Botanical Journal of the Linnean Society, 2007, **153**, 203–211. With 19 figures

Chromosome numbers in the tribe Anthemideae (Asteraceae) from north-east Anatolia

HUSEYIN INCEER[1]* and SEMA HAYIRLIOGLU-AYAZ

Department of Biology, Faculty of Sciences and Arts, Karadeniz Technical University, 61080 Trabzon, Turkey

Received November 2005; accepted for publication July 2006

Twenty-two chromosome counts of 19 taxa in the tribe Anthemideae of the family Asteraceae are reported from north-east Anatolia, Turkey. The taxa belong to the subtribes Achilleinae (four *Achillea* taxa), Anthemidinae (five *Anthemis* taxa), Artemisiinae (two *Artemisia* species), Leucantheminae (one *Lecanthemum* species), Matricariinae (two *Tripleurospermum* species) and Tanacetinae (five *Tanacetum* taxa). Six counts are new reports, seven are not consistent with previous counts, and the remainder are confirmations of very limited previous data. Most of the populations of Anthemideae studied have the basic number $x = 9$, with ploidy levels ranging from $2x$ to 7 to $8x$, but dysploidy is also present, with one diploid species, *Artemisia austriaca*, having $x = 8$. © 2007 The Linnean Society of London, *Botanical Journal of the Linnean Society*, 2007, **153**, 203–211.

ADDITIONAL KEYWORDS: *Achillea* – *Anthemis* – *Artemisia* – Compositae – dysploidy – karyology – *Leucanthemum* – polyploidy – *Tanacetum* – *Tripleurospermum*.

INTRODUCTION

The Asteraceae is one of the largest plant families (Bremer, 1994). Its many genera and species, its worldwide distribution and the fact that it comprises many useful plants have made it the subject of large numbers of karyological studies (Watanabe, 2002 and references therein). The Anthemideae is a medium-sized tribe in the family, with about 1800 species (Valles *et al*., 2005). It is generally accepted as a relatively natural assemblage.

The tribe has a worldwide distribution but with main concentrations of taxa in Central Asia, the Mediteranean region and South Africa. Some members of the subtribes Ursiniinae, Artemisiinae, Chrysantheminae, Leucantheminae, Anthemidinae and Matricarinae are pernicious weeds, such as some of the *Ursinia* species introduced in Australia and New Zeland; species of *Chrysanthemum*, *Anthemis*, *Artemisia*, *Achillea*, *Leucanthemum*, *Tripleurospermum* and *Matricaria* are more widespread weeds in both the northern and southern hemispheres. However, most taxa have discrete ranges and very obvious areas of endemism (Bremer & Humphries, 1993).

The principal taxonomic problems within the tribe are almost entirely relationships between genera, but also circumscription of genera, especially within subtribal groups such as the Artemiisinae, Chrysantheminae and Tanacetinae (Bremer & Humphries, 1993). Although the Anthemideae tribe has been reviewed extensively (Bremer & Humphries, 1993), a complete convenient classification has not yet been achieved.

The relevance of karyological information to knowledge of the systematics and evolution of the tribe was noted long ago. In spite of the very large number of counts in the tribe, chromosomal data on Turkish populations are scarce, with chromosome numbers currently known for less than 14% of the taxa. Table 1 shows some previous counts made on Turkish material. The aim of the present study is to verify or to establish the chromosome numbers of several representatives of the Anthemideae from north-east Anatolian localities. Some of our data are new counts; others confirm unique or very scarce previous reports, or represent numbers which are different from those cited previously. We also discuss several systematic and

*Corresponding author. E-mail: inceer@ktu.edu.tr

Downloaded from https://academic.oup.com/botlinnean/article-abstract/153/2/203/2420485 by Karadeniz Teknik University Library (KTU) user on 08 June 2020

Table 1. Previous counts in some taxa of the tribe Anthemideae in Turkey

Genus	Taxon	2*n*	Localities	Authors
Achillea	*A. multifida*	18	Bursa: Ulu Dağ	Martin-Nouet (1969)
	A. setacea	18	Bursa: Ulu Dağ	Martin-Nouet (1969)
	A. spinulifolia	18	Nigde/Adana: Ak Dağ	Martin-Nouet (1969)
Anthemis	*A. altissima*	18	Tekirdağ: İnecik	Strid (1980)
	A. cretica ssp. *leucanthemoides*	36	Manisa: Manisa Dağı	Strid (1987)
	A. cretica s. l.	18	Muğla: Çal Dağı	Strid (1987)
	A. tinctoria	18	Tekirdağ: Kesan to Tekirdağ	Strid (1980)
Artemisia	*A. abrotanum*	18	Erzurum: Oltu-Göle	Johnson & Brandham (1997)
		18	Erzurum: Erzurum-Tortum	Johnson & Brandham (1997)
	A. caucasica	16	Çorum: Çorum-Merzifon	Johnson & Brandham (1997)
	A. chamaemelifolia	18	Kars: Susuz-Hasköy	Johnson & Brandham (1997)
	A. scoparia	16	Ağrı: Hamur-Tutak	Johnson & Brandham (1997)
		17, 18	Erzurum: Tortum-Olur	Johnson & Brandham (1997)
		17	Erzurum: Erzurum-Artvin	Johnson & Brandham (1997)
Chrysanthemum	*C. coronarium*	18	İzmir: Bornova	Nemli (1977)
Tanacetum	*T. argenteum*	18	Konya: Teke Dağı	Martin-Nouet (1969)
	T. densum	18	Adana/Niğde: ibid.	Martin-Nouet (1969)
Tripleurospermum	*T. callosum*	36	Gümüshane/Bayburt: Kop Dağı	Inceer & Beyazoglu (2004)
		36	Rize: Ikizdere	Garcia *et al*. (2005)
	T. caucasicum	18	Gümüshane: Köse Dağı	Inceer & Beyazoglu (2004)
		36	Rize: Ikizdere	Inceer & Beyazoglu (2004)
	T. oreades var. *oreades*	36	Trabzon: Zigana Dağı pass	Inceer & Beyazoglu (2004)
		36	Gümüshane: Köse Dağı	Garcia *et al*. (2005)
	T. repens	36	Rize: Ikizdere	Inceer & Beyazoglu (2004)
		36	Rize: Ikizdere	Garcia *et al*. (2005)
	T. transcaucasicum	18	Rize: Ikizdere	Inceer & Beyazoglu (2004)

