UNIVERSITI PUTRA MALAYSIA

TOWARDS SUSTAINABLE MANAGEMENT OF PINEAPPLE RESIDUES

OSUMANU HARUNA AHMED

FP 2002 19
TOWARDS SUSTAINABLE MANAGEMENT OF PINEAPPLE RESIDUES

OSUMANU HARUNA AHMED

DOCTOR OF PHILOSOPHY
UNIVERSITI PUTRA MALAYSIA
TOWARDS SUSTAINABLE MANAGEMENT OF PINEAPPLE RESIDUES

By

OSUMANU HARUNA AHMED

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

April 2002
DEDICATION

This work is dedicated to the needy and the sincere helpers of the needy.
Abstract of the thesis submitted to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

TOWARDS SUSTAINABLE MANAGEMENT OF PINEAPPLE RESIDUES

By

OSUMANU HARUNA AHMED

Chairman: Ahmad Husni Mohd. Hanif, Ph.D.
Faculty: Agriculture

Studies were conducted to: (i) Investigate the effect of the modification of the existing N, P, and K programme and residue management practice on pineapple fruit yield, (ii) Compare the economic viability of in situ decomposition of pineapple residues untouched (IDPR), i.e. stacking of pineapple residue (leaves, crowns, and peduncles) slashed and raked from 0.60 m x 10 m rows into 0.90 m x 10 m rows (ZBT-zero burn technique), and in situ burning pineapple residues (IBPR) (iii) Quantify the amount of humic acid (HA) that could be extracted from composted pineapple leaves using 0.10 M potassium hydroxide (KOH) produced from pineapple leaves and that of analytical grade (0.10 M KOH), (iv) Compare the elemental composition (C, H, N, O, and S), functional groups (carboxylic, phenolic OH, and total acidity), and spectral characteristics of HA extracted from composted pineapple leaves using KOH from pineapple leaves and that of analytical grade, and (v) Investigate the potential value added agricultural products that could be produced from pineapple leaves.
The fertiliser programmes studied were: (i) Application of N (176, 176, 176, and 176 kg ha$^{-1}$), P (11, 11, 7, and 7 kg ha$^{-1}$), and K (89, 89, 188, and 188 kg ha$^{-1}$) fertilisers at 65, 135, 191, and 233 days after planting (DAP) (FP1), respectively (the usual practice); (ii) Application of N (176, 176, and 176 kg ha$^{-1}$), P (11, 11, and 7 kg ha$^{-1}$) and K (89, 89, and 188 kg ha$^{-1}$) fertilisers at 65, 135, and 191 DAP (FP2), respectively, and (iii) Application of N (176, 264, and 264 kg ha$^{-1}$), P (11, 14, and 11 kg ha$^{-1}$) and K (89, 183, and 285 kg ha$^{-1}$) fertilisers at 65, 135, and 191 DAP (FP3), respectively. The performances of these rates were studied under IDPR, ZBT, and IBPR (the usual practice).

In situ decomposition of pineapple residues without any interference (IDPR), ZBT, or IBPR did not improve fruit yield in the first rotation of the pineapple planting. Fruits yields of FP1, FP2, and FP3 under each of IDPR, ZBT, and IBPR were not statistically different. Application of N, P and K fertilisers at 65, 135 and 191 DAP (FP2) can serve as a competitive alternative to PF1 (existing fertilisation programme) as besides the fact that N, P, and K uptake and the yields of the two programmes were not statistically different, it was possible to save as much as US$ 110.17 ha$^{-1}$ under FP2 through a reduction of N, P, and K fertilisers by 176, 7, and 188 kg ha$^{-1}$, respectively.

Taking into account the cost of environmental pollution associated with burning of pineapple residues, net present value (NPV) analysis revealed that either the IDPR
or the ZBT practices can serve as an economically competitive alternative to IBPR.

