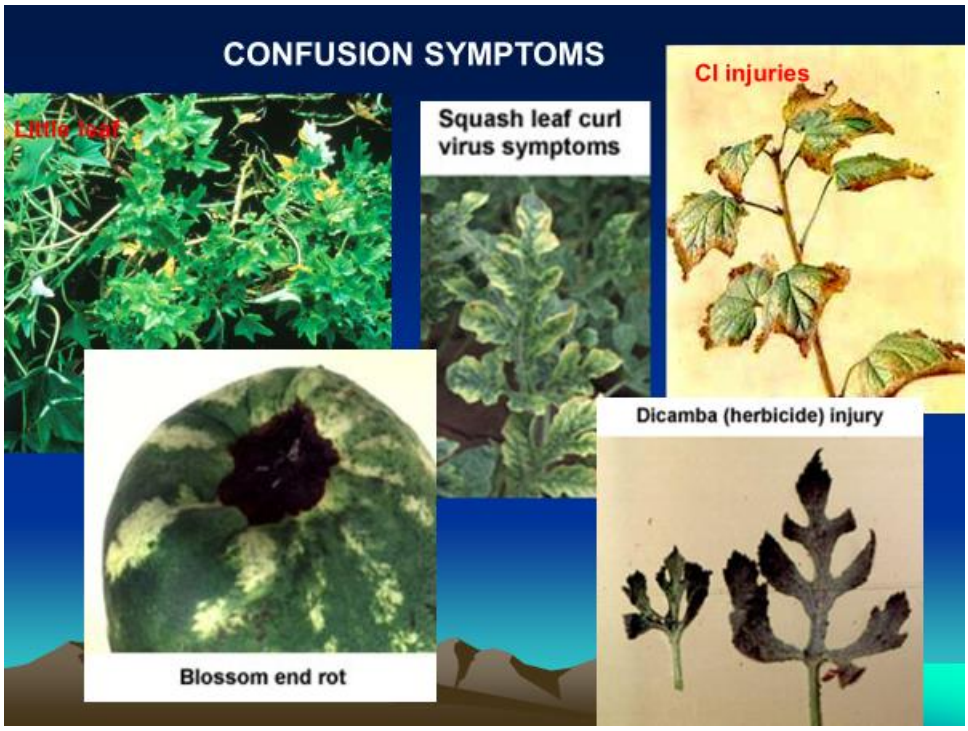


Fig 8.Confusing symptoms to be cautious with in the field.

Responses from Stakeholders

The response from the Pacific Soils project coordinator Mr. Vunivesi Minoneti summed up the results of the training in diagnosis of nutrient deficiencies: *It was a good training, the research staff were very interested as they learned new skills especially on diagnosis of nutrient disorders.* The extension staff were very positive in their wanting to master the diagnostic keys. They were told to use the keys a few times to identify the deficiencies and after a few successful attempts – they will master the diagnostic keys.

The consultant and MAFF staff (Research and Extension) will work with the farmer groups to design some on-farm trials to look at improving pesticide use and fertilizer use.

The way forward will be the farmers groups, MAFF and the consultant will run a training on soil analyses and the use of results to develop fertilizer recommendations (part of this training).

For most farmers diagnosis of nutrient deficiencies is new to them and would like further training in this area.

Training in Quick Soil Testing and Developing Fertilizer Recommendations from Soil Test Results

Five rapid soil testing workshops for farmers and MAFF staff were organised. The workshops were learning platforms for stakeholders to learn how to take representative soil

samples, and how to perform quick soil tests analysing their samples using the Hanna HI 3895 quick soil test kit. The kit can measure pH, N, P and K. This test kit measures the concentration of nutrients using colour intensity. The stronger the colour the more the nutrients. It measures them as traces, low, medium and high. Nishi Trading and MORDI made a video of the soil testing training and will be sent separately as part of this report.

The Palintest SKW 500 soil test kit which measures the nutrient concentrations quantitatively, was used to demonstrate to the participants quantitatively how much is low, medium and high. These values were used to show the participants how to develop fertilizer recommendations from soil test values.

Each stakeholder group was asked to nominate about 15 people (Table 3) to attend the quick soil test training. Only six participants were females – 4 from MAFF and two from Nishi Trading.

Table 3 shows the number of people from each stakeholder that attended the trainings. (Participant lists in Appendix 1)

Stakeholders	Training Workshop	Participants
Nishi Trading	Use of soil test kits	15
Nishi Trading	Fertilizer recommendations	11
Eastern District growers	Use of soil test kits	16
Eastern District growers	Fertilizer recommendations	16
MAFF	Use of soil test kits and fertilizer recommendations	15
Total		**73**

The trainees were first shown how to take a representative soil sample by transecting a zigzag pattern in the field (Fig 9) and taking 4 to 5 samples per arm and then mix them well. Take a 500g sample and place in a plastic bag and then labelled with name, field and crops to be grown.

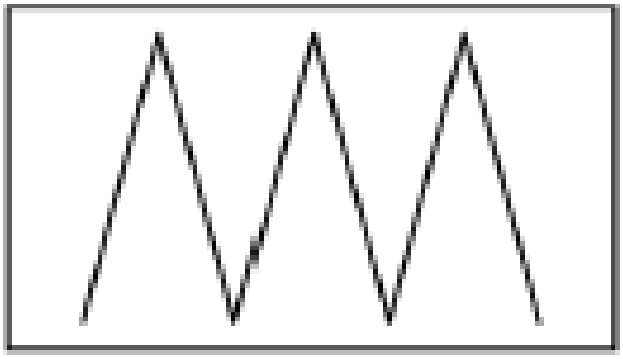


Fig 9. Zigzag pattern for taking representative soil sample for soil analysis

Next the participants were asked to read the instruction in the manual for the Hanna HI 3895 kit and do the pH, N, and P (Fig 10). With pH, a half teaspoon of soil was added to 2.5 ml of distilled water, and then content of a packet of HI3895pH-0 pH reagent and shaken for 30 seconds then allowed to stand for 5 minutes. Match the colour developed with the pH colour chart as in Fig 9 and read the pH value.

For N and P, add 1 part soil to 8 parts water and shake gently for one minuts and then leave to settle for about 30 minutes or overnight.

For N test. Use a pipette and transfer 2.5ml of the clear soil extract to a clean test tube. Add content of one packet of HI3895N-0 Nitrogen agent to the test tube and close cap and shake for 30 seconds to dissolve agent. Allow tube to stand for 30 seconds and then match the pink colour to the Nitrogen colour-card as in Fig 9.

For P test. Use a pipette and transfer 2.5ml of the clear soil extract to a clean test tube. Add content of one packet of HI3895P-0 Phosphorus agent to the test tube and close cap and shake for 30 seconds to dissolve agent. Allow tube to stand for 30 seconds and then match the blue colour against the Phosphorus colour-card for P concentration as in Fig 9.

Fig 10. Sample extraction, colour development for pH, N and P.

Samples were also tested with the Palintest SKW 500 for quantitative values to be used for the fertilizer calculations and to correlate colour coded levels of Hanna HI3895 kit. Again N and P were extracted with reagents and colour then developed and read with a meter (see Fig 11).

Fig. 11. Hanna soil test kit (left) and the Palintest SKW 500 soil test kit (right).

Fertilizer Recommendations based on soil testing

To facilitate development of fertilizer recommendations based on soil test results, several soil samples from the two farmer groups (Nishi Trading and Eastern District watermelon growers) were taken and tested using the Hanna HI 3895 quick soil test kit and the Palintest

SKW 500 soil test kit. Table 4 shows the draft correlation between the Hanna kit colour coded levels and the Palintest SKW 500 quantitative values in mg/l (ppm).

Table 4. Draft correlations between Hanna HI 3895 soil test kit colour codes and Palintest SKW 500 quantitative values.

