Inter Specific Gene Transfer in *Arachis hypogaea* L, in Relation to the Behaviour of Triploid, Pentaploid and Hexaploid Derivatives

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Bharathi *et al.* (1982) have analysed the cytological and embryological behaviour of triploid inter-specific hybrids between 9 cultivated varieties of *Arachis hypogaea* L. and *A. chacoense* Krap. et Greg. nom. nud. (PI 276235) a diploid wild species with recorded resistance to leaf spot, rust, thrips and aphids. Based on the occurrence of restitution of chromosomes on the female side, they concluded that production of triploid hybrids, selection for fertile types and isolation of desirable types provides a rapid method for alien incorporation in groundnut. Subsequently triploid hybrids were obtained from crosses of *A. hypogaea* with two more diploid species *A. correntina* (Burk) Krap. et Greg. nom. nud. (PI 331194) and *A. villosa* Benth and in the present study results of cytological analysis of these triploids, and their derivatives consisting of tetraploids, pentaploids and hexaploids have been presented.

Materials and methods

Five out of the 9 triploid hybrids from crosses of *A. hypogaea* × *A. chacoense* reported by Bharathi *et al.* (1982) set seed in small quantities. In addition, two more triploids *A. hypogaea* (TMV-2) × *A. correntina* and *A. hypogaea* (M13) × *A. villosa* were found to set seed.

The progeny resulting from such seed was observed to consist of 5 tetraploids, 1 pentaploid and 25 hexaploids. Four of the tetraploid plants (*A. hypogaea* (TMV-2) × *A. chacoense*, *A. hypogaea* (Florunner) × *A. chacoense*, *A. hypogaea* (TMV-2) × *A. correntina* and *A. hypogaea* (M13) × *A. villosa*) were fertile and set seed. The progenies from such seed consisted of 13 tetraploids in F3 generation. In F4 progeny of about 100 plants was raised. Thirty one plants from these progenies were analysed and were found to be all tetraploids.

The hexaploids obtained in the F2 gave a varying amount of seed set. A single plant out of each F3 progeny of the hexaploids was analysed. The 25 plants thus analysed were all hexaploids.

The various polyploids were grown under field conditions at Hyderabad. Standard iron acetocarmine squashes were used for cytological examination of PMCs. Chromosome associations and chiasma frequencies were analysed at MI. Pollen fertilities and meiotic abnormalities were also determined in the various taxa.
Results

1. Triploids

Chromosome associations in triploids ranged from univalents to quadrivalents. Meiosis in general was more regular in the dry season than in the wet season as seen from the frequency of chromosome associations, chiasmata and meiotic abnormalities (Table 1) although there was no seasonal effect on pollen fertilities.

Mean chromosome associations did not differ in the various triploids. But differences could be noted in the maximum, minimum and modal associations in the different triploids (Table 2), indicating that the genotypes of the cultivated varieties are structurally differentiated to varying extents. The maximum type of association observed was 2I and 14II in \( GDM \times A. \) villosa and the minimum was 12I and 9II in \( Florunner \times A. \) chacoense.

2. Tetraploids

Meiosis in the 5 \( F_2 \), 14 \( F_3 \) and 31 \( F_4 \) tetraploid plants can be called fairly regular and is similar to that of cultivated groundnut (Jahnavi et al. 1981) although there occurred some univalents, trivalents and quadrivalents in addition to the predominant formation of bivalents. Minor variation occurred among PMCs of the same plant, among the different plants of a particular cross and among the plants from different crosses of the same generation (Tables 3, 4, and 5). Therefore the data from the various crosses was pooled and the different generations were compared in respect to chromosome configurations, chiasmata, and meiotic abnormalities (Table 6).

A consistent trend was exhibited by the cytological parameters among the different generations. The frequency of univalents and trivalents decreased from \( F_2 \) to \( F_4 \) generation. The frequency of bivalents and chiasmata increased from \( F_2 \) to \( F_4 \) generation. Trivalent frequencies, as well as meiotic abnormalities exhibited a little instability but in the \( F_4 \) generation, their frequencies were on par with those of cultivated varieties.

