A PHENETICS STUDY FOR INFRAGENERIC GROUPING OF LIMONIUM MILL. GENUS (PLUMBAGINACEAE) IN TURKEY

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY
FATİH FAZLIOĞLU

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
BIOLOGY

SEPTEMBER 2011

Approval of the thesis:

A PHENETICS STUDY FOR INFRAGENERIC GROUPING OF LIMONIUM MILL. GENUS (PLUMBAGINACEAE) IN TURKEY

submitted by **FATİH FAZLIOĞLU** in partial fulfillment of the requirements for the degree of **Master of Science in Biology Department, Middle East Technical University** by,

Prof. Dr. Canan Özgen _____
Dean, Graduate School of **Natural and Applied Sciences**

Prof. Dr. Musa Doğan _____
Head of Department, **Biology**

Prof. Dr. Musa Doğan
Supervisor, **Biology Dept., METU** _____

Examining Committee Members:

Prof. Dr. Zeki Kaya _____
Biology Dept., METU

Prof. Dr. Musa Doğan _____
Biology Dept., METU

Prof. Dr. Latif Kurt _____
Biology Dept., Ankara University

Assoc. Prof. Dr. Sertaç Önde _____
Biology Dept., METU

Dr. Hüseyin Atilla Atik _____
Ministry of Forestry and Water

Date: 07.09.2011

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last Name: Fatih FAZLIOĞLU

Signature :

ABSTRACT

A PHENETICS STUDY FOR
INFRAGENERIC GROUPING OF *LIMONIUM* MILL. GENUS
(PLUMBAGINACEAE) IN TURKEY

FAZLIOĞLU, Fatih

M.Sc., Department of Biology

Supervisor: Prof. Dr. Musa DOĞAN

September 2011, 96 pages

In this study, current infrageneric taxonomic status of *Limonium* Mill. in Turkey was assessed by using numerical taxonomy (phenetics) method. Herbarium materials belong to 21 species of *Limonium* Mill., collected all around Turkey, and were examined. In order to evaluate the infrageneric status, 52 characters based on ecological and morphological features of the genus were determined and recorded to construct a data matrix which was analyzed by Multi Variate Statistical Package (MVSP) and Statistica software with Unweighted Pair Group Method with Arithmetic Mean (UPGMA) method to construct phenograms. Then, by assesing the phenograms, an overall comparison of *Limonium* Mill. species were made and infrageneric taxonomic status of the genus was discussed.

The result of this study indicated that 5 sections of the genus are represented in phenograms which was a compatible result with theoretical information written in 7th Volume of "Flora of Turkey".

Moreover, in UPGMA trees, a new section (belonging Section Limonium) is observed. Section nova species live only near seashore and distinctively separated from other Section Limonium species in phenograms and Principle Component Analysis (PCA). PCA was carried out to indicate most important characters used in this study.

In addition, in this study, a dichotomous key comprising all the species of *Limonium* Mill. in Turkey was also presented. In appendix part, brief information about each species such as distribution, habitat, conservation status, habit, endemism ratio, flowering period, IUCN categories was given to review all *Limonium* Mill. species in Turkey.

Keywords: Plumbaginaceae, *Limonium*, numerical taxonomy, cluster analysis, infrageneric taxonomy

ÖZ

TÜRKİYE'DEKİ LİMONİUM MİLL. (PLUMBAGINACEAE)
CİNSİNİN CİNSİÇİ GRUPLANDIRILMASINA
İLİŞKİN FENETİK BİR ÇALIŞMA

FAZLIOĞLU, Fatih

Yüksek Lisans, Biyoloji Bölümü

Tez Danışmanı: Prof. Dr. Musa DOĞAN

Eylül 2011, 96 sayfa

Bu çalışmada, numerik taksonomi (fenetik) metodu kullanılarak Türkiye'deki *Limonium* Mill. cinsinin cinsiçi taksonomik durumunun değerlendirilmesi yapılmıştır. Tüm Türkiye'den toplanan 21 *Limonium* Mill. türünün herbaryum materyalleri incelenmiştir. Cinsiçi sınıflandırma için türün ekolojik ve morfolojik özelliklerini içeren 52 karakter tespit edilmiş ve kayıt edilerek bir data matriksi oluşturulmuştur. Bu data matriksi de UPGMA metodu ile MVSP ve Statistica adlı programlar ile analiz edilerek fenogramlar oluşturulmuştur. Fenogramların incelenmesi ile tüm *Limonium* Mill. türlerinin karşılaştırılması yapılmış ve cinsin cinsiçi taksonomik durumu tartışılmıştır.

Bu çalışmanın sonucunda elde edilen fenogramlara gore cins içerisinde 5 seksiyon bulunmaktadır. Bu durumun "Türkiye Florası" adlı eserin 7. cildindeki teorik bilgi ile uyumlu olduğu görülmüştür.

Buna ek olarak, UPGMA gruplandırmasında yeni bir seksiyon (Seksiyon Limonium'a ait) gözlemlenmiştir. Yeni seksiyondaki türler sadece deniz kenarında yaşamaktadır ve fenogramlarda ve Temel Bileşen Analizinde (PCA) diğer Seksiyon Limonium türlerinden ise belirgin bir şekilde ayrılmaktadır. PCA ise bu çalışmadaki en önemli karakterleri belirlemek için kullanılmıştır.

Ayrıca, bu çalışmada Türkiye'deki tüm *Limonium* Mill. türleri için bir anahtar verilmiştir. Tezin ek kısmında ise tüm türler hakkında yayılış, habitat, korunma statüsü, yapısı, endemizm oranı, çiçeklenme periyodu ve IUCN kategorileri gibi kısaca bilgiler de verilerek Türkiye'deki *Limonium* Mill. türleri incelenmiştir.

Anahtar Kelimeler: Plumbaginaceae, *Limonium*, numerik taksonomi, kümeleme analizi, cinsiçi sınıflandırma

Ode to my family,

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my supervisor Prof. Dr. Musa Doğan for his guidance, encouragement, advice, criticism and insight throughout this study.

I appreciate for the patience, criticism and advice of my thesis examining committee members; Prof. Dr. Zeki Kaya, Assoc. Prof. Dr. Sertaç Önde, Prof. Dr. Latif Kurt and Dr. Hüseyin Atilla Atik while reading and commenting on my thesis study.

I would like to express my special thanks to Assist. Prof. Dr. Ferhat Celep, Hüseyin Çıldır and my friends for their support and technical assistance.

I am thankful to the Graduate School of Natural and Applied Sciences of Middle East Technical University for supporting this study with grants for graduate students.

TABLE OF CONTENTS

LIST OF TABLES

TABLE

LIST OF FIGURES

FIGURES

ABBREVATIONS

Boiss……Boissier, François de Sauvages de Lacroix

Brongn……...Brongniart, Adolphe Theodore

cm……..……centimeter

CR .....…….Critically Endangered

Dumort……..Dumortier, Barthélemy Charles Joseph

EN……Endangered

et al…….et alii (and others)

fl……..…….flower

Heldr……..Heldreich, Theodor Heinrich Hermann von

IUCN…….International Union for Conservation of Nature and Natural Resources

Juss……..……...Jussieu, Antoine Laurent de

L.……Linnaeus, Carolus

LC……Least Concerned

Lindl……..Lindley, John

m……meter

Mill……Miller, Philip

mm……..millimeter

MVSP…….Multi Variate Statistical Package

OTU……..Operational Taxonomic Unit

PCO……....Principle Component Analysis

Rech…….. Rechinger, Karl

Sauv…….Sauvage, Charles Philippe Félix

sect……...section

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

subsp……..subspecies

Takht……..Takhtajan, Armen

UPGMA…… Unweighted Pair Group Method with Arithmetic Mean

VU…….....Vulnerable

Willd……...……Willdenow, Carl Ludwig

Based on: International Code of Botanical Nomenclature (Vienna Code), Regnum Vegetabile 146. A.R.G. Gantner Verlag KG, Austria, adopted by the Seventeenth International Botanical Congress, Vienna, July 2006

CHAPTER 1

INTRODUCTION

1.1. Brief History and Significance of Taxonomy

Brief History of Taxonomy

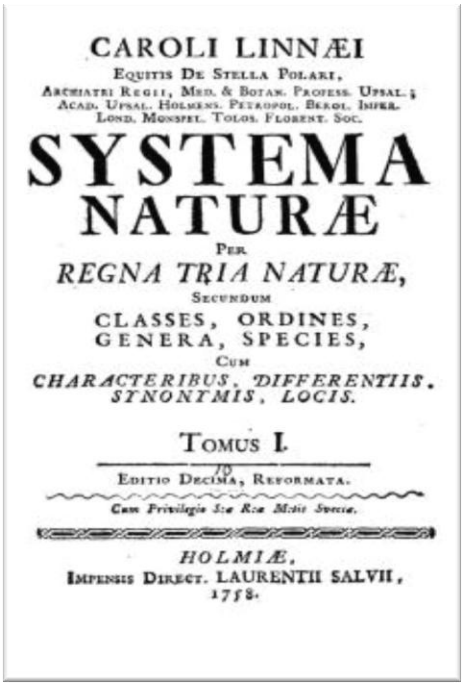
Life on Earth evolved about 3,5 billion years ago and the progress of speciation has been still going on while scientists, all around the world, are trying to identify species as much as possible. While taxonomists identified 1,78 million of species so far, 5 to 30 million of species are assumed to exist in the world. (Millennium Ecosystem Assessment, 2005)

As an illustration of the ratio of described versus unknown species in the world, the rate of known species in Asia might be given: Bacteria/Archaea % 0,5; Non-vascular plants % 1; Protozoa % 1,5; Vertebrates % 3,2; Fungi/Yeast % 4,5; Vascular plants % 16,8; Invertebrates % 68,5 (Shimura, 2003)

Since the beginning of the humanity, human being had a natural instinct for ordering whatever around them in order to be able to understand and manage their surroundings. Hence, the first attempts of classification can be even observed in the ancient Greek period. Aristotle (384-322 BC) classified living things according to their appearances and assumed that features of species were not changing and they were fixed. His student Theophrastus (372-287 BC) carried forward his studies and developed classification system for plants. Thus, he was called father of botany.

After the Greek period, until 16th century AD, there were no such significant studies. During the exploration of new continents, collecting of plants was mostly due to medical purposes instead of taxonomic studies. Andrea Cesalpino (1519-1603) was called as the first taxonomist and he named about 1500 plants. Gaspard Bauhin (1560-1620) used binomial nomenclature and named about 6000 species. In 1682, publication of John Ray included about 18.000 species and he promoted the concept of species.

A milestone in taxonomy was the 'binomial nomenclature' system which was developed by Karl von Linne (Carolus Linnaeus) in 1753 by publishing Species Plantarum and Systema Naturae in 1758. These publications were regarded as beginning of the modern taxonomy. He named about 9.000 species of plants and animals. (Manktelow, 2010)



CAROLI LINNÆI

EQUITIS DE STELLA POLARI,

ARCHIATRI REGII, MED. & BOTAN. PROFESS. UPSAL.;
ACAD. UPSAL. HOLMENS. PETROPOL. BEROL. IMPER.
LOND. MONSPEL. TOLOS. FLORENT. SOC.

SYSTEMA NATURÆ

PER

REGNA TRIA NATURÆ,

SECUNDUM

CLASSES, ORDINES,
GENERA, SPECIES,

CUM

CHARACTERIBUS, DIFFERENTIIS,
SYNONYMIS, LOCIS.

TOMUS I.

EDITIO DECIMA, REFORMATA.

Cum Privilegio Sæ Reæ Mtis Suecia.

HOLMIÆ,
IMPENSIS DIRECT. LAURENTII SALVII,
1758.

Figure 1: Title page of Systema Natura

After Linnean period, Georges-Luise Leclerc de Buffon (1707–1788) emphasized on infraspecific concept. In 1789, Antoine Laurent de Jussieu (1748–1836) changed the system of plant classification which was regarded as the modern classification.

After the evolution theory, hierarchy of living things was explained by phylogenetic systems in evolutionary terms. This approach was continued to the present day. (Stuessy, 2009)

Significance of Taxonomy

- Taxonomy provides invaluable information to human being about diversity of life by identifying, describing, naming and classifying the living organisms in nature. It builds the catalogue of life.

- Taxonomy connects many fields of biology such as genetics, morphology, anatomy, ecology, geology and chemistry in order to enlighten the evolutionary pathways.

- Taxonomy provides information about a species by the way of phylogenetic relationships to a related well known species.

- By explaining infrageneric and infraspecific relationships, taxonomy plays a vital role in conservation biology and helps us to know evolutionary history of species. (Simpson, 2006)

- A single method of nomenclature provides a unifying system in taxonomy and prevents problems of having many local vernacular names for a single species. Hence, taxonomy enables a coherent work between scientists all around the world.

As a deep rooted, old and rapidly growing science importance of taxonomy is appreciated by the United Nations (UN) either. UN declared 2010 to be the International Year of Biodiversity and 2011 to be the International Year of Forests.

Figure 2: Logos of United Nations for years of 2010 and 2011 (www.unep.org/iyb, www.un.org)

For better understanding of biodiversity and forests and in order to raise the public awareness all around the world, many scientific activities were scheduled at the regional, national and international levels in 2010 and 2011 by UN.

Some Major Terms in Taxonomy

In taxonomy, some terms are used interchangeable and might be unclear. For that reason, some confusing terms such as taxonomy, classification, systematics and biosystematics are explained below:

- Classification is a process of gathering information by grouping similar taxa. It identifies and defines taxa of organisms those have common characters. It builds hierarchical groups in which larger groups include smaller groups.

- Taxonomy is the science of classification which includes also its own principles. It is dedicated to name, describe and classify living things. (Davis and Heywood, 1963)

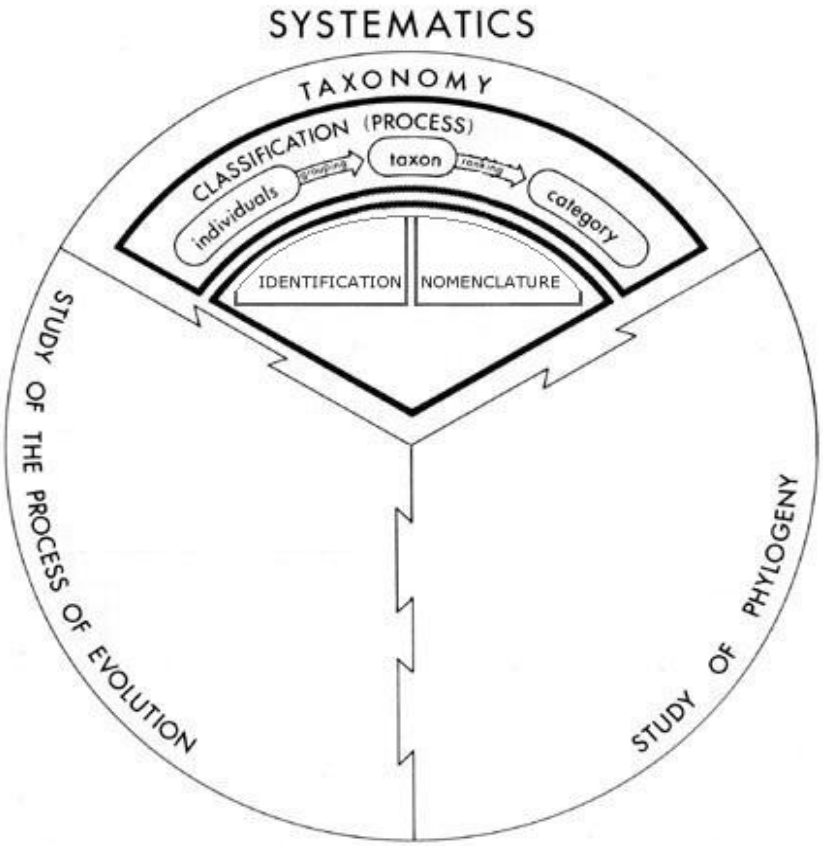


Figure 3: Relationships between the systematic terms (edited from Stuessy, Plant Taxonomy, 1990)

- Systematics investigates the diversity of living things and tries to comprehend the relationships between organisms. It is the body of general theory serves as a basis for classification. (Crowson, 1970)

- Biosystematics is a new method in systematics to obtain information by using different supplies such as genetics, behavior, ecology, morphology. (Leveque and Mounolou, 2004)

1.2. Systematic Studies on the Plumbaginaceae Juss. Family and Its General Characteristics

Kingdom: **Plantae**

Subkingdom: **Tracheobionta**

Division: **Magnoliophyta** Cronquist, Takht. & Zimmerm. ex Reveal

Class: **Magnoliopsida** Brongn.

Subclass: **Caryophyllidae** Takht.

Order: **Plumbaginales** Lindl.

Family: **Plumbaginaceae** Juss.

Plumbaginaceae is the only family in the order of Plumbaginales. This family was described by Antoine Laurent de Jussieu in 1789. (Jussieu, 1789)

In this family, there are about 775 species in 24 genera in the world. (Heywood, 1978) Later, a new genus was described and called as *Myriolimon* which used to be included under Limonium section as *Myriolepis* Boiss. (Lledó, et al., 2005)

Hence, total genera number is currently 28 and those are:

Acantholimon, Aegialitis, Afrolimon, Armeria, Bakerolimon, Bamiana, Bukiniczia, Cephalorhizum, Ceratostigma, Chaetolimon, Dictyolimon, Dyerophytum, Eremolimon, Gladiolimon, Ghaznianthus, Goniolimon, Ikonnikovia, Limoniastrum, Limoniopsis, Limonium, Meullerolimon, Myriolimon, Neogontscharovia, Plumbagella, Plumbago, Popoviolimon, Psylliostachys, Vasssilczenkoa (Kubitzki, 1993)

In Turkey, the first revision of Plumbaginaceae was prepared by Boissier and published in the 4th volume of 'Flora Orientalis'. The family was described as including 7 genera and 121 species. (Boissier, 1848, 1879)

Some major genera in this family are *Limonium* (includes around 400 species), *Acantholimon* (includes around 165 species) and *Armeria* (includes around 90 species). Phytogeographically, they are mostly found in Irano-Turanian (Mediterranean), but also South Africa, South America and Western Australia. (Erben, 1993)

- Plants in this family are mostly perennial and found in the form of herbs, sub-shrubs or shrubs.

- Leaves have alternating arrangement or at the base of stems in rosette form. They also have broad bases, short petiole and smooth margins.

- Flowers are radially symmetric and have proportionally large and colorful calyx, both male (stamen) and female organs (pistil). Inflorescence types are spicate, paniculate and capitate.

- Calyx has tubular (cylindrical), funnel or conical shapes and calyx lips are usually membranous.

- Coralla have 5 petals and petals are usually free (one exception is Plumbago L. genus).

- Stamens are 5 pieces and have positions on petals or opposite to petals. Filaments are expanded.

- Ovarium is in superior position, has one loculus and connected to ovule with long stalk. Styles are 5 pieces or have a stigma with 5 lobes.

- Fruit has a single seed covered with calyx. Fruit covering is dry and membranous.

