Karyogenetical Studies on Rye
I. A trisomic plant*

by
Fumi Takagi

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I. Introduction

Secale cereale has usually 14 chromosomes in diploid number. However, several investigators (Gotoh 1924, 1932, Emme 1928, Levitsky 1929, 1931, Hasegawa 1934) have also observed in ordinary rye populations 16 chromosome plants with one pair of supernumerary small chromosomes which the 14 chromosome plants do not possess. Also 15 chromosome plants with one small extra chromosome have been found. As to the origin of the deviating chromosome numbers the opinions are still divided. Gotoh (1924) assumes that one of the largest rye chromosomes is liable to segmentation which results in two chromosomes, i.e. a small one without constriction, the K-chromosome, and another of medium size, the L-chromosome; the latter can not be distinguished by its size alone from the other rye chromosomes. The other investigators assume that the

Fig. 1. The autotrisomic besides a normal plant (1/10). a. Normal. b. Autotrisomic.

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small chromosomes are additional chromosomes to the ordinary set of *Secale cereale* and maintain that they have a subterminal constriction.

Also plants with more than two small extra chromosomes have been found. The plants with such aberrant chromosome numbers do not differ in phenotype from normal 14 chromosome plants and have a high fertility. Both facts indicate some kind of genic inactivity of the small chromosome.

### II. Material and Methods

From one ear of a 15 chromosome plant with one small extra chromosome 34 seeds were obtained in 1933 by open pollination. They gave in 1934, among 22 plants, one which was very delicate, with slender stems and leaves. It is shown in fig. 1 beside a normal plant. The chromosome behaviour of this dwarf like plant was investigated in root tips and pollen-mother-cells. The root tips were fixed with NAVASHIN’s solution and stained with NEWTON’s gentian violet. The pollen-mother-cells were fixed with FLEMING’s solution and stained with HEIDENHAIN’s iron-alum-haematoxylin. Sections of the former were cut 10 μ and of the latter 12–16 μ thick.

### III. Observations

#### Root tips

In the root tip cells 15 chromosomes were observed. There was no K-chromosome among them but three chromosomes with two constrictions could be clearly distinguished (fig. 2). As normal rye has only one pair of twice constricted chromosomes, it seemed obvious that the plant was a trisomic in regard to this morphologically distinctive member of the normal chromosome complement of *Secale*. This assumption was further corroborated by the examination of the pollen-mother-cells.

**Fig. 2.** Metaphase of mitosis in root tip of the trisomic plant (ca. x1800). The letter a indicates the chromosome with two constrictions.

#### Pollen-mother-cells

At diakinesis in about 50% of the pollen-mother-cells six chromosome pairs and one trivalent could be seen (fig. 3). The remaining 50% showed 7 pairs and one univalent (fig. 4). At this stage it is remarkable that the univalents show two distinct constrictions. Cells with three univalents could not be found at this stage.
Figs. 3-8. Meiosis in P.M.C. of the trisomic plant (ca. ×1800). Fig. 3. Diakinesis with a trivalent. Fig. 4. Diakinesis with one univalent. Fig. 5. First metaphase with a trivalent (side view). Fig. 6. First metaphase with one univalent (side view). Fig. 7. First metaphase with three univalents (side view). Fig. 8. Several forms of trivalents.

At first metaphase the proportion of P.M.C. with one trivalent (fig. 5) and those with one univalent (fig. 6) was nearly the same as at diakinesis (table 1). But at this time, occasionally, cells with three univalents could be observed (fig. 7). The univalents showed no constrictions. The trivalents were mostly V-shaped but other forms also occurred (fig. 8).

At first anaphase the trivalents divided as usual, i.e. two chromosomes passed to one pole and one to the opposite pole. They were included in the daughter nuclei (fig. 9). No delayed chromosomes could be observed in the equatorial region at interkinesis (fig. 10). Accordingly, at second metaphase 7 respectively 8 chromosomes could be counted in the daughter cells (fig. 11), and, as a rule, almost no chromosome elimination was observable at second anaphase.