A comparison was also made of the minimum, maximum and modal chromosome associations in the various crosses and generations (Tables 7, 8 and 9). There were some differences between the crosses and between the three different generations of a particular cross in respect of the minimum, maximum and the modal chromosome association. The maximum possible association was 18II+11IV. In the \( F_2 \) generation, a tetraploid plant of \( TMV-2 \times A. \) correntina and \( M-13 \times A. \) villosa had 20 bivalents as not only maximum but also as the modal chromosomes association. The tetraploids got stabilized \( F_2 \) through \( F_3 \) and in \( F_4 \) all the crosses had 18 bivalents and 1 quadrivalent as the modal as well as the maximum association. This type of association is identical to that of cultivated groundnut.

3. Pentaploid

A single pentaploid plant was observed in the progeny of the triploid hybrid \( GDM \times A. \) chacoense. The pentaploid was analysed cytologically. All possible chromosome associations ranging from univalents to those involving 5 chromosomes were observed. It exhibited on an average, 2.9I; 19.1II; 1.2III; 1.3IV and 0.1V.
Table 1. Frequency of chromosome associations and chiasmata in triploids in two seasons (dry (D) and wet (W))

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Pedigree</th>
<th>Number of cells analysed</th>
<th>Mean number/cell of respective chromosome associations</th>
<th>Mean number/cell of chiasmata</th>
<th>Pollen fertility (%)</th>
<th>Total number of meiotic abnormalities (mean number of laggards at AI and TI and disjunction bridges at AI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>W  D  W  D  W  D  W  D  W  D</td>
<td>W  D</td>
<td>W  D</td>
<td>W  D</td>
</tr>
<tr>
<td>1</td>
<td>TMV-2 × A. chacoense</td>
<td>35</td>
<td>4.4 8.7 10.4 8.2 1.2 1.5 0.3 0.1</td>
<td>18.0 17.5</td>
<td>53 55.5</td>
<td>15.7 18.9</td>
</tr>
<tr>
<td>2</td>
<td>M-13 × A. chacoense</td>
<td>40</td>
<td>6.3 8.0 9.5 8.7 1.3 1.4 0.2 0.1</td>
<td>17.9 17.6</td>
<td>54 49.7</td>
<td>16.7 19.0</td>
</tr>
<tr>
<td>3</td>
<td>Chico × A. chacoense</td>
<td>35</td>
<td>6.0 8.2 10.1 8.3 1.2 1.6 0.1 0.1</td>
<td>19.7 17.5</td>
<td>55 54</td>
<td>15.0 14.2</td>
</tr>
<tr>
<td>4</td>
<td>Florunner × A. chacoense</td>
<td>40</td>
<td>6.3 7.1 9.3 8.4 1.6 1.9 0.9 0.1</td>
<td>17.5 17.1</td>
<td>53 55.3</td>
<td>16.7 18.9</td>
</tr>
<tr>
<td>5</td>
<td>GDM × A. villosa</td>
<td>35</td>
<td>2.9 7.7 11.4 8.7 1.3 1.5 0.1 0.1</td>
<td>18.0 17.2</td>
<td>54 53.2</td>
<td>18.0 19.0</td>
</tr>
<tr>
<td>6</td>
<td>M-13 × A. villosa</td>
<td>35</td>
<td>5.8 7.1 9.9 9.3 1.2 1.3 0.2 0.1</td>
<td>17.5 16.2</td>
<td>54 52.2</td>
<td>15 13</td>
</tr>
<tr>
<td>7</td>
<td>TMV-2 × A. correntina</td>
<td>40</td>
<td>6.5 4.9 9.4 10.1 1.3 1.5 0.2 0.1</td>
<td>17.3 17.5</td>
<td>53 54.1</td>
<td>17 22</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td>5.4 7.4 9.9 8.8 1.3 1.5 0.17 0.1</td>
<td>17.7 17.2</td>
<td>53.7 54.8</td>
<td>16.3 17.8</td>
</tr>
</tbody>
</table>
Table 2. Minimum, maximum and modal chromosome associations, and meiotic behaviour of triploids