(Davis, et al., 1982, Kubitzki, K, 1993, Watson etl al., 2000)

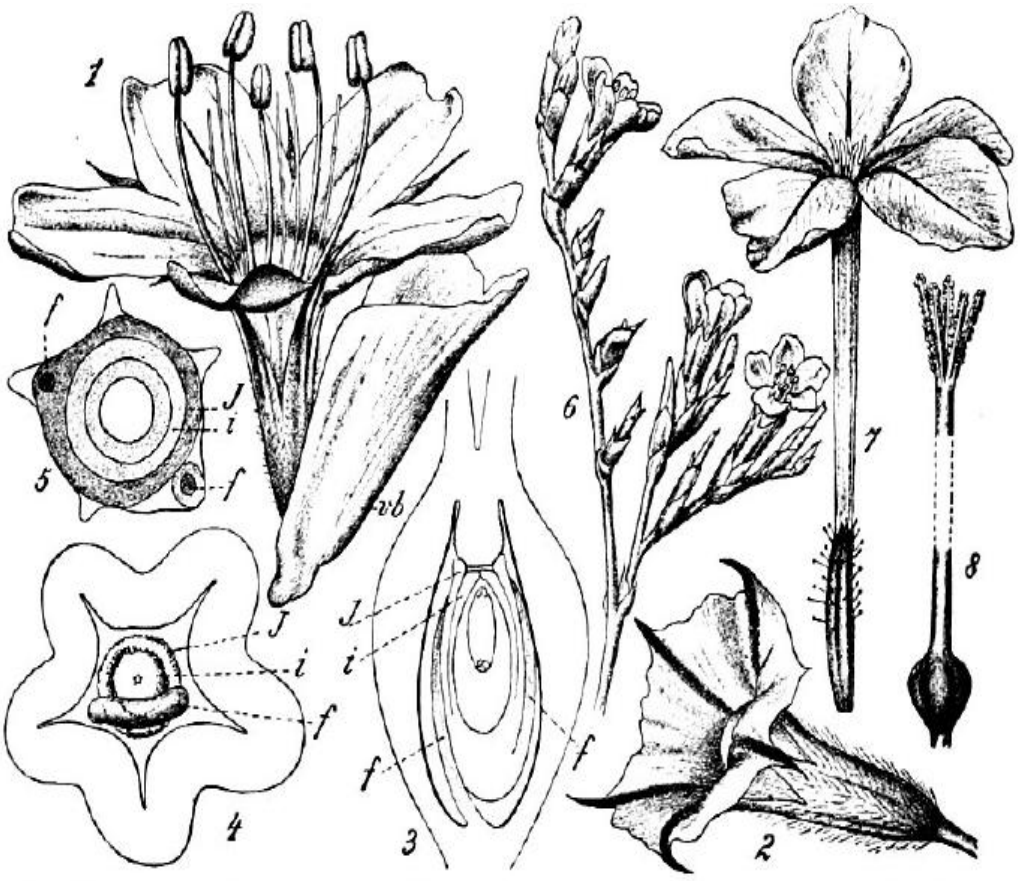


Figure 4: Plumbaginaceae family. 1-5: *Armeria alpine*, 6: *Limonium vulgare*, 7: flower of *Plumbago capensis*, 8: Gynaeceum (edited from Richard Wettstein, Handbuch der Systematischen Botanik, 1924)

1.3. Taxonomic Studies on Limonium Mill. Genus and Its General Characteristics

Limonium Mill. genus is the largest genus in the Plumbaginaceae family and has around 400 species all around the world. (Erben, 1993)

Systematic hierarchy of *Limonium* Mill. genus was given below:

Kingdom: **Plantae**
- Subkingdom: **Tracheobionta**
  - Division: **Magnoliophyta** Cronquist, Takht. & Zimmerm. ex Reveal
    - Class: **Magnoliopsida** Brongn.
      - Subclass: **Caryophyllidae** Takht.
        - Order: **Plumbaginales** Lindl.
          - Family: **Plumbaginaceae** Juss.
            - Genus: **Limonium** Mill.

Taxonomic Studies on *Limonium* Mill. Genus

Philip Miller is the botanist who was the author of *Limonium* genus. Mill. abbreviation is used to cite Miller. He was head gardener at the Chelsea Physic Garden and author of "The Gardener's and Florists Dictionary or a Complete System of Horticulture" and "The Gardener's Dictionary" in 1724 and 1731 respectively. (H. Le Rougetel, 1971)

However, the first detailed taxonomic treatment of *Limonium* Mill. genus was accomplished by Boissier in his synopsis of Plumbaginaceae. (Boissier, 1848) Boisier divided *Limonium* genus into 12 sections which also included some subsections.

In 1897, Bentham and Hooker divided this genus into 3 subgenera and 10 sections. Later, some of these sections became separate genera by Russian botanists. As an example: *Limonium owerinii* Boiss. species became a genus and was called as *Limoniopsis owerinii* (Boiss.) Lincz in 1952. Another example is Myriolimon genus which was subgenus under Limonium (Lledo et al., 2005)

Figure 5: Common Sea Lavender (edited from Illustrations of the British Flora, 1924)

In 1970-1972, an important taxonomic analysis was carried out by Bokhari who prepared "Synopsis of Plumbaginaceae in Turkey"

Later, a detailed study was carried out by M. Erben which included descriptions of 59 *Limonium* species in Western Europe. (Erben, 1978)

In 1982, Bokhari and Edmondson in the 7th volume of 'Flora of Turkey and the East Aegean Islands' (Davis, P.H., Edmondson, J.R., Mill, R.R., Tan, K, 1982) 17 species in 5 sections were described in Turkey which are:

Limonium sinuatum, Limonium gmelinii, Limonium angustifolium, Limonium meyeri, Limonium effusum, Limonium ocymifolium, Limonium virgatum, Limonium graecum, Limonium sieberi, Limonium bellidifolium, Limonium iconicum, Limonium tamaricoides, Limonium lilacinum, Limonium pycnanthum, Limonium globuliferum, Limonium anatolicum, Limonium echioides.

In addition, in the supplement volume of 'Flora of Turkey and the East Aegean Islands' (Davis, P. H., Mill, R.R., Tan, K, 10th Volume, 1988) 2 more species were added to the list and these are: *L. vanense* Kit Tan & Sorger and *L. caspium* (Willd.) Gams.

Later, two articles about the species were published in 2007 and 2008. In these articles, 2 new species in Turkey were described which are: *Limonium smithii* and *Limonium gueneri*. (Akaydın, 2007 and Doğan et al., 2008) Hence, the total number of *Limonium* species existing in Turkey is currently 21.

General Characteristics

Limonium Mill. is also the most diverse genus within the Plumbaginaceae family in terms of the habitat range. It spreads from the Western Mediterranean to Central Asia, mostly on the coasts of temperate and subtropical regions and also in saline terrestrial habitats.

Mediterranean region is the diversity center of this genus due to high complexity and diversity. Evolution in this family has begun around 18-16 million years ago. Due to asexual reproduction and variants in different geographic areas, *Limonium* genus has a complicated taxonomic order. (Lledó et al., 2003).

Figure 6: *Limonium sinuatum* (L.) P. Mill.

There are 21 species belonging to 5 sections in *Limonium* Mill. genus species in Turkey and those are listed below:

1. <u>Section Pteroclados</u> (Sauv. and Vindt)

1. *L. sinuatum* (L.) P. Mill.

2. <u>Section Limonium</u>

2. *L. meyeri* (Boiss.) O.Kuntze
3. *L. angustifolium* (Tausch) Turrill
4. *L. effusum* (Boiss.) O.Kuntze
5. *L. gmelinii* (Willd.) O.Kuntze
6. *L. gueneri* Dogan, Duman & Akaydın, *sp.nova*
7. *L. bellidifolium* (Gouan) Dumort.
8. *L. vanense* Kit Tan & Sorger

9. *L. caspium* (Willd.) Gams

10. *L. smithii* Akaydın sp.nov.

11. *L. graecum* (Poiret) Rech. Fil

- variety: *graceum*
- variety: *hyssopifolium*

12. *L. virgatum* (Willd.) Fourr.

13. *L. sieberi* (Boiss.) O.Kuntze

14. *L. tamaricoides* Bokhari

15. *L. iconium* (Boiss. & Heldr.) O.Kuntze

16. *L. ocymifolium* (Poiret) O.Kuntze

3. Section Sphaerostachys (Boiss.) Bokhari

17. *L. globuliferum* (Boiss. & Heldr.) O.Kuntze

18. *L. lilacinum* (Boiss. & Bal.) Wagenitz

19. *L. pycnanthum* (C.Koch) O.Kuntze

4. Section Sarcophyllum (Boiss.) Lincz

20. *L. anatolicum* Hedge

5. Section Schizyhymenium (Boiss.) Bokhari

21. *L. echioides* (L.) Miller

General features of these 5 sections have been given below:

- Section Pteroclados: annual or perennial, herbaceous or subshrubs, leaves are entire or sinuate margin, has winged scape, calyx is infundibular and veins of calyx are below margins.

- Section Limonium: perennial, herbaceous with caudex, leaves entire, scape with sterile branches, calyx obconical or infundibular, pilose, veins of calyx are below margins.

- Section Sarcophyllum: perennial, subshrubs, scape with woody branches, leaves fleshy, calyx tubular, obconical or infundibular,

- Section Schizyhymenium: annual, herbaceous, leaves entire, scape without sterile branches, calyx is tubular and has hook shape veins above margins.

- Section Sphaerostachys: perennial, herbaceous, leaves entire, scape without sterile branches, calyx obconical, highly pilose, veins of calyx are below margins. (Davis et al., 1982)

In Table 1, a dichotomous identification key for *Limonium* Mill. species in Turkey was given which includes all 21 species.

Table 1: Dichotomous identification key for *Limonium* Mill. species in Turkey. (Akaydın, G., Doğan M., TUBITAK project, 2006)

1. Annual; calyx veins extend the margins and like hooked barbs……...….*L. echioides*

1. Perennial; calyx veins ends below the margins

2. Leaves have uneven margins; scape is with wings; calyx limb ends abruptly……...…..*L. sinuatum*

2. Leaves have smooth margins; scape is without wings; calyx limb has 5 to 10 lobes

3. Sub-shrub; leaves are found in many clusters of rosettes on woody annual shoots which are below the scape…...*L. anatolicum*

3. Herb; leaves are found in basal rosettes, also rarely on branches of scape

4. Scape has many forked sterile branches in the lower part

5. Leaves are dying before flowering is over; sterile branches are fragile; mature spikelets are around 5 mm; outer bract is completely hyalinized

6. Base of stem has many overlapping brown scales; spikelets have rounded heads; calyx lobes are shallowly notched - have pointed tips……*L. tamaricoides*

6. Base of stem has no scales; spikelets are in compact form on spikes; calyx lobes are egg-shaped - rounded

7. Spikelets are 2 to 3 mm; second inner bract is hyalinized except the base part; calyx is 1,5 to 2,5 mm long; calyx tube is pilose……...……...*L. iconicum*

7. Spikelets are 3,5 to 5 mm; 2/3 of second inner bract is herbaceous; calyx tube is pilose on 2 veins

Table 1 (Continued)

8. First inner bract has shallow notch and has 2 lobes……..……..……*L.caspium*

8. First inner bract has shallow notch and without 2 lobes

9. Plant is erect and leaves are 20 to 50 x 15 to 20 mm……...……*L.bellidifolium*

9. Plant is creeping and leaves are 15 to 30 mm x 3 to 6 mm……*L.smithii*

5. Leaves are not dying before flowering is over; sterile branches are thick; mature spikelets are longer than 7 mm; outer bract has brown color and margins are narrowly hyalinized

10. Scape and leaves are not smooth-covered with wart-like projections; scape branches are jointed…...*L.graceum*

10. Scape and leaves have smooth surface; scape branches are not jointed

11. Spikelets have 1 to 2 flowers; not compacted; calyx is almost straight……..**.....***L.sieberi*

11. Spikelets have 2 to 12 flowers; compacted; calyx is curved

12. Spikelets have 2 to 3 (4) flowers; calyx is pilose……*L.virgatum*

12. Spikelets have 8 and more flowers; calyx is not pilose

4. Scape has no repeatedly forked branches

13. Leaves are at most 2 to 5 x 1,5 cm

14. Spikelets are 6 to 8 mm and have 2 to 3 flowers……..*L.ocymifolium*

14. Spikelets are 4 to 5 mm and have 4 to 5 flowers……..……...*L.gueneri*

13. Leaves are at least 6 x 3 cm

Table 1 (Continued)

15. Leaves are fleshy; lateral veins are not very clear; petiole has hyalinized margin
    16. Spikelets are in compact form and with rounded heads……...…….*L.globuliferum*
    16. Spikelets are not in compact form and with rounded heads
        17. Spikelets are 4 to 5 mm; with 2 to 4 flowers; calyx has shallow 5 lobes; lobes are not sharp…….……..….... *L.lilacinum*
        17. Spikelets are 2,5 to 3,5 mm; with 1 to 2 flowers; calyx has deep 5 lobes; lobes have sharp points…….……..……... *L.pycnanthum*
15. Leaves are leathery; lateral veins are clear; petiole has no hyalinized margin
    18. Spikelets are in dense form
        19. Spikelets are 5 to 6 mm
            20. Leaf width is 1 to 2 cm
            20. Leaf width is 2 to 6 cm; spikelet with 1 to 3 flowers; outer bract is 1,5 to 2 mm…….……*L.angustifolium*
        19. Spikelets are 3 to 4 (5) mm
            21. Leaves 3 to 6 x 0.7 to 1.5 cm; spikelet is with 1 to 2 flowers……..…..*L.vanense*
            21. Leaves 6 to 25 x 2 to 8 cm; spikelet is with 2 to 3 flowers

Table 1 (Continued)

22. Outer bract is 0,5 to 1 mm; first inner bract is 1 to 2 mm; notched;

22. Outer bract is 1 to 2 mm; first inner bract is 2 to 3 mm; not notched; second inner bract is 3 to 4 mm; calyx is 4 to 5 mm long……..*L.gmelinii*

18. Spikelets are not in dense form

23. Spikelet is 5 to 6 mm long……..…….……*L.angustifolium*

23. Spikelet is 4 to 5 mm long

24. Leaves are 6 to 25 x 3 to 7 cm; with sharp end; calyx is 3 to 3.5 mm……..*L.effusum*

24. Leaves are 20 to 40 x 5 to 8 cm; without sharp ends; calyx is 4 to 5 mm…..*L.meyeri*

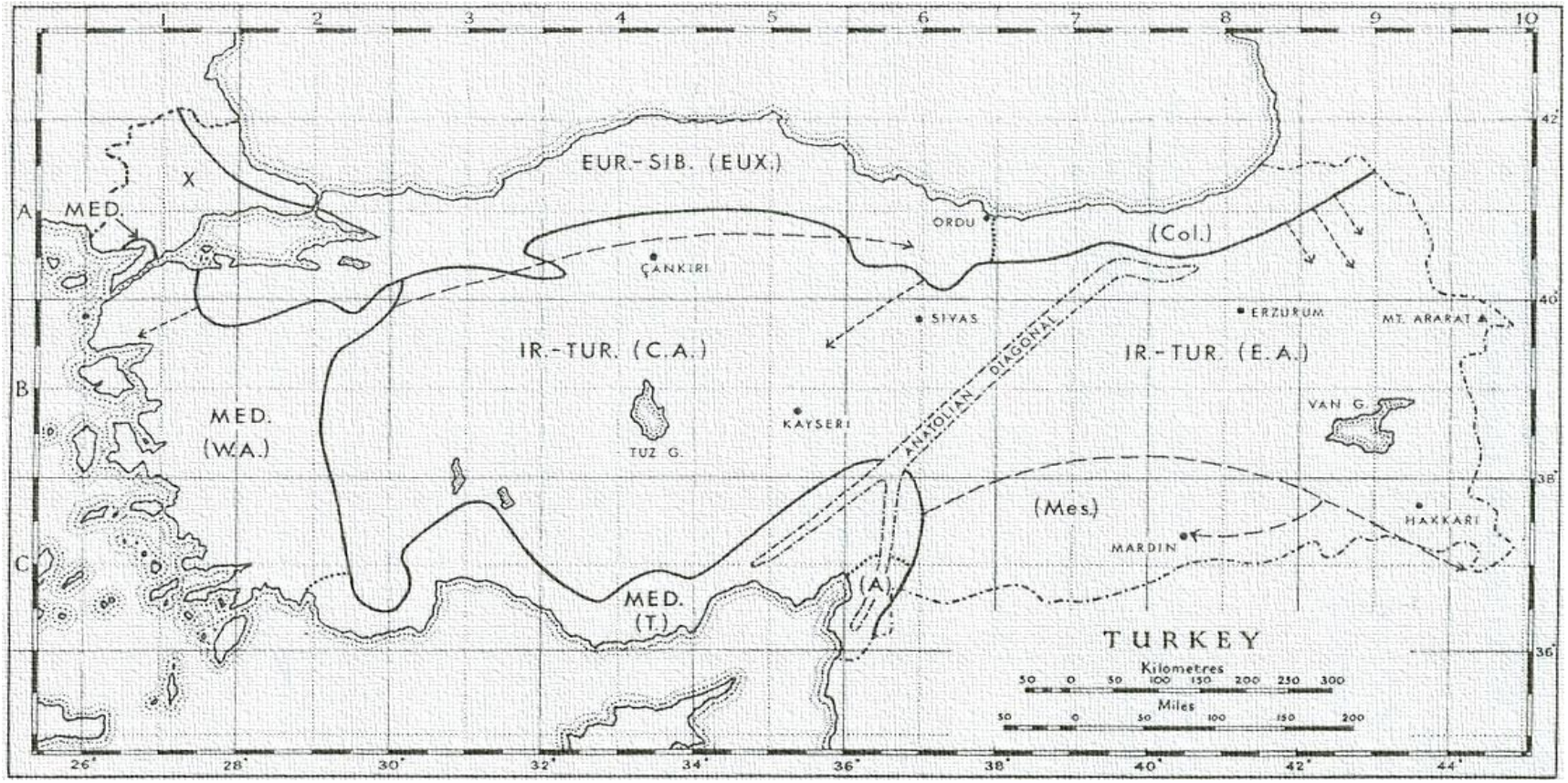


Figure 7: Grid Square System in Turkey as indicated in the 'Flora of Turkey and the East Aegean Islands' (Davis et all., 1965)

1.4. Ecological Features of *Limonium* Mill. in Turkey

In this section, ecological features of *Limonium* Mill. species were presented which are namely: distribution, habitat, conservation status, endemism ratio and flowering period.

1.4.1. Phytogeographic Distribution of *Limonium* Mill. Species in Turkey

Turkey has very diverse flora due to its climatic and topographical diversity. In Turkey, 3 biogeopraphic regions exist and these are listed below:

a. **Irano-Turanian Region:** includes regions of Central Anatolia, Eastern Anatolia and Southeastern Anatolia. The type of climate in this region is continental steppe. These regions are mostly covered with semiarid open steppe. The highest endemic plant number in Turkey exists in the Irano-Turanian regions.

b. **Mediterranean Region:** covers regions near Marmara Sea, Aegean Sea and Mediterranean Sea coasts. The climate is hot and dry during summers, in winters it is rainy and mild. Typical vegetation is maquis which is comprised of shrubs mostly. In terms of the endemic plant number in Turkey, Mediterranean regions are in the 2nd rank after Irano-Turanian.

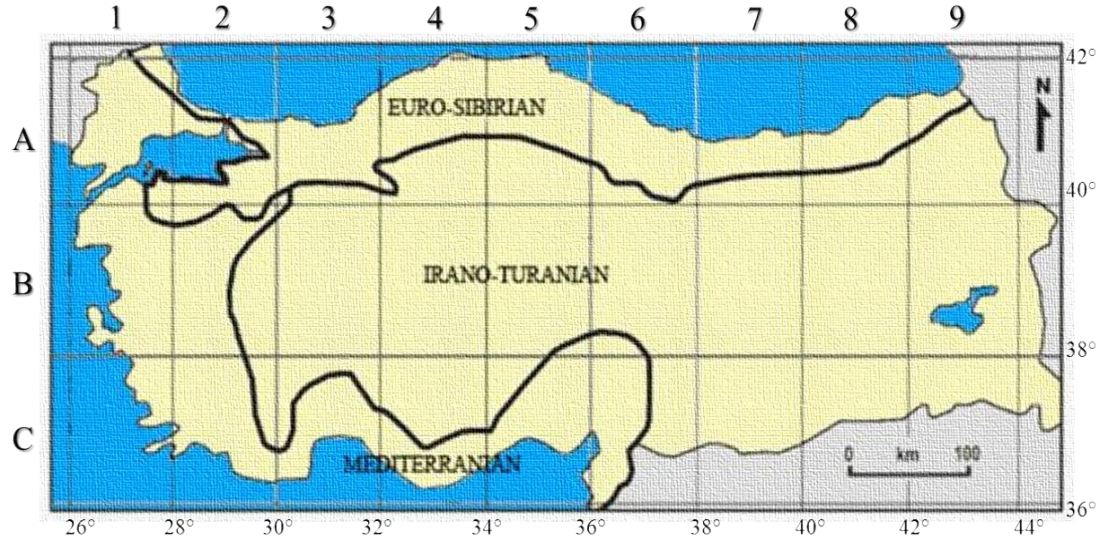
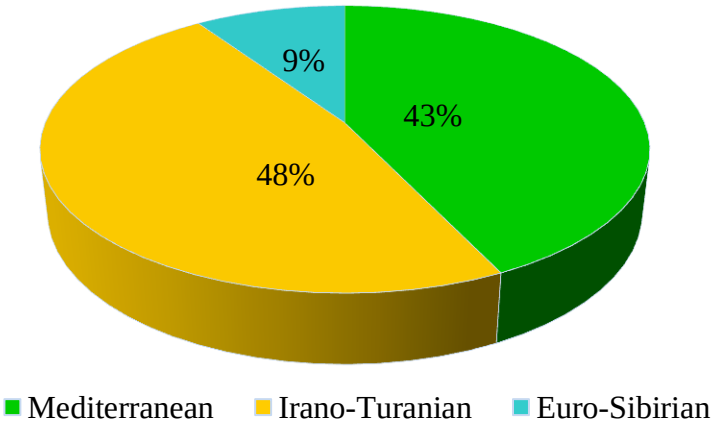


Figure 8: Biogeographic map of Turkey and grid square system (edited from Faculty of Forestry-Istanbul University website)

c. **Euro-Sibirian Region:** covers the regions near Black Sea coast. These regions have high rainfall rates and are mostly covered with forests. The climate is mild both in summers and winters. In terms of the endemic plant number in Turkey, Euro-Sibirian regions are in the 3rd rank. (UN Convention of Biological Diversity 4th National Report, Republic of Turkey)

In the Irano-Turanian region 10 species of *Limonium* Mill., in the Mediterranean region 9 species and in the Euro-Sibirian region 2 species are distributed. (Davis, et al., 1982)

Table 2: Percentages of *Limonium* Mill. species in Turkey according to their biogeographic regions.