Potassium hydroxide (0.10M) from pineapple leaves extracted 20% HA from composted pineapple leaves while that of analytical grade (0.10M KOH) extracted 30%. However, the elemental composition (C, H, N, O, and S), the functional groups (carboxylic, phenolic OH, and total acidity), and the spectra characteristics of the HA extracted using these extractants were generally similar. Potassium hydroxide from pineapple leaves can therefore be used to extract some reasonable amount of HA without appreciably altering the elemental and functional groups constitution as well as the spectral characteristics of this humic substance. The potential of using KOH from pineapple leaves in humic substances extraction therefore looks promising. Useful products such as K-humate, and K-fulvate were also produced from pineapple leaves.
Abstrak tesis yang di kemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi syarat untuk mendapatkan ijazah Doktor Falsafah

KE ARAH PENGURUSAN LESTARI SISA NENAS

Oleh

OSUMANU HARUNA AHMED

Pengerusi: Ahmad Husni Mohd. Hanif, Ph.D.
Fakulti: Pertanian

Kajian telah di jalankan untuk: (i) Mengkaji kesan perubahan kepada pengubahsuaian program pembajaan N, P, K dan kaedah pengurusan sisa terhadap penghasilan buah nenas, (ii) Membandingkan viabiliti ekonomi penguraian sisa nenas secara in situ tanpa di ganggu (IDPR), iaitu menindan sisa nenas (daun, 'crown' dan tangkai), di potong dan dikumpul daripada baris 0.6 m x 10 m kepada 0.9 m x 10 m (ZBT-teknik pembakaran sifar), dan pembakaran sisa nenas secara in situ (IBPR), (iii) Menentukan kuantiti asid humik (HA) yang boleh di ekstrak daripada daun nenas yang di kompos menggunakan 0.10M kalium hidroksida (KOH) yang di hasilkan daripada daun nenas dan daripada gred analitik (0.10M KOH), (iv) Membandingkan komposisi elemen (C, H, N, O, dan S), kumpulan berfungsi (karboksilik, OH fenolik dan jumlah keasidan), dan ciri-ciri spektral HA yang di ekstrak daripada daun nenas yang di kompos dan daripada gred analitik, dan (v) Mengkaji potensi produk pertanian yang di tambah nilainya yang dapat di hasilkan daripada sisa daun nenas.
Program pembajaan yang digunakan adalah: (i) Pembajaan N (176, 176, 176, dan 176 kg ha\(^{-1}\)), P (11, 11, 7, dan 7 kg ha\(^{-1}\)), dan K (89, 89, 188, dan 188 kg ha\(^{-1}\)) pada 65, 135, 191, dan 233 hari selepas penanaman (FP1), (amalan biasa), (ii) pembajaan N (176, 176, dan 176 kg ha\(^{-1}\)), P (11, 11, dan 7 kg ha\(^{-1}\)), dan K (89, 89, dan 188 kg ha\(^{-1}\)) pada 65, 135, dan 191 hari selapas tanam (FP2), dan (iii) Pembajaan N (176, 264, dan 264 kg ha\(^{-1}\)), P (11, 14, dan 11 kg ha\(^{-1}\)) dan K (89, 183, dan 285 kg ha\(^{-1}\)) pada 65, 135, dan 191 hari selapas tanam (FP3). Kesanan pembajaan ini di kaji, di bawah IDPR, ZBT, dan IBPR (amalan biasa).

Penguraian secara in situ sisa nenas tanpa sebarang gangguan (IDPR), ZBT atau IBPR tidak menambahkan hasil nenas pada pusingan pertama tanaman. Hasil buah untuk FP1, FP2, dan FP3 di bawah IDPR, ZBT, dan IBPR tidak berbeza secara statistik. Pembajaan N, P, dan K pada 65, 135, dan 191 hari selapas tanam (FP2) boleh menjadi suatu saingan alternatif kepada FP2 (amalan pembajaan biasa) selain dari pada bukti bahawa pengambilan N, P, dan K dan hasil daripada kedua-kedua program pembajaan tidak berbeza secara statistik. Ia berkemungkinan memberi penjimatan sebanyak US$ 110.17 di bawah FP2 melalui pengurangan baja N, P, dan K masing-masing sebanyak 176, 7, dan 188 kg ha\(^{-1}\).

Dengan mengambil kira kos pencemaran alam sekitar yang berkaitan dengan pembakaran sisa nenas, analisis nilai kini bersih telah menunjukkan bahawa amalan IDPR atau ZBT boleh menjadi satu saingan secara alternatif kepada IBPR.
Kalium hidroksida (0.10M KOH) daripada sisa daun nenas telah mengestrak 20% HA daripada sisa daun nenas yang di kompos manakala kalium hidroksida daripada gred analitik (0.10M KOH) telah mengekstrak 30%, tetapi, komposisi elemen (C, H, N, O, dan S), kumpulan berfungsi (karboksilik, OH fenolik dan jumlah keasidan), dan ciri-ciri spektra adalah sama secara amnya. Kalium hidroksida daripada daun nenas boleh di gunakan untuk mengekstrak jumlah HA tanpa mengubah kandungan elemen dan kumpulan berfungsi serta ciri-ciri bahan humik. Ini memberikan suatu pandangan yang merangsangkan. Produk berguna seperti K-humate, dan K-fulvate juga dapat di hasilkan daripada sisa daun nenas.
ACKNOWLEDGEMENTS

My sincere gratitude goes to Associate Professor Dr. Ahmad Husni Mohd. Hanif, the Chairman of my Supervisory Committee for his keen interest, valuable contribution, and tireless guidance during the preparation of this thesis. His countless patience, encouragement, and generosity are commendable.

