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ANTIOXIDANT CAPACITY OF PHENOLICS IN SOME REPRESENTATIVES OF THE TRIBE ANTHEMIDEAE (ASTERACEAE) FROM TURKEY

Nesrin Colak [1], Huseyin Inceer [1], Jiri Gruz [2], Miroslav Strnad [2], Sema Hayirlioglu-Ayaz [1], Nursen Aksu-Kalmuk [1] and Faik Ahmet Ayaz [*1]

Department of Biology [1], Faculty of Science, Karadeniz Technical University - 61080, Trabzon, Turkey. Laboratory of Growth Regulators and Department of Chemical Biology and Genetics [2], Centre of the Region Hana for Biotechnological and Agricultural Research, Faculty of Science, Palacky University and Institute of Experimental Botany AS CR, Slechtitelu 11, CZ-783 71 Olomouc, Czech Republic.

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Correspondence to Author:
Prof. Dr. Faik Ahmet Ayaz

PhD,
Department of Biology,
Faculty of Science, Karadeniz Technical University - 61080,
Trabzon, Turkey.

E-mail: faa@ktu.edu.tr

ABSTRACT: Members of the tribe Anthemideae (Asteraceae) attract considerable medicinal attention worldwide and are used for the treatment of many infectious and degenerative diseases in humans due to their biologically active compounds. The aim of this study was to evaluate the antioxidant property of total phenolic compounds (TPC) and flavonoids (TF) in the capitula of 41 representatives and endemic taxa belonging to seven genera (*Achillea*, *Anthemis*, *Artemisia*, *Glebionis*, *Matricaria*, *Tanacetum* and *Tripleurospermum*) native to Turkey. The results of the experiments showed that the phenolics of the taxa were significantly correlated and associated with their antioxidant capacity values. Our findings will be useful to researchers and others who are interested in the antioxidant potentials of the herbs as dietary supplements. This is the first report to describe the phenolic compound and antioxidant capacity values of capitula only in selected taxa of Anthemideae.

INTRODUCTION: The health promoting effects of plant phenolic compounds as natural chemo-preventive compounds against infectious or age-related degenerative diseases have received wide attention in the past two decades. This interest has opened up a new era in terms of using the unique source of biologically active compounds to scavenge free radicals and reactive oxygen species (ROS) in biological systems synthesized as a consequence of both enzymatic and non-enzymatic reactions in many diseases [1, 2].

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Many edible plants (mostly spices and aromatic herbs) are capable of producing these natural chemo-preventive compounds which have no synthetic counterparts and which play a protective role in human health maintenance [3].

Some 5% or more of inhaled oxygen (O_2) is converted into highly reactive and potentially harmful oxygen-containing free radicals known as reactive oxygen species (ROS) [hydroxyl radical ($^{\bullet}OH$), superoxide anion radical ($O^{\bullet-}_2$), hydrogen peroxide (H_2O_2), oxygen singlet ($^1O_2$), hypochlorite (ClO^{1-}), nitric oxide radical ($\cdot NO$) and peroxynitrite radical ($ONOO^-$)] in many diseases, in the respiratory chain, in phagocytosis, in prostaglandin synthesis, and in the cytochrome P-450 system, *etc.* [1, 2]. The adverse effects of ROS or free radicals on normal growth, development and metabolism in plants and animals can be eliminated by natural

(phenolics, flavonoids, anthocyanins) or synthetic antioxidants (butylated hydroxyl anisole [BHA], butylated hydroxyl toluene [BHT]) [4]. Synthetic antioxidants are commercially available and are used in 50,200 ppm in foods. However, these have many side-effects in humans, such as mutagenesis and carcinogenesis. Natural antioxidants are safe and also bioactive, being able to quench oxygen-derived free radicals, or ROS, by donating a hydrogen atom or an electron to the free radical [2].

Epidemiological studies have demonstrated a positive linear correlation between the phenolic content and antioxidant capacity of fruits, vegetables and herbs. Various studies have also confirmed a relationship leading to potential health-promoting effects in humans. The antioxidant capacities of phenolic compounds are mainly due to their redox properties, which can play an important role in adsorbing and neutralizing free radicals, quenching singlet and triplet oxygen or decomposing peroxide and exhibiting anti-inflammatory, anti-carcinogenic and anti-atherosclerotic properties [2, 5]. In addition to fruits and vegetables, another important source of antioxidants is herbs that contain high levels of antioxidant compounds (phenolics, flavonoids, anthocyanins, Vitamin C, Vitamin E, carotenoids, *etc*.). A lower risk of age-related disease, such as CVDs and also many types of cancer, has been attributed to frequent consumption of these. The total antioxidant potential of phenolic substances (flavonoids, phenolic acids and tannins, *etc*.) in a balanced diet in terms of daily intake is therefore more effective compared to the individual levels of specific antioxidants such as Vitamin C and Vitamin E in protecting the body against various oxidative stresses [6].

Polynutrients and nutraceuticals obtained from herbs have been used for a wide range of purposes (including for medicines, nutrition, flavorings, beverages, dyes, pest repellents, fragrances, cosmetics, charms, and for smoking) and industrial uses since prehistoric times. This use is continuing to expand rapidly across the world, with many people now employing such products to treat various health issues in different national healthcare settings. It is important to emphasize the rapidity at which interest in and use of herbal medicines is expanding. Over the past decade, the use of herbal medicines represents approximately 40% of all healthcare services delivered in China, while the percentages of the population that have used herbal medicines at least once in Australia, Canada, the USA, Belgium, and France are estimated at 48%, 70%, 42%, 38%, and 75%, respectively [7]. Interest is also growing among consumers and the scientific community in finding safe, naturally occurring antioxidants, particularly those also present in herbs, for use in foods or medicinal materials to replace synthetic antioxidants, which are being restricted due to their carcinogenicity [6].

Although distributed worldwide, the taxa of the tribe Anthemideae (Asteraceae) are concentrated in Central Asia, the Mediterranean region and South Africa. Some members of the sub-tribe have discrete ranges and very obvious areas of endemism [8]. Aerial parts of the members of the tribe have for long been used as medicinal herbs in folk and alternative medicines or traditional medicines in most countries [9]. These may possess more potent antioxidant activity than common dietary plants. Capitula are one of the best potential sources of biologically active compounds due to the flavonoids being in the plants, rather than in the leaves. They are often used as herbal teas and decoction preparations in the home. Much research has been conducted into essential oil compositions of the taxa in the tribe [9]. Fatty acids in the composition of the capitula of 44 taxa belonging to seven genera (*Achillea, Anthemis, Artemisia, Glebionis, Matricaria, Tanacetum* and *Tripleurospermum*) of the tribe Anthemideae (Asteraceae) from Turkey have recently been reported [3]. However, little is known about their phenolic compound content and antioxidant capacity. This scarcity prompted us to investigate and report the antioxidant capacity (ORAC, DPPH, FRAP and CUPRAC) and total phenolic compounds (TPC) or flavonoids (TF) contents in the capitula of 41 taxa belonging to seven genera (*Achillea, Anthemis, Artemisia, Glebionis, Matricaria, Tanacetum* and *Tripleurospermum*) in the tribe native to Turkey. This is the first report to describe the phenolic compound and antioxidant capacity values measured using four assays (ORAC, DPPH, FRAP and CUPRAC) of capitula in some representatives of Anthemideae.

MATERIALS AND METHODS:

Plant Material: Mature capitula of 41 taxa, belonging to 42 populations, in the tribe Anthemideae were used for chemical analysis. Capitula belonging to 5 individual taxa from the populations were collected from natural bulk populations in Turkey (**Table 1**). Plant vouchers are deposited in the herbarium at the Karadeniz Technical University, Department of Biology (KTUB). The capitula were removed from the fruit debrises and used for extraction.

