THE UNIVERSITY OF THE SOUTH PACIFIC
LIBRARY
DIGITAL THESES PROJECT

Author: Statement of Accessibility- Part 2- Permission for Internet Access

Name of Candidate: Mr. Joel S. Gauwae

Degree: M. Sc.

Department/School: The University of the South Pacific

Institution/University: ____________________________

Thesis Title: Effect of potassium on cane yield and the potassium status of some cane growing soils of Fiji

Date of completion of requirements for award: ____________________________

1. I authorise the University to make this thesis available on the Internet for access by
USP authorised users.

2. I authorise the University to make this thesis available on the Internet under the
International digital theses project

Signed: ____________________________

Date: ____________

Contact Address Permanent Address

O. O. Box 3570

Lautoka

___

1981

E-mail: joel@usc.com.fj e-mail: ____________________________

July 2004

SB 239 F 5 3.29 1997.

EF
EFFECT OF POTASSIUM ON CANE YIELD
AND THE POTASSIUM STATUS OF SOME
CANE GROWING SOILS OF FIJI

A thesis presented in partial fulfilment of the
requirements for the degree of Master of Science at
The University of South Pacific

JAI S GAWANDER
1997
DECLARATION

I declare that this thesis is a report of research work carried out by me and has not been submitted in any form for another degree or diploma at any university. Information obtained from the published or unpublished work of others and help received in setting up of field studies have been acknowledged.

JAI S GAWANDER
This study investigated aspects of potassium in sugarcane agronomy - the potassium status of sugar-growing soils, potassium response and uptake in field trials, and a preliminary budget for potassium in sugarcane growth in Fiji. The potassium (K) status of eight soils representing the major cane growing soils of Fiji was evaluated. Samples were taken from fields that were under cultivation and also from sites which were not cultivated for at least 30 years.

The potassium status of soils, as measured by levels of exchangeable K and soil solution K, was low on most soils. Five sites were on highly weathered oxidic soils where the total K content was low and K retention capacity also tended to be low. The two less weathered soils contained significant amounts of 2:1 expandable layer silicate minerals and had much higher total K and non-exchangeable K compared with five strongly weathered soils. However, on both of the less weathered soils intensive cultivation resulted in a decrease in non-exchangeable as well as exchangeable K in comparison with fallowed sites. This indicates that removal of K was occurring at the intensively cultivated sites.

The laboratory studies indicated that less weathered soils had reasonably high negative surface charges and potassium
contents compared to highly weathered soils. These soils had greater capacity to retain potassium.

The effects of various rates of potassium on the growth and yield of sugarcane was studied by establishing three field trials. The results from the three trials showed no significant effect of various rates of potassium fertilizer on germination and number of tillers per stool. However, stalk length and population increased with increasing rates of added K. The results indicated that significant response to cane and sugar yields were obtained in plant and succeeding ratoon crops at sites where the initial exchangeable potassium level in the soil was 42 and 72 mg/kg. There was no significant response with increasing rates of potassium at the site where the initial potassium level was 96 mg/kg. This clearly indicated that the threshold values of < 72 mg/kg (critically deficient) and (72-110) mg/kg (deficiency range) for plant and ratoon crop respectively derived from many field trials and observations could still be used as a good indicator for yield response to potassium fertilizer application.

The long term cultivation of cane farms requires that nutrient inputs should balance losses if the soil fertility is to be maintained for the industry to be sustainable. The inputs of potassium on the cane farms are from fertilizer, mill mud, animal waste, ash, burning of trash and organic matter.
Losses are mainly from leaching, soil erosion and cane removed from field. The results in this study indicated that by not applying any fertilizer the land loses at least 287 kg K/ha during the cropping cycle. However, a net gain is achieved if the fields are fertilized with 250 or 500 kg K/ha each year for plant and two ratoon crops. The preliminary budget clearly indicates that the existing cane farming system is mining the land of potassium.
I like to express my sincere thanks to Professor John Morrison for his never ending enthusiasm, motivation and guidance during the study period. I am thankful to Messrs Masilaca, Prem Naidu and Ramma for maintaining and caring for the trials in Labasa. I am very much indebted to Mr Param Sivam for managing the trial at Kabisi and for his assistance in compiling the data. The hard work of the General Employees of the Agronomy Department at the Sugarcane Research Centre and those at Labasa is also acknowledged.

Dr Ravindra Naidu of CSIRO, Adelaide for his assistance and advice during the studies. A special note of appreciation to my supervisor Dr Philomena Gangaiya of The University of South Pacific for her guidance in the preparation of the thesis.

My sincere thanks to Fiji Sugar Corporation Limited for financial support and time is gratefully acknowledged. Mrs Saroj Lal is thanked for the typing of the thesis, tables and figures. Mrs Sunita Dutt, Mrs Meena Nair and Mrs S Damuni are also thanked for their assistance.
TABLE OF CONTENTS

DECLARATION ................................................................. ii
ABSTRACT .................................................................. iii
ACKNOWLEDGEMENTS .................................................. vi
TABLE OF CONTENTS .................................................... vii
LIST OF FIGURES ........................................................... vii
LIST OF TABLES .......................................................... x

CHAPTER 1

GENERAL INTRODUCTION ................................................. 1
  1.1 Introduction ......................................................... 1
  1.2 Role of Potassium(K) in Plants ............................... 5
  1.3 Potassium Deficiency ............................................. 9
  1.4 Soil Potassium ..................................................... 10
     1.4.1 Total Potassium ............................................ 10
     1.4.2 Form of Potassium ....................................... 12
     1.4.3 Soil Solution Potassium ................................... 14
     1.4.4 Exchangeable Potassium ................................. 14
     1.4.5 Non-exchangeable Potassium ........................... 15
     1.4.6 Primary and Secondary Minerals ...................... 16
     1.4.7 Potassium Release & Uptake ........................... 18
     1.4.8 Potassium Availability ................................... 19
  1.5 Losses of Potassium from Cane Fields .................... 20
  1.6 Potassium Threshold in Sugarcane ......................... 24
  1.7 Effect of Potassium on Sugarcane Yields .................. 25
  1.8 Potassium usage in the Fiji Sugar Industry .............. 27
  1.9 Aim of Study ...................................................... 28

CHAPTER 2

GENERAL MATERIALS AND METHODS .............................. 30
  2.1 Soils ................................................................. 30
     2.1.1 Introduction ............................................... 30
     2.1.2 Soil Sampling .............................................. 30
     2.1.3 Soil Preparation .......................................... 32
     2.1.4 pH (0.01M CaCl2) ....................................... 32
     2.1.5 pH (water) ................................................ 32
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2 Soil Potassium, Calcium and Phosphorus</td>
<td>32</td>
</tr>
<tr>
<td>2.2.1 Potassium ion in External Solution</td>
<td>32</td>
</tr>
<tr>
<td>2.2.2 Exchangeable K and Ca</td>
<td>33</td>
</tr>
<tr>
<td>2.2.3 Non Exchangeable K</td>
<td>33</td>
</tr>
<tr>
<td>2.2.4 450°C Exchangeable K</td>
<td>33</td>
</tr>
<tr>
<td>2.2.5 Total Potassium</td>
<td>34</td>
</tr>
<tr>
<td>2.2.6 Soil Phosphorus (modified Troup)</td>
<td>34</td>
</tr>
<tr>
<td>2.3 Negative &amp; Positive Charge</td>
<td>35</td>
</tr>
<tr>
<td>2.4 Plant Tissue Potassium Determination</td>
<td>36</td>
</tr>
<tr>
<td>2.5 Organic Carbon</td>
<td>37</td>
</tr>
<tr>
<td>2.6 Mineralogy</td>
<td>37</td>
</tr>
<tr>
<td>2.7 Potassium Sorption Studies</td>
<td>38</td>
</tr>
</tbody>
</table>

**CHAPTER 3**

**POTASSIUM STATUS OF SOME SUGARCANE GROWING SOILS IN FIJI**

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Introduction</td>
<td>39</td>
</tr>
<tr>
<td>3.1.1 Total Potassium</td>
<td>43</td>
</tr>
<tr>
<td>3.1.2 Exchangeable Potassium</td>
<td>45</td>
</tr>
<tr>
<td>3.1.3 Non-Exchangeable Potassium</td>
<td>47</td>
</tr>
<tr>
<td>3.1.4 Soil Solution Potassium</td>
<td>49</td>
</tr>
<tr>
<td>3.1.5 Potassium Sorption</td>
<td>50</td>
</tr>
<tr>
<td>3.1.6 Summary</td>
<td>52</td>
</tr>
</tbody>
</table>

**CHAPTER 4**

**EFFECT OF POTASSIUM FERTILIZER ON CANE AND SUCROSE YIELDS**

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Introduction</td>
<td>54</td>
</tr>
<tr>
<td>4.2 Materials and Methods</td>
<td>55</td>
</tr>
<tr>
<td>4.2.1 Field Experiment</td>
<td>55</td>
</tr>
<tr>
<td>4.2.2 Soil Type and Analysis</td>
<td>56</td>
</tr>
<tr>
<td>4.2.3 Trial Design</td>
<td>57</td>
</tr>
<tr>
<td>4.2.4 Location</td>
<td>59</td>
</tr>
<tr>
<td>4.2.5 Size of Plots</td>
<td>59</td>
</tr>
<tr>
<td>4.2.6 Cane Varieties</td>
<td>59</td>
</tr>
<tr>
<td>4.2.7 Seed Cane</td>
<td>60</td>
</tr>
<tr>
<td>4.2.8 Planting</td>
<td>60</td>
</tr>
<tr>
<td>4.2.9 Fertilizer Application</td>
<td>61</td>
</tr>
<tr>
<td>4.2.9.1 Site 1</td>
<td>61</td>
</tr>
<tr>
<td>Table</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>1.1 Effect of potassium on photosynthesis rate of sugarcane</td>
<td>8</td>
</tr>
<tr>
<td>3.1 Some properties of the soils studied</td>
<td>40</td>
</tr>
<tr>
<td>3.2 The potassium status of the soils studied</td>
<td>41</td>
</tr>
<tr>
<td>3.3 Different forms of potassium as a percentage of the total potassium</td>
<td>42</td>
</tr>
<tr>
<td>4.1 Information on trial locations, statistical design, replication, treatments and varieties</td>
<td>56</td>
</tr>
<tr>
<td>4.2 Initial soil analysis data for the trial sites</td>
<td>57</td>
</tr>
<tr>
<td>4.3 Percent germination in each plot at the 3 sites</td>
<td>66</td>
</tr>
<tr>
<td>4.4 Effect of potassium fertilizer on tillers per stool</td>
<td>68</td>
</tr>
<tr>
<td>4.5 Effect of potassium fertilizer on stalk height</td>
<td>70</td>
</tr>
<tr>
<td>4.6 Effect of potassium fertilizer on stalk population</td>
<td>72</td>
</tr>
<tr>
<td>4.7 Effect of potassium fertilizer on cane and sucrose yields on a migrescent soil (Kabisi) and Rainfall at the Site</td>
<td>75</td>
</tr>
<tr>
<td>4.8 Effect of potassium fertilizer on cane and sucrose yields on a ferruginous latoisol soil (Salove) and Rainfall at the Site</td>
<td>82</td>
</tr>
<tr>
<td>4.9 Effect of potassium fertilizer on cane and sucrose yields on a ferruginous latoisol soil (Lalakoro) and Rainfall at the Site</td>
<td>88</td>
</tr>
<tr>
<td>5.1 Changes in K levels in soil and potassium balance in sugarcane during plant, first and second ratoon crops (mean of 5 replications)</td>
<td>101</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table                                                    Page

1.1 Effect of potassium on photosynthesis rate of sugarcane ................................. 8

3.1 Some properties of the soils studied ......................40

3.2 The potassium status of the soils studied..............41

3.3 Different forms of potassium as a percentage of the total potassium ..................42

4.1 Information on trial locations, statistical design, replication, treatments and varieties........56

4.2 Initial soil analysis data for the trial sites........57

4.3 Percent germination in each plot at the 3 sites......66

4.4 Effect of potassium fertilizer on tillers per stool ........................................68

4.5 Effect of potassium fertilizer on stalk height......70

4.6 Effect of potassium fertilizer on stalk population...72

4.7 Effect of potassium fertilizer on cane and sucrose yields on a nigrescent soil (Kabisi) and Rainfall at the Site ...............................................75

4.8 Effect of potassium fertilizer on cane and sucrose yields on a ferruginous latosol soil (Salove) and Rainfall at the Site.................................82

4.9 Effect of potassium fertilizer on cane and sucrose yields on a ferruginous latosol soil (Lalakoro) and Rainfall at the Site ......................................88

5.1 Changes in K levels in soil and potassium balance in sugarcane during plant, first and second ratoon crops (mean of 5 replications) .......................101
CHAPTER 1

GENERAL INTRODUCTION

1.1 Introduction

The sweet sugarcane is a member of the family Gramineae of the genus *Saccharum* which is placed in the tribe Andropogoneae. The Andropogoneae are characteristically tropical and thus thrived in the rain-forest belts of the Pacific and the Indian subcontinent. The sweet cane (*Saccharum officinarum*) varieties were found growing naturally in Indonesia, Philippines, Fiji and Papua New Guinea (Deerr, 1911; Potts, 1955). The proposed centres of origin for sweet sugarcane may have been India but these varieties disappeared from the subcontinent and thrived in the rainforest of Papua New Guinea, Hawaii and Fiji (Panje, 1971, Sreenivasan, 1987).

Today, sugarcane is a major agricultural crop in some sixty subtropical and tropical countries with a total production of approximately 110 million tonnes of sugar per annum (ISO, 1996). In 1975, world sugar demand was approximately 75 million tonnes and since then, it has risen by 50% to almost 114 million tonnes in 1994, a growth rate of 2.1% sugar per year (Fry, 1997). In these countries, sugarcane produced is three times larger than the rice paddy crop and five times larger than wheat or corn crops. The value of sugarcane crop
is exceeded only by the value of the rice paddy crop. In these same countries, some seven to eight million people are employed in the sugar industry and thirty million or more are directly dependent on sugar industry income.

The Colonial Sugar Refinery Company (CSR) came to Fiji in the 1880's when men had to accept the sugarcane plant as it was found in nature. The only sugarcane available had originally been obtained from native gardens. These plants had thick brightly coloured stalks that contained sweet juice. They were low in fibre and easy to chew and crush in mills. The sugarcane scientists of the day were so much impressed with their handsome appearance that they called them the "noble" space canes. The first step CSR made in improving cane production, was to import the best varieties (germplasm) from overseas and then select the best for the Fijian conditions. By 1903, a breeding station was established at Rarawai, Fiji. This was the third sugarcane breeding station to be established in the world, preceding the better known stations such as Coimbatore, India, and Canal Point, Florida, which were not established until after 1910.

Sugarcane has been responsible for shaping the history of Fiji with the establishment of commercial cane farms and the arrival of indentured labourers brought over from India to
work on the plantations. After World War II, the demand for sugar increased and large areas in Western Viti Levu were brought under cane mostly on undulating terrain with poor soils (Valaibula, 1984). With independence, the need for sugar dollars was even more demanding and despite the various expansions there was a period of decline in yield from about 1970 to 1975 (Valaibula, 1984). The attractive prices during mid-seventies and the desire to increase production of sugar resulted in the expansion of the industry to less fertile and strongly weathered soils. These soils are generally low in major nutrients and many also have high levels of potentially toxic metals such as Al and Mn.

Despite the various expansions of the sugarcane growing areas, the Fiji sugar industry has consistently had difficulty in achieving the target figure of 500,000 tonnes of sugar annually. This is not surprising as although better sugarcane varieties have been produced through plant breeding research, very little effort has been directed towards soil fertility studies.

Sugarcane like all plants feed from soil, air and water. Plants essentially consists of water and organic material. The so called structural elements, carbon, hydrogen and oxygen comprises approximately 90-95% of the fresh mass of the plant.
The remaining 5-10% consists of mineral elements. This includes six macro elements, nitrogen, phosphorus, potassium, calcium, magnesium and sulphur and six micro elements, zinc, molybdenum, copper, manganese, boron and iron. These mineral nutrients come from the soil and the list given should not be regarded as final. The availability of some major soil nutrients to cane is discussed briefly:

**Nitrogen**

In its elemental form nitrogen is useless to higher plants. Gains in nitrogen occur through fixation of elemental N by micro-organisms, rhizobia and also through ammonia and nitrates in rainfall. Losses occur through crop removal, leaching, volatilization and denitrification. Within the soil a cycle operates through which mineral and available N become immobilized by microbial action and is incorporated into soil organic matter during the decay of plant residues. Some of this immobilized N is subsequently mineralised for crop use.

**Phosphorus**

The amount of phosphorus in a soil is much lower than nitrogen and most of the phosphorus in soils is normally unavailable to plants. In addition, when soluble sources of phosphorus are supplied to soils in the form of fertilizers, the P is often fixed and rendered unavailable even under the most ideal conditions.
Soil phosphorus can be divided into three fractions according to their availability to the plant: (i) readily available, (ii) slowly available, and (iii) very slowly available. All fractions are in equilibrium with each other, so that removal of P from any fraction will cause the system to move in a direction to restore the former equilibrium. Phosphorus fixation poses a greater problem than does K fixation. Availability of P is largely pH dependent.

