UNIVERSITI PUTRA MALAYSIA

Performance of Oil Palm (Elaeis Guineensis Jacq.) DxP Progenies from Different Agencies under Various Planting Densities

MOHD ISA BIN ZAINOL ABIDIN

FP 2007 19
Performance of Oil Palm (*Elaeis Guineensis* Jacq.) DxP Progenies from Different Agencies under Various Planting Densities

By

MOHD ISA BIN ZAINOL ABIDIN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Agricultural Science

August 2007
Performance of Oil Palm (*Elaeis Guineensis* Jacq.) DxP Progenies from Different Agencies under Various Planting Densities

By

MOHD ISA ZAINOL ABIDIN

August 2007

Chairman:  Mohd Rafii Hj. Yusop, PhD

Faculty:  Agriculture

Fifteen *dura x pisifera* (DxP) bi-parental crosses from six Malaysian seed producers (agencies) were studied for yield, bunch quality, vegetative characters and physiological traits in four planting densities. Analysis of variance indicated significant differences among the fifteen progenies that were obtained from six agencies and planted under four planting densities. However, all the progenies and agencies were considered responding similarly across planting densities for all the 34 traits studied by showing no significant difference in genotype x planting density interaction, pooled over years. Broad-sense heritability estimates ($h^2_B$) using intra-class correlation varied between 13.3% and 47.6%. Generally, the genetic variations and heritability estimates were low, which may restrict further improvements of the parental stocks. On the other hand, uniform performance for yield is advantageous in commercial plantings. The difference in yield among progenies and among agencies reflected the different genetic background and selection pressure. The low genetic variability could be due to the narrow genetic base. The fresh fruit bunch (FFB) yield of the six agencies ranged from
18.41 to 21.46 t/ha/yr. The highest FFB yield in agency A2 was attributed to its high bunch number (BNO). Oil to bunch (O/B) varied from 25.93 to 28.21% with the latter extreme observed in agency A1. Heights (HT) of the 21-year old palms were between 8.97m and 10.02m with the height increment of between 47cm and 53cm among agencies, while the HT among densities were between 8.73m and 10.43m with the height increment of between 46cm (density D1) and 55cm (density D4). Agencies A1 and A6 had the lowest HT increment reflecting the dumpy ancestry. Oil yield (OY), which ranged from 5.11 t/ha/yr to 6.03 t/ha/yr was highest in agency A2, due its high FFB. Bunch index (BI) ranged between 0.39 and 0.43 with agency A2 was the highest. Agency A2 produced the best total economic product (TEP) at 6.93 t/ha/yr. Minimum TEP of 5.80 t/ha/yr was produced by agency A3. Density D2 (148 palms/ha) recorded the highest FFB and OY with 21.74 and 6.0 t/ha/yr, respectively. Densities D3 (170 palms/ha), D4 (215 palms/ha) and D1 (120 palms/ha) was the second, third and fourth (lowest) respectively, in FFB and OY productions. Density 2 (148 palms/ha) was the ideal planting density for maximum oil yield per unit land area. This density (148 palms/ha) is the current planting density used in commercial oil palm cultivation on inland soil.
Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains Pertanian

Prestasi Progeni Kelapa Sawit (*Elaeis Guineensis* Jacq.) DxP daripada Agensi yang Berbeza di Berbagai Kepadatan Tanaman

