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IRRIGATION AND DISEASE IN A CITRUS ORCHARD: A PRELIMINARY STUDY.

A report of a 2 day study into the irrigation and disease problems at the Fiji Citrus Company Batiri orchard.

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INTRODUCTION

All higher plants rely upon water from the soil for growth and survival. The availability or otherwise of water is a major determinant of species distribution and success in any given environment. Water availability can fluctuate naturally over a period of hours, days, weeks or months, and it is the job of irrigation manager to ensure that these changes do not impede the growth and yield of the crop in the field, that is, that water does not become a limiting factor to the productivity of the crop. Given an adequate supply of water and also an adequate distribution system, the problem becomes one of knowing when to irrigate and how much to irrigate. These are the central issues addressed first in this preliminary study. Recommendations are made detailing the data required for the rapid and accurate solution of these problems on this site so that the timing and quantity of irrigation can be optimised within the limitations of the water supply system present.

A second facet of this study was the estimation of damage incurred to the trees and fruit due to disease. Disease here encompasses viral, bacterial, fungal and insect attack on leaves, bark and fruit. The central questions addressed were - what diseases are present, and how best to estimate the extent of the disease from the entire orchard? From this it will be possible for the orchard manager to determine the point at which control by spraying becomes economical.

PART ONE - IRRIGATION.

THEORETICAL BACKGROUND.

It is felt that the presentation of a brief theoretical background to the irrigation study will help the reader view the recommendations in a wider context.

During the day, water is lost from the leaves of a plant to the atmosphere. This evaporation from the interior of the leaf occurs via the stomata. Stomata are the pores in the leaf surface which allow carbon dioxide (CO_2) into and H_2O out of the leaf. The plant has the ability to open and close these stomata in response to a wide range of stimuli. Only whilst the stomata are open can photosynthesis occur (in most plants), and hence, is yield produced. Most plants (including citrus) open their stomata during the day and close them at night. Some species, including pineapple, open their stomata at night and not during the day. This accounts for pineapples lower consumption of water.

Stomata respond actively and rapidly to water stress by closing, the degree of closure being approximately proportional to the degree of water stress. This response is intuitively correct since plants need to prevent excessive water loss to allow growth. Thus when water becomes less available, the plant needs to conserve water and reduce loss. However, at some point a dilemma arises because eventually the reduction in stomatal aperture will cause a reduction in rates of photosynthesis since CO_2 input to the leaf is reduced. Clearly, the response of the stomata can provide a reliable index to plant water status and potential productivity, and the recommendations following are based on this view.

The rate at which water is lost from a leaf (Jv) is determined by the gradient of water vapour density (difference in water vapour concentration, or humidity), between leaf interior and atmosphere; and the resistance to vapour diffusion. Thus:

$$Jv = \frac{\text{water vapour concentration difference}}{\text{resistance to flow}}$$

where Jv = rate of water loss, in cubic centimetres of water lost per square centimetre of leaf per second ($cm^3\ cm^{-2}\ sec^{-1}$),

water vapour concentration difference = the difference between the volume of water per cubic centimetre of air in the leaf (assumed to be saturated, i.e 100% humidity at the ambient temperature) and the volume of water per cubic centimetre of air in the atmosphere (measured using wet and dry bulb temperatures,) and resistance to flow = a measure of the stomatal opening. The less open the stomata the higher the resistance, and the less easy it is for water vapour to leave the leaf. Measured using the portable porometer, with units of seconds per centimetre.

This is a useful relationship since it tells us just how much water is being lost from a leaf, and hence from a tree, if the resistance of the leaf is known and the humidity and air temperature are known. These parameters are very simple to measure. This will provide a base line of water consumption. If there is no input of water to the soil from rain or groundwater, then water must be supplied by irrigation at a minimum rate equivalent to evaporative loss.

As the plant transpires and water leaves the leaf, water is taken up from the soil. Soil water is replenished from three sources- rainfall, irrigation and groundwater. As long as the soil water content remains sufficiently high the plant will be able to take up water fast enough to prevent the development of a water deficit in the plant. Only small water deficits need occur to reduce plant growth and development significantly. A major cause of reduced yield during periods of water stress is the reduction in stomatal aperture (increased stomatal resistance) which limits CO_2 influx and hence reduces photosynthesis.