TABLE 1: LOCALITY AND VOUCHER NUMBER OF THE INVESTIGATED SPECIES

Taxon	Locality	Voucher
Achillea arabica Kotschy	A7 Gumushane: Kose Mountain, 1800 m a.s.l., 23.vii.2001.	Inceer 142
A. bisserata M. Bieb.	A7 Gumushane: Zigana Mountain, between Zigana Pass and Torul, 1200-1300 m a.s.l., 22.vii.2008.	Inceer 668
A. multifida (DC.) Griseb.	A2 Bursa: Uludag, 1820 m a.s.l., 27.vi.2007.	Inceer 357
A. santolinoides subsp. *wilhelmsii* (K. Koch) Greuter	A7 Gumushane: Near Keci Castle, 1526 m a.s.l., 04.iv.2007.	Inceer 377
Anthemis cotula L.	A2 Bursa: Uludag-Bursa road, 1050 m a.s.l., 28.vi.2007.	Inceer 368
A. macrotis (Rech. f.) Oberpr. and Vogt	C1 Mugla: Near Koycegiz, 11 m a.s.l., 10.iv.2008.	Inceer 498
Artemisia annua L.	A7 Trabzon: Near KTU, Kanuni Campus, 100 m a.s.l., 02.x.2008.	Inceer 708
A. austriaca Jacq.	A7 Gumushane: Kose Mountain, 1800 m a.s.l., 23.vii.2001.	Inceer 140
A. santonicum L.	A9 Erzurum: Near Olur, 983 m a.s.l., 19.vii.2007.	Inceer 445
Glebionis coronaria (L.) Spach	C1 Aydin: Kusadası, 10 m a.s.l., 08.iv.2008.	Inceer 483
Matricaria aurea (Loefl.) Sch. Bip.	C1 Gaziantep/Sanliurfa: Between Nizip-Birecik, near Dutlu, 440 m a.s.l., 08.v.2007.	Inceer 322
M. chamomilla L. *var. chamomilla*	C3 Antalya: Between Tahtalibeli and Antalya, 618 m a.s.l., 19.iv.2007.	Inceer 318
M. chamomilla L. *var. recutita* (L.) Fiori	1A Edirne: From Tekirdag to Kesan, near Kesan, 100 m a.s.l., 11.v.2007.	Inceer 326
M. matricarioides (Less.) Porter ex Britton	A9 Kars: Kar - Ardahan, Gole Road, 1800 m a.s.l., 18.vii.2007.	Inceer 420
Tanacetum vulgare L.	A7 Giresun: Between Sehitler Pass and Sebinkarahisar, 1583 m a.s.l., 21.vii.2008.	Inceer 662
Tripleurospermum callosum (Boiss and Hedlr.) E. Hossain	A5 Kastamonu: Tosya, Ilgaz Mountain Pass, 1620 m a.s.l., 25.vii.2007.	Inceer 451
T. caucasicum (Willd.) Hayek	A8 Rize: Ayder, Yukari Kavrun, 2000 m a.s.l., 11.vii.2009.	Inceer 765
T. conoclinium (Boiss. and Bal.) Hayek	B2 Izmir: Bozdag, 1178 m a.s.l., 14.iv.2007.	Inceer 264
T. corymbosum E. Hossain	B9 Agri: Sulucem (Musun), Balik Golu, 2098 m a.s.l., 11.vii.2008.	Inceer 612
T. decipiens (Fisch. and C. A. Mey.) Bornm.	B3 Eskisehir: From Eskisehir to Emirdag, 968m a.s.l., 10.vi.2008.	Inceer 549
T. disciforme(C. A. Mey.) Sch. Bip.	B2 Izmir: Bozdaglar, Golcuk Plateau, 1057 m a.s.l., 06.vii.2008.	Inceer 593
T. elongatum (DC.) Bornm.	A8 Rize: Between Rize and Ispir, Yukariozbag Village, 1245 m a.s.l., 28.v.2008.	Inceer 517
T. fissurale (Sosn.) E. Hossain	A8 Artvin: Between Ispir and Yusufeli, 10 km to Yusufeli, 653 m a.s.l., 31.v.2008.	Inceer 533
T. heterolepis (Freyn and Sint.) Bornm.	A7 Gumushane: Kecikaya Village, 1618 m a.s.l., 04.vii.2007.	Inceer 382b
T. hygrophilum (Bornm.) Bornm.	B1 Izmir: Yamanlar Mountain, 900 m a.s.l., 15.iv.2007.	Inceer 274
T. inodorum (L.) Sch. Bip.	A9: Erzurum: Between Horasan and Karaurgan, 1936 m a.s.l., 11.vii.2008.	Inceer 603
T. kotschyi (Boiss.) E. Hossain	C5 Nigde: Ulukişla, Bolkar Mountains, near Karagol, 2600 m a.s.l., 29.vii.2008.	Inceer 702
T. melanolepis (Boiss. and Buhse)	A9 Artvin: Savsat, near Camlibel Pass, 2550-2600	Inceer 741

Pobed.	m a.s.l., 20.vi.2009.	
T. microcephalum (Boiss.) Bornm.	B8 Mus: Near fallow fields, 1323 m a.s.l., 09.vii.2008.	Inceer 594
T. monticolum (Bornm. and A. Huet) Bornm.	B8 Erzurum: Palandoken Mountain, 2907 m a.s.l., 13.vii.2008.	Inceer 639
T. oreades var. oreades (Boiss.) Rech. f.	A8 Erzurum: Ispir, Ovit Mountain, 2418 m a.s.l., 05.vii.2009.	Inceer 761
T. oreades (Boiss.) Rech. f. var. *tchihatchewii* (Boiss.) E. Hossain	A8 Rize: Ikizdere, Ovit Mountain, 2240 m a.s.l., 05.vii.2009.	Inceer 760
T. parviflorum (Willd.) Pobed	B2 Izmir: Bozdag, 1154 m a.s.l., 14.iv.2007.	Inceer 265
T. pichleri (Boiss.) Bornm.	A2 Bursa: Uludag, near hotels, 1900 m a. s. l., 27.vi.2007.	Inceer 362
T. rosellum (Boiss. and Orph.) Hayek var. *album* E. Hossain	A1 Canakkale: Gokceada, between centrum and Derekoy, 220 m a.s.l., 17.iv.2009.	Inceer 719
T. rosellum (Boiss. and Orph.) Hayek var. *album* E. Hossain	A8 Rize: Between Ikizdere and Cimil, 1800-1850 m a.s.l., 23.vii.2009.	Inceer 766
T. sevanense (Manden.) Pobed.	B3 Eskişehir: Catacık, 1304 m a.s.l., 27.vi.2007.	Inceer 369b
T. subnivale Pobed.	A8 Rize: Ayder, Yukari Kavrun, 2278 m a.s.l., 23.vii.2008.	Inceer 671
T. tempskyanum (Freyn and Sint.) Hayek	A2 Bursa: Near Uludag hotels, 1690 m a.s.l., 27.vi. 2007.	Inceer 354
T. tenuifolium (Kit.) Freyn	A2 Bursa: Uludag, near hotels, 1690 m a.s.l., 27.vi.2007.	Inceer 353
T. transcaucasicum (Manden.) Pobed.	A9 Kars: Yalnizcam Mountains, from Gole to Olur, 1980 m a.s.l., 19.vii.2007.	Inceer 438
T. ziganaense Inceer and Hayirlıoglu-Ayaz	A7 Gumushane: Zigana Mountain, between Zigana Pass and Torul, 1300 m a.s.l., 22.vii.2008.	Inceer 666

Extraction: Approximately 1 g of pulverized dry capitulum sample was first extracted twice (10 mL for each) with petroleum ether to remove fat and other non-polar compounds. The defatted sample was then extracted for TPC content using aqueous methanol (80%, v/v, 10mL for each). The homogenates were combined and centrifuged at 8000 g for 20 min at 15 °C. The supernatants were next concentrated using a rotary evaporator (Heidolph Instruments GmbH and Co. KG, Germany) under reduced pressure at 35 °C with N_2 (0.999%) flash. The residue was then dried using a lyophilizator (Christ, Alpha 1-2LD plus, Germany), dissolved in 10ml deionized water (DIW) and used for measurements.