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Pedigree</th>
<th>Nature of chromosome</th>
<th>Minimum</th>
<th>Maximum</th>
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<td></td>
<td></td>
<td></td>
<td>W</td>
<td>D</td>
</tr>
<tr>
<td>1</td>
<td>TMV-2×A. chacoense</td>
<td></td>
<td>10I;</td>
<td>10I;</td>
</tr>
<tr>
<td>2</td>
<td>M-11×A. chacoense</td>
<td></td>
<td>8I; 11I</td>
<td>10I; 10I</td>
</tr>
<tr>
<td>3</td>
<td>Chico×A. chacoense</td>
<td></td>
<td>8I; 11I</td>
<td>10I; 10I</td>
</tr>
<tr>
<td>4</td>
<td>Florunner×A. chacoense</td>
<td></td>
<td>12I; 9I</td>
<td>10I; 10I</td>
</tr>
<tr>
<td>5</td>
<td>GDM×A. villosa</td>
<td></td>
<td>6I; 12I</td>
<td>8I; 11I</td>
</tr>
<tr>
<td>6</td>
<td>M-13×A. villosa</td>
<td></td>
<td>6I; 11I</td>
<td>8I; 11I</td>
</tr>
<tr>
<td>7</td>
<td>TMV-2×A. correntina</td>
<td></td>
<td>10I;</td>
<td>10I;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>8.8I</td>
<td>10.51I</td>
<td>9.4I</td>
<td>10.2II</td>
</tr>
</tbody>
</table>

Table 3. Frequency of chromosome associations and chiasmata in tetraploids (F2 generation)

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Pedigree</th>
<th>Number of cells analysed</th>
<th>Mean number/cell of respective chromosome associations</th>
<th>Mean number/cell of chiasmata</th>
<th>Pollen fertility (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>I</td>
<td>Rod II</td>
<td>Ring II</td>
</tr>
<tr>
<td>1</td>
<td>TMV-2×A. chacoense</td>
<td>35</td>
<td>3.5</td>
<td>4.5</td>
<td>10.4</td>
</tr>
<tr>
<td>2</td>
<td>TMV-2×A. chacoense</td>
<td>40</td>
<td>1.4</td>
<td>4.5</td>
<td>11.0</td>
</tr>
<tr>
<td>3</td>
<td>Florunner×A. chacoense</td>
<td></td>
<td>40</td>
<td>1.1</td>
<td>4.0</td>
</tr>
<tr>
<td>4</td>
<td>TMV-2×A. correntina</td>
<td>40</td>
<td>0.8</td>
<td>8.9</td>
<td>8.4</td>
</tr>
<tr>
<td>5</td>
<td>M-13×A. villosa</td>
<td>40</td>
<td>0.4</td>
<td>3.0</td>
<td>14.5</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td>1.4</td>
<td>5.1</td>
<td>11.4</td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td></td>
<td>1.1</td>
<td>1.5</td>
<td>2.1</td>
</tr>
</tbody>
</table>

The mean number of chiasmata was 1.44. The pentaploid had highly irregular meiosis. However, considerable number of pollen fertility (55.3 %) was exhibited. The pentaploid did not set any seed.

4. Hexaploids

The maximum associations in hexaploids involved six chromosomes. However, hexavalent frequency was very low compared to the frequency of bivalents and quadrivalents. No marked differences could be observed in the frequency of different chromosome associations, chiasmata, pollen fertilities and meiotic abnormalities in the different hexaploids. The data were therefore pooled generation wise and compared (Table 10). Such a comparison has revealed that although some minor changes could be noticed, the hexaploid generation was neither stable nor was there any spectacular instability. This conclusion is in agreement with a broad general morphological observation that the hexaploids in F3 generation contained
several unhealthy looking or stunted or non-flowering plants and at the same time, some of the plants were as good as their parents. An examination of the minimum, maximum and modal chromosome associations (Tables 11 and 12) also did not suggest that the hexaploids had any consistent pairing behaviour indicative of amphidiploidy, or autohexaploidy, but that pairing is more or less random.

### Table 2. Abnormalities of triploids in two seasons (wet (W) and dry (D))

<table>
<thead>
<tr>
<th>Maximum</th>
<th>Modal</th>
</tr>
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<tbody>
<tr>
<td>D</td>
<td>W</td>
</tr>
<tr>
<td>3I; 12I; 1III</td>
<td>10I; 10II</td>
</tr>
<tr>
<td>4I; 11III; IV</td>
<td>5I; 11III; 1III</td>
</tr>
<tr>
<td>6I; 12II</td>
<td>10I; 10II</td>
</tr>
<tr>
<td>3I; 12II; 1III</td>
<td>4I; 13II</td>
</tr>
<tr>
<td>3I; 12II; 1III</td>
<td>10I; 10II</td>
</tr>
<tr>
<td>2I; 11III; 2III</td>
<td>2I; 11III; 2III</td>
</tr>
<tr>
<td>2I; 14III;</td>
<td>10I; 10II</td>
</tr>
</tbody>
</table>