Oleh

MOHD ISA ZAINOL ABIDIN

Ogos 2007

Pengerusi: Mohd Rafii Hj. Yusop, PhD

Fakulti: Pertanian

Lima belas progeni *dura x pisifera* (DxP) kacukan dwi-induk dari enam pengeluar benih kelapa sawit di Malaysia (agensi) telah dikaji dari segi hasil buah tandan segar, kualiti tandan, sifat vegetatif dan ciri fisiologi di empat kepadatan tanaman. Analisis varians antara lima belas progeni, enam agensi dan empat jarak tanaman menunjukkan perbezaan yang bererti di antara progeni, agensi dan kepadatan tanaman. Bagaimanapun, kesemua 34 ciri yang kaji tidak menunjukkan perbezaan yang bererti terhadap kesan interaksi antara progeni atau agensi dengan kepadatan tanaman. Anggaran heritabiliti luas (*h*B) menggunakan korelasi intra-kelas adalah pada julat 13.3% hingga 47.6%. Secara umumnya, variasi genetik dan anggaran nilai heritabiliti adalah rendah yang mungkin menghadkan usaha penambahbaikan. Sebaliknya, keseragaman di dalam progeni memudahkan pemilihan bagi penghasilan bahan tanaman komersil. Prestasi hasil yang berbeza di antara progeni dan antara agensi mencerminkan kesan pemilihan dan sumber genetik yang berbeza. Variabiliti genetik yang rendah bagi hampir semua ciri mungkin disebabkan bahan tanaman yang
I am indebted to the Director General of Malaysian Palm Oil Board (MPOB) for the opportunity given to do this work.

My deep appreciation goes to the Chairman of my Supervisory Committee, Dr. Hj. Mohd Rafii Hj. Yusop, for his patience, guidance and endless encouragement throughout my graduate studies and research. I would also like to thank the other committee members, Prof. Dr. Ghizan Saleh and Dr. A. Kushairi Din for their valuable inputs and comments on my thesis. I would like to give my special thanks to Dr. N. Rajanaidu, for his encouragements and support.

I wish also to thank the staff of the Breeding Section at the MPOB Station, Hulu Paka for assistance with the data collection. I am grateful to Mr. Mukesh Sharma at Messieurs United Plantations Malaysia Berhad, Mr. Ng Woo Jien of Felda Agricultural Services Sendirian Berhad, Mr. Mohaimi Mohamed of Golden Hope Plantations Berhad and Mr. Mustafa Kamal Mohamed of Chemara Research, Guthrie Malaysia.

I would like to express my deepest thanks to my parents and other family members for their love, support, and encouragements. I would not have had it completed without my wife Maimunah Abu Samah’s love, support and prayers.
I certify that an Examination Committee has met on 29th August 2007 to conduct the final examination of Mohd Isa bin Zainol Abidin on his Master of Science thesis entitled “Performance of Oil Palm (Elaeis guineensis Jacq.) DxP Progenies from Different Agencies under Various Planting Densities” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the degree of Master of Science.

Members of the Examination Committee were as follows:

**Mihdzar bin Abdul Kadir, PhD**
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

**Mohd Said bin Saad, PhD**
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

**Sheikh Awadz bin Sheikh Abdullah, PhD**
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

**Othman bin Omar, PhD**
Malaysian Agricultural Research and Development Institute
(External Examiner)

---

**HASANAH MOHD. GHAZALI, PhD**
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:
This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Agricultural Science. The members of the Supervisory Committee were as follows:

**Mohd Rafii Hj. Yusop, PhD**  
Associate Professor  
Faculty of Agriculture  
Universiti Putra Malaysia  
(Chairman)

**Ghizan Saleh, PhD**  
Professor  
Faculty of Agriculture  
Universiti Putra Malaysia  
(Member)

**Ahmad Kushairi Din, PhD**  
Director of Biological Research  
Malaysian Palm Oil Board  
(Member)

---

**AINI IDERIS, PhD**  
Professor and Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date: 21 February 2008
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 Universiti Putra Malaysia or other institutions.