Determination of Total Phenolic Compounds (TPC) Content: The TPC content of the extract was determined colorimetrically using Folic-Ciocalteu (FC) reagent (Merck, Darmstad) as described by Slinkard and Singleton [10]. Different concentrations of gallic acid (GA) were prepared for a standard curve, and the results were expressed as gallic acid equivalents per gram dry weight (mg GAE/g dw). Briefly, a 1.5 mL reaction mixture (500 µL sample, 975 µL 2% Na_2CO_3 and 25 µL FC reagent) was allowed to stand at room temperature (25 °C) for 30 min and was then measured against a blank at 750 nm a UV-VIS spectrophotometer (Thermo, Evolution 100, England) to elicit absorbance.

Determination of Total Flavonoid (TF) Content: An aluminum chloride colorimetric assay as described elsewhere [11] was used to determine TF content in the capitula samples. Quercetin solution (5 mg/10 mL in methanol) was used to produce a standard calibration curve in different concentrations. A total of 3.2 mL reaction mixture [(0.3 mL Na_2CO_3 (5%), 0.3 mL 10% $AlCl_3$, 2 mL NaOH (1 M) and 0.6 mL sample)] was mixed gently. After allowing a half-time this was measured against a prepared reagent blank at 510nm using a UV-VIS spectrophotometer (Thermo, Evolution 100, England) for absorbance. Total flavonoid content was expressed as mg quercetin equivalent per g dry weight (mg QE/g dw).

2, 2-Diphenyl-1-Picrylhydrazyl (DPPH) Assay: The method described by Blois [12] was employed to measure the antioxidant capacity of phenolics in the capitula samples through evaluation of the extract's free radical-scavenging effect on 2, 2-

diphenyl-1-picrylhydrazyl (DPPH) radical. A stock DPPH solution was freshly prepared (10 mg DPPH with 300 mL methanol), and 1mL DPPH solution was added to the aqueous extract obtained in section 2 (0.1mL). The reaction mixture was incubated in the dark at room temperature for 30 min. The absorbance of the resulting mixture was measured at 520 nm using a UV-VIS spectrophotometer (Thermo, Evolution 100, England), and DPPH values were expressed as µmol Trolox equivalent per 100 g dry weight (µmol TE/g dw).

Ferric Reducing Antioxidant Power (FRAP): Total antioxidant capacity was measured using the Ferric Reducing Antioxidant Power (FRAP) assay as described by Benzie and Strain [13], with slight modifications. A FRAP reagent containing acetate buffer (300 mM; PH 3.6), TPTZ (2, 4, 6-tripyridyl-s-triazine, 10 mM) and $FeCl.6H_2O$ (20 mM) in proportions of 10:1:1 (v/v/v) was freshly prepared. In brief, 0.1 mL of each sample was mixed with 2.9 mL FRAP reagent, and the reaction mixture was then incubated at 37 °C for 30 min in a water bath. FRAP was expressed as µmol Trolox equivalents per g dry weight (µmol TE/g dw) through a calibration curve with Trolox on which the absorbance was obtained at 593 nm using a UV-VIS spectrophotometer (Thermo, Evolution 100, England) against a blank.

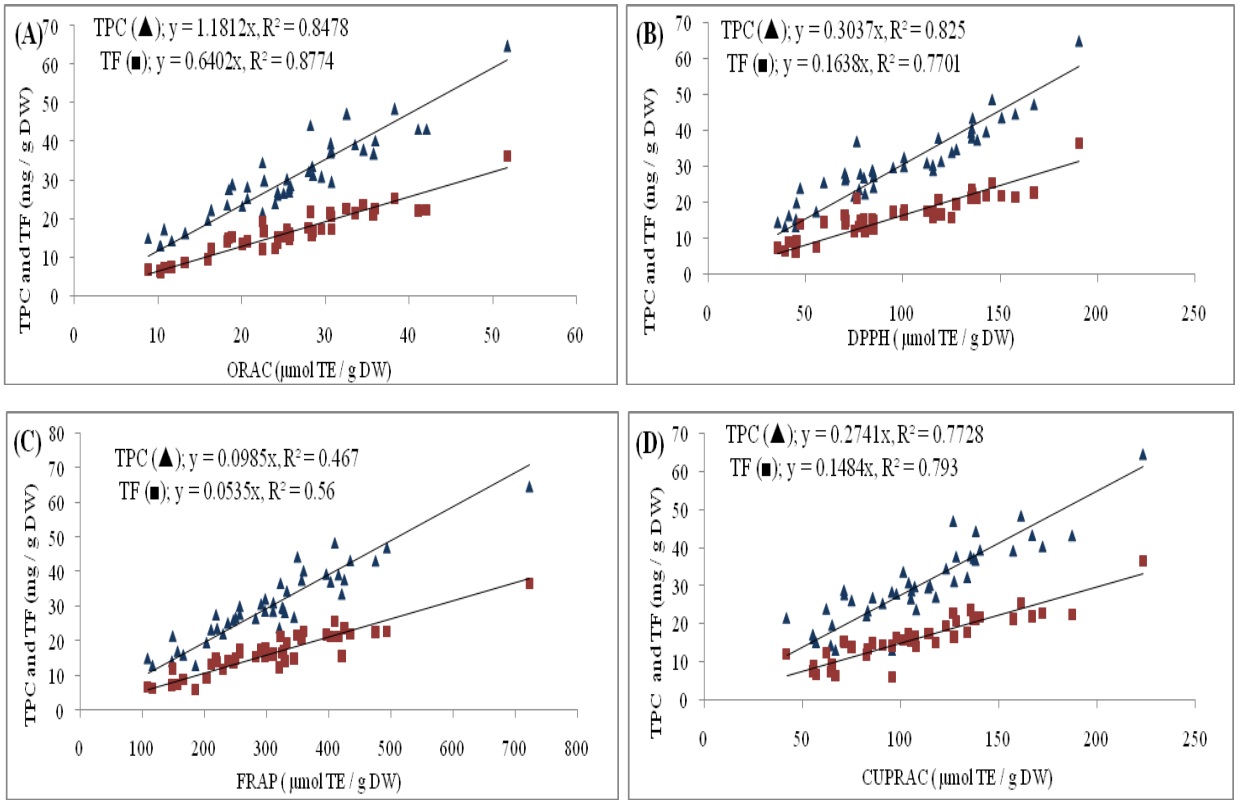
Cupric Ion Reducing Antioxidant Capacity (CUPRAC) Assay: The method describes by Apak *et al.,* [14] was employed to determine the cupric ion (Cu^{2+}) reducing ability of aqueous extracts of capitula samples. In this assay, the reaction mixture, containing 1ml of sample extract, 1mL of $CuCl_2$ (10 mM), 1mL of acetate buffer (1 mM, PH 7) and 1ml of 7.5 mM neocuproine (total 4mL reaction mixture), was incubated for 30 min at room temperature. The absorbance of the mixture was then measured at 450 nm using a UV-VIS spectrophotometer (Thermo, Evolution 100, England) against a reagent blank. The CUPRAC values of the samples were expressed as µmol Trolox equivalent per g dry weight (µmol TE/g dw).