Potassium

Most potassium in soil exists in strictly inorganic forms, the majority of which are unavailable to plants. Soil potassium like phosphorus can be divided into three fractions at least. Potassium released by weathering of minerals is dissolved in soil solution. It can then be taken up directly by plant roots or be adsorbed by soil colloids. An equilibrium is thus set up between $K^+$ on the soil colloids and the free $K^+$ in soil solution. Field experience shows that over-exploitation of soil occurs and growers often rely entirely on natural high K reserves in the soil without adding K fertilizers. Good crops may be supported for ten or more years, but the time will come when leaf analysis indicates that soil reserves are insufficient to meet K requirements, particularly in the case of a high K consuming crop such as sugarcane.
1.2 Role of Potassium (K) in Plants

The major functions of potassium in plants can be stated briefly as follows (Beringer, 1978; FAO, 1984; Mengel and Kirkby, 1987):

- activation of a number of enzymes (about 60) involved in photosynthesis, metabolism of carbohydrates and proteins;
- assistance in the synthesis and translocation of carbohydrates (example: movement from leaves to grains or tubers or fruits), protein synthesis, membrane permeability, stomatal regulation and water utilization;
- improved utilization of nitrogen;
- improved utilization of sunlight during cool and cloudy periods;
- enhanced resistance of plants in many cases to withstand pests, diseases and stresses such as those created by drought, frost, salinity, sodicity, etc.
- improved crop quality characteristics in a number of crops, in addition to yield increases which may be as important as yield increases.

The potassium concentration in the cell sap of plants generally ranges between 100 and 200 millimole K+/L (Beringer and Nothdurft, 1985). Hence, potassium is the most important inorganic osmotic component and stimulates growth primarily by its effects on cell extension. Larger cells, as a result of
adequate K-nutrition, imply more synthesis of cell-wall material. Frequently, cell walls are also thicker and this provides more tissue stability and improves the resistance of crops against lodging, pests and diseases. Adequate supply of potash increases the number of storage cells in cereals and may also influence structural compartmentalisation in potato tuber cells and hence the magnitude of starch accumulation. (Tandon and Sekhon, 1988)

Studies on sugarcane in Hawaii in the 1950s suggested that potassium deficient sugarcane plants were unable to maintain normal photosynthesis rates (Anon, 1960). The rate of photosynthesis in leaf samples having no visible deficiency symptoms and containing 0.91% potassium was reduced by 10 percent and in severe K-deficient samples it would be restricted substantially more. Further investigation by Hartt (1970) indicated that deficient potassium levels had a more pronounced effect on sucrose transport than photosynthesis. Hartt's findings are consistent with those of Peaslee and Moss (1966) that potassium deficiency alters photosynthesis rates without causing permanent damage to the photosynthetic apparatus. In essence, the maize finding by Peaslee and Moss, and the sugarcane finding by Hartt, point to a potassium effect on leaf permeability, which in turn affects the leaf moisture status.
In 1965, Hartt and Burr (1967) reported positive correlations between low photosynthesis and low potassium or calcium content of sugarcane leaves. Working with the Hawaiian (H) varieties H. 37-1933 and H. 50-7209, it was found that potassium deficiency suppressed photosynthesis when the foliar potassium percentage fell to about 0.40%. The variety H. 37-1933 was apparently more sensitive to low potassium than was H.50-7209. The latter variety tended to retain higher potassium levels, but photosynthesis restriction was nonetheless evident in the older blades (Table 1.1).

Table 1.1: Effect of potassium on photosynthesis rate of sugarcane*
[After Hartt and Burr (1967)]

<table>
<thead>
<tr>
<th>Age (months)</th>
<th>Blade rank</th>
<th>Photosynthesis (ml CO₂/dm²/h)</th>
<th>K (% dry wt.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Control -K</td>
<td>Control -K</td>
</tr>
<tr>
<td>3.8</td>
<td>4</td>
<td>16.6</td>
<td>16.6</td>
</tr>
<tr>
<td>4.3</td>
<td>4</td>
<td>19.6</td>
<td>20.4</td>
</tr>
<tr>
<td>4.7</td>
<td>4</td>
<td>20.3</td>
<td>21.6</td>
</tr>
<tr>
<td>5.1</td>
<td>4</td>
<td>24.0</td>
<td>21.3</td>
</tr>
<tr>
<td>5.5</td>
<td>4</td>
<td>25.0</td>
<td>22.1</td>
</tr>
<tr>
<td>5.8</td>
<td>4</td>
<td>22.6</td>
<td>18.2</td>
</tr>
<tr>
<td>6.3</td>
<td>4</td>
<td>26.3</td>
<td>23.2</td>
</tr>
<tr>
<td>6.6</td>
<td>4</td>
<td>20.5</td>
<td>20.2</td>
</tr>
<tr>
<td>6.8</td>
<td>4</td>
<td>23.2</td>
<td>16.8</td>
</tr>
<tr>
<td>7.1</td>
<td>4</td>
<td>15.2</td>
<td>17.9</td>
</tr>
<tr>
<td>7.3</td>
<td>4</td>
<td>20.8</td>
<td>17.1</td>
</tr>
<tr>
<td>7.3</td>
<td>8</td>
<td>21.0</td>
<td>1.9</td>
</tr>
<tr>
<td>7.4</td>
<td>5</td>
<td>18.5</td>
<td>7.2</td>
</tr>
<tr>
<td>7.4</td>
<td>6</td>
<td>20.7</td>
<td>11.9</td>
</tr>
<tr>
<td>7.4</td>
<td>7</td>
<td>17.2</td>
<td>2.1</td>
</tr>
</tbody>
</table>

* Variety H.50-7209. Plants were grown in nutrient solutions with and without K.
It is thus evident that potassium holds an important position in the metabolism of sugarcane plants and in particular in the translocation of sucrose to the parenchyma cells of the stems (Blackburn, 1983).

1.3 Potassium Deficiency

Sugarcane has a very high demand for potassium in comparison to many other agricultural crops with amounts of up to 125 to 220 kg K per hectare being removed (Husz, 1972). Thus the natural potassium reserves can be depleted on most soils within a short period of time and potassium deficiency symptoms can be seen.

Several authors (e.g., Martin, 1938; van Dillewijn, 1952; Humbert, 1968; Barnes, 1964; Alvarez, 1975) have described potassium deficiency symptoms in sugarcane. These may be summarized as follows:

1. Since potassium is a highly mobile nutrient in the plant, early symptoms may be seen in the older leaves. Leaf borders and tips show yellow-orange chlorosis, with numerous chlorotic spots that subsequently coalesce into brownish chlorotic blotches. Lower leaves die prematurely and have a burned appearance in the final stages.
2. Plant growth is retarded. Internodes are shorter. Stalks are shorter and smaller in diameter than those of normal plants.

3. The upper part of the midrib may show reddish spots, which in a vein cross section are limited to the epidermis. The main differences between such spots and those observed in red rot disease caused by *Colletotrichum falcatum* (Went) is that the disease occupies the entire cross section of the midrib.


5. Potassium-deficient plants may have higher concentrations of N, P, Ca, Mg, S, and Fe and lower sugar contents. Normally, potassium deficiency delays the development of the root system of sugarcane plants. In K-deficient plants, excessive Fe absorption by roots may occur, accumulating in stalk nodes, causing phytotoxicity symptoms (van Dillewijn, 1952).

1.4 Soil Potassium

1.4.1 Total Potassium

The potassium in soil is difficult to assess as little data is
available on losses of potassium by leaching, crop removal, runoff and erosion under sugarcane farming system in Fiji. The potassium in a given soil at a given time represents the influence of the parent materials of the soil, the extent of weathering, the quantity of potassium fertilizer added and the losses mentioned earlier. Potassium makes up an average of 2.6% of the Earth's crust (Schroeder, 1978). The potassium content of soils generally ranges between 0.04 to 3% potassium and at these levels potassium is the most abundant macronutrient in the top 15 cm of soil (Sparks, 1988).

The potassium content of rocks also varies widely with average values of 1 to 2 percent (Wedepohl, 1978). The two groups of potassium-bearing minerals which occur in rocks and soils in large amounts are the micas muscovite (KAl_3(AlSi_3O_{10})(OH)_2) and biotite (K(Mg,Fe)_(2),[AlSi_3O_{10}] (OH)_2), and the feldspars orthoclase and microcline (KAlSi_3O_8). These minerals occur extensively in sialic rocks (rich in Si and Al) such as granite, but are present in smaller amounts in mafic rocks (rich in Mg and Fe) which therefore, have low total potassium contents. The potassium content of sedimentary rocks varies with their content of clay minerals and especially illite. Sandstones have generally very low potassium contents, clays and shales may contain 2 - 4 percent potassium and in calcareous rocks the potassium content varies with their clay content.
1.4.2 Forms of Potassium

Potassium is present in soils in various forms, namely:

(a) $K^+$ in soil solution, in equilibrium and difficult to distinguish from;

(b) exchangeable $K^+$ defined as the fraction that occupies surface sites in the soil colloidal complex;

(c) fixed potassium, which occupies internal positions of clay sheets as well as hexagonal cavities of certain minerals, such as illites.

It may also be appropriate to include the potassium contained in organic matter as another form of potassium. However, generally the amount in organic matter is insignificant.

These forms of potassium are present in all soils though their quantity and relative proportions vary widely. However, it is important to note that all these are in a dynamic equilibrium, as shown in Figure 1.1.
Fig 1.1 Schematic presentation of the dynamics of K
1.4.3 Soil Solution Potassium

Plants take up potassium as K⁺ ions from the soil solution. The amount of potassium needed in the soil solution varies considerably with type and requirement of the crop. It is generally too low to meet the requirements of most crops during a growing season. Singh and Jones (1975) using a sorption isotherm technique found that for high potassium requirement crops like celery and potatoes, 14.5 mg/L potassium in the equilibrium solution was sufficient for optimum yields.

1.4.4 Exchangeable Potassium

Plants take up potassium from the soil solution which is in equilibrium with exchangeable potassium. Like other exchangeable cations, the potassium ion is held around negatively charged sites on clay particle surfaces by electrostatic attraction. Potassium or any cation held in this manner can easily be exchanged when soil is in contact with neutral salt solutions like ammonium acetate. These potassium ions which are held on the surfaces of the soil particles readily exchange with other cations and replenish the solution.
Exchangeable potassium is often a fairly satisfactory index of the quantity of potassium available to plants (Wild, 1988).

The exchangeable potassium on soil colloids is not homogeneous. The potassium ions are held on at least three types of exchangeable sites or binding positions. The sites are on the outside surface of some phyllosilicates, the edge positions and the inner positions. The potassium ions bound by the planar positions are in equilibrium with fairly high potassium concentration of the soil solution, whereas concentrations of soil solution potassium in equilibrium with potassium held on internal and edge sites is rather low.

1.4.5 Non-Exchangeable Potassium

The two forms of potassium discussed so far are regarded as easily or readily available but in most soils they represent only a limited proportion of the total potassium. The bulk of the potassium in soils is generally referred to as non-exchangeable and mineral potassium. The mineral potassium is also largely unavailable in comparison to active non-exchangeable potassium occurring in illitic clay and other 2:1 type minerals. Potassium associated with these clay minerals is generally considered to be slowly available.
Even though the non-exchangeable potassium is not easily available, it contributes significantly towards the maintenance of the labile potassium pool in the soil. In some soils, non-exchangeable potassium becomes available as the exchangeable and water soluble potassium are removed either by leaching or by a crop. In other soils the release from non-exchangeable reserves is too slow to meet crop needs. This form of potassium is a constituent of primary and secondary minerals.

1.4.6 Primary & Secondary Minerals

Feldspars and micas (phlogopites, muscovites, biotite) are the principle potassium bearing minerals originating from the parent rock. Feldspars have a three dimensional crystal structure with potassium located at the interstices throughout the mineral lattice, i.e., the structural units of feldspars are tetrahedra of SiO$_4^-$ and octahedra of Al(OH)$_6^-$ in a proportion of 4:1. The excess negative charge resulting from the replacement of Si$^4+$ by Al$^3+$ is compensated by the entry of K$^+$ into the crystal lattice (Rich, 1968). The general formula for feldspars is KAlSi$_3$O$_8$. The main members are orthoclase (K,Na)AlSi$_3$O$_8$, sanidine KAlSi$_3$O$_8$ and microcline (Na, K) AlSi$_3$O$_8$.

The micas are 2:1 layer structured silicates composed of a sheet of alumina octahedra between two sheets of silica
tetrahedra. Micas may either be dioctahedral (muscovite-type) or trioctahedral (biotite-type). Dioctahedral micas are ideally potassium-aluminum silicates. The chief differences between muscovite and biotite are as follows: muscovite-dioctahedral mica, two of the three octahedral positions are occupied by Al or by Fe or Mg as a result of isomorphic substitution; biotite-trioctahedral mica in which all positions in the centre of the octohedra are taken by Mg, as a rule, instead of being filled by Al.

Weathering processes bring about the breakdown of micas and feldspars so that the minerals are reduced in particle size and changed in chemical composition. Feldspars weather much more slowly than micas. These minerals dissolve incongruently, that is the dissolution of silica and alumina lags behind that of potash, so that the feldspar surface is soon coated with a protective layer which reduces the minerals reactivity and weatherability (Rasmussen, 1972). However, according to Sparks and Huang (1985), as alkannity develops, the release of K⁺ from muscovite and feldspar approaches similar levels but the differential increases with the development of acidity. The minerals are decomposed by hydrolysis and by the action of organic acids which act as proton donors and complexing agents. Pedro (1973) distinguished different types of hydrolysis of feldspars:
(i) total hydrolysis leads to precipitation of aluminium oxyhydroxides, solubilization of silica, and liberation of K⁺;
(ii) partial hydrolysis produces layer clay silicates (kaolinite or montmorillonite type), soluble silica and K⁺ being liberated as in the previous case.

The products of weathering include both 2:1 and 1:1 clay minerals, iron and aluminium oxyhydroxides, silicic acid and potassium, and other ions including Na⁺, Ca²⁺ and Mg²⁺, which are released into solution and could be retained as exchangeable ions or leached out.

1.4.7 Potassium Release and Uptake

The ability of soils to hold potassium and other cations depends on the formation of secondary clay minerals during weathering process. It is the non-exchangeable potassium that supplies the potassium to the soil which is in equilibrium with exchangeable potassium. The potassium in the soil solution and in the exchangeable form is generally taken up by plants and the rate at which non-exchangeable potassium is released to replenish the supply is a very important aspect for plant growth. The rate and amount of potassium released from the non-exchangeable form depends on the potassium levels in the soil solution and the type and amount of clay minerals.
According to Grimme (1985), the release depends on the extent of reduction of potassium concentration in the soil solution, originating either from the exchangeable pool only, or from the non-exchangeable pool to replenish the soil solution potassium. This indicates that non-exchangeable potassium release from the inter-lattice sites of clay minerals will probably be greatest in the soil nearest to root surface (Claassen and Jungk, 1982). Grimme (1985) stated that the release of potassium from inter-lattice sites is a slow process when compared with potassium mobility in solutions.

Soils with a high proportion of 2:1 lattice clay minerals such as vermiculite and montmorillonite (smectite) will normally hold more potassium than the more strongly weathered soils which contain large proportions of kaolinite, a 1:1 lattice clay mineral of low K selectivity.

1.4.8 Potassium Availability

Difficulties have been encountered in identifying critical limits of crop available potassium. Wood and Meyer (1986), found that sugarcane yields were very marginally affected in succeeding ratoons in heavy textured soils due to built-up of residual K from previous applications. Thus exchangeable
20.

Potassium may not be the best predictor of potassium uptake by plants. Humbert (1968) reported that high levels of calcium and magnesium of many neutral and alkaline soils limit the uptake of potassium by sugarcane plants. Potassium deficiencies may exist in areas of high calcium and magnesium. It is considered that the nutrient imbalance in the soil solution will cause calcium and magnesium ions in excess of those required by the plant to move to the surface of roots by mass flow in the transpiration stream at the expense of potassium ions, which move to the root largely by diffusion or chemical gradient. Thus to increase the amount of potassium delivered by mass-flow, soil potassium concentrations would need to be greatly increased by means of potassium fertilization.

1.5 Losses of Potassium from Cane Fields

Potassium losses from the cane field can occur by one or more of the following processes:

a. Crop removal;

b. Leaching;

c. Fixation into unavailable forms; and

d. Erosion.
The demand for potassium by different crops varies substantially. In comparison with most crops, sugarcane has a great demand for potassium and the bulk of the potassium removed by sugarcane ends up in the byproduct molasses. Various workers have shown that the potassium removed by a 100 t/ha cane crop varies significantly. This value ranges from 125 to 220 kg K per hectare (Husz, 1972). Orlando Filho and Zambello (1980) showed that removal of potassium by leaves is higher than that by the stalk. In Fiji, since burning of trash in the cane fields is common, most of the K⁺ taken up by the cane leaves is returned to the soil as ash. It may also be that a little is lost due to wind transportation as ash fly all over the place.

Losses of potassium by leaching are more variable than losses by plant uptake. The variability depends on the:

(a) nature of soil which influences the movement of water through the soil (soil texture, CEC and pore size);

(b) the quantity of water moving through the soil profile.

Munson and Nelson (1963) indicated that there existed a wide variance in the amount of K⁺ lost by leaching, ranging from negligible quantities in fine textured soils to somewhat appreciable amounts in sandy or coarse-textured soils. For example, lysimeter studies conducted on ten fallowed silt loam
soils in Illinois, U.S.A. demonstrated leaching losses of only 0.6 to 1.5 kg K per hectare per year (Stauffer, 1942), whereas losses on a fallowed soil from the Caroline Coastal Plain, U.S.A., were found to be as high as 12.8 kg K per hectare per year (Allison et al., 1959). Reduction in leaching by cropping has been demonstrated in several lysimeter studies (Volk and Bell, 1945; Nolan and Prichett, 1960) and has been attributed to potassium assimilation and reduced percolation resulting from evapotranspiration. The upward movement of potassium salts accompanying the movement of water during periods of high evapotranspiration has also been noted (Gammon, 1957).