I am also grateful to Dr. Anuar Abd. Rahim, and Associate Professor Dr. Mohd Hanafi. Musa, the members of the Supervisory Committee for their invaluable assistance and guidance at the various stages of my research. Special thanks go to Dr. Anuar Abd. Rahim for his fatherly concern of my well-being throughout my study. The intermittent but timely religious admonishment and the financial help of Dr. Syed Omar Syed Rastan are very much appreciated.

I owe the members of my family particularly my parents an incalculable debt for their love, care, sacrifices, and the spiritual support through their fervent prayers that have made me what I am today. Lovely family, your reward is in heaven. The innumerable financial and spiritual support of Mr. David Yeboah (guardian) is appreciated and cannot be given a passing comment.

I am thankful to the entire management of Simpang Rengam Pineapple Estate, Johor, Malaysia with special reference to Messrs. Koh Soo Koon, Lee Sing Kim, and Faizul Abdul Ghani for the dedication and commitment to the
partnership in the collaborative research. The financial supports of the National Council for Scientific Research and Development, Malaysia through the Intensification of Research in Priority Areas (IRPA) funding, and the encouragement of UPM in research and development are acknowledged.

I am greatly indebted to the entire technical staff of the Department of Land Management for their diverse cooperation that led to the smooth running of all my experiments. Help from caring and lovely friends and the hospitality of the Malaysian community is gratifying.

Best of all, all praises and thanks be to ALLAH (GOD) the creator of this magnificent universe of ours and its constituents for the immeasurable guidance, good health, and direction. His Name shall ever be praised and glorified.
I certify that an Examination Committee met on 9th April 2002 to conduct the final examination of Osumanu Haruna Ahmed on his Doctor of Philosophy thesis entitled “Towards Sustainable Management of Pineapple Residues” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

Ahmad Husni bin Mohd. Hanif, Ph.D.
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Anuar Abd. Rahim Ph.D.
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

Mohd Hanafi bin Musa, Ph.D.
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

Mohamed Selamat Madom, Ph.D.
Fruit Research Division
Malaysian Agricultural Research and Development Institute
Kluang, Johore
(Independent Examiner)

SHAMSHER MOHAMAD RAMADILI, Ph.D.
Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 03 JUN 2002
This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy.

AINI IDERIS, Ph.D.
Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 08 AUG 2002
DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

OSUMANU HARUNA AHMED

Date: 3/06/02
# Table of Contents

**DEDICATION** .......................................................... ii  
**ABSTRACT** .............................................................. iii  
**ABSTRAK** ............................................................... vi  
**ACKNOWLEDGEMENTS** ................................................... ix  
**APPROVAL SHEET** ....................................................... xi  
**DECLARATION FORM** .................................................... xiii  
**LIST OF TABLES** ........................................................ xvi  
**LIST OF FIGURES** ....................................................... xxi

## Chapter 1  
**INTRODUCTION** .......................................................... 1  

## Chapter 2  
**LITERATURE REVIEW** .................................................... 6  
- Sustainable Agriculture .................................................. 6  
- Overview of Tropical Peats ............................................... 7  
  - Definition and Types ................................................... 7  
  - Physical Properties ................................................... 9  
  - Chemical Properties ................................................... 12  
  - Nitrogen, Phosphorus, and Potassium Fertilizers Use on peat .................................................. 15  
- Fertilizers Use and Some Related Issues ................................ 17  
  - Soil Fertility Loss ................................................... 17  
  - Causes of Nutrient Loss ................................................. 18  
- Soil Fertility Maintenance and the Global Fertiliser Use Trends  .................................................. 18  
- Fertiliser Use and Some Environmental Issues ................................ 19  
- Crop Residue Management Practices and Fertiliser Use .............. 22  
- Composting of Organic Materials ........................................ 23  
- Incineration of Agricultural Wastes and Open Burning of Agricultural Wastes .................................................. 24  
- Production of Potassium Hydroxide ..................................... 26  
  - Potassium Hydroxide Production Using Mercury Cells ............ 27  
  - Potassium Hydroxide Production Using Diaphragm Cells ........... 28  
  - Potassium Hydroxide Production Using Membrane Cells .......... 28  
  - Production of Potassium Hydroxide from Crop Residues ........... 29  
- Humic Substances .................................................... 29  
  - Synthesis of Humic Substances ........................................ 31  

