A NUMERICAL TAXONOMIC STUDY ON THE FAMILY PLUMBAGINACEAE IN TURKEY

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A NUMERICAL TAXONOMIC STUDY ON THE FAMILY PLUMBAGINACEAE IN TURKEY

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ABSTRACT

A NUMERICAL TAXONOMIC STUDY
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IN TURKEY

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The aim of this study was to make evaluation of existing structure of Plumbaginaceae in Turkey in order to see infrafamilial grouping as well as infrageneric arrangement of the big genera (*Limonium* and *Acantholimon*). For this purpose, numerical taxonomic method and clustering analysis were used. Also, this was the first time that all the genera of Plumbaginaceae found in Turkey were examined together, within the same study. Herbarium specimens of 61 species were evaluated on the base of 57 morphological characters to construct data matrix. Data matrix was analysed by Multi Variate Statistical Package (MVSP) software. First, Unweighted Pair Group Method with Arithmetic Mean (UPGMA) analysis was used to construct phenograms. Later, Principal Component Analysis (PCA) was performed to indicate which characters were the most significant for the outcome of the analysis. Obtained results were discussed, and compared with previous findings.

According to UPGMA phenogram, the genera in our study were well separated from one another, exhibiting quite natural structure. *Plumbago* and *Ceratostigma* formed one cluster that correspond to the Plumbaginoideae subfamily. The other cluster analogous to subfamily Staticoidea was formed by *Goniolimon*,

Limoniopsis, Armeria, *Psylliostachys, Acantholimon* and *Limonium*. Within genera *Acantholimon* and *Limonium* clusters equivalent to the main sections were observed. Furthermore, it was seen that our findings were largely supported the taxonomic treatments given in the Flora of Turkey and the subsequent revisional studies.

Eventually, a new generic identification key for the Plumbaginaceae in Turkey including the newly recorded genus *Psylliostachys* is provided.

Keywords: Plumbaginaceae, numerical taxonomy, cluster analysis, Turkey

ÖZ

TÜRKİYE'DEKİ PLUMBAGİNACEAE FAMİLYASI ÜZERİNDE
BİR NÜMERİK TAXONOMİK
ÇALIŞMA

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Bu çalışmanın amacı, Türkiye'deki Plumbaginaceae familyasındaki mevcut familya içi sınıflandırmanın yanısıra büyük cinslere (*Limonium* ve *Acantholimon*) ait cins içi sınıflandırmayı ortaya koymaktır. Bu amaçla, nümerik taksonomi metodu ve kümeleme analizi kullanılmıştır. Ayrıca, bu çalışma Türkiye'de bulunan tüm Plumbaginaceae cinslerini kapsayacak şekilde ilk kez aynı çalışma içerisinde ele alınmıştır. Data matriksi oluşturmak için 61 türe ait herbaryum örnekleri, 57 morfolojik karakter tabanında değerlendirilmiştir. Veri matrisi MVSP yazılımı kullanılarak analiz edilmiştir. İlk olarak, UPGMA analizi fenogramlar oluşturmak için kullanılmıştır. Daha sonra, analizin en belirgin karakterlerinin hangileri olduğunu belirlemek için PCA kullanılmıştır. Elde edilen sonuçlar tartışılmış ve daha önceki bulgular ile karşılaştırılmıştır.

UPGMA fenogramına göre çalışmadaki cinsler birbirinden açık bir şekilde ayrılarak neredeyse doğal bir yapı göstermektedir. *Plumbago* ve *Ceratostigma*, Plumbaginoideae alt familyasına karşılık gelen tek bir kümelenme oluşturmuştur. Staticoidea alt familyasına ait diğer kümelenme analojisi *Goniolimon*, *Limoniopsis*,

Armeria, *Psylliostachys*, *Acantholimon* ve *Limonium* tarafından oluşturulmuştur. *Acantholimon* ve *Limonium* cinslerinde cins içi sınıflandırma daha önceki değerlendirmeleri desteklemektedir. Ayrıca, bulgularımızın Türkiye Flora'sında verilen taksonomik düzenlemelere ve sonrasındaki yeniden düzenleme çalışmalarıyla büyük ölçüde uyumlu olduğu görülmüştür.

Sonuç olarak, Plumbaginaceae familyasına ilişkin yeni bir cins anahtarı yakın zamanda Türkiye'den kaydedilmiş olan *Psylliostschys* cinsinide içerecek şekilde verilmiştir.

Anahtar Kelimeler: Plumbaginaceae, nümerik taksonomi, kümelenme analizi, Türkiye

To my beloved husband and my families

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ABBREVIATIONS

A. Huet ……..... Pavillon, Alfred Huet du
APG II system ……..…… Angiosperm Phylogeny Group II system
Berthel. ……..... Berthelot, Sabin
Boiss. ……..…… Boissier, François de Sauvages de Lacroix
Brongn. …… Brongniart, Adolphe Theodore
cm ……...……. centimeter
C ……..……. Central
CR .....…… Critically Endangered
Dumort …… Dumortier, Barthélemy Charles Joseph
E. ...……..... East
(E) ……..... Royal Botanic Garden, Edinburgh
EN …..…… Endangered
et al ……. et alii (and others)
Fourr. ……..…..… Fourreau, JulesPierre
Griseb. …….. Grisebach, August Heinrich Rudolf
Hausskn. ……... Haussknecht, Heinrich Carl
Heldr. ……... Heldreich, Theodor Heinrich Hermann von
IUCN …… International Union for Conservation of Nature and Natural Resources
Jaub. ……. Jaubert, Hippolyte Francois
Juss. ……..……... Jussieu, Antoine Laurent de
K. Koch …….. Koch, Karl Heinrich Emil
Kusn. ……. Kusnezow, Ivan V.
L. ……..……. Linnaeus, Carolus
Lam. ……..... Lamarck, Jean-Baptiste
Lestib. ……..... Lestiboudois, Gaspard Thémistocle
Lincz. …..……..... Linczevski, Igor Alexandrovich
LC …….. Least Concerned
Lindl. …….. Lindley, John

m …… meter

Mill. …… Miller, Philip

mm …… millimeter

MVSP ……... Multi Variate Statistical Package

N. ...…….. North

NT ……. Near Threatened Species

OTU ……..... Operational Taxonomic Unit

PCA ...……... Principal Component Analysis

Poir. ……...…… Poiret, Jean Louis Marie

Rech. …… Rechinger, Karl

Reichenb. ..…….....….. Reichenbach, Heinrich Gustav

S. …….. South

Sauv. …….. Sauvage, Charles Philippe Félix

Sect. ……... section

Sint. …….. Sintenis, Paul Ernst Emil

Sosn. ……. Sosnowsky, Dmitrii Ivanovich

sp. nov. ……... species nova (new species)

stat. nov. …… status novus (new status)

subsp. ……... subspecies

syn. ……. synonym

Takht. ……... Takhtajan, Armen

Thunb. ...…….. Thunberg, Carl Peter

UPGMA …… Unweighted Pair Group Method with Arithmetic Mean

var. ...…….. variety

Viv. ……. Viviani, Domenico

VU …….. Vulnerable

W ……. West

Willd. ……...……. Willdenow, Carl Ludwig

Zimmerm. ……..…….. Zimmerman, Walter Max

CHAPTER 1

INTRODUCTION

1.1. Systematic Studies on Plumbaginaceae Juss.

A detailed worldwide revisional study of Plumbaginaceaae as a whole has not been done so far**.** Most of the studies in past were done in the regional level, as a part of the floristic studies. The main focus of the research was usually on the biggest genera *Acantholimon* Boiss. and *Limonium* Mill. The first revision of the Plumbaginaceae was done by Boissier in his 4th volume of "Flora Orientalis", in which he described 7 genera and 121 species (Boissier, 1879). Flora of USSR, 18th volume, accepted 11 genera and 131 species (Komarov, 1967). In the 3rd volume of Flora Europaea, 8 genera and 146 species were recognized (Tutin et al, 1972). Flora Iranica includes, 8 genera and 192 species (Rechinger and Schiman-Czeika, 1974). In the 15th volume of Flora of China, 7 genera and 46 species were accepted (Wu and Raven, 1996).

The major contribution in studying and describing Plumbaginaceae in Turkey was made in P.H. Davis', 7th volume of Flora of Turkey and the East Aegean Islands, revised by M.H. Bokhari and J.R. Edmonsdon. In this flora, 6 genera were accepted, namely: *Plumbago* L., *Limonium* Mill., *Goniolimon* Boiss., *Limoniopsis* Lincz., *Acantholimon* Boiss. and *Armeria* Willd. In this family they recognized 52 species within those genera. (Davis et al., 1982, 1988). Also, Bokhari had made a taxonomic study on the South West Asian Plumbaginaceae. Beside revision and description of new taxa, he also recognized the taxonomic values of stigma, pollen types and anatomical features (Bokhari, 1970).

The most recent revisional study of the Plumbaginaceae in Turkey was conducted by Doğan and Akaydın. In six years, they carried out extensive field

studies, gathered specimen all over Turkey and examined material housed in various herbaria in Turkey, as well as abroad. Specimen were studied for assembling morphological, anatomical, palynological, ecological and biogeographic information. The study included the genera: *Plumbago* L., *Limonium* Mill., *Goniolimon* Boiss., *Limoniopsis* Lincz. and *Armeria* Willd. This project was preceded with profound revision of *Acantholimon* in 2003. Hence, the final result of those studies was 13 new species of *Acantholimon*, 2 new species of *Limonium*, and a few new subspecies and varieties. Also, the presence of *Ceratostigma plumbaginoides* Bunge, *Plumbago capensis* Thunb and *Goniolimon besseranum* (Shultes ex. Reichenb.) Kusn. as ornamental plants was recorded from Turkey (Doğan and Akaydın, 2003a, 2006).

1.2. General Characteristics of Plumbaginaceae Juss.

Plumbaginaceae Juss. was described first time by Antoine Laurent de Jussieu in 1789, in his book Genera Plantarum (Jussieu, 1789). It was the only family in the order Plumbaginales Lindl. However, APG II system (Angiosperm Phylogeny Group II system) of plant classification that was published in 2003 by the Angiosperm Phylogeny Group, placed Plumbaginaceae in the order Caryophyllales Perleb. Hence, the most recent systematic classification of the Plumbaginaceae family is given below:

Kingdom: **Plantae**
Subkingdom: **Tracheobionta**
Division: **Magnoliophyta** Cronquist, Takht. & Zimmerm. ex Reveal
Class: **Magnoliopsida** Brongn.
Subclass: **Caryophyllidae** Takht.
Order: **Caryophyllales** Perleb
Family: **Plumbaginaceae** Juss.

Common name of the Plumbaginaceae is leadworts, from the Latin words plumbum ("lead") and agere ("to resemble"). Family includes 27 genera and 730-836 species (Simpson, 2010). Based on morphological and chemical features this family was divided in two subfamilies Plumbaginoideae and Staticoideae

(Kubitzki, 1993; Simpson, 2010). This was also supported by phylogenetic studies using plastid DNA sequences (Moharrek et al., 2014). The genera of Plumbaginaceae are as follows: *Acantholimon*, *Aegialitis*, *Afrolimon*, *Armeria*, *Bakerolimon*, *Bamiania*, *Bukiniczia*, *Cephalorrhizum*, *Ceratostigma*, *Chaetolimon*, *Dictyolimon*, *Dyerophytum*, *Eremolimon*, *Ghaznianthus*, *Gladiolimon*, *Goniolimon*, *Ikonnikovia*, *Limoniastrum*, *Limoniopsis*, *Limonium*, *Muellerolimon*, *Neogontscharovia*, *Plumbagella*, *Plumbago*, *Popoviolimon*, *Psylliostachys*, *Vasssilczenkoa* (Kubitzki, 1993). Genus *Myriolimon* that was previously treated as a section *Myriolepis* Boiss. in *Limonium*, was segregated from it and recognized as a genus (Lledó, et al, 2003, 2005). Thus, currently family has 28 genera.

The taxa of Plumbaginaceae are mostly perennial (with few exceptions of annual). They are in a form of shrubs, subshrubs, lianas or herbs. The leaves are alternately arranged, in basal rosettes, or in fascicular rosettes on annual shoots below scapes. Foliage is simple with entire margin, rarely pinnatifid. Usually leaves are with short or without petiole. Chalk glands that exude calcium salts and water for neutralizing salt from ground, are often present on the leaves and stem. Inflorescence is spicate, paniculate, subcapitate or capitate. Flowers are bisexual, actinomorphic, mostly arranged into bracteate spikelets. Calyx is gamosepalous. It can be tubular, subtubular, obconical or infundibular. It has 5 lobes and 5 or 10 ribs. In some taxa calyx is hairy and/ or glandular. Calyx lip is often hyalinated. Corolla consists of 5 petals which are completely free or connected at the base only. Exception are genera *Plumbago* and *Psylliostachys* with gamopetalous corolla. Flower has five stamens. Ovary has superior position, one loculus and it is connected to ovule with long stalk. The number of styles is 5 or 1. If it is 1 than it has five-lobbed stigma (genera *Plumbago* and *Ceratostigma*). Stigma is capitate to cylindrically filiform. Fruit has dry, membranous cover and contains a single seed. (Davis, et al., 1982, Kubitzki, 1993, Simpson, 2010).

Even though Plumbaginaceae members seems to have cosmopolitan distribution, the center of diversity is in the Mediterranean area and central and

western parts of Asia. Members of this family especially prefer coastal habitats, inland salty area, steppes, or rocky highlands.

1.2.1. The Genus *Plumbago* L.

Plumbago species are shrubs, herbs or lianas. Their leaves are alternate and simple. Inflorescence are terminal, capitate spikes, compound of spikelets with 3 bracts and 1 flower. Calyx is tubular, with dentate lip and large stalked glands. Corolla is gamopetalous. There is one glandular style and stigma is filiform (Davis et al, 1982). This genus is widely spread through the tropic regions, especially Africa. In the Flora of Tropical East Africa 8 indigenous species of *Plumbago* were recorded (Friss et al, 2012). Also, species of this genus are often cultivated as ornamentals.

Figure 1: *Plumbago europaea* L. (edited from the Plant illustrations webpage; Sibthrop, J., Smith, J.E., Flora Graeca, vol. 2, p. 75, 1813)

Plumbago europaea L. is the only native species of *Plumbago* in Europe as well as in Turkey (Tutin et al, 1972, Davis et al, 1982). Another species that is common at the coast of Turkey is *Plumbago capensis* Thunb. (syn. *Plumbago auriculata* Lam., due to its auriculate leaves). This species is native to South Africa, but it is also cultivated as a garden plant, in all warm parts of the world. Occasional escapes of cultivation and naturalization are recorded, as well.

Figure 2: *Plumbago capensis* Thunb. (edited from the Plant illustrations webpage; d' Orbigny, C.V.D., Dictionnaire universel d'histoire naturelle, plates vol. 3, t. 44, Dicotylédones 13, 1841-1849)

1.2.2. The Genus *Limonium* Mill.

Plants from *Limonium* genus are subshrubs or herbs, mostly perennieal with few exceptions of annuals. Leaves are usually arranged in basal rosettes. In some of the species leaves dry up before the end of the flowering time. Scapes are often with

paniculate or subcorymbose branching, and may have sterile branches, as well. Inflorescence is spicate, spikes consist of many spikelets, with 1 up to (8-12) florets. Calyx is infundibuliform, obconical or tubular, with hyaline lip. Stigma is cylindrically filiform (Davis et al, 1982, Kubitzki, 1993). The very center of *Limonium* diversity is in the Mediterranean region, but its species might be found in other parts of the world with Mediterranean-like climate. *Limonium* species prefer coastal habitats or salty marches, as well as inland salty areas. That is where their common name Sea Lavenders came from.

Figure 3: *Limonium bellidifolium* Dumort (edited from the Plant illustrations webpage; Sibthrop, J., Smith, J.E., Flora Graeca, vol. 3: p. 90, t. 295, 1819)

This is one of the largest genus of Plumbaginaceae, roughly it has around 350 species (Kubitzki, 1993). Also, it is quite complex genus and there are constant changes within it. Since new species are being described and some of the species are being segregated from *Limonium*. Even though the first detailed study of *Limonium* was done by Boissier in 1848, it was segregated from genus *Statice* L. later, by

Miller. As previously mentioned, variety of species within this genus is very wide and complex that makes establishing firm and objective sectional separation quite hard. For example, in the flora of U.S.S.R. 32 species are separated into 5 sections: *Pteroclados* Sauv. & Vindt, *Platyhymenium* Boiss., *Limonium* Boiss., *Sarcophyllum* (Boiss.) Lincz. (this section was previously considered as subsection of the section *Limonium* by Boissier) and new section *Siphonocalyx* Lincz. (Komarov, 1967). Separation is mostly done on account of scape and calyx features. Flora of Iran contains almost same organization of sections with omission of *Siphonocalyx* and establishment of new section *Nephrophylum* Rech. (Rechinger and Schiman-Czeika, 1974). Approach to intrageneric structure of *Limonium* in Flora Europea is different in a sense that all species are divided into 3 subgenera by: *Pteroclados*, *Myriolepis* (previously it was one of the section of the *Statice* that Boissier had described) and *Limonium* (Tutin et al, 1972). The latest change in structure of *Limonium* genus is that subgenus *Myriolepis* is segregated and raised into generic level, under the name *Myriolimon* (Lledo et al, 2003, 2005).

In the Flora of Turkey, 17 species of the *Limonium* had been described and splitted into 5 sections, as: *Pteroclados*, *Limonium*, *Sarcophyllum*, *Sphaerostachys* and *Schizyhymenium*. The last two sections were established by Bokhari (Davis et al, 1982). Later in the supplement volume of the Flora of Turkey two new species were added, as *Limonium vanense* Kit Tan & Sorger and *Limonium caspium* (Willd.) Gams (Davis et al, 1988). Recently, two more species were described and published as *Limonium smithii* Akaydın (Akaydın, 2007) and *Limonium gueneri* Doğan, Duman & Akaydın (Doğan et al, 2008). Beside these, in the METU herbarium there are specimens named as *Limonium davisii*, *Limonium didimense* and *Limonium marmarisense* that are suspected to be a new species. Those specimens are included in this study in order to compare them with other species and to determine their potential placement within the sections of *Limonium*.

1.2.3. The Genus *Goniolimon* Boiss.

All the species of *Goniolmon* are herbs, with short woody caudex and leaves in basal rosettes. Scapes are winged, panicled or sybcorymbose. Calyx is

infundıbular, plicate. Styles are with long hairs at lower part. Stigma is depressed capitate (Davis et al, 1982). Distribution range of the genus spreads from the North Africa and east Mediterranean till to China and Mongolia. The highest number of species is described from Europe and Russia. Flora of U.S.S.R mentions 12 species, divided in two sections, *Unicuspidaria* and *Tricuspidaria* according to the number of cusps on the 2nd inner bract. Within section *Tricuspidaria* additional subsection and series are also described (Komarov, 1967). In the European flora 11 species are present, without sectional differentiation (Tutin et al, 1972). Flora of China contains only 4 *Goniolimon* species (Wu and Raven, 1996).

Figure 4: *Goniolimon* Boiss. (edited from the Muséum national d'histoire naturelle webpage, Collection des vélins du Muséum national d'histoire naturelle, vol.16: t.78)

In Turkey only one *Goniolimon* species is present. This species was described in the Flora of Turkey as a *Goniolimon collinum* (Griseb.) Boiss. (Davis et al, 1982). However, in later revision this species was referred as *Goniolimon incanum* (L.) Hepper (Davis et al, 1988). Doğan and Akaydın (2006) in their revision of

Plumbaginaceae in Turkey, recorded presence of the *Goniolimon besseranum*, as a cultivated garden plant. Normally this species grows in east parts of Europe.

1.2.4. The Genus *Limoniopsis* Lincz.

Plants with short woody caudex and leaves arranged in rosettes. Scape is panicled, spiklets are with remote spacing and 1-3 flowered. Calyx is subtubular. Stigma is capitate (Komarov, 1967).

This genus has only two species. *Limoniopsis owerini* (Boiss.) Lincz. was described by Boissier as a *Statice owerinii*. Later *Limoniopsis* was segregated from *Statice* and established as a monotypic genus by Linczevski. It mostly grows at eastern Caucasus. In Turkey it is found around Kemaliye in Erzincan province. *Limoniopsis davisii* Bokhari, is endemic species of Van province in South East Anatolia (Davis et al, 1982).

Figure 5: *Limoniopsis owerinii* (Boiss.) Lincz (edited from the Russian Federation Plant's Redlist webpage (Красная Книга Российской Федерации (Растения))

1.2.5. The Genus *Acantholimon* Bioss.

Subshrubs or shrublets with cushion formation. Leaves are rigid, linear, triquetrous and pungent, homomorphic or heteomorphic. Scape is with scales. Inflorescense is in a form of branched or not branched spikes, in some cases capitate or paniculate. Spiklets are 1-flowered or 2-5 (6) flowered, with 3 or more bracts. Calyx infundibular, with hyaline lip. Stigma is oblong-capitate. (Davis et al, 1982).

The genus contains about 165 species (Kubitzki, 1993). Its distribution range stretches form the southern Greece, over Turkey, Iran, Afghanistan, to the west Tibet. Most of the species are confined to mountainous regions, usually in dry, stony soils and exposed rocky slopes (Komarov, 1967). The rate of endemism in this genus is very high. Most of the species are local endemics, with narrow distribution range. After *Limonium*, this is the second most species rich genus in Plumbaginaceae. Same as *Limonium*, *Acantholimon* genus is very complex and shows great variation in characters between species, which makes grouping within genus and sectional delimitation quite complicated.

Acantholimon was first known as subgenus *Armeriastrum* Jaub. & Spach in *Statice* L. genus (Lledo et al, 2003). Boissier, was the first who described the *Acantholimon*, as a separate genus and provided its earliest classification, in 1846. He divided genus into following sections: *Armeriopsis*, *Staticopsis* and *Glumaria* (Moharrek et al, 2014). Russian botanist, Bunge had published in 1872 a very first detail revision of the genus and organized 83 known species into 7 sections: *Armeriopsis*, *Staticopsis*, *Glumaria*, *Acmostegia*, *Cymaria*, *Pterostegia* and *Tragacanthina* (Doğan and Akaydın, 2003a). This Bunges classification was revised by Boissier in 1879. by addition of the section *Pulvinaria*. Mobayen recognized 112 species and made a change in this classification by removing *Cymaria* and *Pulvinaria* sections and describing new *Dracogina* section (Moharrek et al, 2014). Linczevski, had accepted sections: *Armeriopsis*, *Glumaria*, *Pterostegia*, *Staticopsis* and *Tragacanthina*, and added section *Gontscharovia*, for the grouping of around 70 species included in flora of U.S.S.R. (Komarov, 1967). Flora of Iran contains 153 *Acantholimon* species, separated into 15 sections (8 old and 7 new). Old sections

established by previously mentioned authors are: *Acmostegia*, *Acantholimon*, *Dracogina*, *Glumaria*, *Gontscharovia*, *Pterostegia*, *Staticopsis* and *Tragacanthina*, New sections that had been described, are: *Bromeliopsis*, *Inermia*, *Physostegia*, *Platystegia*, *Poicilocephala*, *Schizostegia* and *Stereophylla* (Reichinger and Schiman-Czeika, 1974). This classification had been revised by Assadi in 2005, by reducing number of sections into 7. He accpeted old ones: *Acmostegia*, *Acantholimon*, *Platystegia*, *Pterostegia*, *Staticopsis*, *Tragacanthina* and added one new, *Microstegia* (Moharrek et al, 2014).