MOHD ISA ZAINOL ABIDIN

Date: 28 December 2007
TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>ABSTRACT</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRAK</td>
<td>iv</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>vi</td>
</tr>
<tr>
<td>APPROVAL</td>
<td>vii</td>
</tr>
<tr>
<td>DECLARATION</td>
<td>ix</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xii</td>
</tr>
<tr>
<td>LIST OF APPENDICES</td>
<td>xv</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>xvii</td>
</tr>
</tbody>
</table>

CHAPTER

1 INTRODUCTION 1

2 LITERATURE REVIEW 6
  2.1 Taxonomy and Habitat of the Oil Palm 6
  2.2 Botanical and Aspects of Oil Palm 6
  2.3 Development of Oil Palm Industry in Malaysia 8
  2.4 Dura and Tenera/Pisifera Breeding Programmes in This Study 9
    2.4.1 Dura Breeding Populations 9
    2.4.2 Tenera/Pisifera Breeding Populations 13
  2.5 Genetic and Heritability Studies 17
  2.6 Phenotypic Correlation 19

3 MATERIALS AND METHODS 20
  3.1 Materials 20
  3.2 Methodology 21
    3.2.1 Planting Density and Experimental Design 21
    3.2.2 Field Maintenance 24
    3.2.3 Data Collection 24
    3.2.4 Statistical Analysis 29
    3.2.5 Correlations 36

4 RESULTS 38
  4.1 Yield Trend 38
  4.2 Progeny Performance and Bi-Parental Analyses among Individual Progenies on Palm Basis 44
    4.2.1 Yield and Yield Components 44
    4.2.2 Bunch Quality Components 47
    4.2.3 Vegetative and Physiological Measurements 52
    4.2.4 Progeny Performance and Bi-Parental Analyses based on Hectarage 58
  4.3 Agency Performance and Bi-Parental Analyses among Agencies Based on Individual Palm Basis 60
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.3.1</td>
<td>Yield and Yield Components</td>
<td>60</td>
</tr>
<tr>
<td>4.3.2</td>
<td>Bunch Quality Characters</td>
<td>62</td>
</tr>
<tr>
<td>4.3.3</td>
<td>Vegetative and Physiological Characters</td>
<td>65</td>
</tr>
<tr>
<td>4.3.4</td>
<td>Agency Performance and Bi-Parental Analyses among Agencies based on hectarage</td>
<td>68</td>
</tr>
<tr>
<td>4.4</td>
<td>Performance of FFB, BNO, OY, KY and TEP in Different Planting Densities</td>
<td>73</td>
</tr>
<tr>
<td>4.4.1</td>
<td>Performance of FFB, BNO, OY, KY and TEP in Different Planting Densities Based on Individual Palm</td>
<td>73</td>
</tr>
<tr>
<td>4.4.2</td>
<td>Performance of FFB, BNO, OY, KY and TEP in Different Planting Densities Based on hectarage</td>
<td>76</td>
</tr>
<tr>
<td>4.6</td>
<td>Phenotypic Correlation among Agronomic Characters</td>
<td>84</td>
</tr>
<tr>
<td>4.6.1</td>
<td>Phenotypic Correlation among Individual Palms</td>
<td>84</td>
</tr>
<tr>
<td>4.6.2</td>
<td>Phenotypic Correlation Based on Hectarage</td>
<td>88</td>
</tr>
</tbody>
</table>

