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Karyomorphological Studies of Ten Taxa of *Barbarea* (Cruciferae) from Turkey

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ABSTRACT

In this research, the somatic chromosome numbers and karyotypes of taxa belonging to the genus Barbarea R.Br. were determined using Image Analysis System. These taxa are Barbarea vulgaris R.Br., B. verna (Mill.) Aschers., B. sicula C. Presl., B. trichopoda Hausskn. ex Bornm., B. auriculata Hausskn. ex Bornm. var. auriculata, B. lutea Cullen & Coode, B. plantaginea DC., B. brachycarpa Boiss. subsp. brachycarpa var. brachycarpa, B. brachycarpa Boiss. subsp. minor (K. Koch) Parolly & Eren var. pilicarpa Parolly & Eren, B. brachycarpa Boiss. subsp. brachycarpa var. ilicifolia Parolly, Nordt & Eren as 2n = 2x = 16. Based on karyological data with this genus, one basic chromosome number in Barbarea taxa were observed (x = 8). Furthermore, ideograms were given for all the studied Barbarea taxa. The research has made contribution to the cytotaxonomic revision of the genus Barbarea in Turkey.

Key Words: Barbarea, Chromosome number, Cruciferae, karyotype.

Türkiye'den On *Barbarea* (Cruciferae) Taksonunda Karyomorfolojik Çalışmalar

ÖZET

Bu çalışmada, *Barbarea* R.Br. cinsine ait taksonlarda somatik kromozom sayıları ve karyotipleri Görüntü Analiz Sistemi aracılığı ile belirlendi. Bu taksonlar; *Barbarea vulgaris* R.Br., *B. verna* (Mill.) Aschers., *B. sicula* C. Presl., *B. trichopoda* Hausskn. ex Bornm., *B. auricula ta* Hausskn. ex Bornm. var. *auriculata* , *B. lutea* Cullen & Coode, *B. plantaginea* DC., *B. brachycarpa* Boiss. subsp. *brachycarpa* var. *brachycarpa*, *B. brachycarpa* Boiss. subsp. *minor* (K. Koch) Parolly & Eren var. *pilicarpa* Parolly & Eren, *B. brachycarpa* Boiss. subsp. *brachycarpa* var. *ilicifolia* Parolly, Nordt & Eren olup kromozom sayıları $2n = 2x = 16$'dır. Bu cinsin karyolojik verileri sonucunda tek temel kromozom sayısı gözlendi ($x = 8$). Ayrıca, çalışılan bütün *Barbarea* taksonlarına ait idiyogramlar verildi. Türkiye'de *Barbarea* cinsinin revizyonuna sitotaksonomik yönden katkıda bulunan bir araştırmadır.

Anahtar Kelimeler: *Barbarea*, kromozom sayısı, Cruciferae, karyotip.

INTRODUCTION

The Cruciferae is a large natural family of major economic importance, containing a wide array of crop plants grown as salads, vegetables, for oilseed, animal feed and condiments, and several well-known garden ornamental plants such as the wallflower, honesty and aubretia [1].

Members of the family are found in most parts of the world but are mainly concentrated in the north temperate region and more especially in the countries surrounding the Mediterranean basin and in southwestern and Central Asia, where more genera occur than anywhere else in the world. The family is only sparingly represented in the Southern Hemisphere, and there are very few species in tropical regions [1]. In the worldwide it is represented more than 338 genus that have about 3709 species [2]. In our country 92 genus and about 583 species are took part in Brassicaceae family [3-6]. 11 species and one subspecies are known only from the Aegean Islands [7]. *Barbarea* R.Br., winter cress,

comprises about 20 outbreeding, diploid species mainly distributed in temperate regions of Eurasia and North America [8-10].

Previous karyological analyses on the taxa of genus *Barbarea* have shown that the chromosome number of these taxa is 2*n* = 14, 16, 17, 18 and 19 [10-20]. There are some karyological, chemical, taxonomical, studies on different *Barbarea* taxa [10-25].

There is a few study on plant cytogenetic in Turkey. The determination of somatic chromosome numbers and karyotypes of taxa are important for the revision and monograph study in plant systematics [26].