At what point do soil water levels become limiting to plant growth? The answer to this depends upon the soil type, the species of plant, plant age, and prior growth conditions. The most accurate way to answer this is to study the actual location, species, and soil type present (see recommendations). Generally a sandy soil holds less available water than a loamy soil, and younger leaves are more susceptible to water stress than older leaves. Citrus trees are accepted as having higher stomatal resistances to water loss than crops such as wheat, soybean and maize.

Water moves from soil to root, and from root to leaf, down a gradient of water potential, that is, water moves from a place of high water potential to a place of lower water potential. The potential of water in the soil and plant is actually influenced by several factors, the sum of which is called the **water potential.** As the water content of the soil changes, the water potential changes. Less water in a soil means a lower water potential. If the soil water potential becomes equal to the root potential water uptake ceases. If soil water potential becomes lower than the root, the root loses water to the soil. A widely accepted view is that when the soil water potential is equal to or lower than 15 bar, plants wilt severely. The water content at which the soil water potential equals 15 bar differs for different soils being primarily determined by particle size distribution and organic matter content. Thus it is necessary to determine for each soil type at what water content soil water potential is 15 bar. However, different species differ in their wilting potential, so this too must be accounted for in the study. (See recommendations)

Soil water potential can be measured in a variety of ways. However, the method available on site at Batiri is by tensiometer. A few points about the correct use of tensiometers may be useful here. First, they are reliable only to values from 0 to 0.7–0.8 bar. Below this value cavitation frequently occurs, or air entry into the pores of the ceramic cup. Once this has occured the tensiometer must be re-established. Tensiometers should be filled with air-free water. This may be obtained by boiling tap water for several minutes prior to use,and then allowing it to cool in a sealed container. Once the instrument has been filled with water and the hole bored with as tight a fit between ceramic cup and soil as possible, it can be inserted to the <u>bottom</u> of the hole. It is beneficial if a slurry of the soil from the bottom of the hole (not the top soil) is made and put down the hole prior to the ceramic cup. This ensures a close water laden junction between cup and soil. It will take 3 or 4 days for the system to equilibrate and give meaningful readings. Alternatively the soil at the bottom of the hole for the cup can be moistened prior to the insertion of the cup.

Tensiometers do not normally measure water potential, but only a component of water potential (the matric potential). Furthermore, tensiometer readings alone are of minimal value unless it is known at what tensiometer value soil water becomes limiting. This varies according to species and soil type, and needs to be correlated on site. In addition, since the tensiometer only covers a small part (up to 0.7 bar) of the soil water content versus water potential curve, it is advisable to use additional equipment to characterise the soil water potential versus water content curve (the water retention curve). However, since it is plant growth and productivity that we are concerned with, these data should be correlated to a plant water staus parameter, that is, a parameter that can be measured on the plant which reflects the water status of the plant. Stomatal aperture is the parameter recommended here. A previous study on Valencia orange (Citrus sinensi) growing on Troyer citrange (Poncirus trifoliata x Citrus sinensis) rootstock in the USA found the following relationship between tensiometer reading and leaf water potential (Fig. 1) and leaf water potential and leaf stomatal resistance in two different humidity regimes (Fig.2a, 2b.) Clearly, with the aid of calibration and a few additional measurements, the tensiometer is of great benefit. However, it is necessary to know at what tensiometer reading soil water becomes limiting. (see recommendations)

