INTRODUCTION

Chrysanthemum (Dendranthema × grandiflorum (Ramat.) Kitam.) is one of the most important ornamental plants in the world. A number of species originated from China, where historically, the chrysanthemum was more associated with herbal rather than with ornamental use [1]. “Shen Nong’s Cannon of Materia and Medica”, which was compiled prior to the Christian era, has documented that chrysanthemum was used for increasing longevity. Its major pharmaceutical properties in traditional Chinese medicine are “paciﬁying the liver”, “improving vision”, “relieving fever” and “removing toxins”. Recently, edible chrysanthemum has become a popular dietary supplement, especially in Japan. Both fresh and dried flowers and various extracts have become commercially available. Although the consumption of chrysanthemum in China has been established long ago, cytogenetics of the species still remain largely unexplored.

Cytogenetic Study of Three Edible Chrysanthemum Cultivars

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Abstract—During past decades, edible chrysanthemum (Dendranthema × grandiflorum) has become a popular dietary supplement. However, only numberable cultivars are available, cytogenetic studies especially meiotic behaviour in them remain largely unexplored. In the present study, we analyzed the karyotype and meiotic behaviour during microsporogenesis in accessions of edible chrysanthemum. This information can be useful in cultivar improvement, as well as in elucidation of the evolution of the species. The three edible cultivars studied all had an intermediate type of interphase nucleus, and their mitotic prophase chromosomes were of the interstitial type. The chromosome number of “Baohuatangyijin” (Bn) varies from 55 to 62. “Zifengmudan” (Zn) has the karyotype $2n = 54 = 38m + 12sm + 4st$, while “Jingxingxiying” (Jg) has $2n = 55 = 38m + 15sm + 2st$. Male meiosis was largely normal. Mean pairing conﬁguration of Zn at diakinesis and metaphase I was $0.94I + 25.07II + 0.14III + 0.63IV$, while for Jg, the equivalent was $1.32I + 24.64II + 0.16III + 0.85IV + 0.05V + 0.04VI$. Chromatid separation was normal during anaphase I and anaphase II in most meiocytes. All three edible chrysanthemums appear to be allopolyploid, and the edible type is probably more primitive than the ornamental type. However, the edible type is probably more closely related to the ornamental than to the medicinal type.

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copy. Classification of the interphase nucleus and mitotic prophase chromosomes followed Tanaka [6, 7]. At least 30 cells from more than 5 plants per cultivar were analysed to produce a somatic chromosome count. Karyotypes were constructed on the basis of five independent cells using Ikaros software. The chromosomes were grouped according to centromere position [8]. Thus the chromosomes with arm ratio (the ratio between the length of the long to the short arm) of 1.01–1.70 were designated as metacentric (m); 1.71–3.00, as submetacentric (sm); 3.01–7.00, as subtelo-centric (st); and >7.01, as telocentric (t). The relative length of each chromosome was defined as the ratio of its length to total length of the haploid genome, and the chromosome length ratio (Lt/St) as the ratio of the length of the longest to that of the shortest chromosome. Karyotype symmetry was classified according to Stebbins [9], using an asymmetry index (As.K%) given by the proportion of the total length of all long arms to the total length of the full chromosome set [10]. The index of relative length (IRL) was calculated as the ratio between the length of an individual chromosome and the mean chromosome length. An IRL of ≥1.26 was designated—L, between 1.00 and 1.26—M1, between 0.76 and 1.00—M2, and <0.76—S [11].

**Meiotic Configurations in Pollen Mother Cells (PMCs)**

Meiotic preparations were made following Li et al., [12]. Briefly, inflorescences of diameter 6–10 mm were fixed in Carnoy’s solution at 4°C for 24 h. The bisexual discoid flower was dissected from the inflorescence, and the anthers squashed in a drop of 45% ace-

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**RESULTS**

**The Morphology of Resting Nuclei and Mitotic Prophase Chromosomes**

The interphase nuclei and mitotic prophase chromosomes of the three cultivars shared a similar morphology. Several darkly-stained chromocentres along with many lightly-stained heterochromatic regions were distributed throughout the interphase nucleus. Following Tanaka [6], this can be classified as an intermediate type (Fig. 1a). At mitotic prophase, hetero- and euchromatic segments were distributed in the distal and interstitial, as well as in the proximal regions. Based on Tanaka [7], the prophase chromosomes belong to the interstitial type (Fig. 1b).

**Mitosis: Metaphase Chromosomes**

Bn proves to be mixoploid, with a chromosome number ranging from 55 to 62; 76% of the cells show either \(2n = 58\) or 61 (Table 1). The 61-chromosome-karyotype consists of 21 pairs of m-, 9 pairs of sm-(numbers 2, 8, 9, 11, 16, 26, 28, 29, 30, see Fig. 1c), and a single t-chromosome (No. 31). The chromosome size and arm ratio of chromosomes nos. 19 and 20 were identical to one another, as were those of numbers. Chromosomes nos. 22, 23 and 24, suggesting the occurrence of duplicated chromosomes. The relative lengths of chromosomes ranged from 2.21 to 4.02, giving a constitution of \(28M_2\), \(30M_1\) and 3S. The Lt/St was 1.81, and 13% of the chromosomes had an arm