# MORPHOMETRIC ANALYSIS OF OAK (*QUERCUS* L.) ACORNS IN TURKEY

by

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# ABSTRACT


MORPHOMETRIC ANALYSIS

OF OAK (*QUERCUS* L.) ACORNS IN TURKEY

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Morphometric analyses of 14 Turkish oak (*Quercus* L.) species were carried out using both quantitative and qualitative acorns' characters. The materials were collected from 47 populations representing different regions of Turkey.

First, investigation of the usefulness of chosen characters was tested for classification of genus *Quercus* L. Second, classifications of traditional studies were compared in order to show the possible congruency of groupings resulted from the morphometric analyses. Finally, it was intended to indicate the spectrum of variation within the quantitative characters chosen for the study.



**Keywords:** Plant taxonomy, morphometric analyses, *Quercus*, oak acorn, Turkey.

# ÖZET

TÜRKİYE'DEKİ MEŞE (*QUERCUS* L.) PALAMUTLARININ

MORFOMETRİK ANALİZİ

Bakış, Yasin

Yüksek Lisans, Biyoloji Bölümü

Tez Danışmanı: Prof. Dr. M. Tekin Babaç

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Türkiye'de bulunan 14 meşe (*Quercus* L.) türünün morfometrik analizleri nitel ve nicel palamut karakterleri kullanılarak yapıldı. Çalışmada kullanılan materyal bütün Türkiye'nin farklı bölgelerini temsil eden 47 populasyondan toplandı.

İlk olarak, seçilen karakterlerin *Quercus* L. cinsinin sınıflandırılmasında kullanılabilirliği araştırıldı. İkinci olarak, geleneksel sınıflama çalışmaları morfometrik analizlerden elde edilen gurupların olası uygunluğunu göstermek için karşılaştırıldı. Son olarak, çalışma için seçilen nicel karakterlerin içindeki çeşitliliğin spektrumunun belirlenmesine çalışıldı.

**Anahtar Kelimeler:** Bitki taksonomisi, morfometrik analizler, *Quercus*, meşe palamutu, Türkiye.

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# ABBREVIATIONS AND SYMBOLS

| | |
|---|---|
| PCA | Principal Component Analysis |
| UPGMA | Unweighted Pair-Group Method of Analysis |
| OTU | Operational Taxonomic Unit |
| PC | Personal Computer |
| EUR.-SIB. (EUX) | Euro-Siberian region - Euxine province |
| (Col) | Colchic sector of Euxine province |
| MED. (T.) | Mediterranean region - east Mediterranean province - Taurus district |
| MED. (W.A.) | Mediterranean region - east Mediterranean province - West Anatolian district |
| IR.-TUR. (C.A.) | Irano-Turanian region - Central Anatolia |
| IR.-TUR. (E.A.) | Irano-Turanian region - East Anatolia |
| URL | Uniform Resource Locator |

# 1. INTRODUCTION

Man seeks to understand whole living world and to pass his knowledge on to others. Faced with the broad diversity in the natural world, man instinctively classifies, divides this diversity up into smaller, more manageable groups (Heywood, 1972). Ancients gave plants a name and put them into categories since their edible, medicinal, and decorative uses. In the late 18th century, Swedish naturalist, Carl Linnaeus set about methodically classifying and naming the whole of the natural world. Today's scientists still struggle with classifying organisms by using extremely developed analyzing methods.

In recent years, there are numerous changes and developments in the outlook and methodology in the fields of biological systematics and population biology. Many of the new approaches are concerned with a variety of mathematical techniques. There has been a considerable development of numerical methods in taxonomy. Numerous new concepts and techniques were gained for systematics. Numerical taxonomy uses the way of grouping by numerical methods of taxonomic units into taxa on the basis of their character states (Sneath and Sokal, 1973; Felsenstein, 1983).

The personal computer (PC) revolution has provided the power of the desktop. Revolutionizing the way scientists can interact and use of personal computer, they have gone from punched cards to speech recognition. Availability of statistical programs and their ease of use rise to a very high rank with ranging from completely integrated computer packages to specialized programs (Hair et al., 1998). Interpretation of taxonomic data thus provides construction of taxa by using morphological characters of organisms. Researchers, today, can find most of the techniques in PC format to use in their studies.

The widespread acceptance of computer-assisted analyzing techniques is becoming influential. Verbal descriptions of characters and character states are not successful presently after the approach of mathematical algorithms for the analysis of phylogenetic data (Rae, 1998). These computer programs work with alphanumeric codes that represent character states. Therefore, raw data of taxonomic biodiversity patterns are required to be translated into these codes. Organisms are considered to belong to the same species. Coded characters representing biodiversity data then will construct taxa by using similarities among character states of taxonomic units.

## 1.1. BIODIVERSITY AND BIOGEOGRAPHY OF TURKEY

Turkey is positioned in the subtropics zone in between 36-42 north latitudes and 26-45 east longitudes. Turkey covers about 78,000,000 hectares total area and the surface area is divided into two parts; Anatolia and Trace by Marmara Sea. Most of Anatolia consists of a plateau; rising steadily towards the east and bounded on the north and south by steep mountain ranges, part of the Alpine-Himalayan system (Ertaş, 1995). Country can be divided into seven geographic regions as in figure 1. Geographically Turkey is a land bridge between Europe and Asia (Aksoy, 2003; Alan, 2001).

In general, the Middle East is rich in flora and plant genetic diversity and Turkey has a number of plant species for which this is higher than all neighboring countries (Alan, 2001). The area, which occupies north-east corner of Africa and south-west edge of Asia, is very heterogeneous physiographically and phytogeographically, because it is a meeting of five world wide phytogeographical regions which differ from one another not only in their inventory flora and vegetation but also their floro-historical past (Zohary, 1971). However, Turkey is divided into three main floristic regions by Davis (1971): the Euro-Siberian, the Mediterranean and the Irano-Turanian Phytogeographical region (Figure 1). It is difficult to discuss the flora in Turkey except in the concept of the three phytogeographical regions present, as mapped by Davis (1971). Of the three phytogeographical regions presents in Turkey, the Mediterranean region is marginally larger than the Euro-Siberian region, but only one-third the size of the Irano-Turanian region of inner Anatolia, which is in contact with the other two areas (Davis, 1974). A great number of community types and habitat mosaic occurs, containing a rich mixture of plant and animal species, many of which are endemic (Kaya and Raynal, 2001). The proportion of endemism varies from group to group, and about 30% of the vascular plant flora are endemic (Davis, 1971-1974; Alan, 2001). Davis (1971) suggested that there was a distributional floral break in central Anatolia; many species do not occur west of the hypothetical diagonal and likewise significant numbers are not known to the east of it. He defined this oblique belt as running from the north-east southwards to the Anti-Taurus; thence with a bifurcation, one fork to the Amanus, the other to the Cilician Taurus. Phytogeographical regions with subregions was represented in most recent study (Borazan and Babaç, 2003) as follows; EUR.-SIB. (EUX): Euro-Siberian region - Euxine province, (Col): Colchic sector of Euxine province, MED. (T.): Mediterranean region - east Mediterranean province – Taurus district, MED. (W.A.): Mediterranean region - east Mediterranean province – west Anatolian district, IR.-TUR. (C.A.): Irano-Turanian region – central Anatolia, IR.-TUR. (E.A.): Irano-Turanian region – east Anatolia.

Davis (1971) suggested that Anatolian Diagonal was the demarcation line between the Central Anatolian and Eastern Anatolian, subdivisions of the Irano-Turanian region. Eastern side of the diagonal has the endemism rate of 30%, while western side has 65% and diagonal species has 75% according to Ekim and Güner (1986). They explained that as; present richness in the neo-endemic steppe species might be caused by migration or evolution. They said that the evolution is the only explanation for the richness, greater neo-endemism than the palaeo-endemism and distribution patterns of the plants related to the Diagonal.

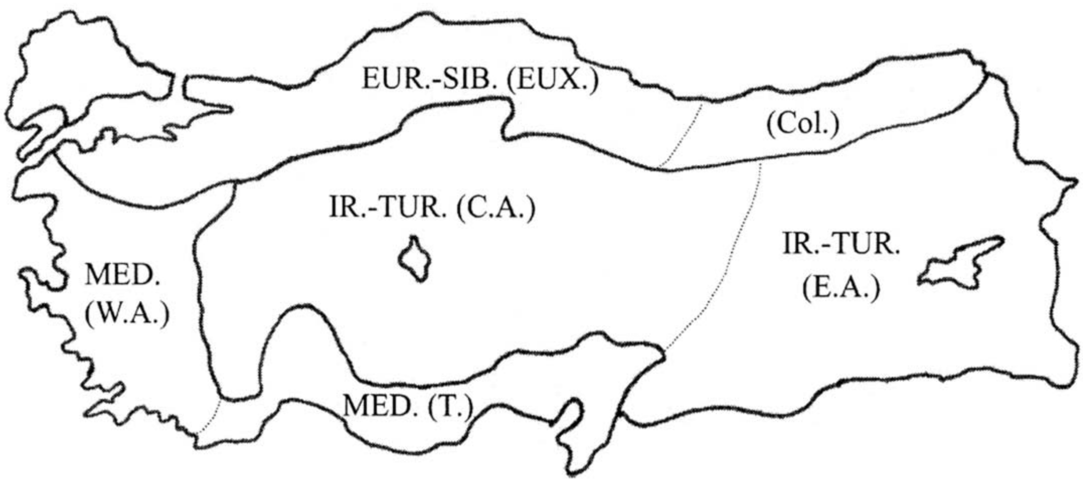


Figure 1 – Phytogeographical regions in Turkey

## 1.2. *QUERCUS*

The oaks constitute one of the most important groups of trees in the world (Wyman, 1962; Manos et al., 1999; Yaltırık, 1984). They are also very abundant and economically important genera of woody plants. Fagaceae family contains the most important representatives of large parts of the forests in the northern hemisphere (Fey and Endress, 1983; Manos et al., 2001). The family Fagaceae currently includes nine genera. *Quercus* is the largest genus in the Fagaceae. Approximately 500 species of trees and shrubs has been recorded from all over the world. With a wide geographic distribution, oaks are obviously important members of the deciduous forests and also important evergreen elements of Mediterranean woodlands and subtropical forests (Manos et al., 1999). Over geologic time, diversity and abundance permitted oaks to assume widespread ecological importance (Pavlik et al., 2002). Oaks provide habitat for many wildlife species. Acorns are essential for oak regeneration and are a major food source for many species of birds and mammals (Al Jassim et al., 1998; Pavlik et al., 2002; Rakic et al., 2005).

The Latin name, *Quercus*, has always stood for oak and was derived from two Celtic words: *quer*, meaning fine and *cuez*, meaning tree (Pavlik et al., 2002). Oaks have carried the meaning of their name in different cultures. Many nations give respectful names, and use them to honor their valiant or leader (Yaltırık, 1984). Human discovered that oaks could supply food, tools, fuel and other valuable resources more than 100 centuries ago. Presently, oaks are estimated especially as valuable timber products. Corks, tannins and dyes come from oaks, as well as valuable wildlife food in the form of acorns.

Their wood is generally strong and durable. On good sites, oaks grow relatively quickly, providing landscape and shade values within five to ten years. Some species of oaks are relatively short-lived. White oaks (Section *Quercus*) over 300 years old are not unusual and live oaks (*Quercus virginiana*) over 500 years old have been documented (Pavlik et al., 2002).

There are more American than Eurasian species, and there is a gradient decreasing species numbers northward and southward (Kaul, 1985). Most of the modern species-groups of *Quercus* are rather restricted geographically, indicating that they were locally evolved after the spread of genus (Trelease, 1924; Axelrod, 1983). Axelrod (1983) suggested that spread of dry climates created isolated groups. These groups underwent rapid speciation, especially in regions of greater topographic diversity. He also suggested that by the late cretaceous, after *Quercus* underwent rapid evolution in regions of mild to warm temperate climates, the family (Fagaceae) probably evolved in the montane tropics and diverged into the living genera. According to Kaul (1985), the modern center of morphological diversity is southeastern Asia and adjacent Pacific islands, and the area might be the family's ancestral home.

Genus is highly specialized within the family Fagaceae. The simplified morphological features of anemophily distinguish it from its closest relatives (Kaul, 1985). It is closest to *Lithocarpus* and in fact it is nearly indistinguishable from it in cupular and most floral features. The validity of species concepts in *Quercus* has been questioned since great variability of in some oaks (Kaul, 1985; Burger, 1975). Oak species are well known for their taxonomically complicated patterns of intraspecific morphological variation which may be due to hybridization (Manos et al., 1999).

### 1.2.1. OAKS IN TURKEY

Turkey has long been blessed by the diversity, abundance, and beauty of oaks. Great variety of oaks present in both Anatolian and European parts of Turkey, ranging from Mediterranean, Aegean, and Black Sea beaches to towering coastal and interior mountains. The group occupies 25 percent of the forest area of Turkey (Ertaş, 1995).

In Turkey, oaks are divided into three section in Flora of Turkey volume seven (Davis, 1982); red oaks, white oaks and evergreen oaks (Table 1). At present, 18 species of oak enrich the country's native flora (Davis, 1982; Yaltırık, 1984; Kasaplıgil, 1992). After the study of Revision of Oaks of Turkey, number of species is decreased from 35 to current view (Yaltırık, 1984; Kasaplıgil, 1992).

According to Yaltırık (1984), some *Quercus* taxa can be present tropics and montane areas since its high durability. Northern part of the Middle East is one of the genetic origins of the genus. Therefore, Turkey is the genetic differentiation of *Quercus* and its spreading area. This makes Turkey one of the richest regions of oak in the world.

Each taxon is strikingly different in growth form and physiology. Some grow as tall, stately trees, while some others scrubby, shrubs that are very short in stature. Some are evergreen, while some others drop their foliage at the beginning of winter. So many variations present in the size, shape, color and texture (Jensen, 1980). It is well known that reproductive barriers between oak species are week (Bacilieri et al., 1996; Manos et al., 1999; Samuel, 1999) and extensive hybridization may occur between species in the same major group or section within the group. Oak species have intraspecific morphological variation due to hybridization (Manos et al., 1999). Since introgressive hybridization occurs heavily, the genus is one of the most problematic groups in Turkey (Davis, 1982). The greatest problems of taxonomic discrimination occur especially in section *Quercus* (Bruschi et al., 2000). In nature, many oak species grow in mixed populations where widespread hybridization is present (Bacilieri et al., 1996).

### 1.2.2. MORPHOLOGY OF *QUERCUS*

The description of genus *Quercus* is as following in the Flora of Turkey (Davis, 1982) by Hedge and Yaltırık;

> "Deciduous or evergreen trees, rarely shrubs; buds spirally arranged, with imbricate scales, clustered at shoot apices. Leaves subsessile or petiolate, penninerved, serrate, dentate, pinnatifid or lobed, lobes rounded without bristles at their tips or sharply pointed with aristate tips, rarely entire. Staminate flowers in long slender pendulous catkins; calyx (4-)6(-7)-partite; stamens (4-)6(-12). Pistillate flowers solitary or 2 to several on a very short to fairly elongate peduncle; ovary 3(-4)-celled. Fruit a nut (acorn), subglobose to oblong or cylindrical, surrounded at base or sometimes nearly enclosed by cup-shaped cupule covered outside with numerous imbricate scales (in Turkish specimes); pericarp thin or thick, endocarp glabrous or pubescent; acorn maturing in one season or two years, sweet or bitter to taste."

Table 1 – Taxonomic hierarchy of genus *Quercus*

Kingdom Plantae -- Plants
  Subkingdom Tracheobionta -- Vascular plants
    Division Magnoliophyta -- Angiosperms, flowering plants
      Class Magnoliopsida -- Dicotyledons
        Subclass Hamamelidae
          Order Fagales
            Family Fagaceae
              Genus *Quercus* L. -- Oaks

Section *Quercus* (Endl.) Örsted: Section Leucobalanus -- White Oaks

- *Q. pontica* C. Koch
- *Q. robur* L.
  - *Q. robur* subsp. *robur*
  - *Q. robur* subsp. *pedunculiflora* (C. Koch) Menitsky
- *Q. hartwissiana* Steven
- *Q. macranthera* subsp. *syspirensis* (C. Koch) Menitsky
- *Q. frainetto* Ten.
- *Q. petraea* (Mattuschka) Liebl.
  - *Q. petraea* subsp. *petraea*
  - *Q. petraea* subsp. *iberica* (Steven ex Bieb.) Krassiln.
  - *Q. petraea* subsp. *pinnatiloba* (C. Koch) Menitsky
- *Q. vulcanica* [Boiss & Heldr. ex] Kotschy
- *Q. infectoria* Olivier
  - *Q. infectoria* subsp. *infectoria*
  - *Q. infectoria* subps. *boissieri* (Reuter) O. Schwarz
- *Q. pubescens* Willd.
- *Q. virgiliana* Ten.

Section *Cerris* Loudon -- Red or Black Oaks

- *Q. cerris* L.
  - *Q. cerris* var. *cerris*
  - *Q. cerris* var. *austriaca* (Willd.) Loudon
- *Q. ithaburensis* subsp. *macrolepis* (Kotschy) Hedge and Yalt.
- *Q. brantii* Lindley
- *Q. libani* Olivier
- *Q. trojana* P.B. Webb.

Section *Ilex* Loudon -- Evergreen Oaks

- *Q. ilex* L.
- *Q. aucheri* Jaub. & Spach
- *Q. coccifera* L.

### 1.2.3. ACORNS

Acorns are important food source for both human (Rakic et al., 2005; Al Jassim et al., 1998) and many wildlife species and the seed source for oak regeneration. An oak begin its life as a dormant embryo within the acorn. Cotyledons found as two large seed leaves and make up most of the acorn. Germination usually occurs in response to fall or winter rains. A typical oak tree has tens of thousands of acorns. Overlapping scales at the base of the female flower become the cupule. Each flower contains six-seed eggs, but usually only one develops to form the single-kernel acorn. The acorn is a dry fruit produced by the female organs, with a hull similar to the walnut, protecting the seed inside. The acorn contains a rich store of fat, starch and protein, which will provide the sapling with enough nutrients for a good start at growth.

Acorns vary greatly in size between and within species, depending on the oak species and its environment. *Q. ithaburensis* probably has the largest acorns of any *Quercus* species, while *Q. petraea* are smallest (Pavlik et al., 2002). This is because the fruits of species within section *Cerris* are maturing in two years, and contains a number of quantities of fat, while *Quercus* section is represented with small fruits without excess amount of fat.

The character of acorn maturation in the first year (annual maturation) or in the second year (biennial maturation) after pollination is commonly used to differentiate major groups within *Quercus* in Flora of Turkey and the East Aegean Islands (Davis, 1982).

*Quercus* has attracted the attention of evolutionists for its very poor reproductive development (Bacilieri et al, 1996). Among-tree relationships based on fruit/bud characters were found to be significantly different from among-tree relationships based on leaf characters (Jensen, 1989-1992). One of the most characteristic and peculiar features of the Fagaceae is the cupule (Fey and Endress, 1983).