3.2I 12.0II 0.7III 0.14Iv 7.2I 10.7II 0.4III 7.2I 11.1III 0.14III

### Table 4. Frequency of chromosome associations and chiasmata in tetraploids (F₃ generations)

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Pedigree</th>
<th>No. of cells analysed</th>
<th>Mean number/cell of respective chromosome associations</th>
<th>Mean number/cell of chiasmata</th>
<th>Pollen fertility (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TMV-2 ×</td>
<td>40</td>
<td>0.1 7.2 10.6 17.8 0.1 1.0</td>
<td>23.7 62.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A. chacoense</td>
<td></td>
<td>I Rod II Ring II Total number of II III IV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>40</td>
<td>1.3 6.7 10.7 17.4 0.1 0.9</td>
<td>32.0 63.1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>35</td>
<td>1.1 6.1 10.5 16.6 0.3 1.2</td>
<td>32.8 60.2</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>40</td>
<td>0.3 6.6 10.7 17.3 0.5 0.9</td>
<td>33.1 64.0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>35</td>
<td>0.1 7.2 11.3 18.5 0.3 0.5</td>
<td>32.7 62.1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Florunner × A. chacoense</td>
<td>40</td>
<td>0.2 4.6 13.0 17.6 0.2 1.0</td>
<td>35.2 63.0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
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<td>0.3 5.1 12.1 17.2 0.3 1.1</td>
<td>34.6 59.0</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>TMV-2 ×</td>
<td>40</td>
<td>0.2 6.5 10.7 17.2 0.2 1.2</td>
<td>33.3 56.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A. correntina</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>9</td>
<td></td>
<td>35</td>
<td>0.3 5.8 11.6 17.4 0.3 1.0</td>
<td>33.9 61.1</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>M-13 × A. villosa</td>
<td>40</td>
<td>1.6 3.3 12.6 15.9 0.6 1.2</td>
<td>35.1 65.0</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>40</td>
<td>0.7 4.4 12.4 16.8 0.7 0.9</td>
<td>34.0 70.0</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>40</td>
<td>0.5 5.0 11.7 16.7 0.3 1.3</td>
<td>33.5 75.0</td>
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<tr>
<td>13</td>
<td></td>
<td>40</td>
<td>0.9 4.0 12.7 16.7 0.3 1.2</td>
<td>35.1 79.0</td>
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</tr>
<tr>
<td>14</td>
<td></td>
<td>40</td>
<td>0.5 6.5 10.5 17.0 0.5 1.0</td>
<td>31.1 70.0</td>
<td></td>
</tr>
</tbody>
</table>

Mean: 0.5 5.6 11.5 17.1 0.3 1.02 33.5 64.9

SD: 0.4 1.2 0.9 0.6 0.1 0.2 1.6 6.1
Table 5. Frequency of chromosome associations and chiasmata in tetraploids (F_4 generation)