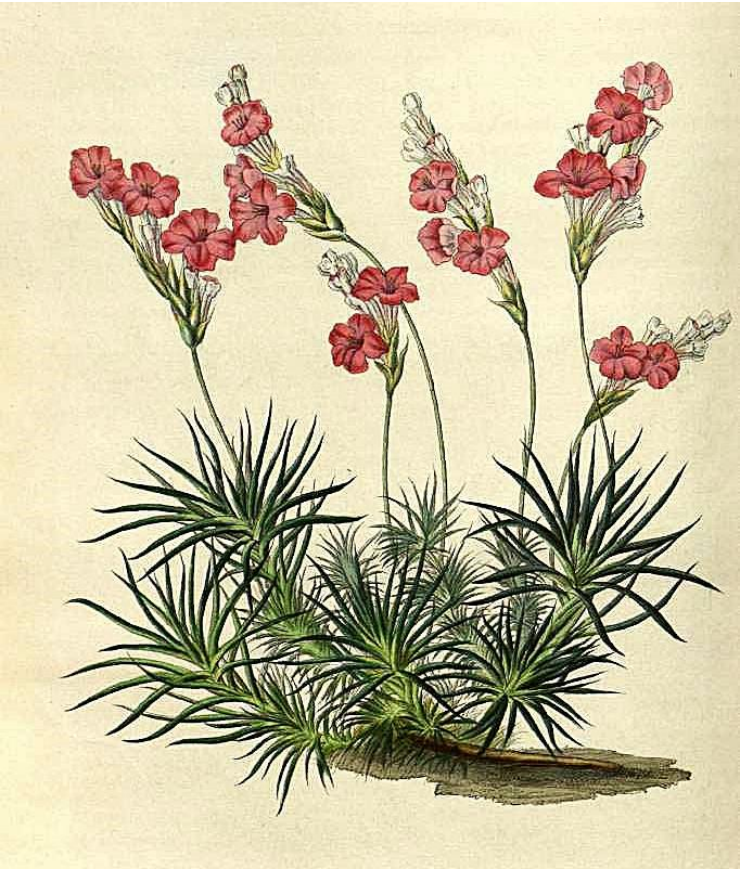

Figure 6: *Acantholimon glumaceum* (Jaub. & Spach) Boiss. (edited from the Plant illustrations webpage; Houtte, L. van, Flore des serres et des jardin de l'Europe, vol.7: t. 677, 1852)

In the Flora of Turkey 25 species had been described, along with 11 doubtfully recorded and 2 imperfectly known species. Those species are divided into

3 main sections: *Acantholimon, Tragacanthina* and *Staticopsis*. Within section *Staticopsis* there are 3 subsections: *Caryophyllacea, Microcalycina* and *Androsacea*. (Davis et al, 1982). Muvaffak and Doğan had described additional subsection Muvaffak and Doğan had described additional subsection *Halophiliacea* (Muvaffak et al, 2001). In a period of three years a very profound study was conducted by Doğan and Akaydın with aim to revise genus *Acantholimon* in Turkey. It included collecting specimen all around Turkey, examining existing specimens at different herbaria, including material cited in Flora of Turkey and East Aegean Islands, 7th volume (Dogan and Akaydın, 2003a). Result of this study showed that there were 52 species, 10 subspecies, and 17 varieties in Turkey. From those 13 of the species were described for the first time: *A.birandii* (Dogan and Akaydın, 2001), *A.avanosicum* (Dogan and Akaydın, 2002a), *A.karamanicum* (Akaydın and Doğan, 2002), *A.anatolicum* (Dogan and Akaydın, 2002b), *A.yildizelicum* (Akaydın,, 2002), *A.köycegizicum* and *A.göksunicum* (Dogan and Akaydın, 2003c), *A.turcicum* (Dogan and Akaydın, 2003b), *A.hoshapicum, A.artosense* and *A.bashkaleicum* (Dogan and Akaydın, 2004), *A.evrenii* (Dogan and Akaydın, 2005), and *A.ekimii* (Doğan and Akaydın, 2007a). Species *A.laxiflorum*, was first described by Boissier. However, probably by mistake, Bokhari and Edmondson, labeled this species as a variety of the *A.venustum*, in the Flora of Turkey. Later, newest research findings showed that species is pretty different, both from *A.venustum*, and the rest of *Acantholimon* species (Doğan et al., 2003d). Presence of the species *A.araxanum* Bunge, *A.hohenackeri* (Jaub. &Spach) Boiss., *A.latifolium* Boiss. and *A.lepturoides* (Jaub. & Spach) Boiss. that were marked as a doubtfully recorded species in the Flora of Turkey, was confirmed, too. Also, species *A.senangense*, *A.fominii* and *A.tragacanthinum*, previously known from other countries, had been found to grow in Turkey, as well (Doğan and Akaydın, 2003a). As a part of this revision, 3 sections within *Acantholimon* genus were accepted: *Acantholimon*, *Tragacanthina* and *Staticopsis*. The species *A.evrenii*, seems to be the only representative of the section *Glumaria* Boiss. in Turkey (Dogan and Akaydın, 2005). Furthermore, *Staticopsis* section was reorganized and the following subsections are suggested: *Robustea* Dogan and Akaydın subsect. nov., *Diantifoliea* Dogan and Akaydın subsect. nov., *Circinnatea* Dogan and Akaydın subsect. nov., *Androsacea* Bunge, *Caryophyllacea*

Bunge (Doğan et al, 2007). As a final result of this study Synopsis of Turkish *Acantholimon* Boiss. (Plumbaginaceae) had been published (Doğan and Akaydın, 2007). In the following years there were two more publications about *Acantholimon* species. First species is *A.doganii* placed under section *Staticopsis* and subsection *Androsacea* (Bağcı et al, 2009). Second species is *A.riyatguelii*, included in section *Staticopsis*. Because of its specific morphology that differs from other species in this section, a new subsection *Exacantha*, was described (Yıldırım and Crespo, 2014).

1.2.6. The Genus *Armeria* Willd.

Armeria species are herbs, with branched woody root stock, and leafless scape. Leaves are linear, arranged in basal rosettes. Inflorescence is capitate, composed of cymose, bracteate, spikelets. Calyx is infundibular. Styles are hairy in lower third. Stigma is filiform (Davis et al, 1982).

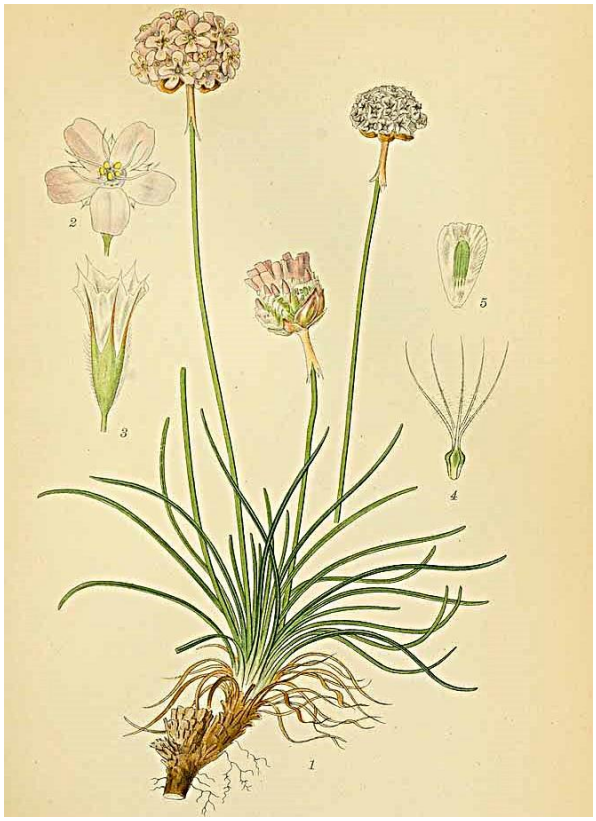

Figure 7**:** *Armeria maritima* Willd. (edited from the Plant illustrations webpage; Lindman, C.A.M., Bilder ur Nordens Flora, vol. 1: t. 140, 1922-1926)

Armeria is distributed in north temperate regions, mostly in Europe, as well as some parts of Chile and Tierra del Fuego in South America. However, center of its diversity is west Mediterranean, especially Iberian Peninsula, where almost 60% of the species are present (Aguilar, 1999). This genus is taxonomically very complex. Since hybridization occurs often, it increases variation of diagnostic characters, and sometimes make boundaries between species hard for determining (Selvi, 2009). Genus was the first time described by Linnaeus as a part of *Statice* L. genus, as a single species *Statice armeria*. It was recognized as a separate genus by Willdenow (Yeşil et al, 2014). In European flora 43 species were accepted and divided in two sections, *Armeria* and *Macrocentron*, based on calyx features (Tutin et al, 1972).

In Turkey there are two native species. *Armeria trojana* is a local endemic, known only from Mount Ida (Kaz Dağı) in Balıkesir province. *Armeria cariensis*, according to the Flora of Turkey, consist of two varieties *Armeria cariensis var. cariensis* and *Armeria cariensis var. rumelica* that was also supported by later revision (Dogan and Akaydın, 2006). Also, there are opinions that those varieties should be recognized as separate species *Armeria cariensis* and *Armeria rumelica* (Yeşil et al, 2014). *Armeria maritima* is not native to Turkey but it may occur as a garden plant.

1.2.7. The Genus *Ceratostigma* Bunge

Plants of this genus are mostly shrubs and herbs. Leaves have ciliate margin. Inflorescences are terminal, subcapitate to capitate spikes, with 3 bracts and 1 flowered spikeletes. Calyx is tubular. Corolla is gamopetalous (Wu and Raven, 1996). *Ceratostigma* is native to China, with wide distribution range from temperate and tropical regions up to Himalayas. One species is also known from east Africa.

Ceratostigma plumbaginoides Bunge, is grown worldwide as a garden plant. Also, there are records that it has been locally naturalized in North West France and North West Italy (Tutin et al, 1972). This species is present in Turkey as well, especially in gardens of coastal area. Due to that we decided to include this species in

the study, in order to compare and contrast it with native Turkish genera of the Plumbaginaceae.

Figure 8: *Ceratostigma plumbaginoides* Bunge (edited from the Plant illustrations webpage; Curtis's Botanical Magazine, vol.76, t.4487, 1850, drawing by W.H. Fitch)

1.2.8. The Genus *Psylliostachys* (Jaub. & Spach.) Nevski

Psylliostachys consist of annual herbs. Leaves are simple or pinnatifid. Inflorescences are terminal and lateral, cylindrical spikes, composed of many spikelets, with 2 bracts and 2-4 florets. Calyx is infundibular. Corolla is gamopetalous. Glandular hairs are present on calyx, leaves and scape (Kubitzki, 1993; Tutin et al, 1972). Boissier considered *Psylliostachys* as a section of the genus *Statice*, and part of the "*Corolla gamopetala*" group (Lledó et al, 2003). Jaubert and Spach raised it at the level of subgenus. Finally, it was recognized as a genus by the Russian botanist Nevski (Rechinger and Schiman-Czeika, 1974). Genus has a

distribution range spreading from Russia and Central Asia, over Caucasus and Iran till to Syria and Palestine.

Figure 9: *Psylliostachys* (Jaub. & Spach.) Nevski (edited from the Plant illustrations webpage; Curtis's Botanical Magazine, vol. 113, t. 6959, 1887, drawing by M.Smith)

In the summer of 2014, research expedition made in the south east Turkey revealed the presence of the species *Phylliostachys spicata*, in the saline areas around the Siirt city. This was the first record of the *Psylliostachys* in Turkey.

1.3. Ecological Features of the Plumbaginaceae Juss. in Turkey

Currently, 83 species, 8 subspecies and 23 varieties of Plumbaginaceae are known from Turkey. They are given in the Table 1. Also, there are 4 nonnative species present as ornamentals, given in a Table 2. Furthermore, both tables contain

additional information about species' habitat preferences, elevation, geographic distribution range, endemism, phytogeography, and IUCN threat categories (Davis et al, 1982; IUCN, 2001; Doğan and Akaydın, 2003a, 2006). Each of those topics will be discussed in details, as follows.

Table 1: The list of Plumbaginaceae native to Turkey and their general ecological information

	Species	Habitat type	Elevation range (m)	Geographic Range	Phytogeography	IUCN status
1.	***Acantholimon acerosum subsp. acerosum var. acerosum*** (Willd.) Boiss.	Rocky igneous slopes, calcareous and sandy soils, steppe	0 - 2400	Anatolia, except S. E., (Turkey), W. Syria, N. Iraq, Iran, Armenia	Irano-Turanian element	**LC**
	subsp. acerosum var. parvifolium Bokhari	Rocky igneous slopes, calcareous and sandy soils, steppe	1070	Endemic from Göksun, Kahramanmaraş province, Turkey	Irano-Turanian element	**VU**
	subsp. brachystachyum (Boiss.)Doğan & Akyadın	Rocky igneous slopes, calcareous and sandy soils, steppe	600- 2000	Endemic of W. and C. Anatolia, Turkey	Irano-Turanian element	**LC**
	subsp. longibracteolorum Doğan & Akyadın	Rocky igneous slopes, calcareous and sandy soils, steppe	780-1400	Endemic of N.W. and W. Anatolia, Turkey	Irano-Turanian element	**LC**
2.	***Acantholimon anatolicum*** Doğan & Akaydın	Gypseous, saline, soil on mountain slopes	1100-1500	Endemic of Nalıhan, Ankara province, Turkey	Irano-Turanian element	**CR**
3.	***Acantholimon araxanum*** Bunge	Sandy slopes, steppes	1200-1500	E. Anatolia (Turkey), Armenia, Caucasus, Iran	Irano-Turanian element	**NT**
4	***Acantholimon armenum var.armenum*** Boiss. & A.Huet.	Sandstone and calcareous slopes, steppes	500-2800	S. and W. Anatolia (Turkey), W. Syria, N. Iraq, Armenia	Irano-Turanian element	**LC**
	var. balansae Boiss. & A.Huet.	Sandstone and calcareous slopes, steppes	00-2800	S. and W. Anatolia (Turkey), Armenia	Irano-Turanian element	**LC**

Table 1. (Continued)

5.	***Acantholimon artosense*** Doğan & Akaydın	Calcareous mountain slopes	2500	Endemic of Artos Mountine, Van province, Turkey	Irano-Turanian element	**CR**
6.	***Acantholimon avanosicum*** Doğan & Akaydın	Calcareous slopes and steppes	950	Endemic from Avanos, Nevşehir province, Turkey	Irano-Turanian element	**CR**
7.	***Acantholimon bashkaleicum*** Doğan & Akaydın	Sedimentary rocks and montane steppes	2100	Endemic from Başkale, Van province, Turkey	Irano-Turanian element	**CR**
8.	***Acantholimon birandii*** Doğan & Akaydın	Calcareous mountain slopes	1600-1700	Endemic from Karaman province, Turkey	Irano-Turanian element	**CR**
9.	***Acantholimon bracteatum*** (Girard) Boiss.	Calcareous, rocky slopes and montane steppes	1700-3100	S. E. Anatolia (Turkey), Armenia, N.W. Iran	Irano-Turanian element	**VU**
10.	***Acantholimon caesareum*** Boiss. & Balansa	Volcanic slopes, steppes	800-2285	Endemic of C. and N. Anatolia, Turkey	Irano-Turanian element	**CR**
11.	***Acantholimon calvertii var. calvertii*** Boiss.	Calcareous and volcanic slopes, steppes	1210-3535	Endemic of E. Anatolia, Turkey	Irano-Turanian element	**LC**
	var. glabrum Doğan & Akaydın	Calcareous and volcanic slopes, steppes	1210-3535	Endemic of E. Anatolia, Turkey	Irano-Turanian element	**VU**
12.	***Acantholimon capitatum subsp.capitatum*** Sosn.	Calcareous and dry slopes	1700-2500	Endemic of E. Anatolia, Turkey	Irano-Turanian element	**VU**
	subsp. sivasicum Doğan &Akaydın	Serpentine rocks, steppe	1400-1500	Endemic of C. Anatolia, Turkey	Irano-Turanian element	**CR**

Table 1. (Continued)

13.	***Acantholimon caryophyllaceum*** Boiss.	Volcanic, calcareous slopes and steppes	1600-2800	E. Anatolia (Turkey), N. Iraq, Armenia, N. and W. Iran	Irano-Turanian element	**LC**
14.	***Acantholimon confertiflorum*** Bokhari	Calcareous, clay slopes or steppes	1100-1450	Endemic of C. Anatolia, Turkey	Irano-Turanian element	**EN**
15.	***Acantholimon damassanum*** Mobayen	Calcareous steppe, stony hills, dry slopes	850-2020	E. Anatolia (Turkey), Syria	Irano-Turanian element	**VU**
16.	***Acantholimon dianthifolium*** Bokhari	Rocky, high montane steppes	2070-3600	S. E. Anatolia (Turkey), N. Iraq	Irano-Turanian element	**VU**
17.	***Acantholimon doganii*** Y.Bağcı, Doğu& Akaydın	*Cedrus* forest glades	1640	Endemic from Sarıveliler, Karaman province, Turkey	Irano-Turanian element	**CR**
18.	***Acantholimon ekimii*** Doğan & Akaydın	High mountain steppes	2300	Endemic from Akçay, Ağrı province, Turkey	Irano-Turanian element	**CR**
19.	***Acantholimon evrenii*** Doğan & Akaydın	Rocky mountain steppes	1200-1600	Endemic from Baltaşı, Elazığ province, Turkey	Irano-Turanian element	**CR**
20.	***Acantholimon fominii*** Kusn.	Sandstone mountain slopes, steppes	2100	E. Anatolia (Turkey),Caucasus, Iran, Azerbaijan	Irano-Turanian element	**VU**
21.	***Acantholimon glumaceum*** (Jaub.& Spach.) Boiss.	Limestone rocks, clay slopes, chalky hills and steppes	1500-2000	E. Anatolia (Turkey), Armenia	Irano-Turanian element	**VU**
22.	***Acantholimon göksunicum*** Doğan & Akaydın	Calcareous slopes, steppes	2100	Endemic from Göksun, Kahramanmaraş province, Turkey	Irano-Turanian element	**CR**

Table 1. (Continued)

23.	***Acantholimon halophilum*** Bokhari	Salt steppes, saline clay hillocks, open *Pinus nigra* forest	800-1200	Endemic of C. Anatolia, Turkey	Irano-Turanian element	**CR**
24.	***Acantholimon hohenackerii*** (Jaub.&Spach)Boiss.	Rocky mountain slopes	2000-2700	E. Anatolia, (Turkey), Iran, Armenia	Irano-Turanian element	**VU**
25.	***Acantholimon hoshapicum*** Doğan & Akaydın	Dry montane steppes	2050	Endemic from Hoşap, Van province,Turkey	Irano-Turanian element	**CR**
26.	***Acantholimon huetii var. huetii*** Boiss.	Calcareous slopes and steppes	1700-2650	Endemic of S. Anatolia, Turkey	Irano-Turanian element	**CR**
	var. breviscapum Doğan & Akaydın	Calcareous slopes and steppes	1700-2650	Endemic of S. Anatolia, Turkey	Irano-Turanian element	**CR**
27.	***Acantholimon hypochaerum*** Bokhari	Volcanic, limestone or clay slopes	1400-2800	Endemic of E. Anatolia, Turkey	Irano-Turanian element	**EN**
28.	***Acantholimon iconicum*** (Boiss.) Boiss. & Heldr.	Sedimentary and calcareous rocks, steppes	1500-2400	Endemic of N. and C. Anatolia, Turkey	Irano-Turanian element	**EN**
29.	***Acantholimon karamanicum*** Akaydın & Doğan	Calcareous mountain slopes, *Quercus* glades, *Astragalus* steppe	1600-1700	Endemic of Karaman province, Turkey	Irano-Turanian element	**CR**
30.	***Acantholimon kotschyi*** (Jaub. & Spach.) Boiss.	Salt steppes, sandy banks, calcareous soils	870-2350	Endemic of S. and C. Anatolia, Turkey	Irano-Turanian element	**LC**
31.	***Acantholimon köycegizicum*** Doğan & Akaydın	Serpentine, rocky stream beds	0-150	Endemic from Köyceğiz, Muğla province, Turkey	Mediterranean element	**CR**
32.	***Acantholimon latifolium*** Boiss.	Calcareous steppe	1350-2100	S. E. Anatolia (Turkey), N. Iraq, W. Iran	Irano-Turanian element	**CR**

Table 1. (Continued)

33.	***Acantholimon laxiflorum*** Boiss.ex Bunge	Serpentine, rocky stream beds	0-50	Endemic from Hatay province, Turkey	Mediterranean element	**CR**
34.	***Acantholimon lepturoides*** (Jaub.& Spach) Boiss.	Limestone and rocky slopes	1400	E. Anatolia (Turkey), Armenia	Irano-Turanian element	**NT**
35.	***Acantholimon libanoticum*** Boiss.	Calcareous, mountain slopes, steppes	1700-2500	S. Anatolia (Turkey), Lebanon	Mediterranean element	**VU**
36.	***Acantholimon lycaonicum var. lycaonicum*** (Boiss.) Boiss. &Heldr.	*Quercus* glades, calcareous and serpentine slopes, sediment rocks, steppes	800-2250	Endemic of S. and C. Anatolia, Turkey	Mediterranean element	**NT**
	var. cappadocicum Akaydın & Doğan	*Quercus* glades, calcareous and serpentine slopes, sediment rocks, steppes	800-2250	Endemic of C. Anatolia, Turkey	Irano-Turanian element	**NT**
37.	***Acantholimon multiflorum*** (Bokhari) Doğan &Akaydın	Dry stony hills	1180-2100	Endemic of E. Anatolia, Turkey	Irano-Turanian element	**VU**
38.	***Acantholimon parviflorum*** (Bokhari) Akaydın &Doğan	Eroded hills and gypsum slopes	350-900	Endemic C. Anatolia, Turkey	Irano-Turanian element	**CR**
39.	***Acantholimon petraeum*** Boiss. & Hausskn. ex Bunge	Volcanic rocks, montane steppes	1900-2650	E. Anatolia (Turkey), Iraq	Irano-Turanian element	**NT**
40.	***Acantholimon petuniiflorum*** Mobayen	Rocky, dry slopes and calcareous montane steppes	1700-2600	S. E. Anatolia (Turkey), N. Iraq	Irano-Turanian element	**CR**
41.	***Acantholimon puberulum subsp. puberulum*** Boiss. & Balansa	Calcareous and serpentine slopes, arid steppes	850-2100	S. and C. Anatolia (Turkey), N. Iraq	Irano-Turanian element	**LC**

Table 1. (Continued)

	subsp. longiscapum (Bokhari) Doğan &Akaydın	Calcareous slopes, *Astragalus* steppes	1600-2000	Endemic of C. Anatolia, Turkey	Irano-Turanian element	**LC**
	subsp. peroninii (Boiss.) Doğan &Akaydın	Calcareous slopes, steppes	1300-2200	Endemic of C. Anatolia, Turkey	Mediterranean element	**LC**
42.	***Acantholimon quinquelobum var. quinquelobum*** Bunge	Saline, dry, sandy hills	800-1300	E. Anatolia (Turkey), Armenia, N. W. Iran	Irano-Turanian element	**EN**
	var. curviflorum (Bunge) Doğan & Akaydın	Saline, dry, sandy hills	800-1300	E. Anatolia (Turkey), W. Iran	Irano-Turanian element	**EN**
43.	***Acantholimon reflexifolium*** Bokhari	Volcanic and limestone rocks, dry stony slopes	1700-3000	Endemic of C. Anatolia, Turkey	Irano-Turanian element	**VU**
44.	***Acantholimon riyatguelii*** Yıldırım & Crespo	Gypsum soils	800-1100	Endemic from Eskişehir province, Turkey	Irano-Turanian element	**CR**
45.	***Acantholimon saxifragiforme*** (Hausskn. & Sint.) Bokhari	Calcareous montane steppes, rocky hills	1000-1570	Endemic of E. Anatolia Turkey	Irano-Turanian element	**CR**
46.	***Acantholimon senganense*** Bunge	Volcanic rocks, montane steppes	2200	E. Anatolia (Turkey), Syria, Iraq, Iran	Irano-Turanian element	**VU**
47.	***Acantholimon spirizianum*** Mobayen	Calcareous slopes and steppes	2150-2800	Endemic of E. Anatolia, Turkey	Irano-Turanian element	**VU**
48.	***Acantholimon strigillosum*** Bokhari	Eroded hills, serpentine rocks	1100-1500	Endemic of E. Anatolia, Turkey	Irano-Turanian element	**VU**
49.	***Acantholimon tragacanthinum*** (Jaub. & Spach.) Boiss.	Saline, dry, sandy hills	1200	E. Anatolia (Turkey), W. Iran	Irano-Turanian element	**NT**

Table 1. (Continued)