Sample	**Nitrogen**		**Phosphorus**	
	Hanna	**Palintest (mg/l)**	**Hanna**	**Palintest (mg/l)**
Nishi				
Pineapple	Low	10.6	Low	12.0
Fruit tree	Low	10.9	Low	13.0
Eastern District Farmers				
P. Funaki	Low	19.3	Low	7.0
Pauli	Medium	33.0	Low	8.0
Kiko Pepa (Hala)	Low	13.6	Low	7.0
Seteone	Medium	22.2	Medium	14.0
Samiu	Low	9.4	Medium	15.0
Tame	Low	9.7	Low	8.0
Tatakamotonga	V. low	1.2	Low	4.0
Alaki Heta	High	40	High	35
Kiko Pepa (Liku)	Low	11.1	Low	10.9

One might question the validity of this correlation but with the current lack of local fertilizer recommendations based on soil test values – before we get a more accurate method – using the quantitative values from Palintest SKW 500 to guide the Hanna HI 3895 colour codes is worth the use.

P fertilizer recommendations

Some of the soil samples above were used to demonstrate development of fertilizer recommendations based of soil test values.

For calculating the fertilizer recommendations – we need to work out the weight of the nutrient in question in the hectare of soil down to the sampling depth (plough depth – usually 30cm).

Calculating the weight of an hectare furrow slice for fertilizer calculation:

Area of 1 hectare = 10,000 m^2

The volume of 1 ha = 10,000 x 0.3 (plough depth) = 3000m^3

What is the weight of the soil in 3000m^3

Weight of soil = volume x bulk density. Bulk density of most volcanic soils in Tonga is about 1g/cm^3

3000 x 1.0 (bulk density) = 3000tons = 3,000,000kg soil

We will use a factor of 3 from (3,000,000kg soil) to multiply the soil test values to get kg of that nutrient/ha.

<10mg/kg (ppm)	10 – 20 mg/kg (ppm)	>20mg/kg (ppm)
Very low to Low	Medium to High	Very high
Soil test 4pm x 3 = 12 kg P/ha 40 ton watermelon 16kg x 2 include biomass = 32kg *Amount of added nutrient = Crop demand – Amount available from soil + Amount of added nutrient lost due to fixation, leaching*, etc Amount = 32 – 12 = 20 x 1.6 = 32kg P Source = 13-13-10 Amount = 100/13 x 32 = 246 (12.5 bags) For this case 14 bags is advisable so that we can target soil test level to get to 10ppm over time.	10.9 ppm x 3 = 32.7 kg P/ha 40 ton watermelon 16kg x 2 include biomass = 32kg *Amount of added nutrient = Crop demand – Amount available from soil + Amount of added nutrient lost due to fixation, leaching*, etc Amount = 32 – 32.7 = -0.7 kg balance The aim here is to maintain nutrient balance and the soil above the critical P level of 10mg/kg 7 bags will add 19kg P	35 ppm x 3 = 105kg P/ha 40 ton watermelon 16kg x 2 include biomass = 32kg *Amount of added nutrient = Crop demand – Amount available from soil + Amount of added nutrient lost due to fixation, leaching*, etc Amount = 32 – 105 = -73kg P balance 2 - 4 bags for maintenance. A drawdown approach will be useful to avoid excessive P that might antagonise other nutrients

Targeting levels of soil test P to near or above critical concentrations is important to consider because crops respond both to P fertilizer and to the background P fertility of the soil.

Nitrogen Fertilizer Recommendations

The soil tests – 12 mg/l (ppm)

Amount in kg/ha = 12 x 3 = 36kg/ha

40 tons watermelon removes about 110kg N

N use efficiency is 50%

Amount of added nutrient = Crop demand – Amount available from soil + Amount of added nutrient lost due to fixation, leaching, etc

Amount = 105 – 36 = 69 x 1.5 = 103.5 kg/ha (taking into account of the 50% loss of N)

Urea = 100/46 x 103.5 = 225kg Urea (11.5 bags)

Responses from Stakeholders

- Some farmers see the nutrient levels with colour intensity but cannot see how to interpret for fertilizer rates.
- Some can see now that one nutrient is limiting in their soils but then why apply NPK fertilizers.
- Some can now see that there should be different fertilizer rates for newly cleared sites from repeatedly cropped sites.
- Some are asking if too much fertilizer can cause pollution.
- A combination of organic and inorganic fertilizers is better long term

National Workshop on Soil Health Management

In Tonga, increasing population pressure has resulted in shortening of the traditional guinea grass dominant "bush fallow" phase from about 15 years to an average of about 3 years, and in many places, to almost continuous cultivation. This has resulted in depletion of soil

organic carbon and associated secondary cascade of problems like depletion of soil nutrients, declining water stable aggregates, declining water holding capacity, declining soil biodiversity, and increased incidences of pests and diseases. In addition, the volcanic ash soils of the higher islands are strongly P-fixing and most are deficient in P for crop production. As responses farmers are pumping large amount of fertilizers into the soils to grow commercial crops and are using large amount pesticides to control pests and diseases and weeds. But on the other hand growing traditional crops involves very little fertilizer inputs.

The nutrient management and diagnostic trainings and the soil testing trainings (reported here) confirmed the concerns on overuse of fertilizer and chemicals on commercial crops and under fertilization of traditional crops.

The objectives of the workshops were:

1. To discuss the implications and potential responses to under fertilization, and declining soil fertility from the farm level through to the national level
2. To discuss the current status of fertilization of commercial crops *(Trend is low fertilizer use efficiency*)
3. To discuss the needs to develop a policy brief on sustainable soil health management

Three workshops were conducted with key stakeholders in 'Eua, Ha'apai, and Tongatapu discussing (Table 5) these issues and needs to develop a policy brief or voluntary guidelines on sustainable soil health management. More than 30% of the participants were women. We had representatives from key agricultural stakeholders in Tonga – FAO National office, Nishi Trading, Tonga Institute of Higher Education, MORDI, Hango Institute of Agriculture, MAFF, University of the South Pacific, Tonga National Youth Congress, Ministry of Trade and Economic Development, Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change and Communication, Policy makers, and politicians, plus farmers.

Table 5. National Workshops on Sustainable Soil Health Managenment and where they were held. (List of participants in Appendix 1)

Island Group	Number of participants
Éua	39
Tongatapu	25
Haápai	15
Total	**79**

The workshops had two technical presentations covering the current issues with sustainable soil management.

The first one was on *Downward Spiral of Soil Productivity in Tonga*

The participants were explained why soils is key to sustainable future of the planet. Five key reasons were discussed:

1. **Healthy soil feeds the world –** Soil is composed of minerals, water, air and organic matter. It is where food begins. The importance of nutrient cycling was discussed. Food, feed, fuel, fiber are essential to man and without soil one cannot access these.

2. **Soil is a non-renewable resource -** 1cm of soil is formed in hundreds of years but bad management can erode in a few years even a few days. During our life time soils cannot be renewed.
3. **Soil can mitigate climate change –** The biggest C sink is the soil – more than vegetation
4. **Soil is alive, teeming with life -** "Without soil and their biodiversity, there is no human life."
5. **Investing in sustainable soil management makes economic and environmental sense -** Managing soil sustainably is cheaper than rehabilitating or restoring soil functions

From these functions of soils – we discussed the current status of our soils in Tonga. With the current population pressures and pressures from other land uses – the fallow periods in Tonga has declined significantly and in many places one almost cannot fallow. As a consequence the soil organic carbon is depleting which in turn results in sol structural degradation, declining water holding capacity, nutrient depletion, and decline in soil biodiversity. This downward spiral in soil productivity is further accentuated by deforestation, coastal erosion, and increasing soil and water pollution as a result of increasing use of fertilizers (Fig 12) and pesticides (Fig 13).