5 DISCUSSION

6 CONCLUSION

REFERENCES

BIODATA OF THE AUTHOR
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>DxP Comparative Trial planted in four planting densities at MPOB Hulu Paka Research Station, Terengganu, Malaysia.</td>
<td>22</td>
</tr>
<tr>
<td>3.2</td>
<td>Genetic background of oil palm progenies from different agencies used for DxP Comparative trial planted in four planting densities at MPOB Hulu Paka Research Station, Terengganu, Malaysia</td>
<td>23</td>
</tr>
<tr>
<td>3.3</td>
<td>Computation formulae for bunch analysis components</td>
<td>28</td>
</tr>
<tr>
<td>3.4</td>
<td>Computation formulae for analyses of morphophysiological traits</td>
<td>30</td>
</tr>
<tr>
<td>3.5</td>
<td>Outline of ANOVA and expected mean squares (EMS) for full-sib analysis pooled over planting densities in oil palm progenies</td>
<td>33</td>
</tr>
<tr>
<td>3.6</td>
<td>Outline of ANOVA and expected mean squares (EMS) for agencies pooled over planting densities in oil palm</td>
<td>35</td>
</tr>
<tr>
<td>4.1</td>
<td>Mean squares of analysis of variance (ANOVA) and progeny means for bunch yields pooled over densities in oil palms planted in four densities.</td>
<td>39</td>
</tr>
<tr>
<td>4.2</td>
<td>Fresh fruit bunch (FFB), bunch number (BNO) and average bunch weight (ABW) in oil palm planted in four planting densities, 1987 - 2003</td>
<td>41</td>
</tr>
<tr>
<td>4.3</td>
<td>Planting density means for fresh fruit bunch/ha (FFB/ha) and bunch number/ha (BNO/ha) over years (1987 - 2003)</td>
<td>43</td>
</tr>
<tr>
<td>4.4</td>
<td>Variance components and heritability estimates for fresh fruit bunch (FFB), bunch number (BNO) and average bunch weight (ABW)</td>
<td>46</td>
</tr>
<tr>
<td>4.5</td>
<td>Mean squares of analysis of variance (ANOVA) and progeny means for bunch quality components pooled over densities in oil palm progenies</td>
<td>48</td>
</tr>
<tr>
<td>4.6</td>
<td>Variance components and heritability estimates for bunch quality components</td>
<td>53</td>
</tr>
<tr>
<td>4.7</td>
<td>Mean squares of analysis of variance (ANOVA) and progeny means for vegetative components and physiological traits pooled over densities in oil palm</td>
<td>54</td>
</tr>
<tr>
<td>Section</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>4.8</td>
<td>Variance components and heritability estimates for vegetative and physiological traits in oil palm.</td>
<td></td>
</tr>
<tr>
<td>4.9</td>
<td>Mean squares of analysis of variance (ANOVA) and progeny means for fresh fruit bunch/ha (FFB/ha), bunch number/ha (BNO/ha), oil yield/ha (OY/ha), kernel yield/ha (KY/ha) and total economic product/ha (TEP/ha) pooled over densities in oil palm</td>
<td></td>
</tr>
<tr>
<td>4.10</td>
<td>Mean squares of analysis of variance (ANOVA) and agency means for bunch yields pooled over densities in oil palm</td>
<td></td>
</tr>
<tr>
<td>4.11</td>
<td>Mean squares of analysis of variance (ANOVA) and agency means for bunch quality components pooled over densities in oil palm</td>
<td></td>
</tr>
<tr>
<td>4.12</td>
<td>Mean squares of analysis of variance (ANOVA) and agency means for vegetative components and physiological traits pooled over densities in oil palm</td>
<td></td>
</tr>
<tr>
<td>4.13</td>
<td>Mean squares of analysis of variance (ANOVA) and agency means for fresh fruit bunch/ha (FFB/ha), bunch number/ha (BNO/ha), oil yield/ha (OY/ha), kernel yield/ha (KY/ha) and total economic product/ha (TEP/ha) pooled over densities in oil palm</td>
<td></td>
</tr>
<tr>
<td>4.14</td>
<td>Mean squares of analysis of variance (ANOVA) and agency mean for fresh fruit bunch/ha (FFB/ha) and bunch number/ha (BNO/ha) for individual years pooled over densities in oil palm</td>
<td></td>
</tr>
<tr>
<td>4.15</td>
<td>Density means for fresh fruit bunch/ha (FFB/ha), bunch number/ha (BNO/ha), oil yield/ha (OY/ha), kernel yield/ha (KY/ha) and total economic product/ha (TEP/ha) and height (HT) in oil palm</td>
<td></td>
</tr>
<tr>
<td>4.16</td>
<td>Density means for fresh fruit bunch (FFB), bunch number (BNO), oil yield (OY), kernel yield (KY) and total economic product (TEP) on individual palm basis</td>
<td></td>
</tr>
<tr>
<td>4.17</td>
<td>Progeny means for fresh fruit bunch (FFB), bunch number (BNO), oil yield (OY), kernel yield (KY) and total economic product (TEP) in different planting densities in oil palm on individual palm basis</td>
<td></td>
</tr>
<tr>
<td>4.18</td>
<td>Agency means for fresh fruit bunch (FFB), bunch number (BNO), oil yield (OY), kernel yield (KY) and total economic product (TEP) in different planting densities in oil palm on individual palm basis</td>
<td></td>
</tr>
<tr>
<td>4.19</td>
<td>Progeny means of fresh fruit bunch/ha (FFB/ha), bunch number/ha (BNO/ha), oil yield/ha (OY/ha) and kernel yield/ha (KY/ha) in oil palm</td>
<td></td>
</tr>
</tbody>
</table>
4.20 Agency means of fresh fruit bunch/ha (FFB/ha), bunch number/ha (BNO/ha), oil yield/ha (OY/ha), kernel yield/ha (KY/ha) and total economic product/ha (TEP/ha) over different planting densities in oil palm
# LIST OF APPENDICES