xiv
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Range and Average Percentage of Important Elements in Organic Soils (Source, Lucas, 1982)</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>Comparison of CEC Values on a Weight and Per Volume Basis</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>Elemental Composition of Soil Humic Substances</td>
<td>48</td>
</tr>
<tr>
<td>4</td>
<td>Atomic Ratios of Humic and Fulvic Acids from Soils</td>
<td>49</td>
</tr>
<tr>
<td>5</td>
<td>Elemental Composition of Humic and Fulvic Acids Extracted from Composted Plant and Woody Residues</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>Atomic Ratios of Humic and Fulvic Acids Extracted from Composted Plant, Wood and from Soils</td>
<td>51</td>
</tr>
<tr>
<td>7</td>
<td>Functional Group Content of Humic and Fulvic Acids Extracted from Plant, wood and from Soils</td>
<td>54</td>
</tr>
<tr>
<td>8</td>
<td>Main IR Absorption Bands of Humic Substances</td>
<td>55</td>
</tr>
<tr>
<td>9</td>
<td>Total N and Extractable P and K before Experimentation</td>
<td>84</td>
</tr>
<tr>
<td>10</td>
<td>Effect of Three Pineapple Residue Management Practices on Total N and Extractable P and K</td>
<td>87</td>
</tr>
<tr>
<td>11</td>
<td>Effect of Three Pineapple Residue Management Practices on Fruit Yield</td>
<td>87</td>
</tr>
<tr>
<td>13</td>
<td>Effect of N, P, and K Fertilisation Programme under Three Residue Management Practices on Fruit Yield</td>
<td>91</td>
</tr>
<tr>
<td>14</td>
<td>Costs Associated with Pineapple Fertilisation Programmes</td>
<td>93</td>
</tr>
<tr>
<td>15</td>
<td>Present Value of Costs of Farm Materials and Other Costs Identical across IDPR, ZBT, and IBPR</td>
<td>99</td>
</tr>
<tr>
<td>16</td>
<td>Pineapple Residue Management Practices and their Effect on Fruit Yield and Residue Production</td>
<td>104</td>
</tr>
</tbody>
</table>
**LIST OF FIGURES**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Soluble K release from Ash Residue</td>
<td>122</td>
</tr>
<tr>
<td>2</td>
<td>Ambient and Compost Temperature vs. Composting Time of Composted Pineapple Leaves</td>
<td>127</td>
</tr>
<tr>
<td>3</td>
<td>Effect of Washing on K Removal from HA</td>
<td>132</td>
</tr>
<tr>
<td>4</td>
<td>Effect of Washing on Ca Removal from HA</td>
<td>132</td>
</tr>
<tr>
<td>5</td>
<td>Effect of Washing on Mg Removal from HA</td>
<td>133</td>
</tr>
<tr>
<td>6</td>
<td>Effect of Washing on Na Removal from HA</td>
<td>133</td>
</tr>
<tr>
<td>7</td>
<td>Effect of Washing on Zn Removal from HA</td>
<td>134</td>
</tr>
<tr>
<td>8</td>
<td>Effect of Washing on Mn Removal from HA</td>
<td>134</td>
</tr>
<tr>
<td>9</td>
<td>Effect of Washing on Cu Removal from HA</td>
<td>134</td>
</tr>
<tr>
<td>10</td>
<td>Equilibrium Study of K in Humic Acids</td>
<td>135</td>
</tr>
<tr>
<td>11</td>
<td>Absorption of Soluble K Release from Ash Residue by Humic Acid</td>
<td>143</td>
</tr>
<tr>
<td>12</td>
<td>Relationship between Soluble K Release from Ash Residue and Absorption by Humic Acid</td>
<td>143</td>
</tr>
<tr>
<td>13</td>
<td>Amounts of K, Ca, and Mg in Humin Extracted from Pineapple Leaves and Analytical Grade at 0.10M KOH Solutions</td>
<td>148</td>
</tr>
<tr>
<td>14</td>
<td>Amounts of Zn, Na, Mn, and Cu in Humin Extracted from Pineapple Leaves and Analytical Grade at 0.10M KOH Solutions</td>
<td>148</td>
</tr>
</tbody>
</table>
CHAPTER I