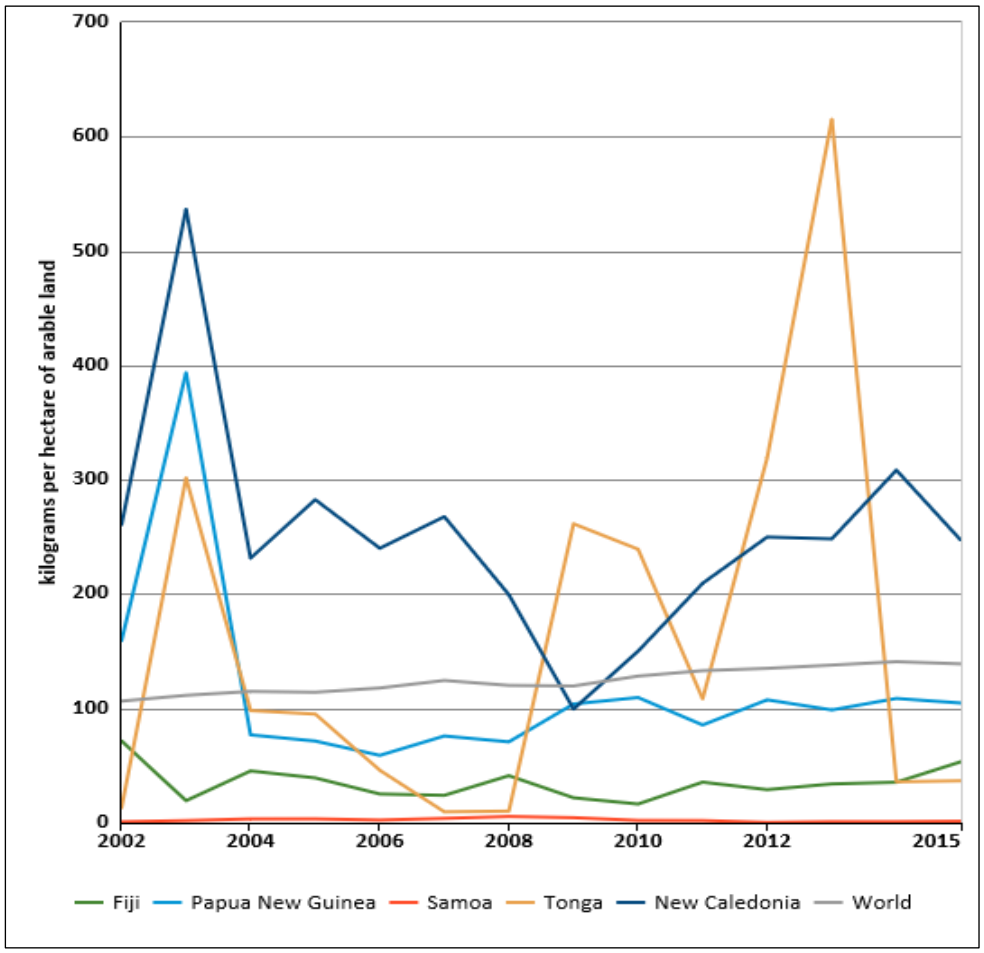


Fig 12. Fertilizer use in the Pacific Islands.

The fertilizer use on commercial crops in Tonga saw so much used in 2012/13. These also have been associated with high levels of nitrate in excess of 50ppm in some of our water wells.

Sample	Lindane	Heptachlor	Aldrin	Endosulfan	DDT
Cabbage	0.08	0.01			
Banana	0.05		0.09		0.02
Cucumber	0.02		0.03		
Tomato	0.01				
Water (n=9)	0.18	0.11	0.09	0.06	0.04
Milk	0.02 – 0.1	0.03 – 0.05	0.01 – 0.07		0.09 – 0.43
Human Fat					1.4 - 42

Fig 13. This table shows biomagnification of organochlorines reported when these pesticides were still used in the country.

The current status of our soils demand discussions on need for a policy brief or voluntary guidelines. The biggest agricultural issue of our time is: *Loss of soil organic carbon which is also associated with a cascade of secondary problems like nutrient depletion, less water availability, structural degradation, increasing pests and diseases.*

The biggest question then is: *How can we continue to intensify food production and yet maintain sustainability of the soils of Tonga in the face of climate change?*

We can learn from our own experiences. Mucuna (*Mucuna pruriens*) is a tropical leguminous cover crop recently introduced into Pacific for this purpose. It nodulates well and grows vigorously without inoculation or fertilizer application on the minerally depleted farmlands of the Pacific Islands including Tonga where it has been introduced.

Mucuna fixes N, mobilizes fixed P and increases soil organic carbon thus restoring health of our soils (Fig 14).

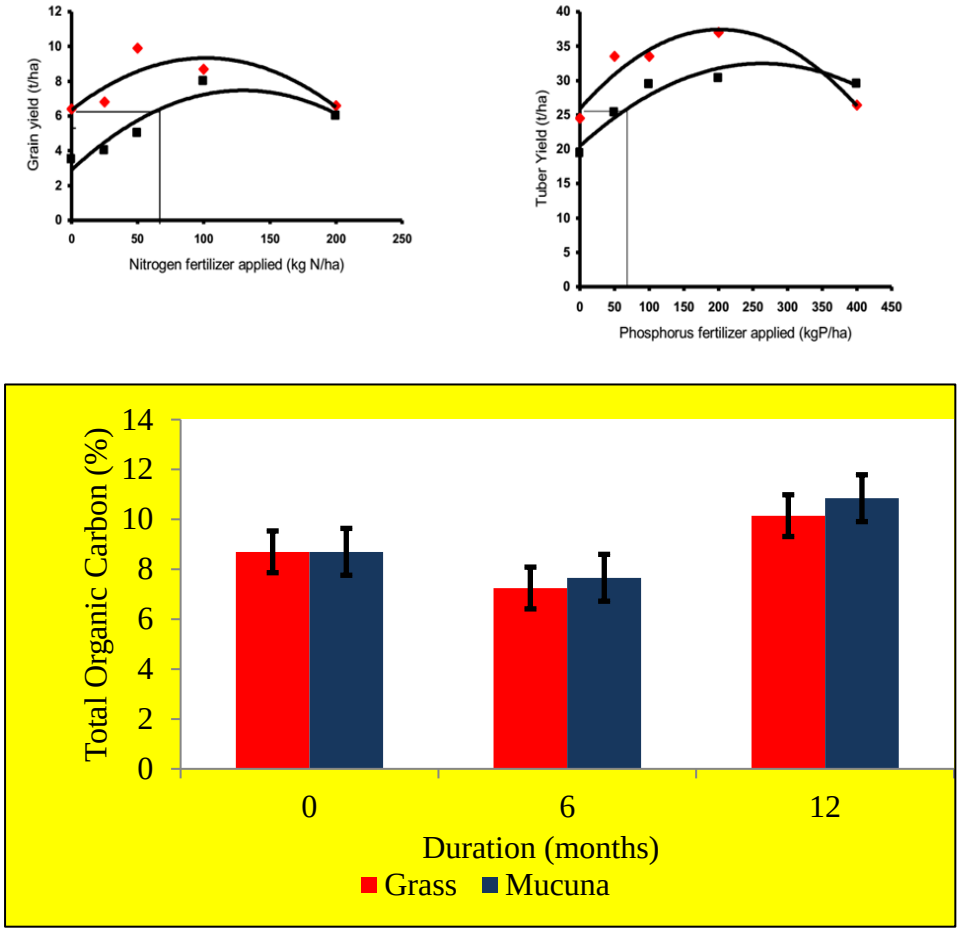


Fig 14. Benefits of Mucuna cover crop – fixing N, mobilise P and increases soil organic carbon.

On sandy atoll islands in Tonga, the use of compost has been proven to improve soil conditions and production.

The second technical presentation was on nutrient management emphasising what was already done in the training on nutrient management but to paint the current total grim picture of soil health in Tonga. The current nutrient management in Tonga can be summarised as inefficient. The strategy to improve nutrient management is to adopt the 4R strategy (Fig 15).