1.4.2. Habitat

7 species of *Limonium* Mill. genus grow in only saline areas near seashore; 11 of them grow in saline areas in middle parts of Turkey and remaining 3 species grow in both saline and arid terrestrial regions. A detailed list of species and their habitats was indicated in Table 5.

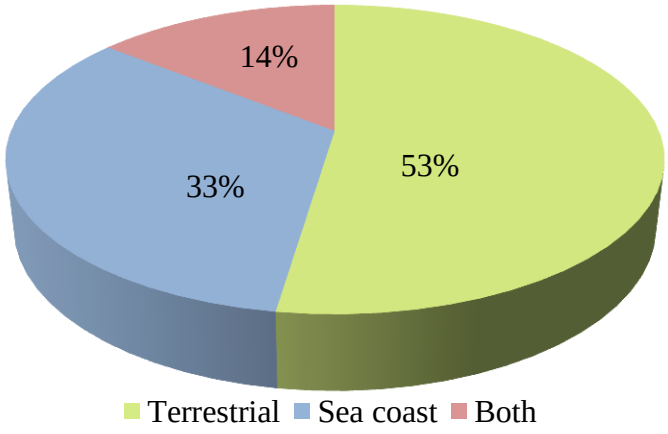


Table 3: Percentages of *Limonium* Mill. species in Turkey according to their phytogeopgraphic information.

1.4.3. Conservation Status of *Limonium* Mill. Genus in Turkey

IUCN (International Union for Conservation of Nature and Natural Resources) Red List surveys status of species according to the categories listed below:

Figure 9: IUCN Red List categories (IUCN, version 3.1)

Some definitions of IUCN Red List categories:

- Vulnerable (VU): have a significant possibility of extinction in medium period of time.
- Endangered (EN): have a high possibility of extinction in near future.
- Critically Endangered (CR): have a very high possibility of extinction in very near future.
- Least Concern (LC): very common hence there is no conservation threat.

In total, 10 species are in CR status, 5 species are in EN status, 5 species are in VU status and 1 species is in LC status in Turkey. (Akaydın, G., Doğan M., TUBITAK project, 2006)

Table 4: Percentages of Limonium Mill. species in Turkey according to their IUCN status.

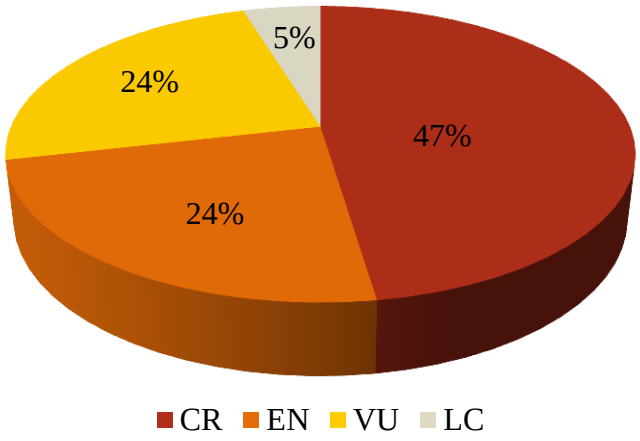


Table 5: List of *Limonium* Mill. species existing in Turkey and their ecologic features

Name of Species (Alphabetically)	**IUCN Category**	**Habitat**	**Information**
Limonium anatolicum Hedge	CR	Terrestrial	Endemic
Limonium angustifolium (Tausch) Turrill	EN	Sea coast	
Limonium bellidifolium (Gouan) Dumort.	EN	Both	
Limonium caspium (Willd.) Gams	CR	Terrestrial	
Limonium echioides (L.) Miller	VU	Sea coast	
Limonium effusum (Boiss.) O.Kuntze	VU	Both	Endemic
Limonium globuliferum (Boiss. & Heldr.) O.Kuntze	EN	Terrestrial	

Table 5 (Continued)

Limonium gmelinii (Willd.) O.Kuntze	LC	Both	
Limonium graecum (Poiret) Rech. Fil. / variety:2	CR	Sea coast	
Limonium gueneri Dogan, Duman & Akaydın, *sp.nova*	CR	Sea coast	Endemic
Limonium iconicum (Boiss. & Heldr.) O.Kuntze	VU	Terrestrial	Endemic
Limonium lilacinum (Boiss. & Bal.) Wagenitz	CR	Terrestrial	Endemic
Limonium meyeri (Boiss.) O.Kuntze	VU	Terrestrial	
Limonium ocymifolium (Poiret) O.Kuntze	CR	Sea coast	
Limonium pycnanthum (C.Koch) O.Kuntze	CR	Terrestrial	Endemic
Limonium sieberi (Boiss.) O.Kuntze	VU	Sea coast	
Limonium sinuatum (L.) P. Mill.	EN	Sea coast	
Limonium smithii Akaydın sp.nov.	CR	Terrestrial	Endemic
Limonium tamaricoides Bokhari	CR	Terrestrial	Endemic
Limonium vanense Kit Tan & Sorger	CR	Terrestrial	Endemic
Limonium virgatum (Willd.) Fourr.	EN	Sea coast	

1.4.4. Endemism Ratio

There are 21 species under this genus and 9 of which are endemic species. Hence, the endemism ratio is % 42,9 (Davis et al., 1982, 1988). Endemic species are listed above in Table 4.

Figure 10: An endemic species -*Limonium vanense* Kit Tan & Sorger - from Turkey (edited from website of Van Herbarium)

1.4.5. Flowering Period

In this part, flowering periods of all *Limonium* Mill. in Turkey was presented in table below.

Table 6: List of *Limonium* Mill. species existing in Turkey and their flowering periods

	April	May	June	July	August	September	October
L.anatolicum				√	√	√	√
L.angustifolium		√	√	√	√	√	√
L.bellidifolium			√	√	√	√	
L.caspium			√	√	√	√	
L.echioides	√	√	√				
L.effusum			√	√	√	√	√
L.globuliferum			√	√	√	√	
L.gmelinii		√	√	√	√	√	√
L.graecum		√	√	√			
L.gueneri				√			
L.iconicum			√	√	√	√	
L.lilacinum			√	√	√	√	
L.meyeri				√	√	√	
L.ocymifolium		√	√	√			
L.pycnanthum			√	√	√	√	
L.sieberi		√	√	√	√		
L.sinuatum		√	√	√	√		
L.smithii			√				
L.tamaricoides			√	√			
L.vananse			√	√	√	√	
L.virgatum		√	√	√			

1.5. Objectives of the Study

As indicated in previous parts, there are yet few taxonomic studies on *Limonuim* Mill. in Turkey. Hence, there is a need for revising taxonomic status of the genus and this study aims this target.

The purpose of this study is simply to evaluate existing infrageneric taxonomic status of *Limonium* Mill. in Turkey and propose a more natural infrageneric status for the genus. To do so, phenetics (numerical taxonomy) method was used for cluster analysis with the assist of MVSP and Statistica software.

In addition, Principle Component Analysis in MVSP was carried out to evaluate the most important characters representing sections in the genus and properties of each section are presented.

Lastly, a review of all *Limonium* Mill. species in Turkey is given as a kind of catalog. For each of species, information about habit, biogeography, IUCN category, flowering period, habitat, characteristics and distribution maps are provided.

CHAPTER 2

MATERIAL AND METHODS

2.1. Material of the Study

All of examined samples in this study were collected in project called "Türkiye'deki Plumbaginaceae Juss. Familyası Üzerinde Revizyonel Çalışmalar" (102T088) which was funded by The Scientific and Research Council of Turkey (TUBITAK) between 2002 and 2006. Assoc. Prof. Galip AKAYDIN and Prof. Dr. Musa DOĞAN participated in the taxonomic revision project. During the project period, around 1000 samples collected from all around Turkey, mostly from seashore and saline places where are the habitats of *Limonium* species. In Table 7, the localities of samples were indicated in detail.

These samples are stored as herbarium material in the laboratory of Prof. Dr. Musa Doğan at Middle East Technical University (METU). During this study, the herbarium materials at METU were used.

2.2. Method of the Study: Numerical Taxonomy (Phenetics)

All field collected metarials, herbarium specimens, were identified according to the 'Flora of Turkey and the East Aegean Islands'. The numerical analysis was carried out according to methods which were proposed by Sneath and Sokal in 1963 and 1973. At least two specimens were used as the represantatives of each species. (Harris, J.G, 2001)

2.2.1. Definition of Numerical Taxonomy (Phenetics)

By definition, numerical taxonomy means categorization of taxonomic units according to their characters with the assist of numerical methods. In numerical taxonomy, chosen characters (either quantitative or qualitative) are changed into numerical forms such as 0, 1 and 2.

Numerical taxonomy, phenetics, depends on morphological characters and accepts the evolutionary distance concept. In other words, it assumes that similarity between the organisms is related to evolutionary differences or likeliness such as ancestral characters. (Sokal and Sneath 1963, 1973)

Numerical taxonomy applies both of empirical (observation) and operational (experimentation) approaches. It has several principles and those are:

- Every character has an equal weight. In other words, no character is more important than other one.

- Classifications are dependent on phenetic similarities and relied on observation.

- Classification quality is connected with the number of characters. The more characters are chosen, the better classification can be carried out.

- Correlations of characters are different in the groups of studied taxa so different taxa can be divided into categories.

- Phylogenetic explanations can be inferred by analyzing the correlations of characters and the structure of constructed groups.

In the numerical taxonomy, the procedure can be followed as below:

Firstly, characters, those are not overlapping, are chosen. Then, each of them are recorded and given a value. Data matrix is constructed which is made of these characters versus values. Lastly, by using software, the comparisons can be made which indicate overall similarities or dissimilarities.

Likeliness of studied taxa is determined by similarity or dissimilarity coefficients (distance). While the similarity coefficient's range is between unity and 0, the dissimilarity coefficient's range is from 0 to an undefined positive value. (Sneath and Sokal 1973)

2.2.2. Definition of Some Important Terms in Numerical Taxonomy (Phenetics)

Some important terms and their definitions were given below:

- **OTUs**: stands for Operational Taxonomic Units. Groups or organisms those are compared in phylogenetic studies. OTU is the sample that is examined which might be genes, species or even genus. In order to evaluate species, local populations are considered as OTU or to analyze a genus, species are defined as OTUs like in this study; each species was treated as an OTU. In Table 7, OTUs used in this study was indicated.

- **Character:** a feature that has different states. In this study, all characters are equally weighted. There is no one character that is important than others in phenetics studies.

- **Phenogram:** is a tree like diagram indicating phenetic similarities between studied taxa.

- **Cluster Analysis:** allows unorganized data to be grouped into clusters. There are different ways of cluster analysis and these are: single linkage analysis (nearest neighbor method), complete linkage analysis (farthest neighbor method) and average linkage analysis.

- **UPGMA:** Unweighted Pair Group Method with Arithmetic Mean. It is a plain method for constructing taxonomic phenograms and phylogenetic trees (Sneath & Sokal 1973). UPGMA calculates the the average similarity or dissimilarty of an Operational Taxonomic Unit (OTU) to a cluster. It estimates that each OTU in the cluster is equal. (Singh, 2004). In UPGMA, the distance between two clusters is depend on the mean distance between all objects in these two clusters.

In phenetics study, OTUs are decribed by using quantitative and qualitative characters and with a similarity or dissimilarity coefficient phenograms are constructed. By inspecting the phenograms, OTUs are grouped into clusters based on overall similarity or dissimilarity. The most similar OTUs are grouped close together and different ones stand far.

During the measurements, averages of at least 2 different localities were calculated. For the measurement of bract and calyx characters binocular microscope with Leica Application Suite-LAS V. 2,5 R1 software was used. After acquiring images of characters, by drawing distance lines on images, quantitative data were recorded on millimetric scale. Based on measured millimetric scales, intervals were determined according to the smallest, middle, the highest values and recorded as 0, 1, 2 in data matrix.

Table 7: Operational Taxonomic Units (OTUs) and their information

Operational Taxonomic Units (OTUs)		**Information**		
Name of Species (Alphabetically)	**Localities**	**Flowering Period**	**Habitat Range (Elevation)**	**Phytogeography**
Limonium anatolicum	B4: Konya, Cihanbeyli-Konya road, around Bolluk Lake, 925 m.	July to October	900-1000 m	Irano-Turanian
Limonium angustifolium	C2: Antalya, Finike-Kale road, around Beymelek, sea coast, pebbled meadows, 0 m.	May to October	0-10 m	Mediterranean
Limonium bellidifolium	B1: Balıkesir, Ayvalık, around Tuzla, saline wetlands, 0 m.	June to September	0-5 m	Euro-Sibirian
Limonium caspium	B4: Ankara, Şereflikoçhisar, around Tuz Gölü, saline areas, 850 m.	June to August	850-1100 m	Irano-Turanian
Limonium echioides	C4: Mersin, Silifke, İncekum Cape, Göksu Delta, sandy places, 3 m.	April to June	0-5 m	Mediterranean
Limonium effusum	C2: Muğla, Köyceğiz, around Hamidiye village, saline wetlands, 0 m.	June to October	0-850 m	Mediterranean
Limonium globuliferum	B4: Aksaray-Konya yolu, around Sultanhisar, saline wetlands, 1000 m.	June to September	900-1100 m	Irano-Turanian

Table 7 (Continued)

Limonium gmelinii	B4: Aksaray, Aksaray-Şereflikoçhisar road 15th km, around Tuz Gölü, saline wetlands, 905 m.	May to October	0-1450 m	Euro-Sibirian
Limonium graecum	C1: Aydin, Didim, Bozbük, sea shore, rockies, 0 m.	May to July	0-5 m	Mediterranean
Limonium gueneri	C2: Antalya, Kaş, Gelemiş (Patara) village, calcerous rockies, 30 m.	July	20 m	Mediterranean
Limonium iconicum	C4: Karapınar-Emirgazi road around 7th km, salty places, 1000 m.	June to September	800-1400 m	Irano-Turanian
Limonium lilacinum	B5: Kayseri, İncesu-Develi road, saline steppes, 1060 m.	June to September	900-1200 m	Irano-Turanian
Limonium meyeri	A9: Kars, Aralık, Tazeköy, 850 m	July to September	800-900 m	Irano-Turanian
Limonium ocymifolium	C1: Muğla, Datça, Knidos, around harbor, 10 m.	May to July	0-10 m	Mediterranean
Limonium pycnanthum	B4: Ankara, Şereflikoçhisar-Ankara road 8th km, around Tuz Gölü, saline wetlands, 940 m.	July to September	850- 1500 m	Irano-Turanian
Limonium sieberi	A1: Çanakkale, Keşan-Gelibolu road, Saroz Bay, salty steppes and wetlands, 0 m.	May to August	0-5 m	Mediterranean

Table 7 (Continued)

Limonium sinuatum	B1 Balıkesir, around Ayvalık-Sarımsaklı, saline pits, 0 m.	May to August	0-100 m	Mediterranean
Limonium smithii	B5: Kırşehir, Badıllı, around Seyfe Lake, saline areas, 1085 m.	June	1085 m	Irano-Turanian
Limonium tamaricoides	B5: Kırşehir, Badılı village, around Seyfe Lake, saline areas, 1085 m.	June to July	950-1100 m	Irano-Turanian
Limonium vananse	B9: Van, Van-Muradiye road 25th km, saline wetlands, meadows, 1730 m.	June to August	1600-2200 m	Irano-Turanian

2.2.3. Characters Used

In this phenetics study, ecological and morphological characteristics of *Limonium* Mill. genus were used. In total, 52 characters were chosen and measured. When choosing characters, features of the genus and some articles were taken into consideration. (Luteyn, 1976; Ingrouille, 1984; Dogan, 2007)

Of these 52 characters, 33 characters are qualitative and 19 are quantitative which are listed in below table. For the qualitative characters, a good representative of each species was selected for each OTU. By making observations, qualitative characters were recorded as in 0,1 scale.

Table 8: Characters for numerical analysis of the *Limonium* Mill. genus in Turkey.

	1. General Characters
1	Annual: (0) / Perennial: (1)
2	Habit: Cushion formation (Pulvinate): (0) / No cushion formation: (1)
3	Shrubs and sub-shrubs: (0) / Herbs: (1)
4	First flowering time: 4^{th} month: (0), 5^{th} month: (1), 6^{th} month: (2), 7^{th} month: (3),
5	Last flowering time: 6^{th} month: (0), 7^{th} month: (1), 8^{th} month: (2), 9^{th} month: (3), 10^{th} month: (4)
6	Phytogeography: Mediterranian: (0) / Irano-Turanian: (1) / Euro-Sibirian: (2)
7	Habitat: Terrestrial: (0) / Sea coast: (1) / Both terrestrial and sea coast: (2)
	2. Scape Characters
8	Height: (in cm) 15-20: (0) / 20-30: (1) / 30-40: (2)
9	Scape with wings: (0) / without wings: (1)

Table 8 (Continued)

10	Scape with caudex: (0) / without caudex: (1)
11	Sterile branches on the scape: (0) / No sterile branches on the scape: (1)
12	Texture: Glabrous: (0) / Papillose, hairy: (1)
13	Scape with leaves: (0) / without leaves: (1)
	3. Leaf Characters
14	Length: (in cm) 0,4-1: (0) / 1-5: (1) / 5-12: (2)
15	Width: (in cm) 0,4-1: (0) / 1-2,5: (1) / 2,4-7: (2)
16	Length/Width ratio 2,3-3: (0) / 3-5: (1) / 5-7: (2)
17	Shape: Oblong, spathulated: (0) / Pinnatifid: (1)
18	Texture: Glabrous: (0) / Hairy: (1)
19	Leaves die before ending of flowering: (0) / do not die: (1)
20	Fleshy: (0) / leathery: (1)
21	Tip: Acute: (0) / Rounded: (1)
22	Tip: With a mucro: (0) / Without a mucro: (1)
23	Leaf Margins: Entire: (0) / Undulate: (1) / Sinuate: (2)
	4. Spike and Spiketlet Characters
24	Spike Length: (in cm) 1-1,5: (0) / 1,5-2: (1)
25	Spikes are congested: (0) / partly dense, lax: (1)
26	Spikelet Length: (in cm) 0,2-0,4: (0) / 0,4-0,6: (1) / 0,6-1: (2)
27	Inflorescence: Unilateral: (0) / Bilateral: (1) / Unilateral or Bilateral: (2)
28	Number of florets per spike: 1-2 fl. (0), 2-3 fl. (1) 4-5 fl. (2)
	5. Bracts
	5.1. Outermost Bract
29	Length: (in mm) 0,7-1,1: (0) / 1,1-1,8: (1) / 1,8-3,3: (2)
30	Width: (in mm) 0,4-0,8: (0) / 0,8-1,3: (1) / 1,3-2,3: (2)
31	Length/Width ratio: 0,6-1,2: (0) / 1,2-2,3: (1) / 2,3-6,7: (2)
32	Shape: Ovate, triangular: (0) / Broadly ovate: (1)

Table 8 (Continued)

33	Shape: Outer bract obtuse at the tip: (0) / Acute at the tip: (1)
34	Margins: Partially hyalinated: (0) / Fully hyalinated: (1) / Fully hyalinated except bottom or central: (2)
	5.2. First Inner Bract
35	Length: (in mm) 1,2-1,7: (0) / 1,7- 3: (1) / 3-7: (2)
36	Width: (in mm) 0,4-1 (0) ; 1-2 (1) ; 2-2,5 (2)
37	Length/Width ratio: 1,1-1,6: (0) / 1,6-2,7: (1) / 2,7-4,5: (2)
38	Shape: Triangular (0) / Rectangular (1)
39	Obtuse at the tip: (0) / Acute at the tip: (1) / With notch at the tip: (2)
40	Margins: Partially hyalinated: (0) / Fully hyalinated: (1) / Fully hyalinated except for veins: (2)
	5.3. Second Inner Bract
41	Length: (in mm) 1-2: (0) / 2-3: (1) / 3-7: (2)
42	Width: (in mm) 0,6-1,2: (0) / 1,2-2: (1) / 2-3: (2)
43	Length/Width ratio: 0,9-2: (0) / 2-3: (1) / 3-5: (2)
44	Shape: Broadly ovate: (0) / Obovate (1)
45	Margins: Partially hyalinated: (0) / Fully hyalinated: (1)
	6. Calyx
46	Length: (in mm) 1,6-3,2: (0) / 3,2-4,5: (1) / 4,5-8: (2)
47	Width: (in mm) 0,45-0,6: (0) / 0,6-1: (1) / 1-1,5: (2)
48	Length/Width ratio: 2,7-3,7: (0) / 3,7-6: (1) / 6-10: (2)
49	Shape: Infundibular: (0) / Obconical: (1) / Tubular: (2)
50	Texture: Glabrous: (0) / Minute hair or pilose: (1)
51	Veins: Reaching into the teeth, excurrent: (0) / Not reaching: (1)
52	Limb lobes: Truncate: (0) / Ovate, rounded: (1) / Acute: (2)

CHAPTER 3

RESULTS

3.1. Constructing Data Matrix

As indicated in Table 7, 52 characters were used for 21 OTUs (each OTU representing a species). A data matrix (given in Appendix I) was constructed. To decrase error rate in continuous quantitative data like length, after taking averages of lengths for each OTU, intervals were determined and quantitative data converted and scored as 0, 1 and 2 scale. In total, around two thousands measurements were made to construct the data matrix. (2 populations per species x 21 species x 52 characters)

3.2. Using Constructed Data Matrix

After obtaining the data matrix, 2 software programs were used to evaluate the data which are:

- MVSP 3.1, A MultiVariate Statistical Package, Kovach Computing Services (Kovach, 1999)
- STATISTICA (data analysis software system), StatSoft, Inc. (2011), v. 10.