The loss of potassium in soil through fixation can be regarded as a temporary loss. During the process of fixation, soil solution K or exchangeable potassium is converted into non-exchangeable forms. Volk (1934) summarised the main factors that affect potassium fixation from the view of soil treatments and mineralogy, namely:

(a) fixation is increased by drying;
(b) fixation depends on the quantity of the clay fraction;
(c) treatment of soil with HCl increased fixation, whereas the treatment with Na2CO3 decreased it;
(d) continuous potassium application decreased further fixation, increasing the formation of muscovite-type minerals;
(e) the absolute quantity of potassium fixed is increased with
the amount of potassium added, whereas the relative value
is decreased.

Potassium fixation occurs in the various clay minerals in the
following decreasing order: vermiculite with high charge
density > vermiculite with low charge density >
montmorillonite with high charge density. Both low-charge
montmorillonite and kaolinite do not exhibit potassium
fixation to any extent.

Even though limited data is available on the loss of K⁺ by
erosion and runoff, the quantities could be significant. Most
of the cane growing soils in Fiji are highly susceptible to
surface erosion because of high intensity rainfall. Clarke
and Morrison (1987) estimated soil losses by erosion using
universal soil loss equation (USLE) under sugarcane crop on a
5 to 8° slope over five years from initial clearing in 1978 to
1983 amounting to 300 t/ha/year at Seaqqa. This resulted in
an increase in the bulk density from 0.85 g/cm³ to 1.1 g/cm³,
an organic matter decline from 4.43 to 3.00% and a significant
decline in soil fertility in terms of exchangeable bases,
calcium, magnesium, potassium, etc. Assuming soil losses of
even 50 t/ha/yr, and an average potassium content of 0.5%,
this represents a loss of 250 kg K/ha/yr.
1.6 Potassium Threshold in Sugarcane

For many years the potassium requirements of sugarcane grown in Swaziland and S. Africa were based on a single soil potassium threshold value of 112 mg/kg as determined by normal ammonium acetate procedure (Du Toit, 1959). This procedure was generally considered reliable in predicting potassium response for light and medium textured soils. Where the soil test value is less than the threshold, good economic responses can be achieved by potassium application. However, this approach was modified in 1982 to accommodate soil texture as an additional factor to be considered following the studies of Wood and Burrows (1980), which established a relationship between the clay content of the soil and threshold value for potassium. Soil threshold values of 112 mg/kg and 150 mg/kg were introduced for soils with clay contents of less than and greater than 30% respectively (Meyer, 1980). Results of various experiments in South Africa indicate that in heavier textured soils containing predominantly 2:1 lattice clay minerals a higher threshold value is required (Wood and Meyer, 1986). In their review of factors affecting potassium nutrition on soils, Wood and Meyer noted that high levels of calcium and magnesium could severely reduce the uptake of potassium despite the fact that soil exchangeable potassium levels were above the threshold value.
A further threshold value of 225 mg/kg was introduced for "heavy" textured base-saturated soils (74% clay) to overcome this problem (Anon., 1989). In Fiji, broad fertilizer recommendations were developed for the sugar industry to provide a practical fertilizer advisory service to a large number of growers producing sugarcane on a complex range of soil types, many of them of low fertility. A yield potential approach was used based on an economic assessment of farm production costs and response data obtained from a wide range of field experiments. These broad recommendations together with the concept of yield potential allowed practical fertilizer advice to be given to individual growers. Soil and leaf analytical data was only used to predict major nutrient deficiencies and fertilizer recommendations were determined by the yield potential of the farm. This system served the growers well and was used till 1990. In the above system, the threshold value for potassium was 72 mg/kg and 110 mg/kg representing critically deficient and deficiency range respectively based on field trials and observation on responses. The deficiency threshold has now been changed to 100 mg/kg to take into consideration soils with slightly higher clay content.

1.7 Effect of Potassium on Sugarcane Yields

Long term trials on potassium nutrition were conducted in S.
Africa on Long Lands (at Shakaskraal) and Hutton (at Pongola) soils types. Even though the exchangeable potassium in the Hutton soil type was almost twice that of the threshold value, small but significant responses, in terms of tons sugar, were measured in the second and successive ratoon crops. Along with cane yield response to applied potassium there was improvement in cane quality (Wood and Meyer, 1986). In the Longlands farm fine sandy loam, a significant response was obtained to 175 kg K/ha in twelve ratoons which was consistent with the deficient level of potassium in the soil. The average cane response for the twelve crops was 24 t/ha. In general the response to 175 kg K/ha treatment was greater with successive ratoons up to the sixth ratoon.

Humbert (1968) and de' Geus (1967) reviewed the influence of potassium fertilization on sugarcane yields in different sugarcane growing countries and concluded that high rates of this nutrient are required for maximum economical sugarcane yields. In clay soils (with 86 mg K/kg), Zambello et al., (1977) did not observe any response to potassium fertilizer in three varieties of ratoon crops. Chapman (1980) observed that in trials of long duration in Australia, 196 kg of potassium per hectare treatments slightly decreased sucrose content in comparison with nil plot.

Holford (1963) studied the relationship of sugarcane yields to
potassium fertilizer rates in Fiji and found one trial out of the six responded linearly and others resembled Mitscherlich curves. Potassium fertilizer trials by Yang and Chen (1992) estimated that most economical fertilization rate in potassium deficient soils in Fiji is in the range of 125-250 kg K/ha.

1.8 Potassium Usage in the Sugar Industry

Amongst the many agricultural inputs to improve productivity, the contribution of fertilizer is only second to water to maximize production. Fertilizers are an integral part of agricultural production strategies. Potassium is one of the sixteen elements which are essential for growth and development of plants. Thus the use of potassium fertilizer in the sugar industry in Fiji goes back as far as the early nineteen hundreds. Information available (Anon, 1929) relates the use of potash in nutritional trials even though Twyford and Wright (1965) reported that exchangeable potash values tended on the whole to be moderate and high rather than low. Thus it was not surprising to see that the potash usage in the sugar industry in 1970 was approximately 2.4 kg/ha. This amount may have maintained the crop in the flat coastal plain areas. However, the expansion of the cane belt into the highly weathered Oxisols and Ultisols necessitated higher rates of potash use. These soils are low in major nutrients and also contain high levels of metal ions such as Al and Mn.
and are strongly phosphorus fixing (Gawander and Naidu, 1989).

Since no significant increase in potash and phosphorus usage by growers was observed, this necessitated the need to formulate blended fertilizers for the sugar industry to overcome the imbalance in fertilizer usage. With the introduction of blended fertilizers a marked change occurred, that is, the average amount of N fertilizer used per hectare declined considerably. Conversely since that introduction of blended fertilizers in 1990 there has been a dramatic increase in the amount of potassium fertilizer usage from an average of 26 kg/ha in 1991 to 69 kg/ha for 1996 crop. Thus blended fertilizers provide a more balanced nutrition for the crop. The growth of cane and its nutritional status has improved considerably particularly on phosphorus and potassium deficient soils in the last six seasons.

1.9 Aim of Study

There is a lack of information on K-dynamics, soil potassium status, mineralogical composition, potassium fractionation and potassium efficiency on major cane growing soils in Fiji. This study was initiated to try and address some issues with regard to potassium use in the sugar industry.

Thus this study was designed to make a preliminary investigation to evaluate the following:
(i) long term effect of cultivation on the potassium status of major cane growing soils of Fiji;
(ii) effect of varying rates of potassium fertilizer on cane and sucrose yields; and 
(iii) a study of soil and plant samples to quantify aspects of the potassium budget for sugarcane crop.

In order to achieve the above aims, the study was divided into two parts; laboratory and field work. The first part was to investigate the potassium status of cultivated and uncultivated soils used for sugarcane production. The second part of the investigation was designed to set up field trials to determine the effect of various rates of potassium fertilizer application on cane and sucrose yields. The results from laboratory and field trials were also used to develop a simple potassium budget.
CHAPTER 2
CHAPTER 2

GENERAL MATERIALS AND METHODS

2.1 Soils

2.1.1 Introduction

To get good representation of the Fijian soils, a wide selection has to be made at various locations on the islands. For laboratory studies, eight locations in the cane belt were selected as follows: Batiri, Drasa, Legalega, Lalakoro, Naduri, Nawaicoba, Seqaqa and Sigatoka as shown in Figure 2.1. The soils from these sites were further divided into two categories: fallow (uncultivated for at least 30 years or virgin) and cultivated land (under cultivation for at least 30 years).

2.1.2 Soil Sampling

Soil samples consisted of 20 sub-samples taken to a depth of 20 cm from each location. Soils from each location were thoroughly mixed and a representative sample for the location was obtained. At each location, sampling of both cultivated and uncultivated soils was made. The uncultivated soils represented either virgin soil or where no cultivation had occurred for the last thirty years.
Figure 2.1

Map of the Fiji Islands showing the locations of soils used for the study
2.1.3 Soil Preparation

The soils were air-dried and ground to pass a 2 mm sieve. The ground samples were put in plastic bags and tightly secured. These were used for analysis as required.

2.1.4 pH (0.01 mol/L CaCl₂)

Soil pH was determined in 1:2.5 soil to 0.01 M CaCl₂ suspension following equilibration for 16 hours. The electrodes were inserted into the bottles and the soil suspension was stirred by swirling the electrode slightly. The pH was read on the pH meter (Metrohm, model-632) which was calibrated with buffers pH 4.8 and 9.

2.1.5 pH (H₂O)

Soil pH was determined in 1:2.5 soil to water suspension following equilibration for at least for 4 hours in constant temperature room. The pH meter was calibrated with pH 7 buffer and with pH 4 buffer. The suspension was stirred by swirling and the pH recorded (Metson, 1956).
2.2. Potassium

2.2.1 Soil Solution Potassium

Air-dried soil (5 g) was weighed into centrifuge tubes in duplicate and distilled water (25 ml) was added to the soil. The suspension was shaken overnight on a multi-shaker and then centrifuged at 7000 rpm for 40 min. The solution was filtered (Whatman 42) and K was determined by atomic absorption spectrophotometry (AAS). The Shimadzu 670-AAS was set at 766.5 nm wavelength, 0.5 nm slit width, hollow cathode lamp current 5 mA and air-acetylene flame was used.

2.2.2 Exchangeable K and Ca

Soil (<2 mm, 10 g) was weighed in duplicate into a centrifuge tube and NH₄OAc (pH 7, 1 mol/L, 25 ml) added and the suspension was shaken for 10 mins in a multi-shaker. The solution was centrifuged at 7000 rpm for 20 min and filtered. AAS was used to determine Ca and K in the filtered solution. Calcium was determined at 422.7 nm wavelength, 0.5 nm slit width, hollow cathode lamp 6 mA AAS conditions (Knudsen, et al. 1982).

2.2.3 Non-exchangeable K

Soil (<2 mm, 2.5 g) was weighed into a 125 ml conical flask,
\( \text{HNO}_3 \text{ acid (1 mol/L, 25 ml) was added and the mixture heated with a bunsen flame. When the boiling started, the flame was reduced and boiling the suspension gently continued for further 10 minutes. The flask was then removed, cooled and the suspension poured into a 100 ml volumetric flask. The soil was washed four times with portions of \text{HNO}_3 (0.1 mol/L, 15 ml). The solution was left to cool and diluted to volume and potassium was determined in the thoroughly mixed solution using AAS (Knudsen, et al. 1982).} \)

2.2.4 450°C Exchangeable K

Soil (5 g) was heated at 450°C in the furnace for 16 hours, then left to cool and transferred to a centrifuge tube. \( \text{NH}_4\text{OAc (pH 7, 1 mol/L, 12.5 ml) was added and the soil mixture was shaken for 10 minutes in a multi-shaker. The mixture was centrifuged at 7000 rpm for 20 minutes, filtered and the solution potassium determined by AAS.} \)

2.2.5 Total Potassium

This was determined at CSIRO, Adelaide by their routine laboratory method using X-ray spectrographic method for the analysis of wide range of geologic sample (Norrish and Hutton, 1969).
2.2.6 Soil Phosphorus (modified Troup)

Air dried soil sample (1 g) was extracted for phosphorus with an extracting reagent (50 ml, 0.01 mol/L H₂SO₄, buffered with ammonium sulphate (1 g/L)). The soil solution was shaken for 20 minutes in a Gyrator shaker and filtered using Whatman No. 2V paper.

The filtered soil solution (10 ml) was pipetted into a volumetric flask (50 ml) and distilled water (-30 ml) was added to it. Troup - Meyer (2 ml, 10 N H₂SO₄, solution containing ammonium molybdate (2.5 g/100 ml)) was also added and the solution shaken thoroughly. Stannous chloride (3 drops, 12.5 g SnCl₂, in 18% HCl) was added and then the solution was diluted to mark with distilled water. The thoroughly mixed solution was allowed to stand for 10 minutes. The absorbance readings were recorded (within a concentration curve 0-2 mg/L P) in a Hitachi U-2000 UV-VIS spectrophotometer at 712.0 nm wavelength.

2.3 Negative and Positive Charge

Positive and negative electric charges on the soils were determined by measuring the adsorption of K⁺ and Cl⁻ as a function of pH to obtain the PZC. The method used was essentially described by Naidu, et al. (1990).
Samples (2 g) of oven-dried soils were placed in pre-weighed centrifuge tubes and KCl solution (0.01 mol/L, 20 ml) was added. Soil pH was adjusted to the desired value by the addition of dilute KCl or NaOH in KCl solution (0.01 mol/L). After 3-4 days when the pH was relatively constant, the tubes were centrifuged. The residue was equilibrated 6 further times with KCl (0.01 mol/L) for two hours using an end-over-end shaker. At the end of the 6th equilibration, the pH of the soil suspension was measured, the mixture centrifuged and the supernatant solution transferred to labelled bottles for K⁺ and Cl⁻ determinations. The tubes plus residue were weighed to determine the entrained solution. The residue was then extracted five times with NH₄NO₃ solution (0.5 mol/L, 20 ml). K⁺ was determined in all of the extracts by atomic emission spectrometry and Cl⁻ was estimated by the colorimetric mercuric thiocyanate method (Vogel, 1978). K⁺ and Cl⁻ retained by the soil were expressed as the equivalent amounts of negative and positive charge respectively after correction for entrained solution.

### 2.4 Plant Tissue Potassium Determination

Plant material (0.25 g) was weighed into a digestion tube and selenium sulphuric acid (2 ml) was added. The mixture was heated gently on a digestion block till the temperature reached 370°C. The mixture was digested for 1 hour at 370°C.
After digestion was completed and the mixture cooled, water (10-15 ml) was carefully added and the tube swirled to dissolve the digest. The digest was filtered into a 100 ml volumetric flask and made up to the mark.

A sample (10 ml) of the digested sample was pipetted into a 50 ml volumetric flask, and CaCl₂ (20,000 mg/l Ca, 5 ml) solution added. The solution was diluted to mark with distilled water, shaken thoroughly and potassium was determined using AAS.

2.5 Organic Carbon

Soil (1 g, <0.5 mm diameter) was weighed into a 50 ml conical flask including a blank with the samples and potassium dichromate solution (0.1667 mol/L, 10 ml) was added and the flask swirled gently to wet the sample thoroughly. In the fumehood concentrated sulphuric acid (20 ml) was carefully added and the flask swirled for one minute ensuring good mixing yet not contaminating the sides of the flask with soil particles.

The suspension was left to stand for 30 minutes and water (200 ml) was added to the flask, filtered and conc. phosphoric acid (10 ml) and five drops of diphenylamine were added to the filtrate. The blank and filtered samples were titrated with ferrous sulphate (1 mol/L) till the end-point, and the organic carbon calculated (Walkley and Black, 1934).
2.6 Mineralogy

The clay fractions of the soils were isolated following the sedimentation procedure of Jackson (1969) except that dispersing agents were not added to minimise changes in the composition of poorly ordered minerals. Following repeated sedimentation, the suspensions were centrifuged and the residues dried in a fan forced oven at 80°C. X-ray diffractograms were obtained using both random oriented aggregates and powder specimens. Smectite was characterised by the expansion of the basal spacing of Mg2+ saturated clays from 14 to 18Å on glycerol solvation and collapse to 10Å on heating at 550°C.

2.7 Potassium Sorption Studies

Replicate soil samples (2 g) from cultivated and uncultivated areas were weighed into a series of polypropylene tubes and background electrolyte CaCl2 (0.002 mol/L, 20 ml) containing different amounts (0 to 1000 µg K) of potassium as potassium chloride was added. The samples were equilibrated on an end-over-end shaker for 16 hours and then centrifuged at 10,000 rpm before filtration through Millipore (0.45 µm) filter paper. The supernatant solutions were analysed for K and Ca. This method used to obtain adsorption isotherms is similar to the batch sorption studies used by Naidu et al. (1994) for Cd adsorption in soils except the background electrolyte was changed to 0.001 mol/L CaCl2, solution.
CHAPTER 3
CHAPTER 3

POTASSIUM STATUS OF SOME CANE GROWING SOILS OF FIJI

3.1 Introduction

The need to assess the potassium levels in the cane growing soils need not be over emphasized in view of the recent price escalation of potassium fertilizers and the depressed price of raw sugar on the world market. The potassium requirement of sugarcane varies with the soil type. Over a substantial period of time the cane farmers in Fiji applied very low levels of potassium, the average application rate between 1973 to 1990 was 26 kilograms of potassium per hectare per annum. This is considered to be low in view of the fact that average potassium fertilizer recommendation is in the range of 130-200 kg K/ha, and the expected potassium removal in crops is of the order of approximately 100 kg/ha/yr. This indicates that soils in the cane growing belt have been providing the balance of potassium since the potassium requirement of cane is high. Generally, the bulk of potassium in soil is in the non-exchangeable form even though smaller amounts are present as exchangeable and in external solution. In this part of the study the potassium levels of some cane growing soils and equivalent fallow soils were assessed and attempts were made to explain the effect of long term cane cultivation on the
potassium status of the soils. The following forms of potassium were determined:

3.1.1 Total potassium;
3.1.2 Exchangeable potassium;
3.1.3 Non-exchangeable RNO$_2$ - K;
3.1.4 Non-exchangeable 450°C - K; and
3.1.5 Soil solution potassium.