evolutionary aspects of the tribe in the light of the cytogenetic data.

MATERIAL AND METHODS

Plant material

The taxa studied were *Achillea biebersteinii* Afan., *A. biserrata* M. Bieb., *A. millefolium* L. ssp. *millefolium*, *A. setacea* Waldst. & Kit., *Anthemis marschalliana* Willd. ssp. *pectinata* (Boiss.) Grierson, *A. melanoloma* Trautv. ssp. *trapezuntica* Grierson, *A. tinctoria* L. var. *pallida* DC., *A. tinctoria* L. var. *tinctoria*, *A. triumfetti* (L.) All., *Artemisia absinthium* L., *A. austriaca* Jacq., *Leucanthemum vulgare* Lam., *Tanecetum albipannosum* Hub.-Mor. & Grierson, *T. coccineum* (Willd.) Grierson ssp. *chamaemelifolium* (Somm. & Lev.). Grierson, *T. macrophyllum* Sch. Bip., *T. parthenium* Sch. Bip., *T. sorbifolium* (Boiss.) Grierson, *Tripleurospermum callosum* (Boiss. & Meldr.) E. Hossain, and *T. sevanense* (Manden.) Pobed. These plants were collected in 2001–05 from the mountains of north-east Anatolia, Turkey. Vouchers are deposited in the herbarium at the Karadeniz Technical University, Department of Biology (KTUB).

Chromosome analysis

Root tip meristerms obtained directly from natural populations were used for chromosome analysis. The tips of roots were cleaned of soil particles, cut off and pretreated with 0.05% colchicine for 2–5 h (Inceer, Hayirlioglu-Ayaz & Beyazoglu, 2002). They were then fixed in ethanol-acetic acid (3:1) for at least 24 h at 4 °C, hydrolysed in 1 N HCl at 60 °C for 10 min and then rinsed in tap water for a minimum of 2–3 min. Staining was carried out in 1% aqueous aceto-orcein for 12–18 h at room temperature, and squashes made in 45% acetic acid. The best metaphase plates were photographed with ISO 50 Ilford film.

In order to assess the existence of published chromosome counts in the taxa studied we used the common indexes of plant chromosome numbers cited by Inceer & Beyazoglu (2004), as well as the on-line chromosome number databases, Index to Plant Chromosome Numbers (Missouri Botanical Garden, http://motot.mobot.org/W3T/Search/ipcn.html) and Index to Chromosome Numbers in the Asteraceae (Watanabe, 2002; http://www-asteraceae.cla.kobe-u.ac.jp/index. html).

Downloaded from https://academic.oup.com/botlinnean/article-abstract/153/2/203/2420485 by Karadeniz Teknik University Library (KTU) user on 08 June 2020

Table 2. Chromosome numbers ($2n$), basic numbers and levels of ploidy of the Anthemideae taxa studied

Genus	Taxon	Chromosome number ($2n$)	Basic number (x)	Ploidy level
Achillea	*A. biebersteinii*	18	9	$2x$
	A. biserrata	18	9	$2x$
	A. millefolium ssp. *millefolium*	67**	9	$7x$-$8x$
	A. setacea	18	9	$2x$
Anthemis	*A. marschalliana* ssp. *pectinata*	18*	9	$2x$
	A. melanoloma ssp. *trapezuntica*	18*	9	$2x$
	A. tinctoria var. *pallida*	18*	9	$2x$
	A. tinctoria var. *tinctoria*	18	9	$2x$
	A. triumfetti	18	9	$2x$
Artemisia	*A. absinthium*	18	9	$2x$
	A. austriaca	16	8	$2x$
Leucanthemum	*L. vulgare*	36	9	$4x$
Tanacetum	*T. albipannosum*	18*	9	$2x$
	T. coccineum ssp. *chamaemelifolium*	18*	9	$2x$
	T. macrophyllum	18	9	$2x$
	T. parthenium	18	9	$2x$
	T. sorbifolium	18*	9	$2x$
Tripleurospermum	*T. callosum*	36	9	$4x$
	T. sevanense	36	9	$4x$

*New record; **new record for the genus.

RESULTS AND DISCUSSION

The chromosome numbers ($2n$), basic numbers and levels of ploidy of the 19 taxa studied are presented in Table 2. Except for the chromosome counts of *Achillea setacea* and *Anthemis tinctoria* var. *tinctoria*, the counts are new to the flora of Turkey. Six of these are also new to science.

The classification adopted here follows that of Bremer & Humphries, 1993).

Subtribe Achilleinae Bremer & Humphries

Achillea biebersteinii Afan.

A7: Gümüshane: near Köse Dağı pass. Grassy stream banks, margins of *Pinus sylvestris* forest, 1800 m a.s.l., 23.vii.2001, *Inceer 142*. $2n = 18$ (Fig. 1).