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Pedigree</th>
<th>No. of cells analysed</th>
<th>I</th>
<th>Rod II</th>
<th>Ring II</th>
<th>Total number of II</th>
<th>III</th>
<th>IV</th>
<th>Maen number/cell of chromosomes association</th>
<th>Pollen fertility (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TMV-2 × A. chacoense</td>
<td>35</td>
<td>0.3</td>
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<td>12.0</td>
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<td>1.0</td>
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<td>60.5</td>
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<tr>
<td>2</td>
<td>&quot; &quot;</td>
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<td>0.5</td>
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<td>12.0</td>
<td>18.0</td>
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<td>0.8</td>
<td>34.0</td>
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<td>0.2</td>
<td>0.5</td>
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<td>0.6</td>
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<td>70.2</td>
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<td>6.0</td>
<td>12.0</td>
<td>18.0</td>
<td>0.1</td>
<td>0.8</td>
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<td>34.0</td>
<td>66.0</td>
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<td>0.2</td>
<td>1.0</td>
<td>34.0</td>
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<td>5.2</td>
<td>12.5</td>
<td>17.7</td>
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<td>0.8</td>
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<td>0.7</td>
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<td>65.0</td>
</tr>
<tr>
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<td>4.8</td>
<td>12.5</td>
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<td>4.0</td>
<td>13.1</td>
<td>17.1</td>
<td>0.4</td>
<td>1.1</td>
<td>34.8</td>
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<tr>
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<tr>
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<td>6.0</td>
<td>11.2</td>
<td>17.2</td>
<td>0.3</td>
<td>0.9</td>
<td>35.0</td>
<td>64.5</td>
</tr>
<tr>
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<td>67.5</td>
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<tr>
<td>19</td>
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<td>13.0</td>
<td>17.0</td>
<td>0.6</td>
<td>1.0</td>
<td>34.0</td>
<td>67.5</td>
</tr>
<tr>
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<td>1.0</td>
<td>34.0</td>
<td>67.5</td>
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<tr>
<td>22</td>
<td>&quot; &quot;</td>
<td>35</td>
<td>0.6</td>
<td>5.0</td>
<td>12.1</td>
<td>17.1</td>
<td>0.4</td>
<td>1.0</td>
<td>34.0</td>
<td>65.3</td>
</tr>
<tr>
<td>23</td>
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<td>40</td>
<td>0.9</td>
<td>5.0</td>
<td>11.6</td>
<td>16.6</td>
<td>0.5</td>
<td>1.1</td>
<td>34.0</td>
<td>64.5</td>
</tr>
<tr>
<td>24</td>
<td>M-13 × A. villosa</td>
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<td>0.1</td>
<td>5.3</td>
<td>12.1</td>
<td>17.4</td>
<td>0.1</td>
<td>1.2</td>
<td>33.7</td>
<td>70.0</td>
</tr>
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<td>72.1</td>
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<tr>
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<td>0.2</td>
<td>1.0</td>
<td>35.0</td>
<td>70.1</td>
</tr>
<tr>
<td>27</td>
<td>&quot; &quot;</td>
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<td>5.0</td>
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<td>18.4</td>
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<td>0.5</td>
<td>34.5</td>
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<tr>
<td>28</td>
<td>&quot; &quot;</td>
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<td>13.3</td>
<td>18.3</td>
<td>0.2</td>
<td>0.6</td>
<td>36.0</td>
<td>68.3</td>
</tr>
<tr>
<td>29</td>
<td>&quot; &quot;</td>
<td>40</td>
<td>0.4</td>
<td>4.6</td>
<td>13.0</td>
<td>17.6</td>
<td>0.4</td>
<td>0.8</td>
<td>33.0</td>
<td>69.7</td>
</tr>
<tr>
<td>30</td>
<td>&quot; &quot;</td>
<td>40</td>
<td>0.1</td>
<td>5.8</td>
<td>12.2</td>
<td>18.0</td>
<td>0.1</td>
<td>0.9</td>
<td>45.0</td>
<td>70.2</td>
</tr>
<tr>
<td>31</td>
<td>&quot; &quot;</td>
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<td>0.2</td>
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<td>14.6</td>
<td>17.8</td>
<td>0.2</td>
<td>0.9</td>
<td>35.0</td>
<td>65.8</td>
</tr>
</tbody>
</table>

Maen 0.5 5.0 12.0 17.0 0.3 1.1 34.2 66.3
SD 0.3 0.8 0.6 3.2 0.7 0.4 2.4 4.4

Discussion

Table 6. Frequency of chromosome associations, and chiasmata in tetraploids (F₂, F₃ and F₄ generations)

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Pedigree</th>
<th>Mean number/cell of respective chromosome associations</th>
<th>Mean number/cell of chiasmata</th>
<th>Mean number/cell of meiotic abnormalities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>F₂  F₃  F₄  F₂  F₃  F₄  F₂  F₃  F₄  F₂  F₃  F₄  F₂  F₃  F₄  F₂  F₃  F₄  F₂  F₃  F₄  F₂  F₃  F₄  F₂  F₃  F₄</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>TMV-2 × A. chacoense</td>
<td>3.5  0.6  0.5  15.8  17.0  17.6  0.3  0.2  0.1  1.0  0.8  0.7  31.1  33.2  34.2  12.5  15.1  8.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>TMV-2 × A. correntina</td>
<td>1.1  4.8  0.5  17.0  17.5  17.2  0.3  0.2  0.2  0.8  1.05  0.9  33.5  34.5  34.2  5.4  7.0  5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Florunex × × A. chacoense</td>
<td>0.8  0.2  0.6  17.3  17.2  17.2  0.2  0.4  1.0  1.0  1.1  1.1  34.0  34.0  34.2  1.5  7.3  5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>M-I3 × A. villosa</td>
<td>0.3  0.9  0.3  17.5  16.6  17.7  0.2  0.4  0.2  1.0  1.1  0.8  35.0  33.5  35.2  18.1  12.2  6.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>1.4  1.6  0.4  16.9  17.0  17.4  0.25  0.3  0.37  0.9  1.0  0.8  33.4  33.8  34.4  9.3  10.3  6.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 7. Minimum, maximum and modal chromosome associations in tetraploids F₂ generation