The aim of the present study is to determine the somatic chromosome numbers and karyotypes of *Barbarea* taxa growing naturally in Turkey.

MATERIAL AND METHODS

The taxa studied were *Barbarea vulgaris*, *B. verna*, *B. sicula*, *B. trich opoda*, *B. auriculata* var. *auriculata* , *B. lutea*, *B. plantaginea*, *B. brachycarpa* subsp. *brachycarpa* var. *brachycarpa*, *B. brachycarpa* subsp. *minor* var. *pilicarpa*, *B. brachycarpa* subsp. *brachycarpa* var. *ilicifolia* (Table 1).

Voucher specimens have been deposited at the herbaria of Niğde University, Faculty of Science and Arts, Niğde. Chromosome numbers and karyotypes were made on somatic metaphases using the squash technique. Root meristems from germinating seeds collected in the wild for each taxa were used. First, root tips were pretreated with α-monobromonaphthalene at 4°C for 16 h. Then, root tips were fixed with Carnoy for 24 h at 4°C. Before staining, the material was hydrolyzed with 1N HCl for 15-20 minutes at room temperature. Root tips were stained with 2% aceto-orcein and then, they were squashed and mounted to slides with 45% acetic acid. For all the chromosome counts, a minimum of five plates from different individuals were examined and for each taxa. Permanent slides were made by using the standard liquid nitrogen method. Photographs were taken through light microscope. The ideograms were prepared with measurements taken on enlarged micrographs of five well spread metaphase plates coming from taxa. The classification of chromosomes, the length of long and short arm, arm ratio, centromeric index and relative chromosomal length were measured by Software Image Analysis (BS200Pro) loaded on a personal computer. The classification of chromosomes into median (m), submedian (sm), subterminal (st) and terminal point (T) was based on the analysis of metaphase chromosomes [27].

Table 1. The information on karyotyped *Barbarea* taxa, their chromosome numbers and localities.

Taxa	2*n*	Locality	Vouchers
B. vulgaris	16	Konya-Beyşehir	Bağcı 3857 & Savran
B. verna	16	Konya-Beyşehir	Bağcı 3861 & Savran
B. sicula	16	Antalya-Tahtalı dağl.	Bağcı 3859 & Savran
B. trichopoda	16	Yozgat	Bağcı 3597 & Savran
B. auricul ata var. *auriculata*	16	Erzincan, Eğin	Bağcı 3728 & Savran
B. lutea	16	Kars, Susuz	Bağcı 3704 & Savran
B. plantaginea	16	Konya-Beyşehir	Bağcı 3864 & Savran
B. br achycarpa subsp. *brachycarpa* var. *brachycarpa*	16	Konya-Beyşehir	Bağcı 3858 & Savran
B. brachycarpa subsp. *minor* var. *pilicarpa*	16	Antalya-Tahtalı dağl.	Bağcı 3862 & Savran
B. br achycarpa subsp. *brachycarpa* var. *ilicifolia*	16	Konya-Bozkır	Bağcı 3746 & Savran

RESULTS

In this study, the somatic chromosome numbers of the six taxa studied were determined and the karyotypes of ten taxa belonging to the genus *Barbarea* are studied for the first time. Five of these taxa are endemic to Turkey (*B. trichopoda*, *B. auriculata* var. *auricula ta*, *B. lut ea*, *B. brachycarpa* subsp. *minor* var. *pilicarpa*, *B. b rachycarpa* subsp. *brachycarpa* var. *ilicifolia*). The detailed karyological features were presented (Table 2).

Table 2. Chromosome comparison in the ten studied taxa of *Barbarea* (AR: arm ratio; CI: centromeric index; THC: total length of haploid complement; M: median; SM: submedian; ST: subterminal).