As for the coefficient, one distance and one similarity coeffient were used to explain infrageneric relationships in the genus. These coefficients are:

a) **Euclidean Distance Coeffecient:** is the most used dissimilarity coefficient. By definition it is the geometric distance (sum of the squared distances of two values) in multidimensional space. One of the advantages of Euclidean is that adding new objects (might be outliying data) does not affect the distance between any two objects.

b) **Gower General Similarity Coeffecient:** is one of the most used similarity coefficient. It is used for mostly data having multiple scales such as binary, qualitative, quantitative characters and also can be used with missing values

(Gower, 1971, 1986; Romesburg, 1984; St-Laurent et al., 2000).

In this study, the main result is based on Euclidean Distance Coeffecient since the constructed data matrix does not have missing values and all data have similar scale as 0, 1, 2, 3, 4.

3.3. UPGMA Trees

In Figure 11, MVSP result with Euclidean Distance Coeffecient Software phenograms indicates that a drawn line at 6 divides the tree into 6 parts. Of these parts, 2 parts are the same section (Section Limonium). In other words, the drawn line at 6 divides the tree into 5 sections. These 5 sections are Section Pteroclados, Section Limonium, Section Sphaerostachys, Section Sarcophyllum and Section Schizyhymenium. Hence, it can be observed that all 5 sections of Limonium Mill. genus are represented in a different part and separated.

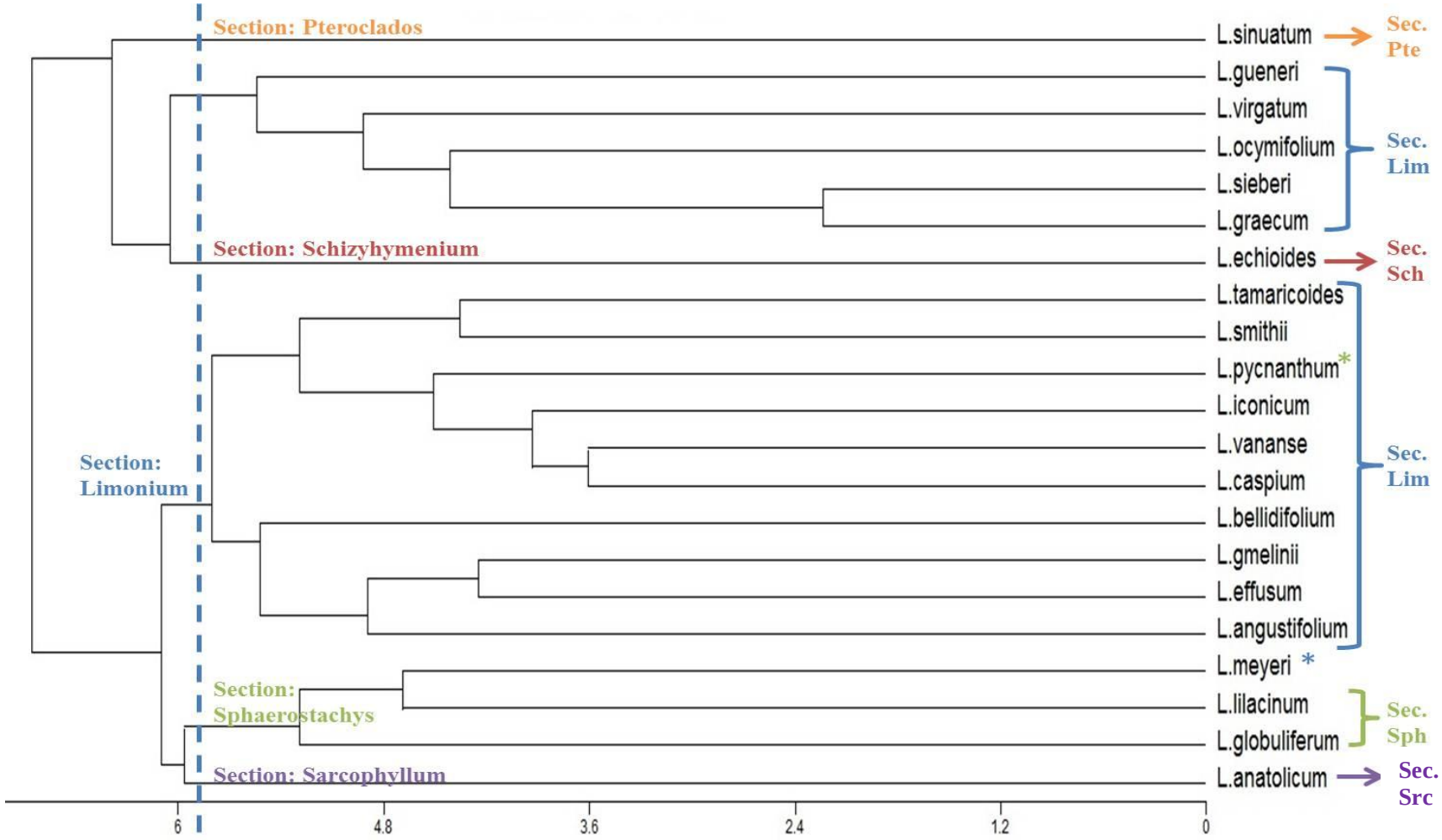


Figure 11: UPGMA Tree for *Limonium* Mill. Genus in Turkey (by using MVSP with Euclidean Distance Coeffecient)

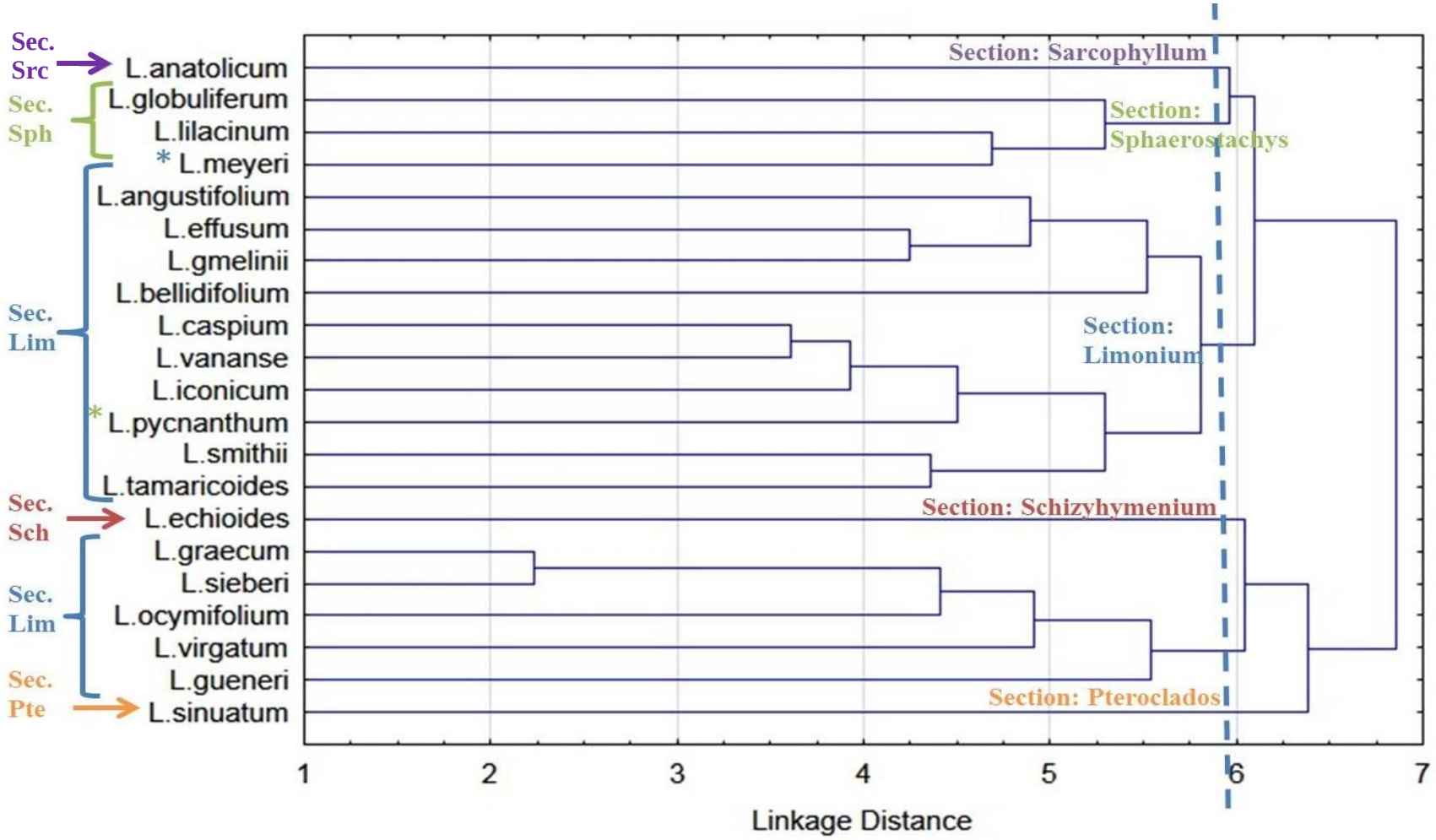


Figure 12: UPGMA Tree for *Limonium* Mill. Genus in Turkey (by using Statistica with Euclidean Distance Coeffecient)

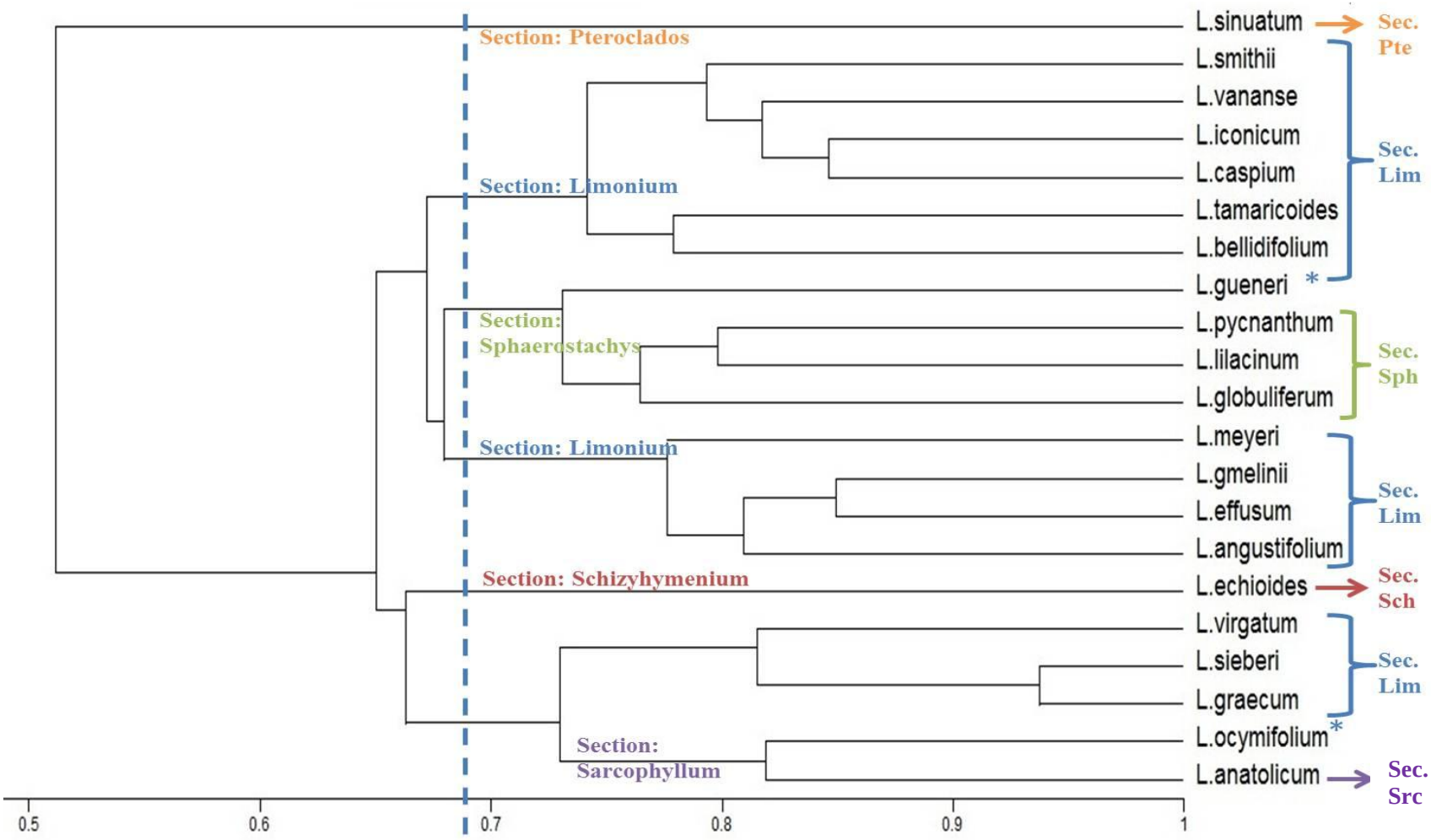


Figure 13: UPGMA Tree for *Limonium* Mill. Genus in Turkey (by using MVSP with Gower General Similarity Coeffecient)

In Figure 12, UPGMA tree by using Statistica with Euclidean Distance Coeffecient was given. The same coeffient was used to crosscheck the tree in Figure 11. When examined, it is observed that trees in Figure 11 and Figure 12 are the same. Hence, it supports that the constructed UPGMA tree is valid.

In Figure 13, MVSP result with Gower General Similarity Coeffecient was given. This UPGMA tree indicates also similar result with the Euclidean Distance Coeffecient. A drawn line at 0,7 separetes the tree into 5 different sections of Limonium. However, Section Sarcophyllum is separated much later and includes a species from Section Limonium (*L. ocymifolium*)

In addition, Principle Componenet Analysis in MVSP was carried out to indicate the most important characters.

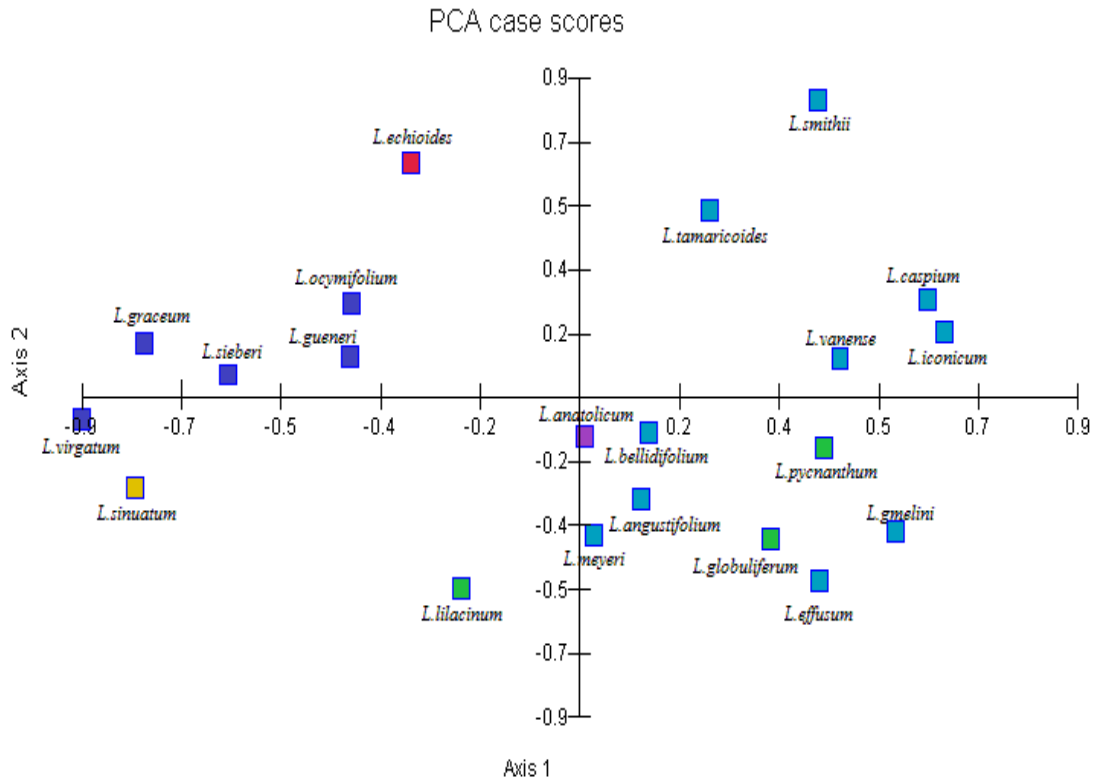


Figure 14: Principle Component Analysis of Limonium Mill. in Turkey with 2 axis.

Table 9: Eigenvalues, percentages and cumulative percentages (Eigenvalues > 1)

Eigenvalues							
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6	Axis 7
Eigenvalues	5.226	2.928	2.059	1.596	1.449	1.186	1.052
Percentage	26.259	14.712	10.348	8.022	7.282	5.960	5.288
Cum. Percentage	26.259	40.971	51.319	59.341	66.623	72.583	77.870

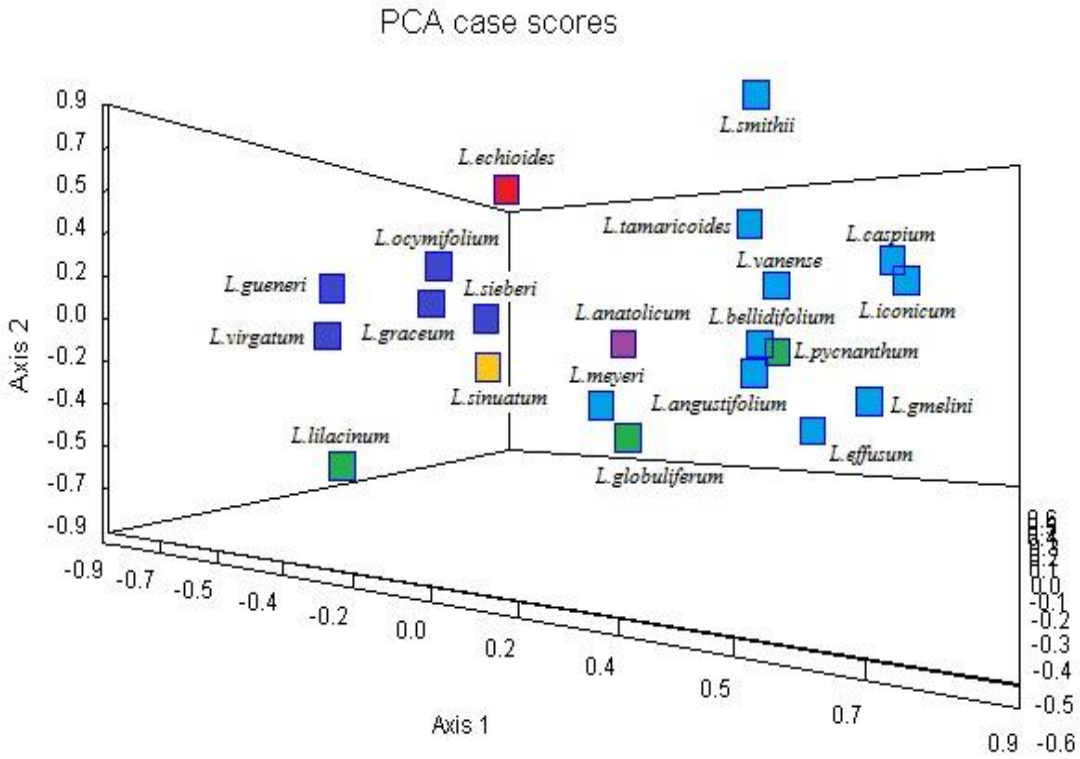


Figure 15: Principle Component Analysis of Limonium Mill. in Turkey with 3 axis.