INTRODUCTION

Pineapple (*Ananas comosus*), a tropical fruit crop (Sampson, 1980) is commonly grown on mineral soils (Py et al., 1987) but in Malaysia, the crop is largely (17,000 hectare), and uniquely cultivated on peat (AGRIQUEST, 1999/2000). This practice has been in existence for nearly a century (Selamat and Ramlah, 1993). The present large scale cultivation started on small scale basis with no fertilisation but after the extensive and comprehensive survey of pineapple cultivation on peat in Malaysia (Dunsmore, 1957), the need to apply balanced fertilisers for a better growth and production of pineapple was apparent. Afterwards, some recommendations (Tay, 1972; Tay, 1973) were put forward. Probably when it became obvious that the existing recommendations have outlived their usefulness, new recommendations were issued (Selamat and Ramlah, 1993; Razzaque, 1999). Despite the fact that pineapple residue management practices such as burning, incorporation, mulching, or zero-burn, each of which, in one way or other forms an integral part of pineapple cultivation, none of the preceding studies took due cognisance of the performances of the fertiliser regimes under any of these residues management practices.
A recent study on the P, K, Ca, and Mg budget in pineapple cultivation has revealed that the existing fertiliser regime (successive applications of N, P, and K fertilisers at 65, 135, 191, and 233 days after planting (DAP)) is inappropriate (Ahmed et al., 2000). This observation has been ascribed to the lack of efficient synchrony between the release of these nutrients from the applied fertilisers (particularly the last stage of fertilisation, 233 DAP) and their uptake. At this period, nutrients are applied at a stage in pineapple growth when active nutrients uptake is quite slow (Py et al., 1987), and hence substantial amounts of nutrients get accumulated. But with average monthly rainfall of 159.75 mm coupled with the low clay in organic soils (Stevenson, 1994), high lost of P and K has been observed (Ahmed et al., 2000; Funakawa et al., 1996). For instance, 32% of P from China phosphate rock and 25.74% of K from muriate of potash of the total amount applied are lost through leaching. In terms of accumulation, 13.89% of P and 47.78% of K, respectively are retained in the soil. The high accumulation of K should be of utmost concern because it seems that there is no guarantee that the residual K can be of any significant benefit in the succeeding cropping years. Studies have shown that even though applied fertiliser K remaining in the exchangeable and solution forms are easily leached under high rainfall, residual K in organic soils is much affected (Shickluna et al., 1972).

From the foregoing nutrient leaching and accumulation estimations, it can be estimated that 46.79% (leaching plus accumulation) of P and as much as 73.52% (leaching plus accumulation) of K are not utilized. This estimation is consistent
with the findings of Ahmed et al. (1999) on P and K fertilisers’ use efficiencies that were found to be 53.21 and 29.91%, respectively. At economic rate of 750 to 872 kg N ha\(^{-1}\), Razzaque (1999) reported about 53.30 to 65.90% and 15 to 16% of N leaching and maximum recovery, respectively.

In spite of the growing concern of the polluting effects of excess fertiliser application on the environment, Malaysia is one of the heaviest users of fertilisers in the world (on unit land area basis) even though most of the fertilisers used in the country are imported. For 1995/96, Malaysia used 223.40 kg ha\(^{-1}\) fertiliser nutrients, compared with a world wide use of only 83.40 kg ha\(^{-1}\) (AGRIQUEST, 1999/2000). It is even thought that Malaysia is the only country in the world with a K requirement higher than N requirement. In 1998 (January to September), the fertiliser import bills for nitrogenous, phosphatic, and potassic fertilisers stood at 106.00 (RM 402.80), 39.39 (RM 149.68), and US$ 115.58 (RM 439.20) million, respectively (AGRIQUEST, 1999/2000).

For the Malaysian pineapple industry to contribute to the reduction of these alarming bills there is a need to judiciously modify the present fertiliser regime. The modification however needs to be in tandem with a superior mode of handling pineapple residues like the modified version of zero-burn technique where with the exception of leaves that need to be removed for value addition instead of burning, roots, stems, crowns, and peduncles could be left to decompose in situ. This