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Pedigree</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Modal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>TMV-2 × A. chacoense</em></td>
<td>5I; 16II; 1III</td>
<td>18II; 1IV; 2I; 17II; 1IV</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td><em>TMV-2 × A. chacoense</em></td>
<td>4I; 16II; 1IV</td>
<td>18II; 1IV; 1IV</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td><em>TMV-2 × A. correntina</em></td>
<td>3I; 17II; 1III</td>
<td>20II</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td><em>Florunner × A. chacoense</em></td>
<td>4I; 14II; 2IV</td>
<td>18II; 1IV</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td><em>M-13 × A. villosa</em></td>
<td>4I; 16II; 1IV</td>
<td>20II</td>
<td></td>
</tr>
</tbody>
</table>

Mean: 4.0I 15.8II 0.4III 0.8IV 18.8II 0.6IV 0.4I 18.6II 0.6IV

Table 8. Minimum, maximum and modal chromosome associations in tetraploids F₃ generation

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Pedigree</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Modal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>TMV-2 × A. chacoense</em></td>
<td>5I; 16II; 1III</td>
<td>18II; 1IV</td>
<td>18II; 1IV</td>
</tr>
<tr>
<td>2</td>
<td><em>TMV-2 × A. correntina</em></td>
<td>3I; 17II; 1III</td>
<td>18II; 1IV</td>
<td>18II; 1IV</td>
</tr>
<tr>
<td>3</td>
<td><em>Florunner × A. chacoense</em></td>
<td>4I; 15II; 2III</td>
<td>18II; 1IV; 2I; 17II; 1IV</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td><em>M-13 × A. villosa</em></td>
<td>2I; 17II; 1IV</td>
<td>18II; 1IV</td>
<td></td>
</tr>
</tbody>
</table>

Mean: 3.5I 16.2II 1III 0.25IV 18II 1IV 0.5I 17.5II 0.2IV

Table 9. Minimum, maximum and modal chromosome associations in tetraploids F₄ generation

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Pedigree</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Modal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>TMV-2 × A. chacoense</em></td>
<td>5I; 16II; 1III</td>
<td>18II; 1IV</td>
<td>18II; 1IV</td>
</tr>
<tr>
<td>2</td>
<td><em>TMV-2 × A. correntina</em></td>
<td>4I; 16II; 1IV</td>
<td>18II; 1IV</td>
<td>18II; 1IV</td>
</tr>
<tr>
<td>3</td>
<td><em>Florunner × A. chacoense</em></td>
<td>3I; 17II; 1III</td>
<td>18II; 1IV</td>
<td>18II; 1IV</td>
</tr>
<tr>
<td>4</td>
<td><em>M-13 × A. villosa</em></td>
<td>4I; 18II</td>
<td>18II; 1IV</td>
<td></td>
</tr>
</tbody>
</table>

Mean: 4I 16.7II 0.5III 0.25IV 18II 1IV 18II 1IV
**Table 10.** Mean frequency of chromosome associations, chiasmata and meiotic abnormalities in hexaploids (F₂ and F₃ generations)

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Pedigree</th>
<th>Mean number/cell of respective chromosome associations</th>
<th>Mean number/cell of chiasmata</th>
<th>Total number of meiotic abnormalities (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>F₂ F₃ F₂ F₃ F₂ F₃ F₂ F₃ F₂ F₃ F₂ F₃ F₂ F₃</td>
<td>F₂ F₃</td>
<td>F₂ F₃</td>
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<tr>
<td>1</td>
<td>TMV-2 × A. chacoense</td>
<td>2.9 1.9 20.0 21.7 2.3 2.7 3.3 1.4 0.07 0.8 0.07 0.05</td>
<td>40.02 41.9</td>
<td>14.0 7.6</td>
</tr>
<tr>
<td>2</td>
<td>Florunner × A. chacoense</td>
<td>3.3 2.5 20.6 21.9 1.3 2.6 1.7 1.6 0.7 0.08 0.1 0.01</td>
<td>42.0 43.1</td>
<td>7.8 5.2</td>
</tr>
<tr>
<td>3</td>
<td>Acholiwhite × A. chacoense</td>
<td>4.1 3.0 19.0 17.9 2.1 2.9 2.1 2.0 0.04 1.16 0.3 0.01</td>
<td>42.5 41.3</td>
<td>1.2 5.8</td>
</tr>
<tr>
<td>4</td>
<td>GDM × A. chacoense</td>
<td>3.4 2.4 20.7 22.8 1.8 3.2 1.1 1.5 0.5 0.6 0.3 0.3</td>
<td>44.1 44.5</td>
<td>9.16 7.2</td>
</tr>
<tr>
<td>5</td>
<td>GDM × A. villosa</td>
<td>3.8 3.0 18.9 23.5 1.5 3.2 1.5 1.4 0.4 0.6 0.7 0.3</td>
<td>42.0 42.1</td>
<td>9.2 6.3</td>
</tr>
</tbody>
</table>

