INDEX

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1. Fruits in human diet</td>
<td>1</td>
</tr>
<tr>
<td>1.2. Potential of Caricaceae</td>
<td>1</td>
</tr>
<tr>
<td>1.2.1. Carica</td>
<td>2</td>
</tr>
<tr>
<td>Figure 1.1. Top nine tropical fresh fruit producing countries</td>
<td>3</td>
</tr>
<tr>
<td>Figure 1.2 Top nine papaya producing countries</td>
<td>4</td>
</tr>
<tr>
<td>1.2.2. Vasconcella</td>
<td>5</td>
</tr>
<tr>
<td>1.3. Taxonomy of papaya</td>
<td>5</td>
</tr>
<tr>
<td>1.4. Spread of papaya</td>
<td>7</td>
</tr>
<tr>
<td>1.5. Classification of papaya genotypes</td>
<td>7</td>
</tr>
<tr>
<td>1.6. Genetic markers in papaya</td>
<td>8</td>
</tr>
<tr>
<td>1.6.1. Morphological markers</td>
<td>9</td>
</tr>
<tr>
<td>1.6.2. Protein markers</td>
<td>9</td>
</tr>
<tr>
<td>1.6.3. DNA Markers</td>
<td>9</td>
</tr>
<tr>
<td>1.6.3.1. Restriction Fragment Length Polymorphism (RFLP)</td>
<td>10</td>
</tr>
<tr>
<td>1.6.3.2. Sequence-Tagged Sites (STS)</td>
<td>10</td>
</tr>
<tr>
<td>1.6.3.3. Allele-Specific Associated Primers (ASAPs)</td>
<td>10</td>
</tr>
<tr>
<td>1.6.3.4. Expressed Sequence Tags (EST)</td>
<td>10</td>
</tr>
<tr>
<td>1.6.3.5. Single Strand Conformation Polymorphism (SSCP)</td>
<td>11</td>
</tr>
<tr>
<td>1.6.3.6. Restriction Land Mark Genomic Scanning (RLGS)</td>
<td>11</td>
</tr>
<tr>
<td>1.6.3.7. Random Amplified Polymorphic DNA (RAPD) Markers</td>
<td>11</td>
</tr>
<tr>
<td>1.6.3.8. Amplified Fragment Length Polymorphism (AFLP)</td>
<td>12</td>
</tr>
<tr>
<td>1.6.3.9. Microsatellites and Minisatellites</td>
<td>12</td>
</tr>
<tr>
<td>1.6.4. Resistance Gene Analogs</td>
<td>15</td>
</tr>
<tr>
<td>Table 1.1. Details of the six major R-gene class</td>
<td>16</td>
</tr>
<tr>
<td>1.6.4.1. N gene from Tobacco</td>
<td>17</td>
</tr>
<tr>
<td>1.6.4.2. Pto gene from Tomato</td>
<td>17</td>
</tr>
<tr>
<td>1.6.4.3. Xa5 gene from Rice</td>
<td>17</td>
</tr>
<tr>
<td>1.6.4.4. Xa21 and Xa21(Al) gene from Rice</td>
<td>17</td>
</tr>
<tr>
<td>1.6.4.5. Xa26 gene from Rice</td>
<td>18</td>
</tr>
<tr>
<td>1.7. Objectives of the program</td>
<td>18</td>
</tr>
</tbody>
</table>
Chapter
MATERIALS AND METHODS
2.1. Plant materials
Table 2.1: Sources of the collected papaya genotypes
2.2. Location, Climate and Soil of the Experimental Farm
Table 2.2. Names and the sources of the collected papaya genotypes
2.3. Cultural practices for papaya cultivation at the experimental farm
2.4. DNA fingerprinting of the 41 papaya genotypes using SSR Markers
2.4.1. Isolation of papaya genomic DNA
Table 2.3. Details of the SSR markers used in this study
2.4.2. PCR amplification of DNA with the primers of SSR markers
2.4.3. PCR amplification of papaya genomic DNA with RGA primer pairs
2.4.4. Native polyacrylamide gel electrophoresis
Table 2.4. Details of the RGA primer pairs used
2.5. Genetic divergence analysis of the 41 papaya genotypes using the DNA profiles generated by the SSR markers and RGA primer pairs
2.6. Sequencing of polymorphic DNA bands for SSR RGA study
2.6.1. Elution of DNA bands from Gel
2.7. Analysis of DNA sequences
2.7.1. Blast search
2.7.2. Multiple sequence alignment using ClustalW