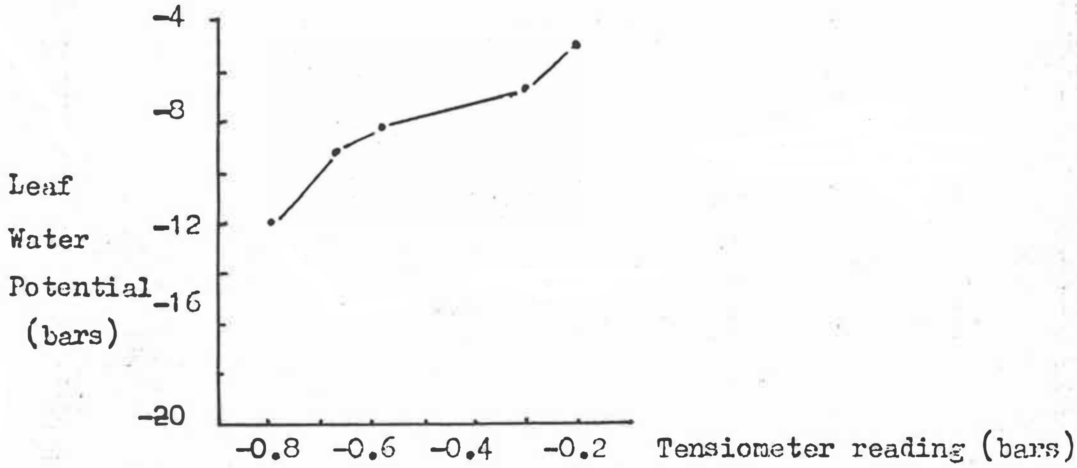

Fig 1. Comparison of sunrise leaf water potential under field conditions for different levels of soil water availability.

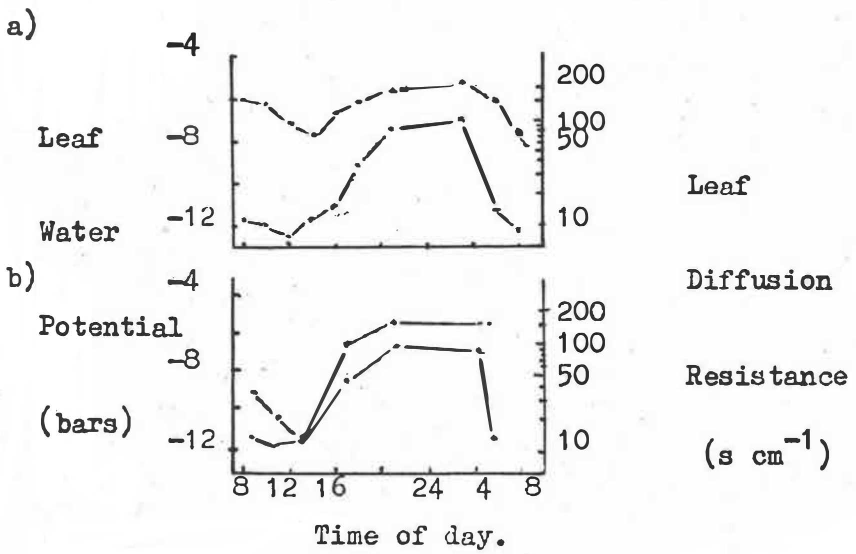

Fig 2. Diurnal variation in leaf water potential and leaf diffusion resistance under non-limiting enviromental conditions for (a) low vapour pressure deficits (1 to 4 mm Hg) and high VPD (up to 20 mm Hg). (b)

(Taken from D.C.Elfving, M.R.Kaufmann and A.E.Hall, 1972, Physiologia Plantarum, 27, p.161-168).)

RECOMMENDATIONS

The following are the recommendations for action, which, if undertaken, will provide the information required to determine when to irrigate, and how much to irrigate, thereby maximising irrigation efficiency. In addition there are further proposals which are aimed at increasing the efficiency of the present system regardless of any other information to be gained in the future.

1) It is necessary first to know exactly the point at which soil water becomes limiting to productivity. The best indicator of plant water status is the plant itself, not some arbitrarily set value of soil water content. To determine this it will be necessary to isolate three trees at different positions in the orchard from any external water source and allow the soil to dry out. Simultaneously tensiometer readings will be made and the stomatal resistance measured on the trees. At some point the trees will experience water stress, the stomata will close and the tensiometer reading corresponding to this soil water content will be known. In addition, soil samples should be taken from various depths to measure the water content gravimetrically, throughout the period of decreasing soil water content. From this it will be possible to know at what tensiometer readings irrigation should start and also the water content of the soil corresponding to the period of study. Since tensiometers have a

limited useful range, it will be necessary to use soil psychrometers to measure soil water potential over the complete range encountered. Furthermore, this will provide an independent check on the accuracy of the tensiometers. Finally, it will allow further charactersization of the soil water retaining capacity, which will be needed to determine how much irrigation is needed (see point 2).