**Table 11.** Minimum, maximum, modal and mean chromosome associations in hexaploids (F₂ generation)

<table>
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<th>Nature of chromosome association</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>1</td>
<td>TMV-2 × A. chacoense</td>
<td>8I; 16I; 4I; 2IV</td>
</tr>
<tr>
<td>2</td>
<td>Florunner × A. chacoense</td>
<td>5I; 19I; 3I; 2IV</td>
</tr>
<tr>
<td>3</td>
<td>Acholiwhite × A. chacoense</td>
<td>5I; 18I; 1I; 4IV</td>
</tr>
<tr>
<td>4</td>
<td>GDM × A. chacoense</td>
<td>27I; 2I</td>
</tr>
<tr>
<td>5</td>
<td>GDM × A. villosa</td>
<td>9I; 20I; 1I; 2IV</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>6.75I</td>
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</table>
Table 12. Minimum, maximum, modal and chromosome association in hexaploids (F1 generation)

<table>
<thead>
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<th>Nature of chromosome association</th>
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<td></td>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>1</td>
<td>TMV-2 × A. chacoense</td>
<td>4I; 21II; 2III; 2IV</td>
</tr>
<tr>
<td>2</td>
<td>Florunner × A. chacoense</td>
<td>8I; 23II; 2III</td>
</tr>
<tr>
<td>3</td>
<td>Achoiwhite × A. chacoense</td>
<td>7I; 17II; 5III; 11V</td>
</tr>
<tr>
<td>4</td>
<td>GDM × A. chacoense</td>
<td>4I; 20II; 1III; 2IV 1V</td>
</tr>
<tr>
<td>5</td>
<td>GDM × A. villosa</td>
<td>5I; 22II; 1III; 2IV</td>
</tr>
</tbody>
</table>

Mean: 5.3I; 20.6II 2.6III 1.4IV 0.2V 2.6I 21.8II 1.6III 2.0IV 0.4V 3.4I 24.6II 0.6III 1.1IV
Peters et al. (1982). Not all these studies have concentrated on chromosome behaviour. Only a few investigators have studied meiosis in a general way. Most studies were confined to estimation of pollen fertility. Triploid hybrids produced in the section Arachis (Spielman et al. 1979), exhibited varying degrees of male sterility and practically most of them were seed sterile. A remarkable triploid hybrid having up to 92% pollen fertility was reported recently by Simpson and Davis (1983). This is a triploid of (A. cardenasii × A. chacoense) × A. hypogaea. Most of these studies indicate that section Arachis species, are closely related except A. batizocoi which produced mostly sterile hybrids not only with diploid Arachis species but also with Arachis hypogaea.

The cultivated varieties of groundnut Arachis hypogaea could be crossed so far with the published species: A. villosa var. correntina, A. villosa and A. monticola and a number of unpublished species like A. batizocoi, A. duranensis, A. correntina, A. stenosperma and A. helodes. All these ten or more species have been grouped under section Arachis by Krapovickas (1968) and Gregory et al. (1973). Except for the reports of Gopinathan Nair et al. (1964), Varisai Muhammad (1973) and Raman (1958, 1959, 1976) there are no instances of successful hybridization of groundnut with species of the other sections. The results of the present study confirm that the section Arachis represents a natural group.

The variation in chromosome pairing in the different triploids suggested variation in the genome of the 1. wild species, 2. cultivated varieties and 3. a seasonal effect. The occurrence of trivalents up to a maximum of 2 per PMC indicates that at least two chromosomes are common between the A and B genomes. To conceive a basic number of 5 in the genus Arachis to explain these trivalents and also quadrivalents as suggested by Raman (1981) cannot be supported, because of the fact that the 10 individual chromosomes of any diploid section Arachis species are unique in their morphology at pachytene (Murty et al. 1982, Bharathi et al. 1983, Kirti et al. 1983). The occurrence of occasional association of 4 and the usually more than 10 bivalents suggests extensive structural repatterning of the genomes of the cultivated groundnut.