Some properties of the soils of the cane growing belt studied are given in Table 3.1 and potassium data is given in Table 3.2.

**Table 3.1: Some Properties of the Soils Studied**

<table>
<thead>
<tr>
<th>Soil</th>
<th>USDA Classification*</th>
<th>Mineralogy of clay fraction*</th>
<th>pH 0.01 CEC</th>
<th>Organic C (%)</th>
<th>Charge (mmol kg$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Negative</td>
</tr>
<tr>
<td>Basin</td>
<td>follow cultivated</td>
<td>Lithic Ustopept</td>
<td>4.5</td>
<td>2.4</td>
<td>49.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K, Gib, Goeth</td>
<td>4.3</td>
<td>5.5</td>
<td>96.2</td>
</tr>
<tr>
<td>Drasa</td>
<td>follow cultivated</td>
<td>Oxic Haplustox</td>
<td>4.4</td>
<td>3.0</td>
<td>38.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K, Gib, Goeth</td>
<td>4.1</td>
<td>1.2</td>
<td>35.3</td>
</tr>
<tr>
<td>Legaiga</td>
<td>follow cultivated</td>
<td>Typic Brunustox</td>
<td>4.2</td>
<td>2.9</td>
<td>32.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K, Gib, Goeth</td>
<td>4.7</td>
<td>2.6</td>
<td>36.4</td>
</tr>
<tr>
<td>Laskato</td>
<td>follow cultivated</td>
<td>Ustorthic Tepalturbart</td>
<td>4.2</td>
<td>5.5</td>
<td>104.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K, Gib, Goeth</td>
<td>4.4</td>
<td>1.4</td>
<td>61.2</td>
</tr>
<tr>
<td>Naderi</td>
<td>follow cultivated</td>
<td>Typic Acrustox</td>
<td>4.4</td>
<td>6.0</td>
<td>59.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S, K, Gib, Goeth</td>
<td>4.0</td>
<td>4.5</td>
<td>47.0</td>
</tr>
<tr>
<td>Nawaloba</td>
<td>follow cultivated</td>
<td>Typic Peluzert</td>
<td>6.2</td>
<td>3.5</td>
<td>439.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S, K</td>
<td>6.0</td>
<td>2.9</td>
<td>579.6</td>
</tr>
<tr>
<td>Signoka</td>
<td>follow cultivated</td>
<td>Typic Hapludol</td>
<td>6.3</td>
<td>2.6</td>
<td>206.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S, K</td>
<td>6.0</td>
<td>2.3</td>
<td>297.5</td>
</tr>
<tr>
<td>Seapaqa</td>
<td>follow cultivated</td>
<td>Tropics Haplustox</td>
<td>4.0</td>
<td>3.0</td>
<td>162.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K, Gib, Goeth</td>
<td>4.3</td>
<td>4.2</td>
<td>202.6</td>
</tr>
</tbody>
</table>

* S = smectite, K = Kaolinit, Gib = Gibbsite, Goeth = goethite and Q = quartz

* Soil Survey Staff (1975)
<table>
<thead>
<tr>
<th>Soil</th>
<th>Total K</th>
<th>Exchangeable K</th>
<th>Non-exchangeable HNO₃ K</th>
<th>Non-exchangeable 450°C-K</th>
<th>Soil solution K (mmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bari</td>
<td>1.92</td>
<td>0.38</td>
<td>0.21</td>
<td>0.12</td>
<td>0.06</td>
</tr>
<tr>
<td>fallow</td>
<td>5.11</td>
<td>2.62</td>
<td>2.21</td>
<td>0.28</td>
<td>0.32</td>
</tr>
<tr>
<td>cultivated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drass</td>
<td>5.43</td>
<td>0.47</td>
<td>1.05</td>
<td>0.26</td>
<td>0.06</td>
</tr>
<tr>
<td>fallow</td>
<td>2.50</td>
<td>0.96</td>
<td>1.05</td>
<td>0.11</td>
<td>0.39</td>
</tr>
<tr>
<td>cultivated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legalega</td>
<td>10.00</td>
<td>1.32</td>
<td>1.74</td>
<td>0.75</td>
<td>0.47</td>
</tr>
<tr>
<td>fallow</td>
<td>13.30</td>
<td>2.06</td>
<td>1.71</td>
<td>1.18</td>
<td>0.66</td>
</tr>
<tr>
<td>cultivated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lalakiro</td>
<td>9.30</td>
<td>4.44</td>
<td>3.78</td>
<td>0.17</td>
<td>1.05</td>
</tr>
<tr>
<td>fallow</td>
<td>5.16</td>
<td>2.30</td>
<td>-</td>
<td>0.69</td>
<td>0.45</td>
</tr>
<tr>
<td>cultivated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naduri</td>
<td>3.51</td>
<td>1.86</td>
<td>0.94</td>
<td>0.24</td>
<td>0.15</td>
</tr>
<tr>
<td>fallow</td>
<td>2.23</td>
<td>0.71</td>
<td>0.80</td>
<td>0.09</td>
<td>0.32</td>
</tr>
<tr>
<td>cultivated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nawalcoba</td>
<td>93.40</td>
<td>1.33</td>
<td>15.10</td>
<td>18.20</td>
<td>0.11</td>
</tr>
<tr>
<td>fallow</td>
<td>94.50</td>
<td>0.44</td>
<td>11.40</td>
<td>8.18</td>
<td>0.08</td>
</tr>
<tr>
<td>cultivated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sigatoka</td>
<td>161.80</td>
<td>19.20</td>
<td>23.50</td>
<td>10.80</td>
<td>1.59</td>
</tr>
<tr>
<td>fallow</td>
<td>147.10</td>
<td>0.97</td>
<td>5.91</td>
<td>6.73</td>
<td>0.08</td>
</tr>
<tr>
<td>cultivated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soapka</td>
<td>3.83</td>
<td>2.18</td>
<td>0.90</td>
<td>0.57</td>
<td>0.31</td>
</tr>
<tr>
<td>fallow</td>
<td>1.70</td>
<td>1.35</td>
<td>0.77</td>
<td>0.45</td>
<td>0.18</td>
</tr>
<tr>
<td>cultivated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Undetectable
Table 3.3: Different Forms of Potassium as a Percentage of the Total Potassium

<table>
<thead>
<tr>
<th>Soil</th>
<th>Total K (mmol/kg)</th>
<th>Exchangeable K (%)</th>
<th>Non-exchangeable K (%)</th>
<th>Soil solution K (%)</th>
<th>Fixed K (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>HNO₃-K</td>
<td>450°C-K</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Butiri</td>
<td>1.92</td>
<td>20.8</td>
<td>10.9</td>
<td>6.3</td>
<td>3.10</td>
</tr>
<tr>
<td>fallow</td>
<td>5.11</td>
<td>39.1</td>
<td>43.2</td>
<td>5.5</td>
<td>6.30</td>
</tr>
<tr>
<td>cultivated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dara</td>
<td>5.43</td>
<td>9.2</td>
<td>19.3</td>
<td>4.8</td>
<td>1.10</td>
</tr>
<tr>
<td>fallow</td>
<td>2.50</td>
<td>40.0</td>
<td>43.6</td>
<td>4.4</td>
<td>15.60</td>
</tr>
<tr>
<td>cultivated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legaegra</td>
<td>10.00</td>
<td>13.0</td>
<td>17.4</td>
<td>7.5</td>
<td>4.70</td>
</tr>
<tr>
<td>fallow</td>
<td>13.30</td>
<td>15.0</td>
<td>12.8</td>
<td>8.8</td>
<td>4.90</td>
</tr>
<tr>
<td>cultivated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lakoore</td>
<td>9.30</td>
<td>47.3</td>
<td>40.6</td>
<td>1.8</td>
<td>11.20</td>
</tr>
<tr>
<td>fallow</td>
<td>5.16</td>
<td>44.6</td>
<td>- *</td>
<td>13.3</td>
<td>8.70</td>
</tr>
<tr>
<td>cultivated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nafuli</td>
<td>3.51</td>
<td>54.1</td>
<td>26.7</td>
<td>6.8</td>
<td>14.20</td>
</tr>
<tr>
<td>fallow</td>
<td>2.23</td>
<td>31.3</td>
<td>35.8</td>
<td>4.0</td>
<td>14.30</td>
</tr>
<tr>
<td>cultivated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nawaiocoba</td>
<td>93.40</td>
<td>1.4</td>
<td>16.1</td>
<td>19.4</td>
<td>0.11</td>
</tr>
<tr>
<td>fallow</td>
<td>94.50</td>
<td>0.4</td>
<td>12.0</td>
<td>8.6</td>
<td>0.08</td>
</tr>
<tr>
<td>cultivated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sigatoka</td>
<td>161.80</td>
<td>11.8</td>
<td>14.5</td>
<td>6.6</td>
<td>9.40</td>
</tr>
<tr>
<td>fallow</td>
<td>147.10</td>
<td>0.7</td>
<td>4.0</td>
<td>4.5</td>
<td>0.03</td>
</tr>
<tr>
<td>cultivated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seqaqa</td>
<td>3.83</td>
<td>57.4</td>
<td>23.4</td>
<td>14.8</td>
<td>8.00</td>
</tr>
<tr>
<td>fallow</td>
<td>1.70</td>
<td>82.3</td>
<td>45.2</td>
<td>26.4</td>
<td>10.50</td>
</tr>
<tr>
<td>cultivated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Undetectable
3.1.1 Total Potassium

The total potassium content of the soils studied varied considerably with a range from 1.7 to 161.8 mmol kg$^{-1}$ and this is dependent on the parent material and the subsequent stages of weathering of the parent material. It is generally accepted that soils of the temperate regions have higher levels of potassium than the more weathered acid soils of the humid tropics (Schroeder, 1978). Castro et al. (1972) verified that higher total potassium content appears in less weathered soils and in soils subject to lower rainfall.

Two broad groups were recognised within the 8 study soils. The Batiri, Drasa, Legalega, Lalako, Naduri and Seaqaqa soils represented acidic, strongly weathered oxidic soils whilst Nawaicoba and Sigatoka were more recent, less weathered soils which had a considerably higher pH than the others (Table 3.1). Total potassium content of strongly weathered soils was low ranging from < 2 mmol kg$^{-1}$ for fallow Batiri soil to 13.3 mmol kg$^{-1}$ for cultivated Legalega soil (Table 3.2). In contrast, the less weathered Nawaicoba and Sigatoka soils had a total potassium content in excess of 90 mmol kg$^{-1}$.

Bear et al. (1945) reported that for 20 soil samples from New Jersey, the average total potassium content was > 450 mmol kg$^{-1}$ and in a more recent study, Sharples and Smith (1988) showed
that the total potassium contents for eight soils from major agricultural areas of the United States ranged from 20 mmol kg$^{-1}$ to > 400 mmol kg$^{-1}$. It is therefore evident that soils in this study, except for Nawaicoba and Sigatoka, have a very low total potassium content. This would be expected since many Fiji soil parent materials are relatively low in potassium, due to lack of potassium bearing primary minerals like feldspars, biotite (MRD, Fiji, pers. comm.). Thus many of the soils have low natural potassium concentration.

The effects of intensive cultivation on total potassium content of soils was variable with increases being recorded in three cases and decreases in the other five cases. Changes in total potassium content will be related to the total inputs and losses of potassium that have occurred during agricultural activity. The only other explanation for a larger value for total potassium in cultivated soils is that samples were possibly taken from a different soil type (that is, a boundary must have been crossed), though every attempt was made in the field to try and locate an uncultivated site on the same soil type. It is essential to note that fertilizer history of soils need to known to accurately determine a net gain or loss for the growing period. Unfortunately this data was unavailable. Where net potassium inputs have occurred (i.e., fertilizer inputs have exceeded losses through crop removal and/or leaching) there will be a gain of soil potassium.
Where losses have exceeded fertilizer inputs a decrease in potassium content due to intensive cultivation will have occurred.

3.1.2 Exchangeable Potassium

The exchangeable potassium plays a very important part in growth of plants because it is only the exchangeable and soil solution potassium which are readily available to plants. The exchangeable potassium content is generally higher in the upper soil layers.

Concentrations of exchangeable potassium varied greatly between soils and between sites on the same soil (Table 3.2). On the cultivated sites exchangeable potassium levels ranged from 0.44 to 2.2 mmol kg\(^{-1}\) with a mean value of 1.34 mmol kg\(^{-1}\). These values are low compared with those normally recommended for sugarcane growing soils. Orlando Filho (1989), for example, observed that critical exchangeable K levels for sugarcane are quoted as 2.6 for Hawaii, 3.2 for Barbados and 2.0 mmol kg\(^{-1}\) for Australia. For South African soils Meyer and Wood (1985) suggest a critical exchangeable potassium level of 2.9 for light and medium textured soils and 5.8 mmol kg\(^{-1}\) for heavy textured soils. It seems likely, therefore, that potassium was deficient in most of the sampled fields, particularly those under intense cultivation. In an overview
of the soil resources of Fiji, Twyford and Wright (1965) suggested that for an average cane yield of 112 tonnes per hectare, critical exchangeable potassium levels ranged from 6.4 to 7.7 mmol kg$^{-1}$.

Intensively cultivated sites had lower exchangeable potassium levels than fallow sites for five of the soils but the reverse was the case for the Batiri, Drasa and Legalega soils. As noted previously, these changes will be related to the relative size of inputs (mainly fertilizer K) versus losses (mainly crop removal and leaching). In order to maintain soil potassium status the amount of potassium removed in the harvested crop (i.e., 125-220 kg K ha$^{-1}$ per 100 t ha$^{-1}$ cane crop) must be applied annually. In addition, in tropical soils, potassium leaching can be a problem so that substantially higher dressings of potassium may need to be applied in order to maintain the soil potassium status. The Batiri, Drasa, Legalega, Lalakoro and Naduri soils all have a relatively low net negative charge (i.e. < 90 mmol kg$^{-1}$) and therefore will tend to have low capacity to retain potassium.

A modifying factor is the amount of reserve potassium present in non-exchangeable forms since, as already noted, this can be released to exchangeable form as exchangeable levels fall. Thus the potassium fertilizer recommendation for the smectitic Nawaicoba and Sigatoka soils (50-150 kg K ha$^{-1}$) is lower than
that for the other study soils (e.g., 250 kg K ha\(^{-1}\)) (Yang and Chen, 1989). It is worth noting, however, that in smectitic soils exchangeable as well as non-exchangeable potassium is being removed at a greater rate than it can be replenished from non-exchangeable forms. Fertilizer potassium rates at these sites need to be raised. A complicating factor may well be that some added fertilizer potassium could be fixed into non-exchangeable forms on these essentially K-deficient smectitic soils.

3.1.3 Non-exchangeable Potassium

In the eight soils studied non-exchangeable potassium was estimated by two different methods.

Firstly, inter-layer potassium was extracted with boiling nitric acid. This is a common method of analysis (Pratt, 1965). An additional method of measurement was also used. Soil was heated to 450°C. This causes exfoliation of micaceous soil materials exposing potassium to ammonium acetate extractant which was formerly inaccessible in contracted inter-layers (Smith and Scott, 1974).

In the majority of soils, levels of non-exchangeable potassium were low, some being < 1 mmol K kg\(^{-1}\) (Table 2). The notable exceptions were the Nawaicoba and Sigatoka soils both of which
contained substantial amounts of \( \text{HNO}_3 \)-K and 450°C-K. Analysis of the mineralogy of the clay fraction of these soils (Table 3.1) showed that both the vertic Nawaicoba soil and the alluvial Sigatoka soil contained significant amounts of the 2:1 mineral smectite. Such soils are characteristically known to have a high potassium status (Yang and Chen, 1989) as 2:1 type clay minerals such as hydrous micas and illite contain potassium which is part of their mineral structure. The potassium is held strongly within the inter-layers of these minerals and is known as non-exchangeable potassium. When soil solution potassium concentrations become low the clay lattice may partially open and non-exchangeable potassium can be released to exchangeable form. Thus soils with a high 2:1 clay content often have a good potassium supply. Nonetheless, when the potassium status of such soils is low and when soil solution potassium is increased through fertilizer additions added potassium may refill the inter-layer sites and become 'fixed' in non-exchangeable form.

The nitric acid non-exchangeable potassium in most of the cultivated soils is less than in the fallow soils. A similar trend is shown in the 450°C non-exchangeable potassium. This clearly indicates that cultivation has a marked effect in the depletion of potassium from areas where cane is continuously cropped. It is notable that even the vertic Nawaicoba soils and alluvial Sigatoka soils which had substantial levels of
non-exchangeable potassium due to significant levels of 2:1 mineral smectite, showed a profound decrease due to long term cultivation. This indicates that there is a net loss of potassium from both the sites under intense cultivation.

At the Batiri and Legalega sites which are known to have low levels of potassium, there has been an increase in not only non-exchangeable and exchangeable potassium but also total potassium possibly due to high rates of application of fertilizer or as stated earlier may be due to different soil type sampled in error. It is not clear, however, as to how these soils have increased the potassium content as they have low net negative charge and therefore are likely to have a relatively weak ability to retain potassium against leaching.

3.1.4 Soil Solution Potassium

Soil solution potassium gives an indication of the potassium intensity factor (i.e., K that is immediately available for plant uptake). Concentrations of potassium in soil solution ranged from 0.06 mmol/L to 1.50 mmol/L with a mean value of 0.31 mmol/L for intensively cultivated soils. The values obtained from the soils studied are low in comparison with the soil solution data compiled from tropical and subtropical region (Fried and Shapiro, 1961) where the range for the soils were 0.2 to 10 mmol/L¹, with an average value of 0.7 mmol/L¹.
In view of the low levels of exchangeable potassium present in the study soils and the fact that soil solution potassium is in equilibrium with exchangeable potassium, low concentrations of soil solution potassium were not unexpected. As expected, soil solution potassium showed similar broad trends to those of exchangeable potassium. That is, intensively cultivated sites had higher levels of soil solution potassium than undisturbed sites for the Batiri, Drasa and Legalega soils but the reverse was true for the remaining five soils.