2) As the water content of the soil decreases the water potential decreases, (that is, becomes more negative) and it is the difference between soil and root water potential that determines the rate of water entry to the root. Different soils have different curves relating soil water content and soil water potential. Thus it will be necessary to construct a water retention curve for the soil under study. Two methods should be employed. First, a gravimetric technique, measuring the water content of the soil on a weight and volume basis, (e.g. 20 grammes of water per 100 grammes of soil) in conjunction with the tensiometer and thermocouple readings made at three trees. This is very accurate, but time consuming. Second, a pressure plate and tension plate apparatus can be used on undisturbed (if possible, since the accuracy and reliability of readings at potentials greater than 10 bar is seriously reduced on disturbed soils) soil samples obtained from a core sample. This is quicker but can only be done in the Institute of Natural Resources

laboratory in Suva. These measurements will then allow the calculation of how much irrigation water is required to bring the soil to field capacity, and hence the optimum time for irrigation pumping. The Field Capacity (FC) can be defined as the water content of the soil, determined gravimetrically, after the soil has equilibrated to a suction pressure of 0.05 bar, or, as the water content of a soil that has drained for 3 days, from saturation, in the absence of surface evaporation. Too little irrigation is clearly of minimal benefit, and too much irrigation can cause root flooding, which reduces water uptake. It also results in reduced root growth due to oxygen depletion, again detrimental to water uptake. The determination of the water retention curve will also allow the calculation of the volume of water held in the soil at any given water potential. Thus if the amount of rainfall is known, adjustment can be made to the amount of irrigation needed. It is common irrigation practice to irrigate when 50-60% of the available water in the root zone has been used.

3) The root system of a tree is typically approximately as wide as the crown of the tree. The most active part of a root for water uptake is the growing region at the tip. Only during water stress does the older part of the root become important in water uptake. The rate of lateral water flow in soil is normally less than the flow in a downwards direction. Thus, it is suggested

that the distance between the water outlet points on the irrigation pipes be incresed substantially, to a distance of 150 cm. If the outflow nozzles cannot be moved it is suggested that they be turned to face outwards (away from the trunk).
An investigation of the root/depth profile and also the water conductance (hydraulic conductivity) of the soil in a vertical and horizontal direction would yield imformation that would allow the positioning of the outflow nozzles to be optimal for this site.

4) A sloping field imposes problems to the management of irrigation. Drainage from the upper to the lower parts will cause unequal requirements for irrigation down the slope. At the moment the supply pipes have been located down the slope, that is, a single supply pipe runs from the top to the bottom of the field, thereby supplying the same amount of water to the upper and lower regions. A better arrangement is to have the pipes running accross the field. In conjunction with this, if the upper and lower halves of the field can have seperate stop taps, such that the upper can receive more water and the lower region less, the accumulation of water at the lower end can be reduced. Furthermore, the irrigation is then tailored more to the need of the trees. The purpose of this recommendation is to increase the efficiency of irrigation. However it is accepted that this proposal may be too costly, time consuming and make the

irrigation system inoperable for too long, to be implemented. Indeed it is the next recommendation which is of more importance.

5) Discussions with different workers gave different answers to the question: is irrigation carried out only during the day, or at night also? Working on the assumption that it is not carried out at night I would strongly recommend that facilities for night-time irrigation be installed, either as an automatic system capable of changing the blocks irrigated after a preset time or as a worker charged with changing the irrigated blocks manually.