Meiotic behaviour of the hexaploids which flowered in a reasonable period of time has not provided any evidence for the occurrence of chromosome elimination, as observed by Spielmen et al. (1979) and Stalker et al. (1979). The non-occurrence of aneuploids in the cytologically analysed hexaploids indicates that perhaps such plants generally do not flower or even if they flower may do so very late. Fertile hexaploids did not exhibit any trend towards stabilization or breakdown. The fertile hexaploids of the F_{5} generation therefore in all probability represent randomly derived plants having fairly balanced genomes derived from the random combination of fairly balanced gametes.

Most of the cytogenetic research in groundnut and Arachis wild species at present is aimed at incorporation of disease, pest and drought resistance from the wild species, into the cultivated varieties. The germplasm of groundnut consists of several thousand accessions of A. hypogaea, but immunity to some of the common pests and diseases is found only in the wild species. The term alien incorporation has been used throughout the following discussion for the process of transfer of
desirable characters from wild species to the cultivated varieties.

Cytogenetic studies have been started in groundnut with this objective since the time of Husted (1931, 1936). The reports have got accumulated gradually (D'Cruz and Tankasale 1961, Gregory et al. 1978, Krapovickas and Rigoni 1957, Raman 1957, Smartt et al. 1978a, b, Moss 1980, Murty et al. 1982, Stalker 1980, Sastry et al. 1982). The studies were concentrated mostly with diploid members of section Arachis, and in the tetraploid member, A. monticola, A. hypogaea could not be hybridized with any of the other sectional species, the only exceptions being those of Raman and his associates.

Murty et al. (1981) have suggested that the genetic resources of groundnut consist of the primary, secondary and tertiary gene pools. The primary gene pool consists of the virginia, valencia, and spanish botanical types and A. monticola. The secondary gene pool consists of section Arachis species and the tertiary gene pool consists of wild species, which are cross incompatible with A. hypogaea. To date, maximum efforts have been made towards the utilization of secondary gene pool.

Various possible methods have been suggested and utilized for this purpose. The methods briefly consist of two steps.
1. Obtaining successful inter-specific hybrids, and restoring fertility.
2. Transferring desirable features at the tetraploid level and isolating tetraploid segregates with desirable features.

Murty et al. (1981) suggested isolation of tetraploids by producing triploids with different groundnut varieties and making selection for fertile types. In the present study seven triploids namely those of TMV-2 × A. chacoense, M-13 × A. villosa, Florunner × A. chacoense, TMV-2 × A. correntina have set seed. This indicated that the effect of varying groundnut genotype is an efficient way of obtaining triploids that set at least a few seeds. An examination of chromosome pairing at meiotic metaphase in the fertile and sterile triploids has not revealed any major differences either in respect of the chromosome associations or chiasmata. It can therefore be concluded that the reasons for fertility are predominantly genetic. The method of selection of fertile triploids is more or less similar to the method followed in the alien incorporation of wheat and barley (Sears 1976). The occurrence of tetraploids, pentaploids and hexaploids in the progenies of triploids has indicated the functioning of haploid, diploid and triploid gametes. It was also clear that a fertile triploid is capable of producing tetraploids and hexaploids. Except in the case of M13 × A. villosa, the progeny plants of the other triploids had both tetraploids and hexaploids.

Utilising this method, as many as 5 tetraploids in the F2 and 14 tetraploids in the F3 and nearly 100 tetraploids in F4 were obtained in the present study. All these tetraploids were fertile; stable and agronomically desirable and had a plant type similar to that of groundnut. The productions and properties of such tetraploids in the present study point out to the efficiency and practability of the technique used. That these tetraploids have some wild species characters incorporated in them was deduced using morphological, cytological and genetical studies by Murty et al. (1984). They have successfully produced derivatives from interspecific crosses,
having immunity to rust and at the same time a plant type analogous to cultivated varieties especially in reproductive features. This indicates that the methods followed in the present study for alien incorporation are quite efficient and practicable (Murty et al. 1984).

References


Simpson, C. E. and Davis, 1983.  Meiotic behavior of a male fertile triploid Arachis L.  Hybrid, Crop Sci. 23: 581-