Maintenance of Interchange Heterozygotes in Annual Chrysanthemum

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Annual chrysanthemum is constituted of two distinct cross pollinated species viz, Chrysanthemum carinatum and C. coronarium. They differ from each other in some morphological characters (Bailey 1949). Their reproductive isolation is achieved through chromosomal differentiation. Maintenance of interchange heterozygosity and its preponderance due to better reproductive fitness in the natural populations of C. carinatum have been reported (Rana and Jain 1965, Rana 1965). The present paper is a report of cytological analysis of natural populations of C. coronarium and C. carinatum.

Materials and methods

Five different populations of C. coronarium—one from Chandra Nursery (Sikim) and rest four from Haringhata (West Bengal) and two different populations of C. carinatum—one from Sikim and other from Santiniketan (West Bengal) were studied. Flower buds were fixed overnight in Carnoy’s fixative (6 ethyl alcohol: 3 chloroform: 1 glacial acetic acid, with trace of ferric chloride) and anthers of suitable size were squashed in propinocarmine using ferric chloride as mordant. Multivalent associations in pollen mother cells were recorded from diakinesis and metaphase I.

Observation

In both the species meiotic analysis revealed the presence of structurally homozygous plants with nine bivalents and heterozygous plants with varying sizes and number of interchange multiples. Number of plants per class of chromosome multiples and association in individual species are shown in Table 1 and 2.

Chrysanthemum coronarium: Out of 185 plants analysed in this species only 20 were structurally homozygous with 9II (Fig. 1). The rest were structurally heterozygous of which 95 plants had 1IV+7II (Fig. 2), 51 had 1VI+6II (Fig. 3), 9 had 2IV+5II (Fig. 4), 4 had 1VIII+5II (Fig. 5), 5 had 1VI+1IV+4II (Fig. 6), and 1 had 1x+1IV+2II (Fig. 7).

Chrysanthemum carinatum: One sample from Sikim and another from
Table 1. Distribution of interchange heterozygosity in *Chrysanthemum coronarium*

<table>
<thead>
<tr>
<th>Population source</th>
<th>Number of plants analysed</th>
<th>Homozygotes</th>
<th>Heterozygotes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I_{IV}+7II</td>
<td>1_{VI}+6II</td>
</tr>
<tr>
<td>Haringhata</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>32</td>
<td>7</td>
<td>20</td>
</tr>
<tr>
<td>B</td>
<td>18</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>C</td>
<td>63</td>
<td>7</td>
<td>35</td>
</tr>
<tr>
<td>D</td>
<td>28</td>
<td>—</td>
<td>11</td>
</tr>
<tr>
<td>Chandran Nursery</td>
<td>44</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>185</td>
<td>20</td>
<td>95</td>
</tr>
</tbody>
</table>

Table 2. Distribution of interchange heterozygosity in *Chrysanthemum carinatum*

<table>
<thead>
<tr>
<th>Population source</th>
<th>Number of plants analysed</th>
<th>Homozygotes</th>
<th>Heterozygotes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I_{IV}+7II</td>
<td>1_{VI}+6II</td>
</tr>
<tr>
<td>Sikim</td>
<td>25</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Santiniketan</td>
<td>43</td>
<td>17</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>68</td>
<td>25</td>
<td>19</td>
</tr>
</tbody>
</table>
Santiniketan were examined for structural heterozygosity in this species. Twenty five plants from Sikim sample were studied, of these 8 plants were homozygotes with 9\(\Pi\) (Fig. 8). The rest were structurally heterozygotes, out of which 9, 4, and 4 plants were with 1\(IV+7\Pi\) (Fig. 9), 2\(IV+5\Pi\) (Fig. 10) and 1\(IV+1VI+4\Pi\) (Fig. 11) respectively. Forty three plants from Santiniketan sample were studied of which 17 plants had 9\(\Pi\), 10 had 1\(IV+7\Pi\), 5 had 1\(VI+6\Pi\) (Fig. 12), 4 had 2\(IV+5\Pi\) and 7 had 1\(IV+1VI+4\Pi\).
Discussion