Chapter
RESULTS
Figure 3.1. Seedlings in the nursery
Figure 3.2. Variation in fruit shapes and size
Figure 3.3. Collection of fruits from different genotypes
Figure 3.4. Collection of fruits from different genotypes
Figure 3.5. Close up views of papaya fruits in the field
Figure 3.6. Close up views of papaya fruits in the field
Figure 3.7. Close up views of papaya fruits in the field
3.1. Analysis of papaya DNA profiles obtained by using 20 SSR markers
3.1.1. Alleles, size range and PIC values of the SSR Markers in the total collection of the 41 papaya genotypes
3.1.1.1. The rare alleles
Figures 3.8 Some representative SSR DNA profiles
Figures 3.9 Some representative SSR DNA profiles
Figures 3.10 Some representative SSR DNA profiles
3.1.1.2. The null alleles
Table 3.1. Details of the SSR alleles of the Total collection of the papaya genotypes
3.1.2. Details of the alleles from the SSR markers for papaya genotypes cultivated in India

Table 3.2. Details of the SSR alleles of the 27 papaya genotypes cultivated in India

3.1.3. Details of the alleles from the SSR markers for the highland papaya genotypes and outliers

Table 3.3. Details of the SSR alleles of the 7 highland papayas and 7 outliers

Table 3.4. Details of the SSR marker-derived rare alleles in the total collection of 41 papaya genotypes

Table 3.5. Details of the SSR marker-derived null alleles in the total collection of 41 papaya genotypes

3.2.1. Genetic relationship of the total collection of genotypes as revealed through SSR polymorphism

List of abbreviations for Figure 3.11

Figure 3.11. Dendrogram of the total collection of papaya genotypes based on SSR polymorphism

3.2.2. Genetic relationship of papaya genotypes popularly cultivated in India as revealed through SSR polymorphism

List of abbreviations for Figure 3.12

Figure 3.12. Dendrogram of the papaya genotypes popularly cultivated in India

3.2.3. Genetic relationship of highland papaya genotypes, outliers and related species as revealed through SSR polymorphism

Figure 3.13. Dendrogram of highland papaya genotypes, outliers and related species

List of abbreviations for Figure 3.13

3.3 Analysis of the DNA sequence data obtained from SSR marker polymorphism

3.3.1. Sequencing of polymorphic bands obtained using the SSR markers

3.3.2. Multiple sequence alignment of the sequenced bands using ClustalW

Table 3.6. Details of the polymorphic bands sequenced including the names of the genotypes and the GenBank accession number

Table 3.7. Details of the MSAs including the names of the genotypes and maximum and minimum length of the sequences

3.3.2.1 Details of the MSA 1 of the DNA sequences obtained using the SSR marker SP1

Table 3.8. Details of the MSA 1 of the DNA sequences obtained using the SSR marker SP1

Figure 3.14. Dendrogram of the six genotypes and the reference genotype SunUp involved in MSA1

3.3.2.2 Details of the MSA 2 of the DNA sequences obtained using the SSR marker SP2

Table 3.9. Details of the MSA 2 of the DNA sequences obtained using the SSR marker SP2

Figure 3.15. Dendrogram of the seven genotypes and the reference genotype SunUp involved in MSA 2

3.3.2.3 Details of the MSA 3 of the DNA sequences obtained using the SSR marker SP3

Table 3.10. Details of the MSA 3 of the DNA sequences obtained using the SSR marker SP3

Figure 3.16. Dendrogram of the eight papaya genotypes and the reference genotype SunUp

Table 3.11. Details of the MSA 4 of the DNA sequences obtained using the SSR marker SP6

Figure 3.17. Dendrogram of the ten genotypes and the reference genotype SunUp

III
3.3.2.5 Details of the MSA 5 of the DNA sequences obtained using the SSR marker SP7
Table 3.12. Details of the MSA 5 of the DNA sequences obtained using the SSR marker SP7
Figure 3.18. Dendrogram of the six papaya genotypes and the reference genotype

3.3.2.6 Details of the MSA 6 of the DNA sequences obtained using the SSR marker SP8
Table 3.13. Details of the MSA 6 of the DNA sequences obtained using the SSR marker SP8
Figure 3.19. Dendrogram of the eight genotypes and the reference genotype

3.3.2.7 Details of the MSA 7 of the DNA sequences obtained using the SSR marker SP9
Table 3.14. Details of the MSA 7 of the DNA sequences obtained using the SSR marker SP9
Figure 3.20. Dendrogram of the four papaya genotypes and the reference genotype

3.3.2.8 Details of the MSA 8 of the DNA sequences obtained using the SSR marker SP10
Table 3.15. Details of the MSA 8 of the DNA sequences obtained using the SSR marker SP10
Figure 3.21. Dendrogram of the five papaya genotypes and the reference genotype