Our count on Turkish material confirms the existence of two ploidy levels in this species. Our diploid report agrees with three reports from different territories (Watanabe, 2002 and references therein), although we found only one previous record of the tetraploid level, occurring in plants from Poland (Dabrowska, 1989).

A. biserrata Bieb.

A8: Trabzon: Caykara, above the village of Akdoğan. Stony pastures, roadsides, 950 m a.s.l., 24.vi.2001, *Inceer 127*. $2n = 18$.

A7: Trabzon: Zigana Dağı. Open slopes, roadsides, 1700 m a.s.l., 28.vi.2005, *Inceer 188*. $2n = 18$ (Fig. 2).

Our two counts agree with one report of somatic number (Daniela, 1997) and one of gametic number (Fedorov, 1969) in plants from Russia.

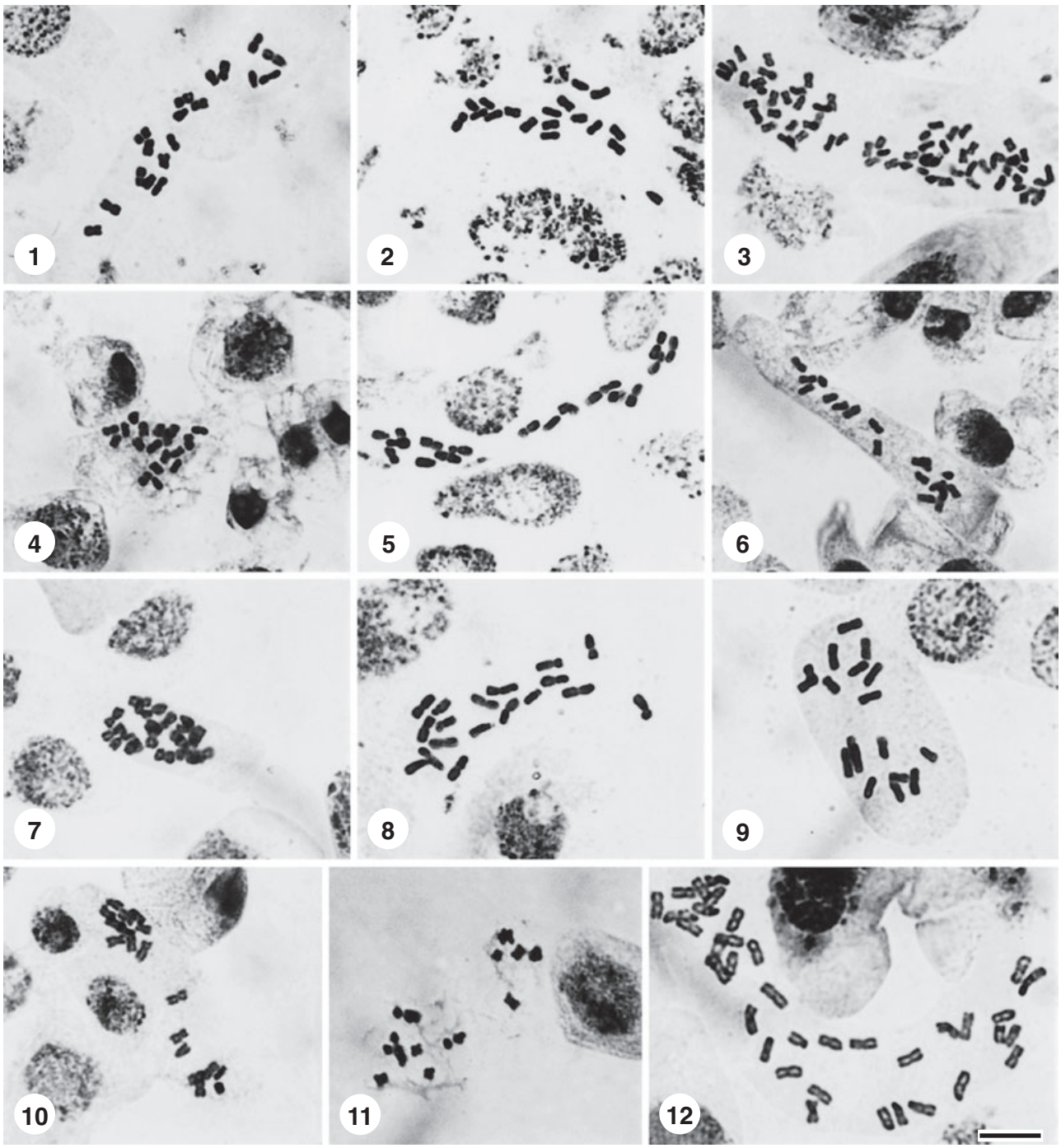
A. millefolium L. ssp. *millefolium*

A7: Gümüshane: Torul. Open slopes, roadsides, 1300 m a.s.l., 28.vi.2005, *Inceer 199*. $2n = 67$ (Fig. 3).

Our count in north-east Anatolian plants disagrees with reports on material from other areas, because many different chromosome numbers and ploidy levels have been assigned to this widespread taxon, $2n = 18$, 27, 34, 35, 36, 44, 45, 48, 54, 63, 72 (Watanabe, 2002 and references therein).

The chromosome number of this taxon was uniform in the five specimens that we studied from one population. It was aneuploid, between $7x$ and $8x$, representing simply a loss of normal chromosomes, as is to be expected of products of the irregular meiosis that occurs in high autopolyploids. The plants' survival results from the presence in them of adequate numbers of complete chromosome sets. This result shows that the aneuploidy in this population is stable. Sexual products of aneuploids at this high ploidy level would be expected to display variation in chromosome number between individuals, so our observations demonstrate that the studied population was a single clone spreading by vegetative or possibly apomictic means.