<p>| Table 1. Number of P.M.C. with 1 univalent, 1 trivalent and 3 univalents at first metaphase. |</p>
<table>
<thead>
<tr>
<th>Chromosome combination</th>
<th>(7_H+1_I)</th>
<th>(6_H+1_{III})</th>
<th>(6_H+3_I)</th>
<th>Total number of P.M.C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of polar views</td>
<td>12</td>
<td>8</td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>Number of side views</td>
<td>105</td>
<td>110</td>
<td>13</td>
<td>228</td>
</tr>
<tr>
<td>Total number of P.M.C.</td>
<td>117</td>
<td>118</td>
<td>15</td>
<td>250</td>
</tr>
</tbody>
</table>
Figs. 9-19. Meiosis in P.M.C. of the trisomic plant (ca. ×1800). Fig. 9. Seven, respectively eight chromosomes at the poles. First anaphase. Fig. 10. The same distribution. First telophase. Fig. 11. The same distribution. Second metaphase. Fig. 12. Showing two halves of a univalent. First anaphase. Fig. 13. The same case. Late anaphase. Fig. 14. Interkinesis with a retarded univalent. Fig. 15. Second metaphase with a retarded univalent (side view). Fig. 16. Second metaphase with half a univalent in each of the daughter cells (side view). Fig. 17. The same case. Second anaphase. The lagging halves show two distinct constrictions. Fig. 18. Showing a micronucleus which consists of one split univalent. First telophase. Fig. 19. Showing a micronucleus which consists of only half a univalent. First telophase.
But if univalents occurred, either one or three, they passed at first anaphase at random to either of the poles. They might lag behind or even stay outside of the daughter nuclei (figs. 13, 15). Sometimes the univalent divided in the first division, and the two halves moved towards the opposite poles (figs. 12, 14). They might be more or less delayed, and might not be included in the daughter nuclei at all (fig. 16). The univalent-halves did not further divide at second metaphase, and passed at second anaphase at random to either of the poles. At this stage they were often retarded, and here again two constrictions could be clearly seen (fig. 17). The split univalents or only single halves might form micronuclei at first anaphase (figs. 18, 19). Table 2 shows the proportion of P.M.C. with retarded chromosomes in the subsequent stages of meiosis from first to second anaphase. From table 3 can be seen the proportion of P.M.C. with univalents divided at first metaphase.

### Table 2. Proportion of P.M.C. with retarded chromosomes from first to second anaphase.

<table>
<thead>
<tr>
<th>Stage</th>
<th>First anaphase</th>
<th>Inter-kinesis</th>
<th>Second metaphase</th>
<th>Second anaphase</th>
<th>Tetrads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of P.M.C. without retarded chromosomes</td>
<td>60</td>
<td>216</td>
<td>50</td>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>Number of P.M.C. with retarded chromosomes</td>
<td>39</td>
<td>15</td>
<td>41</td>
<td>50</td>
<td>6</td>
</tr>
<tr>
<td>Total number of P.M.C.</td>
<td>99</td>
<td>231</td>
<td>91</td>
<td>100</td>
<td>61</td>
</tr>
</tbody>
</table>

The fertility of the trisomic plant was fairly good. Twenty four seeds were obtained through pollination with pollen of a normal 14 chromosome plant, and 12 seeds by open pollination. The former produced 12 and the latter 6 plants. All these plants were of normal phenotype.

### Table 3. Proportion of P.M.C. with halves of a univalent at second metaphase (polar view).

<table>
<thead>
<tr>
<th>Chromosome number on both nuclear plates</th>
<th>7+half and 7+half</th>
<th>7 and 8</th>
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<tbody>
<tr>
<td>Number of P.M.C.</td>
<td>18</td>
<td>24</td>
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**IV. Conclusion**

From the observations described above the author draws the conclusion that the dwarf like 15 chromosome plant was an autotrisomic (cf. NISHIYAMA 1934) with regard to the chromosome pair with two constrictions. The shape of the single extra chromosome could be clearly seen not only in somatic divisions but also in the stages of diakinesis and second metaphase. Therefore there can be no doubt about the identification of the supernumerary chromosome.

It is assumed that the trisomic plant was the result of non-disjunction. The author has, even in normal 14 chromosome plants, sometimes
observed failure to pair in one bivalent. Through passage of both accidentally unmated chromosomes to one pole a gamete with one duplicated chromosome would be formed. The trisomic plant, most probably, arose from the meeting of an egg cell with such a chromosome complement and a normal 7 chromosome sperm cell.

The chromosome behaviour of the trisomic was, as in many other trisomics, described by Blakeslee and Belling (1924), Blakeslee (1927), Clausen and Goodspeed (1924) and other authors.

In closing the writer wishes to express her gratitude to Prof. Dr. H. Kihara for his valuable advice and kind guidance throughout the course of this work. Her hearty thanks are also due to Dr. F. Liliendfeld for her useful suggestions.

**Literature**