Taxa	2*n*	Chromosome sizes (µm)	AR	CI	THC (µm)	M	SM	ST
Barbarea vulgaris	16	0.98-2.33	-	-	12.49	-	-	-
B. verna	16	0.77-1.12	-	-	7.37	-	-	-
B. sicula	16	0.77-2.19	-	-	10.68	-	-	-
B. trichopoda	16	1.55-3.73	1.94	4.31	21.91	2	5	1
B. auriculata var. *auriculata*	16	1.30-1.72	1.52	5.00	11.65	6	2	-
B. lutea	16	1.57-2.54	1.60	4.92	17.07	6	2	-
B. plantaginea	16	1.41-2.45	1.54	5.13	14.41	5	3	-
B. brachycarpa subsp. *brachycarpa* var. *brachycarpa*	16	1.75-2.68	1.37	5.28	17.27	8	-	-
B. brachycarpa subsp. *minor* var. *pilicarpa*	16	0.95-1.60	-	-	9.68	-	-	-
B. brachycarpa subsp. *brachycarpa* var. *ilicifolia*	16	0.55-1.46	-	-	7.75	-	-	-

Barbarea vulgaris

The somatic chromosome number is 2n = 2x = 16 (Fig. 1a). The chromosome morphology was reported for the first time. The somatic chromosome lengths ranging from 2.33 µm to 0.98 µm, total haploid chromosome length is 12.49 µm. The ideogram was given (Fig. 2a).

Barbarea verna

The somatic chromosome number is 2n = 2x = 16 (Fig. 1b). The chromosome morphology was reported for the first time. Metaphase chromosome lengths ranging from 1.12 µm to 0.77 µm, total haploid chromosome length is 7.37 µm. The ideogram was given (Fig. 2b).

Barbarea sicula

The somatic chromosome number is 2n = 2x = 16 (Fig. 1c). The chromosome morphology was reported for the first time. Metaphase chromosome lengths ranging from 2.19 µm to 0.77 µm, total haploid chromosome length is 10.68 µm. The ideogram was given (Fig. 2c).

Barbarea trichopoda

The karyotype formula is 2n = 2x = 16 = 2m+5sm+1st (Fig. 1d). The chromosome number and morphology were reported for the first time. Metaphase chromosome lengths ranging from 3.73 µm to 1.55 µm, total haploid chromosome length is 21.91 µm. The ideogram was given (Fig. 2d).

Barbarea auriculata var. auriculata

The karyotype formula is 2n = 2x = 16 = 6m+2sm (Fig. 1e). The chromosome number and morphology were reported for the first time. Metaphase chromosome lengths ranging from 1.72 µm to 1.30 µm, total haploid chromosome length is 11.65 µm. The ideogram was given (Fig. 2e).

Barbarea lutea

The karyotype formula is 2n = 2x = 16 = 6m+2sm (Fig. 1f). The chromosome number and morphology were reported for the first time. Metaphase chromosome lengths ranging from 2.54 µm to 1.57 µm, total haploid chromosome length is 17.07 µm. The ideogram was given (Fig. 2f).

Barbarea plantaginea

The karyotype formula is 2n = 2x = 16 = 5m+3sm (Fig. 1g). The chromosome morphology was reported for the first time. Metaphase chromosome lengths ranging from 2.45 µm to 1.41 µm, total haploid chromosome length is 14.41 µm. The ideogram was given (Fig. 2g).