An acorn is the fruit of the oak, being an oval nut growing in a woody cup or cupule. Nut is the fruit of trees and shrubs consisting of a hard and indehiscent shell inclosing a kernel (URL22). Cupule is a massive, robust and often compound envelope of fruits (Fey and Endress, 1983).

a) b)

Figure 2 – (a) Typical acorns; nuts, cupules and stalk (b) acorn transection

(Image adopted from URL23)

## 1.3. CHARACTERS

A character is a feature of an organism that can be measured, counted or otherwise assessed (Heywood, 1972). Characters are concerned with identification and classification of organisms (Karamura, 1998). A good classification of objects will largely depend on the characters selected, how varied they are, whether they show discontinuities and also the way they are treated (Pankhurst, 1991; MacLeod and Forey, 2002).

Morphological characters are commonly used in identifying plants. Good characters are not easily modified by environmental factors and have a genetic basis such that they are unlikely to change readily (Heywood, 1972; MacLeod and Forey, 2002). These may be referred to as constant characters and are highly heritable. On the other hand, bad characters are easily modified by the environment. These bad characters are not useful during classifying organisms. Stace (1989) argued that reproductive characters are sometimes unhelpful in classification. But in Jensen (1992) fruit/bud characters were found to be useful in identifying in their study with multivariate analysis.

In phenetic classification, it has been argued that as many characters as possible ought to be used when classifying organisms (Sneath and Sokal, 1973; Felsenstein, 1983). Pheneticists believe therefore that we should start with as many characters as possible giving equal weight to each character.

In phylogenetic or cladistic classifications it is argued that only characters which bear evolutionary significance must be used and other characters must be ignored (Pankhurst, 1991). However, cladistic classification can make various assumptions about the direction of evolution in any given character; they do not wait to discover fossil records.

# 2. AIM OF THE STUDY

Oaks are well known with their problematic taxonomies. Since many characters of the many populations are needed to be analyzed, multivariate analysis methods are used to treat the large number of characters expressed from taxa sampled from different populations.

In a regular taxonomic classification, a wide spectrum of variation of taxonomic characters should be exposed before a revisional study. In most cases, as a rule, plant taxonomists prefer the reproductive characters in their classifications, because of showing fewer variations with regard to having large variations of vegetative characters in different habitats. In *Quercus* taxonomy, vegetative characters, especially leaves, are commonly used instead of acorn characters. Although there are some traditional classification based on acorn characters, the numbers of quantitative ones are quite low, and it is predicted that their taxonomic values of acorn characters are not valuable (Jensen, 1989).

Because of these reasons, aims of the study are stated as follows:

1. to investigate the usefulness of some quantitative and qualitative acorn characters for classifying Turkish *Quercus* by using of morphometric analyses,

2. to compare the groups obtained from the morphometric analyses and traditional classifications, and

3. to describe the variation of some acorn characters within and between populations.

# 3. MATERIALS AND METHODS

## 3.1. SAMPLING METHOD

Acorns were collected directly from the trees. Generally picking up from the tree was chosen, because those that fall to the ground often dry out and are damaged. Mature acorns with regular shapes were chosen while collecting from trees randomly. While collecting samples, we paid attention to choose acorns with cupules, since cupules were also used during character selection. During sampling, possible hybrid individuals were not included in the study, in order to eliminate their negative effects on species boundaries. Also, infraspecific identification of taxa was not considered due to not having enough material for the study.

Collected acorns put into paper bags and then allowed to dry in a place with no humid. Each paper bag represents a tree and labeled with its station number, tree number in that station and year of collection. All materials were desiccated at least for one year.

Samples were collected from Anatolia and European part of Turkey. During journey, locations known previously and unknown locations that were subsequently seen on the way have composed station list (Table 2; Figure 3). Each station represents an oak population and has many trees with herbarium samples (leaves and acorns).

In this study each species represented approximately by 4 populations, each station by 3 trees, and each tree by 5 acorns. While choosing samples it was noticed that each species should be represented by samples from trees of different stations and chosen randomly. Totally 14 species, 47 populations studied from 43 stations.

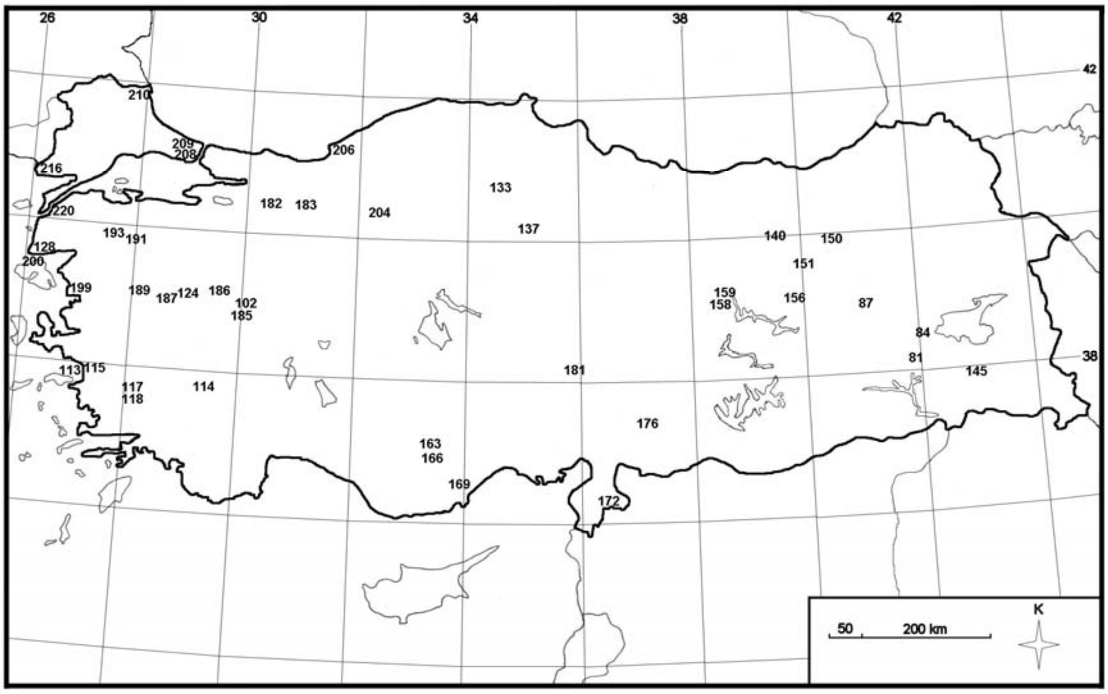


Figure 3 – Distributions and locations of the collected populations

## 3.2. CHARACTERS AND METHOD OF SCORING

Forty characters were selected to be used in the study (Table 3). Some of the characters are adopted from different sources such as Flora of Turkey and The East Aegean Islands (Davis, 1982), Annotated Checklist of the Flowering Plants of Nepal (URL1), Flora of China (URL2), Flora of Missouri (URL3), Flora of North America (URL4), Flora of Pakistan (URL5; Nasir, 1976), Chinese Plant Names (URL6), Flora of Missouri (URL7), Flora of Taiwan Checklist (URL8), Flora of Australia Online (URL9), Flora of Texas (URL10; Diggs et al., 1999), Ornamental Plants From Russia And Adjacent States Of The Former Soviet Union (URL11), South China Botanical Garden Herbarium (URL12), South China Botanical Garden Type Specimens (URL13), Dinghushan Plant Checklist (URL14), Interactive Keys by Xiangying Wen (URL15), ActKey (URL16), A Key To the Common Trees of Camp Conestoga (URL17), The Forestry OutReach Site - Tree Identification (URL18), Upper Peninsula - Tree Identification Key (URL19), World Wide Flowering Plant Family Identification (URL20), TÜBİVES (URL21; Babaç, 2003), The Identification of Flowering Plant Families (Davis and Cullen, 1980), How to Identify Flowering Plant Families (Baumgardt, 2001), and some other studies (Jensen, 1980-1989-1992; Stace, 1989; Borazan and Babaç, 2003). Other characters were based on the researcher's experience with the variation found in the oaks of Turkey.

Totally 19 qualitative and 21 quantitative characters included. All the characters were derived from reproductive parts (Table 4); 7 characters from nut, 17 characters from cupule, 4 characters from stalk, 8 characters derived by indexing, and 3 characters included from Flora of Turkey (Davis, 1982). Altitude was also used as supplementary character in some analyses.

According to Scotland and Pennigton (2000) and Wiens (2000) simple two-state qualitative characters e.g. stalk present or stalk absent, were coded as binary e.g. by scoring 1 for stalk present and 0 for stalk absent. Multistate characters were coded as series of discrete states. For example if there were three states of cupule scale direction, individuals could be scored 1 for forward, 2 for outward and 3 for backward. If there was variation within an accession for qualitative characters, the overall score considered was for the majority of the five plants under study i.e. three out of four plants scored.

Table 2 – Sampled populations with coordinates, altitudes, population codes

| Species name | Population code | Station number | Altitude (m) | Coordinates N | Coordinates E |
|---|---|---|---|---|---|
| *Q. aucheri* | AUC114 | 114 | 90 | 37°44.967 | 029°16.360 |
| *Q. aucheri* | AUC117 | 117 | 180 | 37°33.558 | 028°04.047 |
| *Q. aucheri* | AUC118 | 118 | 300 | 37°32.889 | 028°05.310 |
| *Q. brantii* | BRA156 | 156 | 1025 | 39°11.541 | 039°42.114 |
| *Q. brantii* | BRA158 | 158 | 1135 | 39°03.650 | 038°30.024 |
| *Q. brantii* | BRA081 | 81 | 1470 | 38°13.157 | 041°52.131 |
| *Q. brantii* | BRA172 | 172 | 500 | 36°28.514 | 036°16.735 |
| *Q. cerris* | CER137 | 137 | 1065 | 40°09.950 | 035°07.235 |
| *Q. cerris* | CER181 | 181 | 1470 | 38°12.485 | 035°53.293 |
| *Q. cerris* | CER210 | 210 | 40 | 41°52.450 | 027°57.408 |
| *Q. cerris* | CER200 | 200 | 500 | 39°15.279 | 026°04.446 |
| *Q. cerris* | CER193 | 193 | 245 | 39°48.725 | 027°37.757 |
| *Q. coccifera* | COC128 | 128 | 140 | 39°29.722 | 026°21.148 |
| *Q. coccifera* | COC166 | 166 | 1415 | 36°51.407 | 033°16.702 |
| *Q. coccifera* | COC176 | 176 | 710 | 37°26.291 | 037°12.226 |
| *Q. coccifera* | COC209 | 209 | 100 | 41°16.197 | 028°40.196 |
| *Q. frainetto* | FRA208 | 208 | 80 | 41°12.036 | 029°00.825 |
| *Q. frainetto* | FRA191 | 191 | 340 | 39°49.444 | 027°48.992 |
| *Q. frainetto* | FRA187 | 187 | 700 | 39°08.550 | 028°43.917 |
| *Q. ilex* | ILX113 | 113 | 110 | 37°41.905 | 027°11.334 |
| *Q. ilex* | ILX206 | 206 | 60 | 41°09.136 | 031°23.627 |
| *Q. infectoria* | INF163 | 163 | 1110 | 37°09.275 | 033°25.859 |
| *Q. infectoria* | INF199 | 199 | 40 | 39°04.500 | 026°56.805 |
| *Q. infectoria* | INF183 | 183 | 650 | 40°27.452 | 030°21.736 |
| *Q. ithaburensis* | ITH216 | 216 | 50 | 40°38.848 | 026°14.970 |
| *Q. ithaburensis* | ITH186 | 186 | 1140 | 39°04.457 | 029°27.465 |
| *Q. ithaburensis* | ITH169 | 169 | 1110 | 36°33.774 | 033°54.779 |
| *Q. ithaburensis* | ITH124 | 124 | 70 | 39°03.309 | 026°53.490 |
| *Q. libani* | LIB220 | 220 | 225 | 40°11.642 | 026°35.124 |
| *Q. libani* | LIB151 | 151 | 1310 | 39°33.334 | 040°02.531 |
| *Q. libani* | LIB159 | 159 | 920 | 39°12.550 | 038°35.229 |
| *Q. libani* | LIB087 | 87 | 1490 | 38°58.110 | 041°05.685 |
| *Q. macranthera* | MAC140 | 140 | 1535 | 39°57.091 | 039°37.896 |
| *Q. macranthera* | MAC150 | 150 | 1975 | 39°51.962 | 040°37.616 |
| *Q. macranthera* | MAC140 | 140 | 1535 | 39°57.091 | 039°37.896 |
| *Q. petraea* | PET145 | 145 | 1500 | 37°54.411 | 042°56.096 |
| *Q. petraea* | PET115 | 115 | 290 | 37°53.422 | 027°21.973 |
| *Q. petraea* | PET087 | 87 | 1490 | 38°58.110 | 041°05.685 |
| *Q. petraea* | PET204 | 204 | 700 | 40°18.258 | 032°25.869 |
| *Q. pubescens* | PUB133 | 133 | 1080 | 40°43.991 | 034°34.512 |
| *Q. pubescens* | PUB102 | 102 | 1050 | 38°58.078 | 030°06.433 |
| *Q. pubescens* | PUB182 | 182 | 660 | 40°31.450 | 031°04.973 |
| *Q. robur* | ROB084 | 84 | 1480 | 38°33.442 | 042°05.492 |
| *Q. robur* | ROB208 | 208 | 80 | 41°12.036 | 029°00.825 |
| *Q. robur* | ROB189 | 189 | 365 | 39°14.093 | 028°06.501 |
| *Q. trojana* | TRO163 | 163 | 1110 | 37°09.275 | 033°25.859 |
| *Q. trojana* | TRO185 | 185 | 970 | 39°21.732 | 030°02.756 |

Table 3 – Characters used in analysis (Binary character data are coded as 0/1)

| | |
|---|---|
| **Nut characters** | |
| **1.** Nut length | Continuous - Quantitative |
| **2.** Nut diameter | Continuous - Quantitative |
| **3.** Nut scar diameter | Continuous - Quantitative |
| **4.** Nut shell thickness | Continuous - Quantitative |
| **5.** Nut tip shape [ Concave / Convex / Flat / Mixed ] | Multistate - Qualitative |
| **6.** Hairs outside nut | Binary - Qualitative |
| **7.** Hairs on nut tip | Binary - Qualitative |
| **Cupule characters** | |
| **8.** Cupule depth | Continuous - Quantitative |
| **9.** Cupule length | Continuous - Quantitative |
| **10.** Cupule inner diameter | Continuous - Quantitative |
| **11.** Cupule outer diameter | Continuous - Quantitative |
| **12.** Cupule thickness (Average) | Continuous - Quantitative |
| **13.** Cupule scale length (maximum) | Continuous - Quantitative |
| **14.** Scales differ in each other [ Yes / No / Mixed ] | Multistate - Qualitative |
| **15.** Cupule scale length at mouth [ Longer / Shorter / Same ] | Multistate - Qualitative |
| **16.** Cupule scale direction [ Forward / Backward / Outward ] | Multistate - Qualitative |
| **17.** Cupule scales woody | Binary - Qualitative |
| **18.** Cupule scales spiny | Binary - Qualitative |
| **19.** Cupule scales filamentous | Binary - Qualitative |
| **20.** Cupule scales velvety | Binary - Qualitative |
| **21.** Cupule-nut attachment | Binary - Qualitative |
| **22.** Cupule with fringe | Binary - Qualitative |
| **23.** Cupule scale shape (being flat or swollen) | Binary - Qualitative |
| **24.** Cupule scales adpressed | Binary - Qualitative |
| **Stalk characters** | |
| **25.** Stalk length | Continuous - Quantitative |
| **26.** Stalk thickness | Continuous - Quantitative |
| **27.** Maximum number of acorns in twinings | Multistate - Qualitative |
| **28.** Stalk situation | Binary - Qualitative |
| **Index characters** | |
| **29.** Cupule length / Nut length | Continuous - Quantitative |
| **30.** Cupule depth / Cupule length | Continuous - Quantitative |
| **31.** Cupule inner diameter / Cupule outer diameter | Continuous - Quantitative |
| **32.** Nut diameter / Nut length | Continuous - Quantitative |
| **33.** Exterior nut / Nut length | Continuous - Quantitative |
| **34.** Interior nut / Nut length | Continuous - Quantitative |
| **35.** Cupule thickness / Cupule outer diameter | Continuous - Quantitative |
| **36.** Nut bottom diameter / Nut diameter | Continuous - Quantitative |
| **Fruit characters** | |
| **37.** Acorn maturing [ in one or two year ] | Multistate - Qualitative |
| **38.** Beginning of fruiting time | Multistate - Qualitative |
| **39.** End of fruiting time | Multistate - Qualitative |
| **Supporter characters** | |
| **40.** Altitude | Continuous - Quantitative |

Quantitative characters were entered directly as raw data. They were measured to the nearest millimeter using caliper. Mean values for continuous quantitative characters for the five randomly selected acorns per tree were calculated. However, some characters cannot be scored e.g. nut color. Likewise characters show great variance, because color of the part may change due to environmental effects such as maturing under shade.

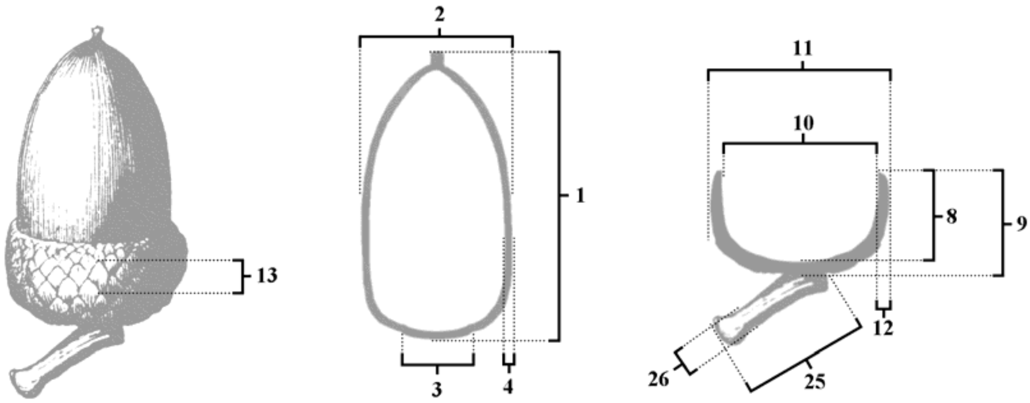


Figure 4 – Quantitative morphometric measurements with character numbers
(Image adopted from URL24)

## 3.3. CALCULATING MEANS

To use within multivariate techniques, raw quantitative data are need to be treated by some preliminary methods to decrease the variation within species and within population. In two steps raw data have been prepared for analyzing. First, graphical representation of the error plots are processed on means. Characters plotted are grouped according to Abbott et al. (1985), and then each group approved as state of the character.

### 3.3.1. MEANS WITH ERROR PLOTS

Means of quantitative characters of trees in each population turned into a matrix as characters versus trees. The data matrix then performed with "Means with Error Plots" graph function of STATISTICA. Whisker's graph type was chosen to get a graph with more explanatory plotting. Standard error option of Whisker value was the best grouping option with 0.95 coefficient value.

### 3.3.2. GROUPING AND CODING CHARACTER STATES

By using the graphs, all quantitative characters are grouped into states. This is performed by grouping the plots (from Figure 11 to Figure 32) by separating them with break lines into discontinuities on the plot. Therefore, each separated group represents a state of that character as indicated in APPENDIX II in this document (from Table 8 to Table 29). Each character state was coded to be represented in multivariate analysis, another data matrix has been created to use within multivariate analyses.