This is needed for the following reasons:
An apparent problem for the orchard is the onset of early rains too soon into the 7-8 week drought period needed to induce dormancy. This results in the entire orchard breaking dormancy and flowering, and hence fruiting simultaneously. Once the entire orchard receives rain it is necessary to irrigate the entire area at this most critical time for fruit set and growth. If the average humidity at this time is 66% and the temperature 30° C and the average leaf area index 5 and the average tree area 15 square metres (these are just representative valus to illustrate the point) then the water consumption of one tree is:

$$Jv = (10\ ug\ cm^{-3})/3\ s\ cm^{-1}$$

$$= 3.3\ ug\ cm^{-2}\ s^{-1}$$

$$=118\ cm^{3}\ m^{-1}\ hr^{-1}$$

If leaf area index is 5 and tree area is $15m^2$,

=8.85 litres of water per tree per hour.

In a 12 hour day this is 106.2 litres of water per day per tree. The rate of water supply is approx. 80 litres per hour. Thus, to supply the water needs will need approx 1.33 hours of irrigation. Since only 5% of the entire orchard can be irrigated at any one time it will take 20 x 1.33 = 26.66 hours to irrigate all the trees. Thus in an 8 hour shift it will take 3 days and 2.66 hours to complete one days worth of transpiration. However, if the irrigation is carried out at night also, then almost the entire orchard can be irrigated in one day. Night time irrigation is also of greater efficiency since a larger proportion of water enters the soil as opposed to being evaporated off by the sun.

6) A means of reducing the rate of transpiration from crops, and hence reducing the irrigation requirements, has been sought for many years. Of the many possibilities, the only relevant one here is the construction of large wind breaks around and through the orchard. This will reduce the rate of transpiration from the entire orchard, but will require detailed planning to be effective. The cost will also be high.

CONCLUSION

Recommendations have been made for 2 sets of action. The first set is to allow the collection of the data needed to answer the questions how to know when to irrigate?' and 'how much to irrigate?' The data is simple to collect and rapidly obtained. The second set are suggestions to improve the existing arrangement for irrigation but the costs involved need to be carefully considered. However, the implementation of night-time irrigation is strongly recommended. With regard to the problem pointed out of the arrival of early rains breaking dormancy throughout the orchard, little can be done, apart from the possibility of trying to start the onset of dormancy early by the cessation of irrigation as early as possible. The potential use of chemicals to induce dormancy remains too distant in the future for further contemplation at this stage.

PART TWO - DISEASE ASPECTS

Pathological Survey of Fiji Citrus Orchards.

An examination of random blocks within the orchard showed the trees to be in poor vigour. Specific indications of this were reduced tree size for their ages, stunted leaf growth, bark splitiing and twig die back. Yields of fruit appeared lower than expectations and the early dropping of fruit prevalent.

The reduced vigour of the trees cannot be explained solely on the basis of disease. Poor climate for the fruit tree species, and poor edaphic conditions contribute significantly to the poor condition of the trees. The high levels of disease observed are a result of, not the cause of, the low vigour. Only healthy trees can remain resistant to infection and maintain yield in the face of infection. Thus it is suggested that the control of disease in the orchard requires not only fungicides, bacteriacides and insecticides, but also the application of appropriate fertiliser to the soil, and the monitoring of soil pH and water content. A soil pH of greater than 5.5 greatly increases the incidence of many diseases, particularily of the roots, in many species, including citrus. The benefit to soil structure, organic content, plant growth and yield after the application of organic fertiliser (mill mud) to one block was highlighted during the stay at Batiri. This should be extended to the entire orchard. Although the soil organic content of the soil has been shown to be reasonable (2-5% Carbon, see INR Report to Batiri, February 1984), the addition of extra organic matter (as Lautoka mill mud) was clearly beneficial. Furthermore, a later INR report (Jan/Feb 1985) indicates that a close watch on available soil phosphorous, nitrogen and Magnesium should be made. Deficiencies in these nutrients may be expected to decrease the disease resistance of the trees.

The following is a description of the symptoms, and treatment of the major diseases observed in the orchard. A simple procedure for the monitoring and measurement of the incidence of mites is also given.