Oxygen Radical Absorbance Capacity ($ORAC_{FL}$) Assay: This procedure was based on a report by Ou *et al.,* [15] with slight modifications. Briefly, 100 µL of 500 nmol/L fluorescein (fluorescein sodium salt) and 25 µL of diluted extracts were pipetted into each working well of the microplate. Next, 25 µL of 250 mmol/L 2, 2'-Azobis (2-methylpropionamidine) dihydrochloride (AAPH) was added. The microplate was shaken for 5 sec, and the fluorescence (excitation and emission wavelengths of 485 nm 510 nm, respectively) was read every 3 min for 90 min using Multiskan Ascent (Labsystems, Helsinki, Finland). Net area under the curve was used to calculate antioxidant capacity expressed as µmol Trolox equivalents per g dry weight (µmol TE/g dw).

Statistical analysis: All extractions and analysis were performed in triplicate (n = 3). Data were expressed as mean ± pooled standard deviation and compared within each column of the data. For comparisons among mean values, analysis of variance (one-way ANOVA) and the Multiple Range Test or Pearson correlation (r) analysis were performed on IBM SPSS Statistics V22.0 software. Linear regression (R) and correlation (r) analysis were carried out on Microsoft Office Excel 2010. Differences at $P<$ 0.01 or 0.05 were considered significant. A statistical package (XLSTAT version 2014.6) using ADDINSOFT (Damrémont, Paris, FRANCE) was used to perform the Principal Component Analysis (PCA).

RESULTS AND DISCUSSION: Forty-one taxa belonging to seven different genera of the Anthemideae tribe were examined in terms of antioxidant capacity (µmol TE/g dw) and total phenolic compound (TPC) (mg GAE/g dw) and and flavonoid (TF) contents (mg QE/g dw) (**Tables 1** and **Table 2**). Wide ranges of antioxidant capacity values and TPC or TF contents were observed within and among the genera, and these varied at the species, varietal and geographical levels. The overall mean TPC content was 37.5 GAE/g dw and the mean TF content was 19.4 mg QE/g dw (**Table 2**). The correlation between antioxidant capacity values and TPC or TF contents in the Anthemideae taxa is presented in **Fig. 1**. The average values for ORAC (r_{TPC} = 0.928, r_{TF} = 0.939), DPPH (r_{TPC} = 0.931, r_{TF} = 0.897), FRAP (r_{TPC} = 0.934, r_{TF} = 0.915) and CUPRAC (r_{TPC} = 0.889, r_{TF} = 0.895) exhibited strong positive correlation with the average values for the TPC and TF contents. These values indicate that the

antioxidant capacity is strongly related to the TPC and TF content of the samples. Our findings also exhibited a strong linear relationship between antioxidant capacity values and TPC (R^2 = 0.467 – 0.847) or TF (R^2 = 0.56 – 0.897) (**Fig. 1**).



Variables	ORAC	DPPH	FRAP	CUPRAC	TPC	TF
ORAC	-	0.851	0.895	0.884	0.928	0.939
DPPH	-	-	0.892	0.824	0.931	0.897
FRAP	-	-	-	0.862	0.934	0.915
CUPRAC	-	-	-	-	0.889	0.895
TPC	-	-	-	-	-	0.980
TF	-	-	-	-	-	-

FIG. 1: PEARSON (*r*) CORRELATION BETWEEN ANTIOXIDANT CAPACITY (ORAC, DPPH, FRAP AND CUPRAC) AND TOTAL PHENOLIC COMPOUNDS (TPC) OR TOTAL FLAVONOID (TF) CONTENTS IN SOME REPRESENTATIVES IN THE TRIBE ANTHEMIDEAE (ASTERACEAE). VALUES IN BOLD ARE DIFFERENT FROM 0 WITH A SIGNIFICANCE LEVEL ALPHA=0.05

Table 2 indicates that 11 out of 41 Anthemideae taxa are endemic (29.3%). The majority of the endemic taxa belong to *Tripleurospermum* (10 taxa), while one belongs to each of *Achillea* and *Anthemis*. Among the studied taxa, *T. corymbosum* had the highest TPC, at a level of 43.37 mg GAE/g dw, while *T. conoclinium* had the lowest TF content, at 13.13 mg QE/g dw. The highest ORAC (51.74), DPPH (190.52), FRAP (723.22) and CUPRAC (223.64) values were attributed to *Achillea santolinoides* subsp. *wilhemsii*. However, the lowest antioxidant capacity (µmol/ g dw) values did not exhibit as much homogeneity as the highest. The lowest ORAC (10.32) value was in *Tanacetum vulgare*, the lowest DPPH (35.88) in *M. chamomilla* var. *chamomilla*, the lowest FRAP (109.39) in *T. callosum* and the lowest CUPRAC (42.19) value in *A. multifida*.

Numerous members of the Anthemideae are important cut-flower and ornamental crops, as well as medicinal and aromatic plants, many of which produce essential oils used in folk and modern medicine, and the cosmetic and pharmaceutical industries [9]. Essential oils, secondary metabolites and medically important compounds with or without bioactivity have been isolated from members of *Achillea*, *Anthemis*, *Artemisia*,

Glebionis, *Matricaria*, *Tanacetum*, and *Tripleurospermum* [9].

One survey of the literature noted that many studies have investigated the phenolic compounds and antioxidant capacity of Anthemidea taxa. The harmonized selected references consisted of reports of root, leaf, flowers or aerial parts of plant in the some members of the tribe. Due to restrictions in terms of reference numbers, we have had to confine the following discussion to various several representative citations related to the studied taxa in the present research.

***Achillea*:** Only four taxa were measured in terms of antioxidant capacity and TPC or TF contents. The average TPC (mg GAE/g dw) and TF contents (mg QE/g dw) of the taxa were 39.51 (range, 64.67 - 21.6) and 22.4 (range, 36.41 – 11.91), respectively, being highest in *A. santolinoides* subsp. *wilhelmsii* and lowest in *A. multifida*. Similarly to the phenolic contents, ORAC (ave. 31.84 µmol TE /g dw), DPPH (132.75 µmol TE/g dw), FRAP (ave. 402.63 µmol TE /g dw) and CUPRAC (ave. 131.69 µmol TE/g dw) values were again high in *A. santolinoides* subsp. *wilhelmsii* and low in *A. multifida* (**Table 2**). Gharibi *et al.* [16] compared the TPC contents and antioxidant capacities of three Iranian endemic species, *Achillea* (*A. pachycephalla, A. kellalensi* and *A.aucherii*). The first species, *A. pachycephalla* (0.61 mg tannic acid equivalent (TAE)/g dw), exhibiteda higher TPC content and antioxidant capacity than the other two species (range, 0.30 – 0.16 mg). Analysis of the TPC content and antioxidant capacity values of water and ethanol extracts of *A. vermicularis* Trin. from northern Iraq revealed that aqueous ethanol extract exhibited the highest TPC content (24.7 mg GAE/g dw) and FRAP (13.0 mmol/L) and DPPH scavenging capacity values (13.1%) (Molan *et al.*, 2012). Nearly the same amount of TPC content was reported for *A. biserrata* and *A. falcata* (6.9 and 6.5 mg PE/g dw) [17].