## 3.4. MULTIVARIATE TECHNIQUES

### 3.4.1. CLUSTER ANALYSIS

Data matrix has been created by characters versus OTUs (variables versus populations). Every cell includes a value of an OTU's character state value which is represented with an ordinal number. Data matrix performed with the cluster analysis module to clustering OTUs as populations. All characters were chosen except import characters. In evolutionary aspect, they just can be used as supporting character.

Euclidean distance was chosen as type of distance since it strengthen tree diagram by geometric distance. Program defaults are used in some cases where situations resulted in the selection of option are not clear. Complete linkage method was chosen instead of single linkage, while introgressive hybridization among species was considered. According to phenetic approach in character weight that, each character has the same weight in species' evolution, unweighted pair-group method using arithmetic averages (UPGMA) method applied (Sneath and Sokal, 1973). To avoid from centroids which deform dendrogram by being center for gravity, UPGMA was chosen instead of unweighted pair-group method using the centroid average.

### 3.4.2. PRINCIPAL COMPONENTS ANALYSIS (PCA)

In order to view visual aid for the classification of variables and cases, data matrix entered into Principal Components & Classification Analysis module. Instead of standardizing, centering data were preferred since great amount of data comes with great amount of variability.

Types of graphs being generated are based on the types of characters entered as variables. There are two types of characters in this study; qualitative and quantitative. Different combinations of the types of characters predict variety of graphs. By process of combinations, four different types of projections were yielded. In first case all characters were used as variables. Second, halves of each type of characters was used as variables and other halves as supplementary variables. In other two cases, one of the types was used as variables, remaining is as supplementary variable. Altitude was not considered as character but used as supplementary variable in some cases. No variables were used as having active cases, analysis were based on correlations. Two dimensional case factor scatter-plots were generated by using most appropriate factors; which are always factor 1 and factor 2 as default of STATISTICA. The factors 1 and 2 were selected since they given most meaningful scattered plots. Others were not included in the study.

Table 4 – Type of characters used in analysis

| Type of characters | Nut | Cupule | Stalk | Index | Other | Import | Total |
|---|---|---|---|---|---|---|---|
| Quantitative | 4 | 6 | 2 | 8 | 1 | 0 | 21 |
| Qualitative | 3 | 11 | 2 | 0 | 0 | 3 | 19 |
| Total | 7 | 17 | 4 | 8 | 1 | 3 | 40 |
| Continuous | 4 | 6 | 2 | 8 | 1 | 0 | 21 |
| Multistate | 1 | 3 | 1 | 0 | 0 | 3 | 8 |
| Binary | 2 | 8 | 1 | 0 | 0 | 0 | 11 |
| Total | 7 | 17 | 4 | 8 | 1 | 3 | 40 |

# 4. RESULTS

## 4.1. CLUSTER ANALYSIS

There were two different dendrograms generated based on linkage rule. In UPGMA (Figure 5) there occurred two separate groups according to phenon line 8. The clusters or groupings at this level represented two section of *Quercus*; section *Quercus* and section *Cerris*. The other section, *Ilex*, is not represented as a separate cluster, but *Q. ilex* and *Q. coccifera* are in turn located as out-group for the cluster representing section *Quercus*. *Q. aucheri*, the third species of the section *Ilex*, was found to be very close with *Q. cerris* in the second cluster which is representing section *Cerris* according to phenon line 5.

In cluster representing section *Quercus* by phenon line 5.5, *Q. frainetto* behaves like an out-group just like *Q. ilex* and *Q. coccifera*. *Q. robur* populations followed them. All populations were located in their own species' cluster except for PUB133. However, it was located in the group of *Q. infectoria* which is combined with *Q. pubescens* by upper linkage. Populations of *Q. pubescens*, *Q. infectoria* and *Q. petraea* were seemed to be located closely within the same group by phenon line 4.

In cluster of section *Cerris*, by phenon line 6.5 there were two groupings; *Q. aucheri*, *Q. cerris* and *Q. brantii* forming one of the clusters, *Q. trojana*, *Q. libani* and *Q. ithaburensis* forming another. All populations were located in their own species' cluster. Populations of *Q. aucheri* and *Q. cerris* were found to be closer in the first cluster while *Q. trojana* and *Q. libani* were found to be closer in the second cluster.

Complete linkage method resulted in a diagram (Figure 6) with many separate clusters. There occurred four clusters according to phenon line 8.5. Three of them were representing three sections, while one cluster – composed of *Q. aucheri* and *Q. cerris* – were not correlating that. In the cluster of section *Q. cerris*, *Q. brantii* populations were distant from others. Populations of *Q. trojana*, *Q. libani* and *Q. ithaburensis* were in the same group.

Section *Ilex* cluster had three species; *Q. ilex*, *Q. coccifera* and *Q. frainetto*. *Q. ilex* was located as an out-group of two others instead of *Q. frainetto*, and *Q. frainetto* was located into cluster of *Ilex* section instead of *Quercus*. The other member of the *Ilex* section was located near to *Q. cerris* populations and closer to *Quercus* section instead of *Ilex*. Populations of *Q. cerris* were also located out of its parent section.

Remaining cluster represents for section *Quercus*. All the members of the section were located in this cluster. *Q. petraea* and *Q. robur* were located in a sub-group while *Q. infectoria*, *Q. pubescens* and *Q. macranthera* were forming a sub-group. All populations were located in their own species' cluster.

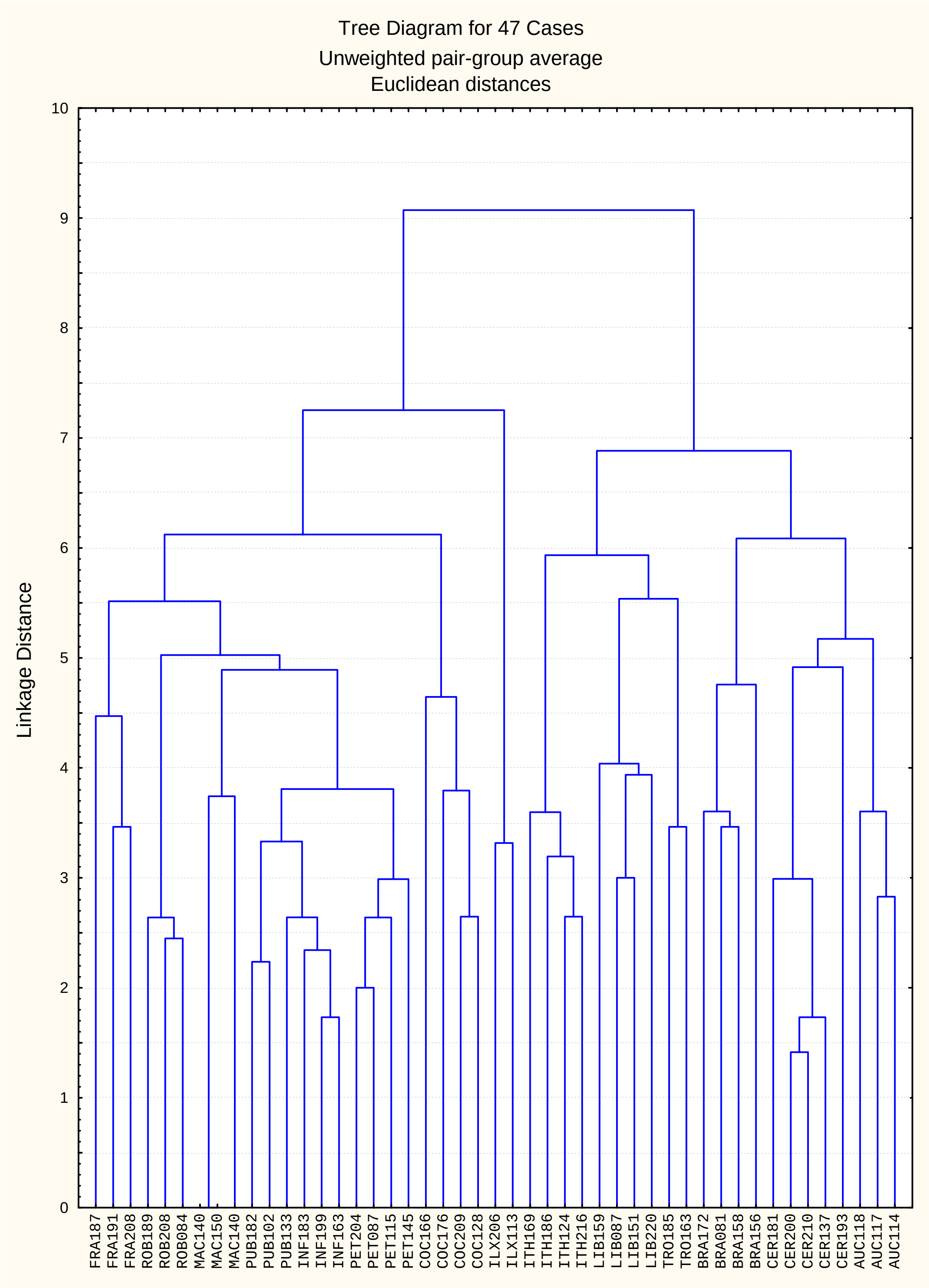


Figure 5 – Phenogram of OTUs resulting from Cluster Analysis with UPGMA

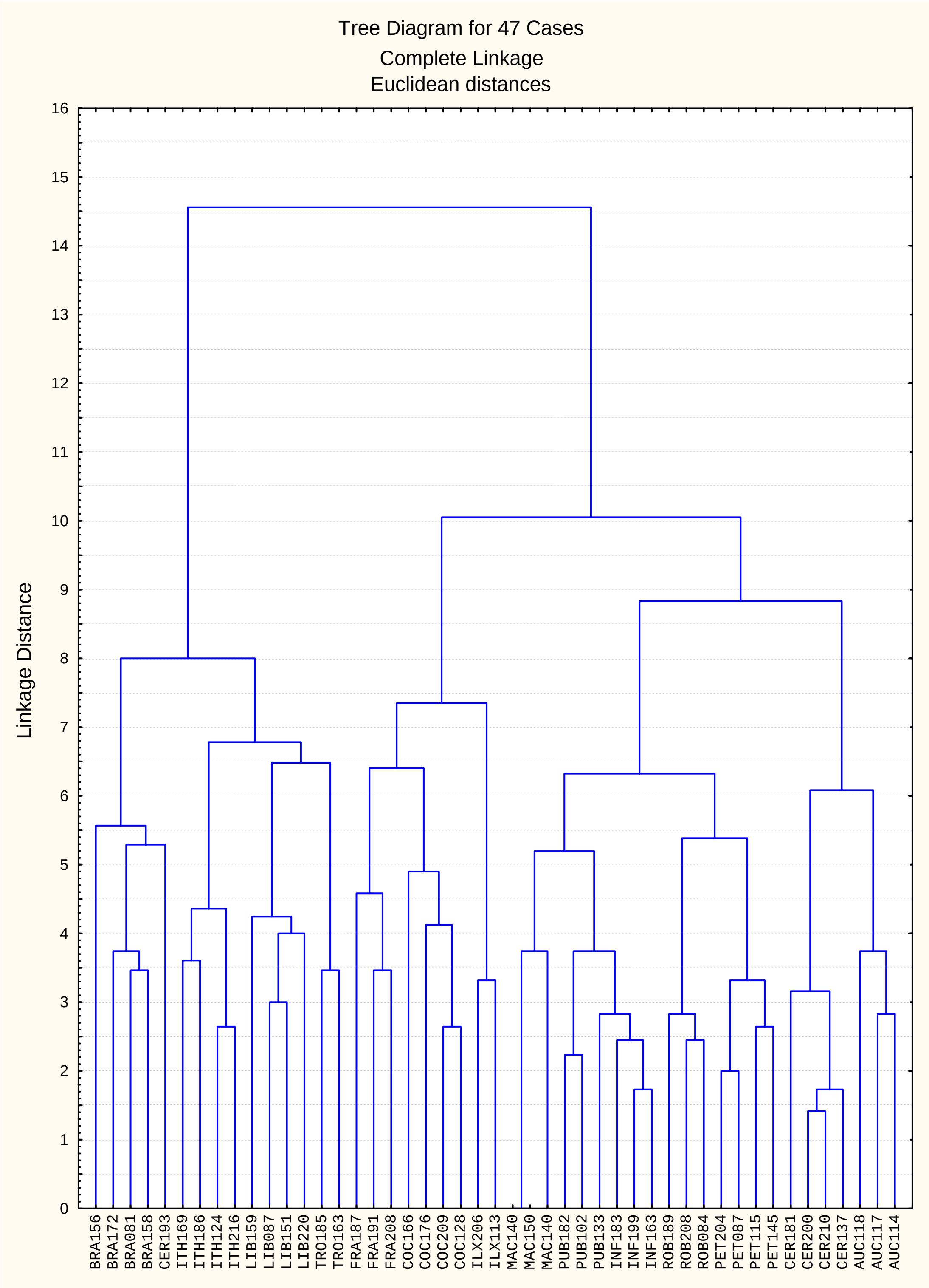


Figure 6 – Phenogram of OTUs resulting from Cluster Analysis with Complete Linkage

## 4.1. PRINCIPAL COMPONENT ANALYSIS

All the PCA projections were found to be similar when upper ranks were considered. In the first projection (Figure 7) with all characters, two sections, *Cerris* and *Quercus*, were separated by the vertical axis clearly. Both sections were in the form of clusters that consisted of populations' projections. Each section was located on the opposite sides of the y axis. Only *Q. frainetto* showed some contradiction to this result. Its populations were located close to the *Q. ilex* and *Q. coccifera* populations. Section *Ilex* was scattered on the graph on a vast scale. *Q. coccifera* and *Q. ilex* were found to be located closely while *Q. aucheri* was between the two other sections, on the y axis. The cluster of species under section *Quercus* was scattered quite densely while species of the section *Ilex* were scattered distant. There were introgressions among the clusters of *Q. robur*, and *Q. pubescens* to some extend. This result supported that it is very difficult to delimit the exact boundaries of these species, since these species form a complex group in nature (Borazan and Babaç, 2003). *Q. infectoria* populations were located within *Q. pubescens*. One population of *Q. robur* (ROB084) laid inside of *Q. pubescens*.

In second plot (Figure 8), projections were nearly the mirror image of the first one. Size of some of the clusters got bigger. *Q. aucheri* were located in the side of section *Cerris* of the y axis. *Q. frainetto* were located close to the group of its section. All populations were clustered in their own groups, except populations in the section *Quercus*. In this section, only *Q. frainetto* formed a separate cluster, while others were in two groups of clusters. *Q. infectoria* were located within the *Q. pubescens*. One of the populations of *Q. robur* also lied inside the *Q. petraea* cluster.

Clusters in projection (Figure 9) based on quantitative characters were scattered wider than the previous two projections. *Q. aucheri* was located on the y axis and between the two sections. *Q. petraea* was closer to *Q. aucheri* than those of *Q. cerris*. There were partly overlaps among or within sections. Cluster of *Q. aucheri* contained one population of *Q. petraea* (PET145) and was close to the section *Quercus*. *Q. infectoria* and *Q. pubescens* did not share the same cluster this time, but they were neighbors with one population. One population of *Q. robur* (ROB084) was located in *Q. pubescens* cluster while others were close to *Q. petraea*. On the other hand, the clusters of *Q. pubescens* and two populations of *Q. robur* (ROB208 and ROB189) overlapped with each other. In the section *Cerris* cluster, populations had wide but regular scatterings except one population of *Q. brantii* (BRA081). One population of *Q. brantii* (BRA081) included in the *Q. trojana* cluster. Another population of *Q. brantii* (BRA156) also lied within the *Q. libani* cluster.

The y axis did not clearly separate the two sections in PCA (Figure 10), but a line still may separate these clusters (sections of *Quercus* and *Cerris*). *Q. infectoria*, *Q. pubescens* and *Q. macranthera* overlapped with each other. *Q. robur* and *Q. petraea* became close to this complex cluster. *Q. frainetto* was close to the populations of section *Ilex*. *Q. aucheri*, in this time, was found to be near to the *Q. ithaburensis* cluster in sections *Cerris*. Some populations in both sections were located at the same points, while in section *Ilex* each species cluster scattered widely and were divided by both axis. It is because; the species in section *Ilex* did not form a group or a cluster in any projections.