Brown Rot of Citrus (*Phytophthora citrophthora*)

P.citrophthora is of world wide distribution and several other species of the same genus can also attack citrus. All parts of the tree are subject to brown rot. Root and trunk infection shows first as an unhealthy and yellowy appearance of the leaves, and the trunk shows small exudation of gum. Infected bark remains firm and attached until drying causes it to shrink away from the wood and crack longitudinally. Brown rot kills bark and cambium but penetrates the underlying wood only minimally. Where lesions occur, secondary infection by other pathogens leads to soft rot characterised by an unpleasant sour smell.

Fruit which drops from an infected tree will infect the soil, whilst rain splash from an infected soil will disperse the spores onto low growing fruit and leaves.

Brown rot can be controlled. If trunk lesions are observed all the infected bark should be stripped away until only green cambium is seen. All <u>brown</u> tissue should be removed. The resulting area and surrounding area should be coated with a <u>PASTE</u> of Bordeaux mixture. When callous formation subsequently occurs, the exposed wood should be further coated with <u>bituminous paint.</u> In addition, the soil of the block should be checked for poor drainage. Phytophthora flourishes well in heavy wet soil and the fungus cannot spread through soil if it is adequately drained.

Control of the infection in the branches is simpler but the overall poor condition and reduced size of the trees at Batiri may make the cure difficult. All leaves and fruits and green living branches within 1 metre of the ground should be removed. Then apply a spray of Bordeaux mixture in a ratio of 6:8:100 in May, followed by a second apray in June. This treatment will also control <u>verrucosis and wither tip.</u>

Whilst it is accepted that the removal of all living tree parts within 1 metre of the ground may appear drastic on small trees, it is the most efficient means of control. Even without a heavy fruit load on the branches a large number of trees were observed to be touching the ground. It is only a matter of time before brown rot is present on all trees in all blocks if this is allowed to continue. Fortunately with the low organic content of the soil and the occurence of dry seasons, it may be expected that phytophora will survive for only a short period in the soil. This may explain the relatively low occurence of collar rot in infected blocks.

MITES (Phyllocoptruta oleivova, citrus rust mite.)

Evidence of mite feeding was observed on the young fruit in all blocks investigated. The symptoms are a brown to grey scabrous type of russetting and results in a reduced fruit, with a physical appearance that makes it unsuitable for fresh fruit marketing. Shipping and storage quality are also reduced, again reducing the fruit value on the fresh fruit market.

Several factors influence the relationship between the intensity of infection and the loss of value during a mite infestation. The two most important are a) the stage of crop development at the time of infestation, and b) the vigour of the trees. This later factor is very relevant to the Batiri orchard.

At temperatures above 28°C mite damage becomes more severe. It is possible to calculate the loss of yield as a function of mite infection rate. Table 1 relates the expected percentage of damaged fruit in relation to percentage of mite infestation. Clearly it is necessary to be able to assess the degree of mite infestation in the orchard. A simple method for this is described after the table.

TABLE 1

Relation of expected percentage of damaged fruit to percentage mite infestation

% mite infestation	Expected % of damaged fruit for a 10 day feeding period. Temp.=28°C.
5	2
10	5
20	10
30	15
50	40
70	60
90	80

Control Procedures

As with all insect attacks it is vital to know WHEN to spray. The following procedure, if carried out, will indicate the degree of infestation within a block, and thus allow the timing of spraying to be determined.

Examine with a X10 hand lens areas of the surface of the fruit that face the trunk. Examine a similar area of fruit surface that faces away from the trunk. Examine a 1 cm^2 area of upper and lower surface of leaves. If a mite is seen this tree is counted as infested.

Examine each block seperately. Examine 20 leaves and 20 fruit from all around the tree canopy, and repeat this on every 6th tree in the rows adjacent to the borders of the block. For a block of 4 hectares, 30 40 trees should be examined. The intensity of infestation is then calculated and expressed as a percentage of the total number of trees examined. The density level of infestation requiring spraying is 20%. Natural factors cause rust mite populations to increase 2 or 3 times per year. Prompt spraying with miticides is therefore needed to prevent a rapid increase in population size.

TWIG DIE-BACK (Corticium salmonocolor, or Colletotrichum gloesporioides.)

