New chromosome counts in the genus *Centaurea* (Asteraceae) from Turkey

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Twenty-two chromosome counts are reported in 16 species, four subspecies and two varieties of the genus *Centaurea*. These are mostly Turkish local endemics of section *Cheirolepis*, a complicated group from the Eastern clade of the *Jacea* group. Twenty-one reports are new. Prevalence of the basic chromosome number $x = 9$ among the eastern sections of the *Jacea* group is confirmed. © 2009 The Linnean Society of London, *Botanical Journal of the Linnean Society*, 2009, 159, 280–286.

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INTRODUCTION

A close correlation between karyology and systematics in the subtribe Centaureinae has been demonstrated repeatedly. In the genus *Centaurea sensu stricto*, in its re-defined circumscription (García-Jacas et al., 2006), basic chromosome numbers are a key character for sectional classification (Guinochet & Foissac, 1962; Tonjan, 1980; García-Jacas & Susanna, 1992; García-Jacas, Susanna & Ilarslan, 1996; Wagenitz & Hellwig, 1996; García-Jacas et al., 1997; Romashchenko et al., 2004).

Turkey is the most important centre of speciation of *Centaurea*, with many narrow endemic species. The majority of these were initially classified in a range of small, narrowly delimited sections: *Cheirolepis* (Boiss.) O. Hoffm., *Plumosipappus* (Czerep.) Wagenitz and *Pseudoseridia* Wagenitz, but recent molecular surveys have indicated that they should be placed in a broadly defined section, *Cheirolepis* (García-Jacas et al., 2006). This comprises some thirty species, with many new taxa recently described in the group (Duran & Duman, 2002; Uzunhisarcıklı, Teksên & Dogan, 2005; Uysal, 2006; Uzunhisarcıklı, Dogan & Duman, 2007).

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In addition to section *Cheirolepis*, this paper also examines other sections of the *Jacea* group: section *Cynaroides* Boiss. ex Walp., endemic in the Iran–Turanian region; section *Jacea* DC., widespread in temperate and Mediterranean Eurasia; and three eastern Mediterranean endemic sections, *Microlopus* (Cass.) DC., *Phaeopappus* (Boiss.) O. Hoffm., and *Pteracantha* Wagenitz.

The other group of *Centaurea* included in this paper is section *Acrocentron*. Turkey and the eastern Mediterranean region have been suggested as one of the oldest centres of speciation of *Acrocentron*, mainly on a karyological basis (García-Jacas & Susanna, 1992). This section has two different basic chromosome numbers, $x = 11$ (ancestral) and $x = 10$ (derived). According to García-Jacas & Susanna (1992), the incidence of counts of $x = 11$ in the eastern Mediterranean region is higher than in the western area. Even although recent surveys have suggested that the ratio $x = 11 : x = 10$ is almost the same in both areas (Routsi & Georgiadis, 1999), the absolute number of species with $x = 11$ in the eastern Mediterranean region remains higher than in the western Mediterranean centre of speciation.

This contribution centres on *Acrocentron*, *Cheirolepis* and other groups, with the aim of verifying previous hypotheses on the correlation of evolution,
descending dysploidy and chromosome numbers in *Centaurea*.

**MATERIAL AND METHODS**

Chromosome counts were made on somatic metaphases using the squash technique. Root meristems from germinating seeds collected in the wild were used. Samples were pretreated with 0.002 M 8-hydroxyquinoline at 4 °C for 8 h. The material was fixed in Carnoy for 24 h at low temperatures. Before staining, the material was hydrolysed with 5 M hydrochloric acid (HCl) for 1 h at room temperature (20 °C), stained with 1% acetic orcein and mounted in 45% acetic acid. For all the counts, at least five metaphase plates were examined from different individuals. Preparations were made permanent by freezing with carbon dioxide (CO2), dehydrating in ethanol and mounting in Canada balsam. Digital photographs were taken using an Olympus 3030 camera mounted on an Olympus microscope U-TV1 X. The preparations and the herbarium vouchers are preserved in the Herbarium KON of Konya and the Department of Biology, Faculty of Science and Art of the University of Selçuk.

**RESULTS**

*CENTAUREA SECTION ACROCENTRON (CASS.) DC.*

*Centaurea athoa DC.*

Turkey, Balikesir: Kaz Mountain National Park, Sarıkız Hill, 1700 m, *Uysal 521*, 16.vii.2003 (KON). 2n = 20 (Fig. 1). This is the first chromosome count for this endemic subspecies.