3.1.5 Potassium Sorption

The soils differed markedly in their ability to adsorb potassium. In general, sorption increased in the order Legalega < Drasa < Naduri < Lalakoro < Batiri < Seaqaqa < Sigatoka < Nawaicoba (Figure 3.1). These differences were most likely due to the large variations in the net negative charge and in the nature and amounts of layer silicate minerals present in the various soils. For instance, the high sorption observed in the Nawaicoba and Sigatoka soils was most likely due to their high net negative charge and the presence of significant amounts of expanding 2:1 smectite minerals. The parameter that may responsible for increased sorption for Seaqaqa is probably a large negative charge (Table 3.1) associated with this soil. However, the high surface negative charge may be related to the large organic matter content.
Figure 3.1

Equilibrium K concentration (mmol dm$^{-3}$)
Surface negative charge reflects the capacity of the soils to retain cations and should be equal to the soils cation exchange capacity if conducted using electrolytes of the same ionic strength as the soil solution. While Drasa and Batiri soils have the same mineralogy the soils have much lower organic matter content and surface negative charge.

Intensive cultivation markedly decreased potassium sorption in the Batiri, Drasa and Legalega soils (Figure 3). This is to be expected since these are the same soils where intensive cultivation resulted in a significant buildup of exchangeable potassium. For the Lalakoro, Naduri, Sigatoka and Seaqaga soils where exchangeable potassium was decreased by intensive cultivation, the potassium sorption capacity was correspondingly increased. For the Sigatoka soil the effect of intensive cropping in increasing potassium sorption was extremely marked. It is notable, however, that for this soil there was also an extremely marked decrease in exchangeable potassium associated with intensive cropping. For Nawaicoba soil, potassium sorption was virtually unaffected by cropping history. As already noted, this soil had the greatest potassium sorption capacity and as a consequence crop history apparently had only a small effect.

3.1.6 Summary

The majority of soils were strongly weathered and had a low content of total, non-exchangeable, exchangeable and soil
solution potassium. These soils also tended to have a low net negative charge and therefore are likely to have a weak ability to retain potassium against leaching. Rates and timing of potassium fertilizer will therefore be important for these soils. Two less weathered soils had a much higher content of total and non-exchangeable potassium than the others. These soils also had a reasonably high net negative charge and therefore a reasonably high capacity to retain potassium. Thus, fertilizer potassium rates required for adequate cane growth in these soils are likely to be less than those for the strongly weathered soils. Nonetheless, the intensively cultivated sites of these two less weathered soils had lower levels of both non-exchangeable and exchangeable potassium than fallow counterparts suggesting that a net loss of potassium sites (presumably mainly through crop removal) was occurring.

Overall, the potassium status of soils was low. Since the potassium requirement of sugarcane is characteristically high and large amounts of potassium are removed in the harvested crop, potassium fertilizer practices need to be scrutinized carefully in the study area. Indeed, on many Fijian soils visual symptoms of potassium deficiency in sugarcane have been noted by the author and other staff of the Fiji Sugar Corporation and this has been confirmed by plant tissue analysis.
CHAPTER 4
CHAPTER 4

EFFECT OF POTASSIUM FERTILIZER ON CANE AND SUCROSE YIELDS

4.1 Introduction

As discussed in Chapter 1, sugarcane is grown on a wide range of highly weathered, nutrient deficient acid soils. A relatively large proportion of these soils has high levels of the potentially toxic aluminium and iron and thus the average cane yields are low on these soils. The sugar industry in Fiji is also experiencing adverse economic conditions due to low sugar prices, high costs of production such as labour, machinery, fertilizer and land rentals. As a result the need to produce optimum yields with minimum fertilizer input is highly desirable while sustaining the levels of soil fertility.

In the Fiji sugar industry prior to the introduction of blended fertilizers in the 1990s, the national average usage of phosphorus and potassium was approximately 10 and 26 kg/ha/yr respectively. These values are very low particularly for potassium in view of the fact that sugarcane has a high uptake value for potassium. However, with the introduction of blended fertilizers a range of blends such as 1:2:0; 12:0:10; 6:1:4 and 6:1:6 are available for growers. As a result the average usage of potassium has dramatically increased from 26 to 60 kg/ha/yr.
Based on ammonium acetate (1 mol/L) extraction procedure for exchangeable bases, a single threshold value for available soil potassium of 112 mg/kg is used by Fiji Sugar Corporation Fertilizer Advisory Service. An application of potassium fertilizer to a potassium deficient soil should significantly increase both cane and sucrose yields. However, the majority of trials conducted prior to this study showed that the addition of potassium has not led to significant increases in cane or sucrose yields.

This chapter discusses a preliminary study of the effect of increasing rates of potassium fertilizer on sugarcane yields. To achieve this objective three potassium trials were established at different trial sites. It was not possible to establish any of the three trials at the sites that were initially characterised due to various reasons such as unavailability of the site, unwillingness of the grower, not suitable site or due to fertility gradient etc.

4.2 Materials and Methods

4.2.1 Field Experiments

Three field experiments were designed to achieve the objective of determining the effect of potassium fertilizer on cane and sucrose yields on medium to poor fertility soils. The trial design for the three experiments was a 5 x 5 latin square
design with five rates of potassium replicated five times randomly. Chemical analysis of the soil at the trial sites showed them to be slightly acidic and the problems associated with such soils for producing sugarcane are substantial.

These soils not only have low nutrient levels but also affect the sugarcane growth due to toxic levels of aluminium and manganese. Table 4.1 provides general information of the three trials.

4.2.2 Soil Type and Analysis

All the three sites where the trials were established were on flat or nearly flat land. The soil type at the sites are classified as Ustic tropudolls (Kabisi site) and Ustoxic tropohumults (Lalakoro and Salove sites) and the initial soil analysis results are given in Table 4.2.

Table 4.1: Information on Trial Locations, Statistical Design, Varieties, Replication and Treatments

<table>
<thead>
<tr>
<th>Location</th>
<th>Trial design</th>
<th>Variety</th>
<th>Rep</th>
<th>Treatments K (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kabisi</td>
<td>LSD</td>
<td>Mana</td>
<td>5</td>
<td>0, 125 250, 375, 500</td>
</tr>
<tr>
<td>Salove</td>
<td>LSD</td>
<td>Vatu</td>
<td>5</td>
<td>0, 125 250, 375, 500</td>
</tr>
<tr>
<td>Lalakoro</td>
<td>LSD</td>
<td>Vatu</td>
<td>5</td>
<td>0, 125 250, 375, 500</td>
</tr>
</tbody>
</table>
Table 4.2: Initial Soil Analysis Data for the Trial Sites

<table>
<thead>
<tr>
<th>Location</th>
<th>pH (H₂O)</th>
<th>Organic C (%)</th>
<th>Mod. Trough P (mg/kg)</th>
<th>Exchangeable K (mg/kg)</th>
<th>Exchangeable Ca (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kabisi</td>
<td>5.0</td>
<td>2.3</td>
<td>20</td>
<td>95</td>
<td>1295</td>
</tr>
<tr>
<td>Salove</td>
<td>5.3</td>
<td>1.5</td>
<td>24</td>
<td>42</td>
<td>500</td>
</tr>
<tr>
<td>Lalakoro</td>
<td>4.8</td>
<td>1.9</td>
<td>30</td>
<td>72</td>
<td>895</td>
</tr>
</tbody>
</table>

4.2.3 Trial Design

For the experiment a 5 x 5 latin square design was used (as shown in Figure 4.1). In this design the randomization of treatments is restricted by grouping them into columns as well as rows. Thus it is possible to remove variability from experimental error associated with both these effects. Each treatment occurs the same number of times in each row and column. This design allows a more precise comparison of treatment effects than the randomized block design when there is appreciable variation associated with the columns. A latin square design has at least as many replications as there are treatments and thus is used only for experiments with only a few treatments.
Figure 4.1. Trial design
A 5 x 5 latin square. Each treatment occurs once in each row and each column. The treatments are five potassium rates for each trial site.

No. of rows in each plot = 6
Length of row in each plot = 10 m
Inter-row space between rows = 1.37 m
2 Guard rows on either side = G.R.
Gaps between plots = 2 m
Headlength = 5 m
4.2.4 Location

All the three trials were established at Kabisi, Salove and Lalakoro in growers farms and all normal cultivation and weeding were carried out by the respective growers.

4.2.5 Size of Plots

In all the trials the plot size was 82.2 m² being 10 m long and 6 rows wide with inter-row spacing of 1.37 m. Of the six rows, the outer two rows act as guard rows and between successive plots there was a two metre gap (Figure 4.1).

4.2.6 Cane Varieties

All the cane varieties except one (Ragnar) approved for commercial planting by our growers are locally bred. The varieties used in the experiment were Mana and Vatu. These are of average sugar content but are high yielding. The varieties Mana and Vatu are highly and moderately resistant to Fiji disease respectively. Both the varieties are, however, susceptible to downy mildew. Mana is the dominant variety used in Fiji accounting for 50 % of the total crop harvested in any one year. The variety Vatu was planted at Salove and Lalakoro sites and Mana was used at Kabisi site.
4.2.7 Seed Cane

Seed cane which was 7 months old and free from disease was used for the experiments. The seed cane was of good quality, with relatively short internodes. The seed cane, however, was not fertilized eight (8) weeks prior to planting as the quality of seed cane from physical inspection was found to be good.

4.2.8 Planting

The trial sites were ploughed twice and harrowed in order to have good soil tilth to a depth of at least 20 cm. All trials were planted during the normal planting season of April to June. The seed cane used for each trial was at the rate of six tonnes per hectare. Each stalk had at least 25 nodes with an eye bud and root primordia in each node. These were cut into three node setts normally known as "three-eye" setts. Each of these setts were planted end to end after dipping in funginex (Triforine). The number of three eye-setts planted in each 10 metre length was recorded to calculate the percentage germination. Soon after determining the germination in each plot, potted single eye setts were planted in each plot to have a uniform stand of cane in all plots.
4.2.9 Fertilizer Application

The three fertilizers used for commercial production of sugarcane at the time of the experiment were ammonium sulphate for nitrogen, superphosphate for phosphorus and potassium chloride for potassium source. The times at which fertilizers were applied at the three sites are as follows: The phosphorus fertilizer was applied at the time of planting and nitrogen and potassium fertilizer was applied seven weeks after planting. In the succeeding ratoon crops nitrogen and potassium was applied two weeks after harvesting at Kabisi and Salove and in the third week at Lalakoro site.

4.2.9.1 Site 1 (Kabisi)

At this trial site the five treatments were 0, 125, 250, 375 and 500 kilograms of potassium per hectare in the plant and succeeding ratoon crops. Nitrogen fertilizer was applied at the rates 110, 120 and 140 kilograms N per hectare and phosphorus was applied at the rate of 60, 0 and 30 kilograms P per hectare in plant, first and second ratoon crops, respectively.

4.2.9.2 Site 2 (Salove)

At the second trial site the five treatments were also 0, 125,
250, 375 and 500 kilograms of potassium per hectare in the plant and successive ratoon crops. In addition nitrogen fertilizer was applied at the rate of 120, 130, 157 kilogram N per hectare and phosphorus was applied at the rate of 60, 0 and 30 kilograms P per hectare in plant, first and second ratoon crops, respectively.

4.2.9.3 Site 3 (Lalakoro)

The third trial site had five treatments of 0, 125, 250, 375 and 500 kilograms of potassium per hectare in the plant and succeeding ratoon crops. Nitrogen fertilizer was also applied at rates of 120, 130, 160 kilogram N per hectare and phosphorus at the rate of 0, 30 and 60 kilogram P per hectare in plant, first and second ratoon crops, respectively.

4.2.10 Weed Control

In all three trials, weeds were controlled by using weedicides and hand weeding. In each of the trials the pre-emergent herbicides diuron 90 and atradex were sprayed at the rate of 3 kg/ha each within three days of planting. No post-emergent herbicides were used. However, manual weeding was carried out approximately ten weeks after planting and just prior to fertilizer application. Seasonal manual weeding was carried out when the cane was eighteen to twenty weeks old.
4.2.11 Crop Growth Measurement

Within eight weeks of planting the germination in the inner four rows of each plot was determined. Where necessary potted single eye setts were planted to have uniform number of tillers during the initial growth period.

When the cane was approximately ten to twelve weeks old, eight stools were chosen at random from each plot and marked to determine the number of tillers per stool and height of stalk. When the crop was twenty weeks old population counting commenced and continued till it was impossible to enter the field without damaging the crop.

No growth measurements were recorded in the ratoon crop except for population determination.

4.2.12 Harvesting

Sugarcane is generally harvested in Fiji at the age of ten to fifteen months. Plant cane requires a little longer growing period than the ratoon crop. All the plant cane in the trials was harvested when the crop age was between thirteen to fifteen months. However, the ratoon crops were harvested when the crop age was between eleven to thirteen months.
In each plot the inner four rows were harvested first and weighed. The weight of all the cane in the four inner rows of the plot was used to determine the yield per unit area.

4.2.13 Soil Sampling

The objective of soil sampling was to obtain a true representation of macronutrient levels of the sites and the various plots after successive harvest.

In all trials, the soils were sampled prior to planting and in the post harvest sampling only the nil (0 kg K/ha), medium (250 kg K/ha) and the highest (500 kg K/ha) treatment plots were sampled. In each sampled plot twenty sub samples were collected diagonally to a depth of 15 cm. The twenty sub samples consisted of six intra-row sample and fourteen inter-row samples. The composite sample from each plot was analysed for exchangeable and solution potassium as described in Chapter 2 and an average of the analyses of all plots of the same treatments was taken as the soil test level for the respective treatment.

4.2.14 Cane Juice Analysis

Cane samples consisted of nine stalk samples taken at random
from the four inner rows of each plot for cane juice analysis. The stalks were chopped into 60 cm pieces, macerated in a Jeffco Cutter Grinder and mixed thoroughly. A kilogram of sample was pressed in a hydraulic press and juice extracted at 510 KPa pressure. The juice was filtered through lead acetate and polarization readings were taken using a Polartronic Universal polarimeter and brix was measured using an Abbe refractometer. To determine the fibre fresh weight, a 100 g sample was weighed.

The pol, brix and fibre values were used to determine the %Pure Obtainable Cane Sugar (%POCS) as described by Powell (1955) and the details are shown in Appendix 1. The product of cane yield per unit area and % POCS gave total tonnes sugar per hectare.

4.3 Results and Discussion

4.3.1 Germination

Germination is defined as percentage of shoots that emerges from the total buds in the planting material. The total number of three-eye setts planted in each plot was recorded at the time of planting.

In each of the trials within six to eight weeks of planting,
germination was recorded. The percentage germination was calculated and the data is presented in Table 4.3.

<table>
<thead>
<tr>
<th>Replication</th>
<th>Treatment</th>
<th>Site 1 (Kabisi)</th>
<th>Site 2 (Salove)</th>
<th>Site 3 (Lalakoro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>86</td>
<td>68</td>
<td>93</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>95</td>
<td>56</td>
<td>88</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>87</td>
<td>64</td>
<td>82</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>81</td>
<td>62</td>
<td>84</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>74</td>
<td>61</td>
<td>86</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>73</td>
<td>55</td>
<td>85</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>86</td>
<td>61</td>
<td>81</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>88</td>
<td>69</td>
<td>88</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>85</td>
<td>63</td>
<td>83</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>96</td>
<td>69</td>
<td>88</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>78</td>
<td>64</td>
<td>85</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>90</td>
<td>65</td>
<td>82</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>86</td>
<td>73</td>
<td>92</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>91</td>
<td>59</td>
<td>95</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>93</td>
<td>57</td>
<td>92</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>85</td>
<td>66</td>
<td>94</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>79</td>
<td>61</td>
<td>83</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>92</td>
<td>70</td>
<td>83</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>85</td>
<td>61</td>
<td>88</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>90</td>
<td>59</td>
<td>87</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>89</td>
<td>59</td>
<td>86</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>83</td>
<td>64</td>
<td>92</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>86</td>
<td>61</td>
<td>88</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>85</td>
<td>55</td>
<td>81</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>92</td>
<td>57</td>
<td>84</td>
</tr>
</tbody>
</table>
4.3.2 Crop Characteristic Growth over the Period

4.3.2.1 Tillers per Stool

Tillering refers to the number of shoots per stool originating from one three-eye sett. During the early growth period the number of tillers per stool varies between 15 and 20 depending on the variety. With age, however, the average number of millable stalks ranges from 6 to 10.

The results (Table 4.3 & 4.4) showed that there were no significant responses obtained with increasing rates of potassium fertilizer on both percent germination and number of tillers per stool.
Table 4.4: Effect of Potassium Fertilizer on Tillers per Stool

<table>
<thead>
<tr>
<th>Treatment K (kg/ha)</th>
<th>Tillers per stool at 3, 5 and 7 months (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Site 1 (Kabisi)</td>
</tr>
<tr>
<td></td>
<td>3m</td>
</tr>
<tr>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>125</td>
<td>12</td>
</tr>
<tr>
<td>250</td>
<td>13</td>
</tr>
<tr>
<td>375</td>
<td>13</td>
</tr>
<tr>
<td>500</td>
<td>14</td>
</tr>
<tr>
<td>LSD 5%</td>
<td>(2.3)</td>
</tr>
<tr>
<td>LSD 1%</td>
<td>(3.4)</td>
</tr>
<tr>
<td>CV%</td>
<td>12.6</td>
</tr>
</tbody>
</table>

* significant at 5% m months after planting

** significant at 1%

( ) non-significant
However, there appears to be a trend that the number of tillers per stool increases till the crop is approximately five months old. By the time the crop is seven months of age the numbers of millable stalks per stool appears to stabilize in the range of six to eight per stool in these trials. The decrease in stalk with age is attributed to mortality due to competition.