CHAPTER 4

DISCUSSION

Infrageneric Grouping of Limonium Mill. in Turkey

In this study, overall relationship of all *Limonium* Mill. in Turkey was demonstrated in constructed UPGMA trees based on chosen 52 characters.

In Figure 11, a line at 6,5 in Euclidean Distance Coeffecient with MVSP divides the UPGMA tree into 2 branches. These two branches represent 2 sub-genus in which *L. sinuatum, L. gueneri, L. virgatum, L. ocymifolium, L. sieberi, L. graecum* and *L. echioides* are found in a branch and *L. tamaricoides, L. smithii, L. pycnanthum, L. iconium, L. vanense, L. caspium, L. bellidifolium, L. gmelinii, L. effusum, L. angustifolium, L. meyeri, L. lilacinum, L. globuliferum, L. anatolicum* species are in another branch.

In Figure 11, a line at 5,9 in Euclidean Distance Coeffecient with MVSP divides the UPGMA tree into 6 branches. In UPGMA tree, from upside to down, respectively, the first branch consists of only one species which is *L. sinuatum.* Hence, this first branch represent the Section Pteroclados. The second branch consists of *L. gueneri, L. virgatum, L. ocymifolium, L. sieberi, L. graecum* which is the Section Limonium. The third branch has only one species: *L. echioides.* Hence, this branch represents the Section Schizyhymenium. The fourth branch is formed by *L. tamaricoides, L. smithii, L. pycnanthum, L. iconium, L. vanense, L. caspium, L. bellidifolium, L. gmelinii, L. effusum, L. angustifolium.* Therefore, it can be said that the fourth branch represents the Section Limonium. The fifth branch is composed of *L. meyeri, L. lilacinum, L. globuliferum* and represents the Section Sphaerostachys.

The sixth branch has a single species: *L. anatolicum* and is equivalent to Section Sarcophyllum. As a result, each branch represents a section in the genus.

As a result, the constructed UPGMA tree has 5 sections (Section Pteroclados, Section Limonium, Section Sphaerostachys, Section Sarcophyllum and Section Schizyhymenium) as separated in different branches which supports the taxonomic information mentioned in Flora of Turkey and the East Aegean Islands, Volume 7 and 10 (Davis et al., 1982, 1988).

What seems different than information in "Flora of Turkey" is that *L.meyeri* is in branch of Section Sphaerostachys instead of Section Limonium and *L. pycnanthum* is in branch of Section Limonium instead of Section Sphaerostachys. This result stems from the choice of characters like leaf type. In addition, *L.meyeri* has common characters with Section Sphaerostachys which are: Perennial; Habit: Cushion formation (Pulvinate); Herbs; Last flowering time: 9^{th} month; Phytogeography: Irano-Turanian; Height: 20-30 cm; Scape without wings; Texture: Glabrous; Scape without leaves; Leaf Length: 5-12 cm; Width: 2,4-7 cm; Shape: Oblong, spathulated; Texture: Glabrous; Leaves do not die before ending of flowering; Number of florets per spike: 2-3 fl.; Outer Bract Shape: acute at the tip; Shape: Triangular; Obtuse at the tip; Second Inner Bract Margins: Partially hyalinated; Calyx Texture: Minute hair or pilose; Veins: not reaching to teeth; Limb lobes: Ovate, rounded. Hence, *L.meyeri* seems to be closer to Section Sphaerostachys more than to Section Limonium.

L. pycnanthum appears to be closer to Section Limonium due to common these common characters: Perennial; Habit: Cushion formation (Pulvinate); Scape without wings; Texture: Glabrous; Scape without leaves; Shape: Oblong, spathulated; Texture: Glabrous; Leaf Margins: Entire; First Inner Bract Length: 1,2-1,7 mm; Width: 0,4-1 mm; obtuse at the tip; Second Inner Bract margins partially hyalinated; Calyx Length: 1,6-3,2 mm; Texture: minute hairs or pilose; Calyx Veins not reaching to teeth.

As indicated in Figure 14, each branch in UPGMA trees (Figure 11, 12) represents a section in *Limonium* Mill. genus as mentioned in Flora of Turkey and the East Aegean Islands (Davis et al., 1982, 1988). This result underpins existing of 5 sections in *Limonium* Mill. genus and a new section of Limonium (in dark blue colour between Section Schizyhymenium and Section Pteroclados) which has only sea coast living species as also indicated in Figure 16.

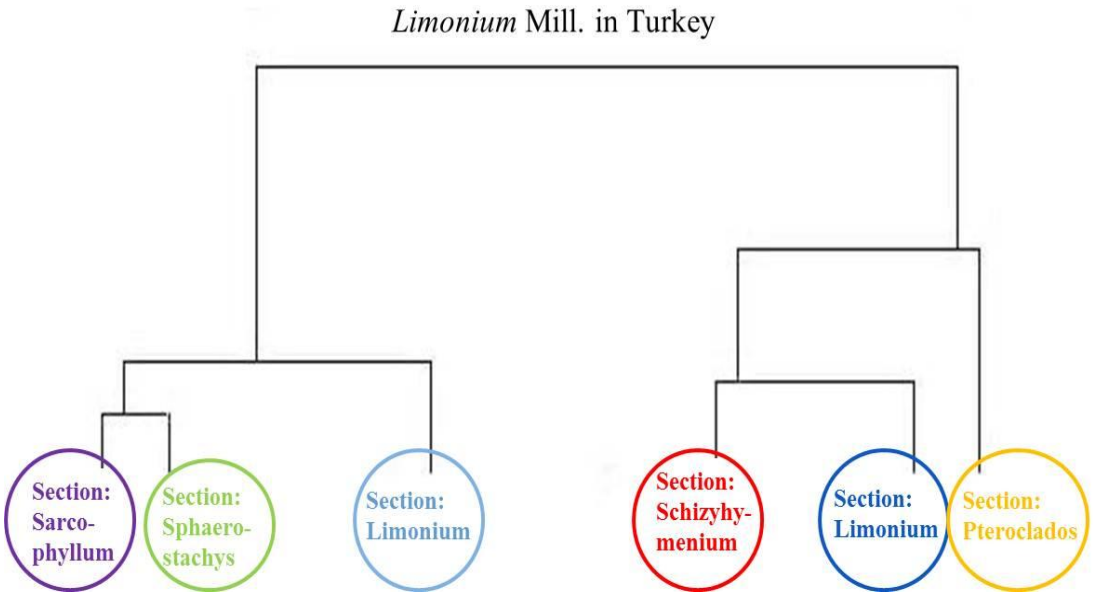


Figure 16: Limonium Mill. genus in Turkey and its sections (with a line at 5,9 in Figure 11)

As another result, Section Limonium was represented in 3 different branches. From this result, it might be deduced that Limonium section is heterogenous. In addition, it is the largest section consisting of 15 species. It has relatively more diverse species within the section when compared to other sections in terms of habitats and morphologies. Hence, branching of Section Limonium into different branches (with a line at 5,6) might be explained by that diversity characteristic of the section. (Figure 15)

In addition, Section Limonium as indicated in all UPGMA trees is represented by 3 separate branches. This outcome evokes that this section is heterogenous and requires a need for revision. Of these 3 branches in Figure 11, the first branch of Section Limonium has *L. gueneri, L. virgatum, L. ocymifolium, L. sieberi, L. graecum*. Habitats of these species are near seacoast. (A1, A2, B1, C1, C2, C3, C5)

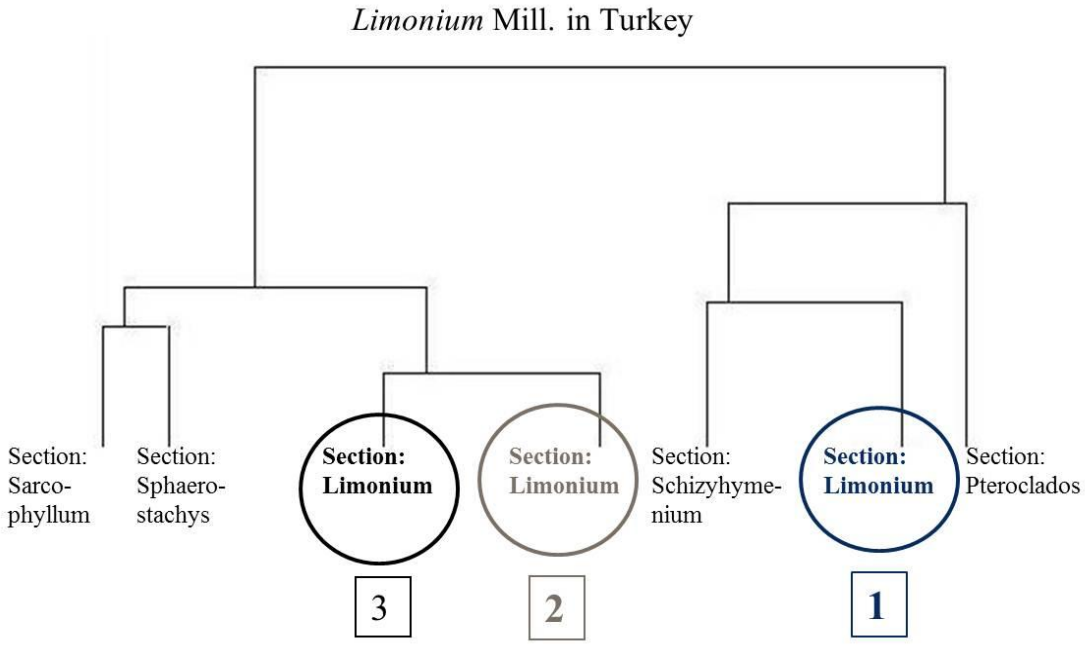


Figure 17: Section Limonium and its branches (with a line at 5,6 in Figure 11)

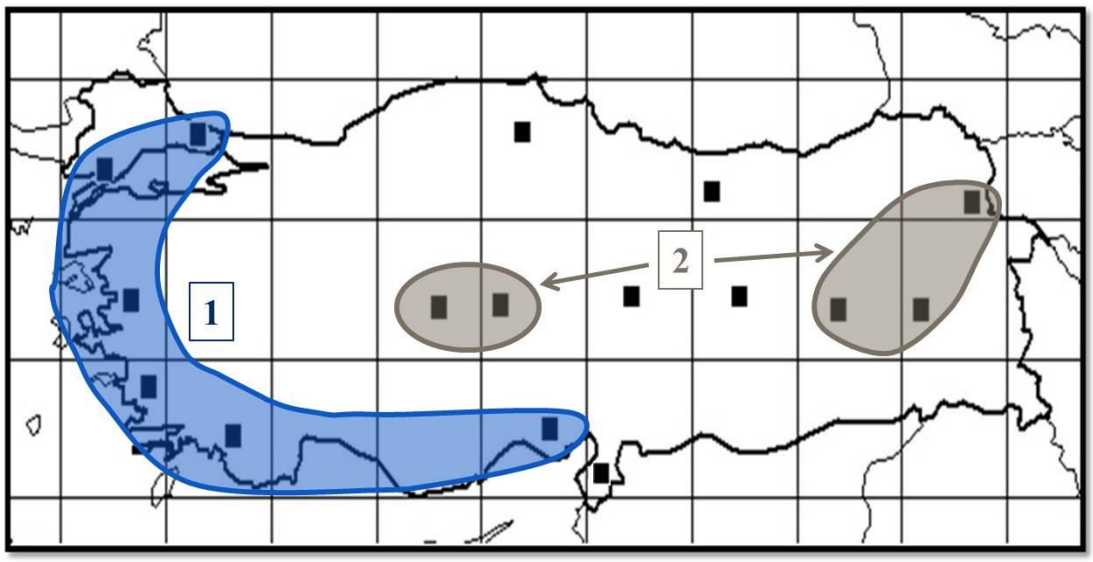


Figure 18: Section Limonium and its branches throughout Turkey.

The second branch of Section Limonium includes *L. tamaricoides, L. smithii, L. pycnanthum, L. iconium, L. vanense, L. caspium* and common feature of these species is the habitat. These species have terrestrial habitat and exist in inland places (A9, A10, B4, B5, B8, B9). In addition, except for *L. caspium,* all species in this branch are endemic species. Since endemism is correlated with ecological features and isolation of habitat, it was observed that endemic species were clustered together.

The third branch includes *L. bellidifolium, L. gmelinii, L. effusum, L. angustifolium* and these species have a cosmopolite distribution living in both terrestrial and seacoast.

As a result, these evidences of Section Limonium points out those habitats of species affect morphological variation and therefore, as in the UPGMA tree, these 3 branches may represent the habitat types (terrestrial, seacoast and both types). In other words, the branching pattern of Section Limonium seems to be consistent with

habitat information of species. Since the chosen characters include morphological and ecological features of species, this outcome is not unexpected.

UPGMA tree in Figure 12 was obtained by using Statistica with Euclidean Distance Coeffecient which is the same with Figure 11 comprised of 6 branches with 5 different sections. Hence, inferences in Figure 11 are the same with Figure 12.

In Figure 13, the UPGMA was constructed by using Gower General Similarity Coeffecient with MVSP. A line at 0,7 in the tree generates 6 branches. The first branch has only one species: *L. sinuatum.* Hence, this first branch repsesents the Section Pteroclados. The second branch consists of *L. smithii, L. vanense, L. iconium, L. caspium, L. tamaricoides* and *L. bellidifolium* those all are species in the Section Limonium. The third branch has *L. gueneri,* by *L. pycnanthum, L. lilacinum* and *L. globuliferum.* Except for *L. gueneri,* remaining species are member of the Section Schizyhymenium.

Section Schizyhymenium in the third branch separates a bit later with a line from 0,75. The fourth branch is composed of *L. meyeri, L. gmelinii, L. effusum* and *L. angustifolium* which are part of Section Limonium. The fifth branch has one species: *L. echioides* and represent the Section Schizyhymenium.

The sixth branch has 2 more branches which have *L. virgatum, L. sieberi, L. graecum* in a branch as the Section Limonium and *L. ocymifolium, L. anatolicum* (Section Sarcophyllum) in a different branch.

What seems interesting is that, in Figure 13 UPGMA, *L. gueneri* seems to be much closer to Section Schizyhymenium than Section Limonium and *L. ocymifolium* is very close to *L. anatolicum* (Section Sarcophyllum). This result is due to the coefficient used and choice of characters.

When all UPGMA trees are compared, it can be cliamed that Euclidean Distance Coeffecient generates a less complex tree than Gower General Similarity Coeffecient and explains the infrageneric relationships in a plain way. The reason behind this situation might be due to properties of coefficients. Since Gower General Similarity Coeffecient is used with missing data and variable types of characters such as quantitative, quantitave and binary, it brings out more general type of tree. In this phenetics study, all values in constructed data matrix are single type and have similar scales. Hence, using Euclidean Distance Coeffecient allows more suitable explanation of infrageneric relationships of *Limonium* Mill. species.

Nevertheless, there are some distinctive species in this genus and those require special attention:

L. sinuatum separates very earlier in the UPGMA tree and seems to be very different than remaining species due to chosen characters such as scape wings, scape texture, leaf texture, leaf margins, keeled outer bract and acute first inner bract. Hence, it might be postulated that this species might be closer to other species in Plumbaginaceae family.

L. echioides is the only annual species in *Limonium* Mill. genus while all other species are perennial. Also it is the only species whose calyx veins are excurrent and has hooked shape. Hence, as can be observed in the tree, it was separated alone as a branch and it is the only species in Section Schizyhymenium.

Briefly, *L. echioides* and *L. sinuatum* might be closer to other species in Plumbaginaceae family or might be regarded as a separate subgenus or genus with the help of morphological, karyological and phytochemical analysis like in case of Myriolimon which was segregated from Limonium Mill. genus (Lledo et al., 2005). Further analyses are required to comment on these species.

In addition, Principle Component Analysis (PCO) by using correlation matrices resulted in 6 groups. (Figure 14) The first 4 principle components explained % 59.341 of total morphometric variation. The first axis explained % 26.26, the second axis % 14.71, the third axis % 10.35 and the fourth axis % 8.02 of total variation (Table 9).

Principle Component Analysis (PCO) resulted in 6 groups (Figure 14 and 15) and it clearly indicates that there is a separate Section Limonium. (Section nova: in dark blue colour)

Table 10: Summary of character loadings (highest 5 loading) on the first 4 axis

Characters	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 4**
3- Shrubs and sub-shrubs, Herbs				-0.250
4- First flowering time				0.281
5- Last flowering time	0.292	-0.586		
8- Scape height		-0.218		
14- Leaf Length		-0.349	0.293	
15- Leaf Width		-0.373		
16- Leaf Length/Width ratio			0.282	0.364
29- Outer Bract Length				0.355
30- Outer Bract Width		-0.205		
34- Outer Bract Margin				0.312
35- First Inner Bract Length	-0.321			
41- Second Inner Bract Length	-0.304			
42- Second Inner Bract Width			-0.372	
43- Second Inner Bract Ratio			0.332	
46- Calyx Length	-0.351			
48- Calyx Ratio	-0.253		0.278	

16 characters which are: Shrubs and sub-shrubs, Herbs; First flowering time; Last flowering time; Scape height; Leaf Length; Leaf Width; Leaf Length/Width ratio; Outer Bract Length; Outer Bract Width; Outer Bract Margin; First Inner Bract Length; Second Inner Bract Length; Second Inner Bract Width; Second Inner Bract Ratio; Calyx Length; Calyx Ratio characters found on axis 4 represent are the most important characters explains most of the variation in clustering of *Limonium* Mill. in Turkey

Review of *Limonium* Mill. in Turkey

In Appendix A, overall current taxonomic status of *Limonium* Mill. genus in Turkey was evaluated. For each of species, information about habit, biogeography, IUCN category, flowering period, habitat, characteristics and distribution map was given.

CHAPTER 5

CONCLUSION

The purpose of this study was to assess infrageneric grouping of *Limonium* Mill. in Turkey. For this reason, cluster analysis with phenetics method was used.

Cluster analysis provides grouping of similar type of elements. In this study the elements (OTUs) were *Limonium* Mill. species and the grouping was succeeded with chosen characters. To summarize, in this phenetic study, the main finding generally supports the infrageneric grouping stated in "Flora of Turkey".

However, Phenograms and PCAs suggest a new Section Limonium (section nova) near South-Western part of Turkey near seacoast which is separated well from other species of Section Limonium. Common properties of Section nova in Limonium according to used characters in this study: Perennial; Habit: Cushion formation (Pulvinate); Flowering time is mostly between May to July. Phytogeography: Mediterranian; Habitat: Sea coast; Scape without wings; Texture: Glabrous; Scape without leaves; Leaf Length: 1-5 cm; Leaf Width: 0,4-1 cm; Leaf Shape: Oblong, spathulated; Texture: Glabrous; Leaves do not die before ending of flowering; Leaf Margins: Entire; Spikelet Length mostly 0,4-0,6 cm; Outer Bract Shape: Ovate, triangular; Outer Bract Margins: Partially hyalinated; First Inner Bract Shape: Triangular; First Inner Bract Length mostly 1,7-3 mm; Obtuse at the tip; Margin: Partially hyalinated; Second Inner Bract Length mostly 3-7 mm; Margin: Partially hyalinated; Calyx Length mostly 4,5-8 mm; Shape mostly Infundibular; has minute hair or pilose; Veins: Not reaching into the teeth; Lobes: Ovate, rounded.

Doubtlessly, only phenetics study does not provide enough evidence for suggestion of a new infrageneric grouping model. Further analysis with several aspects including different fields such as ecology, biogeochemistry, cytology and genetics are required for a better and healthier classification.

Samples from other countries are needed as well; examining only Turkish species may prevent to see the overall picture of taxonomic status of *Limonium* Mill. Moreover, molecular and karyological studies could help to explain the status of Section nova.