The present study has revealed that both *carinatum* and *coronarium* maintain significant amount of interchange heterozygosity in natural populations which clearly established the adaptive role of these chromosomal rearrangements in the evolution of diploid species of *Chrysanthemum*. The selection in favour of structural heterozygosity including that resulting from interchanges has been reported earlier in several plant and animal species (Darlington 1956, Dobzhansky 1957, Burnham 1956, Rees 1961, John and Lewis 1958). Rana and Jain (1965) have reported the maintenance of interchange heterozygosity in *Chrysanthemum carinatum*. They observed that the same two pairs of chromosomes were involved in rearrangement in geographically isolated different varieties of *C. carinatum*. Majority of the heterozygotes contained

Figs. 8-12. *Chrysanthemum carinatum*. 8, PMC with 9II. 9, PMC with 1IV and 7II. 10, with 2IV and 5II. 11, PMC with 1IV (→), 1V (→) and 4II. 12, PMC with 1VI and 6II.
one quadrivalent and rest of the heterozygotes contained two quadrivalents. The present study on C. carinatum has indicated clearly that more than two pairs of chromosomes are involved in interchange (vide Table 2). The frequencies of plants with different sizes of multiples in C. carinatum in the present study are different from those reported by Rana and Jain (1965). This difference in frequencies can be attributed to the geographical difference.

The other species Chrysanthemum coronarium also maintains interchange heterozygosity. The sizes of translocation vary from single quadrivalent involving two pairs of chromosomes to decavalent-quadrivalent involving as many as five and two pairs of chromosomes in a plant (vide Table 1). The two species differ in the extent and intensity of homozygote and heterozygote distribution (heterogenity $\chi^2 = 52.22; P < 0.05$); which may be treated as expression of hybridity optimum of individual species (Darlington 1963) implying that each species has an optimum degree of heterozygosity to which it is accustomed. Though breeding system of these species are completely outcrossing (Rana and Jain 1965), under continued selection for uniformity of these two species, an increasing degree of restriction of the possible number of recombinants is imposed and under such a situation structurally heterozygous individuals tend to replace the homozygous ones (Darlington and La Cour 1950, John and Lewis 1958). In annual chrysanthemum, the possibility that the establishment of structural heterozygosity owes itself to similar condition can not be ruled out. Immediate value of such chromosomal rearrangement can not explain fully the tendency of increase in multiple size in diploid Chrysanthemum. It is obvious from present study that structural heterozygosity is favoured in general rather than translocation in particular pairs of chromosome.

It is likely that the chromosomal rearrangements found in these species has a role in establishment of adaptively favourable linked combination of genes. Such groups of linked genes would correspond to what Darlington and Mather (1952) have called a “super gene” or “co-adapted gene complex” of Dobzhansky (1950) and would be inherited as a unit because of the suppression of random crossing over not only in these rearranged segments but also in the other parts of chromosome. In other words structural heterozygosity would tend to localize the distribution of chiasmata and thus brings about the constancy as well as flexibility of genotypes. Fluctuating ecological stress many demand more of chromosomal rearrangements in chrysanthemum. The present study indicates that a complex interchange multiple involving more than 14 chromosomes, as has been observed, could be isolated from the population of more fluctuating winter climate.

Rana (1966) has pointed out that Chrysanthemum enters in the list of classic organism like Oenothera, Rhoeo and Cockroaches in whose case interchange heterozygosity has been found to have adaptive significance. The interspecific variations regarding interchange heterozygosity found in Oenothera is present
at intraspecific inter-ecotype level of Chrysanthemum carinatum. This is clear from comparison between the data presented by Rana and Jain (1965) and the data of the present study on C. carinatum. It is also clear that in the present case C. coronarium and C. carinatum regarding the maximum size of the multiples are different although both the species have the tendency to increase the multiple size.

Summary

Different samples of two species of annual chrysanthemum—C. carinatum and C. coronarium were analysed cytologically. These two species were found to maintain a significant amount of interchange heterozygosity. Presence of heterozygosity in C. coronarium has been observed for the first time and the variation in the size of multiples from the earlier studies on C. carinatum was also observed. This difference is concluded to be due to the difference in climatic factor.

Acknowledgment

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References