*Centaurea pseudoscabiosa Boiss. & Buhse subsp. araratica (Azn.) Wagenitz*

Turkey, Erzurum: between Erzurum and Varto, 13 km from Varto, 1700 m, *Uysal 893*, 31.vii.2004 (KON). 2n = 22 (Fig. 2). This is the first chromosome count for this endemic subspecies.

There is a previous record for *C. pseudoscabiosa* subsp. *pseudoscabiosa* with the same result (Ghaffari, 1999). Despite the name and the morphological similarities, this result excludes any relationship to *C. scabiosa*, with x = 10 (Guinochet & Foissac, 1962). Our result for *C. pseudoscabiosa* confirms the presence of x = 11 among the Turkish–Iranian species of section *Acrocentron*. A previous hypothesis on the evolution of section *Acrocentron* suggested that the Iranian group of taxa was derived (Garcia-Jacas et al., 1998b) and thereafter no record of the ancestral basic number was expected. In any case, this is the only record of x = 11 in the area, as all the other Turkish–Iranian species of *Acrocentron* counted previously have x = 10.

*CENTAUREA SECTION CHEIROLEPIS (BOISS.)*

*O.HOFFM.*

*Centaurea cankiriense A. Duran & H. Duman*

Turkey, Çankırı: Kalfat-Atkaracalar Road, Nebiyesi, 1455 m, 40°41′49″N, 032°05′27″E, *Uysal 524*, 26.vii.2003 (KON). 2n = 18 (Fig. 8). This is the first chromosome count for this local endemic.

*Centaurea derderiifolia Wagenitz*

Turkey, Elazığ: between Elazığ and Pertek, 16 km from Pertek, Saklaya Village, by stream place, in vineyard, 1002 m, 38°46′09″N, 39°12′35″E, *Uysal 902*, 02.viii.2004 (KON). 2n = 18 (Fig. 4). This is the first chromosome count for this endemic species.

*Centaurea drabifolia Sm. subsp. drabifolia*

Turkey, Bursa: Uludağ summit, 2000–2100 m, *Uysal 569*, 30.vii.2004 (KON). 2n = 18 (Fig. 5). This is the first chromosome count for this endemic subspecies.

*Centaurea drabifolia Sm. subsp. austro-occidentalis Wagenitz*

Turkey, Balikesir: Harmançik–Bursa Road, open space in pine forest, rocky slopes, 1050 m, 39°43′36″N, 029°03′E, *Uysal 88*, 30.vii.2004; Eskisieh: between Erzurum and Varto, 910 m, 39°14′30″N, 46°05′07″E, *Uysal 580*, 02.viii.2004 (KON). 2n = 18 (Fig. 6). This is the first chromosome count for this endemic subspecies.

*Centaurea drabifolia Sm. subsp. cappadoica (DC.) Wagenitz*

Turkey, Niğde: Bolkar Mountains, Bulgarmadeni, 2300 m, 37°27′48″N, 34°40′65″E, *Uysal 855*, 28.vii.2004 (KON). 2n = 18 (Fig. 7). This is the first chromosome count for this endemic subspecies.

*Centaurea drabifolia Sm. subsp. detonsa (Bornm.) Wagenitz*

Turkey, Ankara: between Haymana and Yenice, roadsides, *Uysal 999*, 30.viii.2004; Eskişehir: between Eskişehir and Kütahya, 18 km from Kütahya, right side of road in fine gravel, 910 m, 39°33′36″N, 30°03′38″E, *Uysal 580*, 30.vii.2004; Kütahya: between Kütahya and Afyon, roadsides, 1100 m, 39°14′94″N, 30°07′46″E, *Uysal 583*, 30.vi.2004 (KON). 2n = 4x = 36 (Fig. 8).

Our counts in this subspecies do not confirm previous records of 2n = 6x = 54 (Bakhshi Khaniki, 1995; Garcia-Jacas et al., 1997). Although we have counted...
many samples from different localities in Turkey, we have always found the same chromosome number in this subspecies.

_Centaurea drabifolia_ Sm. subsp. _glabrescens_ Uysal & Ertugrul subsp. nov. ined

Turkey, Konya: Seydişehir, Hügülü town, Durak village, Rizebeli, east ridges of Akdağ Mountain, above steep rocks, 2000 m, _Uysal_ 505, 12.vii.2003 (KON). \(2n = 4x = 36\) (Fig. 9). This is the first chromosome count for this endemic new subspecies.