50.	***Acantholimon turcicum*** Doğan & Akaydın	Calcareous mountain scree	1300-1700	Endemic of E. Anatolia, Turkey	Irano-Turanian element	**CR**
51.	***Acantholimon ulicinum var. ulicinum*** (Willd. ex Schultes) Boiss	Calcareous, serpentine or exposed rocky slopes	1600-2350	Albania, Greece, W. and S. Anatolia (Turkey)	Mediterranean element	**LC**
	var. purpurascens (Bokhari) Bokhari & Edmondson	Calcareous, serpentine or exposed rocky slopes	1750-2500	Endemic of S. W. Anatolia Turkey	Mediterranean element	**CR**
	var. creticum (Boiss.) Bokhari & Edmondson	Calcareous, serpentine or exposed rocky slopes	670-2500	C. and S. Anatolia (Turkey), Greece	Mediterranean element	**LC**
52.	***Acantholimon venustum var. venustum*** Boiss.	Rocky volcanic slopes, limestone hills, mountain steppes, *Pinus* and mixed forests	690-2650	C., E. and S. Anatolia (Turkey), W. Syria, N. Iraq, W. Iran	Irano-Turanian element	**LC**
	var. assyriacum (Boiss.) Boiss.	Rocky volcanic slopes, limestone hills, mountain steppes, *Pinus* and mixed forests	1400-1700	Endemic of E. Anatolia, Turkey	Irano-Turanian element	**VU**
53.	***Acantholimon wiedemannii*** Bunge	Claystone slopes, steppes	1250-1500	Endemic of C. Anatolia, Turkey	Irano-Turanian element	**VU**
54.	***Acantholimon yıldıelicum*** Akaydın	Calcareous and volcanic, dry mountain slopes and steppes	1700	Endemic of Yıldızeli, Sivas province, Turkey	Irano-Turanian element	**CR**
55.	***Armeria cariensis*** Boiss.	Grasslands and montane steppes	0-1300	N. E. Greece, N.W. and W. Turkey	Mediterranean element	**EN**
56.	***Armeria rumelica*** Boiss	Grasslands and montane steppes	0-1300	S. E. Balkans	Mediterranean element	**EN**

Table 1. (Continued)

57.	***Armeria trojana*** Bokhari & Quézel	Siliceous rocks, stony places	1500-1750	Endemic of Kaz Mountain, Turkey	Mediterranean element	**CR**
58.	***Goniolimon incanum*** (L.) Hepper	Steppe, fallow fields, chalky and serpentine hills, stream beds, rocky sea shores	5-1000	From South Balkan to Syria	Mediterranean element	**LC**
59.	***Limoniopsis davisii*** Bokhari	Limestone mountain slopes	1900-2700	Endemic of S. E. Anatolia, Turkey	Irano-Turanian element	**CR**
60.	***Limoniopsis owerinii*** (Boiss.) Lincz.	Rocky mountain slopes	450-920	E. Anatolia (Turkey), E. Caucasus	Irano-Turanian element	**CR**
61.	***Limonium anatolicum*** Hedge	Continental saline areas	900-1000	Endemic of C. Anatolia, Turkey	Irano-Turanian element	**CR**
62.	***Limonium angustifolium*** (Tausch) Turrill	Seaside salt-flats, rocky limestone slopes	0-10	Mediterranean area	Mediterranean element	**EN**
63.	***Limonium bellidifolium*** (Gouan) Dumort.	Coastal and inland saline areas	0-1010	W. Turkey, S. and C. Europe, Crimea, C.Asia	Euro-Siberian element	**EN**
64.	***Limonium caspium*** (Willd.) Gams	Continental salty areas	850-1100	C. Anatolia, (Turkey), N.W. Iran, Azerbaijan, Siberia, C. Asia	Irano-Turanian element	**CR**
65.	***Limonium effusum*** (Boiss.) Kuntze	Salty and arid areas	0-10	Endemic of W. and S.W. Anatolia, Turkey	Mediterranean element	**EN**
66.	***Limonium echioides*** (L.) Miller	Muddy salt-flats, sandy areas near sea shore	0-5	W. and S. Anatolia (Turkey), Mediterranean	Mediterranean element	**VU**

Table 1. (Continued)

67.	***Limonium globuliferum var. globuliferum*** (Boiss. & Heldr.) Kuntze	Continental salty areas	900-1100	C. Anatolia (Turkey), Syrian Desert	Irano-Turanian element	**CR**
	var. subglobosum Doğan & Akaydın	Continental salty areas	900-1100	Endemic of C. Anatolia, Turkey	Irano-Turanian element	**CR**
68.	***Limonium gmelinii*** (Willd.) Kuntze	Sea shore, saline or gypsuous inland places	0-1450	Turkey, C. Europe, Balkans, Caucasus, Crimea, Iran, C. Asia	Euro-Siberian element	**LC**
69.	***Limonium graecum var. graecum*** (Poir.) Rech.	Sea shores, sands, volcanic and limestone rocks	0-5	W. Anatolia (Turkey), Greece, Aegean islands	Mediterranean element	**CR**
	var.hyssopifolium (Girard) Bokhari	Sea shores, sands, volcanic and limestone rocks	0-5	W. Anatolia (Turkey), S. Greece, Aegean islands	Mediterranean element	**CR**
70.	***Limonium guenerii*** Doğan, Duman & Akaydın	Steep coastal calcareous cliffs	20	Endemic from Kaş, Antalia province, Turkey	Mediterranean element	**CR**
71.	***Limonium iconicum*** (Boiss. & Heldr.) Kuntze	Continental salt steppes and carbonate rocks	800-1400	Endemic of C. Anatolia (Turkey)	Irano-Turanian element	**EN**
72.	***Limonium lilacinum var. lilacinum*** (Boiss.& Balansa) Wagenitz	Continental saline areas	900-1200	Endemic of C. Anatolia, Turkey	Irano-Turanian element	**CR**

Table 1 (Continued)

	var. laxiflorum Doğan & Akaydın	Continental saline areas	900-1200	Endemic of C. Anatolia, Turkey	Irano-Turanian element	**CR**
73.	***Limonium meyeri*** (Boiss.) Kuntze	Continental saline areas	800-900	N.E. Anatolia (Turkey), Russia, Crimea, C. Asia Caucasus	Irano-Turanian element	**VU**
74.	***Limonium ocymifolium*** (Poir.) Kuntze	Sandy shores, calcareous and metamorphic littoral rocks	0-10	W. Anatolia (Turkey), Greece and Aegean Islands	Mediterranean element	**CR**
75.	***Limonium pycnanthum*** (K.Koch) Kuntze	Continental saline areas	850-1500	Endemic of C. Anatolia, Turkey	Irano-Turanian element	**CR**
76.	***Limonium sieberi*** (Boiss.) Kuntze	Sea shores and salt marches	0-5	S. and S.W. Anatolia (Turkey), S. Greece, Aegean islands	Mediterranean element	**EN**
77.	***Limonium sinuatum*** (L.) Miller	Coastal cliffs, beaches, sandy shores, pastures	0-100	W. and S. Anatolia (Turkey), Mediterranean, Georgia	Mediterranean element	**EN**
78.	***Limonium smithii*** Doğan & Akaydın	Continental salty areas	1085	Endemic from Seyfe lake area, Kırşehir province,Turkey	Irano-Turanian element	**CR**
79.	***Limonium tamaricoides*** Bokhari	Continental salty areas	950-1100	Endemic of C. Anatolia, Turkey	Irano-Turanian element	**CR**

Table 1 (Continued)

80.	***Limonium vanense*** Kit Tan & Sorger	Saline meadows and marches	1600-2200	Endemic of E. Anatolia, Turkey	Irano-Turanian element	**CR**
81.	***Limonium virgatum*** (Willd.) Fourr.	Sea shores, maritime rocks, saline waste fields	0-20	W. Turkey, Mediterranean area, W.Europe	Mediterranean element	**EN**
82.	***Plumbago europaea*** L.	Dry gravelly slopes, limestone, igneous slopes, fallow fields and waste places	10-1900	Mediterranean, Central Europe, Armenia, N. Iran, Azerbaijan, Iraq	Euro-Siberian element	**LC**
83.	***Psylliostachys spicata*** (Willd.) Nevski	Saline clays and sandy soils, in low foothills, on plains, along sea coast	0-1500	Russia, C. Asia, Caucasus, Iran, Syria, Palestine, S. E. Anatolia (Turkey)	Irano-Turanian element	**LC**

Table 2: The list of Plumbaginaceae that are present in Turkey as ornamental plants and their general ecological information

	Species	Habitat type	Elevation range (m)	Geographic Range	IUCN status
1.	***Armeria maritima*** Willd.	Sea shore, sandy soils	0	Most of the Europe, except S. E. and most of the islands	**LC**
2.	***Ceratostigma plumbaginoides*** Bunge	Rocky places, often in foothills	20-800	Native to E. China, in other places present as ornamental plant	**LC**
3.	***Goniolimon besseranum*** (Schult. ex Rchb.) Kusn.	Steppes, on fine earth, chalky, and stony slopes, saline soils	0-500	Native to area from N.E. Bulgaria to S. and C. Ukraine	**EN**
4.	***Plumbago capensis*** Thunb.	Streambeds, canyons in coastal scrubs	0-150	Native to South Africa, in other places present as ornamental plant	**LC**

1.3.1. Phytogeographic distribution of the Plumbaginaceae in Turkey

Turkey is divided in 3 phytogeographic regions as a consequence of wide variation in climate and topography. These are the Euro-Siberian, the Mediterranean and the Irano-Turanian region (Davis at all, 1965).

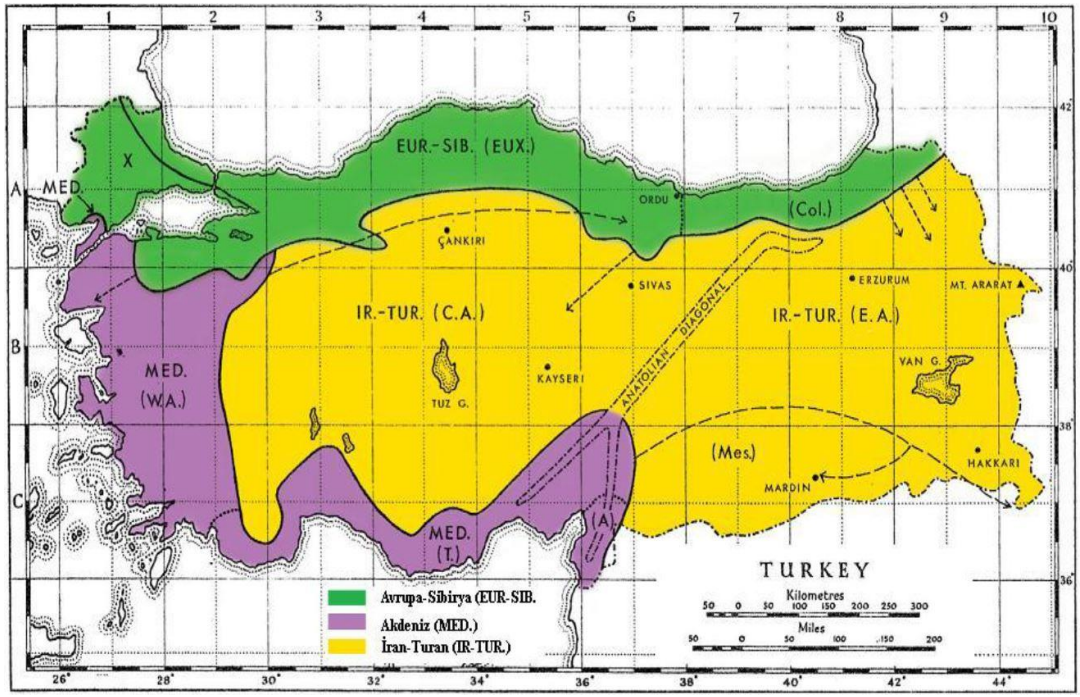

Figure 10: Phytogeographic regions of Turkey (edited from the Ecopangea webpage)

The Euro-Siberian region includes the major part of the North Anatolia and the narrow area of the Black Sea coast of the European part of Turkey. Climate in this region is very humid and has high rainfall. Vegetation consists of deciduous forest that is gradually passing into conifer forest with increasment of elevation (Davis at all, 1965). Since this type of habitat is not suitable for the growth of Plumbaginaceae they are vary rare in this region and represented only with 2 *Limonium* and 1 *Plumbago* species. This is only 3.61 % of the current total number of Plumbaginaceae in Turkey.

The Mediterranean region of Turkey consists of the Gallipoli peninsula and West and South Anatolia. The climate is typical Mediterranean, with dry, hot summers, with drought and mild, rainy winters, without frost. The dominant

vegetation are evergreen, mostly aromatic shrubs, called macchie, which are replaced by conifers at higher elevation (Davis at all, 1965). There are 5 species of *Acantholimon*, 3 species of *Armeria*, 1 species of *Goniolimon*, and 9 species of *Limonium* in this region, which is forming 21.69% of Turkish Plumbaginaceae.

Irano-Turanian region is the largest from all and richest in species content. It covers Central and East Anatolia, and consist of mountains and highland plateaus in between. Climate in this region is typical continental, in some areas, gradually passing into semi desert. Summers are hot and dry. Winters are cold, with very low temperatures and high snow cover, which is the main source of precipitation. Rain is mostly present during spring. Also, open plateau areas are often very windy which increases dryness and affects tree growth. Temperature oscillation are high, both at annual and daily base. This kind of harsh climate is favoring vegetation dominant by herbaceous plants, especially grasses that form steppes and shrubs that occasionally may pass into rare, open conifer forest, in the areas where amount of moisture allows that. Vegetation growth period is during late spring and early summer. Except at high altitudes, the Irano-Turanian region in Turkey is divided in two vegetation areas: 1. a broad outer area of deciduous scrub and rare park-like forest; 2. inner areas of the real steppe without trees. The main part of steppe area is the Central Anatolian steppe that eastward, gradually passes into montane steppes or mountain cushion vegetation of the East Anatolian highlands (Davis at all, 1965). This is the most suitable region for the growth of Plumbaginaceae in Turkey. Hence, 2 *Limoniopsis*, 10 *Limonium*, 49 *Acantholimon* and 1 *Psylliostachys* species are present in this region. In total that is 62 species or 74.7 %.

1.3.2. Habitat preferences of the Plumbaginaceae in Turkey

Plumbaginaceae prefers two main types of habitats. First type is the coastal areas (seaside cliffs, sandy shores, or salty marches), where around half of the *Limonium* and all of the *Armeria* species are present. Also, *Phylliostachys* spicata is found on saline clay and sandy soil on planes or along sea coasts. Second type includes continental habitats that can be: typical steppe or montane steppe, inland salty areas, or dry, rocky, exposed mountain slopes. The other half of *Limonium*

species prefer inland salty areas, as well as some species of *Acanthalimon*. The majority of *Acantholimon* is confined to highlands and mountain area, and dry, rocky or limestone slopes. Some are present in steppes and mountain steppes, too. *Plumbago europea* may grow at volcanic or limestone slopes and uncultivated fields or waste areas. *Goniolimon incanum* is present in the steppes, uncultivated fields, or on the serpentine and chalky hills.

1.3.3. Endemism

From the currently accepted 83 species of Plumbaginaceae in Turkey 44 species are endemics (53.01%). Also there are 6 endemic subspecies and 8 endemic varieties. The highest number of endemics are present in *Acantholimon*, 33 species (61% of the *Acantholimon* species growing in Turkey), from which most are very narrowly distributed local endemics. In *Limonium* there are 9 endemic species (42.86%). Also, there is 1 endemic in *Limoniopsis* (*L.davisii*) and 1 in *Armeria* (*A.trojana*). The highest number of endemics is present in Irano-Turanian region, especially mountain areas of South East Anatolia. The number of endemic species in this region is 38 or 86.36% of all Turkish Plumbaginaceae endemics. From those 30 species are *Acantholimon*, 7 are *Limonium* and 1 is *Limoniopsis*. The number of endemics is lower in the Mediterranean region. In here, there are 3 *Acantholimon*, 1 *Armeria* and 9 *Limonium* endemic species, which is 13.64% of all endemics in this family. So far there are no records of endemic Plumbaginaceae from Euro-Siberian region (Davis et all, 1982, 1988; Dogan and Akaydın, 2003a, 2006).

1.3.4. Conservation Status of the Plumbaginaceae in Turkey

According to the IUCN (International Union for Conservation of Nature and Natural Resources) threat categories, in Turkey: 37 Plumbaginaceae species (44.58%), are in CR (Critically Endangered) category, 13 species (15.66%) are EN (Endangered), 17 species (20.48%) are VU (Vulnerable), 5 species (6.02 %) are NT (Near Threatened) and 12 species (14.46%) are LC (Least Concern) (Doğan & Akaydın, 2003a, 2006). All of the threat categories of the taxa are given on the basis of IUCN. Red List Categories: Version 3.1. (IUCN, 2001).

The most threatened species are the local endemics with very narrow distribution range and small populations. The main threat to them is habitat destruction caused by human effect, erosion and extensive grazing. Consequently, the highest number of species in CR category is among *Acantholimon* species.

Figure 11: *Acantholimon avanosicum*, Critically Endangered species, local endemic of Avanos, Nevşehir province (edited from the article, Doğan and Akaydın, 2002a)

1.4. Numerical taxonomy

Taxonomy is a part of systematics that includes four main components: description, identification, nomenclature and classification of taxa (Simpson, 2010). Taxa (singular taxon) is a defined or delimited groups of organisms.

The very first classification system used since the time of Ancient Greece was the artificial system of classification. This kind of system makes comparison of objects depending on, only one or at most few characters. It was replaced by natural system of classification, built upon several to many characters that bring together organisms into natural groups that have highest number of shared features. Further, Darwin's theory of evolution brought new approach to classification, phyletic or evolutionary classification. Although, it offered explanation for homogeneity of classified groups, through the idea that similarity of organisms was a result of

descent from the common ancestor, it did not bring new methods to taxonomy. All those approaches share the common problem that they are highly subjective. In the sense that selection of characters and their comparison and evaluation depend largely on individual approach of taxonomists. Numerical taxonomy (phenetics), as a new approach, was created in 1960's by Robert R. Sokal and Peter H.A. Sneath as a reaction to that situation. Their main aim was to classify organisms based on their overall similarity and all available characters without any weighting, by clearly defined numerical procedures, in order to avoid high level of subjectivity that exists in previous systems of classification. Therefore, numerical taxonomy was defined as a: "Grouping by numerical methods of taxonomic units on the basis of their character states" (Sneath and Sokal, 1973).

1.5. Objectives of the Study

There seems to be only a few taxonomic studies ever done on Plumbaginaceae in Turkey and they always gave highest attention to *Acantholimon* and *Limonium*. Furthermore, in the recent years, some new species were described, a few imperfectly known, potential species still exist, and even a new genus, *Psylliostachys* (Jaub. & Spach.) Nevski, had been recorded in Turkey. Also, some of the species such as, *Armeria cariensis* and the genera *Limonium* and *Acantholimon* have unresolved taxonomic structure. Hence, we believe that, there is a need for reexamination of the taxa in order to construct more natural classification.

For the first time all the genera of Plumbaginaceae, existing in Turkey, have been evaluated all together, by the use of numerical taxonomy. Our main aim is to see linear arrangement of genera within family. Also, to see infrageneric grouping in the big genera like *Limonium* and *Acantholimon*. As well as, to discover potential placement, of the new species and genus in existing taxonomic structure. The highest possible number of the character and character states will be used, in order to obtain the most objective result and to produce long lasting natural grouping in the family. At the end obtained result will be discussed, and compared with previous findings. Also, a potential changes in the structure of genera or the family will be suggested.

CHAPTER 2

MATERIAL AND METHOD

2.1. Material of the Study

Majority of the samples examined in this study had been collected as a part of two projects supported by The Scientific and Research Council of Turkey (TÜBITAK): "Türkiye'nin *Acantholimon* Boiss. (Plumbaginaceae) Türlerinin Revizyonu"(199T011) (Doğan and Akaydın, 2003a) and Türkiye'deki Plumbaginaceae Juss. Familyası Üzerinde Revizyonel Çalışmalar" (102T088) (Doğan and Akaydın, 2006). Those studies had been conducted by Prof. Dr. Musa Doğan and Prof. Dr. Galip Akaydın, between 2000 and 2006. Those specimens are kept as a herbarium material in the Plant Systematics Laboratory, Middle East Technical University (METU). Some of the duplicate specimens of *Acantholimon* from the Royal Botanic Garden, Edinburgh (E), are part of the collection, as well.

The specimens had been identified by the use of the relevant floras, as Flora of Turkey and the East Aegean Islands (Davis at all,1982, 1988), then Flora Iranica (Rechinger and Schiman-Czeika, 1974), Flora Europaea (Tutin et al, 1972), Flora of USSR (Komarov, 1967), etc.

2.2. Method of the Study

As a method of the study numerical taxonomic analysis has been performed, following the procedure steps suggested by Stussey (Stuessy, 2009), which are based on methods proposed by Sneath and Sokal (1963,1973) in their books, Principles of Numerical Taxonomy and Numerical Taxonomy.

2.2.1. Selection of Operational Taxonomic Units (OTU's)

First step in numerical taxonomic analysis is to select Operational Taxonomic Units (OTUs). OTUs could be individuals, populations, species, genera, etc. OTUs in this study are species of the genera of Plumbaginaceae present in Turkey. In total 61 OTUs (species) was used. They belong to genera *Plumbago* (2), *Ceratostigma* (1), *Goniolimon* (1), *Limoniopsis* (1), *Armeria* (3), *Psylliostachys* (1), *Limonium* (24) and *Acantholimon* (28). In the case of *Acantholimon*, species for the study had been selected with intention to include a few representatives of all section and subsections, as well as to include all available specimen of the species that are newly described. For the rest of genera all of the species available in METU herbarium were used. For each species at least two of the specimen had been examined. All specimens are supplied with identification number and additional information about locality (from where it was collected and position of the locality in the grid square system in Turkey defined by Davis (Davis et al, 1965). As well as, habitat type, elevation, date (when it was collected) person who collected and /or identified specimens. Complete list of the used OTUs, is given in the Table B1 in the Appendix B.

2.2.2. Selection of characters and coding of character states

Second step is selection of characters and coding of the character states. In numerical taxonomy, the conventional approach is to use as wide as possible range of the characters, choosen in an objective way, with avoidance of overlapping. It is advisable to select characters from all parts of the OTUs. Characters are usually combination of quantitative and qualitative features. They may have two opposite states or characters may have multi states. About number of selected characters, it is considered that it is ideal to choose as many characters as possible, by expecting that resulted correlations between OTUs will be more reliable if the number of character is higher. Also, one of the basic ideas of numerical taxonomy is that all characters should be unweighted or equally weighted, without giving any priority to some of the features. In accordance with those principles 57 characters were selected for this study. Characters are morphological and chosen from all part of OTUs: 5 general characters (life form, life length, etc.), 6 scape characters, 14 leaf characters, 7

inflorescence character, 9 bracts characters, 10 calyx characters, 2 corolla characters and 4 characters regarding stigma and style features. Data are mixed types, and include 46 qualitative characters and 11 quantitative (from those 3 characters were coded and the rest were used as numeric value). In the following step character states of selected characters are described, measured and coded. Complete list of characters and their states and codes is given below in the Table 3.