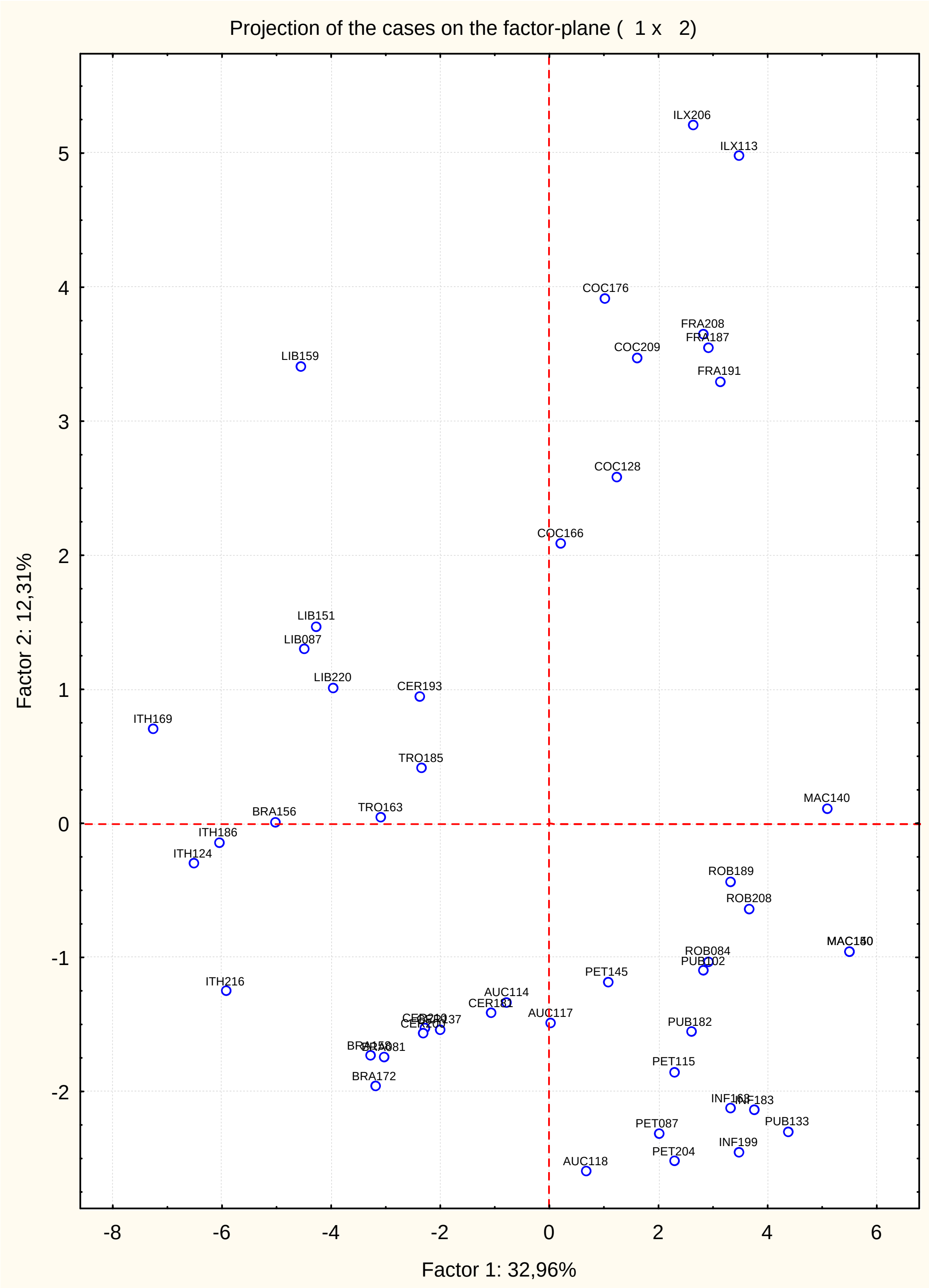


Figure 7 – Resulting projection of PCA with all of the characters

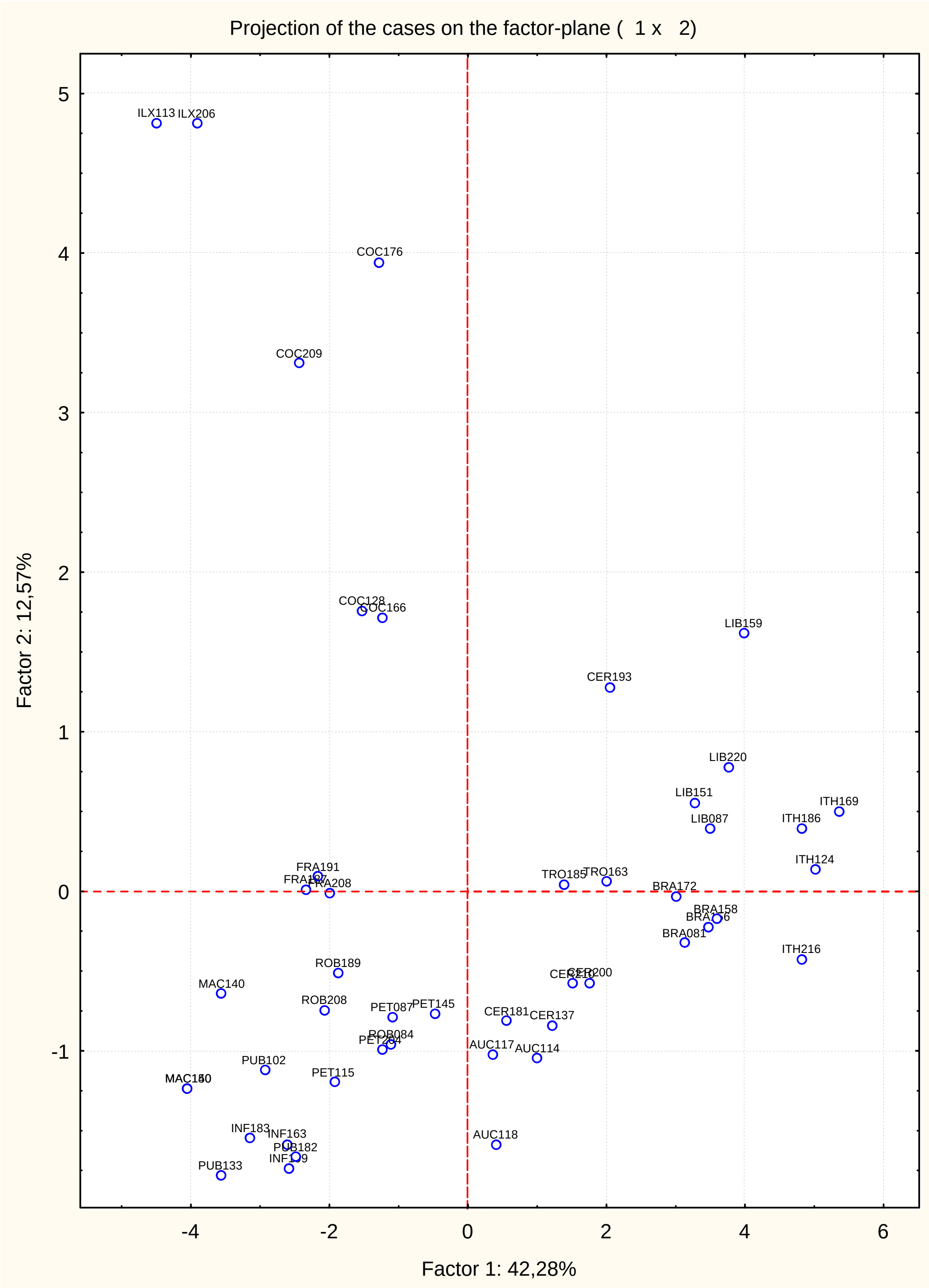


Figure 8 – Resulting projection of PCA with 10 qualitative and 10 quantitative variables for analysis; and rest as supplementary variables


Figure 9 – Resulting projection of PCA with quantitative variables for analyzing and qualitative supplementary variables

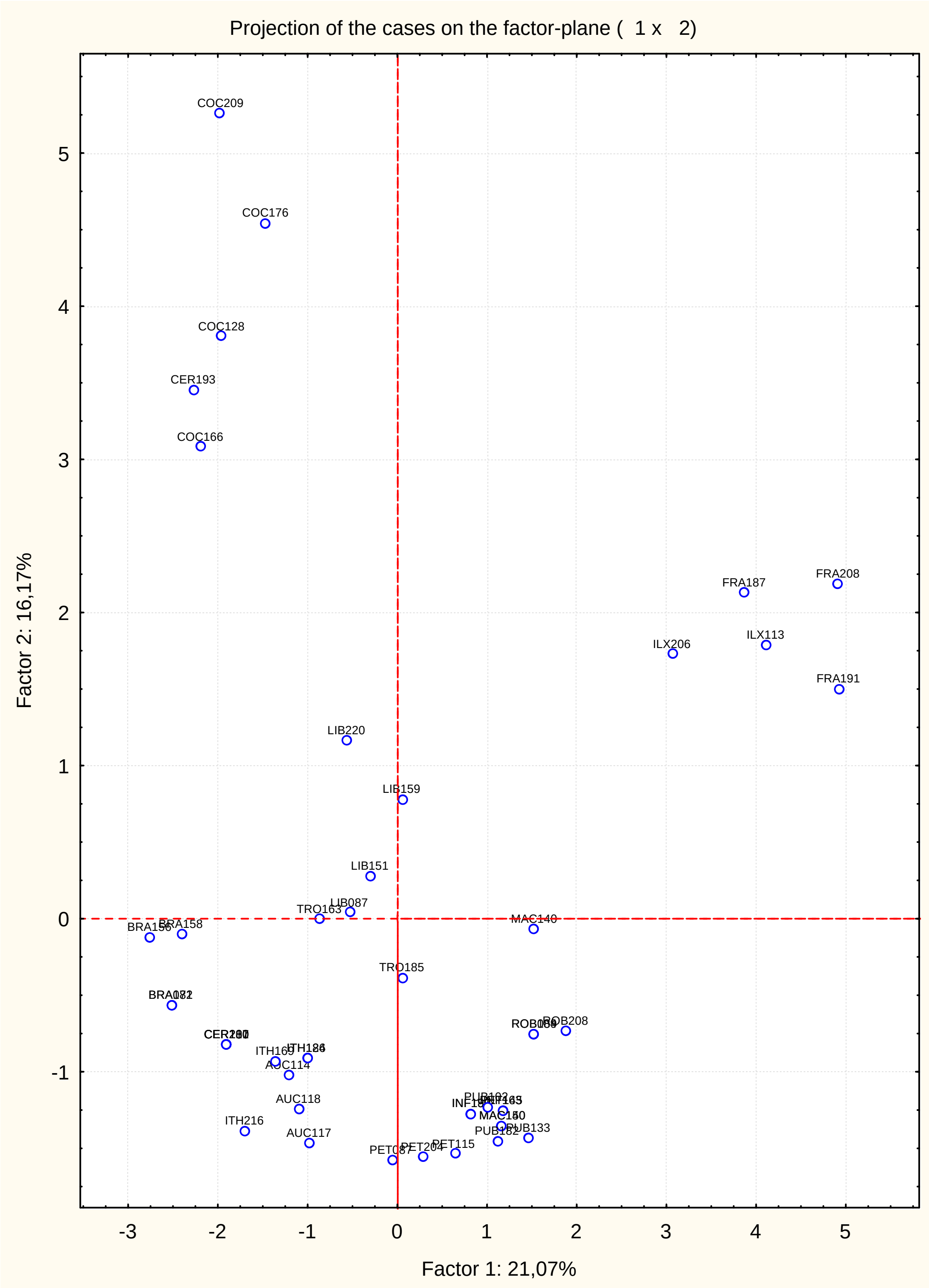


Figure 10 – Resulting projection of PCA with qualitative variables for analyzing and quantitative supplementary variables

# 5. DISCUSSION

Results of Cluster analysis with UPGMA and Complete Linkage have shown correlation with the results of PCA. However, with the knowledge that; all characters have equal weights in phenetic approach, UPGMA was preferred method of Cluster Analysis. But in respect to estimate the behavior of different methods as supplementary view, Complete Linkage method had also been used during analyses. Discussions then have been performed over results of UPGMA and with the assistance of Complete Linkage.

The methods used in PCA vary only in the type of characters of the entered data, which are qualitative, scored quantitative or both, to understand the effect of data type in PCA. Results of PCA have shown that the number of characters used in analysis is more important than the type of characters. While decreasing the number of characters, resolution on the graph also decreases, as can be understood from the figures (Figure 7, Figure 8, Figure 9, and Figure 10). Quantitative characters were found to work efficiently in cases with low amount of characters, whereas rough-and-tumbles are constituted for qualitative characters. This is because small changes always occur in quantitative characters. Qualitative characters are more distant. Small amounts of qualitative characters did not give good separations to delimit the populations. Because of this reason, in a *Quercus* classification, both quantitative and qualitative characters should be involved to delimit the species boundaries and to express the populations' states. Here, the qualitative characters should be chosen carefully for morphometric analyses. The results of PCAs based on especially quantitative characters were quite satisfactory from the view point of traditional classification of *Quercus* populations. But, in the qualitative characters, the results of PCA gave rather good separations to some extent.

The resulting phenogram of UPGMA indicated that there were two separate groups at phenon line 8 (linkage distance) in Figure 5, representing section *Quercus* and section *Cerris*, while populations of species in section *Ilex* were not clustered under a separate linkage. All species belong to section *Quercus* were grouped together which were isolated from *Q. coccifera* and *Q. ilex*. In resulting phenogram of Complete Linkage method, except *Q. frainetto*, *Quercus* section formed clusters containing their own species' populations. This was figured out that; the species in the section connected with strong linkages because of their high phenetic similarities. The result has correlated with some other molecular studies (Manos, 1999; Bellarosa, 2002). These studies have also affirmed that section *Ilex* was closer to section *Cerris*, than to section *Quercus*. But in findings on the Cluster Analysis and PCA, *Q. ilex* and *Q. coccifera* were found to be near to section *Quercus* as out-groups. That may be caused by morphological similarity in acorns of section *Quercus* and the two species, since the acorns of mentioned taxa were both small and maturated within one year. However, the reason of some loosely scattered clusters may be the results of large variation within characters.

On the contrary, *Q. aucheri* was in a close relationship with *Q. cerris* in Cluster Analysis and located between sections of *Quercus* and *Cerris* in PCA results. Not only morphological features of acorns, but also many morphological features of *Q. aucheri* and *Q. cerris* were similar. They are alike species in some extent, but *Q. aucheri* separated into different section than section *Quercus* with its feature of being evergreen. The taxon, *Q. aucheri*, presents an open area to study, since it is an endemic species and a few studies have been done on morphology and taxonomic position so far.

*Quercus* frainetto was located always close to *Q. coccifera* and *Q. ilex* in the results of Cluster Analysis and especially with qualitative characters in PCA. In Bellarosa (2002), *Q. frainetto* was found in the most distant linkage to section *Ilex* and was introduced to be the most devoted element in cluster of section *Quercus*. A similar case was occurred in *Q. aucheri*.

# 6. CONCLUSIONS

The morphometric techniques involved in this study gave satisfactory good results in point of phenetic groupings. The results of UPGMA and PCA techniques, except *Ilex* section, showed a congruency with those of traditional classifications at every level of taxonomic ranks. In the traditional classifications (Davis, 1982) *Q. ilex Q. coccifera* and *Q. aucheri* are included in section *Ilex*. In this study these species do not form a clear-cut group such as section *Ilex*. *Quercus aucheri* endemic in the Flora of Turkey and the East Aegean Islands (Davis, 1982) included in section *Cerris* via a linkage of *Q. cerris*. On the other hand *Q. coccifera* and *Q. ilex* formed separate clusters, and though these clusters did not link to each other. Instead, *Q. coccifera* first linked to the cluster of section *Quercus*. Then, *Q. ilex* linked to this group.

This result may think of a complex and an artificial section of *Ilex*. At the same time including of *Q. aucheri* in section *Cerris* may strengthen this hypothesis to much. Because, these three species have been included in section *Ilex,* according to the traditional classification based on only morphological characters. As it may be seen, that mostly leaves' properties are weighted in such classifications. The most weighted characters are evergreen and hard-leather-like leaves, and absent or present of spiny leave. Some phylogenetical studies (Rushton, 1978; Jensen, 1989; Bellarosa, 2002; Borazan and Babaç, 2003) showed a different grouping from those of this study. It was found that *Q. ilex* and *Q. coccifera* were quite similar but they were included in section *Cerris* by Manos et al. (1999). These results do not show any congruencies with traditional classification and as the groupings of this study.

*Quercus aucheri* enter the section *Cerris* only in this study. If we accept that this species is a member of section *Ilex*, the result obtained in this study showed a similarity to the results of phylogenetical groupings (Manos et al., 1999). At this point it may be thought that *Q. aucheri* may be a result of convergence evolution, approaching to the section *Cerris*.

On the other hand according to the acorn characters involved in this study, may point out that, section *Ilex* was also formed a convergence evolution, approaching to section *Quercus*. For obtaining more healthy findings, more samples, more taxonomic characters, and more detailed analyses should be required to delimit the boundaries of species and section of *Quercus*.

On the other hand, it may be suggested that, *Q. aucheri* is a member of section *Cerris* according to the results obtained in this study. Therefore, it may be concluded that;

1. the groupings based on only acorn characters, except section *Ilex*, support the two sections (section *Cerris* and section *Quercus*);
2. section *Ilex* may be an artificial group to some extent; and
3. by means of aposteriori approaches, the morphometric analyses showed more meaningful results regarding to those of traditional groupings

in this study.

According to the findings of the study, the following suggestions may be proposed;

1. First of all, morphometric studies should be executed with more samples from populations.
2. A revision of Turkish *Quercus* should be made in which beside the morphological characters, chemical and biochemical characteristics of taxa must be involved.
3. Separately, the three species (*Q. ilex*, *Q. coccifera* and especially *Q. aucheri*) should be studied in details as a preliminary observation for a revisional study.

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**URL1** Annotated Checklist of the Flowering Plants of Nepal

[http://www.efloras.org/flora_page.aspx?flora_id=110]

**URL2** Flora of China

[http://www.efloras.org/flora_page.aspx?flora_id=2]

**URL3** Flora of Missouri

[http://www.efloras.org/flora_page.aspx?flora_id=11]

**URL4** Flora of North America

[http://www.efloras.org/flora_page.aspx?flora_id=1]

**URL5** Flora of Pakistan

[http://www.efloras.org/flora_page.aspx?flora_id=5]

**URL6** Chinese Plant Names

[http://www.efloras.org/flora_page.aspx?flora_id=3]

**URL7** Flora of Missouri

[http://www.efloras.org/flora_page.aspx?flora_id=11]

**URL8** Flora of Taiwan Checklist

[http://www.efloras.org/flora_page.aspx?flora_id=101]

**URL9** Flora of Australia Online

[http://www.deh.gov.au/biodiversity/abrs/online-resources/flora/main/index.html]

**URL10** Flora of Texas

[http://www.texasflora.org/]

**URL11** Ornamental Plants from Russia & Adjacent States

[http://www.efloras.org/flora_page.aspx?flora_id=120]

**URL12** South China Botanical Garden Herbarium

[http://www.efloras.org/flora_page.aspx?flora_id=600]

**URL13** South China Botanical Garden Type Specimens

[http://www.efloras.org/flora_page.aspx?flora_id=601]

**URL14** Dinghushan Plant Checklist

[http://www.efloras.org/flora_page.aspx?flora_id=620]

**URL15** Interactive Keys by Xiangying Wen

[http://www.efloras.org/flora_page.aspx?flora_id=1001]

**URL16** ActKey

[http://flora.huh.harvard.edu:8080/actkey/index.jsp]

**URL17** A Key To the Common Trees of Camp Conestoga

[http://ostermiller.org/tree/]

**URL18** The Forestry OutReach Site (FORSite) - Tree Identification

[http://www.fw.vt.edu/dendro/forsite/Idtree.htm]

**URL19** Upper Peninsula - Tree Identification Key

[http://forestry.msu.edu/uptreeid/]

**URL20** World Wide Flowering Plant Family Identification

[http://www.colby.edu/info.tech/BI211/PlantFamilyID.html]

**URL21** TÜBİVES – Türkiye Bitkileri Veri Servisi

[http://www.tubitak.gov.tr/tubives/]

**URL22** Kertenkele Sözlük

[http://herb.ibu.edu.tr/sozluk/]

**URL23** Biologie et Multimedia

[http://www.snv.jussieu.fr/bmedia/]

**URL24** Clipart ETC

[http://etc.usf.edu/clipart/]

# APPENDIX I – GENERAL INFORMATION ON TAXA

Table 5 – General features of species of genus *Quercus*

| Taxa | Structure | Fruiting season | Elevation | Endemism |
|---|---|---|---|---|
| *Quercus aucheri* | Tree or shrub | 9 - 10 | 0 - 450 | - |
| *Quercus brantii* | Small tree or shrub | 8 - 9 | 350 - 1700 | - |
| *Quercus cerris* var. *austriaca* | Tree | 8 - 9 | 100 - 200 | - |
| *Quercus cerris* var. *cerris* | Tree | 8 - 9 | 0 - 1900 | - |
| *Quercus coccifera* | Small tree or shrub | 9 - 9 | 0 - 1500 | - |
| *Quercus frainetto* | Tree | 5 - 5 | 20 - 1000 | - |
| *Quercus hartwissiana* | Tree | 7 - 8 | 20 - 1750 | - |
| *Quercus ilex* | Tree or tall shrub | 8 - 8 | 0 - 450 | - |
| *Quercus infectoria* subsp. *boissieri* | Small tree or shrub | 8 - 9 | 200 - 1850 | - |
| *Quercus infectoria* subsp. *infectoria* | Small tree or shrub | 8 - 8 | 150 - 850 | - |
| *Quercus ithaburensis* subsp. *macrolepis* | Tree | 8 - 9 | 50 - 1700 | - |
| *Quercus libani* | Small tree or shrub | 8 - 10 | 700 - 2000 | - |
| *Quercus macranthera* subsp. *syspirensis* | Small tree | 8 - 10 | 1000 - 1900 | + |
| *Quercus petraea* subsp. *iberica* | Tree | 9 - 10 | 0 - 1600 | - |
| *Quercus petraea* subsp. *petraea* | Tree | 9 - 10 | 200 - 200 | - |
| *Quercus petraea* subsp. *pinnatiloba* | Tree | 8 - 9 | 1200 - 2200 | + |
| *Quercus pontica* | Tall shrub | 8 - 9 | 800 - 2100 | - |
| *Quercus pubescens* | Small tree | 9 - 10 | 0 - 1700 | - |
| *Quercus robur* subsp. *pedunculiflora* | Tree | 8 - 9 | 1200 - 1800 | - |
| *Quercus robur* subsp. *robur* | Tree | 8 - 9 | 100 - 1000 | - |
| *Quercus trojana* | Tree | 8 - 10 | 300 - 1800 | - |
| *Quercus virgiliana* | Tree | 9 - 10 | 100 - 1150 | - |
| *Quercus vulcanica* | Tree | 8 - 9 | 1300 - 1800 | + |