Barbarea brachycarpa subsp. brachycarpa var. brachycarpa

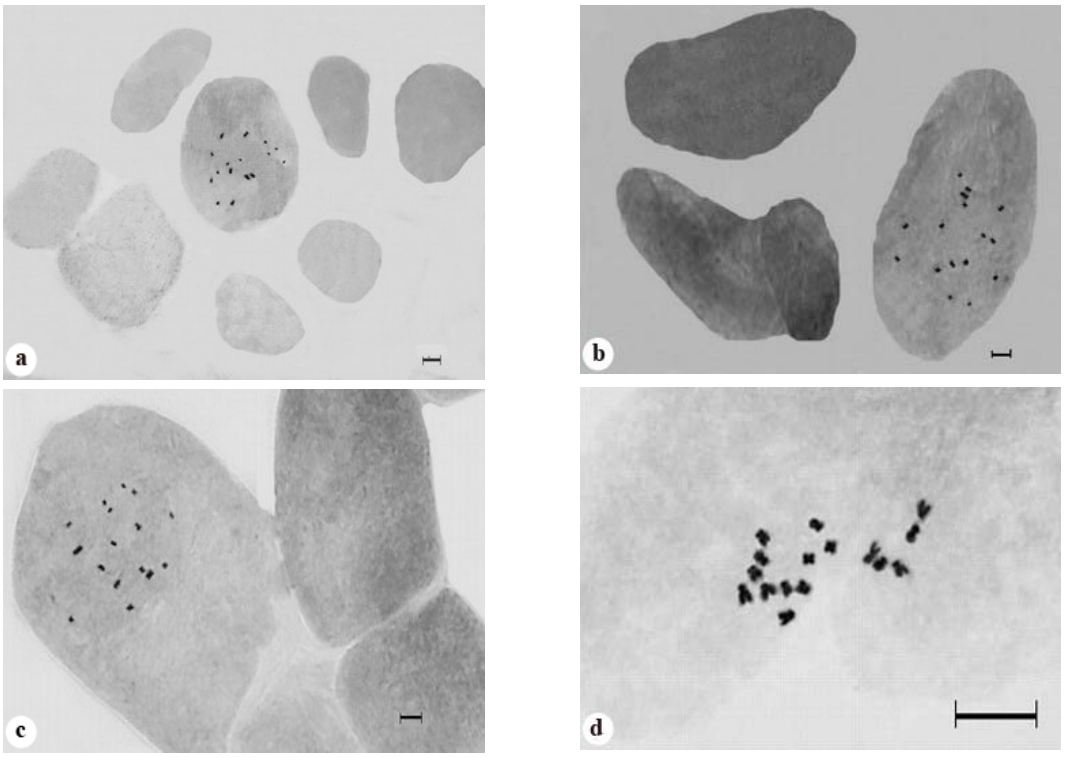
The karyotype formula is 2n = 2x = 16 = 8m (Fig. 1h). The chromosome number and morphology were reported for the first time. Metaphase chromosome lengths ranging from 2.68 µm to 1.75 µm, total haploid chromosome length is 17.27 µm. The ideogram was given (Fig. 2h).

Barbarea brachycarpa subsp. minor var. pilicarpa

The somatic chromosome number is 2n = 2x = 16 (Fig. 1i). The chromosome number and morphology were reported for the first time. Metaphase chromosome lengths ranging from 1.60 µm to 0.95 µm, total haploid chromosome length is 9.68 µm. The ideogram was given (Fig. 2i).

Barbarea brachycarpa subsp. brachycarpa var. ilicifolia

The somatic chromosome number is 2n = 2x = 16 (Fig. 1j). The chromosome number and morphology were reported for the first time. Metaphase chromosome lengths ranging from 1.46 µm to 0.55 µm, total haploid chromosome length is 7.75 µm. The ideogram was given (Fig. 2j).