REFERENCES

Akaydın, G., A new species of Limonium Mill. from the Central Anatolian Salt Steppe, Turkey, World Applied Sciences Journal 2 (4): 406-411, 2007

Akaydın, G., Doğan M., Taxonomic Revision of Plumbaginaceae Juss. Family in Turkey, TUBITAK project, 2006

Baker, H.G; Dimorphism and Monomorphism in the Plumbaginaceae: III. Correlation of Geographical Distribution Patterns with Dimorphism and Monomorphism in Limonium, Annals of Botany, Volume:17, Issue:4, pp. 615-628, 1953

Boissier, E. P., Plumbaginaceae, In De Candolle, A., (Ed.): Prodromus Systematis Naturalis Regnis Vegetabilis, Volume: 12, pp. 617-696, Paris, 1848

Boissier, E., Flora Orientalis, Reg. Acad. Scient., Basel., Volume 4: 858:872, 1879

Bokhari, M.H., Edmondson, J.R., Limonium Miller In: Davis PH, ed. Flora of Turkey and the East Aegean Islands, 7th Volume., Edinburgh University Press, Edinburgh, pp. 465–476, 1982

Bokhari, M.H., Materials for a Flora of Turkey XXII: Plumbaginaceae, Notes Royal Botanic Garden, Edinburgh, 30: 295-304, 1970

Bokhari, M.H., Synopsis of Plumbaginaceae in Turkey, Notes Royal Botanic Garden, Edinburgh 32: pp. 57-77, 1972

Bokhari, M.H., Taxonomic Studies in S.W. Asian Plumbaginaceae (Ph.D. Thesis), The University of Edinburgh in the Faculty of Science, 1970

Cowan, R., Ingrouille, Martin J., Lledó, M. Dolores, The Taxonomic Treatment of Agamosperms in the Genus Limonium Mill. (Plumbaginaceae), Folia Geobotanica, Vol. 33, No. 3, pp. 353-366, 1998

Crowson, R. A., Classification and Biology. IX, pp.19, 1970

Davis, P. H, Flora of Turkey and the East Aegean Islands, Vol. 1, Edinburgh University Press, Edinburgh, 1965

Davis, P. H., Edmondson, J.R., Mill, R.R., Tan, K., Limonium Miller (Plumbaginaceae), Flora of Turkey and the East Aegean Islands, Vol. 7., Edinburgh University Press, Edinburgh, pp. 465-476, 1982

Davis, P. H., Mill, R.R., Tan, K., Flora of Turkey and the East Aegean Islands, Vol. 10 (Supplement), Edinburgh University Press, Edinburgh, pp. 210-211, 1988

Davis, P.H. and V. H. Heywood, Principles of Angiosperms Taxonomy, D. Van Nostrand Company, Inc., New York, 1963

Doğan, M., Akaydin, G. and Çakaroğulları, D., Infrageneric Grouping of Turkish Acantholimon Boiss. (Plumbaginaceae) Assessed by Numerical Taxonomy, Advan. Biol. Res., 1 (3-4): pp.85-91, 2007

Doğan, M., Duman, H., Akaydın, G., Limonium gueneri (Plumbaginaceae), a new species from Turkey, Ann. Bot. Fennici, 45: pp. 389-393, 2008

Erben, M., Die Gattung Limonium in südwestmediterranen Raum. Mitt Bot Staatssamml München, 14:361–631, 1978

Erben, M., Limonium Mill.- In: Castroviejo, S., Aedo C., Cirujano, S., Lainz, M., Montserrat, P., Morales, R., Munoz Garmendia, F., Navarro, C., Paiva, J. & Soriano, C. (eds.), Flora Iberica: 2-143, Servicio de Publicaciones del CSIC, Madrid, 1993

Gower J. C., A general coefficient of similarity and some of its properties, Biometrics 27: 857-871, 1971

Gower J.C., and Legendre P, Metric and Euclidean properties of dissimilarity coefficients. J. Classif. 3: 5-48, 1986

Harris, James G. and Harris, Melinde W., Plant Identification Terminology: An Illustrated Glossary, 2nd Edition, 2001

Heywood, A V. H., Flora Europaea Notulae Systematicae ad Floram Europaeam spectantes, Botanical Journal of the Linnean Society Volume 76, Issue 4, pp. 297–384, 1978

Ingrouille, M. J., A Taxometric Analysis of *Limonium (Plumbaginaceae)* in Western Europe, P1ant Systematics and Evolution, 147:103-118, 1984

IUCN, IUCN Red list categories and criteria: Version 3.1. IUCN Species Survival Commission, Gland & Cambridge, 2001

Jussieu, A.L. de, Genera Plantarum, secundum ordines naturales disposita juxta methodum in Horto Regio Parisiensi exaratam, 1789

Karis, P.O., Taxonomy, phylogeny and biogeography of Limonium sect. Pteroclados (Plumbaginaceae) based on morphological data, Bot. J. Linn. Soc., 144: pp. 461-482, 2004

Kovach WL, MVSP, a multivariate statistical package for Windows, Version 3.1. Pentraeth, Wales: Kovach Computing Services, 1999

Kubitzki, K., Plumbaginaceae, The Families and Genera of Vascular Plants, vol. 2., pp. 523–530, 1993

Leveque, Christian and Mounolou, Jean-Claude, Biodiversity, John Wiley & Sons, Ltd, Chapter 2, 2004

Lledó, M. D., Erben, M., Crespo, M. B., Mryiolepis, a new genus segregated from Limonium (Plumbaginaceae), Taxon, 52: pp. 67-73, 2003

Lledó, M. D., Erben, M., Crespo, M. B., Myriolimon, a New Name for the Recently Published Myriolepis (Plumbaginaceae), Taxon, 54: pp. 811-812, 2005

Lledó, M.D., Crespo, M.B., Fay, M.F., Chase, M.W., Molecular phylogenetics of Limonium and related genera (Plumbaginaceae): Biogeographical and systematic implications, American Journal of Botany, Volume 92, Issue 7, pp. 1189-1198, 2005

Luteyn, James L., Revision of Limonium (Plumbaginaceae) in Eastern North America, Brittonia, 28: pp. 303-317, 1976

Manktelow, Mariette, History of Taxonomy, Department of Systematic Biology, Evolutionary Biology Centre, Uppsala University, 2010

Millennium Ecosystem Assessment, Ecosystems and Human Well-being: Biodiversity Synthesis, World Resources Institute, Washington, DC, 2005.

Radford, A. E., W. C. Dickison, J. R. Massey, C. R. Bell., Vascular Plant Systematics, Harper and Row, New York, 1976.

Romesburg H.C., Cluster analysis for researchers. Lifetime learning 315 publications. pp. 333-334. Belmont: Lulu Press, 1984

Rougetel, H. Le, Gardener extraordinary: Philip Miller of Chelsea (1691-1771), Journal of the Royal Horticultural Society, 96, pp. 556-63, 1971

Shimura, J., (Ed.), Global Taxonomy Initiative in Asia. Report and Proceedings of the 1st GTI Regional Workshop in Asia. Putrajaya, Malaysia, NIES, Japan, pp. 314, 2003

Simpson, Michael G., Plant Systematics, Elsevier Academic Press, 2006

Singh, Gurcharan, Plant systematics: an integrated approach, Science Publishers, Chapter 1, 2004

Sneath, P. H. A & Sokal, R. R., Numerical taxonomy: the principle and practice of numerical classification, San Francisco: Freeman, pp. 573, 1973

Sokal R R & Sneath PH A. Principles of numerical taxonomy. San Francisco: Freeman, pp.359, 1963

Stace, C. A, Plant Taxonomy and Biosystematics, Hodder & Sloughton, London, 1989

Stevens, P. F., (2001 onwards), Angiosperm Phylogeny Website, Version 9, 2008 http://www.mobot.org/MOBOT/research/APweb

St-Laurent L, Baum BR, Akpagana K & Arnason JT, A numerical taxonomic study of Trema (Ulmaceae) from Togo, West Africa. Syst Bot 30: 399-413, 2000

Stuessy, T. F, Paradigms in biological classification (1707-2007): Has anything really changed? Taxon, Volume 58, Issue 1, 2009, pp. 68-76

Stuessy, T. F, Plant taxonomy, the systematic evaluation of comparative data, Columbia University Press, New York, 1990

UN Convention of Biological Diversity 4th National Report, Ministry of Environment and Forestry, Republic of Turkey, 2009

Watson, L. and Dallwitz, M. J., The Families of Flowering Plants: Descriptions, Illustrations, Identification and Information Retrieval. Version: 14th December 2000. http://biodiversity.uno.edu/delta

Websites:

http://turkherb.ibu.edu.tr (Turkish Plants Data Service); Last visited on 25/04/2011

http://bioces.tubitak.gov.tr (TÜBİTAK – Turkish Taxonomic Species Database); Last visited on 20/03/2011

http://www.ipni.org (The International Plant Names Index); Last visited on 17/07/2011

http://www.un.org (United Nations); Last visited on 25/04/2011

http://arctos.database.museum (Multi-Institution, Multi-Collection Museum Database); Last visited on 03/07/2011

http://www.maweb.org (The Millennium Ecosystem Assessment); Last visited on 25/03/2011

http://ibot.sav.sk/icbn/main.htm (International Code of Botanical Nomenclature); Last visited on 23/07/2011

http://www.cbd.int/gti/taxonomy.shtml (Global Taxonomy Initiative); Last visited on 25/03/2011

http://www.plantsystematics.org; Last visited on 05/06/2011

http://www.biodiversitylibrary.org; Last visited on 25/04/2011

http://www.statsoft.com/textbook/cluster-analysis/#joining; Last visited on 17/08/2011

http://www.biologie.uni-hamburg.de/b-online/delta/angio/www/plumbagi.htm; Last visited on 13/06/2011

http://botanydictionary.org; Last visited on 05/08/2011

http://www.ibiblio.org/botnet/glossary; Last visited on 12/08/2011

Figures:

http://gdz.sub.uni-goettingen.de/dms/load/img/?PPN=PPN362053006 (Title page of Systema Natura); Last visited on 25/04/2011

http://herbaceousplants.homestead.com/Ann8.html (*Limonium sinuatum*); Last visited on 05/05/2011

http://www.orman.istanbul.edu.tr/en/node/10609 (Biogeographic map of Turkey); Last visited on 10/05/2011

http://www.vanherbaryum.yyu.edu.tr/flora/famgenustur/pl/lim/index.htm (*Limonium vanense*); Last visited on 25/05/2011

http://www.biolib.de (Richard Wettstein - Handbuch der Systematischen Botanik, 1924); Last visited on 17/05/2011

Hippolyte Coste, Flore descriptive et illustrée de la France, de la Corse et des contrées limitrophes, 1901-1906

Walter Hood Fitch, Illustrations of the British Flora, 1924

James Edward Smith, English botany; or coloured figures of British plants, London, C.E. Sowerby, 1836, 2nd edition, volume 3

Software:

Leica Application Suite, LAS V. 2,50 R1, Leica MICROSYSTEMS (Switzerland) Limited, CMS, GmbH.

MVSP 3.1, A MultiVariate Statistical Package, Kovach Computing Services kovcomp.co.uk

StatSoft, Inc. (2011). STATISTICA (data analysis software system), version 10. www.statsoft.com

APPENDICES

APPENDIX A

REVIEW OF *LIMONIUM* MILL. IN TURKEY

Section Pteroclados (Sauv. and Vindt)

A.1. *Limonium sinuatum* (L.) P. Mill.

Habit: Perennial; Mediterranean element; IUCN Category: EN; Flowering Period: May-August; Habitat: 0-100 m.

Table 11: General characteristics of *Limonium sinuatum*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	15-40 cm	3-10 x 1-3 cm	1,5-2 cm	1-1,5 cm	5-7 mm	6-8 mm	7-9 mm	10-15 mm
Shape	herba-ceous	oblong	com pact		triang le	keeled		infun dibular
Other				3-4 fl.				trunca-te lobe

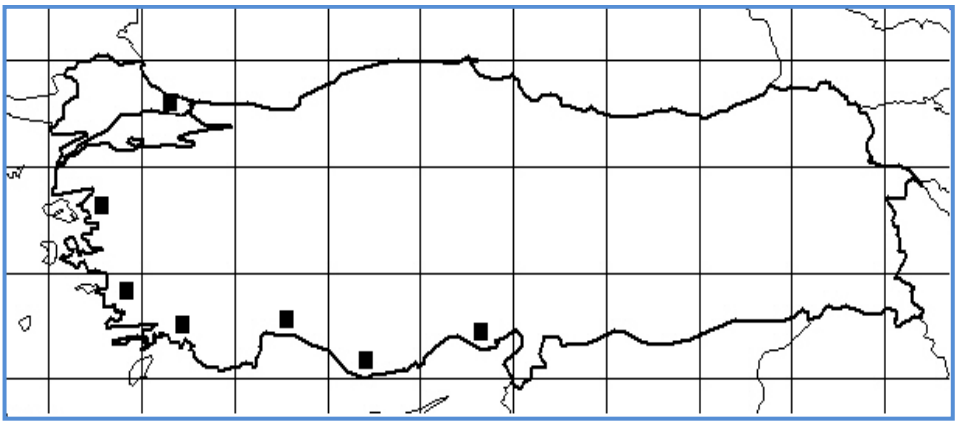


Figure 19: Distribution map of *Limonium sinuatum* (A2, B1, C1, C2, C3, C4, C5)

Figure 20: *Limonium sinuatum* (edited from Flore descriptive et illustrée de la France)

Section Limonium

A.2. *Limonium meyeri* (Boiss.) O.Kuntze

Habit: Perennial; Irano-Turanian element; IUCN Category: VU; Flowering Period: July-September; Habitat: 800-900 m.

Table 12: General characteristics of *Limonium meyeri*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	40-90 cm	20-40 x 5-8 cm	1,5-2 cm	0,4-0,5 cm	1-1,5 mm	2-2,5 mm	3-4 mm	4-5 mm
Shape	herba-ceous	elliptic	lax		ovate	membra nous		obconi-cal
Other		leathe ry		2-3 fl.				pilose

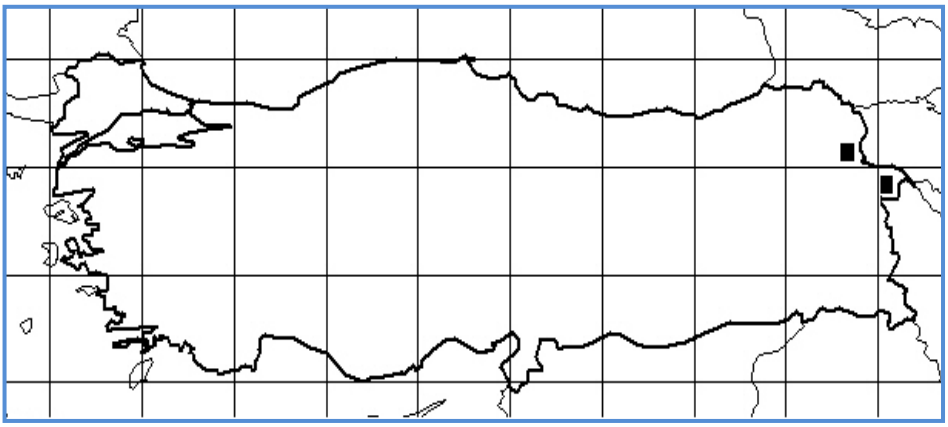


Figure 21: Distribution map of *Limonium meyeri* (B9, B10)

A.3. *Limonium angustifolium* (Tausch) Turrill

Habit: Perennial; Mediterranean element; IUCN Category: EN; Flowering Period: May-October; Habitat: 0-10 m.

Table 13: General characteristics of *Limonium angustifolium*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	50-70 cm	4-18 x 2-6 cm	1,5-2 cm	0,5-0,6 cm	1,5-2 mm	2-3 mm	3-4,5 mm	4-5 mm
Shape	herba-ceous	elliptic	com-pact		ovate	elongate		obconi cal
Other				1-3 fl.	membra nous			

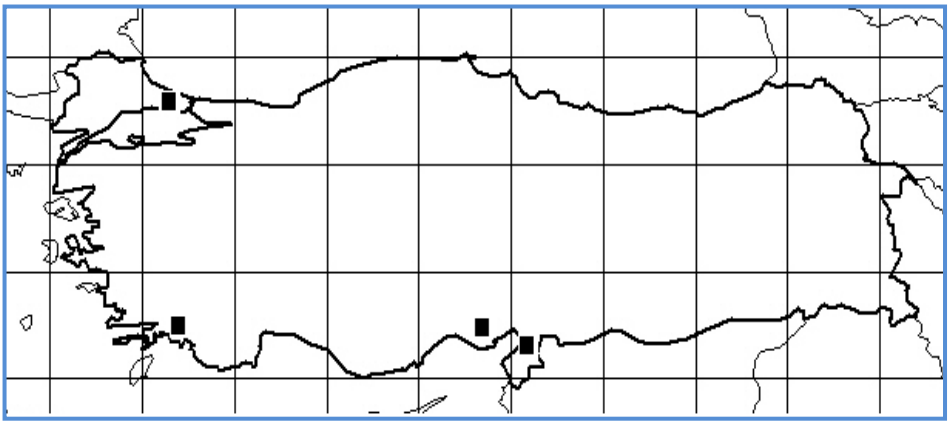


Figure 22: Distribution map of *Limonium angustifolium* (A2, C2, C5, C6)

A.4. *Limonium effusum* (Boiss.) O.Kuntze

Habit: Perennial, Endemic; Mediterranean element; IUCN Category: EN; Flowering Period: June-October; Habitat: 0-850 m.

Table 14: General characteristics of *Limonium effusum*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	40-50 cm	5-20 x 3-7 cm	1,5-2 cm	0,4-0,6 cm	1-1,5 mm	1,5-2,5 mm	2,5-3 mm	3-3,5 mm
Shape	herba-ceous		lax		ovate	membra nous		obconi cal
Other		leathe ry		1-2 fl.				pilose

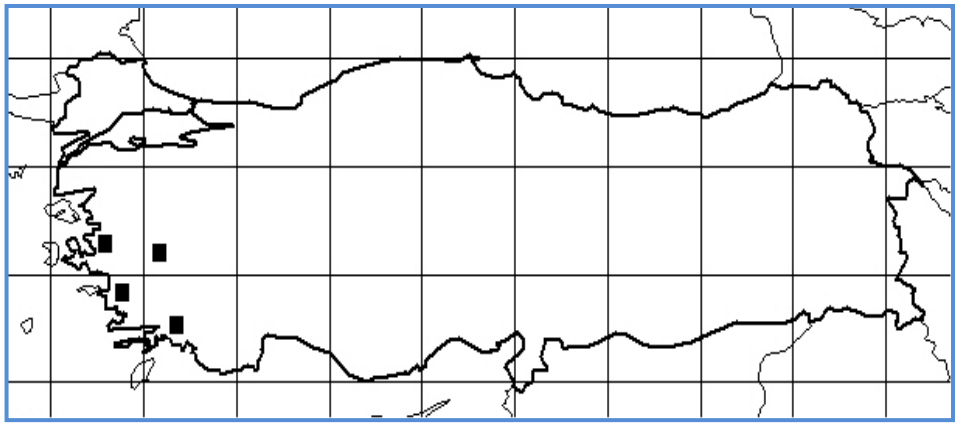


Figure 23: Distribution map of *Limonium effusum* (B1, B2, C1, C2)

A.5. *Limonium gmelinii* (Willd.) O.Kuntze

Habit: Perennial; Euro-Sibirian element; IUCN Category: LC; Flowering Period: May-October; Habitat: 0-1450 m.

Table 15: General characteristics of *Limonium gmelinii*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	25-55 cm	6-20 x 2-7 cm	1-1,5 cm	0,3-0,5 cm	1-1,5 mm	2-3 mm	3-4 mm	2,5-3,5 mm
Shape	herba-ceous	elliptic, ovate	com pact		ovate	elongate ovate		obconi cal
Other				2-3 fl.				pilose

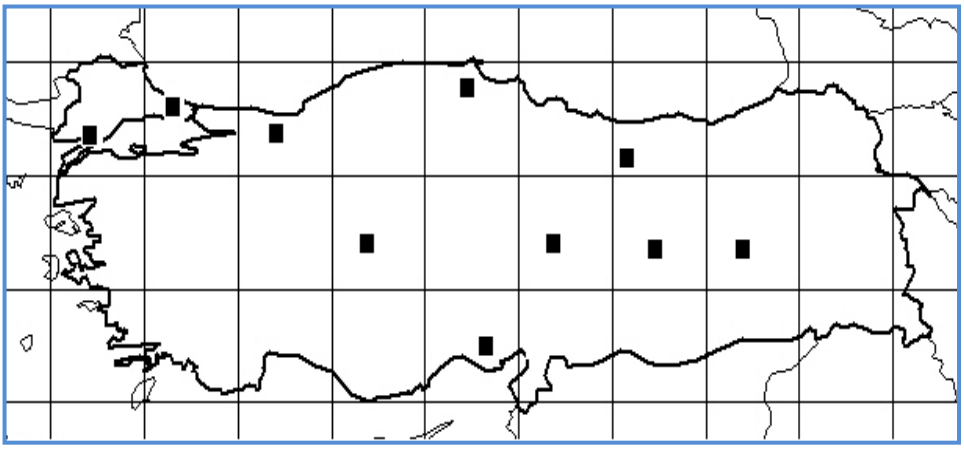


Figure 24: Distribution map of *Limonium gmelinii* (A1, A2, A3, A5, A7, B4, B6, B7, B8, C4)

A.6. *Limonium gueneri* Dogan, Duman & Akaydın, sp.nova

Habit: Perennial, Endemic; Mediterranean element; IUCN Category: CR; Flowering Period: July; Habitat: 20 m.