***Anthemis*:** Two taxa were examined for the genus. The average TPC and TF contents were 31.73 mg GAE/g dw and 16.11 mg QE/g dw, respectively, for the two *Anthemis* species examined in this study (**Table 2**). The highest antioxidant capacity and TPC or TF contents were attributed to *A. cotula*. Different parts of *Anthemis cretica* (root, leaf and flower) exhibited significant antioxidant capacity (DPPH and CUPRAC) values, TPC and TF contents in an increasing trend, depending on the type of solvent, such as water, acetone, ethanol and methanol [18]. Accordingly, the roots of *A. cretica* had the highest antioxidant capacity values (mg TE/g dw) for the roots (ave. 24.2 for DPPH, range 18.79 -35.24) and flowers (ave. 77.2 for CUPRAC, range, 65.47 - 96.25) and the lowest in leaves (ave. 19.1 and 53.54 for DPPH and CUPRAC, range 14.80 - 25.01 and 45.81 - 69.89). However, the highest TPC (ave. 44.6, range 34.72 – 61.61 mg GAE/g dw) and TF (ave. 20.2, range 21.72 – 30.73 mg QE/g dw) contents were obtained from the roots, followed by flowers (ave. 36.1 and 21.5, range, 27.98 - 45.76 and 18.34 - 25.26), and the leaves and flowers had approximately the same TF contents (ave. 20.2 and 21.5, range, 15.58 - 26.89 and 18.34 - 25.26) in *A. cretica* [18]. An Algerian *Anthemis* species [19], *A. arvensis* contained noticeably high TPC content (115.2 mg GAE/g dw) and antioxidant capacity values (0.73 mmol TE/g dw). Earlier, two *Anthemis* species, *A. tinctoria ssp. tinctoria* and *A. triumfettii*, were shown not to differ in terms of TPC contents (9.5 and 9.6 mg PE/g dw), while differing in terms of total condensed tannin contents (146 and 122.9 mg TA/g dw) [17]. Our findings for the two *Anthemis* taxa concur with the ranges reported in the literature.

***Artemisia*:** The average antioxidant capacity values were 28.4 µmol TE /g dw for ORAC, 326.70 µmol TE /g dw for FRAP and 123.92 µmol TE /g dw for CUPRAC, being the highest in *A. annua*, and 125.68 µmol TE /g dw for DPPH, being highest in *A. santonicum*. Similarly, TPC or TF contents were highest in *A. annua* (48.43 mg GAE/g dw and 25.47 mg QE/g dw). Ayaz *et al.*, [17] reported no difference in TPC content between *A. tournefortiana* and *A. absinthium*. The antioxidant capacity of water extract from *A. selegensis* Turcz measured by DPPH (1081.7 µM ascorbic acid/100 g dw) and ABTS (886.9 µM TE/100 g dw)was higher than those of extracts prepared with aqueous ethanol (70 and 95%), petroleum ether, ethylacetate and n-buthanol, ranging from 15.8 to 823.8 µM ascorbic acid and 4.5 to 583.3 µM TE/100 g dw, respectively [20].

Similarly to the antioxidant capacity values, they observed a high TPC content (5.57 mg GAE/g dw)

in the water extract. However, the highest TF content was determined for the extract prepared from 70% aqueous ethanol (9.87 mg RE/g dw) [20]. In *A. santolina*, both aqueous and methanol extracts gave approximately the same amount of TPC content, 0.21 and 0.19 mg GAE/g dw, respectively [21]. However, they reported a significant difference in antioxidant capacity values (72.6 and 60.2 μmol TE/g dw, respectively) between the two extracts. In contrast, the same authors [22] reported an equal amount of TPC (28.1 and 28.4 mg/g dw) and antioxidant capacity values for FRAP (13.4 and 13.6 mmol/L), and a noticeably high DPPH value (17.7 and 32.7 %) from the water and ethanol extracts of *A. herba-alba* Asso. Sengul *et al.,* [23] observed a low antioxidant capacity (62.86%, β-caroten bleaching assay) and high TPC content (15.38 mg GAE/g dw), but a high antioxidant capacity (71.78%) and low TPC content (9.79 mg GAE/g dw) in a comparison of two *Artemisia* species, *A. absinthium* and *A. santonicum*, respectively. The TPC content (1.34 and 1.3 mg/g dw, water and methanol extract, respectively) of *A. absinthium* from Korea reported by Lee *et al.,* [24] was lower than that that reported by Sengul *et al.,* [23] for the same species, and also the antioxidant capacity.

Among three Algerian *Artemisia* species, *A. campestris* had a higher TPC content (35.8 mg GAE/g dw) and antioxidant capacity value (0.57 mmol TE/g dw, TEAC assay) than those of *A. herba-alba* (35.8 and 0.28) and *A. arboresens* (16.7 and ~ 0.1), respectively [25]. Due to differences in expressing the unit of antioxidant capacity values of the taxa we are unable to make any comparison, but the cited taxa exhibited different TPC and antioxidant capacity values at the taxa and geography levels. For instance, we observed a remarkably high TPC content for *A. santonium*.

***Glebionis*:** The aerial parts of *Glebionis coronaria* (L.) Tzveleu collected from Egypt had 25.69 and 19.35 mg/g dw TPC and TF contents with a 109.65 μg/mL (EC_{50}) antioxidant capacity value [26]. In the present study, we determined approximately 1.8-fold higher TPC (47.07 mg/g dw) and 1.2-fold higher TF (22.62 mg/g dw) contents in *G. coronaria* from the Turkey population. In terms of antioxidant capacity values, the taxa had moderately high values when compared to the other taxa studied (30.61, 167.41, 494.06 and 121.65 μmol TE/g dw, ORAC, DPPH, FRAP and CUPRAC, respectively) (**Table 2**).

***Matricaria*:** Four taxa were examined from this genus. Average TPC and TF contents were 22.79 mg GAE/g dw and 12.77 mg QE/g dw. The antioxidant capacity values (μmol TE/g dw) were 19.75 for ORAC, 50.34 for DPPH, 214.91 for FRAP and 91.85 for CUPRAC. *M. matricarioides* had the highest TPC (36.80 mg GAE/g dw) and TF (21.11 mg QE/g dw) contents, while *M. chamomilla* var. *chamomilla* had the lowest TPC and TF contents (14.37 mg GAE/g dw and 7.24 mg QE/g dw) (**Table 2**). Vinha *et al.,* [27] noted a remarkable difference between antioxidant capacity (89.7 and 44.5%, DPPH assay) and TPC (0.67 mg CE/g dw) or TF (57.28 and 0.41 mg CE/g dw) contents in *M. officinalis* and *M. chamomilla*, respectively, from Portugal. *M. recutita* collected from the Jordanian [21] population had a 20.60 mg GE/g dw TPC content in aqueous and 15.10 mg GE/g dw in methanol extracts, whereas the extracts antioxidant capacity values were more or less the same (147.6 and 142.6 μmol TE/g dw). Solvent efficacy was more affected by antioxidant capacity of phenolics in *M. pubescens* [28]. Extracts of water and pure acetone, ethanol and methanol of *M. pubescens* yielded average an 1.56 g AAE/100 g FRAP value (range, 1.43 -1.85), while the aqueous solutions (50%) of the three solvents exhibited an average 7.51g AAE/100 g FRAP value (range, 7.18 - 7.85). The average DPPH value (IC_{50}) was almost the same (ave. 4.29 mg/mL, range, 4.14 - 4.38), but there was a significant difference in terms of ORAC values (mmol TE/100 g dw) for water (23.19) and aqueous solvents (50%) (ave. 41.78, range 41.46 - 42.14) and for their pure extracts (ave. 18.72, range, 4.58 – 30.84). Similarly, the highest TPC contents obtained from the aqueous acetone, ethanol and methanolic extracts of *M. pubescens* ranged around 25.0 mg GAE/g dw.