<table>
<thead>
<tr>
<th>Appendix</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Flow Chart of Bunch Analysis Method</td>
<td>105</td>
</tr>
<tr>
<td>A2</td>
<td>Oil Extraction of 5g Mesocarp Samples</td>
<td>106</td>
</tr>
<tr>
<td>B1</td>
<td>Mean squares of analysis of variance (ANOVA) and progeny means for bunch yield over year (1987)</td>
<td>107</td>
</tr>
<tr>
<td>B2</td>
<td>Mean squares of analysis of variance (ANOVA) and progeny means for bunch yield over year (1988)</td>
<td>108</td>
</tr>
<tr>
<td>B3</td>
<td>Mean squares of analysis of variance (ANOVA) and progeny means for bunch yield over year (1989)</td>
<td>109</td>
</tr>
<tr>
<td>B4</td>
<td>Mean squares of analysis of variance (ANOVA) and progeny means for bunch yield over year (1990)</td>
<td>110</td>
</tr>
<tr>
<td>B5</td>
<td>Mean squares of analysis of variance (ANOVA) and progeny means for bunch yield over year (1991)</td>
<td>111</td>
</tr>
<tr>
<td>B6</td>
<td>Mean squares of analysis of variance (ANOVA) and progeny means for bunch yield over year (1992)</td>
<td>112</td>
</tr>
<tr>
<td>B7</td>
<td>Mean squares of analysis of variance (ANOVA) and progeny means for bunch yield over year (1993)</td>
<td>113</td>
</tr>
<tr>
<td>B8</td>
<td>Mean squares of analysis of variance (ANOVA) and progeny means for bunch yield over year (1994)</td>
<td>114</td>
</tr>
<tr>
<td>B9</td>
<td>Mean squares of analysis of variance (ANOVA) and progeny means for bunch yield over year (1995)</td>
<td>115</td>
</tr>
<tr>
<td>B10</td>
<td>Mean squares of analysis of variance (ANOVA) and progeny means for bunch yield over year (1996)</td>
<td>116</td>
</tr>
<tr>
<td>B11</td>
<td>Mean squares of analysis of variance (ANOVA) and progeny means for bunch yield over year (1997)</td>
<td>117</td>
</tr>
<tr>
<td>B12</td>
<td>Mean squares of analysis of variance (ANOVA) and progeny means for bunch yield over year (1998)</td>
<td>118</td>
</tr>
<tr>
<td>B13</td>
<td>Mean squares of analysis of variance (ANOVA) and progeny means for bunch yield over year (1999)</td>
<td>119</td>
</tr>
</tbody>
</table>
B14 Mean squares of analysis of variance (ANOVA) and progeny means for bunch yield over year (2000) 120