Occasional twig die-back was observed where pink fungal growth was present on dead wood. Without laboratory facilities, it is not possible to classify the fungus definitively. However it is most likely to be a form of wither tip which has infected the new bud at the apex of the branch. This disease is common in Australia and is of (usually) minor importance. Infected branches branches may assume a yellowish colouration and the leaves drop off. Actual leaf infection is rare. The occasional fruit infection is characterised by depressed brown lesions.

Control of twig die-back is achieved by foliar application of FERBAM (1.5 lbs per 100 gal. water.) at 7-10 day intervals in severe attacks. Primary control is to prune and remove infected branches if infection is only scattered.

BARK SPLITTING

Bark splitting was observed on many trees in all blocks studied. When the wounds were investigated, healthy green cambium was found in the splits, indicating that fungal infection was not the causal agent. Neither did the trees show symptoms synonomous with the Exocotis virus or gumnosis.

Several bark rots proposed to be viral in cause are found in China, Indonesia and the Phillipines. However a previous investigation into the occurence of viral particles by Dr.P.Whitney at Batiri did not reveal any viruses. However it is recommended that annual tests are made on new lesions for viral presence. Assuming the trees to be free of viral infection the bark splitting must be concluded as reflecting a physiological disorder imposed by climate or soil conditions. To prevent secondary infection lesions should be sprayed with half-strength Alliete solution.

SOOTY MOLD.

This is caused by heavily pigmented fungi of the Deuteromycete and Ascomycete Divisions growing on the leaf surface. Technically it is not a tree pathogen since it does not parisitize the host. They obtain nutrients from the honey-dew excreted from sap sucking insects. In dense infection sites (as were observed in the orchard) the fungi reduce photosynthetic production due to the blocking out of light. Since the fungi feed off insect derived nutrients, the high incidence of sooty mold reflects high insect presence (particularily aphids). The method for estimating mite population size can equally be used for aphid population estimates. Without the aphid the sooty mold will decrease to low levels. Sprays for aphids are widely available.

LEAF SPOT (Cause unknown)

Extensive leaf spotting on new flush growth was in block 1 and should be checked for throughout the orchard. A higher incidence on high branches may reflect a wind borne disease. Further extensive laboratory studies would be needed for an identification to be made.

An apparently genetic disorder in Valencia sweet orange has been noted in some studies. This disorder produces lesions resembling those of bacterial canker and is known as crancroid spot. Furthermore, scab (verrucosis) leprosis and anthracnose all produce symptoms similar to those found in block 1. As the disease was not positively identified as not being canker, it is strongly recommended that the Ministry for Primary Industries in Vanua Levu be informed and asked to identify the symptoms. Samples cannot be sent to Viti Levu and the export sale of fruit should be postponed until verification of the disease causing organism is made. It is hoped that this matter will have been attended to before this report reaches the Batiri managers.

PINEAPPLE.

The pineapple plants observed were healthy and in very good vigour, especially those of the fertilised plots. The lodging of fruit was a result of the weight of the fruit and not due to bacterial heart rot (Erwinia carotovova). Some heart rot due to Phytophthora parasitica was observed but was not extensive and may be dealt with by using fungicidal sprays.

On only one occasion was a cut pineapple observed, when it was found to be infected with Pseudomonas ananus, which is the brown spots/flecks visible in the fruitlet after cutting, when the fruit ripens. It does not continue throughout storage and the bacterium is most prevalent in the temperature range 31-33°C. It is not visible externally prior to harvest and thus difficult to diagnose. It should not affect the processing quality of the fruit.

CONCLUSION

Much of the disease problem associated with the trees is a product of poor tree vigour, and the reticence to cut the branches of the trees that lie within 1 metre of the ground. The benefit of adding organic fertilizer to the soil can be seen easily, and this should be extended to the entire orchard. This will benefit all the problems present— water storage and drainage of the soil; improved tree growth and yield; and increased disease resistance. The move to a new crop is strongly supported, and the choice of pineapple fortuitous since the water requirement of these plants is much less than the citrus, thus making irrigation easier. Furthermore the commercial availabilty of pineapple flower inducing hormone (it is not available for citrus) makes the timing of the fruit collection for the maximising of factory productivity easier.