Table 3: Character table

No	**Characters:**	**Character states:**
	General characters:	
1.	**Life length**:	Perennial (0) Annual (1)
2.	**Life form**:	Shrub /subshrub/ shrublet (0) Herb (1)
3.	**Habit forms:**	Cushion formation (0) Not cushion formation (1)
4.	**Stem is:**	Branched (0) Not branched (1)
5.	**Woody caudex**:	With woody caudex (0) Without woody caudex (1)
	Scape characters:	
6.	**Scape is:**	With scales (0) Without scales (1)
7.	**Scape is:**	With wings (0) Without wings (1)
8.	**Scape is:**	Branched (0) Not branched (1)
9.	**Scape is:**	With sterile branched (0) Without sterile branches (1)
10.	**Scape is:**	Glabrous (0) Without aglandular hairs (1) With glandular hairs (2)
11.	**Scape length:**	cm
	Leaf characters:	
12.	**Leaves are:**	Rigid, linear, triquetrous, and pungent (0) Fleshy or leathery, never pungent (1)
13.	**Duration of the leaves:**	Leaves dry up before ending of flowering (0) Leaves do not dry up (1)
14.	**Leaves are**:	Arranged into basal rosettes (0) Arranged into fascicular rosettes on shoots below the scape (1) Not arranged into rosettes (2)

Table 3. (Continued)

15.	**Shape of the leaves:**	Linear (0) Lanceolate (1) Lanceolate to oblong - lancelolate (2) Broadly ovate to obovate (3) Elliptic (4) Elliptic to oblong obovate (5) Spathulate (6) Oblong – spathulate (7) Obovate - spathulate (8) Polymorphic leaves (9)
16.	**Leaves are**:	With petiole (0) Without petiole (1) Usually down leaves are with petiole, medium and upper leaves are sessile or auricular (2)
17.	**Leaf margin is:**	Entire (0) Pinnatifid (1)
18.	**Leaves are**:	Glabrous (0) Glabrous with scabridulous margin (1) Glabrous with ciliate/ciliolate margin (2) With aglandular hairs (3) With aglandular hairs and scabridulous margin (4) With glandular hairs (5)
19.	**Leaf tip is:**	Acute (0) Obtuse to rounded (1) Both type of the leaves are present (2)
20.	**Leaf tip is:**	Without mucro (0) Mucronate (1) Apiculate (2) Spinose or pungent (3)
21.	**Average leaf length:**	mm
22.	**Average leaf width:**	mm
23.	**Length/Width ratio:**	ratio
24.	**Leaves are:**	Homomorphic (0) Heteromorphic (1)
25.	**Previous year's leaf bases are**:	Circinnate (0) Not circinnate (1)
	Inflorescence characters:	
26.	**Inflorescence is:**	Spicate (0) Terminal and lateral cylindrical spikes (1) Terminal, subcapitate to capitate spikes (2) Capitate condensed spikes (3) Capitate (4) Paniculate (5) Corymbose to paniculate (6) Globose (7)

Table 3. (Continued)

27.	**Inflorescence is:**	Unilateral (0) Bilateral (1) Both unilateral and bilateral (2) Not as above (3)
28.	**Average inflorescence length:**	cm
29.	**Average number of spikelet per inflorescence:**	number
30.	**Number of florets per spikelet is:**	1 floret per spiklet (0) 1-(2)-(3)-(4) florets per spikelet (1) 2-(3)-(4)-(5) florets per spiklet (2) 3-(4)-(6) florets per spiklet (3) 4-5 florets per spiklet (4) 8-12 florets per spiklet (5)
31.	**Average spikelet length:**	mm
32.	**1st internode is:**	Longer than spikelet (0) Shorter than spikelet (1)
	Bract characters:	
33.	**Number of bracts is:**	Less than three (0) Three (1) More than three (2)
34.	**Outer bract's tip is:**	Acute (0) Obtuse (1)
35.	**Outer bract's vein is:**	Not excurrent (0) Excurrent (1)
36.	**Outer bract's margin is:**	Not hyalinated (0) Fully hyalinated (1) Fully hyalinated except vein (2)
37.	**Outer bract is:**	Glabrous (0) With aglandular hairs (1) With glandular hairs (2)
38.	**1st inner bract's tip is:**	Acute (0) Obtuse (1) Emarginate (2)
39.	**1st inner bract's vein is:**	Not excurrent (0) Excurrent (1)
40.	**1st inner bract's margin is:**	Not hyalinated (0) Fully hyalinated (1) Fully hyalinated except vein (2)
41.	**1st inner bract is:**	Glabrous (0) With aglandular hairs (1) With glandular hairs (2)
	Calyx characters:	
42.	**Sepals are:**	Connate (0) Free (1)
43.	**Calyx shape is:**	Tubular (0) Infundibular (1) Subtubular to tubular (2) Obconical (3**)**

Table 3. (Continued)

44.	**Calyx duration:**	Calyx is permanent (0) Calyx is not permanent (1)
45.	**Calyx is:**	Glabrous (0) With aglandular hairs (1) With glandular hairs (2) With glandular and aglandular hairs (3)
46.	**Calyx is:**	Not hyalinated (0) Hyalinated (1) Partially hyalinated (2)
47.	**Calyx veins are:**	Not excurrent (0) Excurrent (1)
48.	**Calyx lip is:**	With lobes (0) Without lobes (1)
49.	**Calyx lip margin is:**	Dentate (0) Not dentate (1) Plicate (2) Undulate (3)
50.	**Calyx lip color is:**	White (0) White to pink (1) White to violet (2) White to purple (3) Pink to purple (4) Pink to clatter red (5) Violet (6) Brownish to pink-purple (7) Brownish (8) Green-whitish (9)
51.	**Average calyx length:**	mm
	Corolla characters:	
52.	**Corolla:**	Corolla is gamopetalous (0) Petals are connate at the base only (1)
53.	**Corolla color is:**	White (0) White to cream (1) White to pale pink (2) Pale pink (3) Pink (4) Pale violet (5) Violet (6) Bluish violet (7) Pale blue (8) Blue (9) Cream to yellow (10)
	Stigma and style characters:	
54.	**Stigma is:**	Filiform – cylindrical (0) Capitate,oblong-capitate,oblique or maleiform (1)
55.	**Style number is:**	One (0) Five (5)
56.	**Styles are:**	United throughout their length, except for the fairly long stigmas (0) Free from the base (1)
57.	**Styles are:**	Glabrous (0) Hairy (1)

After selection of characters and coding of their states, the numerical data are placed into basic data matrix, which will be used for computing similarities or dissimilarities between OTUs, by comparison of character states.

2.2.3. Construction of data matrix and its use

Data matrix was constructed based on 61 operational taxonomic units indicated in the Table B1 in the Appendix B and 57 characters indicated in the Table 3. Complete data matrix is given in the Table C1 in the Appendix C. Qualitative data were coded into binary states (0 or 1) for the presence or absence of character state, or multi states (from 0 to n states). Quantitative characters counted by number of flowers, spikelets, bracts, etc. are coded as well, because there are specific patterns within genera that allow clear delimitation of groups with specific number of flowers, bracts, etc. Quantitative data such as length, width and ratios are represented by arithmetic mean of at least 10 measurements of particular plant part and from at least 2 specimen from each species. Those data are not converted into codes and they are kept as numerical value within 0.01 scale.

2.2.4. The comparison of character states

Comparison of the character states has two main steps. First, is to select particular statistics for measuring similarity within OTUs, by using some of the coefficients of similarity. They all serve for calculations of affinity between OTUs. In this study Gower General Similarity Coefficient, a type of association coefficient, was used. Because it is the most suitable and most commonly used for the mixed data (such as using both qualitative and quantitative characters that have binary states or multistate, and missing data are acceptable as well).

Second, is to select an algorithm to determine phenetic relationship among all the OTUs. For the second step there are two main approach: clustering and ordination. Clustering is the most commonly used method and there are three basic types: single linkage (nearest neighbor technique), complete linkage (farest neighbor technique) and average linkage. Average linkage is effort to connect new OTU to an average value of the particular group rather than to the extreme similarity or

difference within it, like with previous two types. Average linkage has two basic types: arithmetic average (it can be unweighted UPGMA and weighted WPGMA) and centroid (unweighted and weighted). In this study UPGMA (Unweighted Pair Group Method with Arithmetic Mean) was used to calculate the average similarity or dissimilarty of an OUT to a cluster. In other words, the distance between two clusters is depend on the mean distance between all objects in these two clusters. Results of phenetic relationships are the most commonly presented graphically, in the form of phenograms or cluster diagrams. Phenogram is constructed to expresses graphically relationships among all OTUs and to reveals the taxonomic structure of groups and subgroups among the OTUs (Stuessy, 2009). It is important to mention that phenograms simply show phenetic similarity based on comparison of character states and that evolutionary pathways are not represented or inferred in any way. Ordination method contains few different approaches which all have the same goal, to calculate and show multidimensional relationships of OTUs. In this study Principal Component Analysis (PCA) was used to reveal multidimensional relationships of OTUs and to indicate which characters are the most important in forming particular clusters.

For the purpose of data evaluation and determination of relationships between OTUs a software program was applied on the previously constructed data matrix. Software used for this purpose was MVSP 3.22. A Multi-Variate Statistical Package by Kovach Computing Services. As it was mentioned before, Gower General Similarity Coefficient was used in this study. Since it was the most suitable for our case with mixed data and few missing data (in the case where character was not applicable to the particular OTU).

After the phenetic relationships had been obtained the next step is to determine ranks of OTUs. Ranking can be done by placing OTUs into informal categories (groups, subgroups, clusters, etc.) or into formal taxonomic categories or subcategories (sections, genera, species, etc.).

CHAPTER 3

RESULT AND DISCUSSION

3.1. Result

3.1.1. Result of the Cluster Analysis and UPGMA phenogram

Result of the cluster analysis performed by MVSP software with Gower Similarity Coefficient was given in the form of UPGMA phenogram in Figure 12. As it is shown in Figure 13, a line drawn at 0.66 separates tree in 2 main subgoups that may correspond to 2 subfamilies: Plumbaginoideae and Staticoideae. Also, drawing a line at 0.85 divides tree into 7 clusters that are equal to genera of Plumbagianceae. The only exception is *Psylliostachys* which shows earlier separation from the rest of genera at 0.71 similarity coefficient. Sections within *Acantholimon* and *Limonium* are observed as well around 0.9 cut off line, Figure 14 and Figure 15.

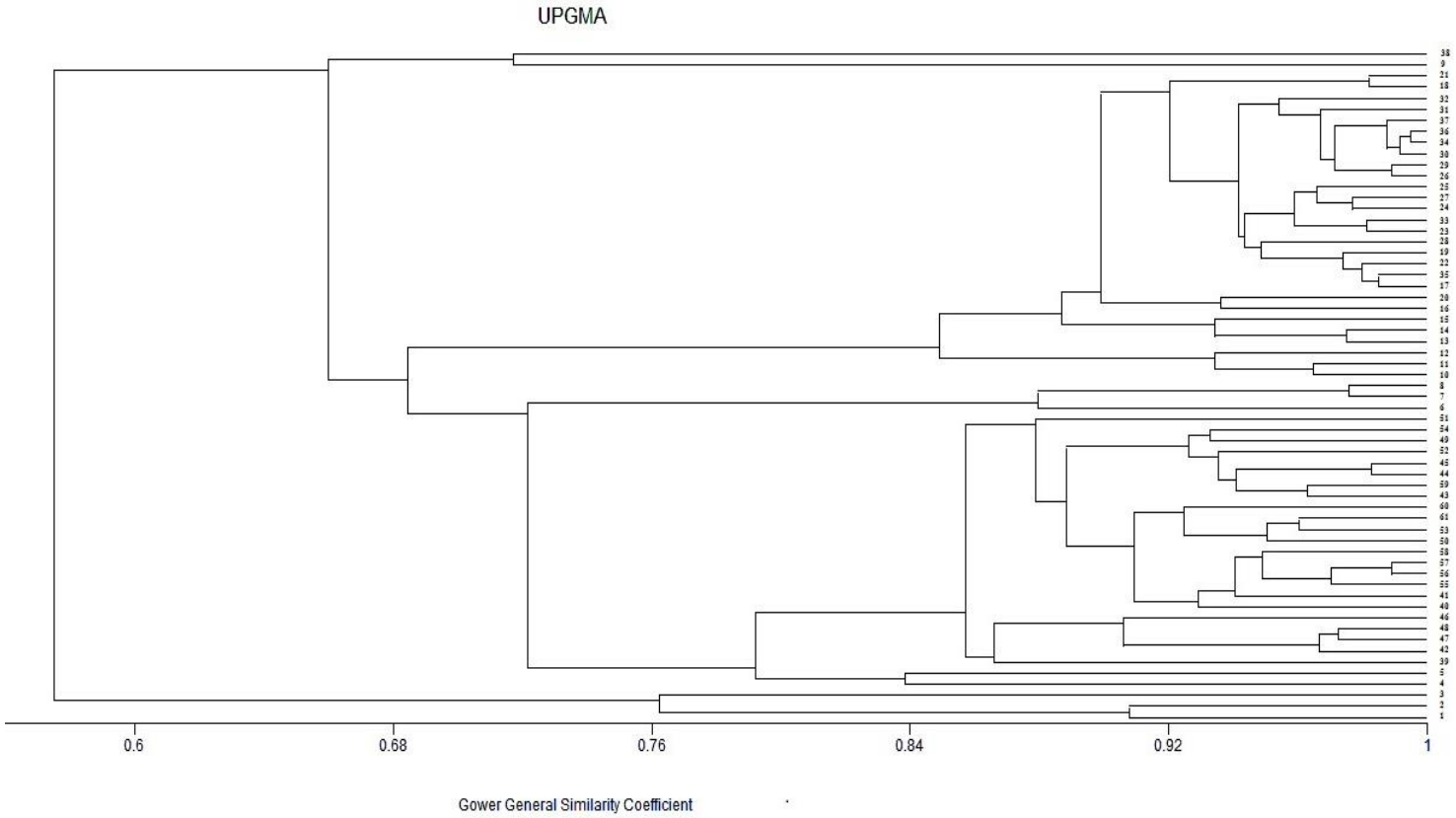

Figure 12: UPGMA phenogram: Plumbaginaceae in Turkey

The list of the species, according to their ordinal numbers in the Figure 12:

1. *Plumbago europaea*
2. *Plumbago capensis*
3. *Ceratodtigma plumbaginoides*
4. *Goniolimon incanum*
5. *Limoniopsis davisii*
6. *Armeria trojana*
7. *Armeria cariensis var.cariensis*
8. *Armeria cariensis var. rumelica*
9. *Psylliostachys spicata*
10. *Acantholimon bracteatum*
11. *Acantholimon capitatum subsp.capitatum*
12. *Acantholimon hoshapicum*
13. *Acantholimon tragacanthinum*
14. *Acantholimon quinquelobum var. quinquelobum*
15. *Acantholimon araxanum*
16. *Acantholimon laxiflorum*
17. *Acantholimon dianthifolium*
18. *Acantholimon calvertii var. calvertii*
19. *Acantholimon hypochaerum*
20. *Acantholimon köycegizicum*
21. *Acantholimon huetii var. huetii*
22. *Acantholimon ulicinum var.ulicinum*
23. *Acantholimon anatolicum*
24. *Acantholimon yıldıelicum*
25. *Acantholimon karamanicum*
26. *Acantholimon confertiflorum*
27. *Acantholimon puberulum subsp. puberulum*
28. *Acantholimon glumaceum*
29. *Acantholimon caryophyllaceum*
30. *Acantholimon avanosicum*
31. *Acantholimon venustum var. venustum*
32. *Acantholimon petraeum*
33. *Acantholimon spirizianum*
34. *Acantholimon kotschyi*
35. *Acantholimon libanoticum*
36. *Acantholimon halophilum*
37. *Acantholimon acerosum subsp. acerosum var. acerosum*
38. *Limonium sinuatum*
39. *Limonium echioides*
40. *Limonium anatolicum*
41. *Limonium ocymifolium*
42. *Limonium meyeri*
43. *Limonium lilacinum var. lilacinum*
44. *Limonium pycnanthum*
45. *Limonium marmarisense*
46. *Limonium angustifolium*
47. *Limonium effusum*
48. *Limonium gmelinni*
49. *Limonium guenerii*
50. *Limonium bellidifolium*
51. *Limonium vanense*
52. *Limonium davisii*
53. *Limonium caspium*
54. *Limonium smithii*
55. *Limonium graecum var. graecum*
56. *Limonium virgatum*
57. *Limonium sieberi*
58. *Limonium didimense*
59. *Limonium globuliferum var. globuliferum*
60. *Limonium tamaricoides*
61. *Limonium iconicum*

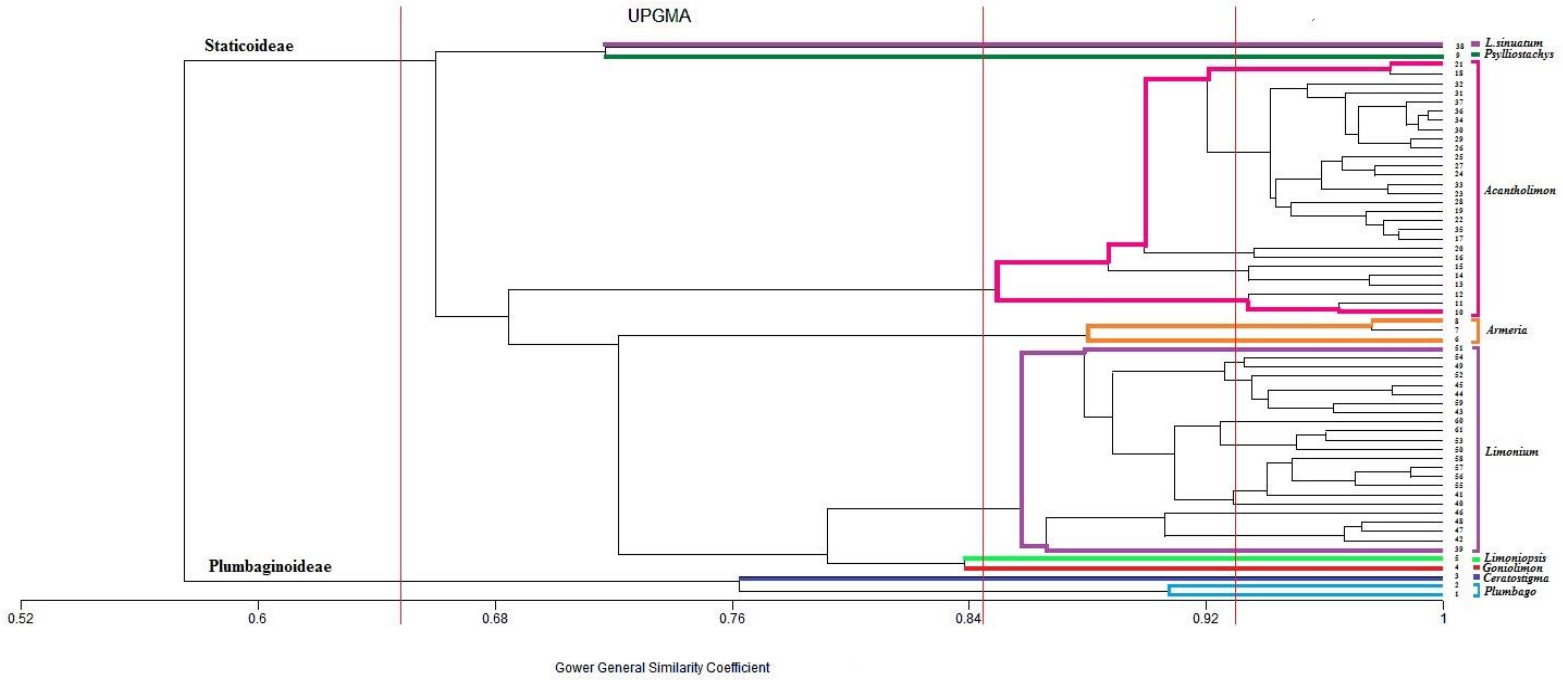

Figure13: UPGMA phenogram: Infrafamilial grouping of the Plumbaginaceae in Turkey

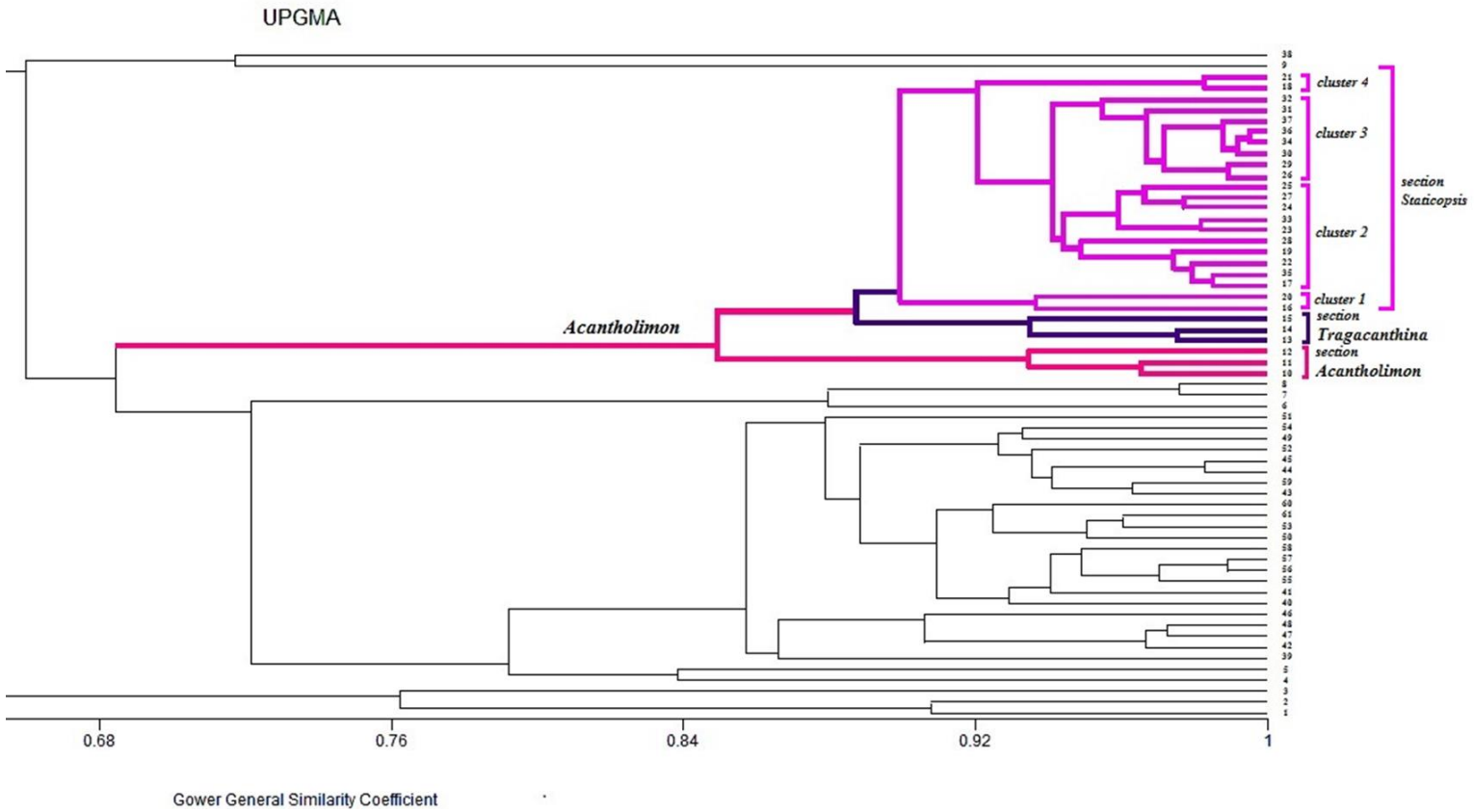

Figure14: UPGMA phenogram: Infrageneric grouping of the *Acantholimon*

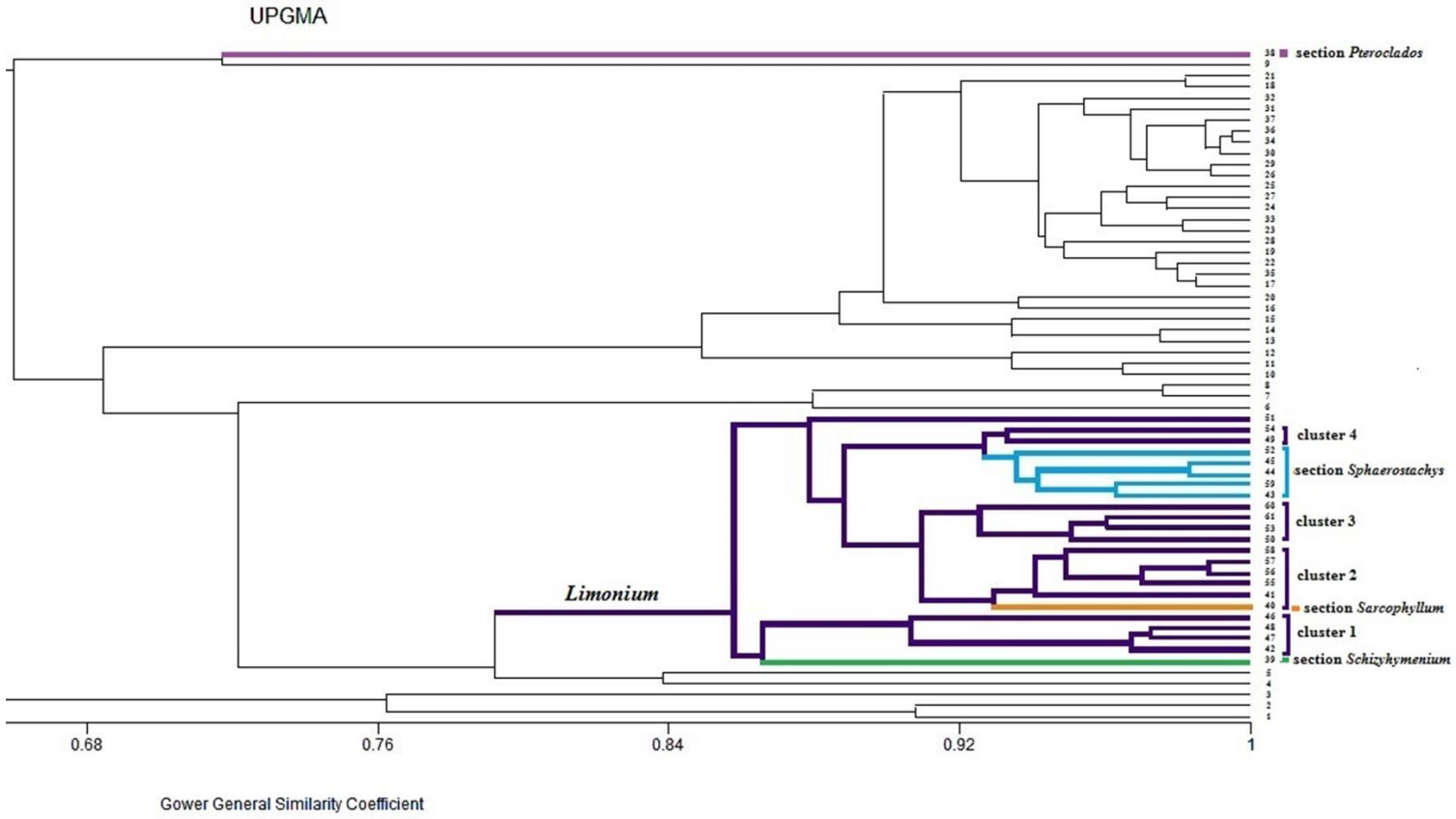

Figure 15: UPGMA phenogram: Infrageneric grouping of the *Limonium*

3.1.2. Result of the Principal Component Analysis

In addition, Principal Component Analysis in MVSP was carried out to indicate the most important characters for the forming of different clusters.