3.3.2.9 Details of the MSA 9 of the DNA sequences obtained using the SSR marker SSPA1
Table 3.16. Details of the MSA 9 of the DNA sequences obtained using the SSR marker SSPA1
Figure 3.22. Dendrogram of the twelve genotypes and the reference genotype

3.3.2.10 Details of the MSA 10 of the DNA sequences obtained using the SSR marker SSPA2
Table 3.17. Details of the MSA 10 of the DNA sequences obtained using the SSR marker SSPA2
Figure 3.23. Dendrogram of the five papaya genotypes and the reference genotype

3.3.2.11 Details of the MSA 11 of the DNA sequences obtained using the SSR marker SSPA3
Table 3.18. Details of the MSA 11 of the DNA sequences obtained using the SSR marker SSPA3
Figure 3.24. Dendrogram of the five papaya genotypes and the reference genotype

3.3.2.12 Details of the MSA 12 of the DNA sequences obtained using the SSR marker SSPA4
Table 3.19. Details of the MSA 12 of the DNA sequences obtained using the SSR marker SSPA4
Figure 3.25. Dendrogram of the five papaya genotypes and the reference genotype

3.3.2.13 Details of the MSA 13 of the DNA sequences obtained using the SSR marker SSPA6
Table 3.20. Details of the MSA 13 of the DNA sequences obtained using the SSR marker SSPA6
Figure 3.26. Dendrogram of the five papaya genotypes and the reference genotype

3.3.2.14 Details of the MSA 14 of the DNA sequences obtained using the SSR marker SSPA7
Table 3.21. Details of the MSA 14 of the DNA sequences obtained using the SSR marker SSPA7

IV
Figure 3.27. Dendrogram of the twelve genotypes and the reference genotype SunUp involved in MSA 14

3.3.2.15. Details of the MSA 15 of the DNA sequences obtained using the SSR marker SSPA 10

Table 3.22. Details of the MSA15 of the DNA sequences obtained using the SSR marker SSPA10

Figure 3.28. Dendrogram of the seven genotypes and the reference genotype SunUp involved in MSA15

3.4. Analysis of papaya DNA profiles obtained using 16 RGA primer pairs

3.4.1. Alleles, size range and PIC values of the RGA primer pairs in the total collection of the 41 papaya genotypes

3.4.1.1. The rare alleles

3.4.1.1.2. The null alleles

Figures 3.29. Representatives of the RGA profiles

Figures 3.30. Representatives of the RGA profiles

Table 3.23. Details of the alleles from the 16 RGA primer pairs in the total collection of papaya genotypes

3.4.2. Details of the alleles from the 16 RGA primer pairs for the papaya genotypes cultivated in India

Table 3.24. Details of the RGA alleles in the 27 papaya genotypes cultivated in India

3.4.3. Details of the alleles from the 16 RGA primer pairs from the highland papaya genotypes and outliers

Table 3.25. Details of the alleles from the 16 RGA primer pairs in the highland papaya genotypes and outliers

3.4.4. Details of the LRR alleles from the total collection of papaya genotypes

Table 3.26. Details of the LRR alleles in the total collection of papaya genotypes

3.4.5. Details of the LRR alleles from the papaya genotypes cultivated in India

Table 3.27. Details of the LRR alleles from the 27 papaya genotypes cultivated in India

3.4.6. Details of the LRR alleles from the highland papaya genotypes and outliers

Table 3.28. Details of the LRR alleles from the 7 highland papaya genotypes and 7 outliers

3.4.7. Details of the Kinase alleles from the total collection of papaya genotypes

Table 3.29. Details of the Kinase alleles from the total collection of papaya genotypes

3.4.8. Details of the Kinase alleles from the papaya genotypes cultivated in India

Table 3.30. Details of the Kinase alleles of the 27 papaya genotypes cultivated in India

3.4.9. Details of the Kinase alleles from the highland papaya genotypes and the outliers

Table 3.31. Details of the Kinase alleles of the 7 highland papaya genotypes and the 7 outliers

Table 3.32. Distribution of the rare alleles in different groups of papaya genotypes at the LRR, the Kinase and other conserved protein motifs

Table 3.33. Distribution of null alleles in different groups of papaya genotypes at the LRR, the Kinase and other conserved protein motifs

3.5. Genetic diversity analysis of the 41 papaya genotypes using pair wise (in all possible genotype combinations) genetic distance/similarity values produced from the polymorphic DNA profiles using the RGA primer pairs
3.5.1. Genetic relationship of the total collection of papaya genotypes as revealed through RGA polymorphism

List of abbreviations for Figure 3.31

Figure 3.31. Dendrogram of the total collection of papaya genotypes as revealed through RGA polymorphism

3.5.2. Genetic relationship of the papaya genotypes cultivated in India as revealed through RGA polymorphism

List of abbreviations for Figure 3.32

Figure 3.32. Dendrogram of the papaya genotypes popularly cultivated in India as revealed through RGA polymorphism