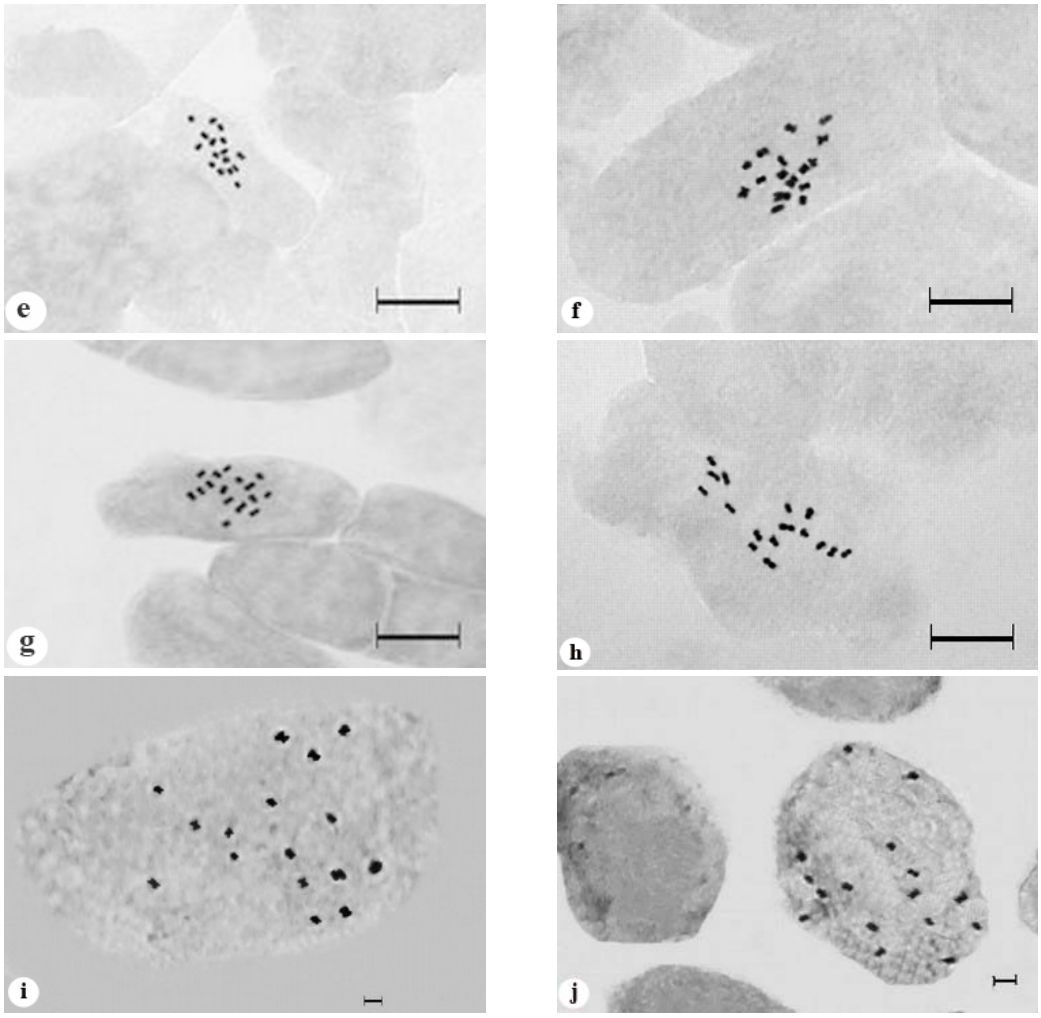


Figure 1. Somatic metaphase chromosomes in study taxa **a).** Barbarea vulgaris, **b).** B. verna, **c).** B. sicula, **d).** B. trichopoda, **e).** B. auriculata var. auriculata, **f).** B. lutea, **g).** B. plantaginea, **h).** B. brachycarpa subsp. brachycarpa var. brachycarpa, **i).** B. brachycarpa subsp. minor var. pilicarpa, **j).** B. brachycarpa subsp. brachycarpa var. ilicifolia Bar: 5 µm.