Table 4: Eigenvalues, percentages and cumulative percentages (Eigenvalues > 1)

Eigenvalues						
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6
Eigenvalues	18.922	8.973	3.338	2.329	1.807	1.074
Percentage	46.412	22.010	8.188	5.712	4.433	2.633
Cum. Percentage	46.412	68.422	76.610	82.322	86.755	89.389

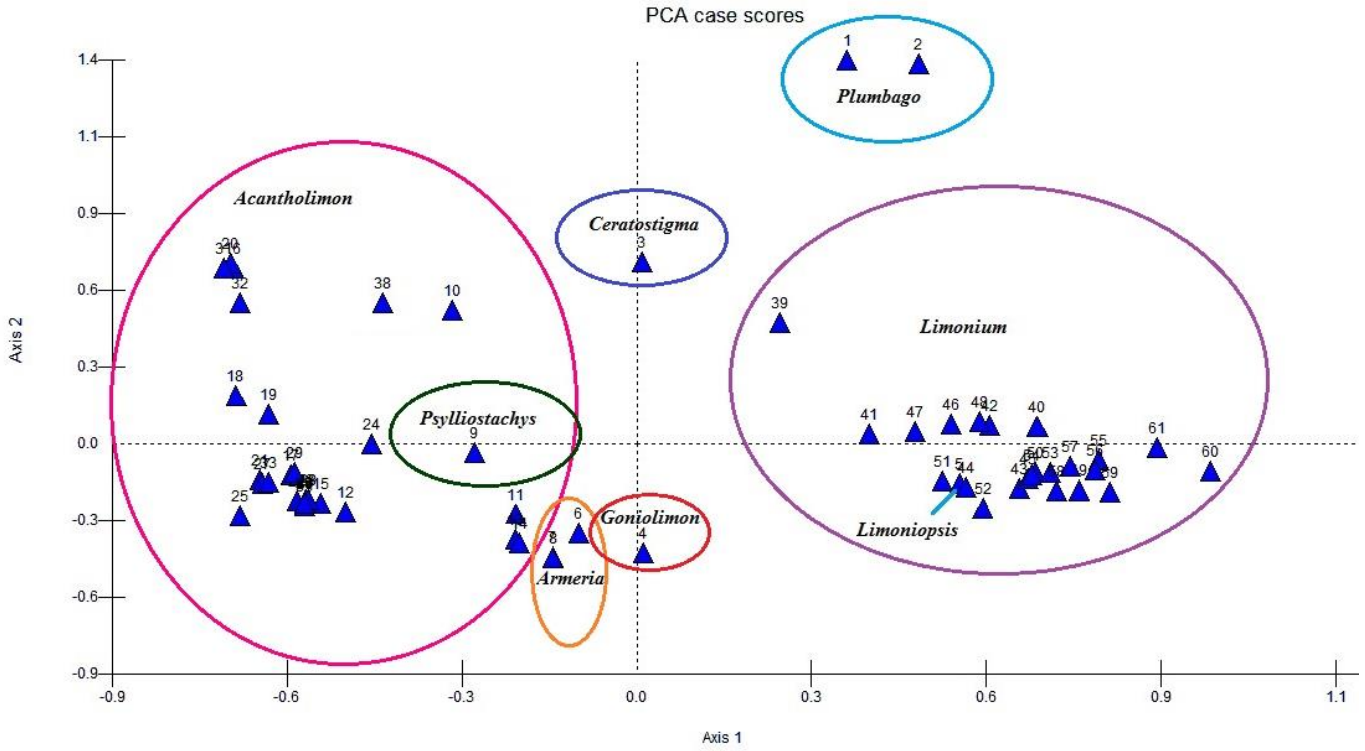

Figure 16: Principal Component Analysis of the Plumbaginaceae in Turkey with 2 axix

The Principal Component Analysis (PCA) exhibited similar result as our phenogram and separation within genera (Figure 16). The first 6 axis of the principal component analysis, resolved 89.389 % of total morphometric variation. The 1st axis explained 46.412 %; the 2nd axis 22.010%; the 3rd axis 8.188 %; the 4th axis 5.712 %; the 5th axis 4.433% and the 6th axis 2.633%; of the total variation within Plumbaginaceae (Table 4). The summary of the character loadings on the first 6 axis are given in the Table 5.

Table 5: The summary of the highest character loadings at the first 6 axis

Character No:	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6
2.					0.129	
3.	0.101					
8.						0.105
10.				-0.168	0.116	
12.	0.101					
14.			0.122			-0.107
15.	0.657	0.294	0.184	-0.393	-0.273	-0.184
16.						-0.151
18.	-0.157	0.163	0.172	-0.400	0.535	-0.157
19.	0.121					
20.	-0.213			0.183		-0.290
26.	0.503	-0.202	-0.440	0.312	0.424	-0.389
27.					0.354	0.293
30.	0.162		-0.211			0.552
33.						0.159
37.				-0.157	0.160	
38.						0.145
39.	-0.107					
40.	-0.107					
41.				-0.124	0.110	
43.					-0.220	
47.						0.167
49.		-0.121			-0.245	0.166
50.	-0.121	0.841	-0.404	0.252	-0.104	
53.	0.239	0.177	0.649	0.585	0.231	0.129
54.						-0.168

Accordingly, the most important characters, found on the first 6 axis that explained most of the variation in clustering of Plumbaginaceae in Turkey are given in the Table 6:

Table 6: The most significant diagnostic features according to PCA

No:	Character:
2.	Life form: shrub /subshrub/ shrublet or herb
3.	Habit is: cushion formation or not cushion formation
8.	Scape is: branched or not branched
10.	Scape is: glabrous, without aglandular hairs or with glandular hairs
12.	Leaves are: rigid, linear, triquetrous, and pungent or fleshy or leathery, never pungent
14.	Leaves are: arranged into basal rosettes, arranged into fascicular rosettes on shoots below the scape or not arranged into rosettes
15.	Shape of the leaves: linear, lanceolate, lanceolate to oblong-lancelolate, broadly ovate to obovate, elliptic, elliptic to oblong obovate, spathulate, oblong-spathulate, obovate-spathulate or polymorphic leaves
16.	Leaves are: with petiole, without petiole or usually down leaves are with petiole, medium and upper leaves are sessile or auricular
18.	Leaves are: glabrous, glabrous with scabridulous margin, glabrous with ciliate/ciliolate margin, with aglandular hairs, with aglandular hairs and scabridulous margin or with glandular hairs
19.	Leaf tip is: acute, obtuse to rounded or both type of the leaves are present
20.	Leaf tip is: without mucro, mucronate, apiculate, or spinose/pungent
26.	Inflorescence is: spicate, terminal and lateral cylindrical spikes, terminal, subcapitate to capitate spikes, capitate condensed spikes, capitate, paniculate, corymbose to paniculate or globose
27.	Inflorescence is: unilateral, bilateral, both unilateral and bilateral or not as above
30.	Number of florets per spikelet is: 1 floret per spiklet, 1-(2)-(3)-(4) florets per spikelet, 2-(3)-(4)-(5) florets per spiklet, 3-(4)-(6) florets per spiklet, 4-5 florets per spiklet or 8-12 florets per spiklet
33.	Number of bracts is: less than three, three or more than three
37.	Outer bract is: glabrous, with aglandular hairs or with glandular hairs; 38. 1st inner bract's tip is: acute, obtuse or emarginated
39.	1st inner bract's vein is: not excurrent or excurrent
40.	1st inner bract's margin is: not hyalinated, fully hyalinated or fully hyalinated except vein

Table 6 (Continued)

41.	1st inner bract is: glabrous, with aglandular hairs or with glandular hairs
43.	Calyx shape is: tubular, infundibular, subtubular to tubular or obconical
47.	Calyx veins are: not excurrent or excurrent
49.	Calyx lip margin is: dentate, not dentate, plicate or undulate
50.	Calyx lip color is: white, white to pink, white to violet, white to purple, pink to purple, pink to claret red, violet, brownish to pink-purple, brownish or green-whitish
53.	Corolla color is: white, white to cream, white to pale pink, pale pink, pink, pale violet, violet, bluish violet, pale blue, blue or cream to yellow
54.	Stigma is: filiform-cylindrical or capitate, oblong-capitate, oblique or maleiform

3.2. Infrafamilial Grouping of the Plumbginaceae Juss. in Turkey

The infrafamilial grouping of Plumbaginaceae Juss. In Turkey, as the final result of this study, was indicated in the UPGMA phenogram in the Figure 12 and the Figure 13. First of all, in the Figure 13, a cut-off line at 0.66 separated the family into two main subgroups. Those two subgroups were considered as tribes by Boissier, and this approach was also accepted in the Flora Europaea, and the tribes were named as Plumbaginae and Staticea (Tutin et al, 1972). From the other point of view, some authors treated these subgroups as subfamilies: Plumbaginoideae and Staticoideae (Komarov, 1967; Kubitzki, 1993; Lledo et al, 2001). Obvious differences between subfamilies in morphology, were also supported by molecular analyses based on plastid DNA sequences and nuclear sequences (Lledo et al, 2001, 2005; Moharrek et al, 2014). Differences in chemical compounds were proven to be usefull for this subgrouping, too. (Hanson et al, 1994; Lledo et al, 2001).

In this study, the following morphological characters typical for the Plumbaginoideae are observed. Inflorescences are terminal spikes (in a form of cluster that moslty consist of 15-30 flowers); corolla is gamopetalous, calyx is tubular, herbaceous and usually glandular, calyx lip is dentate, leaves are usually polymorphic within the same species, with or without petiole, mucronate, with or

without glandular hairs, and do not form rosette. Stigma is filiform, number of the styles is 1 and styles are usually hairy. Only two genera are present in Turkey from this subfamily, as *Plumbago* (*P.europaea*, *P.capensis*, former as a native and latter as ornamental plant) and *Ceratostigma*, (*C.plumbaginoides*, as ornamental). In our phenogram (Figure 13) the separation line between them is at 0.76, and it is based on the character mentioned below.

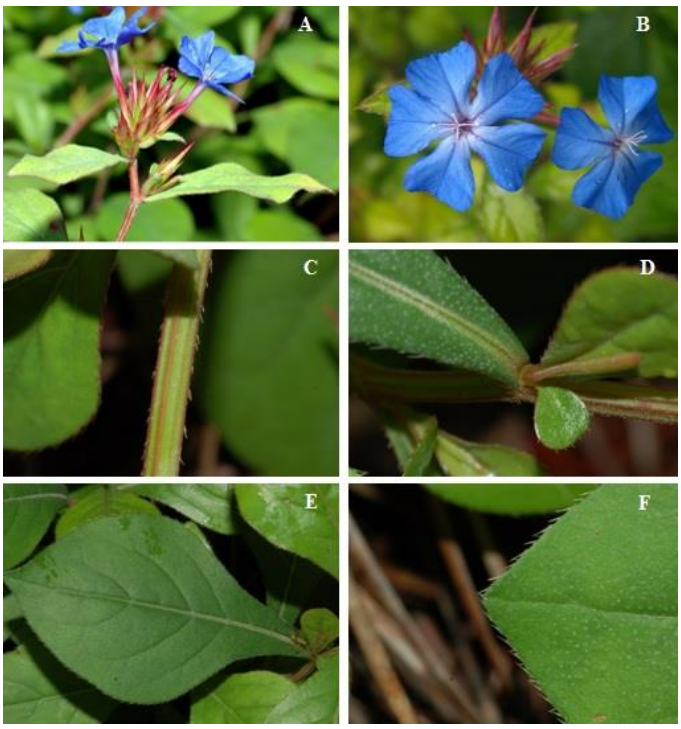

Figure 17: *Ceratostigma plumbaginoides*: A. inflorescence; B. flower; C.stem; D.leaf base; E.leaf; F.leaf tip and margin. (edited from Discover life webpage and Wikimedia commons webpage)

Ceratostigma has glabrous leaves, without petiole and with ciliate margin; bracts with excurrent veins and fully hyalinated margin; free sepals; permanent, not glandular calyx, with pink to clatter red lip; glabrous style. *Plumbago* has polymorphic leaves, with or without petiole, with glandular or aglandular hairs; bracts without excurrent veins and not hyalinated; connate sepals; not permanent, glandular calyx, with green- white lip color; hairy style.

Figure 18: *Plumbago europaea*: A, B. inflorescence; C.stem and leaves; D. calyx and bracts (edited from Acta Plantarum webpage)

Figure 19: *Plumbago capensis*: A, B. inflorescence; C.stem and leaves; D. calyx and bracts. (edited from Phyto Images, International Carnivorous Plants Society; Toowoomba Plants and Vascular Plants Image Library webpages)

Beside genera separation, we also got insight into differences between *P.europea* (the only *Plumbago* that is present in Europe and Turkey) and *P.capensis* (a representative of the rest of *Plumbago* that is mostly confined to tropical regions of Africa and Asia), that split at 0.91 line. First one is herb, with glandular hairs present on leaves and scape and violet rose flowers. Second is a shrub, with long branches terminating with many flowered inflorescences (20-40 light blue flowers); with aglandular hairs on the scape, leaves and calyx.

All of the rest genera included in this study belong to subfamily Staticoideae, which is also more variable in all of the characters we applied for numeric taxonomic analysis. Cut off line between those genera is drawn at 0.85, on the UPGMA phenogram (Figure 13). The only exceptions are *Psylliostachys* and the species *L.sinuatum* that are separated from the rest of genera at 0.67 point, and one from the other at 0.71 point. They seemed to be morphologically quite distinctive from the rest of Staticoideae in Turkey.

Psyllioststachys (*P.spicata*) was for the first time recorded from Turkey in 2014. Also, this is the first time that it is compared with the rest of Plumbaginaceae in Turkey, trough a numerical taxonomic analysis. Characters that showed this species to be very different from the others are: these are annual plants; glandular hairs are present on scape, leaves, and bracts; leaves are with pinnatifit margin; inflorescences are terminal or lateral, cylindrical spikes compound from many (up to 50 or more) spikelets with 2-4 flowers, and only 2 bract; calyx is glandular; corolla is gamopetalous (it is the only genus in Staticoideae with gamopetalous corolla).

Parallel molecular and morphological studies of Plumbaginaceae in Spain including *Psylliostachys* gave different outcomes. Molecular analyses based on plastid DNA sequences showed that *Psylliostachys* if forming a clade with *Armeria* (with 100% probability), but this was supported by morphology with 69% (Lledo et al, 2001). Another molecular work showed existence of this clade, too. This was supported by 0.69 when plastid DNA and 0.96 when nuclear DNA sequences were used (Moharrek et al, 2014). What *L.sinuatum* brought close to *Psylliostachys spicata* are numerous differences that both species show comparing with other

Plumbaginaceae in Turkey. However, these species do not share many common characters, except pinnatifid leaves and hairiness of the scape, leaf and bracts, but type of the hairs is different. Due to that, they split early, at 0.71 point.

Figure 20: *Psylliostachys spicata*: A. habit; B. spikelet. (edited from the Plantarium webpage and Forestry Images webpage)

As it is mentioned before, the rest of genera within Staticoideae are proved to be well separated and defined clusters. *Limonium*, *Limioniopsis* and *Goniolimon* look more close to each other than *Armeria* and *Acantholimon*.

Goniolimon and *Limoniopsis* are closest to each other according to the results of this study. *Goniolimon* (*G.incanum*) differ from the *Limoniopsis* (*L.davisi*) in: winged, glabrous scape; lanceolate to oblong-lanceolate, glabrous leaves, with ciliolate margin, acute and mucronate leaf tip, and bigger leaf size; corymbose to paniculate inflorescence; 1 flower per spikelet; obtuse outer bract and obtuse and tricuspidate 2nd inner bract; infundibular calyx; white corolla; styles with long hairs.

Figure 21: *Goniolimon incanum*: A. habit; B. leaves; C. inflorescence (METU herbarium, photo by Jelena Erdal)

Figure 22: *Limoniopsis davisii*: A. habit; B. leaves; C. inflorescence; (METU herbarium, photo by Jelena Erdal)

On the other side, *L.davisii*, has: scape hairy at base and without wings; oblong-spathulate leaves, glabrous, obtuse and apiculate leaf tip, smaller leaf size; paniculate inflorescence; 1 (occasionally 2) flower per spikelet, and large spacing between spikelets; acute outer bract and 1st inner bract, non excurrent vein of 1st inner bract; subtubular to tubular calyx; pale pink corolla, and glabrous styles. They both differ from *Limonium* in capitate stigma; not hyalinated calyx lip, with plicate margin; numbers of spikelet per inflorescence and flowers per spikelet. *Limoniopsis* species have not been used in the molecular based research so far. *Goniolimon* was included in the previously mentioned molecular work and it was forming clade together with *Acanholimon* and *Dyctiolimon*, which supposed to be a sister clade of clade formed by *Psylliostachys* and *Armeria* (Lledo et al, 2001).

Limonium is well separated from the rest of genera in this study with exception of the species *L.sinuatum* (Figure 13, Figure 15). However, this kind of result was not a surprise, because taxonomic status of *L.sinuatum* and section *Pteroclados*, where it belongs, are not clearly defined, and different points of view exist about this issue. Also, within the cluster representing *Limonium*, a smaller clusters corresponding to the sections were observed. Beside that within section *Limonium* a possible subsections are indicated, at the 0.92 cut off line. The typical features of the genus *Limonium* are: herb or shrub life form; leaves mostly in basal rosettes; sterile branches present or not; spikelets grouped terminally (sometimes in capitate like structures); 3 bracts usually present; calyx infundibular, obconical or tubular; petals are connate at the base only; stigma is cylindrically filiform.

L.sinuatum is the only representative of the section *Pteroclados* Sauv. & Vindt. and it has very specific morphology comparing with the rest of the *Limonium* species, in Turkey. It has winged, hairy scape; pinnatifit, hairy leaves arranged into basal rosettes; 3-4(6) flowered spikelets; more than 3 bracts; very characteristic 1st inner bract, which is herbaceous, hairy and 2-3 toothed, with long exccurent veins; truncate calyx lip margin; white to cream flowers. For this reason, *L.sinuatum* appeared on phenogram as a completely separated branch, not only from the rest of *Limonium* species, but also from the rest of Plumbaginaceae in Turkey. Similar

results regarding *L.sinuatum* were obtained in the past (Ingrouille, 1984; Doğan and Akaydın, 2006; Fazlıoğlu, 2011) which justifies need for reconsideration of taxonomic status of section *Pteroclados*.

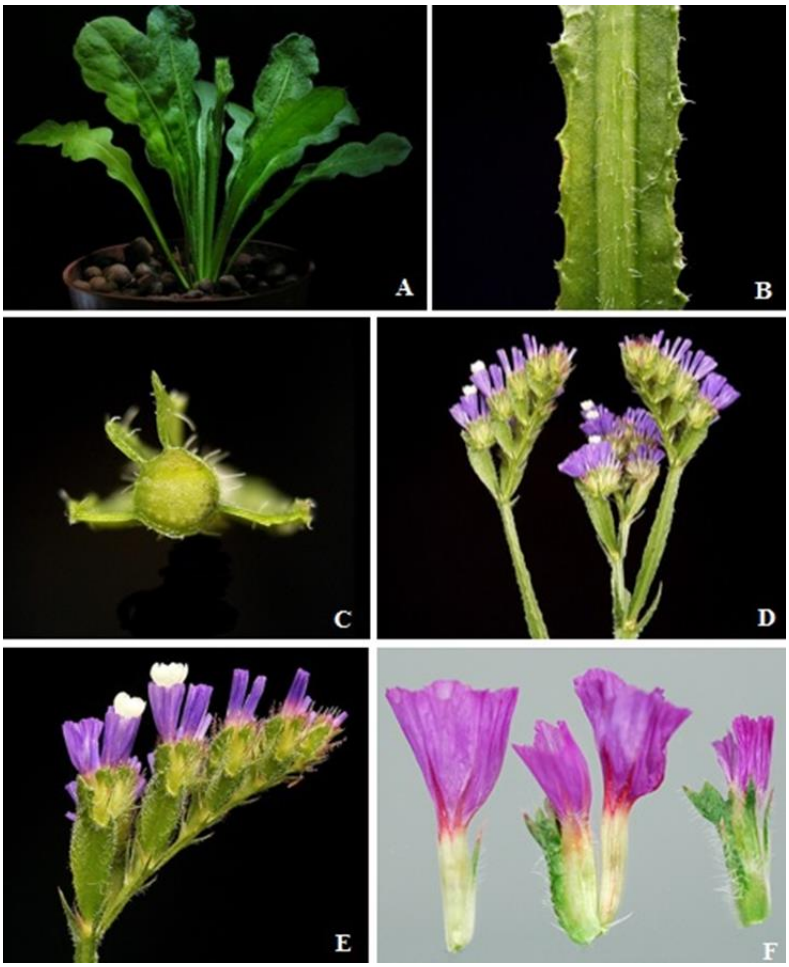

Figure 23: *Limonium sinuatum*, section *Pteroclados*: A. leaves; B, C. stem; D, E. inflorescence; F. flowers (edited from Wikimedia Commons and Cut Flowers Exports of Africa webpages)

Considering that this section consists of more species outside Turkey, beside *L.sinuatum*, it is necessary to look at the broader picture. In the Flora Europaea this section has status of subgenus *Pteroclados* (Boiss.) Pignatti, which consists of species: *Limonium sinuatum* Miller, *Limonium bonduellei* (Lestib.) O.Kuntze, *Limonium thouinii* (Viv.) O.Kuntze, *Limonium brassicifolium* (Webb & Berthel.) O.Kuntze. Those species are annual or perennial herbs, with sinuate or

lobed leaves, and winged scape (Tutin et al, 1972). Another subgenus recognized in the same flora as the subgenus *Myriolepis* (Boiss.) Pignatti was segregated from *Limonium* as separate genus, *Myriolimon* (Boiss.) Lledó, Erben & M. B. Crespo (Tutin et al, 1972; Lledo et al, 2003, 2005a). From that point of view it might be possible to do the same with section *Pteroclados*. Section *Pteroclados* has in total around 18 species. Beside *L.sinuaum* and European species mentioned above, there are *L.beaumieranum*, *L.mouretii* and *L.bonduellei* from Marocoo, *L.lobatum* (wide spread From Canary Island over North Africa till to Iran) and the rest of species are endemics to the Canary Islands. Molecular studies also support clear separation of this group from the rest of *Limonium* species (Lledo et al, 2005, 2011; Akhani et al, 2013). What makes researches hesitant in segregation of this section from the *Limonium* into a separate genus is the lack of unique characters of this group (Karis, 2003; Lledo et al, 2005, 2011). Because when we observe section *Pteroclados* next to the rest of *Limonium* it looks undoubtedly different, but the characters that make it unique within *Limonium*, are not unique comparing with other genera of Plumbaginaceae. For example, the typical features of this section are also present in another genera, such as: winged scape in *Goniolimon*, or sinuate leaves in *Psyllisotachys*. Even though, this section was subject of various studies, final solution for its taxonomic position has not been found so far.