B15 Mean squares of analysis of variance (ANOVA) and progeny means for bunch yield over year (2001) 121

B16 Mean squares of analysis of variance (ANOVA) and progeny means for bunch yield over year (2002) 122

B17 Mean squares of analysis of variance (ANOVA) and progeny means for bunch yield over year (2003) 123

C Phenotypic Correlation among FFB, Bunch Quality, Vegetative Components and Physiological Traits over Different Planting Densities and Pooled over Densities 124 – 130

D1 Mean squares of analysis of variance (ANOVA) and agency means for bunch yields (1987 - 1989). 131

D2 Mean squares of analysis of variance (ANOVA) and agency means for bunch yields (1990 - 1992). 132

D3 Mean squares of analysis of variance (ANOVA) and agency means for bunch yields (1993 - 1995). 133

D4 Mean squares of analysis of variance (ANOVA) and agency means for bunch yields (1996 - 1998). 134

D5 Mean squares of analysis of variance (ANOVA) and agency means for bunch yields (1999 - 2001) 135

D6 Mean squares of analysis of variance (ANOVA) and agency means for bunch yields (2002 - 2003). 136

E Phenotypic Correlation among FFB/ha, BNO/ha, ABW, O/B, K/B, OY/ha and TEP/ha in Individual Densities and Pooled over Densities 137
## LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFB</td>
<td>fresh fruit bunch</td>
</tr>
<tr>
<td>BNO</td>
<td>bunch number</td>
</tr>
<tr>
<td>ABW</td>
<td>average bunch weight</td>
</tr>
<tr>
<td>BWT</td>
<td>bunch weight</td>
</tr>
<tr>
<td>MFW</td>
<td>fruit weight</td>
</tr>
<tr>
<td>P/B</td>
<td>parthenocarpic/bunch</td>
</tr>
<tr>
<td>M/F</td>
<td>mesocarp/fruit</td>
</tr>
<tr>
<td>K/F</td>
<td>kernel/fruit</td>
</tr>
<tr>
<td>S/F</td>
<td>shell/fruit</td>
</tr>
<tr>
<td>O/DM</td>
<td>oil/dry mesocarp</td>
</tr>
<tr>
<td>O/WM</td>
<td>oil/wet mesocarp</td>
</tr>
<tr>
<td>F/B</td>
<td>fruit/bunch</td>
</tr>
<tr>
<td>O/B</td>
<td>oil/bunch</td>
</tr>
<tr>
<td>K/B</td>
<td>kernel/bunch</td>
</tr>
<tr>
<td>OY</td>
<td>oil yield (kg/palm/yr)</td>
</tr>
<tr>
<td>KY</td>
<td>kernel yield kernel/palm/year</td>
</tr>
<tr>
<td>TEP</td>
<td>total economic product (kg/palm/yr)</td>
</tr>
<tr>
<td>FP</td>
<td>frond production</td>
</tr>
<tr>
<td>PCS</td>
<td>petiole cross-section</td>
</tr>
<tr>
<td>RL</td>
<td>rachis length</td>
</tr>
<tr>
<td>LL</td>
<td>leaflet length</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>LW</td>
<td>leaflet width</td>
</tr>
<tr>
<td>LN</td>
<td>leaflet number</td>
</tr>
<tr>
<td>HT</td>
<td>palm height</td>
</tr>
<tr>
<td>LA</td>
<td>leaf area</td>
</tr>
<tr>
<td>LAI</td>
<td>leaf area index</td>
</tr>
<tr>
<td>DIA</td>
<td>diameter</td>
</tr>
<tr>
<td>LDW</td>
<td>leaf dry weight</td>
</tr>
<tr>
<td>TDW</td>
<td>trunk dry weight</td>
</tr>
<tr>
<td>FDW</td>
<td>frond dry weight</td>
</tr>
<tr>
<td>LAR</td>
<td>leaf area ratio</td>
</tr>
<tr>
<td>VDM</td>
<td>vegetative dry matter</td>
</tr>
<tr>
<td>BDM</td>
<td>bunch dry matter</td>
</tr>
<tr>
<td>TDM</td>
<td>total dry matter</td>
</tr>
<tr>
<td>BI</td>
<td>bunch index</td>
</tr>
<tr>
<td>NAR</td>
<td>net assimilation rate</td>
</tr>
<tr>
<td>SD</td>
<td>standard deviation</td>
</tr>
<tr>
<td>CV</td>
<td>coefficient of variation</td>
</tr>
<tr>
<td>ANOVA</td>
<td>analysis of variance</td>
</tr>
<tr>
<td>FS</td>
<td>full-sib</td>
</tr>
<tr>
<td>BIPS</td>
<td>bi-parental</td>
</tr>
<tr>
<td>r</td>
<td>correlation coefficient of variation</td>
</tr>
<tr>
<td>df</td>
<td>degree of freedom</td>
</tr>
<tr>
<td>$h^2_B$</td>
<td>broad-sense heritability</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>MS</td>
<td>mean squares</td>
</tr>
<tr>
<td>EMS</td>
<td>expected mean squares</td>
</tr>
<tr>
<td>D1</td>
<td>density 1 (120 palms/ha/year planted at 9.79m distance)</td>
</tr>
<tr>
<td>D2</td>
<td>density 2 (148 palms/ha/year planted at 8.81m distance)</td>
</tr>
<tr>
<td>D3</td>
<td>density 3 (170 palms/ha/year planted at 8.22m distance)</td>
</tr>
<tr>
<td>D4</td>
<td>density 4 (215 palms/ha/year planted at 7.31m distance)</td>
</tr>
<tr>
<td>AVROS</td>
<td>Algemene Vereniging van Rubber-planters ten Oostkust van Sumatera (now known as Balai Penelitian Pekebun Medan)</td>
</tr>
<tr>
<td>MPOB</td>
<td>Malaysian Palm Oil Board</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