Downloaded from https://academic.oup.com/botlinnean/article-abstract/153/2/203/2420485 by Karadeniz Teknik University Library (KTU) user on 08 June 2020



Figures 1–12. Somatic metaphases. Fig. 1. *Achillea biebersteinii* (2*n* = 18). Fig. 2. *A. biserrata* (A7 Trabzon, 2*n* = 18). Fig. 3. *A. millefolium* ssp. *millefolium* (2*n* = 67). Fig. 4. *A. setacea* (2*n* = 18). Fig. 5. *Anthemis marschalliana* ssp. *pectinata* (2*n* = 18). Fig. 6. *A. melanoloma* ssp. *trapezuntica* (2*n* = 18). Fig. 7. *A. tinctoria* var. *pallida* (2*n* = 18). Fig. 8. *A. tinctoria* var. *tinctoria* (2*n* = 18). Fig. 9. *A. triumfetti* (2*n* = 18). Fig. 10. *Artemisia absinthium* (2*n* = 18). Fig. 11. *A. austriaca* (2*n* = 16). Fig. 12. *Leucanthemum vulgare* (Zigana Dağı, 2*n* = 36). Scale bar = 10 μm.

Downloaded from https://academic.oup.com/botlinnean/article-abstract/153/2/203/2420485 by Karadeniz Teknik University Library (KTU) user on 08 June 2020

A. setacea Waldst. & Kit.
A7: Trabzon: Zigana Dağı pass. Damp alpine meadows, 2000 m a.s.l., 10.vii.2001, *Inceer 131*. $2n = 18$ (Fig. 4).

Our diploid count agrees with one report from Turkey and many others from different countries (Ehrendorfer, 1959; Gadella & Kliphuis, 1970; Kuzmanov, Georgieva & Nikolava, 1986; Kuzmanov, Zdravkova & Georgieva, 1989; Khaniki, 1995). We found only one previous record of the tetraploid level, in Russian plants (Androshchuk & Kostinenko, 1981).

Subtribe Anthemidinae Dumorf. emend. Bremer & Humphries

Anthemis marschalliana Willd. ssp. *pectinata* (Boiss.) Grierson
A7: Gümüshane: near Limonsuyu. Roadsides and distributed steppe, 2300 m a.s.l., 24.vii.2005, *Inceer 205*. $2n = 18$ (Fig. 5).

According to our data, this is the first report of the chromosome number of the subspecies. It agrees with the number recorded for the species in Russian plants (Watanabe, 2002).

A. melanoloma Trautv. ssp. *trapezuntica* Grierson
A7: Gümüshane: near Limonsuyu. Limestone slopes and screes, distributed steppe, 2300 m a.s.l., 24.vii.2005, *Inceer 204*. $2n = 18$ (Fig. 6).

To our knowledge, this is the first report for this subspecies. It agrees with the number recorded for the species in Russian plants (Magulaev, 1992).

A. tinctoria L. var. *pallida* DC.
A7: Trabzon: Araklı above village of Ayvadere. Roadsides, margins of fields, boggy ground, 300 m a.s.l., 2.vii.2005, *Inceer 202*. $2n = 18$ (Fig. 7).

According to our data, this is the first report of the chromosome number of this variety. It agrees with the number recorded for the species (Watanabe, 2002 and references therein).

A. tinctoria L. var. *tinctoria*
A7: Gümüshane: *Pinus* forests near Torul. Roadsides, streamsides, 1400 m a.s.l., 28.vi.2005, *Inceer 194*. $2n = 18$ (Fig. 8).

Our diploid count agrees with one report from Turkish material and many others from different territories (Watanabe, 2002 and references therein). This number is shown to be very stable, because it is also the same in many other reports based on plants from very different regions.

A. triumfetti (L.) All.
A7: Gümüshane: *Pinus* forests near Köse Dağı pass. Rocky slopes and meadows, 1800 m a.s.l., 23.vii.2001, *Inceer 141*. $2n = 18$ (Fig. 9).

Our count agrees with the only three previous ones, on Spanish and Italian plants (Watanabe, 2002 and references therein).

Subtribe Artemisiinae Less. emend. Bremer & Humphries

Artemisia absinthium L.
A7: Gümüshane*: Pinus* forests near Köse Dağı pass. Slopes, streamsides, 1800 m a.s.l., 23.vii.2001, *Inceer 139*. $2n = 18$ (Fig. 10).

Our count agrees with many others from different territories (Watanabe, 2002 and references therein). This number is shown to be very stable, because it is also the same in many other reports based on plants from different regions.

A. austriaca Jacq.
A7: Gümüshane: *Pinus* forests near Köse Dağı pass. Slopes, streamsides, roadsides, 23.vii.2001, *Inceer 140*. $2n = 16$ (Fig. 11).

Different chromosome numbers and ploidy levels have been assigned to this species; $2n = 16$ in populations from Poland (Skalinska, Czapic & Piotrowicz, 1959) and Bulgaria (Kuzmanov *et al.*, 1986; Kuzmanov, 1993); $2n = 32$ in a Russian population (Lavrenko & Serditov, 1991); $2n = 36$ in a Slovak population (Kawatani & Ohno, 1964); $2n = 48$ in a Slovak population (Majovsky & Murin, 1987); one Hungarian and one Austrian population (Feráková, 1997) and one Armenian and one Iranian population (Torrel *et al*., 2001) and $2n = 54$ in an Iranian population (Tavassoli & Derakhshandeh-Peikar, 1993) and in a Slovak population (Feráková, 1997).