Limonium echioides is a single species representing the section *Schizyhymenium* (Boiss.) Bokhari, and within our *Limonium* cluster it is segregated from the rest of the species as a single branch. This is the only annual *Limonium* in Turkey with very distinguishing morphology. It has tuberculate leaves organized into basal rosette; very unusual calyx with long exccurent calyx veins forming hooks; and characteristic large, tuberculate, 3-veined, 2nd inner bract. Recent molecular study revealed a moderately supported connection of *L.echioides* as a single branch and clade formed by Mediterranean species as *L.delicatulum*, *L.furfuraceum*, *L.cymanum*, *L.minutum* (Akhani et al, 2013). Nonetheless, further and different types of analyses are needed to reveal the most suitable taxonomic status of this peculiar species, and show its potential to be regarded as a subgenus of *Limonium* or an independent genus of its own.

Figure 24: *Limonium echioides*, section *Schizyhymenium*: A. habit; B. leaves; C.spikelet. (edited from the Plantes del Litoral webpage and Flora silvestre del Mediterráneo by Jose Quiles webpage)

The cluster that consists of the species: *L.lilacinum*, *L.globuliferum* and *L.pycnanthum* is matching with the section *Sphaerostachys* (Boiss.) Bokhari. One of the imperfectly known specimens from our study *L.marmarisense* seems to belong together with this group, as particularly close to *L.pycnanthum*. Distinct morphological characters of this cluster are: herbaceous habit; eliptic or spathulate leaves, with obtuse, mucronate tip; inflorescence corymbose-paniculate, both unilateral and bilateral; more than 3 bracts; infundibular calyx (exception is *L.globuliferum* that has globose inflorescence; 3 bracts and obconical calyx). Another imperfectly known species, *L.davisii*, also share many common characters with this group, except that it has 3 bracts; emarginate 1st inner bract, and obconical, glabrous, calyx. Previously mentioned, species are Irano-Turanian elements, mostly from Central Anatolia, with exeption of *L.marmarisense* which is found in coast of Marmaris in Muğla province. For this reason, it is necessary to give more attention to this imperfectly known species in order to resolve its potential taxonomic status.

Figure 25: *Limonium lilacinum*, section Sphaerostachys: A. habit; B. leaves; C.inflorescence. (METU herbarium, photo by Jelena Erdal)

The rest of the *Limonium* species belong to the section *Limonium* that seems quite heterogeneous. Because it did not appear as a single cluster in this study, instead four well defined clusters were formed (Figure 15). Those clusters are morphologically and ecologically different and may have potential to be recognized as a subsections within section *Limonium*.

Species *L.meyeri*, *L.effusum*, *L.gmelinii* and *L.angustifolium* form cluster 1. They are all herbs, with large, eliptic to oblong-obovate leaves arranged in basal rosettes, quite tall scapes, paniculate inflorescence, and obconical calyx. Species *L.gmelinii* and *L.meyeri* have wide distribution ranges spreading from Europe till to Central Asia, both in coastal and inland salty areas. *L.effusum* is endemics of South and South West Anatolia and *L.angustifolium* grows all around the Mediterranean.

Figure 26: *Limonium gmelini*, section *Limonium*: A. habit; B. inflorescence. (METU herbarium, photo by Jelena Erdal)

Another clearly distinguished cluster is cluster 2, formed by *L.graecum*, *L.virgatum* and *L.sieberi*. One of the specimen, suspected to be a new species, named as *L.didimense*, is shown to belong next to those. Same as, *L.ocymifolium* that have different position in various studies. In the Flora of Turkey *L.ocymifolium* is accepted to belong to section *Limonium*, in the later studies it was appearing in section *Sarcophyllum* along with *L.anatolicum* (Doğan and Akaydın, 2006; Fazlıoğlu, 2011). Our result is in accordance with the first opinion that *L.ocymifolium* is a part of section *Limonium*, because at phenogram, it seems closer to *L.greacum*, *L.virgatum*, *L.sieberi* and *L.didimense* than to *L.anatolicum*. Those species are differing from the other species in the following morphological characters: subshrub form, with woody caudex; sterile branches on the scape; small spathulate leaves, without mucro, organized in fascicular rosettes; inflorescence paniculate, usually unilateral; calyx infundibular; corolla pale violet. They are all Meditteranean elements, found in similar types of habitat and form one well circumscribed group.

Figure 27: *Limonium graecum*, section *Limonium*: A. habit; B. inflorescence; C.leaves. (METU herbarium, photo by Jelena Erdal)

Figure 28**:** *Limonium anatolicum*, section *Sarcophyllum*: A. habit; B. branch; C.inflorescence; D. leaves. (METU herbarium, photo by Jelena Erdal)

L.anatolicum is the only representative of the section *Sarcophyllum* (Boiss.) Lincz in Turkey and it seems to be closest to the previous group. Since it appears as a joint branch of the cluster 2, according to our phenogram (Figure 15). *L.anatolicum*, also, has some specific morphological features such as: very narrowly spathulate leaves, with short, flat, narrow petiole, forming numerous dense fascicular rosettes; capitate-like inflorescence, formed by condensed spikes; tubular calyx; whitish to pale blue corolla. Beside distinctive morphology this species is also Irano-Turanian element, an endemic of Central Anatolia, confined to continental saline areas, that again supports its segregation from the previous group.

L.bellidifolium, *L.caspium* and *L.iconicum* form cluster 3. The main morphological characters of this groups are: subshrub form with woody caudex; sterile branches on the scape; leaves that dry up before the end of the flowering; inflorescence bilateral, paniculate; calyx obconical; corolla color bluish-violet. *L.tamaricoides* seems closest to this group according to our tree, what makes it different from the other three species is: hairy scape, with paniculate branching and globose, many flowered inflorescence.

Those species are Irano-Turanian elements with exception of *L.bellidifolium* which is known as a Euro-Siberian element in Turkey, but it has wide distribution range from South and Central Europe till to Central Asia. Accordingly, it is regarded as Mediterranean or Irano-Turanian element in other regions or countries. Furthermore, all the species share same habitat preferences and grow in salty inland areas. Ecological features of this group also support its separation from other previously mentioned Mediterranean group. Connection between *L.bellidifolium* and *L.caspium* as well as few more Irano–Turanian species was revealed by molecular study, where authors assumed two possible pathways by which *L.bellidifolium* was related to similar Irano-Turanian species. One hyposthesis is Irano-Turanian origin of the group with secondary distribution into other regions. Another hypothesis is a migration of a common ancestor from another region to Irano-Turanian region (Akhani et al, 2013).

Figure 29: *Limonium bellidifolium*, section *Limonium*: A. habit; B. inflorescence; C.leaves and sterile branches. (METU herbarium, photo by Jelena Erdal)

There are three species, *L.gueneri*, *L.smithii* and *L.vanense* on our phenogram that seem to be out of the main clusters that appeared within section *Limonim*. Even though, *L. gueneri* and *L. smithii* form small cluster 4, they look distant one from the other. Also, *L.vanense* appears as a single branch not closely related to the rest of the clusters. Actually, those three species could be taken as an example how number and weigthing of the characters may affect classification. Because if we classify those species on the base of a few the most important diagnostic characters, they would be easily placed within the cluster 2 (*L.gueneri*) and cluster 3 (*L.smithii* and *L.vanense*). However, when we use 57 characters that are all equally important, differences between clusters are becoming more obvious and they are placed out of the main clusters.

L.gueneri is one of the recently described species. It is a Mediterranean element, a local endemic growing around ancient city of Patara in Antalya province. This species is a maritime element, morphologically closest to *L.ocymifolium* (Doğan et al, 2008). From that point of view, it might be expected to see this species together

in cluster with the *L.ocymifolium* and joined with *L.greacum*, *L.virgatum*, *L.sieberi* and *L.didimense*. Still, there are significant differences in morphological characters between this cluster and *L.guenrerii*. First of all, is absence of the sterile branches on the scape, further, *L.guenerii* has herbaceous scape on woody caudex; obtuse to acute, mucronate leaves; inflorescence is corymbose-paniculate, bilateral, with a very specific number of flowers per spiklet (4-5).

Figure 30: *Limonium gueneri*, section *Limonium*: A.habit; B. leaves; C.inflorescence. (METU herbarium, photo by Jelena Erdal)

L.smithii is an Irano-Turanian element, an endemic of Seyfe lake area in Kırşehir province and it grows naturally together with *L.tamaricoides* (Akaydın, 2007). Hence, it is supposed to appear together in cluster with *L.bellidifolium*, *L.caspium*, *L.iconicum* and *L.tamaricoides*, as the most closely resembleing *L.*caspium (Akaydın, 2007). However, there are few differences in characthers with the species forming this cluster *L.smithii* that caused this kind of outcome, such as: average scape length, leaf shape, length, width and ratio; average number of spikelets per inflorescence; number of florets per spikelet; 1st inner bract not emarginated; average calyx length and corolla color.

Figure 31: *Limonium smithii*, section *Limonium*: A. habit; B. leaves; C.inflorescence. (METU herbarium, photo by Jelena Erdal)

According to our phenogram *L.vanense* look quite far from the clusters mentioned above. It is an Irano-Turanian element, endemic to East Anatolia and one of the species with leaves that dry up before end of the flowering. For this reason, it was expected that this species appears together with the *L.bellidifolium*, *L.caspium*, *L.iconicum* and *L.tamaricoides*. Nevertheless, closer examination of the morphological characters provided better insight into their differences and showed that *L.vanense* has: herbaceous form, with woody caudex, others are subshrubs; missing sterile branches on the scape; eliptic to oblong-obovate leaves with, acute and apiculate leaf tip, others have spathulate leaves, with obtuse and mucronate leaf tip; calyx is infundibular, obconical in others. It would be interesting to study further this group of species with the leaves drying up before flowering, in order to see weather this character is result of their common origin or it is just parallel structure independently developed in different species.

Figure 32: *Limonium vanense*, section *Limonium*: A. habit; B. leaves; C.inflorescence. (METU herbarium, photo by Jelena Erdal)

The cluster representing the genus *Armeria* is well isolated in our phenogram, regarding to its distinctive features: unbranched, leafless scape, without scaly leaves; growing from branched woody rootstock; fleshy, linear leaves; capitate inflorescence, with many 2-4 flowered spikelets; more than 3 bracts (6); emarginate 1st inner bract and styles that are hairy at lower third. *Armeria* in Turkey is represented by 2 native species, *A.trojana* and *A.cariensis*. *A.trojana* is a local endemic confined to Mount Ida (Kaz Dağı) in Balıkesir province. Because of its specific dwarf habit, hairy base of the scape and ciliolate leaf margin and 2-3 flowers per spikelet, it is clearly separated from *A.cariensis*.

Figure 33**:** *Armeria trojana* (METU herbarium, photo by Jelena Erdal)

Taxonomic status of the *A.cariensis* with its two varieties *A.cariensis var. cariensis* and *A.cariensis var. rumelica,* is a source of long lasting debate. Some of the authors accept these varieties (Davis et all, 1982; Doğan and Akaydın, 2006), while the others treat those varieties as a separate species *A.cariensis* and *A.rumelica* (Tutin et all, 1972; Yeşil et al, 2014). For this reason we included both of the varieties in this study. As a result, our phenogram did not show overlapping in morphological characters, and separate this two with the cut off line through 0.97 similarity. Characters that were indicating differences are: scape length, heteromorphic leaves in *A.cariensis cariensis* and calyx length and structure. However, situation is not simple how it seems at the first glance. In general, the whole structure of *Armeria* is pretty complicated. Beacause of the often hybridization, mostly sympatric distribution and occasionally uncertain borders between species. *A.cariensis cariensis* has range covering west Turkey and western and eastern parts of Trace region. *A.cariensis rumelica* is present in the whole Thrace region covering southeast Balkans. Consequently, those species show sympatric distribution in the Thrace region which includes European part of Turkey as we can see in the Figure 36.

Figure 34: *Armeria cariensis var. cariensis*: A.habit; B.leaves; C. inflorescence (METU herbarium, photo by Jelena Erdal)

Figure 35: *Armeria cariensis var. rumelica*: A. habit; B. leaves; C. inflorescence (METU herbarium, photo by Jelena Erdal)

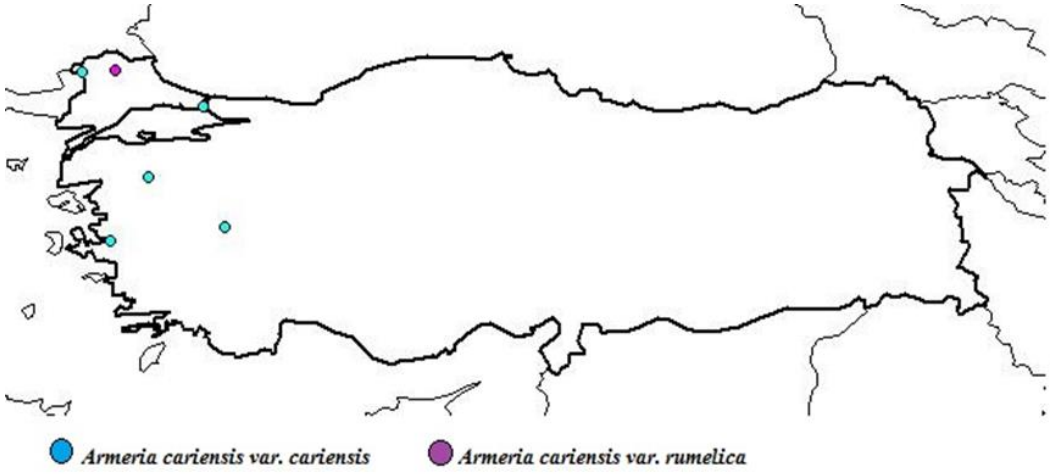

Figure 36: Geographic distribution of *A.cariensis var. cariensis* and *A. cariensis var. rumelica* in Turkey (edited from TÜBİVES website)

Since most of the studies, regarding this issue, are done on the specimen only from Turkey (Davis at all, 1982; Doğan and Akaydın, 2006), including this one, there is not enough evidence to make firm separation of these two varieties into species. Even though, this has been done by the group that also had available some of the Bulgarian specimen and did anatomical studies as support of the claim (Yeşil et al, 2014). Nevertheless, we believe that without profound study based on the specimen from all of the distribution range, including Greece, Bulgaria and Turkey, and different types of analyses, it is not possible to give a final word about this issue.

Acanholimon is clearly split from rest of the genera according to phenogram (Figure 13). Characters that keep it apart from other genera are: cushion formation; rigid, linear, triquetrous, pungent leaves, without petiole and with glabrous or scabridulous margin; usually spicate inflorescense; bracts with excurrent veins and fully hyalinated except the vein part; influndibular, hairy, hyanlinated calyx, with mostly white calyx lip; corolla usually in different nuances of pink color; capitate stigma; glabrous styles. Three section are present in Turkey: *Acantholimon*, *Tragacanthina* Bunge and *Staticopsis* Boiss. They were accepted in the Flora of Turkey (Davis et al, 1982) and confirmed by the later revision of *Acantholimon*

(Doğan & Akaydın, 2003a). Those sections seem well circumscribed on our tree and separated from each other by the 0.93 cut off line (Figure 14).

Section *Acantholimon* is represented by 3 species in this study: *A.bracteatum*, *A.capitatum* and *A. hoshapicum*. It has quite sharp character difference comparing to rest of the *Acantholimon*, such as: heteromorphic leaves and persistent spring leaves; unbranched scape; capitate inflorescence formed by condensed spikes, with 2-5 flowered spikelets and 2-6 obtuse, bracts; infundibular, hairy calyx. These species are Irano-Turanian elements confined to East Anatolia.

Figure 37: *Acantholimon bracteatum*, section *Acantholimon*: A. habit; B.inflorescence. (METU herbarium, photo by Jelena Erdal)

Second section *Tragacanthina* included 3 species in this study: *A.tragacanthinum*, *A.quinquelobum* and *A.araxanum*. It also has specific morphological characters: heteromorphic leaves and deciduous spring leaves; branched scape; paniculate diffuse inflorescecense, with 1- flowered spikelets, and 3 bracts; tubular calyx. *A.tragacanthinum* and *A.quinquelobum* are typical representatives of the section and they appear close to each other on phenogram. From the other hand *A.araxanum* look distant, but still belonging to same cluster. Reason for that is that it shares many common morphological characters with the group, but it has homomorphic leaves and infundibular calyx. All, species are Irano-

Turanian elements from East Anatolia and west to north west Iran, and have preferences to dry sandy slopes, as a habitat.

Figure 38: *Acantholimon quinquelobum*, section *Tragacanthina*: A. habit; B.inflorescence; C. spikelet. (METU herbarium, photo by Jelena Erdal)

The last section *Staticopsis* is separated from the others by the following characters: monomorphic leaves; spicate, simple or branched inflorescence, with 1-flowered spikelet; 3 bracts and infundibular calyx. Within this section a few subclusters equate to subsection are observable at the 0.94 cut off line. First subcluster consist of *A.laxiflorum* and *A.köycegizicum* and they look pretty isolated from the rest of the species in this section. Considering that both species have circinnate previous year's leaf bases, it might be expected to see them within subsection *Circinnatea* Doğan & Akaydın. However, in the case of *A.laxiflorum* this result was not surprising, since it differs a lot from the other species with circinnate leaf base, and the special subsection *Robustea* Doğan and Akaydın, was established for it (Doğan et al, 2007). Characters shown to be specific for *A.laxiflorum* are: glabrous, really long (average 29 cm) scape; long spikes (average 22.5 cm), with average 26 spikelets, 1st internode shorter than spikelet; non excurrent calyx vein; brownish calyx lip.

At the other side *A.köycegizicum*, morphologically resembles other members of *Circinnatea*, but there are also significant difference that bring it close to

A.laxiflorum. First of all, *A.köycegizicum* has quite robust habit, too. It has: long scape (22cm average), 12 spikelets per infloescence in average; 1st internode longer than spikelet; nonexcurrent calyx vein and brownish calyx lip color. Important difference between these two species is that: in *A.laxiflorum* spikes are unbranched, laxly distichous, in *A.köycegizicum* spikes are branched and they consist of 2-5 distichous branches (Dogan and Akaydın, 2003c, 2003d).

Figure 39: *Acantholimon laxiflorum*, section *Staticopsis*: A. habit; B. inflorescence (METU herbarium, photo by Jelena Erdal)

Both of the species are Mediterranean elements, preferring serpentine, rocky stream beds as a habitat, which also clearly separates them form the rest of the subsection *Circinnatea* that are Irano-Turanian species, occurring in highlands and mountains of South East Anatolia. Accordingly, taxonomic status of *A.köycegizicum*, should be more closely examined. Even though, it belongs to same floristic region, share same habitat demands, and robustness of the appearance as *A.laxiflorum*, still it does not seem suitable to include *A.köycegizicum* it in the subsection *Robustea*. Because of the very obvious difference in inflorescence morphology. From the other hand, as a pure coastal, Mediterranean element it should not be kept together with the

highland, mountain elements of Irano-Turanian region in the subsection *Circinnatea*. Establishing of two series within subsection *Circinnatea* one including *A.köycegizicum* and another including the rest of the species with circinnate leaf bases, might be one of the possible solutions. Also, in this case different type of analyses, beside morphology and ecology, would possibly offer better understanding of this issue.

Figure 40**:** *Acantholimon köycegizicum*, section *Staticopsis*: A. habit; B. inflorescence (METU herbarium, photo by Jelena Erdal)

Second subcluster within section *Staticopsis* was formed by the *A.calvertii* and *A.huetii*, matching with the subsection *Circinnatea* Doğan & Akaydın. This subcluster is separated on the account of the following morphological characters: hairy scape; previous year's leaf bases circinnate; hairy leaves with scabridulous margin; branched spicate inflorescence; 1st internode shorter than spikelet; excurrent calyx veins; average calyx length 12,5 mm; calyx lip color white to purple. Both species are Irano-Turanian elements, endemics, restricted to South East Anatolia. They grow at highland steppes and calcareous or volcanic slopes, at high elevations (from 1200 up to 3500 m).

Figure 41: *Acantolimon calverti*, section *Staticopsis*: A. habit; B. inflorescence. (METU herbarium, photo by Jelena Erdal)

The rest of the *Acantholimon* species form two big clusters associated to the subsections *Androsacea* Bunge and *Caryophyllacea* Bunge. First cluster, analogous to subsection *Caryophyllacea* include species: *A.caryophyllaceum*, *A.confertiflorum*, *A.avanosicum*, *A.venustum*, *A.petraeum*, *A.acerosum*, *A.halophilum* and *A.kotschyi*.

Figure 42: *Acantolimon caryophyllaceum*, section *Staticopsis*: A. habit; B.inflorescence. (METU herbarium, photo by Jelena Erdal)

Second cluster regarding subsection *Androsacea* consists of the species: *A.ulicinum, A.anatolicum, A.glumaceum, A.yıldızelicum, A.hypochareum, A.puberulum, A.spirizianum, A.karamanicum, A.libanoticum* and *A.diantifolium.*

Figure 43: *Acantolimon ulicinum*, section *Staticopsis*: A. habit; B.inflorescence. (METU herbarium, photo by Jelena Erdal)

All of those species are Irano-Turanian elements (except *A.libanoticum*), growing on different types of rocks or montane steppes. Difference between those two groups lays in inflorescence structure. *Androsacea* has simple or shorlty branched spikes, and terminally densely congested spikelets and *Caryophyllacea* has, simple, lax, 2-ranked spikes (Doğan et al, 2007). Beside this, characters shown to be responsible for the separation of those groups are: scape length; inflorescence length; texture of outer and 1st inner bract and calyx lip color. Structure of the groups is mostly in harmony with the ones accepted in the Flora of Turkey and the later revision of the *Acantholimon* (Davis et al, 1982; Doğan & Akaydın, 2003a; Doğan et al, 2007). Nevertheless, there are few exceptions. One of those is *A.diantifolium*. This species was segregated in subsection *Diantifoliea* Doğan & Akaydın (Doğan et al, 2007). However, in our phenogram it appeared as a part of subsection *Caryophyllacea*, which is in accordance with the old position of the species suggested by Flora of Turkey (Davis et al, 1982). Characters that caused this kind of placement are: scape and inflorescence length; texture of outer bract; shape of the 1st inner bract and calyx lip color. Another species with unexpected placement is

A.spirinzianum. In the Flora of Turkey (Davis et al, 1982) it was placed within subsection *Mycrocalicina* Bunge, during *Acantholimon* revision (Doğan and Akaydın, 2003; Doğan et al, 2007) it was moved to subsection *Caryophyllacea*, and in our study it appeared as a part of subsection *Androsacea*. This kind of position was determined by the following characters: scape and inflorescence length; branched spikes; outer bract texture; 1st inner bract shape and texture and calyx lip color. Last exception is *A.libanoticum* that was expected to be found within subsection *Caryophyllacea*, but in our tree it appeared within subsection *Androsacea*, which was caused by scape and inflorescence length; number of spikelets per spike and 1st inner bract shape.