***Tanacetum*:** Only one taxon was examined in the present study. Significant variations have been reported between antioxidant capacity values (ave. 114.9 μg/mL, range, 59.6 - 157.2) measured DPPH assay and TPC (ave. 37.1 mg/g dw, range, 28.9 - 47.1) or TF (ave. 22.1 mg/g dw, range, 14.23 - 40.3) contents of six *Tanacetum* species, being highest in, order, in *T. tabrisianum*, *T. hololeucum*

and *T. kotschyi* [29]. Both leaf and flower parts of *Tanacetum balsamita* differed in terms of TPC contents (14.8 and12.52 mg/g fw, leaf and flower, respectively) and total antioxidant power capacity (0.74 and 0.64 mmol Fe/100g fw) [19]. The TPC content of nine *Tanacetum* species from Turkey varied between 5.9 and 21.7 mg PE/g dw (ave. 10.0), three of the nine had nearly the same TPC content, with an average value of 9.5 (range, 9.3 - 9.7) [17]. Our data obtained in the present study for *T. vulgare* were in the ranges cited in the literature.

***Tripleurospermum*:** Twenty-eight taxa were examined in this genus. The average TPC content was 29.17 mg GAE/g dw and the average TF content 15.80 *T. corymbosum* had the highest TPC content (43.37 mg GAE/g dw) among the taxa, followed by *T. temskyanum* (43.27 mg GAE/g dw), while *T. conoclinum* had the lowest TF content (13.13 mg QE/g dw), and *T. callosum* (15.17mg GAE/g dw) had the lowest TPC contents. The average antioxidant capacity for *Tripleurospermum* taxa was 24.05 μmol TE/g dw for ORAC (highest in *T. rosellum* var. *album*, 42.14), 92.64 μmol TE/g dw for DPPH (highest in *T. corymbosum*, 150.81), 286.74 μmol TE/g dw for FRAP (highest in *T. corymbosum*, 435.15) and 88.2 μmol TE/g dw for CUPRAC (highest in *T. temskyanum*, 187.56).

A varietal difference in TPC content was noted between *T. oreades* var. *tchihatchewii* (19.6 mg PE/g dw) and *T. oreades* (13.9 mg PE/g dw) [17]. The present findings and above citations confirmed that members of the tribe Anthemideae have high phenolic contents and considerable antioxidant capacity values that vary significantly within and among the taxa. The citations also show that selected group of antioxidants can be extracted, using different polarities, from different parts of the plants (leaf, flower, and roots). Antioxidant capacity estimation depends on the TPC or TF contents. High variation of phenolic compounds content and antioxidant capacity among the studied and the cited taxa, whether collected from the same or different geographical region, was observed in the present study. Altitude and temperature have been shown to be one of the major environmental factors affecting plant composition and properties, despite genetic differences among various species [16]. For instance, *Achillea pachycephala*, collected from a higher altitude (2200 m) compared to *A. kellalensis* and *A. aucherii* (2093 and 1735 m), had the highest TPC content and antioxidant capacity values, inspite of genetic variation [16].

Similarly, altitude as well geography was found to affect the phenolic content and antioxidant capacity values between two *T. rosellum* var. *album* locations, one at 220m in Çanakkale provience (Gökçeada) and the other at 1800 - 185 m in Rize (İkizdere/Cimil) province in the far West and East of Turkey, respectively. A 1.7- and 1.6-fold increase in TPC and TF contents and a 1.7-, 1.2-, 2.0- and 1.9- fold increase in antioxidant capacity values were determined in the capitulum of *T. rosellum* var. *album* collected from Rize province.

In addition, a varietal difference in antioxidant capacity values and TPC or TF contents in the capitulum was determined between *T. oreades* var. *tchihatchewii* growing at 2185 m in Artvin (Şavşat) province and *T. oreades* var. *oreades* growing at 1719 m in Giresun (Kümbet) province. A 1.6- and 1.9- fold increase in TPC and TF contents, respectively, and anapproximately ~1.5-fold increase in the antioxidant capacity values was observed in *T. oreades* var. *tchihatchewii*. This increase in phenolics and antioxidant capacity can be attributed to ultraviolet changes in altitudes and low temperatures at high altitudes, as Gharibi *et al.*, [16] quite correctly stated in their review.

TABLE 2: ANTIOXIDANT CAPACITY (ORAC, DPPH, FRAP AND CUPRAC) VALUES (μmol TE /g DW) AND TOTAL PHENOLIC COMPOUNDS (TPC) (mg GAE/g DW) OR TOTAL FLAVONOIDS (TF) CONTNTS (mg QE/g DW) IN VARIOUS SPECIES IN THE TRIBE ANTHEMIDEA (ASTERACEAE). VALUES, MEANS OF THREE INDEPENDENT EXTRACTION AND DETERMINATIONS WITH STANDARD DEVIATIONS FOR EACH SAMPLING. ANALYSIS OF VARIANCE (ONE-WAY ANOVA) WAS USED FOR COMPARISONS. MEANS IN COLUMNS FOLLOWED BY DIFFERENT LETTERS AT SUPERSCRIPT ARE SIGNIFICANT AT *P*<0.05

Taxa	TPC	TF	ORAC	DPPH	FRAP	CUPRAC
			Achillea			
A. arabica	34.57 ± 1.70^{b}	19.45 ± 0.10^{b}	22.46 ± 0.97^{a}	127.05 ± 0.15^{b}	333.72 ± 9.04^{b}	123.45 ± 0.09^{b}
A. bisserata	37.20 ± 1.99^{b}	21.20 ± 0.10^{c}	30.70 ± 1.30^{b}	138.27 ± 0.05^{c}	403.78 ± 12.56^{c}	137.46 ± 15.16^{c}
*A. multifida**	21.60 ± 0.27^{a}	11.91 ± 0.19^{a}	22.46 ± 0.79^{a}	75.16 ± 0.12^{a}	149.81 ± 7.89^{a}	42.19 ± 0.39^{a}