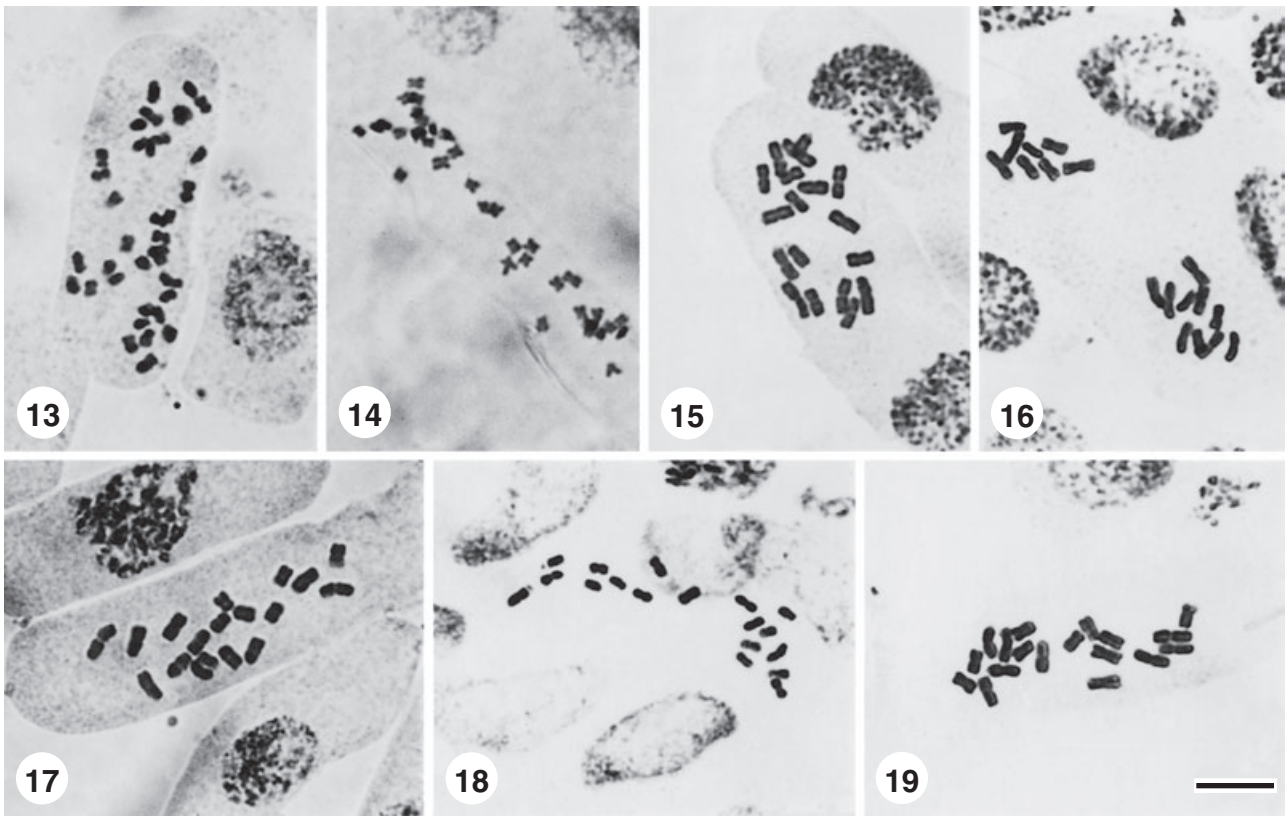
Our diploid count is based on $x = 8$. This basic number is frequent in section *Absinthium*; moreover, some members of section *Artemisia* with $x = 8$ appear in the *Absinthium* clade in the ITS phylogeny (Torrel *et al*., 1999). For *A. austriaca*, Feráková (1997) concluded that the diploid populations belong to var. *advena* Rech. f., but did not cite the tetraploid and the hexaploid cytotypes based on $x = 9$.

Subtribe Lecantheminae Bremer & Humphries

Leucanthemum vulgare Lam.
A7: Trabzon: Zigana Dağı. Grassy slopes, stony pastures, meadows, 1700 m a.s.l., 30.vi.2005, *Inceer 200*. $2n = 36$ (Fig. 12).
A7: Trabzon: Araklı, above Catak. Roadsides, 900 m a.s.l., 31.vii.2005. $2n = 36$.

Our counts agree with many other reports on material from other areas (Watanabe, 2002 and references therein). They confirm that the tetraploid level predominates in this species, although diploid, hexaploid and octoploid levels have also been reported in Austrian, Bulgarian and German plants ($2n = 18$;

Downloaded from https://academic.oup.com/botlinnean/article-abstract/153/2/203/2420485 by Karadeniz Teknik University Library (KTU) user on 08 June 2020



Figures 13–19. Somatic metaphases. Fig. 13. *Tripleurospermum callosum* (2*n* = 36). Fig. 14. *T. sevanense* (2*n* = 36). Fig. 15. *Tanacetum albipannosum* (2*n* = 18). Fig. 16. *T. coccineum* ssp. *chamaemelifolium* (Artvin, 2*n* = 18). Fig. 17. *T. macrophyllum* (2*n* = 18). Fig. 18. *T. parthenium* (2*n* = 18). Fig. 19. *T. sorbifolium* (2*n* = 18). Scale bar = 10 μm.

Teppner, 1980: 2*n* = 54; Van Loon & Van Setten, 1982: 2*n* = 72; Lippert & Heubl, 1989).