CHAPTER 4

CONCLUSIONS

The main aim of this study was to make evaluation of existing structure of Plumbaginaceae in Turkey in order to see infrafamilial grouping as well as infrageneric arrangement of the big genera (*Limonium* and *Acantholimon*) and their naturalness. For this purpose, numerical taxonomic method and clustering analysis were used. Also, this was the first time, that all Turkish genera of Plumbaginaceae were evaluated together, within the same study, represented by high number of species.

Eventually, clear separation of subfamilies and genera within Plumbaginaceae, as well as, sections within genera were observed. The two subfamilies Plumbaginoideae and Staticoideae are well separated from each other on an account of the: shape and structure of corolla, calyx and leaves; stigma type and style number. Within subfamily Plumbaginoideae two main branches are observed. First one is representing genus *Ceratostigma* (*C.plumbaginoides*), other *Plumbago* (that further branches in two species *P.europae* and *P.capensis*). *Ceratostigma* and *Plumbago* differ in: leaf shape and texture; bracts structure; features of the calyx and style texture. Within subfamily Staticoidea 6 clusters were formed, analogus to the genera: *Psylliostachys*, *Goniolimon*, *Limoniopsis*, *Limonium*, *Armeria* and *Acantholimon*. For the first time we got an insight into taxonomic position of the genus *Psylliostachys* (*P.spicata*) newly recorded from Turkey. This genus seems morphologically quite distant from the rest of the Turkish Plumbaginaceae, based on: scape, leaves, bract and calyx texture, with glandular hairs; shape of the leaves, inflorescence and corolla; structure of the inflorescence and bracts number. Also, this is an annual species. *Goniolimon* (*G.incanum*) and *Limoniopsis* (*L.davisii*) look closest to each other with difference in: shape and texture of the scape and leaves;

infloresecence type and structure; structure of the bracts; calyx shape; corolla color, and style texture. They both differ from *Limonium* in stigma type; inflorescence structure and calyx features.

Limonium was well isolated from the rest of genera with an exception of *L.sinuatum* (the only representative of the section *Pteroclados* Sauv. & Vindt. in Turkey) that appeared on phenogram as a completely separated branch, both from the rest of *Limonium* and the rest of the genera. This was caused by its peculiar morphology (shape, structure and texture of the scape, leaves, inflorescence, bracts and calyx). Still, this kind of result was in accordance with the existing studies on *L.sinuatum* and its section *Pteroclados*, since their taxonomic status is under long lasting debate. Within *Limonium* cluster sections: *Sphaerostachys* (Boiss.) Bokhari, and *Schizyhymenium* (Boiss.) Bokhari were seen. The cluster equate to the section *Sphaerostachys* includes species (*L.lilacinum*, *L.globuliferum*, *L.pycnanthum*, *L.davisii* and *L.marmarisense*). They are distinguished on account of: habit features; leaf shape; infloresecence shape and structure; bracts number and calyx type. A single separate branch correspond to the *L.echioides*, the only Turkish reparesntative of the section *Schizyhymenium*. It has very distinct morphological features, such as: tuberculate leaves; very unusual calyx and 2nd inner bract structure. Also, it is the only annual *Limonium* in Turkey. Species that represent section *Limonium* did not form a single cluster in our study, instead 4 well- formed clusters are observed. First cluster consists of the: *L.meyeri*, *L.effusum*, *L.gmelinii* and *L.angustifolium* that are mostly species with broad distribution range, with large, herbaceous habit, without sterile branches on the scape and leaves that are green during flowering. Second cluster includes: *L.greacum*, *L.virgatum*, *L.sieberi*, *L.didimense* and *L.ocymifolium*, which are all typical Mediterannean elements, subshrubs with sterile branches on the scape, with green leaves during flowering and usually unilateral inflorescence. *L.anatolicum*, the only species from the section *Sarcophyllum* in Turkey, appeared as a joint branch of the second cluster. However it also has very specific: leaves' shape and arrangement; inflorescence shape and structure; calyx shape and corolla color. Third cluster is formed by: *L.bellidifolium*, *L.caspium*, *L.iconicum* and *L.tamaricoides* that are mainly Irano-Turanian elements, with sterile branches on the

scape and leaves that dry up before the end of the floweing. Fourth cluster is small and consists of the *L.gueneri* and *L.smithii* that also seems distant from the other clusters and one from the other. Accordingly, some of those clusters may have potential to be recognized as a subsections within section *Limonium*.

A cluster equivalent to *Armeria* is well segregated from the other genera, based on its leafless scape, capitate inflorescence and texture of the style. Even though in this study varieties, *A.cariensis cariensis* and *A.cariensis rumelica*, did not show overlapping, we believe that species *A.cariensis* demands additional attention and studies based on the specimens from the whole Trace region and with application of different studying methods.

Finally, *Acantholimon* is represented by one well circumscribed cluster on our phenogram. It is separated from the other genera because of it's: cushion formation, leaves', bracts and calyx shape and structure; corolla color (usually in different nuances of pink); shape of the stigma and texture of the styles. Within *Acantholimon* in Turkey 3 cluster analogus to the sections *Acantholimon*, *Tragacanthina* and *Staticopsis*, are observed. They differ one from the others in presence or absence of heteromorphic leaves; inflorescence type; number of flowers per spikelet; bract number and calyx shape. Within the section *Staticopsis* a few subclusters that equate to subsections were found. First subcluster consists of *A.laxiflorum* and *A.köycegizicum*. Finding objective taxonomic position of the *A.köycegizicum* within subsections of the section *Staticopsis*, seems challenging. Since it has similarities and differences with the both subsection Robustea (represented only by *A.laxifloum*) and subsection *Circinnatea* (represented by *A.calvertii* and *A.huetii* in this study) where it should belong according to its robust habit and circinnate leaves. Both subsections *Robustea* and *Circinnatea* have circinnate previous year's leaf bases, but they differ in robustness of the habit and the inflorescence structure. Other identified subsections are *Caryophyllacea* and *Anderosacea*. They usually do not have circinnate previous year's leaf bases and differ in the infloresecence structure. In our study subsection *Caryophyllacea* included species: *A.caryophyllaceum*, *A.venustum*, *A.petraeum*, *A.acerosum*,

A.halophilum, *A.kotschyi*, *A.avanosicum* and *A.confertiflorum*. Subsection *Androsacea* included species: *A.ulicinum*, *A.karamanicum* *A.anatolicum*, *A.glumaceum*, *A.yıldızelicum*, *A.hypochareum*, *A.puberulum*, *A.spirizianum*, *A.libanoticum* and *A.diantifolium*.

Features that are found to be most important and that explained most of the variation in clustering of Plumbaginaceae in Turkey are: life form; habit in the form of cushion formation or not; scape structure and texture; leaves'shape, arrangement, texture, tip and presence or absence of petiole; inflorescence's type, structure and symmetry; number of florets per spikelet; number of bracts; outer bract's and 1st inner bract's shape, structure and texture; calyx' shape, structure, texture and calyx lip margin shape and color; corolla color; shape of the stigma.

Eventually, it was shown that genera in our study were well separated from one another, exhibiting quite natural structure and the following linear arrangement. *Plumbago* and *Ceratostigma* formed one cluster that correspond to the Plumbaginoideae subfamily and it is separated form the other cluster that corespond to Staticoideae subfamily. Within second cluster *Goniolimon* and *Limoniopsis* are closest to each other, and next similar to them is *Limonium*. *Armeria* seems quite different from them as well as *Acantholimon* and both of them are well formed separate clusters. *Psylliostachys* exhibited lowest level of similarity with the rest of genera of Plumbaginaceae in Turkey.

Even though, it is an excellent method for creating more natural grouping of the taxa, numerical taxonomic study as a single approach might not be always sufficient for establishing a new taxonomic arrangements. In order to lay the foundation of more objective and solid taxonomic structures, in general it is necessary to conduct various studies including different fields beside morphology, such as: anatomy, palynology, cytology, phytochemistry, genetics and population genetics, ecology, etc.

Another important issue is that most of the studies including ours are performed within a political borders (countries, regions, etc.). Since distribution

ranges of the taxa may go far beyond those borders more joint studies including different countries and regions are needed. Because examination of the specimens from particular and all parts of their distribution range, would provide much better understanding of the taxa and their taxonomic positions.

At last, a generic key for the Plumbaginaceae in Turkey is given in the Appendix A, in order to include newly recorded genus *Psylliostachys*.

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APPENDIX A

A NEW IDENTIFICATION KEY TO THE GENERA OF PLUMBAGINACEAE IN TURKEY

1**.** Styles united trough out all their length except for the stigmas; corolla always gamopetalous …….....**2**

2. Calyx glandular; sepals connate.....……. ***Plumbago***

2. Calyx not glandular; sepals free…….……..……. ***Ceratostigma***

1. Styles free from the base; petals usually connate only at the base ……....…….**3**

3. Stigmas capitate …….……..... **4**

4. Shrubs or subshrubs with cushion formation; leaves rigid, linear, triquetrous or, pungent …...…..……. ***Acantholimon***

4. Subshrubs or herbs, often with woody caudex; leaves fleshy or leathery, never pungent ……**5**

5. Styles hairy …….……..…….. ***Goniolimon***

5. Styles glabrous……..... ***Limoniopsis***

3. Stigmas filiform …..……..…..…. **6**

6. Annual herbs; corolla gamopetalous; inflorescence cylindrical and compact.……. ***Psylliostachys***

6. Perennial herbs or subshrubs; petals free except for the base; inflorescence not cylindrical ……... **7**

7. Inflorescence capitate borne on leafless scape ……..... ***Armeria***

7. Flowers in single or many flowered spikelets, organized in spikes; scape less or more leafy, with paniculate or corymbose-paniculate branching pattern……..……..... ***Limonium***

APPENDIX B

LIST OF THE OPERATIONAL TAXONOMIC UNITS

In the Table B1 operational taxonomic units are listed, followed by general information about specimens that were used in this study.

Table B1: List of Operational Taxonomic Units and general information about specimens

	OTUs	Specimen information (Code, Locality, Date and Collector)
1.	***Plumbago europaea***	**8153** B8 Bingöl, Bingöl- Elazığ road, around Kuruca mountain pass, 1860 m, 14.08.2003, Doğan & Akaydın **8115** B9 Van, Çaldıran – Van road, 1750 m, 12.08.2003, Doğan & Akaydın
2.	***Plumbago capensis***	**10561** C1 Muğla, Bodrum, Yahşi Beldesi, Yeşilyurtlular Tatil sitesi, cultivated, 100m, 01.09.2005, Akaydın **9922** C2 Antalya, Kaş, cultivated, 50 m, 30.07.2004, Doğan & Akaydın
3.	***Ceratostigma plumbaginoides***	**ISTE 43888** A2(A) Istanbul, Anadoluhisar, 10.11.1979, A.Baytop
4.	***Goniolimon incanum***	**9303** A1 Balıkersir, Bandırma- Marmara island, Asmalı village, 5 m, 05.07.2004, Doğan & Akaydın **10272** B2 Manisa, Salihli, Karayahşi village, Gümbürdek hill, 120 m, 27.07.2005, Akaydın
5.	***Limoniopsis davisii***	**8121** B9 Van, Van – Başkale road, Zernek dam, Hamur village, 1990 m, 12.08.2003, Doğan & Akaydın **8126** B9 Van, Gevaş, Artos mountain, Askan plateau, 2200 m, 13.08.2003, Doğan &Akaydın
6.	***Armeria trojana***	**8018** B1 Balıkesir, Edremit, Mount Ida (Kaz Dağı),Kartal Çimeni, 1750 m, 06.08.2003, Doğan & Akaydın
7.	***Armeria cariensis var. cariensis***	**7798** B1 Manisa, Salihli – Ödemiş road, around Kırkoluk fountain, 1100 m, 07.08.2003, Doğan &Akaydın **7822** B1 Manisa, Salihli, Bozdağ Municipality, 1550 m, 07.07.2003, Doğan &Akaydın

Table B1 (Continued)

8.	***Armeria cariensis var. rumelica***	**9263** A1 Tekirdağ, Çerkezköy – Çorlu road, around Veliköy, 180 m, 03.07.2004, Doğan & Akaydın **9298** A1 Tekirdağ, Demirköy, 760 - 860 m, 04.06.2004, Doğan & Akaydın
9.	***Psylliostachys spicata***	C9 Siirt, Pervari, around Tuzcular, 1400 m, summer 2014, Osman Karabacak
10.	***Acantholimon bracteatum***	**7006** B9 Van, Başkale, Gürpınar – Başkale road, Esentepe pass,2800 m, 19.07.2001, Doğan &Akaydın **7555** C9 Hakkari, around Behçelen, 2500 m, 07.07.2002, Doğan &Akaydın
11.	***Acantholimon capitatum subsp.capitatum***	**6990** B9 Van, Van – Erciş road, 1700 m, 18.07.2001, Doğan &Akaydın **7528** B9 Van, Gevaş, Artos Mountain 2350m, 05.07.2002, Doğan & Akaydın
12.	***Acantholimon hoshapicum***	**9263** B9 Van, Gürpınar – Başkale road, around Hoşap, 2050 m, 06.07.2002, Doğan & Akaydın
13.	***Acantholimon tragacanthinum***	**6957** A9 Kars, around Kağızman – Tuzluca road, 1200 m, 18.07.2001, Doğan &Akaydın
14.	***Acantholimon quinquelobum var. quinquelobum***	**6955** A9 Kars, Kağızman – Tuzluca road, 1200 m, 18.07.2001, Doğan &Akaydın **6957** A9 Kars, Kağızman – Tuzluca road, 1200 m, 18.07.2001, Doğan & Akaydın
15.	***Acantholimon araxanum***	**7492** A9 Erzurum, between Horasan and Kağızman, 1200 m, 03.07.2002, Doğan &Akaydın **8101** A9 Iğdır, around Doğubeyazıt, 1500 m, 11.08.2003, Doğan & Akaydın
16.	***Acantholimon laxiflorum***	**8422** C5 Hatay, Arsuz, Avcılarsuyu valley, 30 m, 09.08.2000, H. Duman

Table B1 (Continued)

17.	***Acantholimon dianthifolium***	**7552** C9 Hakkari, Hakkari – Van old road, around Karadağ, 2500 m, 07.07.2002, Doğan & Akaydın
18.	***Acantholimon calvertii var. calvertii***	**6760** B7 Elazığ, Sivrice, Hazarbaba Mountain, around ski center, 2050m, 04.07.2001, Doğan & Akaydın **6959** B9 Ağrı, Akçay- Cumaçay road, 2300 m, 18.07.2001, Doğan & Akaydın
19.	***Acantholimon hypochaerum***	**6955** A8 Gümüşhane, around Değirmendere, 1950 m, 15.07.2001, Doğan & Akaydın **6869** B7 Erzincan, Erzincan – Sivas road, Sakaltutan pass, 2160 m, 15.07.2001, Doğan & Akaydın
20.	***Acantholimon köycegizicum***	**7237** C2 Muğla, Fethiye, Köyceğiz, Sultaniye 20 m, 23.08.2001, Doğan & Akaydın **7238** C2 Muğla, between Köyceğiz and Kaplıcalar, 20 m, 23.08.2001, Doğan & Akaydın
21.	***Acantholimon huetii var. huetii***	**7154** C6 Kahramanmaraş, Göksun, Keklikoluk village, 2300 m, 18.08.2001, Doğan & Akaydın **7161** C6 Kahramanmaraş, Göksun – Sarız road, 1700 m, 19.08.2001, Doğan & Akaydın
22.	***Acantholimon ulicinum var. ulicinum***	**6525** C3 Isparta, Sütçüler, 1600 m, 10.09.2000, Doğan & Akaydın **7209** C4 Karaman, Hadim – Beyleri road, 1950 m, 21.08.2001, Doğan & Akaydın
23.	***Acantholimon anatolicum***	**6760** B7 Elazığ, Sivrice, Hazarbaba Mountain, around ski center, 2050m, 04.07.2001,Doğan & Akaydın **6959** B9 Ağrı, Akçay- Cumaçay road, 2300 m, 18.07.2001, Doğan & Akaydın

Table B1 (Continued)

24.	***Acantholimon yıldıelicum***	**7101** B6 Sivas, Yıldıeli, Çamlıbel Mountain, Çamlıbel pass, 1700 m, 17.08.2001, Doğan &Akaydın
25.	***Acantholimon karamanicum***	**6576** C4 Karaman, between Ermenek and Anamur,Abanoz plateau,1700 m,13.09.2000, Doğan&Akaydın **6512** C6 Karaman, between Ermenek and Balkusan,1600 m, 28.08.2000, Doğan & Akaydın
26.	***Acantholimon confertiflorum***	**6528** C4 Konya, Bozkır, 1300 m, 24.08.2000, Doğan & Akaydın **6513b** C4 Karaman, Gökçe pine grow, 1400 m, 24.08.2000, Doğan & Akaydın
27.	***Acantholimon puberulum subsp. puberulum***	**6573** C4 Karaman, Ermenek – Anamur road, Taşeli plateau, 1600m, 13.09.2000, Doğan & Akaydın **6507** C4 Karaman, Ermenek, Balkusan village, 1750 m, 23.08.2000, Doğan &Akaydın
28.	***Acantholimon glumaceum***	**6947** A9 Kars, Arpaçay – Çıldır road, 1850 m, 17.07.2001, Doğan & Akaydın **6968** B9 Ağrı, between Akçay and Cumaçay, 1700 m, 18.07. 2001. Doğan &Akaydın
29.	***Acantholimon caryophyllaceum***	**7462** B8 Erzincan, between Erzincan and Tercan, 1600 m, 03.07.2002, Doğan & Akaydın **7017** C10 Hakkari, Yüksekova – Dağlıca road, 1900m, 19.07.2001, Doğan &Akaydın
30.	***Acantholimon avanosicum***	**6466** B5 Nevşehir, between Avanos and Hacıbektaş, 950 m, 20.08.2000, Doğan & Akaydın
31.	***Acantholimon venustum var. venustum***	**6698** B5 Kayseri, Develi, 1950 m, 02.07.2001, Doğan & Akaydın **6857** B7 Erzincan, around İmranlı, 1820 m, 15.07.2001, Doğan & Akaydın

Table B1 (Continued)

32.	***Acantholimon petraeum***	**7053** B9 Bitlis, Adilcevaz, Süphan Mountain, Sütay plateau, 2650 m, 20.07.2001, Doğan & Akaydın **6981** B10 Iğdır, Doğubeyazıt - Çaldıran road, 2200 m, 18.07.2001, Doğan & Akaydın
33.	***Acantholimon spirizianum***	**6986** B9: Iğdır, Çaldıran, Soğuksu village, 2150 m, 18.07.2001. Doğan & Akaydın **6981** B10 Iğdır, Doğubeyazıt – Çaldıran road, 2200 m, 18.07.2001, Doğan &Akaydın
34.	***Acantholimon kotschyi***	**6614** B4 Konya, Kulu – Cihanbeyli road, 1050 m, 26.06.2001, Doğan & Akaydın **6666** B5 Nevşehir, Kılıçlar village, 1150 m, 01.07.2001, Doğan & Akaydın
35.	***Acantholimon libanoticum***	**6787** B6 Kahramanmaraş, Göksun, Güneyoluk, 2100 m, 09.07.2001, Doğan & Akaydın **6197** C6 Adana, Kozan, Feke Mountine, Görpiyez plateau, 1700 m, 08.07.2001, Doğan & Akaydın
36.	***Acantholimon halophilum***	**7408** B4 Ankara, Şereflikoçhisar, Tuz lake, 930 m, 04.06.2002, Doğan & Akaydın **7365** B4 Aksaray, Emirgazi road, 1200 m, 21.06.2002, Doğan & Akaydın
37.	***Acantholimon acerosum subsp. acerosum var. acerosum***	**7621** B3 Afyon, Bolvadin – Emirdağ road, 1200 m, 16.07.2002, Doğan & Akaydın **6984** B10 Iğdır, Doğubeyazıt - Çaldıran road, 2200m, 18.07.2001, Doğan &Akaydın
38.	***Limonium sinuatum***	**7847** B1 Izmir, Karaburun – Küçükbahçe road, 15m, 08.06.2003, Doğan &Akaydın **9912** C1 Muğla, Datça,around Knidos port, 10m, 28.07.2004, Doğan &Akaydın
39.	***Limonium echioides***	**10217** C4 Mersin, Silifke, İncekum Burnu, Göksu delta, 2 m, 06.05.2005, Akaydın

Table B1 (Continued)

40.	***Limonium anatolicum***	**7686** B4 Ankara, Şereflikoçhisar – Ankara road, around Tuz lake, 940 m, 22.09.2002, Doğan & Akaydın **9259** B4 Konya, Cihanbeyli – Konya road, around Bolluk lake, 925 m, 02.07.2004, Doğan & Akaydın
41.	***Limonium ocymifolium***	**9913** C1 Muğla, Datça,around Knidos port, 10m, 28.07.2004, Doğan &Akaydın
42.	***Limonium meyeri***	**7660** C2 Denizli, Pamukkale, 375 m, 30.08.2002, Doğan & Akaydın **8210** B1 Izmir, Çiğli – Kuşcenneti road, 0m, 06.09.2003, Doğan &Akaydın
43.	***Limonium lilacinum var. lilacinum***	**7873** B4 Aksaray, Aksaray – Adana road, 950 m, 18.06.2003, Doğan &Akaydın **8161** B5 Kayseri, Incesu – Develi road, 1060 m, 15.08.2003, Doğan &Akaydın
44.	***Limonium pycnanthum***	**7872** B4 Aksaray, around Univeristy campus, 950 m, 08.06.2003, Doğan & Akaydın **8163** B4 Ankara, Şereflikoçhisar – Ankara road, around Tuz lake, 875m, 22.09.2002, Doğan & Akaydın
45.	***Limonium marmarisense***	**9910** C1 Muğla, Marmaris, Bozburun, Müskebi island, 0 m, 28.07.2004, Doğan &Akaydın
46.	***Limonium angustifolium***	**7990** A1, Tekirdağ, Kumbağ – Şarköy road, around Gaziköy, 0 m, 05.08.2003,Doğan &Akaydın **7706** C2 Antalya, Finike – Kale road, Beymelek, 0 m, 09.11.2002, Doğan & Akaydın
47.	***Limonium effusum***	**7687** C1 Aydın, Didim, Bozbük, 0 m, 29.10.2002, Doğan & Akaydın **7702** C2 Antalya, Finike – Kale road, Beymelek, 0 m, 09.11.2002, Doğan & Akaydın

Table B1 (Continued)

48.	***Limonium gmelinii***	**7709** C1 Aydın, Didim, Bozbük, 0 m, 10.11.2002, Doğan & Akaydın **9896** C1 Muğla, Datça – Bozburun road, Orhaniye, 0m, 27.07.2004, Doğa & Akaydın
49.	***Limonium guenerii***	**12329** C2 Antalya, Kaş, Gelemiş (Patara) village, 30 m, 17.08.1996, A.Güner, H.Duman, and S.S. Çağlar **9920** C2 Antalya, Kaş, Patara, 20 m, 30.07.2004, Doğan & Akaydın
50.	***Limonium bellidifolium***	**8005** A1 Çanakkale, Keşan – Gelibolu road, Saroz gulf, 0 m, 28.07.2004, Doğan &Akaydın **7973** B1 Balıkesir, Ayvalık, Sarımsaklı, Badavut, 0 m, 25.06.2003. Doğan & Akaydın
51.	***Limonium vanense***	**7479** A9 Erzurum, Pasinler – Ağrı road, Aras, 1600 m, 03.06.2002, Doğan &Akaydın **8117** B9 Van, Van - Muradiye road, 1730 m, 12.08.2003, Doğan & Akaydın
52.	***Limonium davisii***	**10120** B4 Aksaray, Aksaray – Konya road, around Sultanhanı, 915 m, 03.10.2004, Doğan & Akaydın
53.	***Limonium caspium***	**8166** B4 Ankara, Şereflikoçhisar, Tuz lake, 865 m, 22.09.2002, Doğan & Akaydın **10432** B5 Kayseri, Sultan Sazlığı, 1000 m, 15.07.2005, Doğan & Akaydın
54.	***Limonium smithii***	**9236** B5 Kırşehir, Kırşehir, Badılı village, around Seyfe lake, 1085 m, 27.06.2004, Doğan & Akaydın
55.	***Limonium graecum var. graecum***	**9864** B1 Izmir, Çeşme, 1 m, 25.07.2004, Doğan & Akaydın **10551** B1 Izmir, around Alaçatı, 1 m, 13.08.2005, Doğan & Akaydın

Table B1 (Continued)

56.	***Limonium virgatum***	**9875** C1 Aydın, Didim, Akbük, 0 m, 26.07.2004, Doğan & Akaydın **9908** C1 Muğla, Bozburun, Bozburun island, 0 m, 28.07.2004, Doğan & Akaydın
57.	***Limonium sieberi***	**9863** B1 Izmir, Çeşme, 1 m, 25.07.2004, Doğan & Akaydın **8003** A1 Çanakkale, Keşan – Gelibolu road, Saroz gulf, 0 m, 05.08.2003, Doğan &Akaydın
58.	***Limonium didimense***	**7690** C1 Aydın, Didim, Bozbük, 0 m, 29.10.2002, Doğan & Akaydın
59.	***Limonium globuliferum var. globuliferum***	**7744** B5 Aksaray, Aksaray – Adana road, 970 m, 25.05.2003, Doğan & Akaydın **9238** B5 Kırşehir, Kırşehir, Badılı village, around Seyfe lake, 1085 m, 27.06.2004, Doğan & Akaydın
10 5 60.	***Limonium tamaricoides***	**9231** B5 Kırşehir, Badılı village, Seyfe lake, 1085 m, 27.06.2004, Doğan & Akaydın
61.	***Limonium iconicum***	**8166** B4 Ankara, Şereflikoçhisar, Tuz lake, 800 m, 23.06.2001, Doğan & Akaydın **7361b** C4 Konya, Karapınar – Emirgazi road, 1000 m, 21.06.2002, Doğan & Akaydın

APPENDIX C

CHARACTERS VS OTUs DATA MATRIX

Table C1 represents data matrix used for obtaining phenogram.The first row represents the characters as indicated in the Table 3 and the first column represents species as indicated in the Table B1, given in the Appendix B.