Table 6 – Information on distribution of species of genus *Quercus*

| Taxa | Phytogeographical distribution | Distribution in Turkey | General Distribution |
|---|---|---|---|
| *Quercus aucheri* | D. Mediterranean | SW Anatolia | Aegean islands |
| *Quercus brantii* | Irano-Turanian | E and SE Anatolia | Syria desert, N Iraq, W and S Iran |
| *Quercus cerris* var. *austriaca* | Euro-Siberian | SW Turkey | M and SW Europe |
| *Quercus cerris* var. *cerris* | Mediterranean | S Turkey, N, S, M and E (W) Anatolia | Europe, Syria, Lebanon |
| *Quercus coccifera* | Mediterranean | NW Turkey, W and S Anatolia | Mediterranean province |
| *Quercus frainetto* | Euro-Siberian | NW Turkey | SE M Europe, S Italy, Balkans |
| *Quercus hartwissiana* | Black Sea | Trace, N. and E. Anatolia | Bulgaria, W Trans-Caucasian |
| *Quercus ilex* | Mediterranean | W and N Anatolia (East of 36 E) | W Mediterranean |
| *Quercus infectoria* subsp. *boissieri* | - | Out and E Anatolia | Cyprus, Palestine, Trans-Caucasian |
| *Quercus infectoria* subsp. *infectoria* | Euro-Siberian | N Turkey | Greece |
| *Quercus ithaburensis* subsp. *macrolepis* | E. Mediterranean | Trace, W, M and S Anatolia | Balkans, SW Italy |
| *Quercus libani* | Irano-Turanian | E Anatolia, from W to S Anatolia (Anti-Taurus) | Latakya, Syria desert? NW Iraq, W Iran |
| *Quercus macranthera* subsp. *syspirensis* | - | Terrestrial Anatolia | Turkey |
| *Quercus petraea* subsp. *iberica* | - | Trace, N. and M (W) Anatolia | Balkans, Caucasian, N Iran |
| *Quercus petraea* subsp. *petraea* | - | NW Turkey | Europe |
| *Quercus petraea* subsp. *pinnatiloba* | - | S (Anti-Taurus, Amanos), E and SE Anatolia | Turkey |
| *Quercus pontica* | Black Sea | NE. Anatolia | Georgia |
| *Quercus pubescens* | - | N Turkey, E of 39 E, W and M Anatolia | W, M and S Europe, Crimea |
| *Quercus robur* subsp. *pedunculiflora* | Irano-Turanian | E. and SE. Anatolia | Trans-Caucasian |
| *Quercus robur* subsp. *robur* | Euro-Siberian | NW. Turkey, M. and S. Anatolia (Mersin province) | Europe, Caucasian? |
| *Quercus trojana* | D. Mediterranean | NW, W and SW Anatolia | SE Italy, Balkans |
| *Quercus virgiliana* | - | NW Turkey, N Anatolia (35 E) | S Europe, from Corsica to Black Sea |
| *Quercus vulcanica* | E. Mediterranean (Mountain) | SW and M Anatolia | Turkey |

Table 7 – Specimen locations with their date of collection

| Species name | Population Code | Station number | Collection Date | Grid | City | Locality |
|---|---|---|---|---|---|---|
| *Q. aucheri* | AUC114 | 114 | 27.10.2002 | C1 | Aydın | Pirene, Söke, Aydın |
| *Q. aucheri* | AUC117 | 117 | 28.10.2002 | C1 | Aydın | Aydın, Çine, across the cemetery of Kuruköy |
| *Q. aucheri* | AUC118 | 118 | 28.10.2002 | C1 | Aydın | Aydın Eskiçine, across the cemetery of Ovacık köyü |
| *Q. brantii* | BRA081 | 81 | 27.09.2002 | B8 | Siirt | Between Baykan and Bitlis, 35-40 km to Bitlis, Şehitlik Köyü |
| *Q. brantii* | BRA156 | 156 | 04.10.2003 | B7 | Tunceli | Between Nazimiye and Tunceli, 2-3 km after Nazimiye |
| *Q. brantii* | BRA158 | 158 | 05.10.2003 | B7 | Elazığ | Between Arapgir and Kemaliye, 5-6 km after Arapgir |
| *Q. brantii* | BRA172 | 172 | 23.10.2003 | C6 | Antakya | Between Belen and Antakya, 10-12km after Belen |
| *Q. cerris* | CER137 | 137 | 28.09.2003 | A5 | Çorum | Between Alaca and Aydıncık, Above Sancı köyü |
| *Q. cerris* | CER181 | 181 | 25.10.2003 | B6 | Adana | After Tufanbeyli and Dereli junction, Saraycık Köyü |
| *Q. cerris* | CER200 | 200 | 10.11.2003 | B1 | İzmir | Between Bergama and Kozak, 42 km to Ayvalık |
| *Q. cerris* | CER210 | 210 | 29.10.2004 | A1 | Edirne | Between Demirköy and İğneada, 3-4 km to İğneada |
| *Q. cerris* | CER193 | 193 | 09.11.2003 | B1 | Balıkesir | After Ilıca-Balya junction, 2-3 km to Gönen |
| *Q. coccifera* | COC128 | 128 | 10.11.2002 | B1 | Çanakkale | Between Assos and Üç kuyular, 2-3 km to Assos |
| *Q. coccifera* | COC166 | 166 | 22.10.2003 | C4 | İçel | Between Karaman and Mut, 10 km below the Sertavul |
| *Q. coccifera* | COC176 | 176 | 24.10.2003 | C6 | K. Maraş | Between Narlı and Pazarcık, 10 km to Pazarcık |
| *Q. coccifera* | COC209 | 209 | 28.10.2004 | A2 | Kırklareli | Between Tayakadın and Saray, 3-4 km after Tayakadın |
| *Q. frainetto* | FRA187 | 187 | 08.11.2003 | B2 | Kütahya | After Simav-Demirci-Sındırgı junction, 3-4 km toward sındırgı |
| *Q. frainetto* | FRA191 | 191 | 09.11.2003 | B2 | Balıkesir | Between Balıkesir and Şamlı, after Şamlı |
| *Q. frainetto* | FRA208 | 208 | 18.10.2004 | A2 | İstanbul | Between Zekeriyaköy and Bahçeköy, 3-4 km after Zekeriyaköy |
| *Q. ilex* | ILX113 | 113 | 27.10.2002 | B1 | İzmir | Kuşadası National Park, Davutlar, dilek peninsula |
| *Q. ilex* | ILX206 | 206 | 24.10.2004 | B3 | Düzce | Between Yığılca and Alaplı, 4-5 km to Alaplı, cemetery |
| *Q. infectoria* | INF163 | 163 | 21.10.2003 | C4 | Karaman | From Karaman-Yeşildere junction toward Yeşildere |
| *Q. infectoria* | INF183 | 183 | 07.11.2003 | A3 | Sakarya | Between Taraklı and Geyve, 5-6 km after Taraklı |
| *Q. infectoria* | INF199 | 199 | 10.11.2003 | B1 | İzmir | Between Dikili and Bergama, 2-3 km after Dikili junction |

Table 7 – Specimen locations with their date of collection (Continued from previous page)

| Species name | Population Code | Station number | Collection Date | Grid | City | Locality |
|---|---|---|---|---|---|---|
| *Q. ithaburensis* | ITH124 | 124 | 09.11.2002 | B1 | İzmir | Between Dikili and Çandarlı, 10 km after Dikili |
| *Q. ithaburensis* | ITH169 | 169 | 22.10.2003 | C4 | İçel | Mut, Between Kırobası and Silifke, 28 km to Silifke, Yeniçıktı köyü |
| *Q. ithaburensis* | ITH186 | 186 | 08.11.2003 | B2 | Kütahya | Between Çavdarhisar and Gediz, 10 km after Çavdarhisar |
| *Q. ithaburensis* | ITH216 | 216 | 30.10.2004 | A1 | Tekirdağ | Between Büyükevren and Keşan, exit of Büyükevren |
| *Q. libani* | LIB087 | 87 | 28.09.2002 | B8 | Bingöl | Between Muş and Solhan, Arakonak köyü |
| *Q. libani* | LIB151 | 151 | 04.10.2003 | B7 | Erzincan | Between Tercan and Üzümlü, 46 km after Tercan |
| *Q. libani* | LIB159 | 159 | 05.10.2003 | B7 | Elazığ | 30 km to Kemaliye |
| *Q. libani* | LIB220 | 220 | 31.10.2004 | A1 | Çanakkale | From Lapseki, 17 km to Çanakkale. Yukarı kızılkeçili, place of Kurttepesi |
| *Q. macranthera* | MAC140 | 140 | 29.09.2003 | B6 | Sivas | Between Sivas and Erzincan, after İmranlı |
| *Q. macranthera* | MAC150 | 150 | 04.10.2003 | B8 | Erzurum | Erzurum-Erzincan junction, After Erzurum |
| *Q. macranthera* | MXR140 | 140 | 29.09.2003 | B6 | Sivas | Between Sivas and Erzincan, after İmranlı |
| *Q. petraea* | PET145 | 145 | 02.10.2003 | B9 | Van | Çatak, 20 km after Dalbastı köyü |
| *Q. petrea* | PET087 | 87 | 28.09.2002 | B8 | Bingöl | Between Muş and Solhan, Arakonak köyü |
| *Q. petrea* | PET115 | 115 | 28.10.2002 | B1 | Aydın | Between Selçuk and Ortaklar, 11-12 km to Ortaklar |
| *Q. petrea* | PET204 | 204 | 23.10.2004 | B4 | Bolu | Between Güdül and Çeltikçi, Karayolları çeşmesi, 15-20 km after Güdül |
| *Q. pubescens* | PUB102 | 102 | 13.10.2002 | B3 | Kütahya | 5 km to Zafertepe |
| *Q. pubescens* | PUB133 | 133 | 27.09.2003 | A5 | Çorum | Between İskilip and Dodurga, 10-15 km from Velek to Dodurga |
| *Q. pubescens* | PUB182 | 182 | 07.11.2003 | A3 | Bolu | Mudurnu, from Göynük to Adapazarı, 10 km after Mudurnu |
| *Q. robur* | ROB084 | 84 | 28.09.2002 | B9 | Bitlis | Between Tatvan and Muş, 4 km to Güroymak |
| *Q. robur* | ROB189 | 189 | 08.11.2003 | B2 | Balıkesir | Between Sındırgı and Gölcük, 15 km to Gölcük |
| *Q. robur* | ROB208 | 208 | 18.10.2004 | A2 | İstanbul | Between Zekeriyaköy and Bahçeköy, 3-4 km after Zekeriyaköy |
| *Q. trojana* | TRO163 | 163 | 21.10.2003 | C4 | Karaman | After Karaman-Yeşildere junction, toward Yeşildere |
| *Q. trojana* | TRO185 | 185 | 08.11.2003 | B3 | Kütahya | After Kütahya-Çavdarhisar junction, 6-7 km toward Çavdarhisar |

# APPENDIX II – STATISTICAL RESULTS

## MEANS WITH STANDARD ERROR PLOTS AND CHARACTER CODING

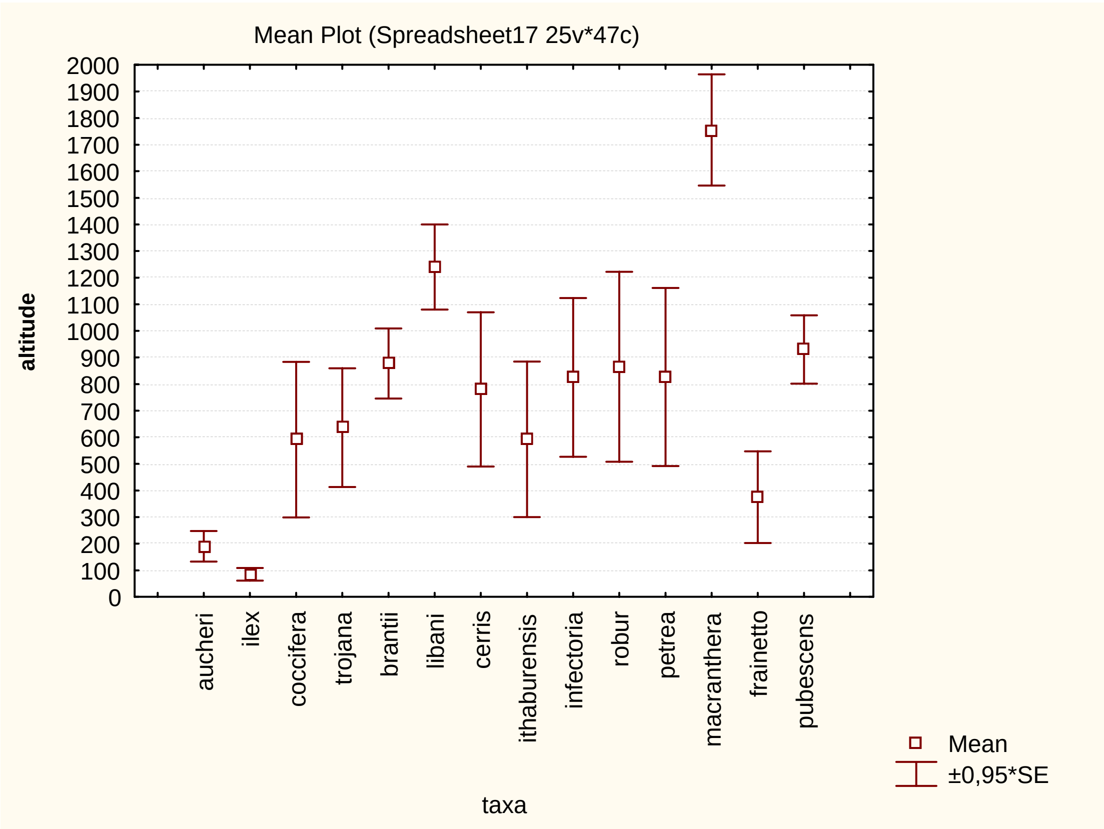


Figure 11 – Means with standard error plots for altitude

Table 8 – Scoring character states for altitude

| Group number | Group range | Coding range | Character state |
|---|---|---|---|
| 1 | 60 | - ∞ | 1 |
| | 109 | 121 | |
| 2 | 132 | | 2 |
| | 1400 | 1473 | |
| 3 | 1546 | | 3 |
| | 1964 | + ∞ | |

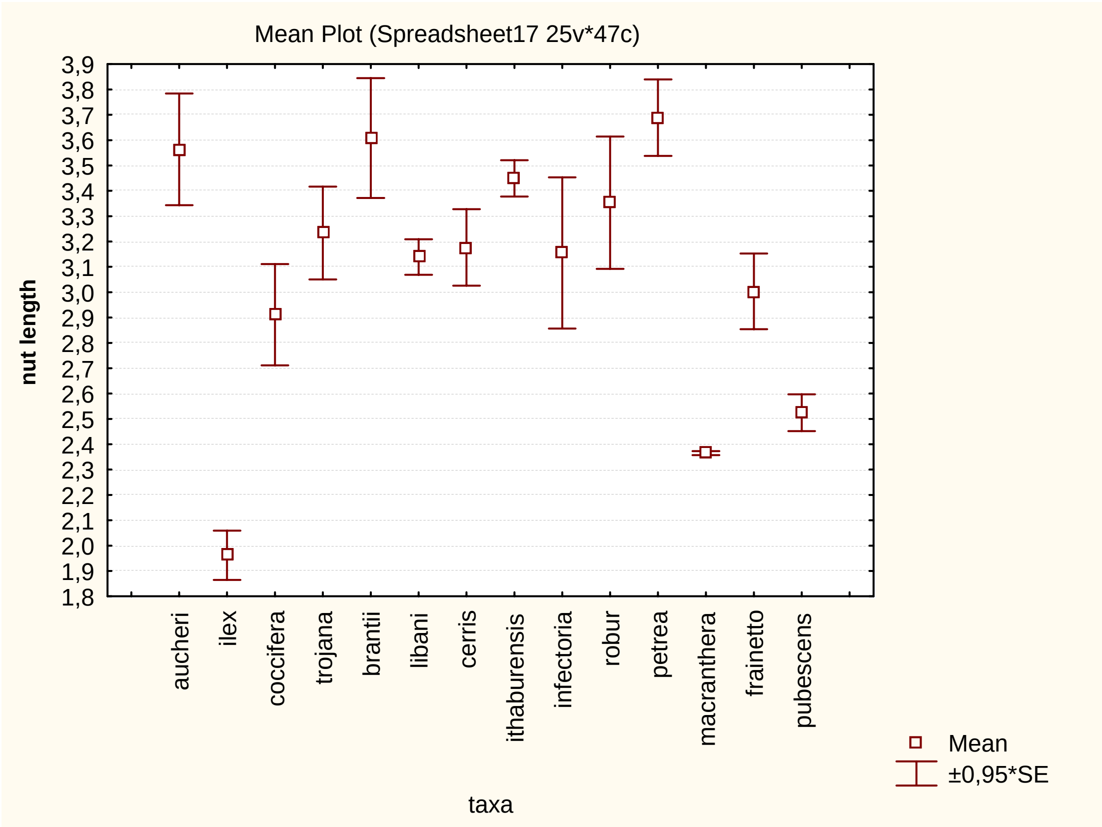


Figure 12 – Means with standard error plots for nut length

Table 9 – Scoring character states for nut length

<table>
<tr><th>Group number</th><th>Group range</th><th>Coding range</th><th>Character state</th></tr>
<tr><td rowspan="2">1</td><td>1,865</td><td>- ∞</td><td rowspan="2">1</td></tr>
<tr><td>2,059</td><td rowspan="2">2,209</td></tr>
<tr><td rowspan="2">2</td><td>2,358</td><td rowspan="2">2</td></tr>
<tr><td>2,373</td><td rowspan="2">2,413</td></tr>
<tr><td rowspan="2">3</td><td>2,452</td><td rowspan="2">3</td></tr>
<tr><td>2,597</td><td rowspan="2">2,655</td></tr>
<tr><td rowspan="2">4</td><td>2,712</td><td rowspan="2">4</td></tr>
<tr><td>3,844</td><td>+ ∞</td></tr>
</table>