Table 16: General characteristics of *Limonium gueneri*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	12-22 cm	2-4 x 0.7-1 cm	1-1,5 cm	0,4-0,5 cm	1-1,5 mm	1,5-2 mm	3-3,5 mm	4-5 mm
Shape	herba-ceous	fleshy	conges ted		ovate	ovate	obovate	infundi bular
Other		mucro		4-5 fl.				

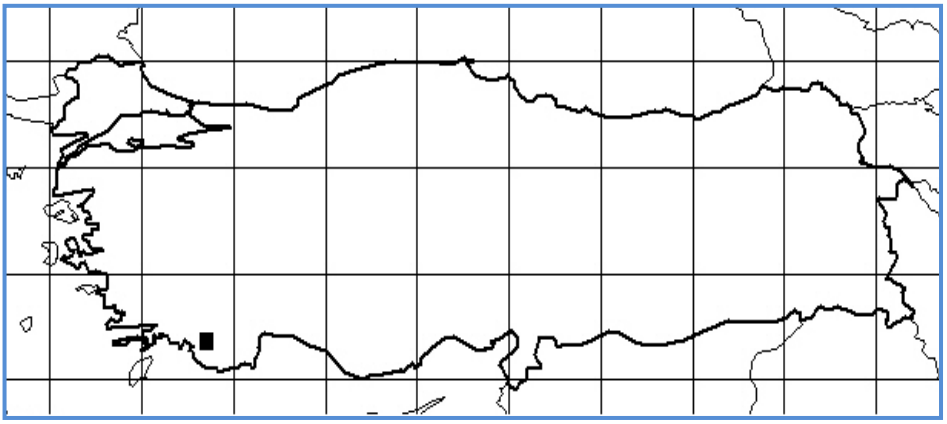


Figure 25: Distribution map of *Limonium gueneri* (C2)

Figure 26: *Limonium gueneri* Dogan, Duman & Akaydın, *sp.nova* (edited from article: Doğan, M., Duman, H., Akaydın, G., 2008)

A.7. *Limonium bellidifolium* (Gouan) Dumort.

Habit: Perennial, sub-shrubs; Euro-Sibirian element; IUCN Category: EN; Flowering Period: June-September; Habitat: 0-1010 m.

Table 17: General characteristics of *Limonium bellidifolium*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	15-40 cm	2-5 x 1,5-2 cm	1-1,5 cm	0,3-0,4 cm	1-1,5 mm	1,5-2 mm	2,5-3,5 mm	3-4,5 mm
Shape	with caudex		compact		ovate	ovate	obovate	obconical
Other				2-3 fl.				pilose

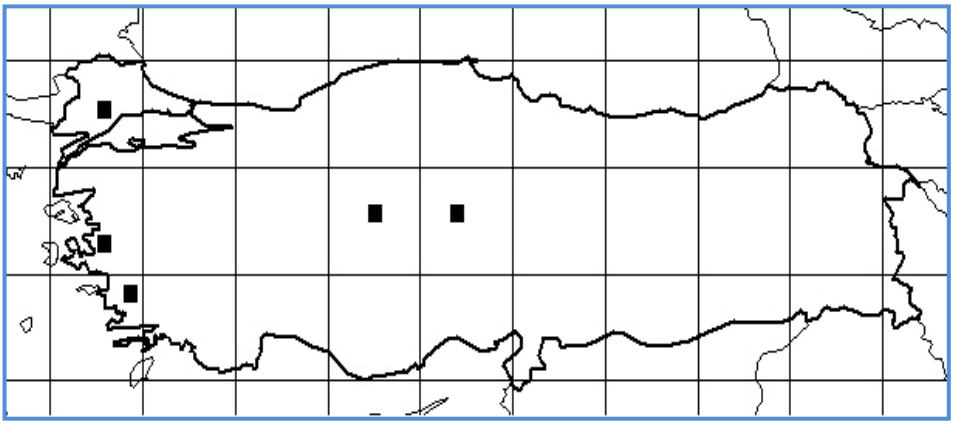


Figure 27: Distribution map of *Limonium bellidifolium* (A1, B1, B4, B5, C1)

Figure 28: *Limonium bellidifolium* (edited from Flore descriptive et illustrée de la France)

A.8. *Limonium vanense* Kit Tan & Sorger

Habit: Perennial; Endemic; Irano-Turanian element. IUCN Category: CR; Flowering Period: June to August; Habitat: 1600-2200 m.

Table 18: General characteristics of *Limonium vanense*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	15-30 cm	3-6 x 0,7-1,5 cm	around 2 cm	0,4-0,5 cm	1-1,8 mm	around 2 mm	2-2,5 mm	3,5-4,5 mm
Shape	herba-ceous	elliptic			keeled	obovate		infundibular
Other				1-2 fl.				

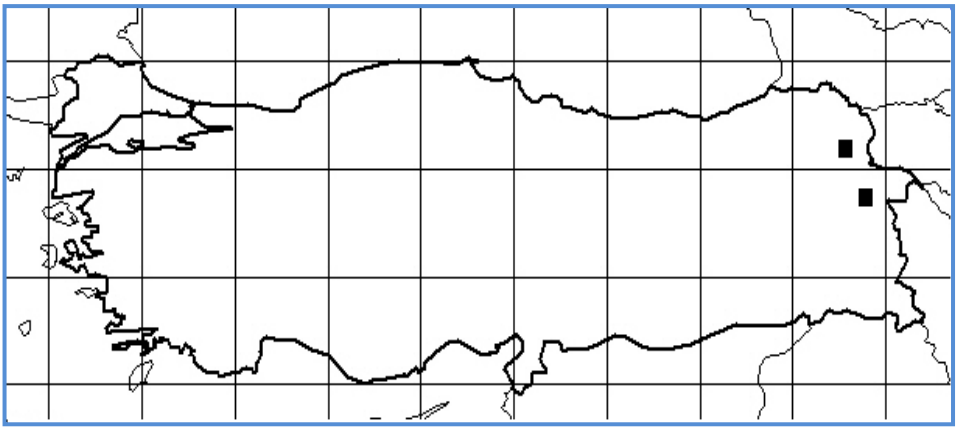


Figure 29: Distribution map of *Limonium vanense* (A9, B9)

A.9. *Limonium caspium* (Willd.) Gams

Habit: Perennial, sub-shrubs; Irano-Turanian element. IUCN Category: CR; Flowering Period: June to August; Habitat: 850-1100 m.

Table 19: General characteristics of *Limonium caspium*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	15- 25 cm	1,5-4 x 0,5-1,5 cm	0,8-1,2 cm	0,3-0,4 cm	0,7-1,3 mm	1,2-1,5 mm	2-2,5 mm	3-3,5 mm
Shape	with caudex	oblong	com pact		ovate	obovate	ovate	obconi cal
Other				1-2 fl.		keeled		pilose

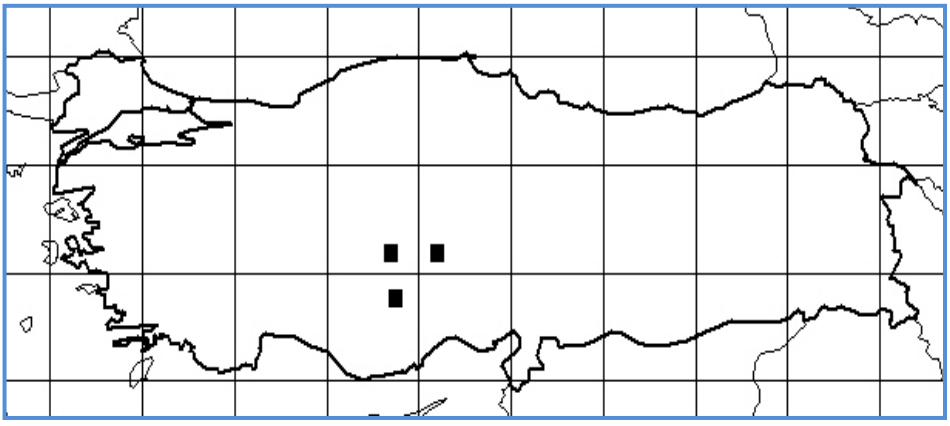


Figure 30: Distribution map of *Limonium caspium* (B4, B5,C4)

A.10. *Limonium smithii* Akaydın sp.nov.

Habit: Perennial, sub-shrubs; Endemic; Irano-Turanian element; IUCN Category: CR; Flowering Period: June; Habitat: 1085 m.

Table 20: General characteristics of *Limonium smithii*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	10-20 cm	1-3 x 0,3-0,6 cm	1-1,5 cm	0,4-0,5 cm	1-1,3 mm	1-1,5 mm	2-2,5 mm	3-4 mm
Shape	with caudex		conges ted		ovate	obovate	ovate	obconi cal
Other				2-3 fl.				

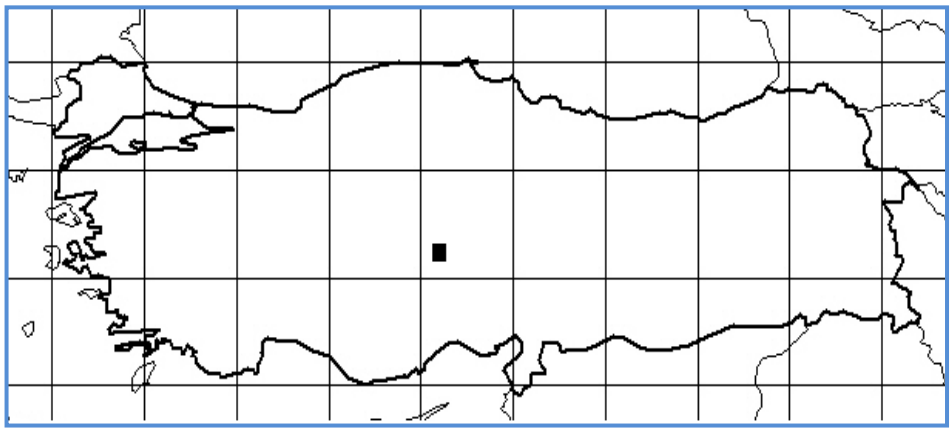


Figure 31: Distribution map of *Limonium smithii* (B5)

Figure 32: *Limonium smithii* (edited from article: Akaydın, G., 2007)

A.11. *Limonium graecum* (Poiret) Rech. Fil.

Habit: Perennial; Mediterranean element; IUCN Category: CR; Flowering Period: May-July; Habitat: 0-5 m.

Table 21: General characteristics of *Limonium graecum*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	15-30 cm	1,5-4 x 0,4-1 cm	1-2 cm	0,7-1 cm	1,5-2,5 mm	3-5 mm	4-6 mm	6-7 mm
Shape	sub-shrub	oblong	lax		ovate	ovate	obovate	infundibular
Other		fleshy		2-3 fl.			hyaline margin	

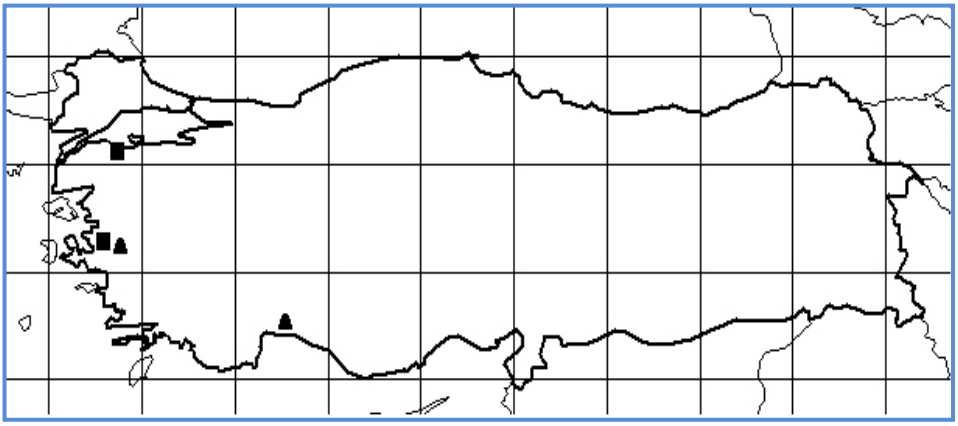


Figure 33: Distribution map of *Limonium graecum* (A1, B1, C3)

variety: graecum (regtangular shape), variety: hyssopifolium (triangular shape)

A.12. *Limonium virgatum* (Willd.) Fourr.

Habit: Perennial; Mediterranean element; IUCN Category: EN; Flowering Period: June to October ; Habitat: 0-20 m.

Table 22: General characteristics of *Limonium virgatum*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	25-40 cm	2-6 x 0,3-1cm	1,5-2 cm	0,7-0,8 cm	1,5-2 mm	2-3 mm	3-6 mm	5-6 mm
Shape	sub-shrub	oblong	com pact		ovate	ovate	ovate	infundi bular
Other				3-4 fl.				

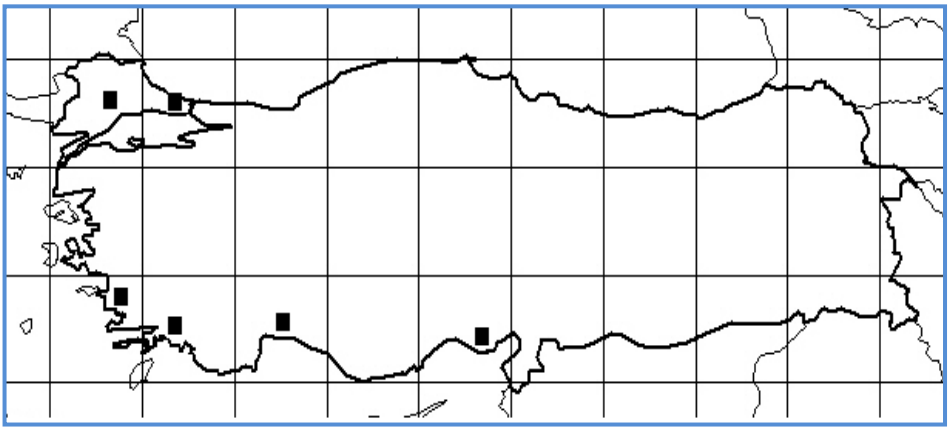


Figure 34: Distribution map of *Limonium virgatum* (A1, A2, B1, C1, C2, C3, C5)

Figure 35: *Limonium virgatum* (edited from Flore descriptive et illustrée de la France)

A.13. *Limonium sieberi* (Boiss.) O.Kuntze

Habit: Perennial; Mediterranean element; IUCN Category: EN; Flowering Period: May-August; Habitat: 0-5 m.

Table 23: General characteristics of *Limonium sieberi*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	20-30 cm	1-5 x 0,3-1 cm	1,5-2 cm	0,6-0,8 cm	1-1,5 mm	1,5-2 mm	2,5-4 mm	3-4 mm
Shape	sub-shrub	rounded	lax		Ovate	ovate	obovate	infundibular
Other				1-2 fl.				pilose

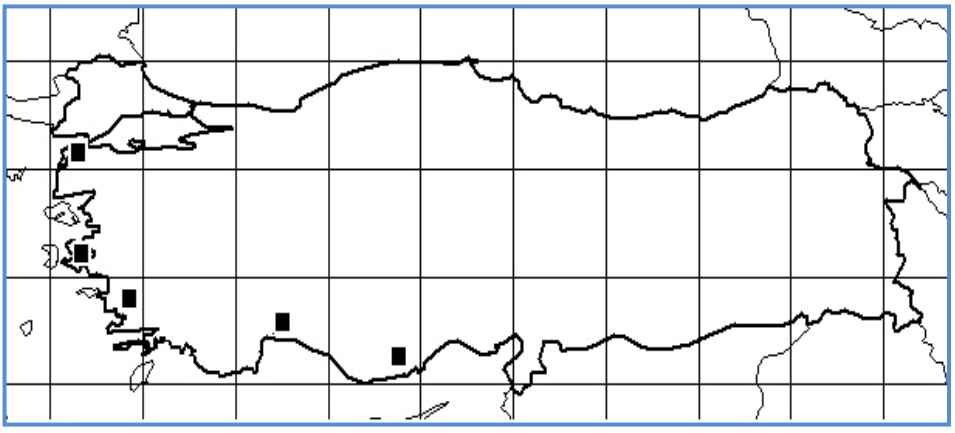


Figure 36: Distribution map of *Limonium sieberi* (A1, B1, C1, C3, C4)

A.14. *Limonium tamaricioides* Bokhari

Habit: Perennial, sub-shrub; Endemic; Irano-Turanian element; IUCN Category: CR; Flowering Period: June-July; Habitat: 950-1100 m.

Table 24: General characteristics of *Limonium tamaricioides*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	15- 25 cm	20-25 x 3-5 mm	1-1,5 cm	0,3-0,4 cm	1-1,3 mm	2-2,5 mm	1-2 mm	2-3 mm
Shape	with caudex				ovate	ovate	ovate	obconical
Other				2-3 fl.				

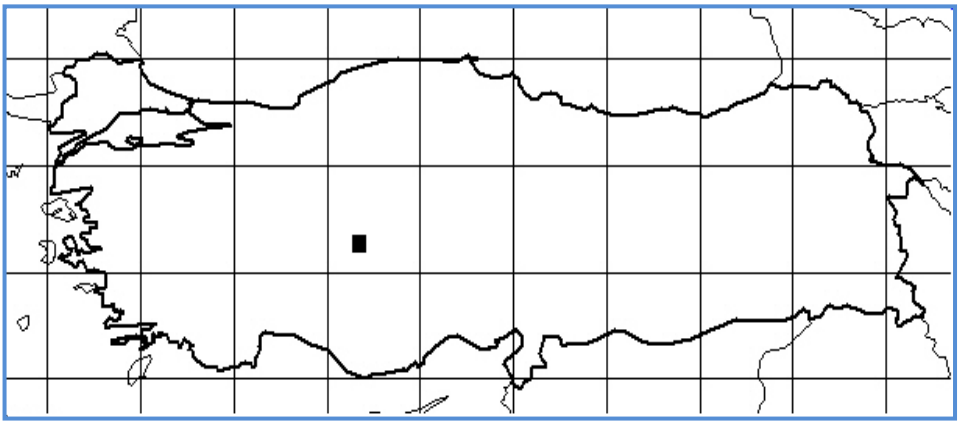


Figure 37: Distribution map of *Limonium tamaricioides* (B4)

A.15. *Limonium iconicum* (Boiss. & Heldr.) O.Kuntze

Habit: Perennial, shrubs; Endemic; Irano-Turanian element; IUCN Category: EN; Flowering Period: June-September; Habitat: 800-1400 m.

Table 25: General characteristics of *Limonium iconicum*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	10-25 cm	2-5 x 0,5-2 cm	1-1,5 cm	0,2-0,3 cm	1-1,5 mm	around 1,5 mm	2-2,5 mm	2-3 mm
Shape	with caudex		lax		ovate	ovate	obovate	infundibular
Other				2 fl.				

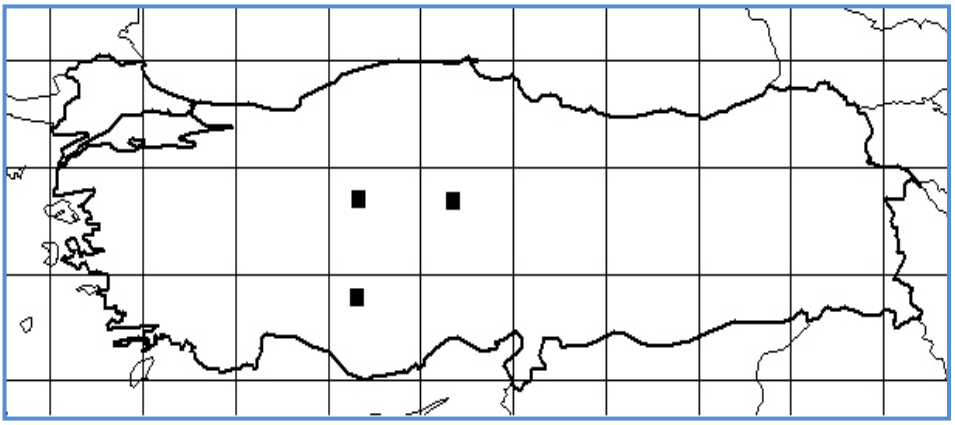


Figure 38: Distribution map of *Limonium iconicum* (B4, B5, C4)

A.16. *Limonium ocymifolium* (Poiret) O.Kuntze

Habit: Perennial; Mediterranean element; IUCN Category: CR; Flowering Period: May-July; Habitat: 0-10 m.