Table C1: Data matrix

	ch.1	ch.2	ch.3	ch.4	ch.5	ch.6	ch.7	ch.8	ch.9	ch.10	ch.11	ch.12	ch.13	ch.14	ch.15	ch.16
1.	0	1	1	0	1	0	1	0	1	2	65	1	1	2	9	2
2.	0	0	1	0	1	0	1	0	1	1	165	1	1	2	9	2
3.	0	1	1	0	1	0	1	0	1	1	40	1	1	2	3	1
4.	0	1	1	0	0	0	0	0	1	0	22.5	1	1	0	2	0
5.	0	1	1	0	0	0	1	0	1	1	22.5	1	1	0	7	0
6.	0	1	1	1	0	1	1	1	1	1	2.85	1	1	0	0	0
7.	0	1	1	1	0	1	1	1	1	0	32.5	1	1	0	0	0
8.	0	1	1	1	0	1	1	1	1	0	17.5	1	1	0	0	0
9.	1	1	1	0	1	0	1	0	1	2	32.5	1	1	0	2	0
10.	0	0	0	0	0	0	1	1	1	0	7.5	0	1	1	1	1
11.	0	0	0	0	0	0	1	1	1	0	9	0	1	1	1	1
12.	0	0	0	0	0	0	1	1	1	0	11	0	1	1	0	1
13.	0	0	0	0	0	0	1	0	1	0	14	0	1	1	0	1
14.	0	0	0	0	0	0	1	0	1	0	14	0	1	1	0	1
15.	0	0	0	0	0	0	1	0	1	0	16	0	1	1	0	1
16.	0	0	0	0	0	0	1	1	1	0	28	0	1	1	0	1
17.	0	0	0	0	0	0	1	1	1	1	3.25	0	1	1	0	1
18.	0	0	0	0	0	0	1	0	1	1	3.5	0	1	1	0	1
19.	0	0	0	0	0	0	1	1	1	1	2.25	0	1	1	0	1
20.	0	0	0	0	0	0	1	0	1	1	22	0	1	1	0	1
21.	0	0	0	0	0	0	1	0	1	1	3.25	0	1	1	0	1
22.	0	0	0	0	0	0	1	1	1	1	1.25	0	1	1	0	1
23.	0	0	0	0	0	0	1	0	1	1	6.5	0	1	1	0	1
24.	0	0	0	0	0	0	1	1	1	1	2.5	0	1	1	0	1

Table C1 (Continued)

	ch.1	ch.2	ch.3	ch.4	ch.5	ch.6	ch.7	ch.8	ch.9	ch.10	ch.11	ch.12	ch.13	ch.14	ch.15	ch.16
25.	0	0	0	0	0	0	1	1	1	1	2.75	0	1	1	0	1
26.	0	0	0	0	0	0	1	1	1	0	6	0	1	1	0	1
27.	0	0	0	0	0	0	1	1	1	1	2.25	0	1	1	0	1
28.	0	0	0	0	0	0	1	0	1	1	9	0	1	1	0	1
29.	0	0	0	0	0	0	1	1	1	0	13.5	0	1	1	0	1
30.	0	0	0	0	0	0	1	1	1	1	5	0	1	1	0	1
31.	0	0	0	0	0	0	1	1	1	1	9	0	1	1	0	1
32.	0	0	0	0	0	0	1	1	1	0	9	0	1	1	0	1
33.	0	0	0	0	0	0	1	0	1	1	2.25	0	1	1	0	1
34.	0	0	0	0	0	0	1	1	1	1	12	0	1	1	0	1
35.	0	0	0	0	0	0	1	1	1	1	3.75	0	1	1	0	1
36.	0	0	0	0	0	0	1	1	1	1	4.25	0	1	1	0	1
37.	0	0	0	0	0	0	1	1	1	1	20	0	1	1	0	1
38.	0	1	1	0	1	0	0	0	1	1	32.5	1	1	0	2	0
39.	1	1	1	0	1	0	1	0	1	0	20	1	1	0	6	0
40.	0	0	1	0	0	0	1	0	1	0	9.5	1	1	1	7	0
41.	0	0	1	0	0	0	1	0	0	0	17.5	1	1	1	7	0
42.	0	1	1	0	1	0	1	0	1	0	65	1	1	0	5	0
43.	0	1	1	0	0	0	1	0	1	0	30	1	1	1	5	0
44.	0	1	1	0	0	0	1	0	1	0	40	1	1	1	4	0
45.	0	1	1	0	0	0	1	0	1	0	32.5	1	1	1	4	0
46.	0	1	1	0	1	0	1	0	1	0	60	1	1	0	5	0
47.	0	1	1	0	1	0	1	0	1	0	50	1	1	0	5	0
48.	0	1	1	0	1	0	1	0	1	0	42.5	1	1	0	5	0

Table C1 (Continued)

	ch.1	ch.2	ch.3	ch.4	ch.5	ch.6	ch.7	ch.8	ch.9	ch.10	ch.11	ch.12	ch.13	ch.14	ch.15	ch.16
49.	0	1	1	0	0	0	1	0	1	0	17	1	0	1	6	0
50.	0	0	1	0	0	0	1	0	0	0	27.5	1	0	1	6	0
51.	0	1	1	0	0	0	1	0	1	0	22.5	1	1	1	5	0
52.	0	1	1	0	0	0	1	0	1	0	25	1	0	1	4	0
53.	0	0	1	0	0	0	1	0	0	0	20	1	1	1	6	0
54.	0	0	1	0	0	0	1	0	1	0	15	1	1	1	6	0
55.	0	0	1	0	0	0	1	0	0	0	22.5	1	1	1	7	0
56.	0	0	1	0	0	0	1	0	0	0	32.5	1	1	1	7	0
57.	0	0	1	0	0	0	1	0	0	0	25	1	1	1	7	0
58.	0	0	1	0	0	0	1	0	0	0	17.5	1	1	1	6	0
59.	0	1	1	0	0	0	1	0	1	0	27.5	1	1	1	6	0
60.	0	0	1	0	0	0	1	0	0	1	25	1	0	1	8	0
61.	0	0	1	0	0	0	1	0	0	0	17.5	1	0	1	8	0

Table C1 (Continued)

	ch.17	ch.18	ch.19	ch.20	ch.21	ch.22	ch.23	ch.24	ch.25	ch.26	ch.27	ch.28	ch.29	ch.30	ch.31
1.	0	5	2	1	45	27.5	1.64	1	1	2	3	2.25	10	0	14
2.	0	3	2	1	50	15	3.33	1	1	2	3	3.75	10	0	35
3.	0	2	2	1	60	29	2.07	0	1	2	3	3.5	15	0	27.5
4.	0	2	0	1	70	14	5	0	1	6	1	1.75	3	0	8
5.	0	0	1	2	24	5	4.8	0	1	5	1	9	8	1	7.5
6.	0	2	0	1	9.5	0.75	12.67	0	1	4	3	0.9	10	2	9
7.	0	0	0	1	75	0.75	100	1	1	4	3	1.75	25	2	14.5
8.	0	0	0	1	75	1.75	42.86	0	1	4	3	1.3	25	2	11.5
9.	1	5	1	1	85	23	3.69	0	1	1	3	21.25	30	2	5
10.	0	1	0	3	37.5	2.25	16.67	1	1	3	3	3.25	8	2	15.5
11.	0	1	0	3	30	1.5	20	1	1	3	3	3.5	8	2	12
12.	0	1	0	3	30	1.25	24	1	1	0	1	4	9	2	12.5
13.	0	1	0	3	35	1.25	28	1	1	5	1	5	7	0	9.5
14.	0	0	0	3	40	1	40	1	1	5	1	8	23	0	9
15.	0	1	0	3	35	1.25	28	0	1	0	1	4.5	7	0	10
16.	0	1	0	3	41.5	1.5	26.27	0	0	0	1	22.5	26	0	14
17.	0	1	0	3	25	1.25	11.11	0	1	0	1	2.75	9	0	13.5
18.	0	4	0	3	27.5	1	27.5	0	0	0	1	1.25	11	0	13
19.	0	1	0	3	32.5	1	32.5	0	1	0	1	2.5	13	0	16.5
20.	0	1	0	3	26	1.25	20.8	0	0	0	1	2.75	12	0	12.25
21.	0	4	0	3	20	1	20	0	0	0	1	2.5	8	0	13
22.	0	1	0	3	14	1	14	0	1	0	1	1.25	5	0	13
23.	0	1	0	3	8.5	0.75	11.33	0	1	0	1	1.75	9	0	12.5
24.	0	4	0	3	15	1	15	0	1	0	1	1.5	4	0	13

Table C1 (Continued)

	ch.17	ch.18	ch.19	ch.20	ch.21	ch.22	ch.23	ch.24	ch.25	ch.26	ch.27	ch.28	ch.29	ch.30	ch.31
25.	0	1	0	3	24	1.25	19.2	0	1	0	1	1.5	5	0	11
26.	0	1	0	3	40	1	40	0	1	0	1	2.25	10	0	12
27.	0	4	0	3	21	0.75	28	0	1	0	1	2.5	7	0	13
28.	0	1	0	3	22.5	0.85	26.47	0	1	0	1	4.5	9	0	14
29.	0	1	0	3	35	1.25	28	0	1	0	1	7	10	0	14.5
30.	0	1	0	3	22.5	1.25	18	0	1	0	1	2.75	11	0	9.5
31.	0	1	0	3	27.5	1.5	18.33	0	1	0	1	4	11	0	13
32.	0	1	0	3	20	1.75	11.43	0	1	0	1	6.5	10	0	11.5
33.	0	4	0	3	10	0.75	13.33	0	1	0	1	2.5	4	0	10.5
34.	0	1	0	3	30	1.5	20	0	1	0	1	7	15	0	12
35.	0	1	0	3	20	1	20	0	1	0	1	2.25	7	0	12.5
36.	0	1	0	3	17.5	1.1	15.91	0	1	0	1	6.5	13	0	10
37.	0	1	0	3	40	1.5	26.67	0	1	0	1	11	10	0	13
38.	1	3	1	2	65	20	3.25	0	1	0	1	1.75	7	3	12.5
39.	0	0	1	0	20	8.5	2.35	0	1	0	2	2	6	1	8
40.	0	0	1	0	9.5	1.5	6.33	0	1	3	3	1.1	6	1	6.5
41.	0	0	1	1	35	9	3.89	0	1	0	2	1.75	6	1	8
42.	0	0	1	1	300	65	4.61	0	1	5	0	1.75	6	2	4.5
43.	0	0	1	1	120	32.5	3.69	0	1	6	2	1.25	6	2	3.75
44.	0	0	1	1	85	27.5	3.09	0	1	6	2	1.25	6	1	3.75
45.	0	0	1	1	80	17.5	4.57	0	1	6	2	1.75	5	3	5.5
46.	0	0	1	2	145	40	3.625	0	1	5	2	1.75	6	1	5.5
47.	0	0	1	2	180	50	3.6	0	1	5	0	1.75	6	1	4.25
48.	0	0	1	2	180	50	3.6	0	1	5	2	1.25	6	2	3.75

Table C1 (Continued)

	ch.17	ch.18	ch.19	ch.20	ch.21	ch.22	ch.23	ch.24	ch.25	ch.26	ch.27	ch.28	ch.29	ch.30	ch.31
49.	0	0	2	1	30	8.5	3.53	0	1	6	1	1.25	6	4	4.5
50.	0	0	1	1	45	17.5	2.57	0	1	5	1	1.25	6	1	4
51.	0	0	0	2	45	11	4.09	0	1	5	1	1	5	1	4.5
52.	0	0	1	1	150	55	2.73	0	1	6	2	2	5	2	4.5
53.	0	0	1	1	32.5	10	3.25	0	1	5	1	1	5	1	3.5
54.	0	0	1	1	22.5	4.5	5	0	1	5	1	1.25	6	2	4.5
55.	0	0	1	0	27.5	6.5	4.23	0	1	5	2	1.75	6	2	8.5
56.	0	0	2	0	40	6.5	6.15	0	1	5	0	1.75	6	3	8
57.	0	0	2	0	30	6.5	4.61	0	1	5	0	1.75	6	1	8
58.	0	0	1	0	27.5	3.5	7.86	0	1	5	0	1.75	6	5	6
59.	0	0	1	1	95	35	2.71	0	1	7	3	1.25	6	2	3.25
60.	0	0	1	1	17.5	4	4.375	0	1	7	3	1.25	8	2	3.25
61.	0	0	1	1	35	12.5	2.8	0	1	5	2	1.25	6	1	2.5

Table C1 (Continued)

	ch.32	ch.33	ch.34	ch.35	ch.36	ch.37	ch.38	ch.39	ch.40	ch.41	ch.42	ch.43	ch.44	ch.45	ch.46
1.	0	1	0	0	0	2	0	0	0	2	0	0	1	2	2
2.	0	1	0	0	0	1	0	0	0	1	0	0	1	3	2
3.	0	1	0	1	2	1	0	2	2	1	1	0	0	1	2
4.	0	1	1	1	2	0	1	2	2	0	0	1	0	0	0
5.	0	1	0	1	2	0	0	0	1	0	0	2	0	0	0
6.	-	2	1	0	1	0	2	0	1	0	0	1	0	1	1
7.	-	2	0	1	2	0	2	1	2	0	0	1	0	1	1
8.	-	2	0	1	2	0	2	1	2	0	0	1	0	1	1
9.	1	0	0	1	2	2	1	1	2	2	0	1	0	2	1
10.	0	2	1	1	2	0	1	1	2	0	0	1	0	1	1
11.	0	2	1	1	2	0	1	1	2	0	0	1	0	1	1
12.	0	2	1	1	2	0	1	1	2	0	0	1	0	1	1
13.	0	1	0	1	2	0	1	1	2	0	0	1	0	0	1
14.	0	1	0	1	2	0	1	1	2	0	0	0	0	0	1
15.	0	1	0	1	2	0	0	1	2	0	0	1	0	1	1
16.	0	1	0	1	2	0	0	1	2	1	0	1	0	1	1
17.	1	1	0	1	2	0	1	1	2	1	0	1	0	1	1
18.	1	1	0	1	2	1	1	1	2	1	0	1	0	1	1
19.	1	1	0	1	2	1	1	1	2	1	0	1	0	1	1
20.	0	1	0	1	2	1	0	1	2	1	0	1	0	1	1
21.	1	1	0	1	2	1	0	1	2	1	0	1	0	1	1
22.	1	1	0	1	2	1	1	1	2	1	0	1	0	1	1
23.	1	1	0	1	2	1	1	1	2	1	0	1	0	1	1
24.	1	1	0	1	2	1	0	1	2	1	0	1	0	1	1

Table C1 (Continued)

	ch.32	ch.33	ch.34	ch.35	ch.36	ch.37	ch.38	ch.39	ch.40	ch.41	ch.42	ch.43	ch.44	ch.45	ch.46
25.	1	1	0	1	2	1	0	1	2	1	0	1	0	1	1
26.	1	1	0	1	2	0	0	1	2	1	0	1	0	1	1
27.	1	1	0	1	2	1	1	1	2	1	0	1	0	1	1
28.	0	1	0	1	2	1	1	1	2	1	0	1	0	1	1
29.	1	1	0	1	2	0	0	1	2	1	0	1	0	1	1
30.	1	1	0	1	2	0	0	1	2	0	0	1	0	1	1
31.	1	1	0	1	2	0	0	1	2	1	0	1	0	1	1
32.	1	1	0	1	2	0	0	1	2	0	0	1	0	1	1
33.	1	1	0	1	2	1	1	1	2	1	0	1	0	1	1
34.	1	1	0	1	2	0	0	1	2	0	0	1	0	1	1
35.	1	1	0	1	2	0	1	1	2	0	0	1	0	1	1
36.	1	1	0	1	2	0	0	1	2	0	0	1	0	1	1
37.	1	1	0	1	2	0	0	1	2	0	0	1	0	1	1
38.	0	2	0	1	2	1	0	1	0	1	0	1	0	1	1
39.	0	1	1	0	1	0	1	0	1	0	0	1	0	1	1
40.	0	1	1	0	1	0	1	0	1	0	0	0	0	1	1
41.	0	1	1	0	1	0	1	0	1	0	0	3	0	1	1
42.	0	1	1	0	1	0	1	0	1	0	0	3	0	1	1
43.	0	2	1	0	1	0	1	0	1	0	0	1	0	1	1
44.	0	2	0	0	1	0	0	0	1	0	0	1	0	1	1
45.	0	2	0	0	1	0	0	0	1	0	0	1	0	1	1
46.	0	1	0	1	2	0	2	0	1	0	0	3	0	1	1
47.	0	1	1	0	1	0	1	0	1	0	0	3	0	1	1
48.	0	1	1	0	1	0	1	0	1	0	0	3	0	1	1

Table C1 (Continued)

	ch.32	ch.33	ch.34	ch.35	ch.36	ch.37	ch.38	ch.39	ch.40	ch.41	ch.42	ch.43	ch.44	ch.45	ch.46
49.	0	1	0	0	1	0	1	0	1	0	0	1	0	0	1
50.	0	1	1	1	2	0	1	0	1	0	0	3	0	1	1
51.	0	1	1	1	2	0	1	0	1	0	0	1	0	1	1
52.	0	1	0	0	1	0	2	0	1	0	0	3	0	0	1
53.	0	1	0	0	1	0	2	0	1	0	0	3	0	1	1
54.	0	1	0	0	1	0	0	0	1	0	0	3	0	1	1
55.	0	1	1	0	1	0	1	0	1	0	0	1	0	1	1
56.	0	1	1	0	1	0	1	0	1	0	0	1	0	1	1
57.	0	1	1	0	1	0	1	0	1	0	0	1	0	1	1
59.	0	1	1	0	1	0	1	0	1	0	0	3	0	1	1
60.	0	1	1	0	1	0	1	0	1	0	0	3	0	1	1
61.	0	1	1	0	1	0	1	0	1	0	0	3	0	1	1

Table C1 (Continued)

	ch.47	ch.48	ch.49	ch.50	ch.51	ch.52	ch.53	ch.54	ch.55	ch.56	ch.57
1.	0	0	0	9	8	0	6	0	0	0	1
2.	0	0	0	9	11.5	0	8	0	0	0	1
3.	0	0	0	5	15	0	9	0	0	0	0
4.	0	0	2	0	7	1	0	1	1	1	1
5.	0	0	2	0	5.5	1	3	1	1	1	0
6.	1	0	2	0	6.5	1	3	0	1	1	1
7.	1	0	2	0	11	1	2	0	1	1	1
8.	1	0	2	0	9	1	2	0	1	1	1
9.	1	0	2	0	3.25	0	3	0	1	1	0
10.	0	1	1	7	11	1	4	1	1	1	0
11.	1	1	1	0	12	1	4	1	1	1	0
12.	1	0	2	0	13.5	1	4	1	1	1	0
13.	0	0	1	0	9	1	4	1	1	1	0
14.	0	0	1	0	7.5	1	4	1	1	1	0
15.	0	0	2	0	10.5	1	4	1	1	1	0
16.	0	0	2	8	12.5	1	4	1	1	1	0
17.	1	0	2	1	12.5	1	4	1	1	1	0
18.	1	0	2	3	12.5	1	4	1	1	1	0
19.	1	0	2	3	15	1	4	1	1	1	0
20.	0	0	2	8	11.5	1	4	1	1	1	0
21.	1	0	2	0	12.5	1	4	1	1	1	0
22.	1	0	2	0	10.5	1	4	1	1	1	0
23.	0	0	2	0	11.5	1	4	1	1	1	0
24.	0	0	2	0	13.5	1	10	1	1	1	0

Table C1 (Continued)

	ch.47	ch.48	ch.49	ch.50	ch.51	ch.52	ch.53	ch.54	ch.55	ch.56	ch.57
25.	0	0	2	0	9.5	1	1	1	1	1	0
26.	0	0	2	0	11.5	1	4	1	1	1	0
27.	0	0	2	0	14	1	4	1	1	1	0
28.	1	0	2	0	13	1	4	1	1	1	0
29.	0	0	2	1	13.5	1	4	1	1	1	0
30.	0	0	2	0	9	1	4	1	1	1	0
31.	0	0	2	8	13.5	1	4	1	1	1	0
32.	1	0	2	7	11.5	1	4	1	1	1	0
33.	0	0	2	0	9.5	1	4	1	1	1	0
34.	0	0	2	0	10	1	4	1	1	1	0
35.	1	0	2	0	11.5	1	4	1	1	1	0
36.	0	0	2	0	10.5	1	4	1	1	1	0
37.	0	0	2	0	11.5	1	4	1	1	1	0
38.	0	1	1	6	12.5	1	1	0	1	1	0
39.	1	0	3	4	5	1	5	0	1	1	0
40.	0	0	3	0	4.25	1	8	0	1	1	0
41.	0	0	3	0	5.5	1	5	0	1	1	0
42.	0	0	3	2	4.5	1	7	0	1	1	0
43.	0	0	3	0	4	1	6	0	1	1	0
44.	0	0	3	0	3	1	7	0	1	1	0
45.	0	0	3	0	3.75	1	9	0	1	1	0
46.	0	0	3	2	4.5	1	7	0	1	1	0
47.	0	0	2	2	3.75	1	5	0	1	1	0
48.	0	0	3	2	2.75	1	7	0	1	1	0

Table C1 (Continued)

	ch.47	ch.48	ch.49	ch.50	ch.51	ch.52	ch.53	ch.54	ch.55	ch.56	ch.57
49.	0	0	3	0	4.5	1	5	0	1	1	0
50.	0	0	3	0	3.75	1	7	0	1	1	0
51.	0	0	3	0	4	1	7	0	1	1	0
52.	0	0	3	0	4.25	1	6	0	1	1	0
53.	0	0	3	0	3.25	1	7	0	1	1	0
54.	0	0	3	0	3.5	1	6	0	1	1	0
55.	0	0	3	0	6.5	1	6	0	1	1	0
56.	0	0	3	0	5.5	1	5	0	1	1	0
57.	0	0	3	0	3.5	1	5	0	1	1	0
58.	0	0	3	0	5.25	1	5	0	1	1	0
60.	0	0	3	0	2.5	1	5	0	1	1	0
61.	0	0	3	0	2.5	1	7	0	1	1	0