_Centaurea kotschyi_ (Boiss. & Heldr.) var. _kotschyi_

Turkey, Konya: Karapınar, Government Protection and Research area, 1800 m, _Uysal_ 535, 30.vii.2003 (KON). \(2n = 4x = 36\) (Fig. 10). This is the first chromosome count for this endemic subspecies.

_Centaurea kotschyi_ (Boiss. & Heldr.) var. _persica_ (Boiss.) Wagenitz

Turkey, Sivas: Hafik (Celalli District), between Süleymanı and Bakmil, roadsides, 1400 m, 39°42′12″N, 37°29′30″E, _Uysal_ 527, 26.vii.2003 (KON). \(2n = 4x = 36\) (Fig. 11).

As in the case of _Centaurea drabifolia_ subsp. _detonsa_, _C. kotschyi_ var. _persica_ is also tetraploid. In previous studies, it had been reported that both taxa were hexaploid (Bakhshi Khaniki, 1995; Garcia-Jacas _et al._, 1997).

_Centaurea lycopifolia_ Boiss. & Kotschy

Turkey, Adana: between Osmaniye and Yarpuz, clearings in pine forests, 800 m, _Uysal_ 534 26.vii.2003 (KON). \(2n = 4x = 36\) (Fig. 12). This is the first chromosome count for this endemic species.

_Centaurea nivea_ Wagenitz

Turkey, Eskişehir: Between Mihaliç and Alpu, 20 km towards Alpu: gypsum hills, 950 m, _Uysal_ 519, 15.vii.2003 (KON). \(2n = 18\) (Fig. 13). This is the first chromosome count for this local endemic.

_Centaurea sericea_ Wagenitz


\(2n = 4x = 36\) (Fig. 14). This is the first chromosome count for this local endemic.

As a result of these chromosome counts in section _Cheirolepis_, we can reconfirm that its basic chromosome number is \(x = 9\). Moreover, polyploidy is frequent and could be an important factor for speciation in this section.

_Centaurea section Cyarioides_ Boiss. ex Walp.

_Centaurea sclerolepis_ Boiss.

Turkey, Diyarbakır: between Diyarbakır and Silvan, 38 km from Diyarbakır, 751 m, _Uysal_ 898, 1.viii.2004 (KON). \(2n = 18\) (Fig. 15). This is the first chromosome count for this endemic species.

_Centaurea fenzlii_ Reichardt

Turkey, Erzurum: between Erzurum and Varto, 1 km from Varto, 1650 m, _Uysal_ 895, 31.vii.2004 (KON). \(2n = 18\) (Fig. 16). This is the first chromosome count for this endemic species.

_Centaurea tomentella_ Hand.-Mazz

Turkey, Maraş: 4 km from Göksun towards Elbistan, 1450 m, _Uysal_ 363, 27.vii.2003 (KON). \(2n = 18\) (Fig. 17). This is the first chromosome count for this endemic species.

Together with previous reports, our counts in section _Cyarioides_ confirm that its basic chromosome number is \(x = 9\). Besides these endemic species, there are other diploid counts of \(2n = 18\) within the section: _C. amanicola_ Huh.-Mor. (Gardou & Tchehrehgocha, 1975), _C. aladaghensis_ Wagenitz, _C. cataonica_ Boiss. & Hausskn., _C. kurzica_ Reichardt from Turkey (Romashchenko _et al._, 2004) and _C. imperialis_ Haussk. ex Bornm. from Iran (Garcia-Jacas, Susanna & Mozaffarian, 1998a; Ghaffari & Shahraki, 2001). There is also a record of tetraploidy in _C. charrellii_ Halácsy & Dörfler, an endemic serpentinicolous species from Greece (Constantinidis, Bareka & Kamari, 2002).
7.vii.2004 (KON). 2n = 22 (Fig. 18). This is the first chromosome count for this endemic species.

Our count confirms previous reports on the chromosome numbers of species in section *Jacea* (2n = 2x = 22, 2n = 4x = 44, Guinochet, 1957). Even although many species of section *Jacea* are polyploid, their basic chromosome numbers are always x = 11.

**CENTAUREA SECTION MICROLOPHUS (CASS.) DC.**

Centaurea babylonica (L.) L.

Turkey, Adana: between Konya and Adana, Pozanti Town, Horozlu village boundary, 965 m, Uysal & O. Tugay 3830, 4.viii.2005, (KON). 2n = 16 (Fig. 19). This is the first chromosome count for this species.