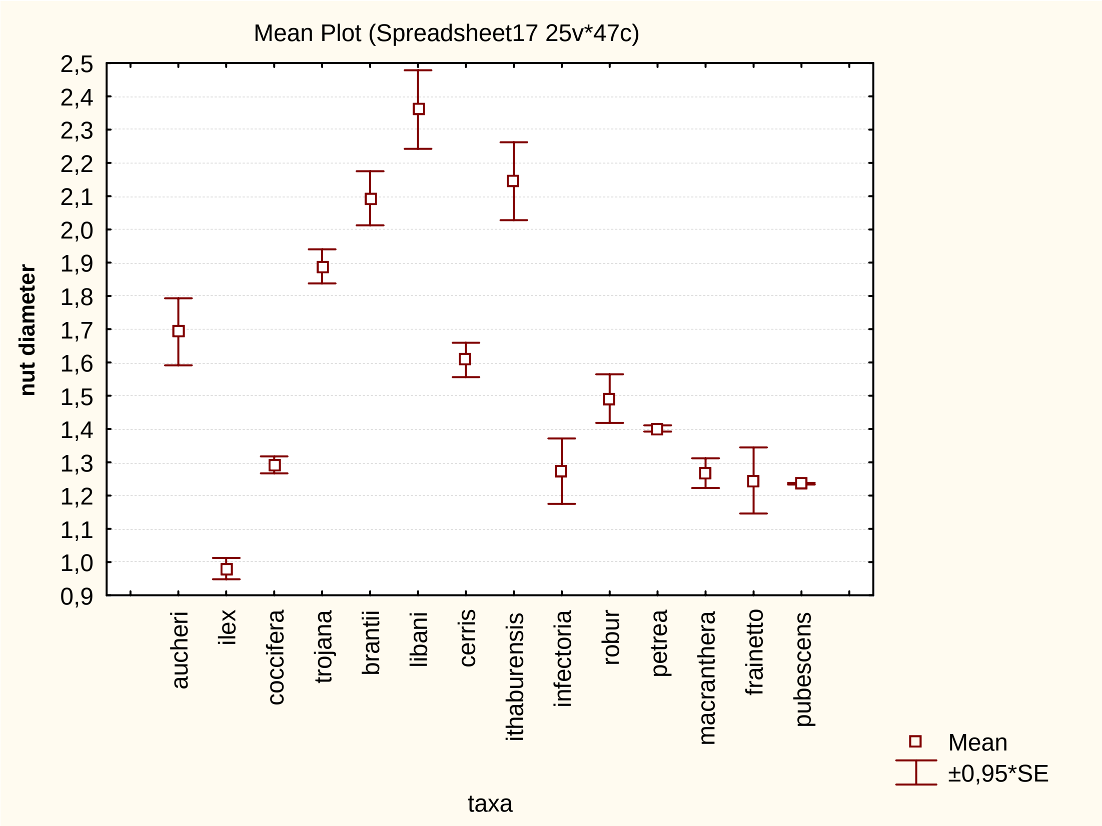


Figure 13 – Means with standard error plots for nut diameter

Table 10 – Scoring character states for nut diameter

<table>
<tr><th>Group number</th><th>Group range</th><th>Coding range</th><th>Character state</th></tr>
<tr><td rowspan="2">1</td><td>0,948</td><td>- ∞</td><td rowspan="2">1</td></tr>
<tr><td>1,013</td><td rowspan="2">1,080</td></tr>
<tr><td rowspan="2">2</td><td>1,146</td><td rowspan="2">2</td></tr>
<tr><td>1,372</td><td rowspan="2">1,383</td></tr>
<tr><td rowspan="2">3</td><td>1,393</td><td rowspan="2">3</td></tr>
<tr><td>1,411</td><td rowspan="2">1,415</td></tr>
<tr><td rowspan="2">4</td><td>1,419</td><td rowspan="2">4</td></tr>
<tr><td>1,793</td><td rowspan="2">1,816</td></tr>
<tr><td rowspan="2">5</td><td>1,838</td><td rowspan="2">5</td></tr>
<tr><td>1,940</td><td rowspan="2">1,976</td></tr>
<tr><td rowspan="2">6</td><td>2,012</td><td rowspan="2">6</td></tr>
<tr><td>2,479</td><td>+ ∞</td></tr>
</table>

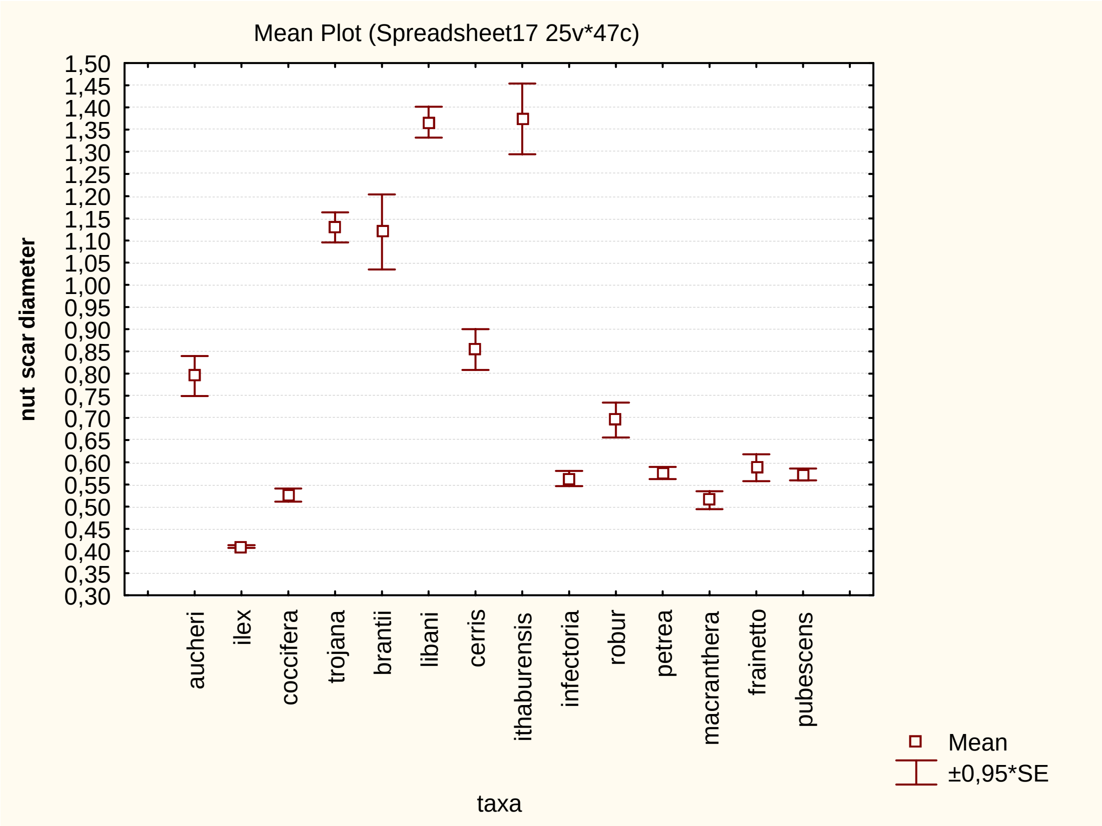


Figure 14 – Means with standard error plots for nut scar diameter

Table 11 – Scoring character states for nut scar diameter

| Group number | Group range | Coding range | Character state |
|---|---|---|---|
| 1 | 0,407 | - ∞ | 1 |
| | 0,413 | 0,454 | |
| 2 | 0,494 | | 2 |
| | 0,541 | 0,544 | |
| 3 | 0,546 | | 3 |
| | 0,618 | 0,637 | |
| 4 | 0,656 | | 4 |
| | 0,735 | 0,765 | |
| 5 | 0,794 | | 5 |
| | 0,900 | 0,968 | |
| 6 | 1,035 | | 6 |
| | 1,204 | 1,249 | |
| 7 | 1,294 | | 7 |
| | 1,454 | + ∞ | |

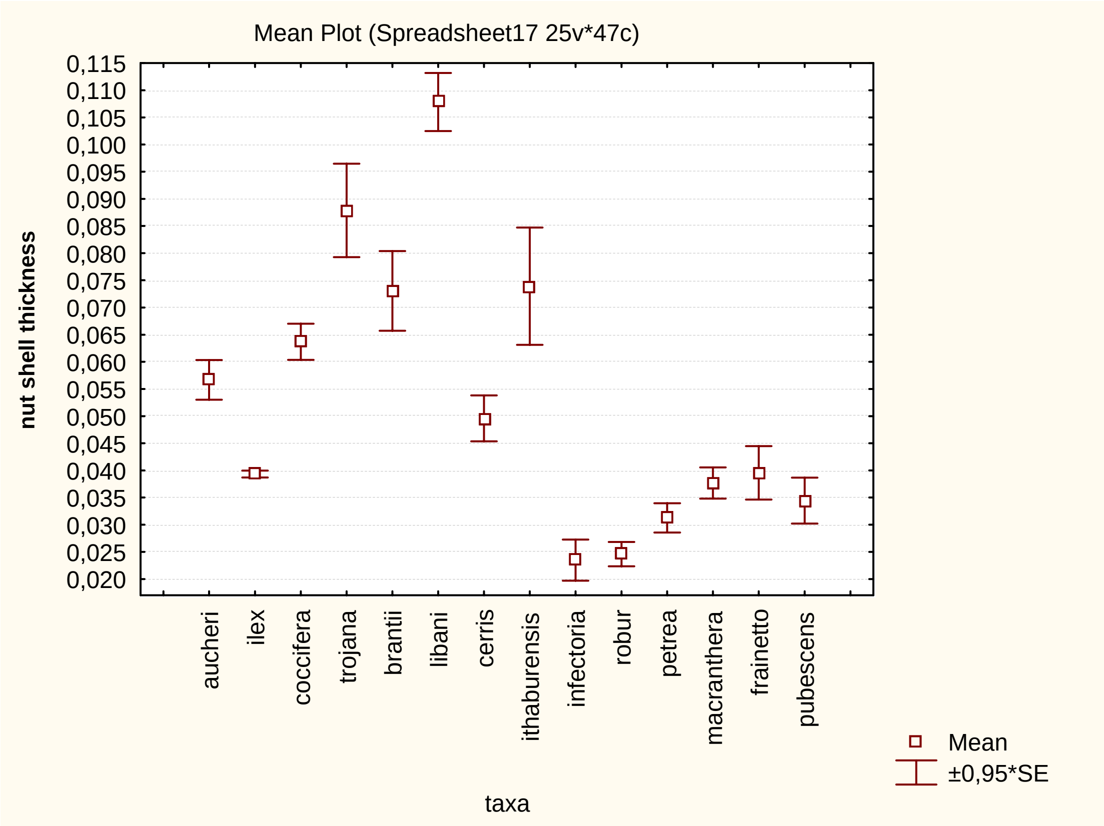


Figure 15 – Means with standard error plots for nut shell thickness

Table 12 – Scoring character states for nut shell thickness

| Group number | Group range | Coding range | Character state |
|---|---|---|---|
| 1 | 0,019 | - ∞ | 1 |
| | 0,027 | 0,028 | |
| 2 | 0,029 | | 2 |
| | 0,045 | 0,045 | |
| 3 | 0,045 | | 3 |
| | 0,097 | 0,100 | |
| 4 | 0,103 | | 4 |
| | 0,113 | + ∞ | |


Figure 16 – Means with standard error plots for cupule depth

Table 13 – Scoring character states for cupule depth

<table>
<tr><th>Group number</th><th>Group range</th><th>Coding range</th><th>Character state</th></tr>
<tr><td rowspan="2">1</td><td>0,476</td><td>- ∞</td><td rowspan="2">1</td></tr>
<tr><td>0,576</td><td rowspan="2">0,600</td></tr>
<tr><td rowspan="2">2</td><td>0,623</td><td rowspan="2">2</td></tr>
<tr><td>0,836</td><td rowspan="2">0,862</td></tr>
<tr><td rowspan="2">3</td><td>0,888</td><td rowspan="2">3</td></tr>
<tr><td>0,960</td><td rowspan="2">0,975</td></tr>
<tr><td rowspan="2">4</td><td>0,990</td><td rowspan="2">4</td></tr>
<tr><td>1,346</td><td rowspan="2">1,374</td></tr>
<tr><td rowspan="2">5</td><td>1,401</td><td rowspan="2">5</td></tr>
<tr><td>1,659</td><td rowspan="2">1,702</td></tr>
<tr><td rowspan="2">6</td><td>1,745</td><td rowspan="2">6</td></tr>
<tr><td>1,827</td><td rowspan="2">1,840</td></tr>
<tr><td rowspan="2">7</td><td>1,852</td><td rowspan="2">7</td></tr>
<tr><td>2,147</td><td>+ ∞</td></tr>
</table>

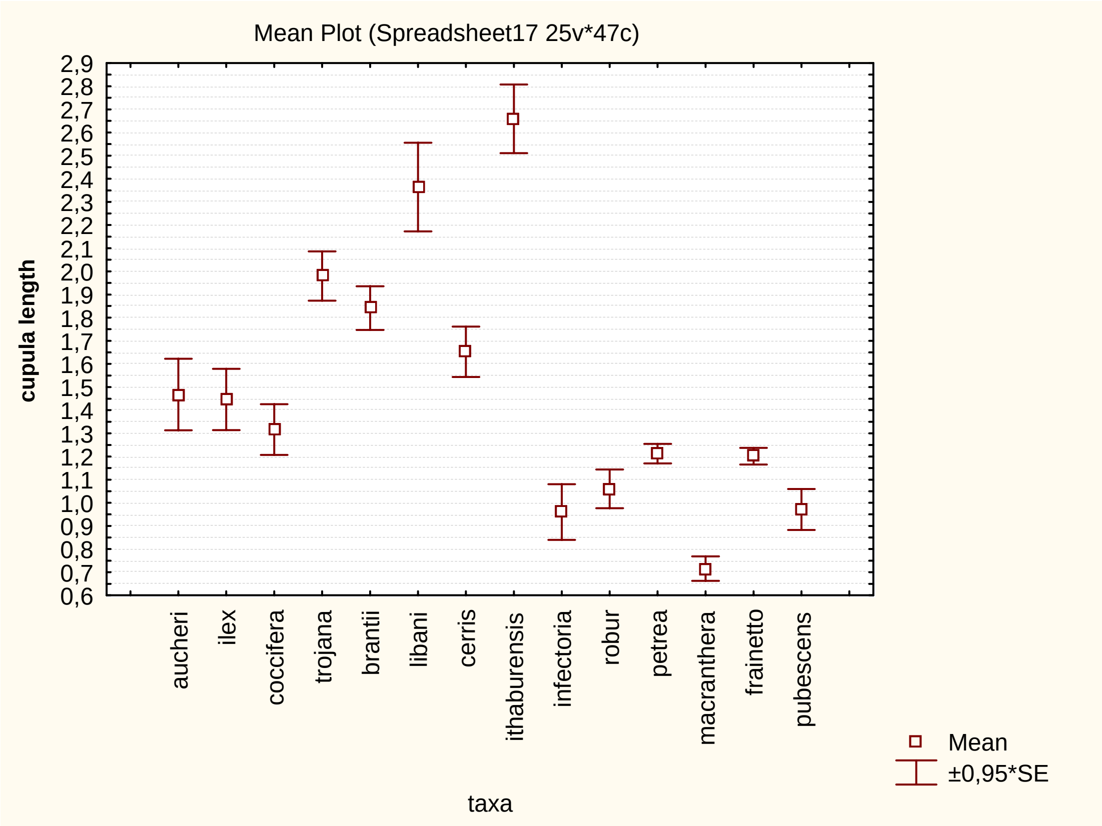


Figure 17 – Means with standard error plots for cupule length

Table 14 – Scoring character states for cupule length

| Group number | Group range | Coding range | Character state |
|---|---|---|---|
| 1 | 0,663 | - ∞ | 1 |
| | 0,769 | 0,805 | |
| 2 | 0,840 | | 2 |
| | 1,144 | 1,155 | |
| 3 | 1,165 | | 3 |
| | 2,086 | 2,130 | |
| 4 | 2,173 | | 4 |
| | 2,807 | + ∞ | |

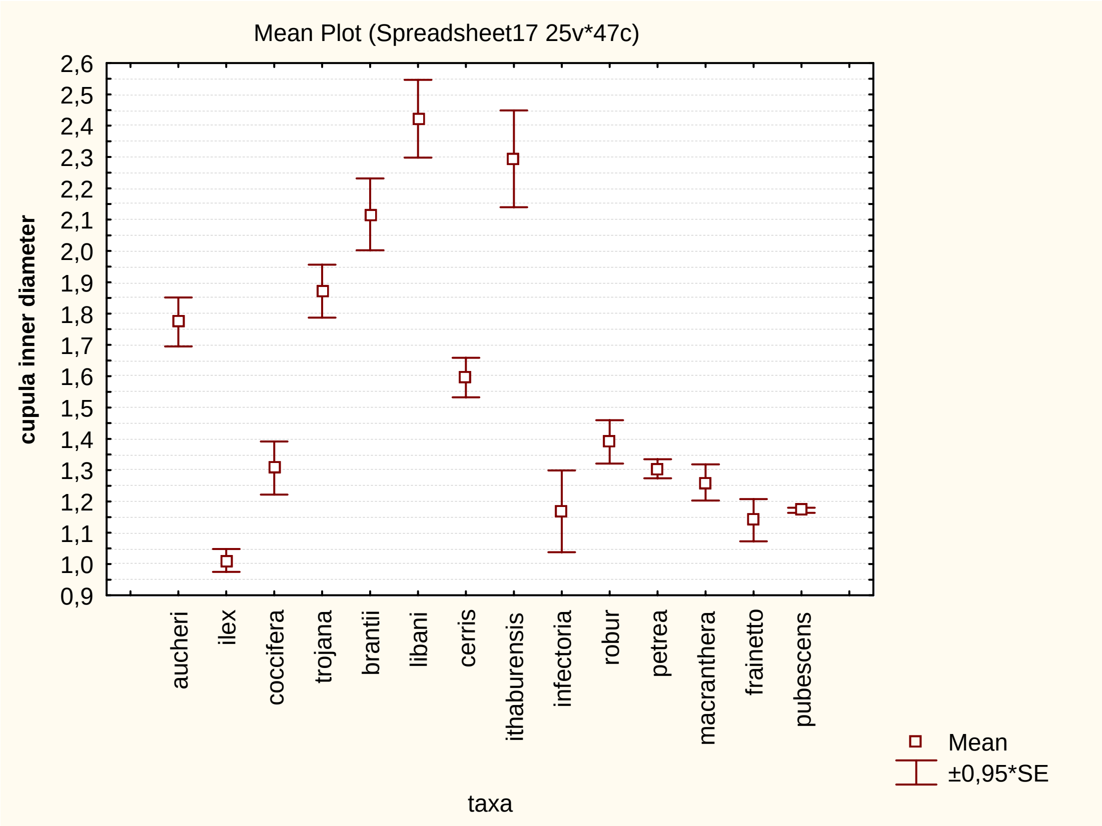


Figure 18 – Means with standard error plots for cupule inner diameter

Table 15 – Scoring character states for cupule inner diameter

| Group number | Group range | Coding range | Character state |
|---|---|---|---|
| 1 | 0,975 | - ∞ | 1 |
| | 1,460 | 1,497 | |
| 2 | 1,533 | | 2 |
| | 1,659 | 1,677 | |
| 3 | 1,695 | | 3 |
| | 1,956 | 1,979 | |
| 4 | 2,002 | | 4 |
| | 2,547 | + ∞ | |