Fig 15. 4R Principles of Nutrient Stewardship (Adopted from IFA Nutrient Management Handbook 2016)

Discussion on Policy Needs

A policy is a plan of action agreed to by a group of people with the power to carry it out and enforce it. Policy outlines rules, provide principles that guide actions, set roles and responsibilities, reflect values and beliefs, and state an intention to do something.

There are various tools we can use to develop and implement our policy. They include:

- Information
- Education/training
- Legislation
- Regulation
- Guidelines
- Standards
- Procedures
- Program

Some of the issues raised in the national workshops were:

- Some farmers have no time to test soils and found it easier to just use compound or mixed NPK fertilizer.
- Tonga National Youth Congress wants to look at using cover crops and compost instead of inorganic fertilizers
- Fertilizer use efficiency - single nutrient fertilizers and slow-release fertilizers are more efficient
- From the political aspect of soil management there are needs:
  - To support the proposed development of the policy brief. It is the responsibility of the Government (MAFF).
  - We need to start somewhere.
  - We need to educate the youth and the community about the policy and convince them to use it for they are the future farmers of Tonga.
  - MAFF does not have the capacity to educate the youth and the community on the policy

- Important to develop the policy and use it
- Climate change is important in relation to agriculture
- Pesticide Act already in place but no motivation to push the public to use it
- If there is no policy there will be no moving forward

- We should use our current experience by including mucuna in the way forward for good soil management - plant it and produce seeds. There is a need to promote compost as well.
- Policy must be environment driven.
- Current trend of farmers mixing very rates of chemicals – need to reduce the mixing rate by explaining to them to understand the consequences e.g. half-life of chemicals. This is also related to soil and water pollution
- TNYC proposed to submit a written report to the Government stating that the stakeholders agreed to make a start in developing a policy.
- The climate change expert who attended supported the development of a policy.
- Soil management and climate change must be included and the agriculture sector must contribute to the National Determined Contribution strategy. Soil management must ensure that methane and nitrous oxide emissions are reduced.

The main recommendation from the National Workshops was to make a start and develop a policy and the policy tool should be a policy brief to inform all stakeholders and a voluntary guidelines on how to handle all issues affecting soil management and spelt out the roles of key stakeholders.

Brokered agreements with stakeholder online platforms to include results from the Pacific Soils project on their portals for sharing information

Discussions were done with 3 of the key agricultural sector stakeholders to share Pacific Soils Project results and information on their online platforms for users like farmers, education establishments, advisors, research scientist and others. Nishi Trading Company Limited, MORDI and MAFF Research Division have agreed that they are willing to house and share Pacific Soil Project information on their portals.

Nishi Trading and MORDI have also collaborated with the consultant in developing a soil testing video and will continue to do for other aspects of farming and exports.

Way Forward

It is very clear from the training/workshops that in Tonga we are in a juncture where we need partnership of key stakeholders to develop a soil health management policy brief and/or a voluntary guidelines. The stakeholders involved in the trainings all agreed that we need to make a start in developing some guidelines.

While a policy is a must, the immediate issues are to improve soil organic carbon in our soils. Our experiences show that we can use cover crops like mucuna or use compost.

The nutrient management trainings showed that our nutrient management in Tonga is quite inefficient and we need to improve nutrient management. This means we need to use soil testing to guide fertilizer recommendations and we need to use different combinations of organic and inorganic fertilizers – this approach will be much more efficient than just use of inorganic fertilizers. We must follow the 4R Principles of nutrient stewardship.

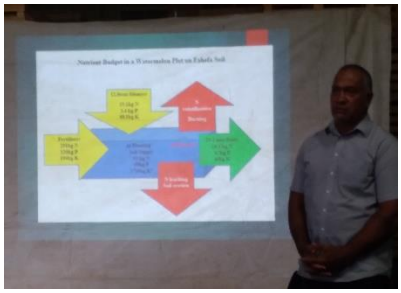
Currently FAO is coordinating the implementation of the Koronivia Joint Works on Agriculture (KJWA) and is promoting improved soil organic carbon, improved nutrient management, and improved livestock systems as well as adaptations and their co-benefits.

The Pacific Soil Project is involved in this initiative from Tonga and Mr. Vunivesi Minoineti will present on nutrient budget work from Tonga and share with FAO's 14 Pacific island countries in a webinar in June. This is probably the project's biggest impact in sharing its results with the countries. The consultant is part of the team organizing these webinars.

KJWA will also look at developing policy briefs on soil management and can take up this work in Tonga.

The Pacific Soils Project in Tonga and the other countries should join the initiatives by KJWA.

Photo Galleries



Nutrient management training with Nishi Trading growers (27/1/2021)



Diagnostic training with Nishi Trading growers (3/2/2021)



Nutrient management and diagnostic training for the MAFF staff (12/2/21)



Nutrient management and diagnostic training for the Eastern District watermelon farmers (18/2/21)



Soil test training with Nishi Trading growers (26/2 and 8/3/21)


Soil test training with Eastern District watermelon growers (3 and 16/3/21)


Soil test training with MAFF staff (12/3/21)



National workshop in Éua (24/2/21)



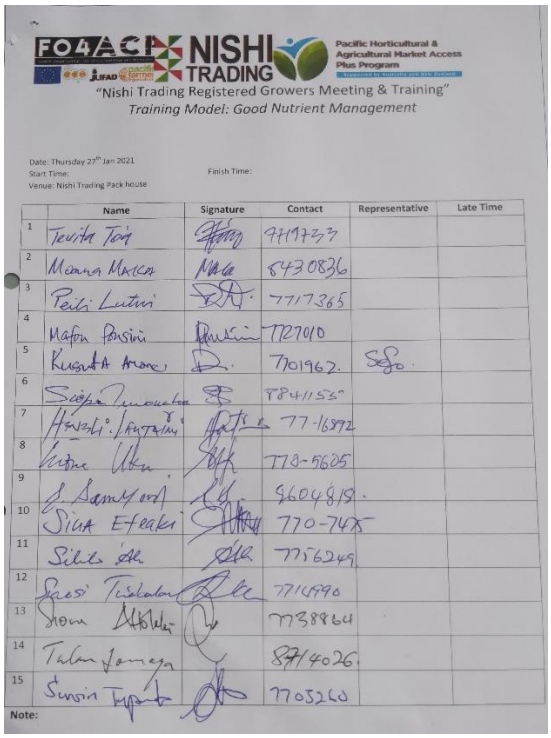
National workshop in Tongatapu (23/3/21)



National workshop in Haápai (31/3/21)

Appendix 1. Lists of participants who attended the trainings

Nutrient management and diagnostic training



FO4ACP NISHI TRADING — Pacific Horticultural & Agricultural Market Access Plus Program

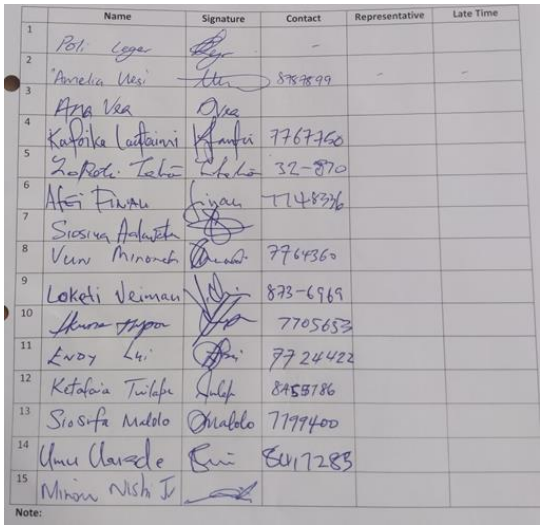
"Nishi Trading Registered Growers Meeting & Training"

Training Model: Good Nutrient Management

Date: Thursday 27th Jan 2021
Start Time: Finish Time:
Venue: Nishi Trading Pack house