4.3.2.2 Stalk Length

Stalk length is determined by measuring the distance between the ground level and up to the top visible dewlap leaf.

The height of stalk at 3, 5 and 7 months after planting showed a highly significant difference with increasing rates of potassium fertilizer in two of the three trials. The trial at site 2 (Salova) did not show any significant difference between treatments (Table 4.5).
### Table 4.5: Effect of Potassium Fertilizer on Stalk Height

<table>
<thead>
<tr>
<th>Treatment K (kg/ha)</th>
<th>Stalk height (cm) at 3, 5 and 7 months (m) after planting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Site 1 (Kabiai)</td>
</tr>
<tr>
<td></td>
<td>3m</td>
</tr>
<tr>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>125</td>
<td>36</td>
</tr>
<tr>
<td>250</td>
<td>38</td>
</tr>
<tr>
<td>375</td>
<td>38</td>
</tr>
<tr>
<td>500</td>
<td>35</td>
</tr>
</tbody>
</table>

LSD 5% | *3.5 | *5.1 | *1.5 | (2.6) | (5.9) | (8.2) | *0.8 | *4.1 | *6.6 |
LSD 1% | **5.3 | **7.6 | **7.6 | (4.0) | (8.9) | (12.4) | **1.2 | **6.1 | **9.9 |
CV%    | 7.8 | 6.9 | 3.1 | 11.4 | 13.4 | 11.4 | 3.6 | 6.3 | 3.8 |

* significant at 5% m 1 months after planting
** significant at 1%
{} non-significant
The trials at site 1 (Kabisi) and site 3 (Lalakoro) showed highly significant treatment related differences in stalk length indicating that all treatments had a significantly higher stalk length in comparison with nil treatment. However, there is no such difference between other treatments. Thus it is evident that different rates of potassium fertilizer did not significantly increase the stalk length. This is further supported by the data of site 2 (Salove) where the results show no significant difference in stalk length with increasing rates of potassium fertilizer.

All three trials also showed that the stalk length increases substantially more in the period when the crop was five to seven months old than when the crop was three to five months old. The vigorous growth during this period is attributed to the rainfall.

4.3.2.3 Stalk Population

The results of observations on stalk population are given in Table 4.6.
Table 4.6: Effect of Potassium Fertilizer on Stalk Population

<table>
<thead>
<tr>
<th>Treatment K (kg/ha)</th>
<th>Stalk population ($x10^4$/ha) at 3, 5 and 7 months after planting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Site 1 (Kabisi)</td>
</tr>
<tr>
<td></td>
<td>3m</td>
</tr>
<tr>
<td>0</td>
<td>75.6</td>
</tr>
<tr>
<td>125</td>
<td>85.6</td>
</tr>
<tr>
<td>250</td>
<td>93.4</td>
</tr>
<tr>
<td>375</td>
<td>90.6</td>
</tr>
<tr>
<td>500</td>
<td>92.8</td>
</tr>
<tr>
<td>LSD 5%</td>
<td>**7.9</td>
</tr>
<tr>
<td>LSD 1%</td>
<td>**11.8</td>
</tr>
<tr>
<td>CV%</td>
<td>7.1</td>
</tr>
</tbody>
</table>

* significant at 5%  
** significant at 1%  
() non-significant  

m months after planting
Two of the three sites (Kabisi and Salove) produced significantly higher number of stalks per unit area between the nil treatment plot and all other plots with increasing levels of potassium applied. However, there is no significant increase in stalk population within all other treatments. In all three experiments the number of stalks per unit area decreases with age of crop due to mortality of weaker tillers within a stool.

4.3.3 Cane and Sucrose Yields in Plant and Ratoon Crops

Throughout the studies, sugarcane yields are expressed as tonnes of sugarcane per hectare. Sugarcane is a vegetative product and the rate of growth thus is not uniform, generally the rate of elongation during December to April (the local wet season being about twice that during the rest of the year. Thus the annual yield of a ten (10) month crop which began its growth in early September and was harvested in early July could appear to be greater than that of fourteen (14) month crop which began its growth in early July and was harvested in early September because the extra four months of growth in the latter crop occurred in slow growth months. Harvesting all trials at the same age was not possible because of the conditions of the industry.
The source for potassium in the trials was muriate of potash. Potassium chloride is a fertilizer which is more susceptible to leaching and subsequent loss from the root zone than superphosphate, and for this reason potash was applied at the same rates in the plant and successive ratoon crops.

The increasing rates of potassium fertilizer applied to the plant and ratoon crops at three different sites produced varying sugarcane yields. Responses to the different treatments in terms of cane and sucrose yields are summarised in Tables 4.7, 4.8 and 4.9. The cane yields varied from a minimum of 39 t/ha at Site 2 to a maximum of 95 t/ha at Site 1. Of the three trial sites the results of Salove and Lalakoro produced a highly significant response in terms of cane and sucrose yields with increasing rates of potassium fertilizer applications. At Kabisi site which produced the highest yields of 97 t/ha, non-significant yield variations were observed.

Site 1 (Kabisi)

Responses to different treatments in terms of cane and sucrose yields are summarised in Table 4.7 and represented graphically in Figures 4.2, 4.3 and 4.4. The results indicate that there were no significant response in cane and sucrose yields with increasing rates of potassium fertilizer in plant and
Table 4.7: The Effect of Potassium Fertiliser on Cane and Sucrose Yields on a Migraceous Soil (Kabisi) and Rainfall at the Site

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant (Apr 88 - Jul 89)</th>
<th>1st ratoon (Jul 89 - Sept 90)</th>
<th>2nd ratoon (Sept 90 - Aug 91)</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg K/ha</td>
<td>tc/ha %POCS ts/ha</td>
<td>tc/ha %POCS ts/ha</td>
<td>tc/ha %POCS ts/ha</td>
</tr>
<tr>
<td>0</td>
<td>88 13.0 11.7</td>
<td>75 15.3 11.5</td>
<td>65 15.9 10.2</td>
</tr>
<tr>
<td>125</td>
<td>92 12.5 11.5</td>
<td>84 15.3 12.8</td>
<td>72 16.1 11.7</td>
</tr>
<tr>
<td>250</td>
<td>96 13.4 12.9</td>
<td>85 15.2 13.0</td>
<td>76 15.5 11.8</td>
</tr>
<tr>
<td>375</td>
<td>97 12.9 12.5</td>
<td>87 15.7 13.7</td>
<td>78 16.5 12.8</td>
</tr>
<tr>
<td>500</td>
<td>94 12.6 11.8</td>
<td>81 15.6 12.7</td>
<td>77 14.3 11.0</td>
</tr>
<tr>
<td>LSD 5%</td>
<td>(15.6) (0.3) (1.8)</td>
<td>(11.8) (1.0) (1.2)</td>
<td>(15.9) (1.3) (2.9)</td>
</tr>
<tr>
<td>LSD 1%</td>
<td>(23.5) (0.5) (2.8)</td>
<td>(17.6) (1.5) (1.9)</td>
<td>(23.8) (1.5) (4.3)</td>
</tr>
<tr>
<td>CV%</td>
<td>13.2 1.8 12.0</td>
<td>11.3 5.3 11.6</td>
<td>17.1 6.4 19.9</td>
</tr>
</tbody>
</table>

Rainfall (mm) | 3133 | 1858 | 2003

* significant at 5% ** significant at 1% () non-significant
Fig 4.2 Effect of potassium fertilizer application on cane yield at Kabisi

\[ y = -8E-05x^2 + 0.0525x + 87.571 \]
\[ R^2 = 0.9676 \]

\[ y = -0.0001x^2 + 0.0783x + 75.257 \]
\[ R^2 = 0.9469 \]

\[ y = -8E-05x^2 + 0.0651x + 65.029 \]
\[ R^2 = 0.9995 \]

Potassium fertilizer rates (kg K/ha)

- Plant
- 1st ratoon
- 2nd ratoon
Fig 4.4 Effect of potassium fertilizer application on sugar yield at Kabisi

\[ y = -2.5E-05x^2 + 0.012x + 11.494 \]
\[ R^2 = 0.9043 \]

\[ y = -3E-05x^2 + 0.0074x + 11.44 \]
\[ R^2 = 0.5 \]

\[ y = -3E-05x^2 + 0.0152x + 10.146 \]
\[ R^2 = 0.8111 \]

Sugar yield (tonnes sugar / ha)

Potassium fertilizer rates (kg K / ha)

- **Plant**
- 1 at ratoon
- 2 nd ratoon
succeeding ratoon crops. However, there was a consistent increase in both cane and sucrose yields at the potassium application rate of 125 kg/ha. The high plant cane yield at this site is attributed to high precipitation during the plant cane growth period. This is also evident from the results obtained from the crop growth data. As a result of high precipitation there were greater number of tillers per stool during the early growth period and the stalk elongation was also greater. The data from crop growth measurements at the Kabisi site shows a significant effect of increasing rates of potassium fertilizer on stalk height. There is also a trend indicating increased population in treated plots with comparison to the control. However, it is surprising that the cane yields with different rates of potassium application did not produce yields which were significantly different. The almost similar cane yields for various treatments at the site may be attributed to the potential of the soils to release non-exchangeable potassium to the crop in significant quantities during the season. The role of non-exchangeable K fraction in releasing potassium for crop uptake has been long recognised and helps to explain crop responses or absence of responses to fertilizer potassium applied at various levels of exchangeable potassium (Tisdale et al., 1985). When potassium release from non-exchangeable fraction is significant, changes in soil test values can be masked and onset of potassium deficiency delayed, although it does result in potassium depletion from the soil.
The cane yields in the first and second ratoon decreased on an average by 10 t/ha for each treatment in comparison with plant crop yields. It is worth noting that the first and second ratoon cane yields for all treatments except nil treatment were similar, that is, within a range of 6 t/ha of that was in the plant cane crop. As a result the difference between treatment means was very small within all treatments except in comparison with nil treatment yields. Cane yields were not significantly affected by potassium treatments, though there was a tendency for yields to slightly improve with progressively higher levels of potassium. At this site the maximum cane yields were produced in the plant and succeeding ratoon crops with potassium application rates of 375 kg potassium per hectare. The cane yields observed indicate that the potassium fertilizer application at various levels applied as top dressing eight weeks after planting in plant crop and three weeks after harvest in ratoon crops were not significantly different from those obtained for 125 kg K/ha. Thus it is apparent from the results that optimum cane and sucrose yields can be produced by application of 125 kg/ha potassium in plant and succeeding ratoon crops at this site.

The results also do not show any trend in %POCS with increasing rates of potassium fertilizer. The %POCS in first and second ratoon crops were approximately two units higher
than those of plant crop. This is attributed to the effect of drier conditions prior to harvesting of the ratoon crop.

Site 2 (Salove)

At this site the potassium fertilizer trial was established on an Ustoxic tropohumult (ferruginous latosol) in October 1991 using Vatu variety. Response to the different treatments in terms of cane and sucrose yields for the plant, first and second ratoon crops are summarised in Table 4.8 and illustrated graphically in Figures 4.5, 4.6, 4.7. Large cane and sucrose yield responses to increasing levels of potassium fertilizer were produced at this site.

At this site the various potassium rates did not significantly affect the number of tillers per stool, or stalk elongation. However, the stalk population during the growth period was very significantly affected by different rates of potassium fertilizer application and this is also reflected in the cane yield results. Cane yields varied in the different plant and ratoon crops with maximum yield of 72, 74 and 91 t/ha produced in the plant and succeeding ratoon crops respectively.
Table 4.8: The Effect of Potassium Fertilizer on Cane and Sucrose Yields on a Ferruginous Latosol Soil (Salve) and Rainfall at the Site

<table>
<thead>
<tr>
<th>Treatment kg K/ha</th>
<th>Plant crop (Oct 91 - Nov 92)</th>
<th>1st ratoon (Nov 92 - Sept 91)</th>
<th>2nd ratoon (Sept 93 - Aug 94)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>tc/ha %POCS ts/ha</td>
<td>tc/ha %POCS ts/ha</td>
<td>tc/ha %POCS ts/ha</td>
</tr>
<tr>
<td>0</td>
<td>39 14.5 5.5 47 12.2 5.7</td>
<td>64 14.0 9.0</td>
<td></td>
</tr>
<tr>
<td>125</td>
<td>61 14.8 9.0 60 12.4 7.5</td>
<td>77 14.3 11.0</td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>62 14.5 8.9 67 12.2 8.2</td>
<td>83 13.7 11.4</td>
<td></td>
</tr>
<tr>
<td>375</td>
<td>72 15.3 11.1 69 12.6 8.6</td>
<td>91 14.3 13.1</td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>65 14.6 9.5 74 12.7 9.4</td>
<td>88 14.2 12.5</td>
<td></td>
</tr>
<tr>
<td>LSD 5%</td>
<td>*6.2 (0.8) *1.7 *8.9 (0.7) *1.1</td>
<td>*5.5 (0.8) *1.1</td>
<td></td>
</tr>
<tr>
<td>LSD 1%</td>
<td>**9.3 (1.2) **2.6 **13.3 (1.0) **1.7 **8.2 (1.2) **1.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CV%</td>
<td>8.2 4.2 15.0 11.0 4.3 11.3 5.4 4.3 7.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rainfall (mm)</td>
<td>1621</td>
<td>1625</td>
<td>1954</td>
</tr>
</tbody>
</table>

* significant at 5%  
** significant at 1%  
( ) non-significant  
tc/ha: tonnes cane per hectare  
POCS: pure obtainable cane sugar
Fig 4.5 Effect of potassium fertilizer application on cane yield at Salove

\[ y = -0.0001x^2 + 0.1182x + 63.214 \]
\[ R^2 = 0.9814 \]

\[ y = -1E-04x^2 + 0.0984x + 47.8 \]
\[ R^2 = 0.9799 \]

\[ y = -0.0002x^2 + 0.1624x + 40.2 \]
\[ R^2 = 0.9245 \]
Fig 4.6 Effect of potassium fertilizer on % pure obtainable cane sugar at Salove

![Graph showing the effect of potassium fertilizer on % pure obtainable cane sugar at Salove.](image-url)
Fig 4.7 Effect of potassium fertilizer application on sugar yield at Salove

\[ y = -2E-05x^3 + 0.0162x + 9.0229 \]
\[ R^2 = 0.9349 \]

\[ y = -4E-05x^2 + 0.0261x + 5.6514 \]
\[ R^2 = 0.8767 \]

\[ y = -1E-05x^2 + 0.0121x + 5.8514 \]
\[ R^2 = 0.9712 \]

Potassium fertilizer rates (kg K/ha)

- Plant
- 1st rainon
- 2nd rainon
In the plant crop, maximum cane yield of 72 t/ha is obtained from potassium fertilizer application rate of 375 kg/ha.

The results from the plant crop yields showed that all treatments produced a highly significant response in comparison to the nil plot treatment. The 375 kg K/ha treatment was significantly different from the 250, 125 and 0 kg K/ha treatments. Thus, in the plant crop, a potassium rate of 375 kg K/ha produced the maximum cane and sucrose yields at this site.

In the first ratoon crop, the cane yields for most treatments were similar to cane yields in the plant crop. All treatments produced significantly higher yields in comparison with the nil treatment in the first ratoon crop. Even though the potassium treatment of 500 kg K/ha produced maximum yield, however, optimum yields were achieved at potassium rates of 250 kg K/ha.

In the second ratoon, optimum and maximum cane and sucrose yields are produced by applying potassium fertilizer at 375 kg per hectare. This application did not have any significant effect on %POCS in this trial. It is worth noting that %POCS in the plant crop and the second ratoon crop is approximately two units higher than that of the first ratoon crop. This is
attributed to the fact that prior to harvest of plant crop on 2nd November 1991 the rainfall for September and October added up to a total 55 mm of rain from only 4 rain days. As a result of this dry spell there was higher %POCS in the plant crop. Drier conditions were also recorded prior to the harvesting of second ratoon crop which resulted in higher %POCS levels. In the first ratoon crop, even though the rainfall was low for the months of June and July, the high precipitation during August of 95 mm was responsible for the lowering of %POCS in the first ratoon crop.

Site 3 (Lalakoro)

The trial at site 3 was established in 1989 on an Ustoxic tropohumult (ferruginous latosol) soil using Vatu variety. The effect of different rates of potassium fertilizer applied on cane and sucrose yields were assessed in plant and succeeding ratoon crops. The results of this trial are summarised in Table 4.9 and illustrated graphically in Figures 4.8, 4.9 and 4.10. This site produced results similar to those at site 2, that is, cane and sucrose yields were highly significantly related to various levels of potassium treatment.