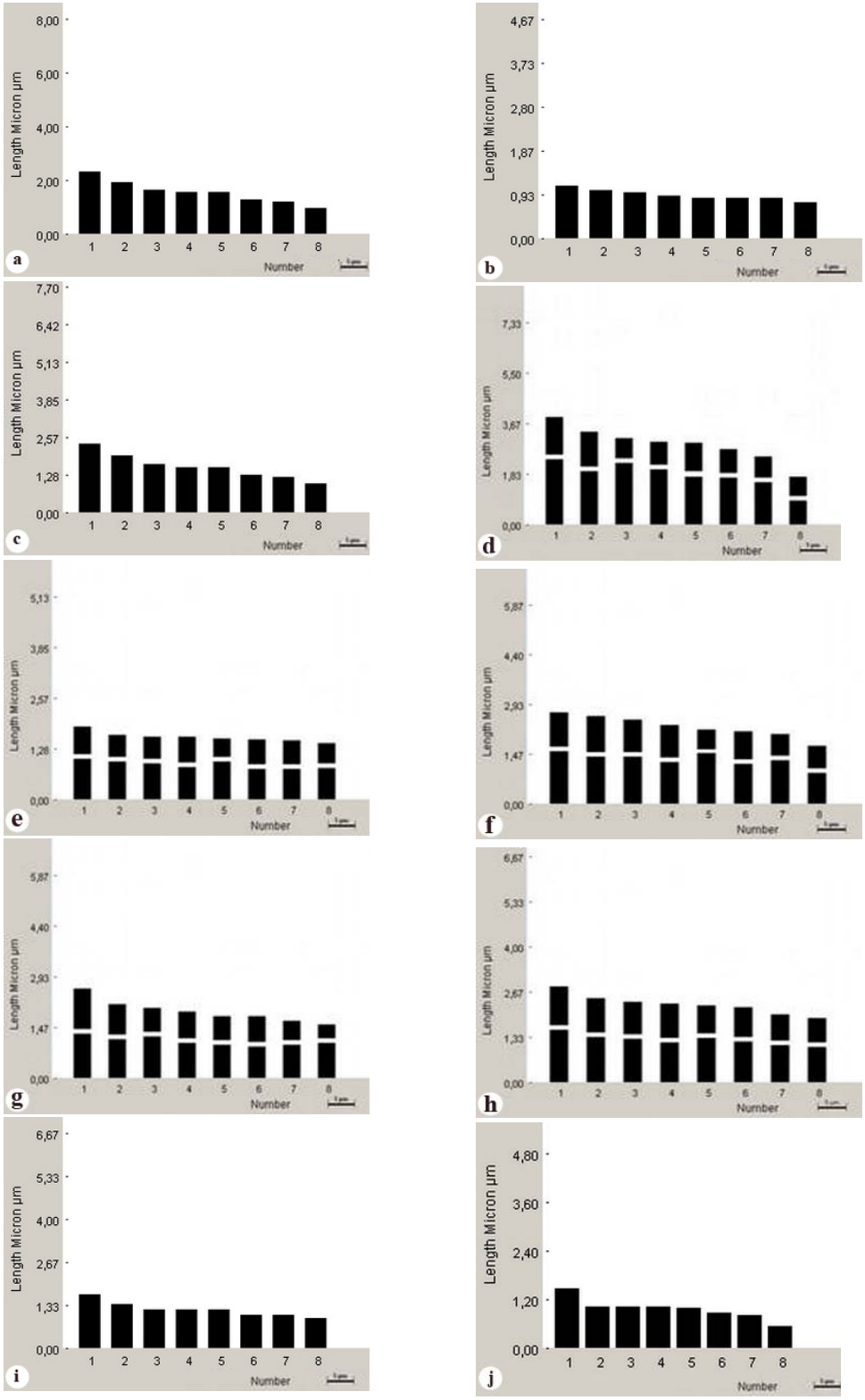


Figure 2. Ideograms in study taxa **a).** Barbarea vulgaris, **b).** B. verna, **c).** B. sicula, **d).** B. trichopoda, **e).** B. auriculata var. auriculata, **f).** B. lutea, **g).** B. plantaginea, **h).** B. brachycarpa subsp. brachycarpa var. brachycarpa, **i).** B. brachycarpa subsp. minor var. pilicarpa, **j).** B. brachycarpa subsp. brachycarpa var. ilicifolia Bar: 5 µm.

DISCUSSION

In this study of ten taxa growing in Turkey revised previous knowledge in literature providing the somatic chromosome numbers of six taxa for the first time. In addition, the karyotypes of ten taxa are examined for the first time. However, chromosomal counting was not possible for the taxa *Barbarea auriculata* Hausskn. ex Bornm. var. *paludosa* Coode & Cullen, *B. p latycarpa* Hausskn. ex Bornm., *B. integrifolia* DC., *B. brachycarpa* subsp. *anfractuosa* (Hartvig & Strid) Parolly & Eren, *B. brachycarpa* subsp. *robusta* (Coode & Cullen) Parolly & Eren, *B. brachycarpa* subsp. *minor* (K. Koch) Parolly & Eren var. *minor* due to the fact that we were unable to germinate the seeds of these taxa.