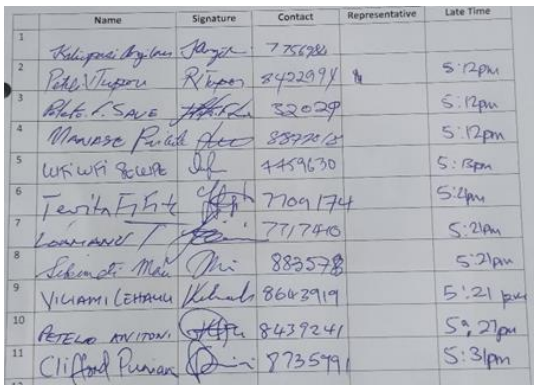
	Name	Signature	Contact	Representative	Late Time
1	Tevita Tori		7717737		
2	Meama Matea		8430836		
3	Peiti Lutui		7717365		
4	Mafoa Fonsini		7727010		
5	Kusuta Amosa		7701962.	Sefo.	
6	Siosifa Tuuvaatau		7841155		
7	Henaki Fonua		77-16872		
8	Vaetua Utia		778-5605		
9	S Samuela		9604819.		
10	Sina Efeaki		770-747		
11	Sikeli Ale		7756249		
12	Saasi Tuiafalani		7714490		
13	Siosa Afeaki		7738864		
14	Talanoa Tamaeya		8714026		
15	Sunsin Tupou		7705260		

Note:



	Name	Signature	Contact	Representative	Late Time
1	Pol. Legaa		-		
2	Amelia Vesi		8788899	-	-
3	Afua Vea				
4	Kafoika Lafaiani		7767760		
5	Sopoli Tabu		32-870		
6	Afoi Finau		7748376		
7	Siosiua Aalaitoa				
8	Vuni Mineti		7764360		
9	Loketi Veimau		873-6969		
10			7705653		
11	Lindy Lui		7724422		
12	Ketaloia Tuilafu		8458786		
13	Siosifa Malolo		7799400		
14	Uma Claude		8417285		
15	Minoa Nishi Jr				

Note:



	Name	Signature	Contact	Representative	Late Time
1			7756280		
2	Peter Tuipolu		8422994		5:12pm
3	Peter T. Salue		32029		5:12pm
4	Manase Paea		8872013		5:12pm
5	Lutiwi Seuse		7459630		5:13pm
6	Tevita Fifita		7709174		5:21pm
7	Lomani		7717410		5:21pm
8	Sekimoti Mau		8835788		5:21pm
9	Viliami Lehaua		8663919		5:21 pm
10	Petelo Anitoni		8439241		5:27pm
11	Clifford Punua		7735791		5:31pm

FO4ACP NISHI TRADING

Pacific Horticultural & Agricultural Market Access Plus Program

"Nishi Trading Registered Growers Meeting & Training"

Training Model: 1. Pest & Disease

2. Diagnostic

Date: Wednesdau 03 Feb 2021

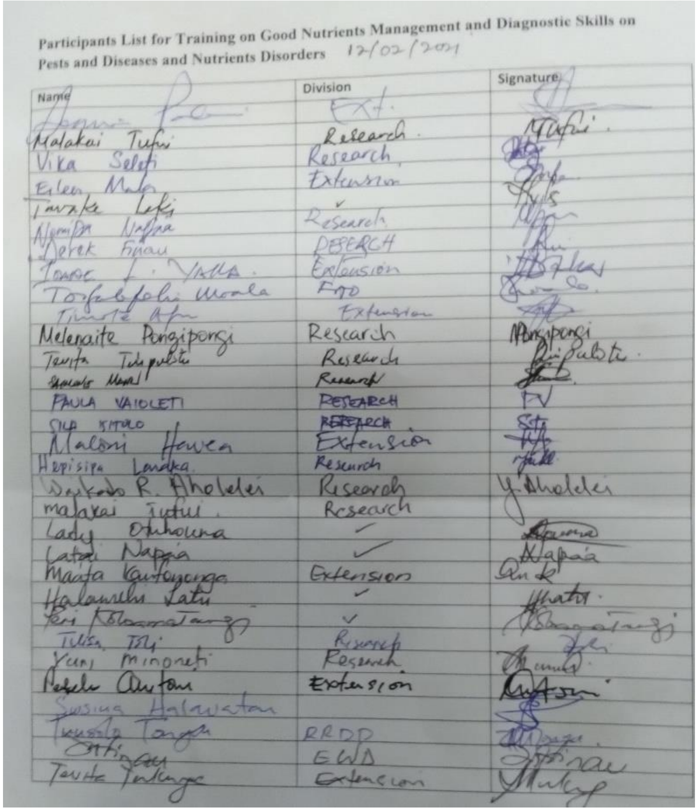
Start Time: [illegible] Finish Time:

Venue: Nishi Trading Pack house

	Name	Signature	Contact	Representative	Late
1	Poli Loger	[illegible]	8705363		
2	S.Halavatau	[illegible]			
3	T Tukunga	[illegible]	7765714		
4	Vuni Minoneti	[illegible]	7764360		
5	Amanofive Naco	[illegible]	8770427		
6	MANU LOMU	[illegible]	8707517		
7	Filise Valanti	[illegible]	7786483		
8	Loketi Veimau	[illegible]	873-6969		
9	Petelo Onuto	[illegible]			
10	Sina Efeaki	[illegible]	770 748		
11	Afai Eivon	[illegible]	774836		
12	WINIFI SELUPE	[illegible]	7459630		
13	Kafoika Laufani	[illegible]	7767750		
14	Kalisopasi Angilau	[illegible]	7756984		
15	Peteli Vaipou	[illegible]	8422288		

	Name	Signature	Contact	Representative
1	Lopeti Tele	L. Tele	32-870	
2	Losaga Amone	[illegible]	7701962	
3	TEVITA MAHE	[illegible]	8845435	
4	Siosifa Tunoraloa	[illegible]	8841155	
5	S. Saniroy	[illegible]	8604818	
6	Hiko Fungaul	[illegible]	7741234	
7	Sione 'Aho	[illegible]	7731990	
8	Sione Ufa	[illegible]	770-5605	
9	MANASE Palu	[illegible]	8872016	
10	Siaosi Tuakalau	[illegible]	7714990	
11	Silila 'Afu	[illegible]	7758249	
12	Tupou Sili	[illegible]	7791995	
13	Tevita Fifita	[illegible]	7709174	
14	Peau Animo	[illegible]	8424694	
15	Mimisi NikJ	[illegible]		

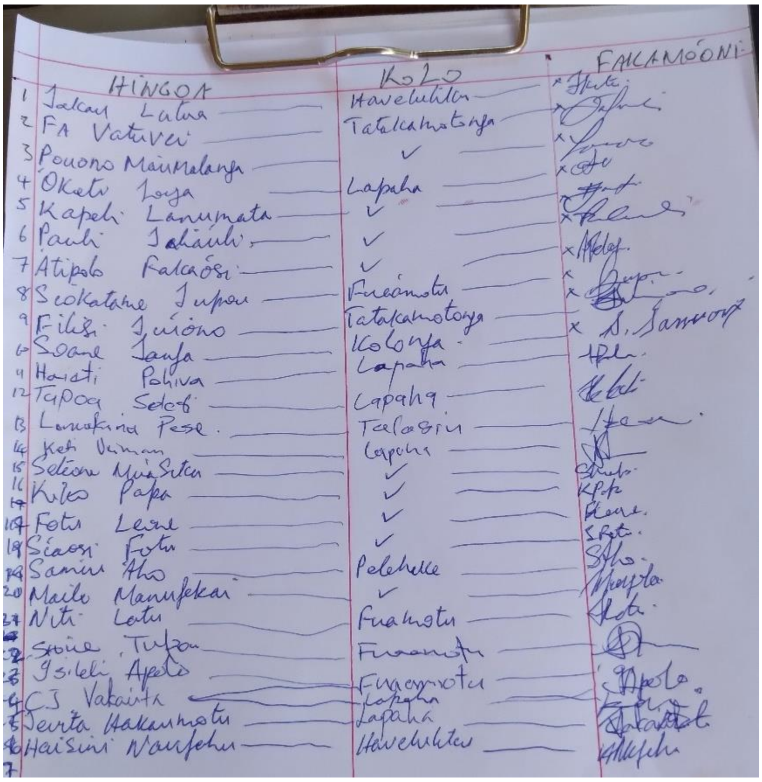
MAFF staff 12/2/21



Participants List for Training on Good Nutrients Management and Diagnostic Skills on Pests and Diseases and Nutrients Disorders 12/02/2021