In the plant crop the cane yield ranged from 52 to 75 t/ha and
the sugar 7.6-11.9 t/ha. At this site the maximum cane yield of 75 t/ha was produced for treatment rate of 500 kg K/ha. However, optimum yields of 71 t/ha of cane were produced by

Table 4.9: The Effect of Potassium Fertilizer on Cane and Sucrose Yields on a Ferruginous Latosol Soil (Lakororo) and Rainfall at the Site

<table>
<thead>
<tr>
<th>Treatment kg K/ha</th>
<th>Plant crop Apr 91 - Aug 92</th>
<th>1st ratoon Aug 92 - Sept 93</th>
<th>2nd ratoon Sept 93 - Sept 94</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>tc/ha</td>
<td>%POCS</td>
<td>ts/ha</td>
</tr>
<tr>
<td>0</td>
<td>52</td>
<td>14.6</td>
<td>7.6</td>
</tr>
<tr>
<td>125</td>
<td>60</td>
<td>14.3</td>
<td>8.5</td>
</tr>
<tr>
<td>250</td>
<td>71</td>
<td>15.6</td>
<td>11.1</td>
</tr>
<tr>
<td>375</td>
<td>69</td>
<td>14.8</td>
<td>10.2</td>
</tr>
<tr>
<td>500</td>
<td>75</td>
<td>15.7</td>
<td>11.8</td>
</tr>
<tr>
<td>LSD 5%</td>
<td>*5.8</td>
<td>*0.3</td>
<td>*0.6</td>
</tr>
<tr>
<td>LSD 1%</td>
<td>**8.7</td>
<td>**0.5</td>
<td>**0.8</td>
</tr>
<tr>
<td>CV%</td>
<td>7.0</td>
<td>1.7</td>
<td>4.5</td>
</tr>
<tr>
<td>Rainfall (mm)</td>
<td>1533</td>
<td></td>
<td>1874</td>
</tr>
</tbody>
</table>

* significant at 5%
** significant at 1%
( ) non-significant
tc/ha tonnes cane per hectare
tc/ha tonnes sugar per hectare
POCS pure obtainable cane sugar
Fig 4.8 Effect of potassium fertilizer application on cane yield at Lalakoro

\[
y = -0.0002x^2 + 0.1526x + 45.214 \\
R^2 = 0.9437
\]

\[
y = -1E-04x^2 + 0.0904x + 51.8 \\
R^2 = 0.9726
\]

\[
y = -8E-05x^2 + 0.0829x + 51.971 \\
R^2 = 0.9261
\]

Potassium fertilizer rates (kg K/ha)

- Plant
- 1st ratoon
- 2nd ratoon
Fig 4.9 Effect of potassium fertilizer on %
pure obtainable cane sugar at Lalakoro

![Graph showing the effect of potassium fertilizer on % pure obtainable cane sugar at Lalakoro. The x-axis represents Potassium fertilizer rates (kg K/ha), and the y-axis represents % Pure obtainable cane sugar. Three lines indicate the effect of different fertilizer rates on cane sugar percentage.]
Fig 4.10 Effect of potassium fertilizer application on sugar yield at Lalakoro

\[ y = -1E-05 x^2 + 0.0129x + 7.52 \]
\[ R^2 = 0.85 \]

\[ y = -3E-05 x^2 + 0.0236x + 5.5771 \]
\[ R^2 = 0.9833 \]

\[ y = -2E-05 x^2 + 0.0144x + 6.9029 \]
\[ R^2 = 0.9726 \]

Sugar yield (tonnes sugar/ha)

Potassium fertilizer rates (kg K/ha)

- Plant
- 1st rate
- 2 nd rate

92
application of 250 kg K/ha. There appears to be a significant effect of various rates of potassium fertilizer on %POCS due to the high %POCS for treatments 250 and 500 kg K/ha. However, these results need to be treated with caution due to the possibility of sampling error. The high %POCS and cane yields for the two treatments mentioned resulted also in high tonnes sugar per hectare for the same treatments. It is apparent from the results that treatments 250, 375 and 500 kg K/ha gave significantly higher cane yields in comparison with treatments 0 and 125 kg K/ha.

In the first ratoon crop, optimum cane and sucrose yields were obtained (as in the plant crop) for treatment of 250 kg K/ha.

In the second ratoon crop, however, optimum cane and sucrose yields were produced by potassium treatment of 375 kg K/ha. It is also evident at this site that there is a significant drop in the cane yield with successive crops for the nil plot treatment. Thus, in poor soils, high rates of potassium are required to maintain reasonable cane yields.

It is worth noting that various rates of potassium had very little or negligible effect on %POCS.
4.4 Conclusion

The results from the three trials indicate that there was no major difference in percentage germination and number of tillers per stool with application of increasing rates of potassium fertilizer. However, stalk length and population showed a highly significant difference with increasing rates of potassium fertilizer application at two of the three trials sites.

The effect of different rates of potassium fertilizer did not produce any significant increase in cane and sucrose yields in plant and successive ratoon crops at the Kabisi site where the initial potassium level in the soil was 95 mg/kg. However, there was a small trend towards increased cane and sucrose yields with increasing rates of potassium application. At this site potassium application rate of 125 kg K/ha for plant and succeeding ratoon crop appeared to produce optimum cane and sucrose yields. By differentiating the best fit quadratic equations obtained for plant and succeeding ratoon crops it is possible to calculate the quantity of fertilizer required by each crop to produce maximum yield. This value shows the maximum cane yields that can be predicted to be produced at the site using regression equations. At Kabisi, the calculated amounts of potassium required to produce maximum cane yields in plant, first and second ratoon crops were 328, 414 and 407 kg K/ha, respectively.
At the second site (Salove) the initial soil analysis results showed that the potassium content of the soil was 42 mg/kg. A highly significant cane and sucrose response in comparison to the nil plot treatment was achieved by all treated plots. At this site, for the plant crop, the results indicated that optimum yields can be obtained by applying 375 kg K/ha. In the first and second ratoon crop optimum yields can be obtained by applying 250 and 375 kg K/ha respectively. The calculated maxima obtained by differentiating the quadratic equations of the plant, first and second ratoon crops were 406, 497 and 590 kg K/ha, respectively. That is, to obtain maximum yields at this site the above amounts of potassium need to be applied in plant and succeeding ratoon crops.

The final site at Lalakoro had an initial soil potassium level of 72 mg/kg. It is apparent from the data that at this site optimum cane and sucrose yields in the plant and ratoon crop was obtained for potassium fertilizer application rates of 250 kg K/ha. However, for the second ratoon crop optimum yields were obtained by potassium treatment rate of 375 kg K/ha. The values calculated to obtain maximum cane yields by differentiating the quadratic equations are 518, 451 and 382 kg K/ha.

The response of most crop yields to most nutrients is to approach an asymptotic level beyond which further nutrient will no longer increase yield and sugarcane plant is no
exception. It is essential that the maxima obtained by differentiating the regression equations for yields need to be treated with caution since the raw data is forced to fit a quadratic polynomial. The results probably better fit an asymptotic response curve than quadratic response curve. Nelder (1966) knowing that asymptotic response curves are a little difficult to manage showed that inverse polynomials, that is relating the reciprocal of yield to some function of the reciprocal of fertilizer level, will most efficiently estimate the optimum rate of fertilizer usage.
CHAPTER 5
CHAPTER 5

SOME INITIAL STUDIES ON THE NUTRIENT BUDGET OF POTASSIUM IN A SUGARCANE CROPPING SYSTEM

5.1. Introduction

5.1.1 Fertilizers

Fertilizers are essential plant nutrients utilised to maintain or improve the fertility of the soils in order to produce economical crop yields. These carriers of nutrients provide that extra fertility which nutrient-deficient soils require to produce optimum yields. The impact of fertilizers on sugarcane crops, soils and the environment depends as much on their composition and properties as in the manner in which they are managed by the farmer.

Unbalanced, or rather lop-sided, use of N fertilizer is one of the biggest factors causing nutrient depletion. The production of high yields by large applications of nitrogen results in unsustainable cropping systems. In such systems, N is only used to mine the soil of other nutrients, with the result that soils initially well-supplied in other nutrients become deficient in them. The consequence of this is not only low yields but also a drop in the efficiency of investments made in N and greater losses leading to adverse effects on environment.
Soil nutrient depletion is caused not only by lop-sided use of N. It also occurs whenever the nutrients removed from the soil, whether through crop uptake, erosion or other channels, are not replaced. While the soil depletion of macro-nutrients is being noticed and addressed, it is not often realised that soil reserves of other essential micro-nutrients are also being diminished.

In Fiji, applied fertilizer rates are generally well below the recommendations based on soil and leaf analysis (Gawander, 1997). A review conducted by Yang and Chen (1989) of fertilizer trials in the sugar industry indicated that nitrogen was the most limiting nutrient for sugarcane production in Fiji, followed by phosphorus and potassium. Thus, in Fiji negative nutrient balances at the farm level represent a major environmental hazard due to depletion of soil nutrients as a result of inadequate replenishment (rather than pollution due to their excessive use). Hence depleting the soil of its nutrient reserves is also degradation of the environment while improving soil fertility is improving the natural resource base and hence, the environment itself.

5.1.2. Potassium Cycle in Sugarcane

The transfer of any nutrient from any given form to the available form in which the plant is able to take it up is
normally complex and often involves several steps. In the earlier chapters it was stated that potassium is present in various forms in the soil and the element has to achieve the soluble form before the plant roots are able to take it up.

There is an equilibrium between the four main forms of potassium in the dynamic soil system (see Figure 1.1). The soil solution potassium and exchangeable potassium equilibrate rapidly whereas fixed potassium equilibrate very slowly with the exchangeable and solution forms. Since potassium is continuously removed by crops and through leaching, a static equilibrium probably never exists.

In the field experiments an attempt was made to investigate the potassium budget in sugarcane field plots. The determination of the budget cycle took into consideration the soil potassium, the different rates of potassium fertilizers added, the amounts removed by cane stalk and cane tops. Determinations were not made for losses due to leaching or erosion. A general picture of the dynamics of potassium in soil-plant-water system, at times referred to as potassium cycling, is shown in Figure 5.1.

5.2. Methods

At the Lalakoro trial site, samples were taken at the time of
POTASSIUM CYCLING

Figure 5.1
harvest in order to prepare a preliminary potassium budget for sugarcane.

The weight of all the cane in the outer two rows of each plots with treatments 0, 250 and 500 kg K/ha was taken with the cane tops. The tops were broken at the natural breaking point and the weight of stalks only was measured. The difference between the two readings provided the yield of cane tops. An average value of the cane tops of all the five replications was determined. An average value for the moisture content of one kilogram cane tops and cane stalks of each of the treatments was also measured by drying replicated samples in the oven for 3-4 days at 75°C. The biomass was thus determined. The levels of potassium in the stalk and leaf samples were determined in duplicate on a dry matter basis by acid digestion and atomic absorption spectrophotometry for each plot of the three treatments. The above was done for the plant, first and second ratoon cane crops.

Soil samples were also taken from each of the plots after harvest to determine exchangeable and soil solution potassium levels and an average value was calculated to determine potassium budget. The cane yields used for the budget were the means of all plots of the same treatments.
The initial potassium value of the site was the value determined from the composite sample made of thirty core samples taken up to a depth of 15 cm of the whole trial site. It was assumed that the potassium absorbed by the crop was from the exchangeable and soil solution pool.

Table 5.1. Changes in K Levels in Soil and Potassium Balance in Sugarcane during Plant, First and Second Ratoon Crops (mean of 5 replications)

<table>
<thead>
<tr>
<th>Tkt K kg/ha</th>
<th>Crop</th>
<th>Init sol</th>
<th>Final sol</th>
<th>N G/L</th>
<th>Init exch</th>
<th>Final exch</th>
<th>N G/L</th>
<th>Plant Input</th>
<th>Uptake by stalks</th>
<th>Tops</th>
<th>Total N G/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>+0</td>
<td>P</td>
<td>24</td>
<td>16</td>
<td>-8</td>
<td>122</td>
<td>80</td>
<td>-42</td>
<td>0</td>
<td>-47</td>
<td>-42</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1R</td>
<td>16</td>
<td>17</td>
<td>+1</td>
<td>80</td>
<td>83</td>
<td>3</td>
<td>0</td>
<td>-42</td>
<td>-42</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2R</td>
<td>17</td>
<td>17</td>
<td>0</td>
<td>83</td>
<td>84</td>
<td>+1</td>
<td>0</td>
<td>-34</td>
<td>-35</td>
<td></td>
</tr>
<tr>
<td>N G/L</td>
<td>-7</td>
<td>-7</td>
<td>-38</td>
<td></td>
<td>-123</td>
<td>-119</td>
<td></td>
<td>-287</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>P</td>
<td>24</td>
<td>20</td>
<td>-4</td>
<td>122</td>
<td>97</td>
<td>-25</td>
<td>250</td>
<td>-81</td>
<td>-96</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1R</td>
<td>20</td>
<td>21</td>
<td>+1</td>
<td>99</td>
<td>100</td>
<td>+3</td>
<td>250</td>
<td>-87</td>
<td>-78</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2R</td>
<td>19</td>
<td>22</td>
<td>+3</td>
<td>100</td>
<td>109</td>
<td>+9</td>
<td>250</td>
<td>-80</td>
<td>-83</td>
<td></td>
</tr>
<tr>
<td>N G/L</td>
<td>0</td>
<td>-13</td>
<td>+750</td>
<td>-248</td>
<td>-257</td>
<td>+222</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>P</td>
<td>24</td>
<td>24</td>
<td>0</td>
<td>122</td>
<td>118</td>
<td>-4</td>
<td>500</td>
<td>-98</td>
<td>-146</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1R</td>
<td>24</td>
<td>24</td>
<td>0</td>
<td>118</td>
<td>122</td>
<td>+4</td>
<td>500</td>
<td>-94</td>
<td>-136</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2R</td>
<td>24</td>
<td>24</td>
<td>0</td>
<td>122</td>
<td>126</td>
<td>+4</td>
<td>500</td>
<td>-104</td>
<td>-143</td>
<td></td>
</tr>
<tr>
<td>N G/L</td>
<td>0</td>
<td>-4</td>
<td>1500</td>
<td>-296</td>
<td>-425</td>
<td>+783</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P plant crop  
1R 1st ratoon crop  
2R 2nd ratoon crop

Init sol initial soil solution K
Final sol final soil solution K
N G/L net gain (+) or loss (-)

Bulk density of soil = 1.1 g/cc
5.3 Results and Discussion

The detailed results of the trial are given in Appendix 2 and summarised data are presented in Table 5.1. The importance of nutrient balance is to understand and maintain fertility. The potassium cycle in sugarcane consists of (i) uptake and removal of potassium by sugarcane and its utilisation by human beings; leaching of soluble potassium beyond the root zone and losses by erosion and (ii) release of K from weathering of minerals and non-exchangeable positions of clay lattice, additions through fertilizers, residue recycling and rainfall.

In this preliminary studies only soil solution K, exchangeable K, fertilizer applied and nutrient K in cane top and stalk were considered. Losses of nutrient may occur to the subsoil and drainage systems. These losses from the system occur as a result of surface runoff and leaching. Generally, runoff of applied nutrient either in the organic or inorganic form is crucial immediately after application and is dependent on weather and soil conditions. Potassium is particularly susceptible to leaching in coarse-textured soils and acid soils that contain little or no illite (Tandon and Sekhon, 1988). Ranganathan and Narayan (1974) have observed that the leaching loss of potassium from tea growing soils in South India ranged from 36 to 57% under simulated rainfall of 5cm. Large quantities of applied nutrient may be lost in this
manner. Sugarcane residues, as is known, contain substantial quantities of potassium. Consequently, the actual amount of K removed depends largely on whether or not the residues are removed from the field.

An attempt was made to develop a simple soil K budget to provide an acceptable account of K input and output in the cane cropping system. Three rates of K (0, 250, 500 kg/ha) were applied in this study and the high application rates of K applied appeared to be fixed in the non-exchangeable pool that is not readily available for plant uptake since the soil solution K appears to be almost constant particularly for the treatment of 500 kg K/ha. The cumulative effects of repeated annual K additions have rarely been previously examined in the sugarcane fertilization programme in Fiji particularly with an annual K input of 500 kg K/ha for three successive years. The high fertilizer K requirement appears to reflect both the large K fixation capacity of the soil and the high K requirement of sugarcane.

During the period of study sugarcane grown in the zero and highest treatment of 500 kg K/ha removed a total 242 and 721 kg K/ha through the cane stalks and tops.

The cumulative response to annual K fertilization was characterised by a yield decline in treatment without K input.
and a yield increase at the highest level of K addition in each successive year. In the 0 and 250 kg K/ha treatment the yields decreased between plant and second ratoon crop, especially in the nil plot. However, plots with 250 kg K/ha treatment produced slightly higher yields in the second ratoon crop in comparison to plant and first ratoon. It is assumed that two processes contribute to this cumulative response. The first involves the effects of previous K input on plant K uptake efficiency from subsequent K additions, and the second concerns the decrease in exchangeable K+ that occurs in soil cropped without K addition.

On a K deficient soil with high K fixation capacity, K uptake efficiency from applied fertilizer would be expected to increase with each successive K addition. Since inter-layer fixation sites are occupied by K+ from prior additions thus a large proportion of a subsequent K application would remain in the 'plant available' soil K pool. The difference between sugarcane K uptake at the highest level of K addition and in the zero K input control treatments was 479 kg K/ha between plant and second ratoon crops. This represents 31% of the net cumulative input of 1500 kg K/ha during the study period. It is apparent that at high rates of K addition it contributes to a large export of K in the stalks and cane tops. However, there was no corresponding significant increase in cane or sucrose yield. It is also essential to mention that under
normal harvesting conditions the cane tops are retained as trash blanket or burnt and in both of these cases the potassium from the cane tops remains mostly in the farm. In this study all the cane tops were removed from the field which is different from normal farming practice. Thus the net gain by the soil would be even more than what is indicated by this study.

The yield decline from plant crop to ratoon crops in plots without K additions is probably associated with a relatively large decrease in exchangeable K⁺ in the surface soil between plant and succeeding ratoon crops (see Table 5.1).

An appropriate balance sheet of potassium in sugarcane in three treatments is presented in Table 5.1. The balance sheet is based on solution K, exchangeable K, fertilizer addition and removal over a period. Bulk density value of 1.1 g/cc and soil depth of 15 cm was used to convert potassium values into kilograms per hectare in Table 5.1. The potassium balance sheet is negative for the nil treatment and positive for 250 and 500 kg K/ha treated plots. As stated in Chapter 1, the national average application rate of potassium in 1996 was 69 kg K/ha, thus all indications are that there is a net export of potassium from the fields due to low application rates. As a result there will be a continuous depletion of the K supplying capacity of soils and a gradual decline in the
potassium fertility status of soils which would eventually affect cane production.