The somatic chromosome number of *Barbarea orthoceras* Ledebour, *B. in termedia* Bor., *B. stric ta* Andrz. ex Besser, *B. vulgaris* R.Br. subsp. *vulgaris*, *B. vulgaris* R.Br. subsp. *arcuata* (Opiz ex J. & C. Presl) Neuman, *B. verna* (Mill.) Aschers., *B. sicula* Bor., and *B. plantaginea* DC. taxa belong to genus *Barbarea* had been previously determined as $2n$ = 14, 16, 17, 18 and 19 [10-11, 14-20, 25].

In all of the taxa examined, the basic chromosome number were x = 8. These findings are in agreement with the basic number and somatic chromosome numbers given for the *Barbarea* genus taxa in the previous research. Also, the somatic chromosome number of *B. sicula*, *B. vulgaris*, *B. verna* and *B. p lantaginea* were reported to be $2n = 2x = 16$ [10, 14-17]. The somatic chromosome number we have obtained in our study is parallel with literature.

Chromosome counts of *Barbarea stricta*, *B. verna*, *B. intermedia* and *B. vulgaris* subsp. *vulgaris* were reported to be $2n$ = 16. A single cell of *B. vulgaris* subsp. *vulgaris* had $2n$ = 17. In accessions and hybrids of *B. vulgaris* subsp. *arcuata* chromosome numbers ranged from $2n$ = 16 to $2n$ = 19 [10].

According to the information in the literature, only one study has been carried out on the chromosome size of the *Barbarea vulgaris* subsp. *arcuata* [20]. In this study, the karyotypes of the ten taxa studied were determined by Image Analysis System belonging to the genus *Barbarea* are studied for the first time in the world.

The number of the somatic chromosomes were identified for *Barbarea plantaginea* , *B. auricu lata* var. *auriculata*, *B. l utea*, *B. trichop oda* and *B. brachycarpa* subsp. *brachycarpa* var. *brachycarpa*. The somatic chromosome numbers in these taxa are $2n$ = 16. Also, their homolog chromosome pairs were determined by the study of their arm ratio, relative length, centromeric index and total length of haploid complement for each taxon.

Ideograms of these taxa were arranged in order of decreasing lengths. Centromers and the type of chromosomes could not be determined, because the chromosomes of these taxa are very small. The number of the somatic chromosomes were examined for *Barbarea vulgaris*, *B. verna, B. sicula*, *B. brachycarpa* subsp. *minor* var. *pilicarpa*, *B. brach ycarpa* subsp. *brachycarpa* var. *ilicifolia*.

The somatic chromosome numbers in these taxa are $2n$ = 16. In addition to their homolog chromosome pairs were determined by the study of their total length, relative length and total haploid chromosome length for each taxon. Ideograms of these taxa were sequenced according to their total lengths. Centromers and the type of chromosomes could not be determined, because the chromosomes of these taxa are very small.

The chromosome morphologies of the genus *Barbarea* taxa studied are different from each other. The length of the smallest chromosome was 0.55 µm and found in *B. brachycarpa* subsp. *brachycarpa* var. *ilicifolia.* The length of the largest chromosome was 3.73 µm and found in *B. trichopoda*. The smallest arm ratio (1.37) in *B. brachycarpa* subsp. *brachycarpa* var. *brachycarpa* and the largest arm ratio (1.94) in *B. trichopoda* were observed. According to the centromeric index, *B. trichopoda* taxon has the smallest (4.31), and *B. brachycarpa* subsp. *brachycarpa* var. *brachycarpa* taxon had the largest (5.28) centromeric index values. The total haploid chromosome length is the shortest in *B. ver na* (7.37 µm), and the longest in *B. trichopoda* (21.91 µm). *Barbarea auriculata* var. *auriculata* and *B. lutea* belonging to the same genus (*Barbarea*) presented clearly same in karyotype formula as 6m+2sm. But, the lengths of somatic chromosomes were also different in both taxa.

Karyotype analyses have been conducted in recent years with similar computer supported programs with different names. The Image Analysis System plays a vital role in the minimization of errors in karyotype analyses. Moreover, the use of Image Analysis System, compared to karyotype analyses which are made using scales and compass, has three chief advantages. First, the preparation of the karyotypes takes less time. Second, it is more practical in the measurement of the chromosomes. Third, the karyograms and ideograms are prepared automatically [28].

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