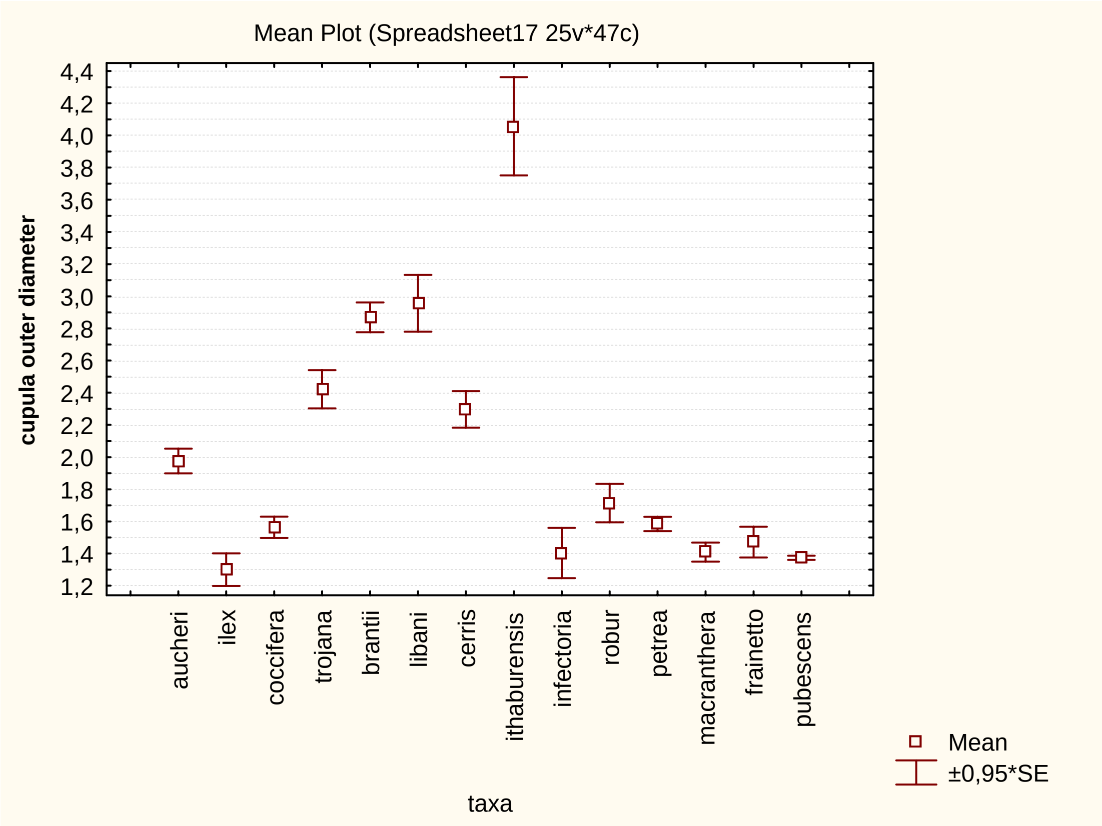


Figure 19 – Means with standard error plots for cupule outer diameter

Table 16 – Scoring character states for cupule outer diameter

| Group number | Group range | Coding range | Character state |
|---|---|---|---|
| 1 | 1,199 | - ∞ | 1 |
| | 1,833 | 1,867 | |
| 2 | 1,900 | | 2 |
| | 2,052 | 2,118 | |
| 3 | 2,183 | | 3 |
| | 2,541 | 2,659 | |
| 4 | 2,777 | | 4 |
| | 3,133 | 3,442 | |
| 5 | 3,751 | | 5 |
| | 4,362 | + ∞ | |

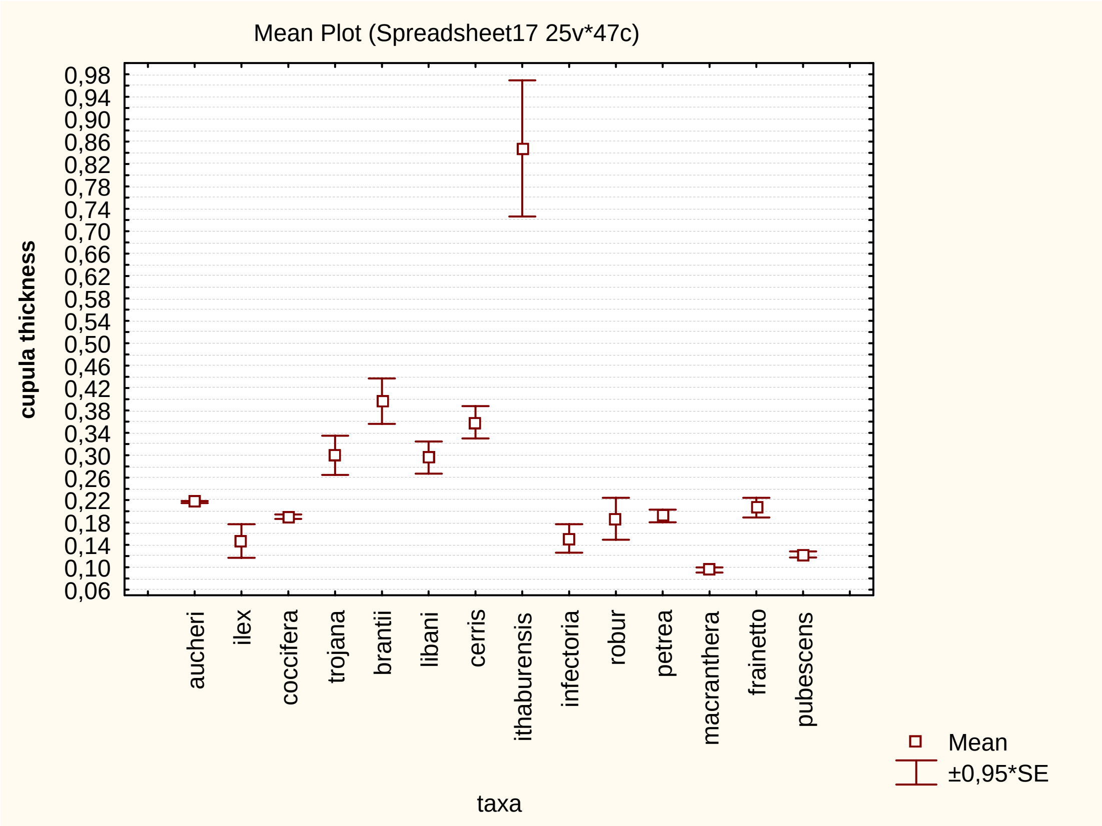


Figure 20 – Means with standard error plots for cupule thickness

Table 17 – Scoring character states for cupule thickness

| Group number | Group range | Coding range | Character state |
|---|---|---|---|
| 1 | 0,091 | - ∞ | 1 |
| | 0,100 | 0,109 | |
| 2 | 0,117 | | 2 |
| | 0,224 | 0,245 | |
| 3 | 0,265 | | 3 |
| | 0,437 | 0,582 | |
| 4 | 0,726 | | 4 |
| | 0,969 | + ∞ | |

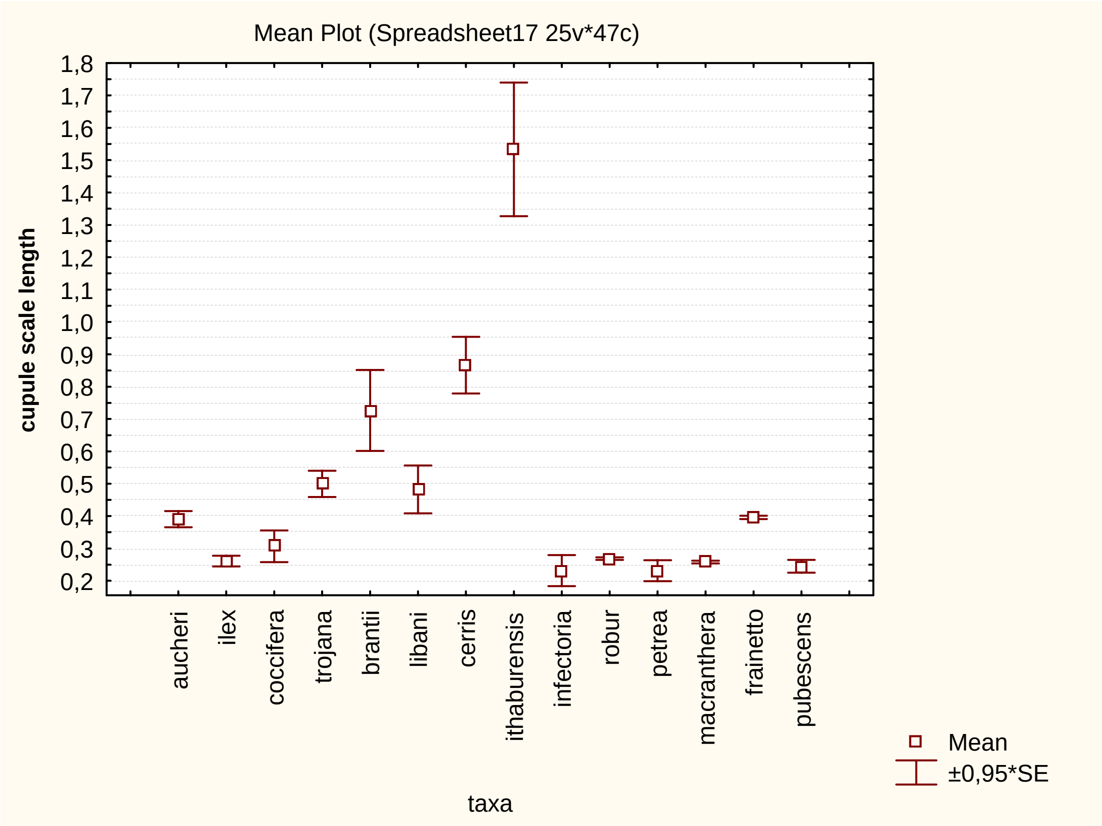


Figure 21 – Means with standard error plots for cupule scale length

Table 18 – Scoring character states for cupule scale length

<table>
<tr><th>Group number</th><th>Group range</th><th>Coding range</th><th>Character state</th></tr>
<tr><td rowspan="2">1</td><td>0,184</td><td>- ∞</td><td rowspan="2">1</td></tr>
<tr><td>0,356</td><td rowspan="2">0,361</td></tr>
<tr><td rowspan="2">2</td><td>0,365</td><td rowspan="2">2</td></tr>
<tr><td>0,556</td><td rowspan="2">0,579</td></tr>
<tr><td rowspan="2">3</td><td>0,601</td><td rowspan="2">3</td></tr>
<tr><td>0,954</td><td rowspan="2">1,141</td></tr>
<tr><td rowspan="2">4</td><td>1,327</td><td rowspan="2">4</td></tr>
<tr><td>1,740</td><td>+ ∞</td></tr>
</table>

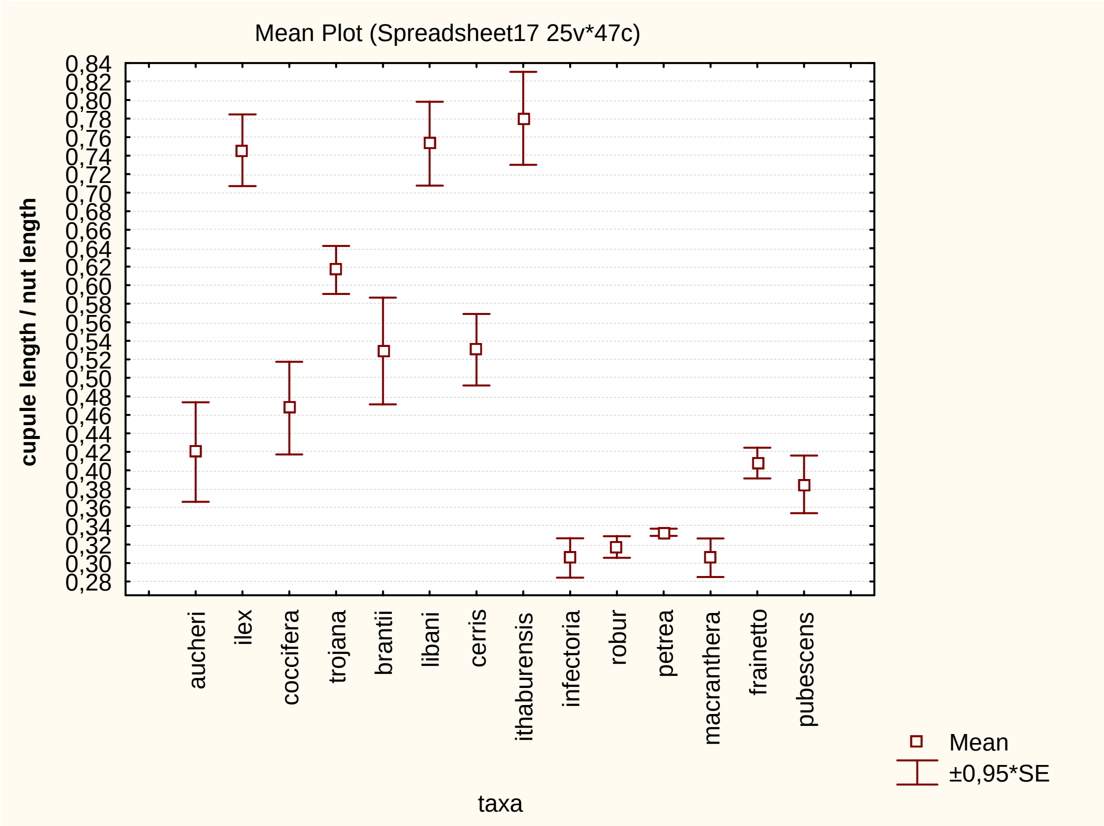


Figure 22 – Means with standard error plots for cupule length / nut length

Table 19 – Scoring character states for cupule length / nut length

| Group number | Group range | Coding range | Character state |
|---|---|---|---|
| 1 | 0,284 | - ∞ | 1 |
| | 0,329 | 0,329 | |
| 2 | 0,329 | | 2 |
| | 0,337 | 0,346 | |
| 3 | 0,354 | | 3 |
| | 0,587 | 0,589 | |
| 4 | 0,590 | | 4 |
| | 0,642 | 0,675 | |
| 5 | 0,707 | | 5 |
| | 0,830 | + ∞ | |

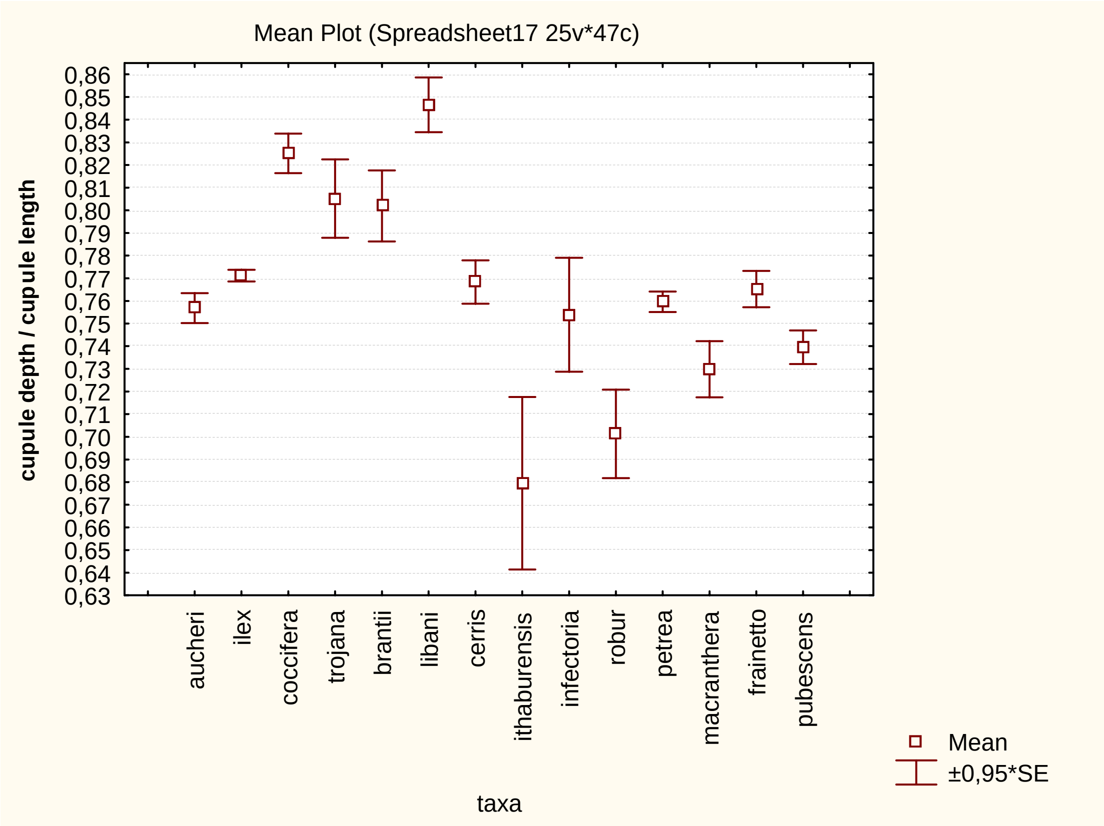


Figure 23 – Means with standard error plots for cupule depth / cupule length

Table 20 – Scoring character states for cupule depth / cupule length

| Group number | Group range | Coding range | Character state |
|---|---|---|---|
| 1 | 0,641 | - ∞ | 1 |
| | 0,779 | 0,783 | |
| 2 | 0,786 | | 2 |
| | 0,834 | 0,834 | |
| 3 | 0,834 | | 3 |
| | 0,859 | + ∞ | |