Removal by stalk is the major route of potassium withdrawal from soil, and losses through leaching and erosion can also be substantial and need to be taken into account when developing a comprehensive balance sheet.

By applying 250 and 500 kg K/ha in plant and the two succeeding cane crops the net gain to the system is 222 and 783 kg K/ha during the cropping period. The solution and exchangeable K values showed a net loss of 13 kg K/ha and a net gain of 4 kg K/ha for plots applied with 250 and 500 kg K/ha respectively. The important issue is, how to account for the missing potassium. Is it lost by erosion, runoff, leaching or does it move into the non-exchangeable sites? Hence, there are important questions that need to be addressed in order to attain a more accurate balance sheet.

5.4 Conclusion

The results of the experiment indicate that more information is needed to develop a comprehensive potassium balance sheet. Under Fiji conditions, no potassium budget has been completed on plant and succeeding sugarcane ratoon crops thus this study
provides some interesting information regarding removal of potassium nutrient from the system. In this study the unaccounted potassium in plots treated with 250 and 500 kg/ha is speculated as being lost through leaching, runoff and fixation. However, this needs to be carefully assessed as the amount in question between plant and succeeding ratoons is substantial. Hence, there is a need to set up experiments to find out the missing K values to develop a nutrient balance sheet which is acceptable.

The existing results clearly shows that at least 287 kg K/ha is removed if potassium fertilizer is not applied to plant and two succeeding ratoon crops. However, a build up of potassium occurs if 250 or 500 kg K/ha is applied to plant and succeeding ratoon crops each year. In Fiji, the national average potassium application rate at present is approximately 69 kg K/ha. Thus in three years on a national scale the total potassium applied to a plant and two succeeding ratoon crops amounts to 207 kg K/ha. As a result, a deficient balance of at least 80 kg K/ha over the three crops can be expected. Thus the net result is that on average at least 26.7 kg K/ha is depleted from all the cane growing areas of Fiji each year. Hence, a net loss of 1689 tonnes of potassium per year from total cane area of 70,000 hectares.
CHAPTER 6

GENERAL CONCLUSION AND RECOMMENDATIONS

6.1. The Fijian cane growing soils studied were generally acidic with varying levels of organic carbon and surface negative charge. The positive surface charge is considerably low for most soils.

6.2. An investigation was conducted to compare various forms of soil potassium in eight soils representative of the cane growing belt. The results of the study showed large differences in the amount of potassium in various forms in each of the soil. The differences in total, non-exchangeable, exchangeable and soil solution potassium may be attributed to various factors, but two which may have the greatest effect are the age of soil and the intensity of weathering.

6.3. Results of soil solution potassium determinations in the eight soil under study showed very low levels in comparison with values obtained by Fried and Shapiro (1961) of 0.2 to 10 mmol/L.

6.4. The determination of pH and total potassium for the eight soils indicated that the recent soils of Nawaicoba
6.5. Exchangeable potassium varied greatly and was found to be low with a mean value of 1.34 mmol/kg. The regularly cultivated sites had low levels of exchangeable potassium at five sites out of the eight. This difference may be due to different levels of input, uptake by crop and losses due to leaching.

6.6. The two less weathered soils (Sigatoka and Nawaicoba) had lower levels of both non-exchangeable and exchangeable potassium in the cultivated soil when compared with the fallow sites suggesting net loss of potassium due to cultivation. However, these soils also had high surface negative charge and thus a better capacity to retain potassium. Thus the issue of cultivation needs to be addressed by conducting further research.

6.7. Of the eight soils studied for potassium absorption, two soils, namely Nawaicoba and Sigatoka, had high sorption levels. It is thus recommended that soils with high potassium sorption capacities should have fertilizer recommendations based not only on available K but also
on potassium absorption levels. The high negative charge and expanding 2:1 minerals appeared to be responsible for the high sorption of the two less weathered soils.

6.8. The high sorption capacity of the Seagaqa soil is attributed to high negative charge when compared to the Batiri and Drasa soils of similar mineralogy. However, it is difficult to explain why this soil had such large negative charge when its clay content was also relatively low. Hence, there is a need to further pursue this investigation.

6.9. In the field experiments, the germination and number of tillers were not affected by different rates of potassium fertilizer application whereas stalk length and population appeared to be affected significantly in two of the three trials. It is difficult, however, to make a conclusive decision on the effect of increasing rates of potassium fertilizer towards early cane growth.

6.10 A study of the effect of increasing rates of potassium fertilizer indicated that no responses in terms of cane and sucrose were obtained for the Kabisi sites with soil potassium levels of 95 mg/kg. On the contrary, very significant responses were achieved at sites with soil potassium levels of 72 and 42 mg/kg at Lalakoro and Salove respectively.
6.11 The field trial results indicated that responses from potassium application can be achieved in plant and ratoon crop if soil potassium levels are equal or below 72 mg/kg.

6.12 For the Kabisi site where no significant response was obtained, it was evident that optimum cane and sugar yields can be achieved by application of 125 kg K/ha. The high %POCS in plant crop achieved on application of 250 kg K/ha may not be due to potassium fertilizer.

6.13 At the Salove site an application of 375 kg K/ha produced optimum cane and sucrose yields for plant and ratoon crops. At this site, for the second ratoon crop, the %POCS were approximately 1½ units above that of first ratoon crop. This has been attributed to the seasonal effects which were responsible for record sugar production in Fiji in 1994.

6.14 At Lalakoro, optimum cane and sucrose yields were achieved by application of 250 kg K/ha in plant and first ratoon crop. In the second ratoon crop optimum yields were obtained for application rate of 375 kg K/ha.

6.15 The data from the field trials were not conclusive to
show that sucrose quality improves significantly with increasing rates of potassium nutrient.

6.16 The potassium balance budget was considered on a gross basis, that is, it did not take into account the efficiency of applied potassium fertilizer or K from any other source. A budget or net basis will be still more negative because the net K-uptake from added sources will certainly be less than the gross amount added.

6.17 In the field experiments, the control plots clearly indicated that substantial quantities of potassium were taken up from the soil in both plant and succeeding ratoon crops.

6.18 The plots treated with 250 and 500 kg/ha potassium showed a net gain in K. However, this should be treated with caution since potassium loss through leaching, run-off, fixation and potassium efficiency were not taken into consideration.

6.19 Since the average usage of potassium in the cane belt is only 68 kg/ha it is possible that in the course of time, some more areas may become potassium deficient or of low potassium status and more frequent instances of
increasing crop responses to potassium application will occur.

6.20 There is a need to increase K fertilizer usage and pay attention to the optimum and efficient use of available crop residues. To decrease the gap between removals and additions of potassium, an approach to integrate the use of mineral fertilizers and crop residues is needed.

6.21 A detailed experiment is needed to further understand the potassium nutrient budget, preferably involving medium to long term studies and careful monitoring of changes in soil fertility and crop productivity.

6.22 Further research is needed to determine at what concentration potassium uptake by sugarcane is excessive and the effect of soil texture on potassium availability.

6.23 Reasons for lack of build-up in available soil potassium upon continuous application of K also need to be investigated.
References


Anon. (1929). Sulphate of Potash Trial - Field 17 Varoka, Ba. CSR Co. Ltd., Internal Report No. 751 N.


APPENDICES
Appendix 1

1A. % POCS Calculations from Polarimeter Recordings

a. \[ \% \text{Cane Sugar in juice} = \text{(Pol reading) x 26.00} \times 99.718 \times \text{App sp gravity 20/20°C} \]

where
- 26.00g is the normal weight when the polarimeter used is fitted with the international scale.
- 99.718 x app. sp gravity 20/20°C is equal to the weight in grams of 100 ml solution.

* Apparent specific gravity 20/20°C is obtained from table 16 in "Cane Sugar Handbook" (Meade and Chen, 1977).

* "Pol reading" is the reading obtained from polarimeter.

b. \[ \% \text{cane sugar in cane} = \% \text{cane sugar in juice} \times \frac{100}{100-germ - 5} \]

c. \[ \% \text{soluble solids in cane} = \text{Brix of juice} \times \frac{100}{100-germ + 3} \]

d. \[ \% \text{Impurities in cane} = (\%\text{Soluble solids in cane}) - (\%\text{Cane sugar in cane}) \]

e. \[ \% \text{POCS} = \% \text{Cane Sugar in cane} - \frac{1}{5}(\% \text{Impurities in cane}) \]

f. \[ \text{Purity} = \frac{\% \text{Cane sugar in cane}}{\% \text{Soluble solids in cane}} = \text{Pol} \% \text{Brix} \]
18 Determination of Polarimeter Readings

a. To a bottle of cane juice extracted from the macerated fibre, powdered dry subacetate of lead was added for clarification. The amount added must be the minimum for clarification as overloading will induce errors. Approximately 0.6 g per 100 ml extract is usually sufficient.

b. Vigorously stir the extract plus lead acetate for 5 seconds and then allow to stand for 30 seconds to permit flocculation of the precipitate.

c. Place filter paper, Whatman No. 91, in a filter funnel.

d. Now place the filter funnel in the mouth of a 125 ml conical flask.

e. Pour the leaded extract, in one operation, into the filter funnel taking care not to overflow the upper edge of the filter paper.

f. Rinse flask with the first 10 ml of the filtrate and discard. Collect clarified filtrate for polar reading.

g. Before polarising check the clarity of the filtrate. If the filtrate shows any sign of haziness, add a few drops of acetic acid to clear.

h. Cool the filtrate to room temp 20°C. At least 50 ml of filtrate is required to adequately rinse and fill the polarimeter tube.

i. Pour all the filtrate into the funnel feeding the polarimeter tube.

j. Record the reading obtained, in the computer input form for processing.
Appendix 2

Potassium Budget for Lalakoro Site

Initial exchangeable $K = 1.9$ mmol/kg $= 122$ kg K/ha

2A: Exchangeable $K$ in Plots after Successive Harvests.

<table>
<thead>
<tr>
<th>Treatment kg/ha</th>
<th>Plant mmol/kg</th>
<th>1st ratoon mmol/kg</th>
<th>2nd ratoon mmol/kg</th>
<th>kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>125</td>
<td>0.129</td>
<td>83.0</td>
<td>0.131</td>
</tr>
<tr>
<td>250</td>
<td>.150</td>
<td>.155</td>
<td>99.7</td>
<td>.170</td>
</tr>
<tr>
<td>500</td>
<td>.194</td>
<td>.189</td>
<td>121.6</td>
<td>.195</td>
</tr>
</tbody>
</table>

2B: Cane Yields for Three Treatments

<table>
<thead>
<tr>
<th>Treatment kg K/ha</th>
<th>Plant Yield (t/ha)</th>
<th>1st ratoon</th>
<th>2nd ratoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>52</td>
<td>51</td>
<td>44</td>
</tr>
<tr>
<td>250</td>
<td>71</td>
<td>69</td>
<td>68</td>
</tr>
<tr>
<td>500</td>
<td>75</td>
<td>74</td>
<td>79</td>
</tr>
</tbody>
</table>

2C: Moisture Content of Cane

<table>
<thead>
<tr>
<th>Treatment kg/ha</th>
<th>% Moisture content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant</td>
<td>1st ratoon</td>
</tr>
<tr>
<td>0</td>
<td>67.9</td>
</tr>
<tr>
<td>250</td>
<td>68.2</td>
</tr>
<tr>
<td>500</td>
<td>69.0</td>
</tr>
</tbody>
</table>
### 2D: Cane Yield on Dry Matter Bases

<table>
<thead>
<tr>
<th>Treatment kg K/ha</th>
<th>Yield t/ha (dry matter)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant</td>
<td>1st ratoon</td>
<td>2nd ratoon</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>16.7</td>
<td>17.4</td>
<td>16.2</td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>22.6</td>
<td>23.9</td>
<td>24.2</td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>23.3</td>
<td>24.3</td>
<td>27.4</td>
<td></td>
</tr>
</tbody>
</table>

### 2E: Percentage Potassium in Stalk of Three Treatments

<table>
<thead>
<tr>
<th>Treatment kg K/ha</th>
<th>% K</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant</td>
<td>1st ratoon</td>
<td>2nd ratoon</td>
</tr>
<tr>
<td>0</td>
<td>.28</td>
<td>.24</td>
<td>.21</td>
</tr>
<tr>
<td>250</td>
<td>.36</td>
<td>.38</td>
<td>.33</td>
</tr>
<tr>
<td>500</td>
<td>.42</td>
<td>.39</td>
<td>.38</td>
</tr>
</tbody>
</table>

### 2F: Potassium Uptake in Stalk

<table>
<thead>
<tr>
<th>Treatment kg K/ha</th>
<th>K uptake (kg/ha)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant</td>
<td>1st ratoon</td>
<td>2nd ratoon</td>
</tr>
<tr>
<td>0</td>
<td>46.7</td>
<td>41.9</td>
<td>34.0</td>
</tr>
<tr>
<td>250</td>
<td>81.3</td>
<td>87.3</td>
<td>80.3</td>
</tr>
<tr>
<td>500</td>
<td>97.7</td>
<td>80.3</td>
<td>104.2</td>
</tr>
</tbody>
</table>

### 2G: Cane Leaf Yields

<table>
<thead>
<tr>
<th>Treatment kg K/ha</th>
<th>Leaf yields (t/ha)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant</td>
<td>1st ratoon</td>
<td>2nd ratoon</td>
</tr>
<tr>
<td>0</td>
<td>7.4</td>
<td>7.2</td>
<td>6.2</td>
</tr>
<tr>
<td>250</td>
<td>11.9</td>
<td>11.5</td>
<td>11.4</td>
</tr>
<tr>
<td>500</td>
<td>16.6</td>
<td>16.4</td>
<td>17.5</td>
</tr>
</tbody>
</table>
### 2K: Moisture Content of Cane Leaf

<table>
<thead>
<tr>
<th>Treatment kg K/ha</th>
<th>% Moisture content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant</td>
</tr>
<tr>
<td>0</td>
<td>54.5</td>
</tr>
<tr>
<td>250</td>
<td>57.7</td>
</tr>
<tr>
<td>500</td>
<td>59.5</td>
</tr>
</tbody>
</table>

### 2I: Leaf Yield on Dry Matter Bases

<table>
<thead>
<tr>
<th>Treatment kg K/ha</th>
<th>Yield t/ha (dry matter)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant</td>
</tr>
<tr>
<td>0</td>
<td>4.0</td>
</tr>
<tr>
<td>250</td>
<td>6.8</td>
</tr>
<tr>
<td>500</td>
<td>9.9</td>
</tr>
</tbody>
</table>

### 2J: Percentage Potassium in Leaf

<table>
<thead>
<tr>
<th>Treatment kg K/ha</th>
<th>% K</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant</td>
</tr>
<tr>
<td>0</td>
<td>1.04</td>
</tr>
<tr>
<td>250</td>
<td>1.41</td>
</tr>
<tr>
<td>500</td>
<td>1.48</td>
</tr>
</tbody>
</table>

### 2K: Potassium Uptake in Leaf

<table>
<thead>
<tr>
<th>Treatment kg K/ha</th>
<th>K uptake (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant</td>
</tr>
<tr>
<td>0</td>
<td>41.8</td>
</tr>
<tr>
<td>250</td>
<td>96.5</td>
</tr>
<tr>
<td>500</td>
<td>146.0</td>
</tr>
</tbody>
</table>
### 2L: Initial and Final Levels of Potassium in 0, 250, 500 kg K treatments of Plant, First and Second Ratoon Crops

<table>
<thead>
<tr>
<th>Trt K kg/ha</th>
<th>Crop</th>
<th>Potassium (kg/ha)</th>
<th>Initial (t)</th>
<th>Final (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Exch(K)</td>
<td>Soln(K)</td>
</tr>
<tr>
<td>0</td>
<td>Plant</td>
<td>122</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1st ratoon</td>
<td>80</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2nd ratoon</td>
<td>83</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>250</td>
<td>Plant</td>
<td>122</td>
<td>24</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>1st ratoon</td>
<td>97</td>
<td>20</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>2nd ratoon</td>
<td>100</td>
<td>19</td>
<td>250</td>
</tr>
<tr>
<td>500</td>
<td>Plant</td>
<td>122</td>
<td>24</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>1st ratoon</td>
<td>118</td>
<td>24</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>2nd ratoon</td>
<td>122</td>
<td>24</td>
<td>500</td>
</tr>
</tbody>
</table>

### 2M: Potassium Budget (Summarised from Table 2L)

<table>
<thead>
<tr>
<th>Trt K kg/ha</th>
<th>Crop</th>
<th>Initial K</th>
<th>Final K</th>
<th>Difference (initial - final)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Plant</td>
<td>146</td>
<td>187</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>1st ratoon</td>
<td>96</td>
<td>185</td>
<td>89</td>
</tr>
<tr>
<td></td>
<td>2nd ratoon</td>
<td>100</td>
<td>170</td>
<td>70</td>
</tr>
<tr>
<td>250</td>
<td>Plant</td>
<td>396</td>
<td>294</td>
<td>(102)</td>
</tr>
<tr>
<td></td>
<td>1st ratoon</td>
<td>367</td>
<td>285</td>
<td>(82)</td>
</tr>
<tr>
<td></td>
<td>2nd ratoon</td>
<td>369</td>
<td>294</td>
<td>(75)</td>
</tr>
<tr>
<td>500</td>
<td>Plant</td>
<td>646</td>
<td>382</td>
<td>(264)</td>
</tr>
<tr>
<td></td>
<td>1st ratoon</td>
<td>642</td>
<td>362</td>
<td>(280)</td>
</tr>
<tr>
<td></td>
<td>2nd ratoon</td>
<td>646</td>
<td>398</td>
<td>(248)</td>
</tr>
</tbody>
</table>