Subtribe Matricariinae Bremer & Humphries

Tripleurospermum callosum (Boiss. & Meldr.) E. Hossain

A9: Artvin: Savsat, above Sahara National Park. Damp subalpine pastures, roadsides and grassy slopes, 1900 m a.s.l., 8.vi.2002, *Inceer 149*. 2*n* = 36 (Fig. 13).

The present count agrees with the previous ones carried on this Turkish endemic species in north-east Anatolian populations (Inceer & Beyazoglu, 2004; Garcia *et al*., 2005).

T. sevanense (Manden.) Pobed.

A8: Rize: Ikizdere, between Ikizdere and Anzer. Streamsides and roadsides, 1400 m a.s.l., 12.vii.2001, *Inceer 138*. 2*n* = 36 (Fig. 14).

Our count confirms the existence of the tetraploid cytotype of this species, reported by Inceer & Beyazoglu (2004) and Garcia *et al*. (2005) on Turkish material. Apart from this, one count on Armenian plants has reported the diploid level, 2*n* = 18 (Avetisian & Oganesian, 1995).

Subtribe Tanacetinae Bremer & Humphries

Tanacetum albipannosum Hub.-Mor. & Grierson

A7: Trabzon: Zigana Dağı. Stony pastures on limestone and roadsides, 1600 m a.s.l., 28.vi.2005, *Inceer 191*. 2*n* = 18 (Fig. 15).

To our knowledge, this is the first report of the chromosome number of this species, which is endemic to Turkey.

T. coccineum (Willd.) Grierson ssp. *chamaemelifolium* (Somm. & Lev.). Grierson

A8: Rize: Caykara, above the village of Akdoğan. Stony pastures, meadows and roadsides, 1450 m a.s.l., 24.vi.2001, *Inceer 125*. 2*n* = 18.

A9: Artvin: Savsat, above Sahara National Park. Damp subalpine pastures on limestone and grassy slopes, 15.vi.2002, *Inceer 153*. 2*n* = 18 (Fig. 16).

According to our data, this is the first report of the chromosome number of subspecies. Our counts, the same in both populations studied, agree with the num-

Downloaded from https://academic.oup.com/botlinnean/article-abstract/153/2/203/2420485 by Karadeniz Teknik University Library (KTU) user on 08 June 2020

ber recorded for the species (Watanabe, 2002 and references therein).

T. macrophyllum Sch. Bip.
A7: Trabzon: Araklı, between Dağbasi and Pazarcik. Roadsides and streamsides, 1300 m a.s.l., 24.vii.2005, *Inceer 203*. $2n = 18$ (Fig. 17).

The count confirms four previous reports on material from other areas (Watanabe, 2002 and references therein), although we found only one previous record of the tetraploid level ($2n = 36$), in Hungarian plants (Sz.-Borsos, 1970). In addition, Kuzmanov, Thin & Georgieva. (1981) reported $2n = 14$ in Bulgarian material.

T. parthenium Sch. Bip.
A7: Gümüshane: *Pinus* forests near Torul. Roadsides, streamsides, stony pastures, 1400 m a.s.l., 28.vi.2005, *Inceer 193*. $2n = 18$ (Fig. 18).

Our count agrees with previous reports (Watanabe, 2002 and references therein), although we found only one previous record of the tetraploid level in German plants (cult.) (Abd. El-Twab & Kordo, 2001). In addition, Vilmorin & Chopinet (1954) reported $2n = 16$ in material from France (cult.).

T. sorbifolium (Boiss.) Grierson
A8: Trabzon: Caykara, above the village of Akdoğan. Stony pastures and roadsides, 950 m a.s.l., 24.vi.2001, *Inceer 129*. $2n = 18$ (Fig. 19).

To our knowledge, this is the first report of the chromosome number of this species.

CONCLUSIONS

Most of the Anthemideae studied have the basic number $x = 9$, which is predominant in this tribe and in the entire family Asteraceae (Solbrig, 1977; Schweizer & Ehrendorfer, 1983; Oliva & Valles, 1994; Valles & Siljak-Yakovlev, 1997; Valles *et al*., 2001; Inceer & Beyazoglu, 2004; Valles *et al*., 2005). Among the considered taxa, only *Artemisia austrica* has the less common basic number $x = 8$; this is evidence for the descending dysploidy that occurs in the genus (Valles & Siljak-Yakovlev, 1997; Torrel *et al*., 2001). This phenomenon is common in many genera of the family Asteraceae (Fernandez Casas & Susanna, 1986; Siljak-Yakovlev, 1996; Torrel *et al*., 2001; Valles *et al*., 2001, 2005).

Polploidy is another relevant evolutionary mechanism in plants (Bretagnolle *et al*., 1998 and references therein) and in some groups of the Anthemideae in particular (Solbrig, 1977; Valles *et al*., 2001, 2005; Inceer & Beyazoglu, 2004; Guo *et al*., 2005). This statement is supported by the present study, because five populations belonging to different Anthemideae genera studied (*Achillea*, *Leucanthemum*, *Tripleurospermum*) are polyploid, four being tetraploid and one heptaploid or octoploid.

Subtribal classifications of the Anthemideae were elaborated cladistically by Bremer & Humphries (1993). In that classification, except for the subtribe Tanacetinae, which is at best paraphyletic, other subtribes (Achilleinae, Anthemidinae, Artemisiinae, Leucantheminae, Matricariinae) are monophyletic. However, molecular studies in the Anthemideae (Francisco-Ortega *et al*., 1997; Oberprieler & Vogt, 2000; Watson, Evans & Boluarte, 2000) revealed that these subtribes are not monophyletic. Chromosome morphometries of the studied genera show that the subtribes of the Anthemideae may be heterogenous groups. A combination of detailed karyotype analysis with molecular studies is needed in order to achieve a convenient classification of this pool of plants.