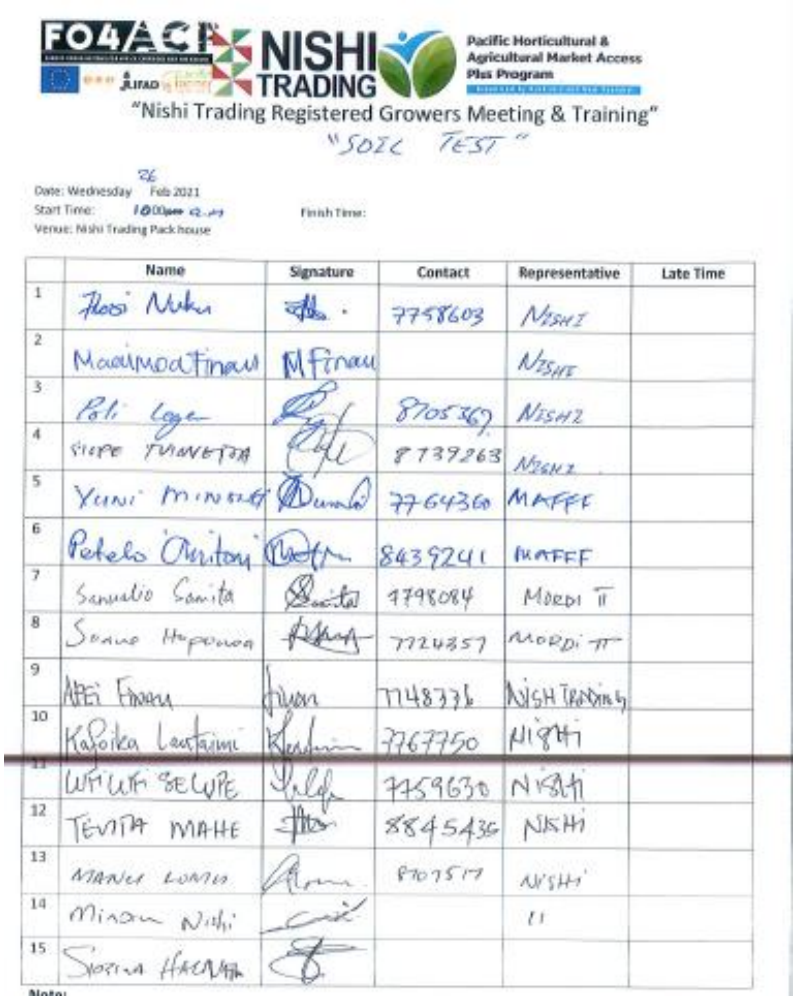
Name	Division	Signature
[illegible]	Ext.	
Malakai Tufui	Research	
Vika Selefi	Research	
Eileen Mafa	Extension	
Tavake Lefi	✓	
Ngamipa Nafisa	Research	
Derek Finau	RESEARCH	
[illegible] L. Vaka	Extension	
Tofakafoli Moala	FPD	
Timote Afu	Extension	
Melenaite Pongipongi	Research	
Taufa Tulipulotu	Research	
[illegible]	Research	
PAULA VAIOLETI	RESEARCH	
SILA KITOLO	RESEARCH	
Maloni Hawea	Extension	
Hepisipa Landaka	Research	
Sailosi R. Aholelei	Research	
malakai Tufui	Research	
Lady Otuhouma	✓	
Latai Nappa	✓	
Maafa Kautoyonga	Extension	
Halaunelu Latu	✓	
Teri Kolomatangi	✓	
Tulisa Tali	Research	
Yuni Minoneti	Research	
Pekeli Antoni	Extension	
Susina Halavatau		
[illegible] Tonga	RRDP	
Oti Finau	EWD	
Tevita Tulunga	Extension	

Eastern District watermelon growers (18/2/21)



HINGOA	KOLO	FAKAMOʻONI
1 Takau Latua	Havelulu	
2 FA Vatuvei	Tatakamotonga	
3 Pouono MauMalanga	✓	
4 Oketi Loya	Lapaha	
5 Kapeli Lanumata	✓	
6 Pauli Tahaului	✓	
7 Atipolo Fakaʻosi	✓	
8 Sioakatame Tupou	Fuaamotu	
9 Filisi Tuʻiono	Tatakamotonga	
6 Soane Taufa	Kolonga	
4 Haisiti Pohiva	Lapaha	
12 Tapoa Selefi	Lapaha	
13 Lamakina Pese.	Talasiu	
14 Keti Vaiman	Lapaha	
15 Seleone MuaSika	✓	
16 Kilo Papa	✓	
17 Fotu Lesa	✓	
18 Sioasi Fotu	✓	
19 Samiu Aho	Pelehake	
20 Mailo Manufekai	✓	
21 Niti Lotu	Fuamotu	
22 Sione Tupou	Fuamotu	
23 Isileli Apolo	Fuaamotu	
24 C.J. Vakaʻuta	Lapaha	
25 Sevita Hakaumotu	Lapaha	
26 Haisini Naufahu	Havelulu	
27		

Soil Tests workshop



FO4ACP NISHI TRADING Pacific Horticultural & Agricultural Market Access Plus Program

"Nishi Trading Registered Growers Meeting & Training"

"SOIL TEST"

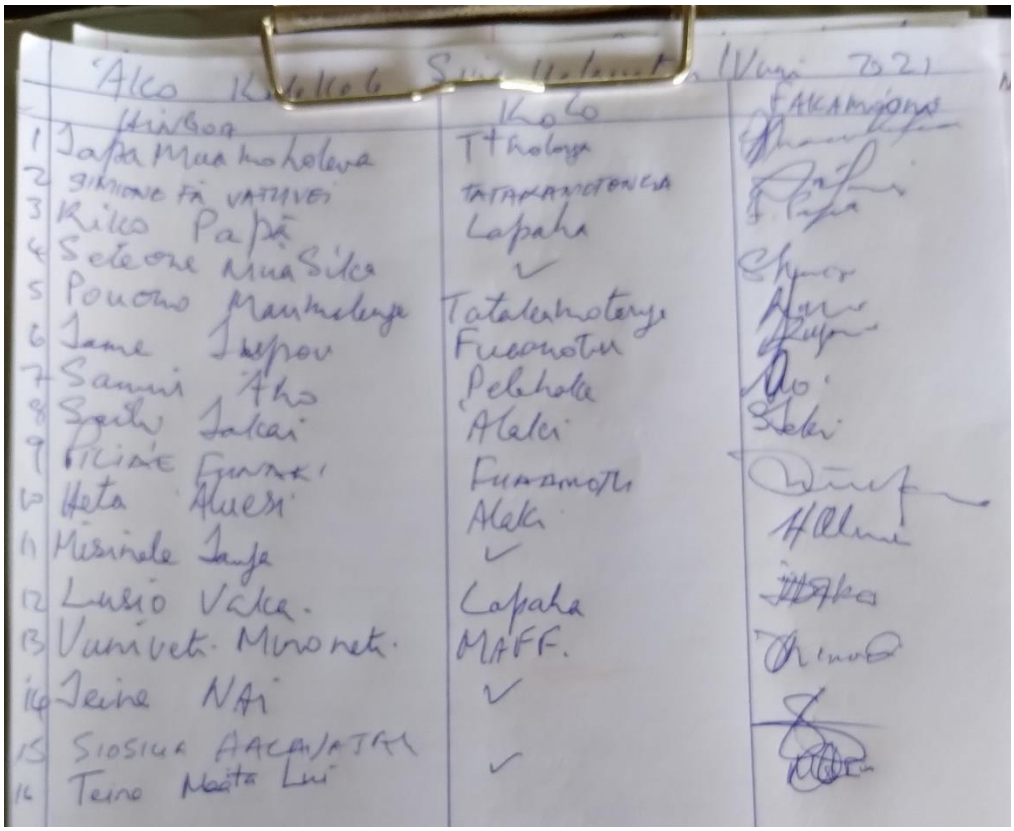
Date: Wednesday 26 Feb 2021
Start Time: 10:00am Finish Time:
Venue: Nishi Trading Pack house