Table 26: General characteristics of *Limonium ocymifolium*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	15-20 cm	3-5 x 0,3-1,5 cm	~ 1,5 cm	0,6-0,8 cm	1-1,5 mm	~ 2,5 mm	4-6 mm	5-6 mm
Shape	shrub	spathulate	congested	erect	ovate, triangle	ovate	elongate ovate	obconical
Other	glabr-ous	fleshy		2-3 fl.				

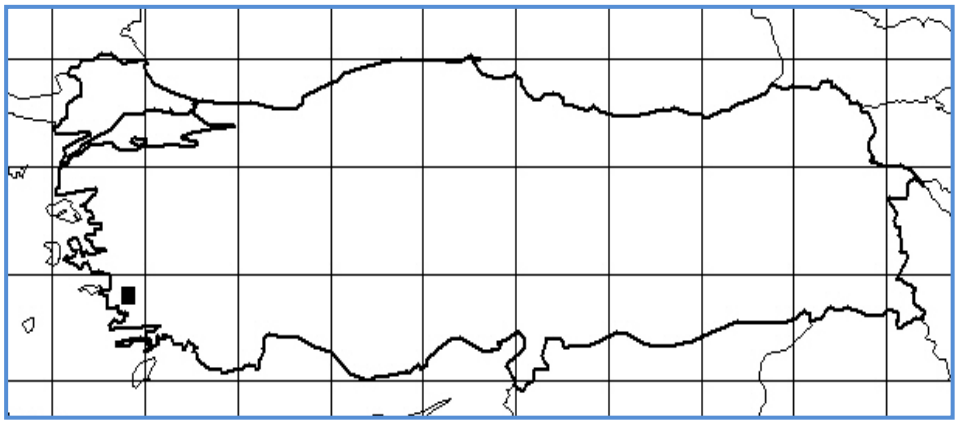


Figure 39: Distribution map of *Limonium ocymifolium* (C1)

Section Sphaerostachys

A.17. *Limonium globuliferum* (Boiss. & Heldr.) O.Kuntze

Habit: Perennial, herbaceous; Endemic; Irano-Turanian element; IUCN Category: CR; Flowering Period: June-September; Habitat: 900-1100 m.

Table 27: General characteristics of *Limonium globuliferum*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	15-40 cm	3-13 x 2-5 cm	1-1,5 cm	0,2-0,4 cm	1,1-5 mm	1,-2,5 mm	2-3 mm	2-3 mm
Shape	with caudex	oblong	com pact		ovate	ovate	ovate	obconi cal
Other				2-3 fl.				hairy

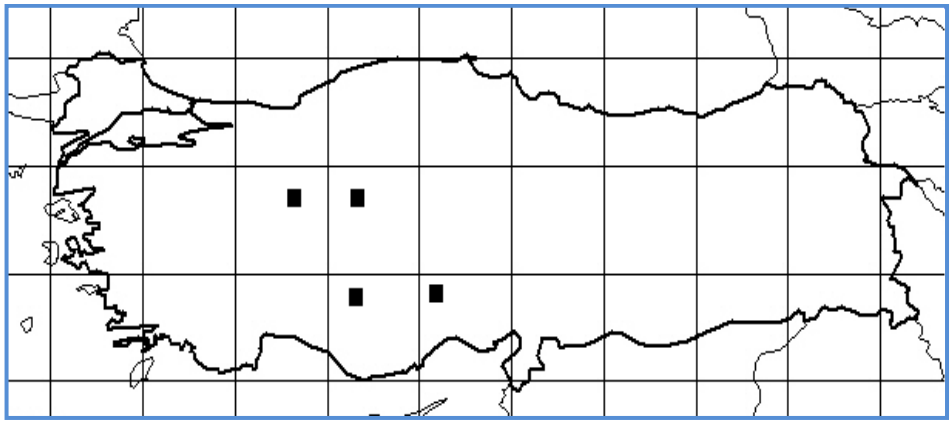


Figure 40: Distribution map of *Limonium globuliferum* (B3, B4, C4, C5)

A.18. *Limonium lilacinum* (Boiss. & Bal.) Wagenitz

Habit: Perennial, herbaceous; Endemic; Irano-Turanian element; IUCN Category: CR; Flowering Period: June-September; Habitat: 900-1200 m.

Table 28: General characteristics of *Limonium lilacinum*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	20-30 cm	4-15 x 1,5-5 cm	1-1,5 cm	0,4-0,5 cm	2-2,5 mm	2,5-3,5 mm	3,5-4 mm	4-5 mm
Shape	with caudex		com pact		tri angle	ovate	obova te	infundi bular
Other				2-4 fl.				

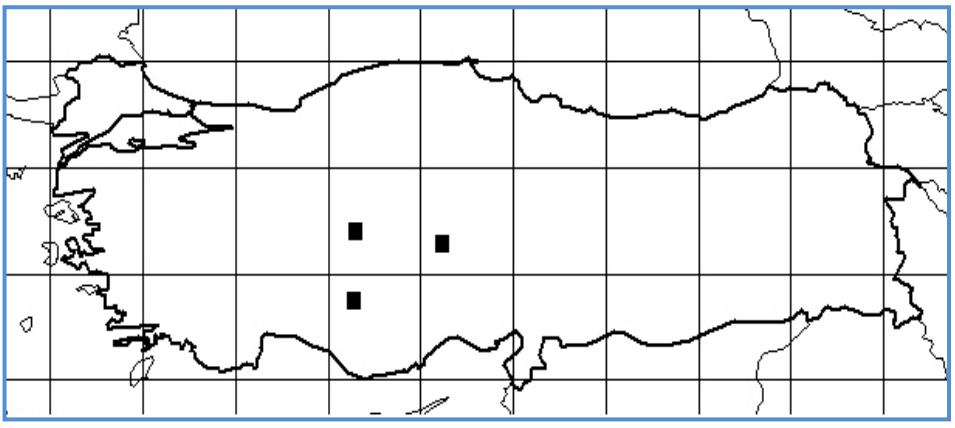


Figure 41: Distribution map of *Limonium lilacinum* (B4, B5, C4)

A.19. *Limonium pycnanthum* (C.Koch) O.Kuntze

Habit: Perennial, herbaceous; Endemic; Irano-Turanian element; IUCN Category: CR; Flowering Period: June-September; Habitat: 850-1500 m.

Table 29: General characteristics of *Limonium pycnanthum*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	20-60 cm	4-10 x 1,5-4 cm	1-1,5 cm	0,2-0,4 cm	1-1,5 mm	1,5-2,5 mm	3-4 mm	2,5-3,5 mm
Shape	with caudex	elliptic	lax		keeled	membranous	rounded	infundibular
Other				1-2 fl.				

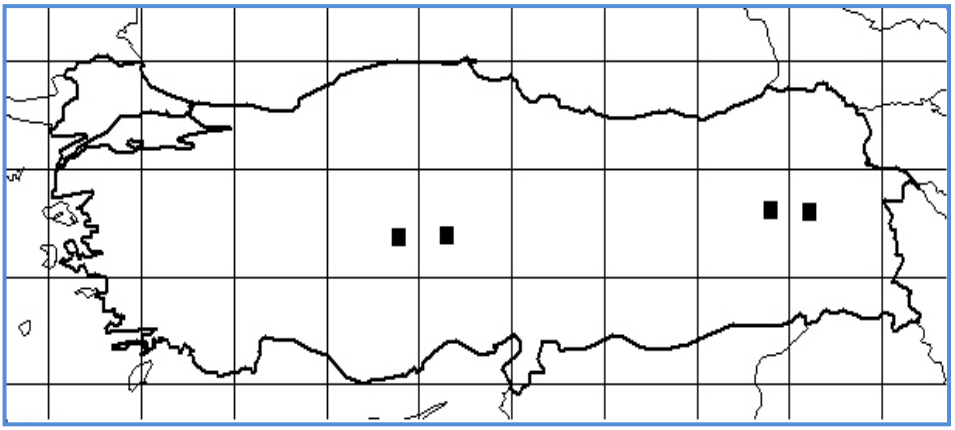


Figure 42: Distribution map of *Limonium pycnanthum* (B4, B5, B8, B9)

Section Sarcophyllum [(Boiss.) Lincz]

A.20. *Limonium anatolicum* Hedge

Habit: Perennial, Endemic; Irano-Turanian element; IUCN Category: CR; Flowering Period: July-October; Habitat: 900-1000 m.

Table 30: General characteristics of *Limonium anatolicum*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	15-20 cm	3-9 x 1-1,5 mm	0,7-1,5 cm	0,6-0,8 cm	1,5-2 mm	2-3 mm	3-4 mm	4-4,5 mm
Shape	sub-shrub	regtangular	congested	sub-erect	triangle	ovate	hyaline margin	tubular
Other		fleshy		1-3 fl.				glabrous

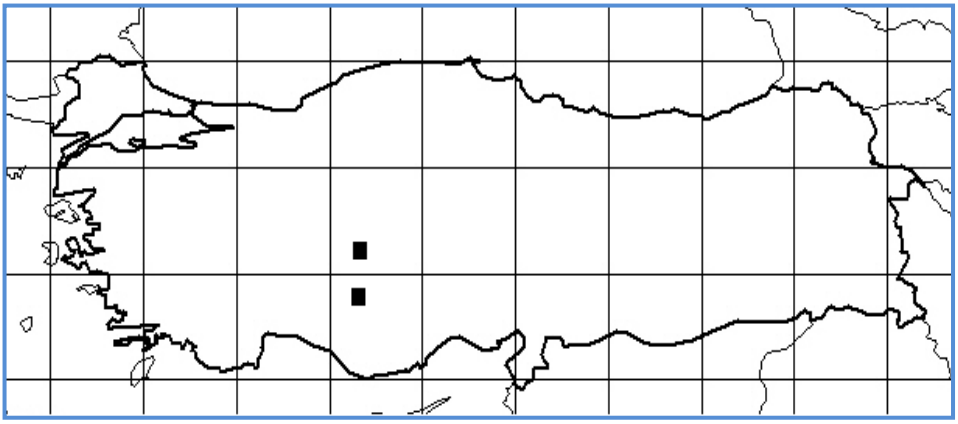


Figure 43: Distribution map of *Limonium anatolicum* (C4, B4)

Section Schizyhymenium [(Boiss.) Bokhari]

A.21. *Limonium echioides* (L.) Miller

Habit: Annual; Mediterranean element; IUCN Category: VU; Flowering Period: April-June; Habitat: 0-5 m.

Table 31: General characteristics of *Limonium echioides*

Info.	Scape	Leaves	Spike	Spikelet	Outer Bract	1st Inner Bract	2nd Inner Bract	Calyx
Size	10-25 cm	1-3 x 0,5-1 cm	1-1,5 cm	0,6-0,7 cm	1,5-2 mm	2-3 mm	5-6 mm	~ 5 mm
Shape	herba-ceous		lax		ovate	ovate	obovate	infund ibular
Other				1-2 fl.				

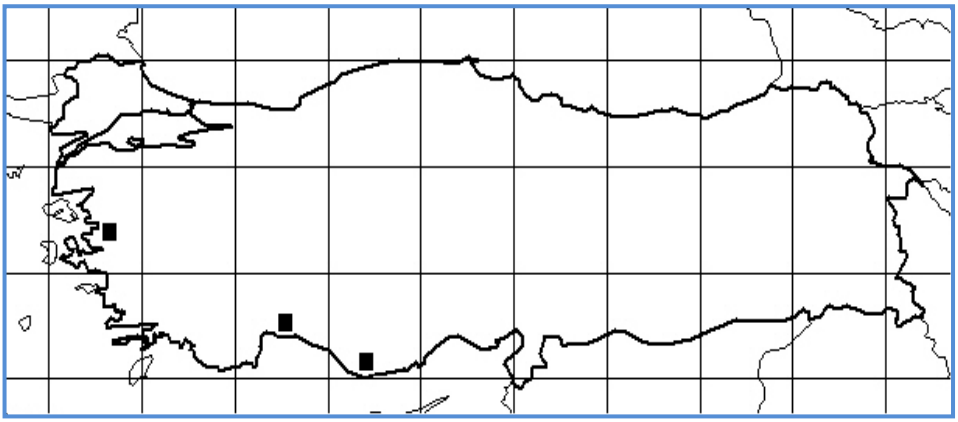


Figure 44: Distribution map of *Limonium echioides* (B1, C3, C4)

Figure 45: *Limonium echioides* (edited from Flore descriptive et illustrée de la France)

APPENDIX B

CHARACTERS VS OTUS DATA MATRIX

(The first row represents the characters as indicated in Table 8)

Table 32: Characters vs OTUs Data Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
L.anatolicum	1	0	0	3	4	1	0	0	1	1	1	0	0	1	0	2	0	0	1	0	1	1	0	0	0	2	1
L.angustifolium	1	0	1	1	4	0	1	2	1	1	0	0	1	2	1	2	0	0	1	1	0	0	0	1	1	1	2
L.bellidifolium	1	0	0	2	3	2	2	2	1	0	0	0	1	2	1	2	0	0	0	1	1	1	0	0	0	0	2
L.caspium	1	0	0	2	3	1	0	1	1	0	0	0	1	1	0	1	0	0	0	1	1	0	0	0	0	0	2
L.echioides	0	0	1	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	1	1	1	1	0	0	1	1	2
L.effusum	1	0	1	2	4	0	2	2	1	1	0	0	1	2	2	0	0	0	1	1	0	0	0	1	1	0	0
L.globuliferum	1	0	1	2	3	1	1	1	1	0	1	0	1	2	2	0	0	0	1	0	0	0	1	0	0	0	1
L.gmelinii	1	0	1	1	4	2	2	1	1	1	0	0	1	2	1	0	0	0	1	1	0	0	0	1	0	0	2
L.graecum	1	0	0	1	1	0	1	1	1	1	0	0	1	1	0	2	0	0	1	0	1	1	0	1	1	1	2
L.gueneri	1	0	1	3	1	0	1	0	1	0	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	1	1
L.iconicum	1	0	0	2	3	1	0	2	1	0	0	0	1	1	1	1	0	0	0	1	1	1	0	0	0	0	2
L.lilacinum	1	0	1	2	3	1	0	1	1	0	1	0	1	2	2	1	0	0	1	0	1	1	0	1	0	1	2
L.meyeri	1	0	1	3	3	1	0	1	1	1	0	0	1	2	2	0	0	0	1	1	1	1	0	1	1	1	2
L.ocymifolium	1	0	0	1	1	0	1	0	1	1	1	0	1	1	0	2	0	0	1	0	1	1	0	0	0	1	1
L.pycnanthum	1	0	1	2	3	1	0	1	1	0	1	0	1	2	2	2	0	0	1	0	1	1	0	0	0	0	2
L.sieberi	1	0	0	1	2	0	1	1	1	1	0	0	1	1	0	2	0	0	1	1	1	1	0	1	1	1	2
L.sinuatum	1	0	1	1	2	0	1	2	0	1	1	1	0	2	1	2	1	1	1	0	0	0	2	1	0	2	2
L.smithii	1	0	0	2	0	1	0	0	1	0	0	0	1	0	0	1	0	0	1	0	1	0	0	0	0	0	1
L.tamaricoides	1	0	0	2	1	1	0	1	1	0	0	0	0	1	0	1	0	0	0	1	1	1	0	1	0	0	1
L.vananse	1	0	1	2	3	1	0	1	1	1	0	0	1	1	0	0	0	0	1	1	1	1	0	0	0	1	2
L.virgatum	1	0	0	1	1	0	1	2	1	1	0	0	1	1	0	2	0	0	1	1	1	1	0	1	0	2	0

Table 32 (Continued)

	28	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**
L.anatolicum	1	2	1	1	0	1	0	1	1	0	0	0	0	1	0	1	0	0	0	0	1	2	1	1	1
L.angustifolium	1	0	0	1	0	1	0	0	0	1	0	0	1	1	0	2	0	0	1	0	1	1	1	1	1
L.bellidifolium	1	1	1	1	0	0	1	1	0	2	0	0	1	1	0	2	1	0	0	0	2	1	1	1	1
L.caspium	0	0	0	1	1	1	0	0	0	0	1	0	2	0	0	0	1	0	0	0	1	1	1	1	1
L.echioides	0	0	0	1	0	1	0	0	0	1	0	0	0	2	1	1	1	0	1	0	2	0	0	0	0
L.effusum	0	0	1	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	1	1	1	1	1
L.globuliferum	1	1	2	0	0	1	2	1	2	0	0	0	1	1	2	0	0	0	0	0	0	1	1	1	1
L.gmelinii	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1
L.graecum	1	2	1	1	0	0	0	2	2	1	0	0	0	2	0	2	1	0	2	1	2	0	1	1	1
L.gueneri	2	1	0	1	0	1	0	1	1	2	0	0	0	2	2	1	0	0	2	1	1	0	1	1	1
L.iconicum	1	0	0	1	0	0	2	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1	1
L.lilacinum	1	2	2	1	0	1	0	2	1	0	0	0	1	2	2	0	1	0	2	2	0	0	1	1	1
L.meyeri	1	0	1	1	1	1	0	1	1	1	0	0	0	2	1	1	0	0	1	1	1	1	1	1	1
L.ocymifolium	1	0	1	0	0	1	0	2	2	0	0	0	0	1	1	1	0	0	1	0	2	1	0	1	1
L.pycnanthum	0	0	0	1	0	1	0	0	0	1	0	0	1	1	1	0	0	0	0	1	0	0	1	1	2
L.sieberi	0	1	1	1	0	1	0	2	2	1	0	0	0	2	0	2	1	0	2	1	2	0	1	1	1
L.sinuatum	2	2	0	2	0	1	0	2	0	2	0	1	0	2	1	2	0	0	2	0	2	0	0	1	0
L.smithii	1	0	0	1	0	1	2	0	0	1	1	0	2	0	0	0	0	0	0	0	0	1	1	1	1
L.tamaricoides	1	1	0	1	0	0	2	0	0	2	0	0	0	0	0	1	0	0	0	0	1	1	1	1	2
L.vananse	0	0	0	1	0	1	0	0	1	0	1	0	1	0	1	0	1	0	0	1	0	0	1	1	1
L.virgatum	2	2	2	1	0	1	0	2	1	2	0	0	0	2	2	1	0	0	2	2	2	0	1	1	1

APPENDIX C

DISTANCE MATRIX

(Species written as integer numbers in columns and rows are in alphabetical order)

Table 33: Distance Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0																				
2	5,83	0																			
3	6	4,9	0																		
4	5,74	5,2	5,39	0																	
5	7,68	6,86	7,55	6,63	0																
6	6,71	4,8	5,92	6	7,62	0															
7	6,24	6,56	6,4	6,32	8	5,29	0														
8	6,56	5	5,74	5,1	7,48	4,24	5,66	0													
9	6,24	6,08	5,92	7,21	6	7,62	7,48	7,62	0												
10	6,48	6,63	6,93	7	5,92	6,86	6,24	7	5,57	0											
11	6,24	5,39	5	3,74	7,07	5,83	5,66	5,29	7,21	7,14	0										
12	6,16	6,63	6,78	6,86	7,68	6,86	5,2	6,71	5,92	5,83	6,56	0									
13	5,48	4,9	5,66	5,74	6,56	5	5,39	5,2	5,92	5,29	5,74	4,69	0								
14	5,39	6,24	6,4	6,32	5,48	6,93	6,16	6,78	4,47	5,39	6,78	6,4	5,92	0							
15	5,92	5	5,57	4,69	6,93	5,48	5,48	5,29	7,07	6,24	4,47	5,2	4,8	6,32	0						
16	6	5,29	5,66	6,56	5,74	7	7,28	7,14	2,24	5,83	6,86	5,83	5,29	4,36	6,56	0					
17	7,28	6,08	6,86	8,37	7,35	8	8	8,12	5,83	6,24	8,25	7	6,86	6,78	7,62	6,08	0				
18	6,93	7,07	6,78	4,8	6,4	7,55	6,56	7,14	7,42	6,32	5	7,87	7,07	6,24	5,92	7,48	8,77	0			
19	6,08	6,08	5	5,29	6,48	6,48	6,63	6,32	6,32	6,08	4,47	7,55	6,08	6,16	5,66	6,4	7,62	4,36	0		
20	5,66	5,48	6,32	3,61	6,08	5,74	5,74	4,8	6,86	6,16	4,12	5,83	4,9	6,08	4,36	6,16	8,19	5,48	5,74	0	
21	7	7	6,86	8,25	7,07	7,62	7,62	8,12	4,47	5,39	8,12	5,92	6,4	5,48	7,62	4,8	6	8,06	6,93	7,55	0