ACKNOWLEDGEMENTS

We thank Miss Melahat Ozcan for her help in collecting some of the plant material. We also thank Dr P. E. Brandham (Royal Botanic Gardens, Kew) for his suggestions that improved the manuscript.

REFERENCES

Abd. El-Twab MH, Kondo K. 2001. Molecular cytogenetic identification of the parental genomes in the intergeneric hybrid between *Leucanthemella linearis* and *Nipponanthemum nipponicum* during meiosis and mitosis. *Cytologia* **54:** 109–114.

Androshchuk AF, Kostinenko LD. 1981. Chromosome numbers of the genus *Achillea* L. certain species cultivated in botanical garden. *Ukrajinsk Botanicheskii Zhurnal (Kiev)* **38:** 53–57.

Avetisian VE, Oganesian ME (eds). 1995. *Flora Armenii 9. Campanulacae, Asteraceae.* Havlickuv Brod: Koeltz Scientific Books.

Bremer K. 1994. *Asteraceae. Cladistics and classification*. Portland, OR: Timber Press.

Bremer K, Humphries CJ. 1993. Generic monograph of the Asteraceae-Anthemideae. *Bulletin of the Natural History Museum of London, Botany Series* **23:** 71–177.

Bretagnolle F, Felber F, Calame FG, Küpfer P. 1998. La polyloidie chez les plantes. *Botanica Helvetica* **108:** 5–37.

Dabrowska J. 1989. The chromosome numbers of several taxa of the genus *Achillea* L. *Acta Societatia Botanicae Polonia* **58:** 163–177.

Daniela I. 1997. IOPB chromosome data 11. *Newsletter of the Institute of Plant Biosystematics (Zürich)* **26–27:** 13–14.

Ehrendorfer F. 1959. Spontane chromosomen aberrationen und andere meiosestoriingen bei diploiden sippen des *Achillea millefolium*-komplexes. *Chromosoma* **10:** 365–406.

Fedorov AA, ed. 1969. *Chromosome numbers of flowering plants*. Leningrad: Nauka.

Downloaded from https://academic.oup.com/botlinnean/article-abstract/153/2/203/2420485 by Karadeniz Teknik University Library (KTU) user on 08 June 2020

Feráková V. 1997. *Artemisia austriaca* – a critical species from the karyotaxonomical point of view. *Preslia* **69:** 95–113.

Fernandez Casas J, Susanna A. 1986. Monografia la section *Chamaecyanus* Willkomm del genero *Centaurea* L. *Treballs de l'Institut Botanic de Barcelona* **10:** 5–174.

Francisco-Ortega J, Santos-Guerra A, Hines A, Jansen RK. 1997. Molecular evidence for a Mediterranean origin of the Macaronesian endemic genus *Argyranthemum* (Asteraceae). *American Journal of Botany* **84:** 1595–1613.

Gadella TWJ, Kliphuis E. 1970. Cytotaxonomic investigations in some angiosperms collected in the Valley of Aosta and in the National Park 'Gran Paradiso'. *Caryologia* **23:** 363–379.

Garcia S, Inceer H, Garnatje T, Valles J. 2005. Genome size variation in some representatives of the genus *Tripleurospermum*. *Biologia Plantarum* **49:** 381–387.

Guo YP, Saukel J, Mittermayr R, Ehrendorfer F. 2005. AFLP analyses demonstrate genetic divergence, hybridization, and multiple polyploidization in the evolution of *Achillea* (Asteraceae-Anthemideae). *New Phytologist* **166:** 273–290.

Inceer H, Beyazoglu O. 2004. Karyological studies in *Tripleurospermum* (Asteraceae, Anthemideae) from north-east Anatolia. *Botanical Journal of the Linnean Society* **146:** 427–438.

Inceer H, Hayirlioglu-Ayaz S, Beyazoglu O. 2002. Cytotaxonomic investigations on some taxa of the genus *Vicia* L. from north-eastern Anatolia. *Acta Botanica Gallica* **149:** 125–138.

Johnson MAT, Brandham PE. 1997. New chromosome numbers in petaloid monocotyledons and other miscellaneous angiosperms. *Kew Bulletin* **52:** 121–138.

Kawatani T, Ohno T. 1964. Chromosome numbers in *Artemisia*. *Bulletin of the National Institute of the Hygienic Sciences* **82:** 183–193.

Khaniki GB. 1995. Chromosome numbers and morphometry in *Achillea* (Anthemideae, Compositae). *Nucleus (Calcutta)* **38:** 104–111.

Kuzmanov B. 1993. Chromosome numbers of Bulgarian angiosperms: An introduction to a chromosome atlas of the Bulgarian flora. *Flora Mediterranea* **3:** 19–163.

Kuzmanov BA, Thin N, Georgieva SB. 1981. A cytotaxonomic study on Bulgarian *Anthemis* species. *Candollea* **36:** 19–76.

Kuzmanov BA, Georgieva SB, Nikolava VA. 1986. Chromosome numbers of Bulgarian flowering plants. I. Fam: Asteraceae. *Fitologija (Sofia)* **31:** 71–74.

Kuzmanov BA, Zdravkova MA, Georgieva SB. 1989. Varibility of the Bulgarian narrow species from the group *Achillea millefolium* and *A. crithmifolia*. I. Morphological and karyological study. *Fitologija (Sofia)* **36:** 26–43.

Lavrenko AN, Serditov NP. 1991. Chisla khromosom nekotorikh vidov rastenii iugo-zapadna Komi ASSR. (Chromosome numbers in some plant species from the south–west of the Komi ASSR.) *Botanicheskii Zhurnal* **76:** 769–771.