	Name	Signature	Contact	Representative	Late Time
1	Filosi Nuku		7758603	NISHI	
2	Maaimoa Finau	M Finau		NISHI	
3	Poli Lega		8705363	NISHI	
4	SIOPE TUAVETTA		8739263	NISHI	
5	Yumi Minoru		7764360	MAFFF	
6	Petelo Ofiritoni		8439241	MAFFF	
7	Samuelio Sanita		7798084	MORDI II	
8	Soane Hapoua		7724857	MORDI II	
9	AFEI FINAU		7748336	NISH TRADING	
10	Kafoika Lautaimi		7767750	NISHI	
11	LUTUI'A SELUPE		7759630	NISHI	
12	TEVITA MAHE		8845436	NISHI	
13	MANU LOMU		8707517	NISHI	
14	Minoru Nishi			"	
15	SIOSIUA HAKAVAKA				

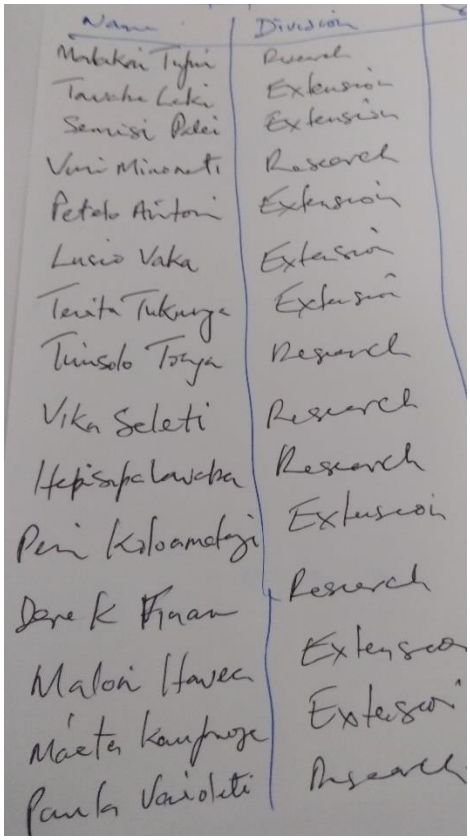
Date: 09/03/21
Start Time: 10:00a.m Finish Time: 12:00
Venue: Nishi Trading Pack house:

	Name	Signature	Contact	Representative
1	Poli Lega		8705363	Nishi
2	Yumi Minoru		7764360	MAFFF
3	Siosiua Hakavaka			
4	AFEI FINAU		7748336	NISHI
5	TEVITA MAHE		8845435	NISHI
6	MANU LOMU			NISHI
7	Uma Uaisele		8417288	Nishi
8	Kafoika Lautaimi		7767750	Nishi
9	Sililo Ah		7756245	Nishi
10	Filosi Nuku		7744145	Nishi
11	Mafu Ponesmi		7727010	Nishi
12				

Eastern District Watermelon growers (3 and 16/3/21)

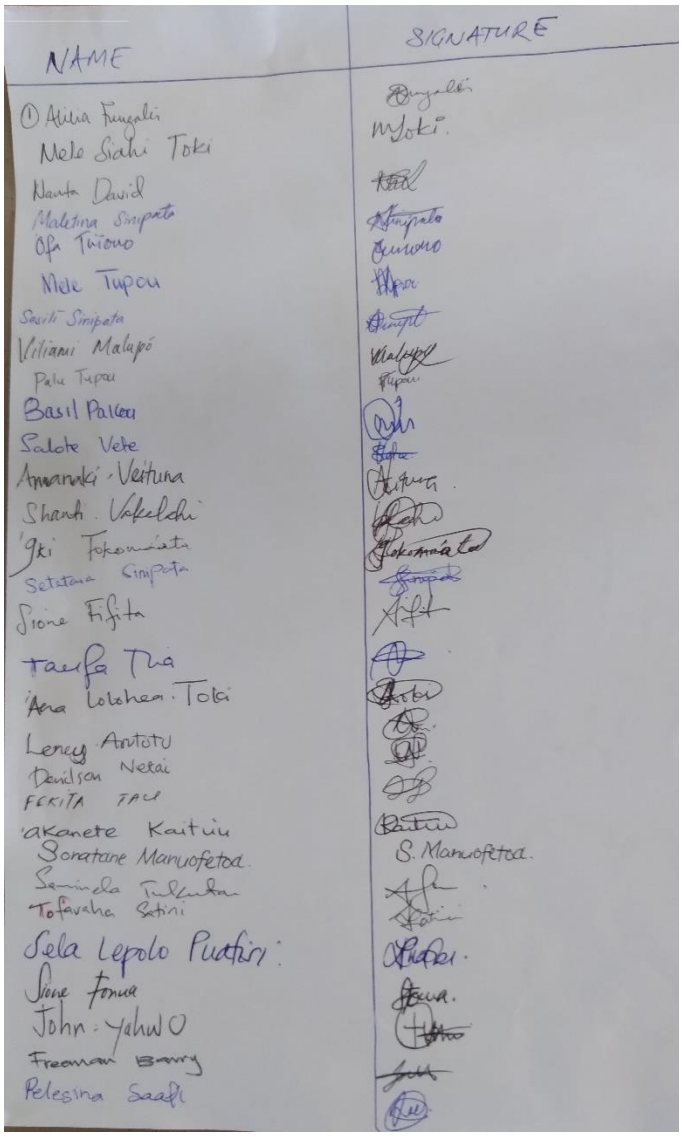


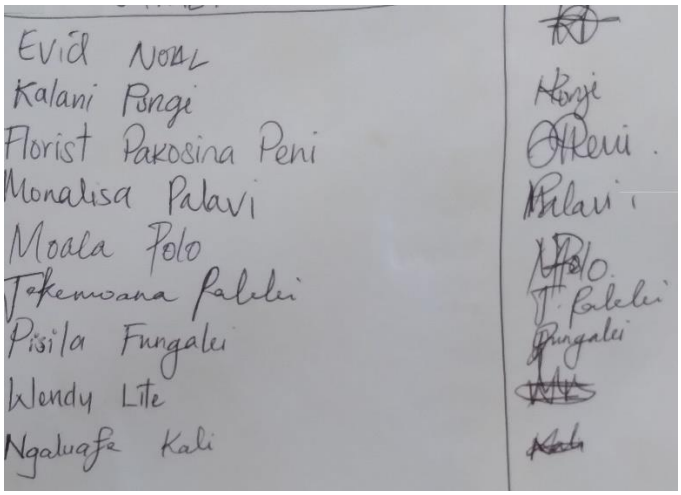
MAFF staff (12/3/21). Only a list was obtained with no signatures