The oil palm (*Elaeis guineensis*) is comparatively the highest oil bearing plant. The increase in yield performance of superior planting materials through proper plantation management and agronomic practices has further enhanced productivity of the crop.

Oil palm development in Malaysia has been phenomenal. Starting off as an ornamental plant, the crop has developed into a multi billion ringgit industry. Malaysia is currently the largest producer and exporter of palm oil in the world supplying 51% of the total world production with 13.4 million tonnes of oil in 2005 (MPOB, 2006). However, the national average of oil palm yield, 3.80 t/ha/yr in 2005 (MPOB, 2006), was about 75% lower than the maximum theoretical potential yield of 18.2 t/ha/yr (Corley, 1996). Thus, efforts towards increasing oil productivity are necessary to reduce this gap.

Increasing oil yield remains the primary objective of oil palm breeding programmes. In order to get optimum oil yield per unit area, options to emphasize on the planting density may be more attractive. Genetic and physiological researches are possible avenues towards this goal by producing planting materials with high FFB yield and high oil yield with high planting density. The optimum planting density will enable optimum growth and economic yield production of oil palm through its life span.
Oil palm planting density has been a topic of interest since the 1970’s. Results have been reported from trials testing various spacing and planting patterns, thinning of existing stands as well as variable density planting *i.e.* deliberately planting at high initial density for future thinning (Mohd Nazeeb *et al*., 1989). High optimal densities, leading to higher early yields, are possible in areas where palms grow relatively slow or if suitable planting materials are used.

Sly and Chapas (1963) reported that FFB yield decline at 180 palms/ha occurred only after the eighth year in Ghana while such decline was observed in Nigeria after the seventh year of planting (Hartley, 1988).