Lippert W, Heubl GR. 1989. Chromosomenzahlen von pflanzen aus Bayern und abgrenzenden Gebieten: (Teil 1). *Berichte der Bayerischen Botanischen Gesellschaft* **60:** 73–83.

Magulaev AJ. 1992. Chromosome numbers in some species of vascular plants of the northern Caucasus flora. *Botanicheskii Zhurnal* **77:** 88–90.

Majovsky J, Murin A (eds). 1987. *Karyotaxonomicky prehl'ad flory Slovenska.* Bratislava: Veda vydavatel'stvo Slovenskej Akademie Vied.

Martin-Noguet D. 1969. Contribution a l'etude cytotaxinomique des *Achillea* et des *Phyrethrum* de Turquie. *Bulletin Societé Botanica de France (Acta Botanica Gallica)* **116:** 197–206.

Nemli Y. 1977. İzmir yöresinde yaygın bazı *Chrysanthemum* türleri üzerinde sitotaksonomik araştırmalar. *Bitki* **4:** 376–380.

Oberprieler C, Vogt R. 2000. The position of *Castrilanthemum* Vogt & Oberprieler and the phylogeny of Mediterranean Anthemideae (Compositae) as inferred from nrDNA ITS and cpDNA *trn*L/*trn*F IGS sequence variation. *Plant Systematics and Evolution* **225:** 145–170.

Oliva M, Valles J. 1994. Karyological studies in some taxa of the genus *Artemisia* (Asteraceae). *Canadian Journal of Botany* **72:** 1126–1135.

Schweizer D, Ehrendorfer F. 1983. Evolution of C-band patterns in Asteraceae-Anthemideae. *Biologisches Zentralblatt* **102:** 637–655.

Siljak-Yakovlev S. 1996. La dysploidie et l'evolution du caryotype. *Bocconea* **5:** 211–220.

Skalinska M, Czapic R, Piotrowicz M. 1959. Further studies in chromosome numbers of Polish angiosperms (dicotyledons). *Acta Societatia Botanicae Poloniae* **28:** 487–529.

Solbrig OT. 1977. Chromosomal cytology and evolution in the family Compositae. In: Heywood VH, Harborne JB, Turner BL, eds. *The biology and chemistry of the Compositae*, Vol. I. London: Academic Press, 269–281.

Strid A. 1987. Chromosome numbers of Turkish mountain plants. An annotated list of 34 taxa. *Notes from the Royal Botanic Garden (Edinburgh)* **44:** 351–356.

Strid A. 1980. IOPB Chromosome number reports LXIX. *Taxon* **29:** 709–710.

Sz.-Borsos O. 1970. Contributions to the knowledge on the chromosome numbers of Phanerogams growing in Hungary and southeastern Europe. *Acta Botanica Academiae Scientiarum Hungarica* **16:** 255–265.

Tavassoli A, Derakhshandeh-Peikar P. 1993. Chromosome numbers of some *Artemisia* L. species from Iran. *Iranian Journal of Botany* **6:** 169–175.

Teppner H. 1980. Karyologie und systematik einiger Gefabpflanzen der Ostalpen. *Phyton (Horn)* **20:** 73–94.

Torrel M, Valles J, Garcia-Jakas N, Mozaffarian V, Gabrielian E. 2001. New or rare chromosome counts in the genus *Artemisia* L. (Asteraceae, Anthemideae) from Armenia and Iran. *Botanical Journal of the Linnean Society* **135:** 51–60.

Torrell M, Garcia-Jacas N, Susana A, Valles J. 1999. Phylogeny in *Artemisia* (Asteraceae, Anthemideae) inferred from nuclear ribosomal DNA (ITS) sequences. *Taxon* **48:** 721–736.

Valles J, Garnatje T, Garcia S, Sanz M, Korobrow A. 2005. Chromosome numbers in the tribes Anthemideae and Inuleae (Asteraceae). *Botanical Journal of the Linnean Society* **148:** 77–85.

Downloaded from https://academic.oup.com/botlinnean/article-abstract/153/2/203/2420485 by Karadeniz Teknik University Library (KTU) user on 08 June 2020

Valles J, Siljak-Yakovlev S. 1997. Cytogenetic studies in the genus *Artemisia* L. fluorochrome banded karyotypes of five taxa, including the Iberian endemic species *Artemisia barrelieri* Beser. *Canadian Journal of Botany* **75:** 595–606.

Valles J, Torrell M, Garcia-Jakas N, Kapustina L. 2001. New or rare chromosome counts in the genera *Artemisia* L. & *Mausolea* Bunge (Asteraceae, Anthemideae) from Uzbekistan. *Botanical Journal of the Linnean Society* **135:** 391–400.

Van Loon JC, Van Setten AK. 1982. IOPB chromosome number reports LXXVI. *Taxon* **31:** 574–598.

Vilmorin R, Chopinet R. 1954. Contribution a I'etude des nombres chromosomiques des races et varietes cultivees chez nos plantes ornamentales. *Caryologia* **6:** 1006–1015.

Watanabe W. 2002. Index to chromosome numbers in Asteraceae. http://www-asteraceae.cla.kobe-u.ac.jp/index.html.

Watson LE, Evans TM, Boluarte T. 2000. Molecular phylogeny and biogeoraphy of tribe Anthemideae (Asteraceae), based on chloroplast gene *ndh*F. *Molecular Phylogenetics and Evolution* **15:** 59–69.

Downloaded from https://academic.oup.com/botlinnean/article-abstract/153/2/203/2420485 by Karadeniz Teknik University Library (KTU) user on 08 June 2020