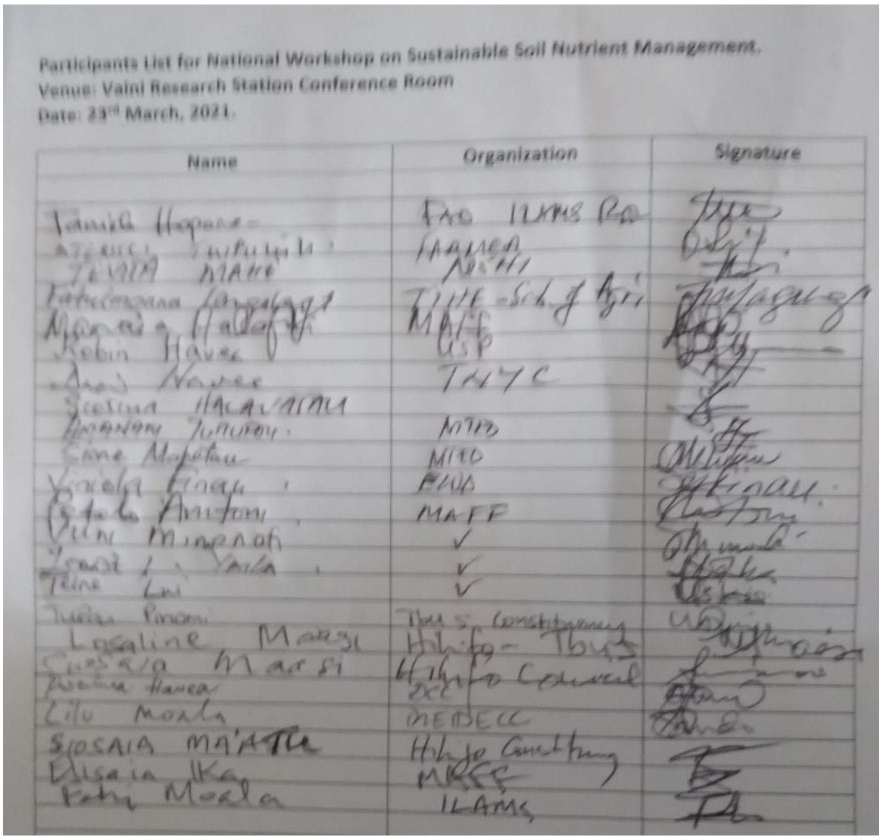
National Workshop

‘Eua 24/2/21





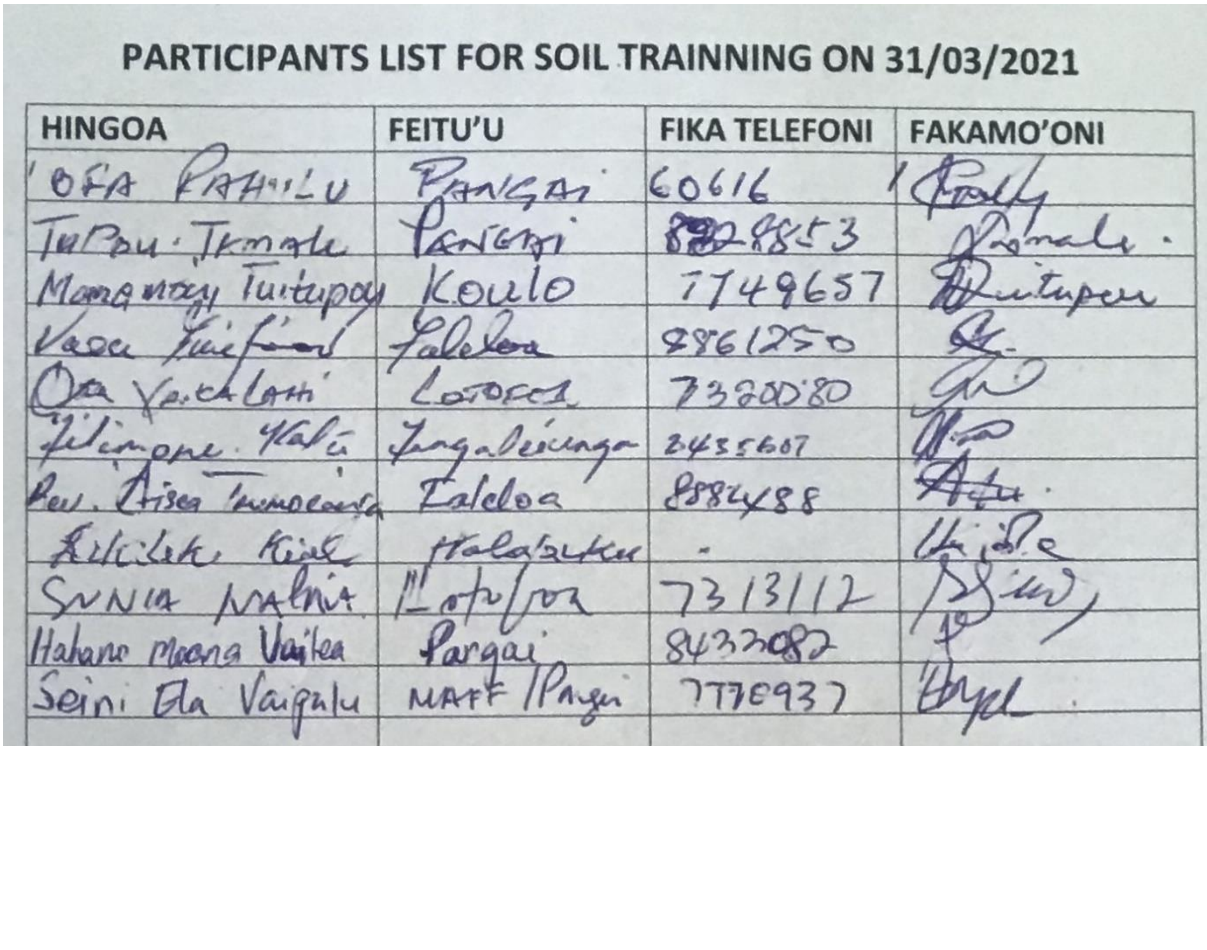
Tongatapu (23/3/21)



Participants List for National Workshop on Sustainable Soil Nutrient Management.
Venue: Vaini Research Station Conference Room
Date: 23rd March, 2021.

Name	Organization	Signature
Tamila Hopane	FAO ILAMS Ra	[illegible]
Ateliei Tuipulotu	FAAMEA	[illegible]
Tevita Mahe	NOSHI	[illegible]
Fatulemoana Langalanga	TIHE - Sch of Agri	[illegible]
Manaia Halafihi	MAFF	[illegible]
Robin Havea	USP	[illegible]
Anai Havea	THYC	[illegible]
Siosiua Halavatau		[illegible]
Ahanisi Tupou	MTED	[illegible]
Sione Mapotau	MTED	[illegible]
Viola Fineau	EWA	[illegible]
Setala Amiton	MAFF	[illegible]
Pita Minenoti	✓	[illegible]
Losaki Vaila	✓	[illegible]
Teine Lui	✓	[illegible]
Tupou Pinomi	Tbu 5 Constituency	[illegible]
Losaline Maasi	Hihifo - Tbu 13	[illegible]
Susana Maasi	Hihifo Council	[illegible]
Pauline Havea	DCC	[illegible]
Lilu Moala	MEIDECC	[illegible]
Siosaia Ma'ata	Hihifo Constituency	[illegible]
Uisaia Ika	MAFF	[illegible]
Fehi Moala	ILAMS	[illegible]

Haápai (31/3/210



PARTICIPANTS LIST FOR SOIL TRAINNING ON 31/03/2021

HINGOA	FEITU'U	FIKA TELEFONI	FAKAMO'ONI
'Ofa Pahulu	Pangai	60616	[illegible]
Tupou Tamale	Pangai	8928853	[illegible]
Mamanoa Tuitupou	Koulo	7749657	[illegible]
Vasa Finifonua	Faleloa	8861250	[illegible]
Ofa Vaitahanoa	Lotofoa	7320080	[illegible]
Filimone Kalu	Tongaleleka	8435607	[illegible]
Rev. 'Aisea Tuimoeanga	Faleloa	888488	[illegible]
Ailileki Kioa	Holopeka	-	[illegible]
Sunia Malua	'Lotofoa	7313112	[illegible]
Hahano Moana Vaitea	Pangai	8433082	[illegible]
Seini Ela Vaipulu	MAFF /Pangai	7776937	[illegible]