A.santolinoides subsp. *wilhelmsii*	64.67 ± 2.12^{c}	36.41 ± 0.15^{d}	51.74 ± 0.32^{a}	190.52 ± 0.69^{d}	723.22 ± 27.24^{d}	223.64 ± 7.52^{d}
means	39.51	22.24	31.84	132.75	402.63	131.69
			Anthemis			
A. cotula	33.73 ± 3.57	16.58 ± 0.15	28.46 ± 0.14	125.23 ± 0.02	421.56 ± 0.22	107.44 ± 4.21
*A. macrotis**	29.73 ± 2.20	15.63 ± 0.17	22.73 ± 0.07	100.69 ± 0.07	325.88 ± 0.27	101.66 ± 3.32
means	31.73	16.11	25.59	112.96	373.72	104.55
			Artemisia			
A. annua	48.43 ± 1.37^{c}	25.47 ± 0.19^{c}	38.28 ± 0.11^{c}	140.92 ± 0.51^{b}	410.37 ± 14.81^{c}	161.58 ± 0.14^{c}
A. austriaca	27.77 ± 1.05^{a}	15.02 ± 0.20^{a}	18.50 ± 1.43^{a}	78.30 ± 9.85^{a}	219.38 ± 8.69^{a}	71.63 ± 1.83^{a}
A. santonicum	44.40 ± 2.15^{b}	21.51 ± 0.07^{b}	28.23 ± 0.06^{b}	157.81 ± 0.36^{c}	350.33 ± 6.99^{b}	138.56 ± 0.11^{b}
means	40.20	20.67	28.34	125.68	326.70	129.92
			Glebionis			
G. coronaria	47.07 ± 2.56	22.62 ± 0.14	32.61 ± 5.21	167.41 ± 0.05	494.06 ± 9.73	127.05 ± 11.92
			Matricaria			
M. chamomilla var. *recutita*	23.80 ± 2.07^{b}	13.95 ± 0.24^{c}	18.24 ± 0.25^{d}	47.41 ± 0.08^{a}	221.16 ± 0.64^{a}	108.23 ± 0.03^{a}
M. matricarioides	36.80 ± 3.08^{c}	21.11 ± 0.06^{d}	35.82 ± 0.22^{b}	76.48 ±0.37^{b}	323.16 ± 0.03^{c}	138.46 ± 0.09^{b}
M. chamomilla var. *chamomilla*	14.37 ± 0.29^{a}	7.24 ± 0.15^{a}	11.66 ± 0.13^{a}	35.88 ± 0.09^{ab}	148.56 ± 0.21^{b}	64.75 ± 0.08^{a}
M. aurea	16.17 ± 1.23^{a}	8.77 ± 0.12^{b}	13.28 ± 0.53^{c}	41.62 ± 0.09^{b}	166.75 ± 0.08^{c}	55.95 ± 0.12^{b}
means	22.79	12.77	19.75	50.34	214.91	91.85
			Tanacetum			
T. vulgare	14.3 ± 1.46	6.02 ± 0.17	10.32 ± 0.10	45.12 ± 0.09	186.38 ± 0.18	95.96 ± 2.05
			Tripleurospermum			
*T. callosum**	15.17 ± 2.15^{ab}	6.64 ± 0.10^{a}	23.99 ± 0.61^{a}	45.26 ± 0.05^{a}	109.39 ± 8.45^{a}	57.23 ± 0.06^{ab}
T. caucasicum	27.07 ± 0.70^{h-j}	14.91 ± 0.04^{fg}	25.68 ± 0.79^{d}	85.13 ± 0.02^{d}	344.88 ± 9.80^{k}	118.21 ± 0.26^{l}
*T. conoclinum**	13.13 ± 1.46^{a}	6.30 ± 0.15^{a}	20.04 ± 0.22^{a}	39.61 ± 2.94^{a}	117.30 ± 3.81^{a}	67.15 ± 0.05^{cd}
*T. corymbosum**	43.37 ± 1.36^{o}	21.85 ± 0.06^{kl}	34.61 ± 1.93^{i}	150.84 ±2.96^{h}	435.15 ± 4.10^{p}	167.24 ± 0.06^{r}
T. decipiens	28.77 ± 0.57^{i-l}	15.72 ± 0.03^{f-j}	25.87 ± 0.93^{d}	115.65 ± 7.30^{f}	311.13 ± 0.04^{i}	105.83 ± 9.47^{k}
T. disciforme	29.53 ± 1.15^{j-m}	17.31 ± 0.08^{ij}	41.12 ± 0.10^{f}	95.12 ± 0.03^{e}	327.46 ± 0.16^{j}	114.33 ± 2.62^{l}
T. elongatum	40.4 ± 0.96^{n}	22.72 ± 0.05^{kl}	10.75 ± 0.16^{h}	135.51 ± 6.64^{g}	360.15 ± 5.02^{l}	172.54 ± 0.14^{r}
*T. fissurale**	32.3 ± 1.54^{m}	17.72 ± 0.10^{j}	28.08 ± 0.07^{e}	100.71 ± 1.99^{e}	298.65 ± 0.04^{h}	134.21 ± 0.17^{no}
*T. heterolepis**	25.4 ± 0.85^{f-h}	14.37 ± 0.15^{f}	20.69 ± 2.20^{c}	59.54 ± 2.51^{b}	238.48 ± 9.29^{d}	91.16 ± 0.06^{gh}
*T. hygrophilum**	27.93 ± 1.65^{h-k}	16.47 ± 0.08^{g-j}	28.57 ± 0.61^{d}	70.34 ± 3.08^{c}	257.56 ± 0.14^{f}	98.15 ± 0.02^{ij}
T. inodorum	26.70 ± 0.52^{g-j}	15.40 ± 0.03^{f-i}	20.69 ± 0.10^{d}	80.14 ± 2.67^{d}	283.13 ± 16.42^{g}	105.53 ± 0.15^{k}
*T. kotschyi**	22.23 ± 0.15^{de}	11.86 ± 0.06^{d}	25.68 ± 0.79^{b}	80.67 ± 1.37^{d}	230.75 ± 2.51^{d}	82.96 ± 4.88^{f}
T. melanolepis	31.23 ± 0.95^{lm}	16.51 ± 0.09^{g-j}	30.73 ± 0.36^{ef}	119.76 ± 7.46^{f}	311.54 ± 8.51^{i}	127.53 ± 0.19^{m}
T. microcephalum	37.87 ± 4.03^{n}	23.61 0.15^{l}	30.70 ± 1.29^{gh}	135.43 ± 0.23^{g}	425.63 ± 0.19^{n}	135.85 ± 0.20^{o}
*T. monticolum**	28.83 ± 0.90^{i-l}	15.39 ± 0.15^{f-i}	25.04 ± 1.76^{c}	84.46 ± 0.16^{d}	298.17 ± 0.26^{h}	71.46 ± 2.56^{de}
T. oreades var. *oreades*	17.23 ± 3.12^{bc}	7.48 ± 0.08^{ab}	15.94 ± 0.12^{d}	55.63 ± 0.04^{b}	157.61 ± 0.19^{b}	55.64 ± 0.28^{a}
T. oreades var. *tchihatchewii*	26.93 ± 0.59^{h-j}	14.80 ±0.05^{fg}	24.33 ± 3.12^{a}	70.96 ± 3.09^{c}	250.84 ± 0.15^{ef}	86.06 ± 5.64^{fg}
T. parvifiorum	30.17 ± 1.15^{k-m}	17.46 ± 0.09^{j}	16.32 ± 0.12^{d}	115.46 ± 0.08^{f}	257.56 ± 0.11^{f}	115.24 ± 0.09^{l}
*T. pichleri**	19.73 ± 2.18^{cd}	9.20 ± 0.19^{bc}	24.33 ± 3.12^{b}	45.53 ± 0.23^{a}	204.16 ± 6.58^{c}	65.42 ± 0.05^{cd}
T. rosellum var. album^{R*}	39.27 ± 2.77^{n}	21.24 ± 0.06^{k}	42.14 ± 0.04^{c}	135.18 ± 5.17^{g}	416.30 ± 5.87^{m}	157.56 ± 0.27^{p}
T. rosellum var.*album*^{Ç*}	23.47 ± 0.93^{ef}	13.27 ± 0.12^{c}	36.02 ± 1.89^{g}	77.67 ± 18.27^{cd}	211.57 ± 0.21^{c}	83.57 ± 0.18^{f}
T. sevanense	28.43 ± 1.24^{i-l}	14.15 ± 0.03^{ef}	30.63 ± 3.37^{c}	84.78 ± 8.65^{d}	330.06 ± 1.12^{j}	95.85 ± 0.18^{hi}
T. subnivale	30.83 ± 0.64^{k-m}	17.36 ± 0.06^{ij}	29.50 ± 2.51^{ef}	112.44 ± 7.46^{f}	291.92 ± 13.08^{h}	104.38 ± 15.53^{jk}
T. tempskyanum	43.27 ± 1.08^{o}	22.47 ±0.08^{kl}	33.52 ± 0.15^{i}	135.90 ± 12.67^{g}	475.86 ± 0.18^{p}	187.56 ± 0.24^{s}
T. tenuifolium	37.73 ± 0.93^{n}	20.72 ± 0.85^{k}	30.73 ± 0.36^{f}	118.37 ± 0.43^{f}	357.12 ± 0.05^{l}	128.56 ± 0.25^{mn}
T. transcaucasicum	24.00 ± 0.44^{e-g}	12.34 ± 0.12^{de}	18.93 ± 0.38^{d}	85.06 ± 0.02^{d}	321.29 ± 6.76^{j}	62.47 ± 0.66^{bc}
*T. ziganaense**	26.20 ± 1.73^{g-i}	13.81 ±0.06^{ef}	8.81 ± 0.42^{d}	70.54 ± 2.83^{c}	247.50 ± 9.31^{e}	75.35 ± 5.24^{e}
means	29.17	15.80	24.05	92.64	286.74	88.32
overall means	30.51	16.42	23.58	100.29	299.58	90.80