Corley (1973a) observed that the general increase in yield with age during the early bearing years was reversed with increasing density. Mok *et al*., (1971) recorded a decrease in bunch weight after the fourth year, especially at densities greater than 225 palms/ha. They also noted apparently greater frond length from the third year in palms the very high densities of 227 and 334 palms/ha. In the very fertile environments at Dami, Papua new Guinea, the rachises of palms at the comparatively lower stand of 148 palms/ha were very significantly longer from the fifth year compared to those grown at 56 or 110 palms/ha (Breure, 1977). On coastal clay soil soils of Peninsular Malaysia, Tan and Ng (1976) observed rachis etiolation in palms at the highest density of 185 palms/ha in the sixth year of planting. Tanipura *et al*., (1985) observed significantly longer rachises from the fifth year in palms grown at 160 and 180 palms/ha on reddish yellow podsols in North Sumatera.
Ramachandran et al., (1973) studied the long term effects of density on yield for the period of seven to eighteen years and noted a consistent reduction in FFB, bunch number and bunch weight at the highest density of 183 palms/ha. They concluded that bunch weight decreases by about one kg for every 25 palms/ha increase in density.

Corley et al., (1973b) found that the optimum density for costal clay soils was 151 palms per hectare, 158 palms per hectare for well-fertilized inland soils and 166 palms per ha for poorer inland soils. Based on equilateral triangular plantings with 111, 136, 161 and 185 palms per hectare, Tan and Ng (1976) observed that on per hectare basis in coastal soils, early yields of the higher density plantings were significantly higher but trend lasted only until the fifth year of harvest, when all treatments gave similar yields. Within the next two years, the density of 136 palms/ha out-yielded 185 palms/ha by 9% or 5 tonnes FFB/ha.

Density effects on eleven years old of ten open-pollinated Nigerian germplasm planted in Kluang in 1976 under three spacings of approximately 125, 175 and 225 palms per hectare gave drastic reduction in FFB yield with increasing density due to reduced bunch number and also reduced bunch weight from fewer and smaller spikelets (Rao et al., 1993). The study showed no significant effect of planting density on oil/bunch (O/B) ratio at the 5% level. Corley (1976) also reported no significant change in O/B with planting density besides no significant difference in fruit/bunch (F/B) ratio.
Hardon et al., (1969) and Corley et al., (1971a) suggested that increasing the leaf area index by high density planting might be a promising way of improving yield of oil palm. It has also been suggested that selection for high harvest index might be a more effective way of increasing oil yield per hectare than selection for individual palm yield. (Rees, 1963; Corley et al., 1971b).

Results based on 13 years yield record of commercial DXP (or 16 years planting) of a spacing trial (120, 160 and 200 palms/ha) at MPOB’s peat area in Teluk Intan showed continued significant increase in FFB yield and O/B with increase in planting densities (Mohd Tayeb et al., 2002).

Two oil palm spacing trials evaluating a range of planting densities on riverine alluvial and organic muck soil in Sabah using four DXP progenies of Oil Palm Research Station, Banting, revealed the strong indications of positive effect of increased planting density on oil and kernel extraction rates, through improved fruit to bunch ratio (Donough and Betty Kwan, 1991). The palm height increment was unaffected by density until seven to eight years after planting. Thereafter, increasing density increased height increment. Donough and Betty Kwan, (1991) estimated that every ten palms per hectare increase in planting density would necessitate earlier replanting by four to six months.

Although various studies were carried out to determine the effect of planting density on oil palm productivity, there has been no known information on interaction between various genotypes and planting densities in oil palm.
This study has the following objectives:

1) To evaluate the agronomic performance of different genotypes of different source of origins planted in four different planting densities.

2) To estimate and quantify the genetic control and heritabilities of various agronomic traits.

3) To estimate the correlation among the agronomic traits i.e. yield, bunch quality and vegetative characters of the different progenies planted in different planting densities.

4) To identify and select high yielding and stable oil palm genotypes with respect to planting density.