This result agrees with other counts in this section (C. polypodiifolia Boiss. and C. rigida Banks & Sol.), but disagrees with other counts of x = 9 in C. *thracica* and x = 17 in C. *behen* (see Romashchenko et al., 2004). Even although differences in basic chromosome number could be as a result of dysploidy (as in the case of section *Acrocentron*), molecular studies suggest that the limits of section *Microlophus* are ill defined (Garcia-Jacas et al., 2006). If we exclude *C. thracica* from the section on molecular grounds, *Microlophus* would exhibit only the basic number x = 8 and the reported amphiploid x = 17, which could be derived from hybridization between x = 8 and x = 9 diploids, followed by doubling of the chromosome number to produce the allotetraploid.

**CENTAUREA SECTION PHAEOPAPPUS (DC.) O.HOFFM.**

Centaurea spectabilis (Fisch. & C. A. Mey.) Schultz Bip. var. microlopha (Boiss.) Wagenitz

Turkey, Van: between Van and Gürpinar, Kurubas pass, 2237 m, Ertuğrul 2941, 5.vii.2003 (KON). 2n = 18 (Fig. 20). This is the first chromosome count for this endemic variety.

Centaurea stapfiana (Hand.-Mazz.) Wagenitz

Turkey, Diyarbakır: 20 km from Diyarbakır towards Yeşilköy, Kendal Hills, 627 m, Uysal 900, 1.vii.2004 (KON). 2n = 18 (Fig. 21). This is the first chromosome count for this local endemic species.
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**CENTAUREA section PTERACANTHA WAGENITZ**

Centaurea odyssae Wagenitz

Turkey, Balikesir: Kaz Mountain National Park, Sarrkuz Hill, 1700 m, Uysal 520, 16.vi.2003 (KON). 2n = 18 (Fig. 22). This is the first chromosome count for this local endemic species. It agrees with the count of the only other species of this section, C. xylobasis Rech.f. by Georgiadis & Christodoulakis (1984).

**DISCUSSION**

One of the better-documented karyological features in *Centaurea* is descending dysploidy, ranging from \( n = 12 \) to \( n = 7 \) (Garcia-Jacas *et al*., 1996). However, interpretation of this general trend has been difficult. Watanabe *et al.* (1999) interpreted it as an adaptation to arid habitats by favouring shorter life cycles in *Pogonolepis, Sondottia* and *Trichantodium* (Gnaphalieae and Pluchaeae, Asteraceae). Selvi & Bigazzi (2002) reported the same trend in *Nonea* (Boraginaceae). The general trend towards descending dysploidy in Centaureinae could be correlated with adaptation of mesophyllous taxa to the xeric conditions of the Mediterranean. Other examples among subtribe Carduinae support this view. In the *Xeranthemum* group, mesophyllous perennial mountain species of *Amphoricarpos* have \( n = 14 \), whereas annual xerophytes of the genera *Chardinia*, *Siebera* and *Xeranthemum* show a dysploid series from \( n = 12 \) to \( n = 5 \) (Garnatje *et al*., 2004). Within the *Arctium* group, the arcioid clade is formed by mountain or mesophyllous taxa that always have \( n = 18 \), whereas the cousinioioid clade, more adapted to the arid conditions of the Irano–Turanian region, show a dysploid series of \( n = 13, 12, 11, 10 \) and 9 (López-Vinyallonga *et al*., in press).

Another widespread feature in Centaureinae is polyploidy, which is especially well documented in our results for the subspecies of *Centaurea drabifolia*. As pointed out by Fernández Casas & Susanna (1986), hybrids between species with the same number are often homoploid. This points out that the arising and success of polyploids, usually sympatric with their progenitors, is probably more related to the availability of new habitats for colonization by the new polyploids (Soltis *et al*., 2007).

Finally, our observations again show an intriguing feature of Centaureinae: the large differences in the size of chromosomes. This has been interpreted repeatedly in the subtribe as a general trend towards increase in chromosome size in close correlation with the dysploid reduction of the basic number, a fact noted by Guinouchet & Foissac (1962). This was confirmed by Garcia-Jacas *et al.* (1996, 2001) who found a correlation between chromosome number and evolution, with early branching groups of the subtribe usually having high numbers (to \( x = 16 \)) of small chromosomes. In contrast, more derived groups usually have lower numbers and larger chromosomes. Nevertheless, this is a general trend and should always be evaluated carefully.

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