*endemic taxa R; Rize province Ç; Çanakkale province

Principal Component Analysis (PCA): Fig. 2 shows the total variation values for antioxidant capacity and TPC or TF in the capitula of the taxa given in **Table 1**. Total variation, explained 93.60%, PC1 accounting for 85.58% of the variance and PC2 for 8.02%. The bi-plot resulted in a complete separation of antioxidant capacity assays and TPC or TF in the right upper and lower quadrants separated 19 taxa of 41 with positive loading. They were also closely associated and positively strong correlated with DPPH, FRAP, CUPRAC and TPC or TF values (ave. r = 0.658, range, 0.823 – 0.934) and moderately with ORAC values (ave. r = 0.893, range, 0.618 - 0.685). PCA confirmed that almost 23 taxa in the left upper (11 taxa) and lower (12 taxa) quadrants of PC2 with positive and negative loadings were not associated or correlated with any of the antioxidant capacity tests assayed and TPC or TF values.

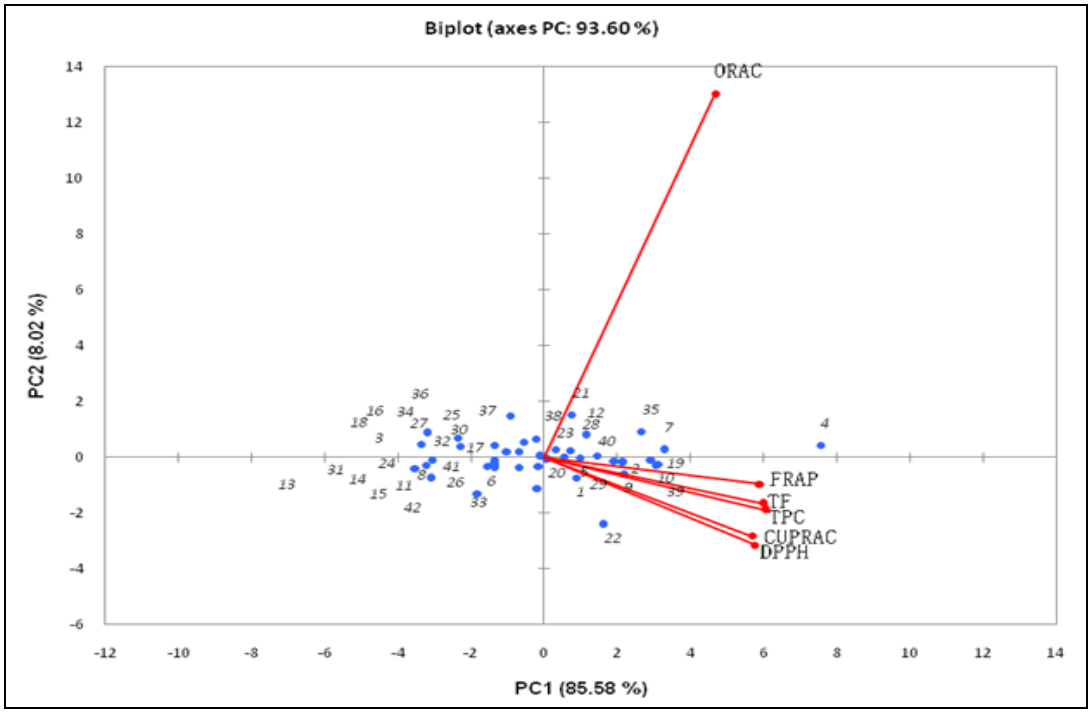


FIG. 2: BI-PLOT OF PCA OF ANTIOXIDANT CAPACITY VALUES AND TOTAL PHENOLIC COMPOUNDS (TPC) OR FLAVONOIDS (TF) CONTENTS IN CAPITULUM IN SOME REPRESENTATIVES IN THE TRIBE ANTHEMIDEAE. THE NUMBERS ON THE PC QUADRANTS REPRESENT THE TAXA AND THE VALUES AT THE LEFT ON UPPER QUADRANT REPRESENT PEARSON CORRELATION (*r*) OF THE VARIABLES (VALUES IN BOLD ARE DIFFERENT FROM 0 WITH A SIGNIFICANCE LEVEL α = 0.05)

1. *Achillea arabica*, 2. *A. bisserata*, 3. *A. multifida**, 4. *A. santolinoides* subsp. *wilhelmsii*, 5. *Anthemis cotula*, 6. *A. macrotis**, 7. *Artemisia annua*, 8. *A. austriaca*, 9. *A. santonicum*, 10. *Glebionis coronaria*, 11. *Matricaria chamomilla* var. *recutita*, 12. *M. matricarioides*, 13. *M. chamomilla* var. *chamomilla*, 14. *M. aurea*, 15. *Tanacetum vulgare*, 16. *Tripleurospermum callosum**, 17. *T. caucasicum*, 18. *T. conoclinium* *, 19. *T. corymbosum**, 20. *T. decipiens*, 21. *T. disciforme*, 22. *T. elongatum*, 23. *T. fissurale**, 24. *T. heterolepis**, 25. *T. hygrophilum**, 26. *T. inodorum*, 27. *T. kotschyi**, 28. *T. melanolepis*, 29. *T. microcephalum*, 30. *T. monticolum**, 31. *T. oreades* var.*oreades*, 32. *T. oreades* var. *tchihatchewii*, 33. *T. parvifiorum*, 34. *T. pichleri**, 35. *T. rosellum* var. *album*^{R*}, 36. *T. rosellum* var.*album*^{Ç*}, 37. *T. sevanense*, 38. *T. subnivale*, 39. *T. tempskyanum*, 40. *T. tenuifolium*, 41. *T. transcaucasicum*, 42. *T. ziganaense**. R; Rize province, Ç; Çanakkale province.

CONCLUSION: This is the first study to assess TPCs and antioxidant capacity in the capitula of the 41 Anthemideae taxa from Turkey. Strong correlations and linear regressions between antioxidant capacity values and TPC or TF contents identified phenolic compounds as the main carriers of antioxidant capacity in the present taxa belonging to different seven genera. Nearly all the genera have high antioxidant capacity values. We also observed an effect of altitude and temperature in several taxa. Our findings clearly demonstrate that the higher the TPC content, the greater their antioxidant capacity. Additionally, TF content was strongly correlated and associated with the antioxidant capacity values of the taxa. Additional investigations of phenolics in these taxa should now be carried out in vivo studies to confirm the health-promoting potentials of these herbs.

Our findings can also form the basis for further studies to isolate their active compounds at compound level using precise chromatographic analytical methods in order to develop scientifically-based natural pharmaceutical prescriptions.

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