3.5.3. Genetic relationship of the highland papaya genotypes, outliers and related species as revealed through RGA polymorphism

List of abbreviations for Figure 3.33

Figure 3.33. Dendrogram of the highland papaya genotypes, outliers and related species as revealed through RGA polymorphism

3.5.4. Genetic relationship of the total collection of genotypes as revealed through RGA polymorphism at the LRR motifs only

List of abbreviations for Figure 3.34

Figure 3.34. Dendrogram of the total collection of papaya genotypes at the LRR motifs only

3.5.5. Genetic relationship of the total collection of papaya resulting from RGA polymorphism at the Kinase motifs

List of abbreviations for Figure 3.35

Figure 3.35. Dendrogram of the total collection of papaya genotypes resulting from RGA polymorphism at the Kinase motifs

3.5.6. Genetic relationship of the Indian papaya genotypes resulting from RGA polymorphism at the LRR motifs only

List of abbreviations for Figure 3.36

Figure 3.36. Dendrogram of the papaya genotypes popularly cultivated in India resulting from RGA polymorphism at the LRR motifs only

3.5.7. Genetic relationship of the Indian papaya genotypes resulting from RGA polymorphism at the Kinase motifs

List of abbreviations for Figure 3.37

Figure 3.37. Dendrogram of the papaya genotypes popularly cultivated in India resulting from RGA polymorphism at the Kinase motifs

3.5.8. Genetic relationship of the highland papaya genotypes, outliers and related species resulting from RGA polymorphism at the LRR motifs

Figure 3.38. Dendrogram of the highland papaya genotypes, outliers and related species resulting from RGA polymorphism at the LRR motifs

List of abbreviations for Figure 3.38

3.5.9. Genetic relationship of the highland papaya genotypes, outliers and related species resulting from RGA polymorphism at the Kinase motifs

Figure 3.39. Dendrogram of the highland papaya genotypes, outliers and related species resulting from RCA polymorphism at the Kinase motifs

List of abbreviations for Figure 3.39

VI
3.6. Analysis of DNA sequence data obtained from RGA primer pairs using ClustalW
Table 3.35. Details of the MSAs including the names of the genotypes and maximum and minimum length of the sequences
3.6.1. Details of the MSA16 of the DNA sequences obtained using the RGA primer pair NLRR R1 and R2
Table 3.36. Details of the MSA16 of the DNA sequences obtained using the RGA primer pair NLRR R1 and R2
Figure 3.40. Dendrogram of the ten genotypes and the reference genotypes Nicotiana glutinosa and Populus trichocarpa involved in MSA16
3.6.2. Details of the MSA17 of the DNA sequences obtained using the RGA primer pair Pto Kin 1 and 2
Table 3.37. Details of the MSA17 of the DNA sequences obtained using the RGA primer pair Pto Kin 1 and 2
Figure 3.41. Dendrogram of the three papaya genotypes and the reference genotypes Lycopersicon pimpinellifolium involved in MSA17
3.6.3. Details of the MSA18 of the DNA sequences obtained using the RGA primer pair BDTG12
Table 3.38. Details of the MSA18 of the DNA sequences obtained using the RGA primer pair BDTG 12
Figure 3.42. Dendrogram of the ten papaya genotypes and the reference genotypes Oryza sativa.cv IIBB5 involved in MSA18

Chapter Page
DISCUSSION 118
4.1. Genetic diversity analysis of the papaya genotypes using the SSR profiles 118
Table 4.1. Comparison of number of alleles, rare alleles, null alleles and PIC values for the total collection, Indian genotypes and highland papayas and outliers 119
4.2 Sequence analysis of polymorphic bands obtained from the SSR markers 122
Table 4.2. Genotypes in each multiple sequence alignments 123
4.3. Genetic diversity analysis of the papaya genotypes as observed from RGA profiles 124
Table 4.3. Comparison of number of alleles, null alleles, rare alleles and PIC values obtained using the RGA primer pairs for the total collection, the Indian genotypes and the highland papayas and outliers 124
4.3.1. The genotypes containing rare alleles and null alleles for both SSR markers and RGA primer pairs 125
Table 4.4. Name of the genotypes showing rare alleles for both the SSR markers and RGA primer pairs 126
Table 4.5. Name of the genotypes showing null alleles for both the SSR markers 126
and RGA primer pairs

4.3.2. Analysis of the genetic diversity as observed from RGA profiles 127

4.4. Sequence analysis of polymorphic bands obtained from the PCR profiles 129

of the RGA primer pairs

4.4.1. Functions of the Resistance Gene analogs identified in papaya 129

Summary and conclusion 131