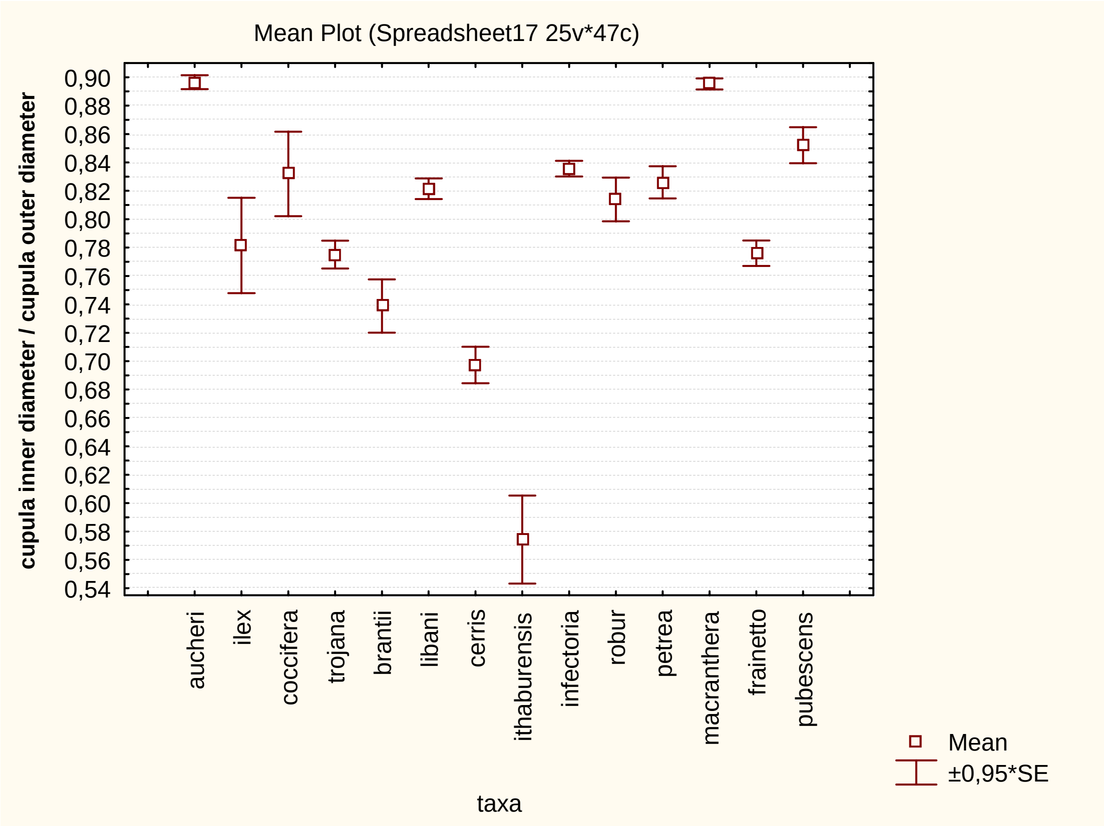


Figure 24 – Means with standard error plots for cupule inner diameter / cupule outer diameter

Table 21 – Scoring character states for cupule inner diameter / cupule outer diameter

<table>
<tr><th>Group number</th><th>Group range</th><th>Coding range</th><th>Character state</th></tr>
<tr><td rowspan="2">1</td><td>0,543</td><td>- ∞</td><td rowspan="2">1</td></tr>
<tr><td>0,605</td><td rowspan="2">0,645</td></tr>
<tr><td rowspan="2">2</td><td>0,684</td><td rowspan="2">2</td></tr>
<tr><td>0,710</td><td rowspan="2">0,715</td></tr>
<tr><td rowspan="2">3</td><td>0,720</td><td rowspan="2">3</td></tr>
<tr><td>0,865</td><td rowspan="2">0,878</td></tr>
<tr><td rowspan="2">4</td><td>0,891</td><td rowspan="2">4</td></tr>
<tr><td>0,901</td><td>+ ∞</td></tr>
</table>

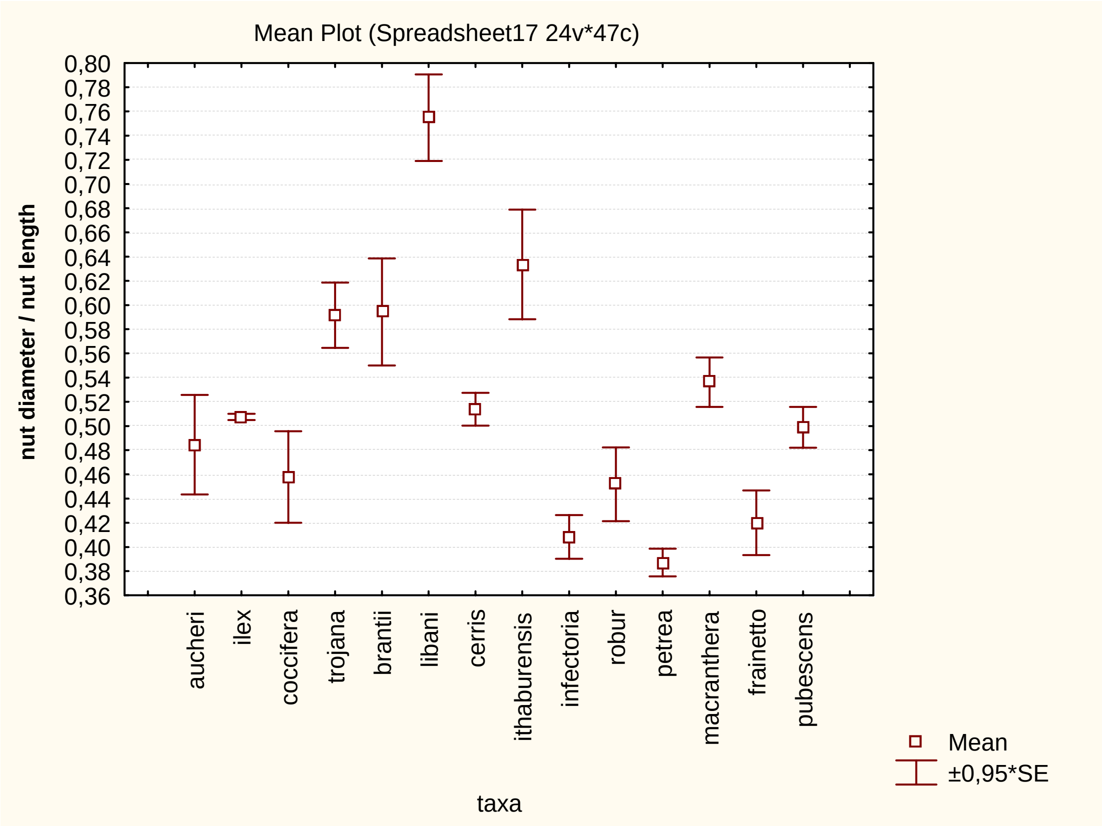


Figure 25 – Means with standard error plots for nut diameter / nut length

Table 22 – Scoring character states for nut diameter / nut length

<table>
<tr><th>Group number</th><th>Group range</th><th>Coding range</th><th>Character state</th></tr>
<tr><td rowspan="2">1</td><td>0,376</td><td>- ∞</td><td rowspan="2">1</td></tr>
<tr><td>0,679</td><td rowspan="2">0,699</td></tr>
<tr><td rowspan="2">2</td><td>0,719</td><td rowspan="2">2</td></tr>
<tr><td>0,791</td><td>+ ∞</td></tr>
</table>

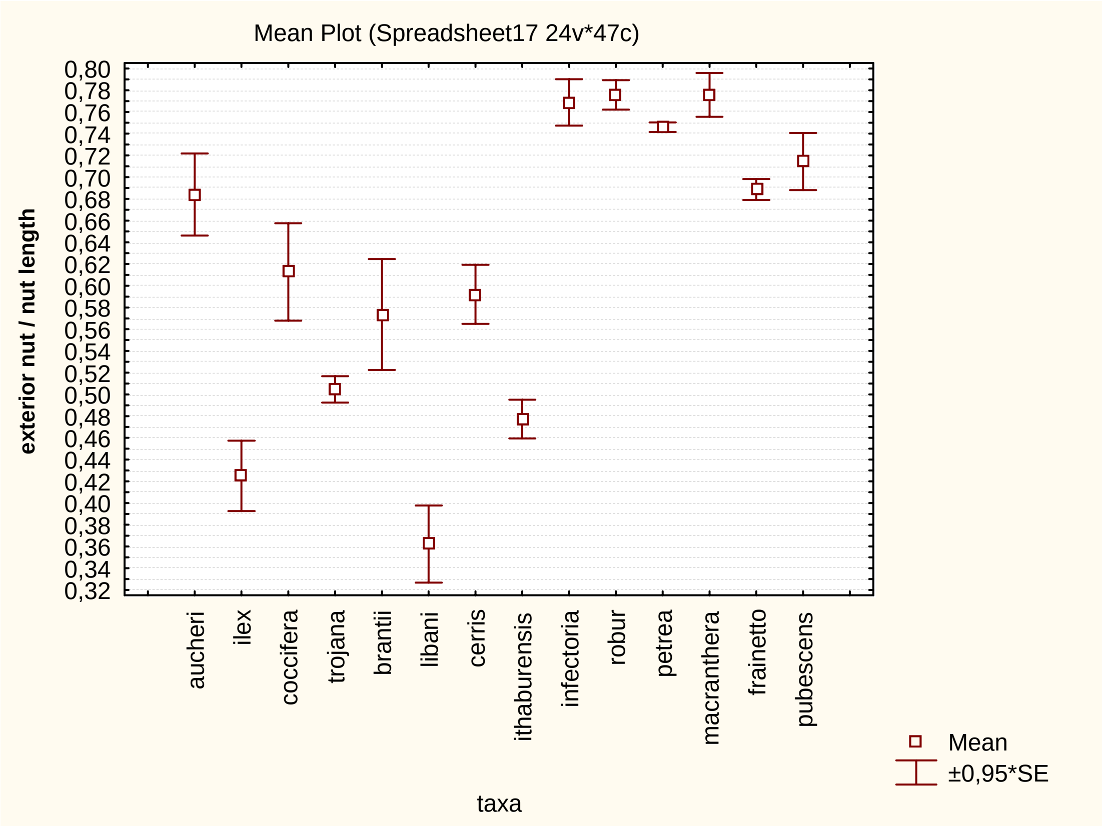


Figure 26 – Means with standard error plots for exterior nut / nut length

Table 23 – Scoring character states for exterior nut / nut length

<table>
<tr><th>Group number</th><th>Group range</th><th>Coding range</th><th>Character state</th></tr>
<tr><td rowspan="2">1</td><td>0,327</td><td>- ∞</td><td rowspan="2">1</td></tr>
<tr><td>0,457</td><td rowspan="2">0,458</td></tr>
<tr><td rowspan="2">2</td><td>0,459</td><td rowspan="2">2</td></tr>
<tr><td>0,517</td><td rowspan="2">0,520</td></tr>
<tr><td rowspan="2">3</td><td>0,522</td><td rowspan="2">3</td></tr>
<tr><td>0,740</td><td rowspan="2">0,741</td></tr>
<tr><td rowspan="2">4</td><td>0,742</td><td rowspan="2">4</td></tr>
<tr><td>0,796</td><td>+ ∞</td></tr>
</table>

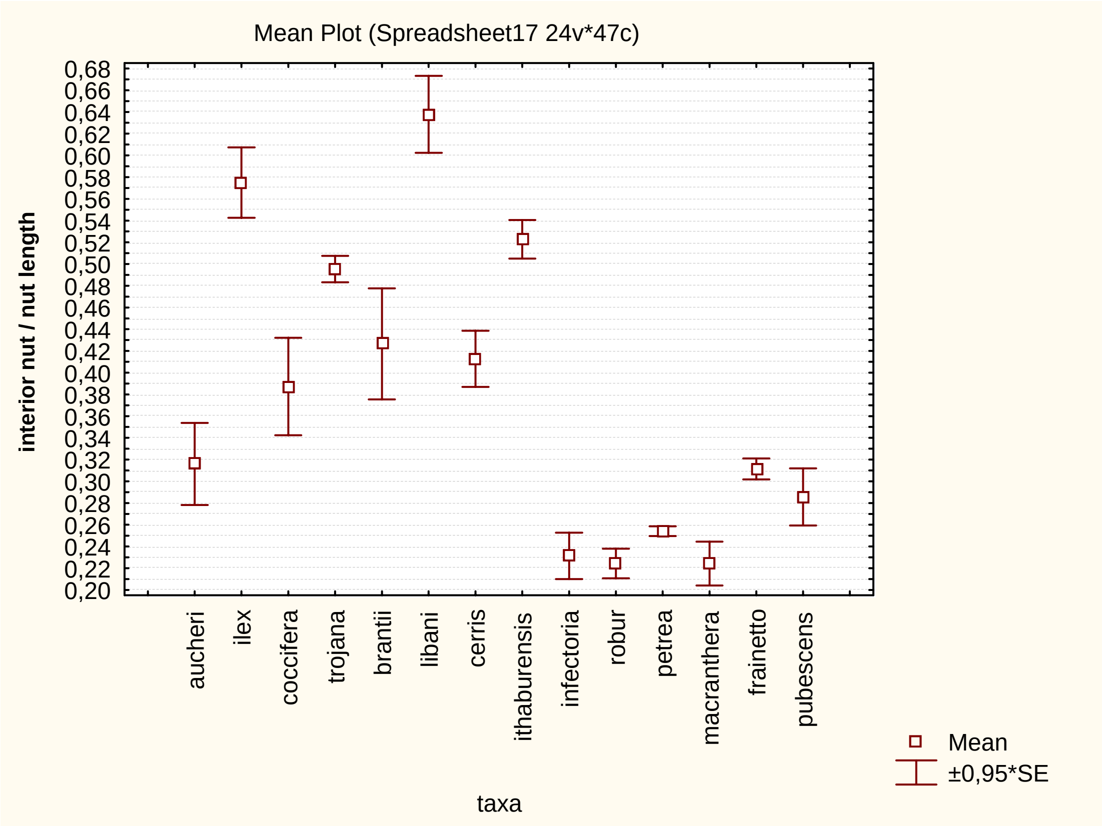


Figure 27 – Means with standard error plots for interior nut / nut length

Table 24 – Scoring character states for interior nut / nut length

<table>
<tr><th>Group number</th><th>Group range</th><th>Coding range</th><th>Character state</th></tr>
<tr><td rowspan="2">1</td><td>0,674</td><td>- ∞</td><td rowspan="2">1</td></tr>
<tr><td>0,542</td><td rowspan="2">0,542</td></tr>
<tr><td rowspan="2">2</td><td>0,542</td><td rowspan="2">2</td></tr>
<tr><td>0,482</td><td rowspan="2">0,480</td></tr>
<tr><td rowspan="2">3</td><td>0,478</td><td rowspan="2">3</td></tr>
<tr><td>0,259</td><td rowspan="2">0,259</td></tr>
<tr><td rowspan="2">4</td><td>0,259</td><td rowspan="2">4</td></tr>
<tr><td>0,204</td><td>+ ∞</td></tr>
</table>

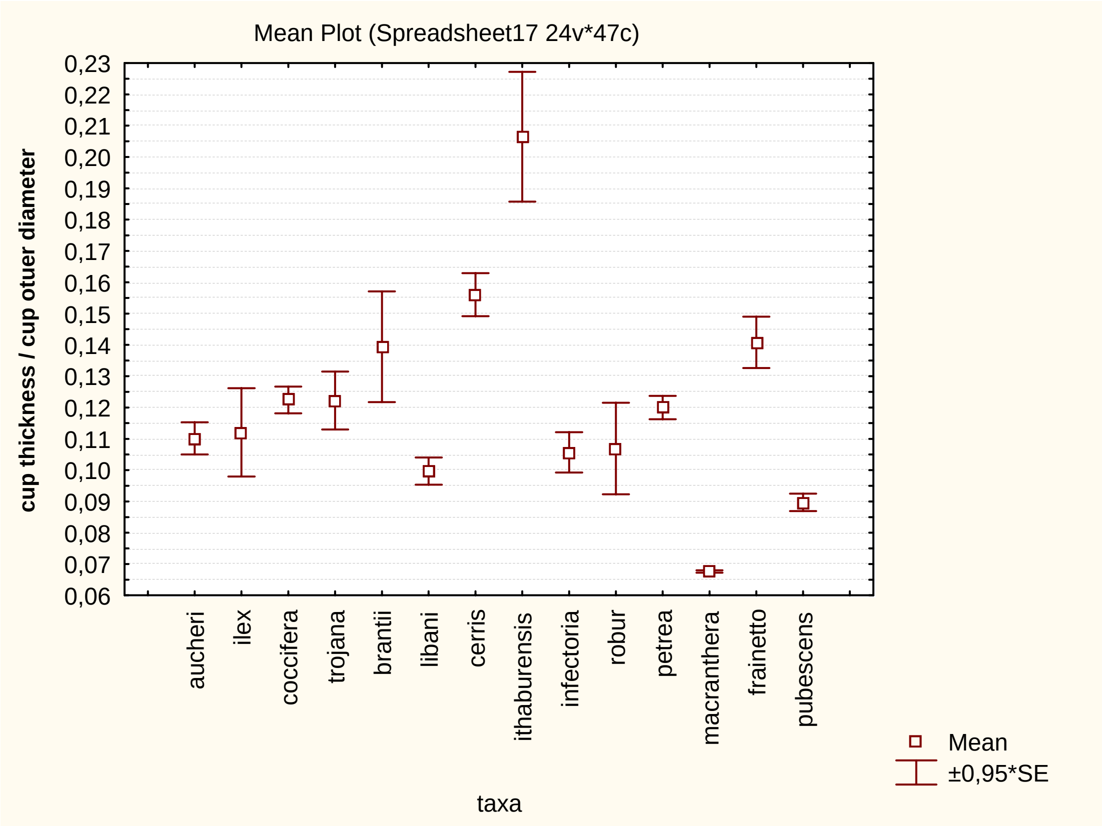


Figure 28 – Means with standard error plots for cupule thickness / cupule outer diameter

Table 25 – Scoring character states for cupule thickness / cupule outer diameter

<table>
<tr><th>Group number</th><th>Group range</th><th>Coding range</th><th>Character state</th></tr>
<tr><td rowspan="2">1</td><td>0,067</td><td>- ∞</td><td rowspan="2">1</td></tr>
<tr><td>0,068</td><td rowspan="2">0,078</td></tr>
<tr><td rowspan="2">2</td><td>0,087</td><td rowspan="2">2</td></tr>
<tr><td>0,163</td><td rowspan="2">0,175</td></tr>
<tr><td rowspan="2">3</td><td>0,186</td><td rowspan="2">3</td></tr>
<tr><td>0,227</td><td>+ ∞</td></tr>
</table>


Figure 29 – Means with standard error plots for nut scar diameter / nut diameter

Table 26 – Scoring character states for nut scar diameter / nut diameter

<table>
<tr><th>Group number</th><th>Group range</th><th>Coding range</th><th>Character state</th></tr>
<tr><td rowspan="2">1</td><td>0,395</td><td>∞</td><td rowspan="2">1</td></tr>
<tr><td>0,492</td><td rowspan="2">0,502</td></tr>
<tr><td rowspan="2">2</td><td>0,512</td><td rowspan="2">2</td></tr>
<tr><td>0,562</td><td rowspan="2">0,562</td></tr>
<tr><td rowspan="2">3</td><td>0,562</td><td rowspan="2">3</td></tr>
<tr><td>0,619</td><td rowspan="2">0,624</td></tr>
<tr><td rowspan="2">4</td><td>0,629</td><td rowspan="2">4</td></tr>
<tr><td>0,653</td><td>+ ∞</td></tr>
</table>


Figure 30 – Means with standard error plots for stalk diameter / stalk length

Table 27 – Scoring character states for stalk diameter / stalk length

| Group number | Group range | Coding range | Character state |
|---|---|---|---|
| 1 | 0,025 | - ∞ | 1 |
| | 0,182 | 0,202 | |
| 2 | 0,221 | | 2 |
| | 0,260 | 0,329 | |
| 3 | 0,398 | | 3 |
| | 0,645 | + ∞ | |

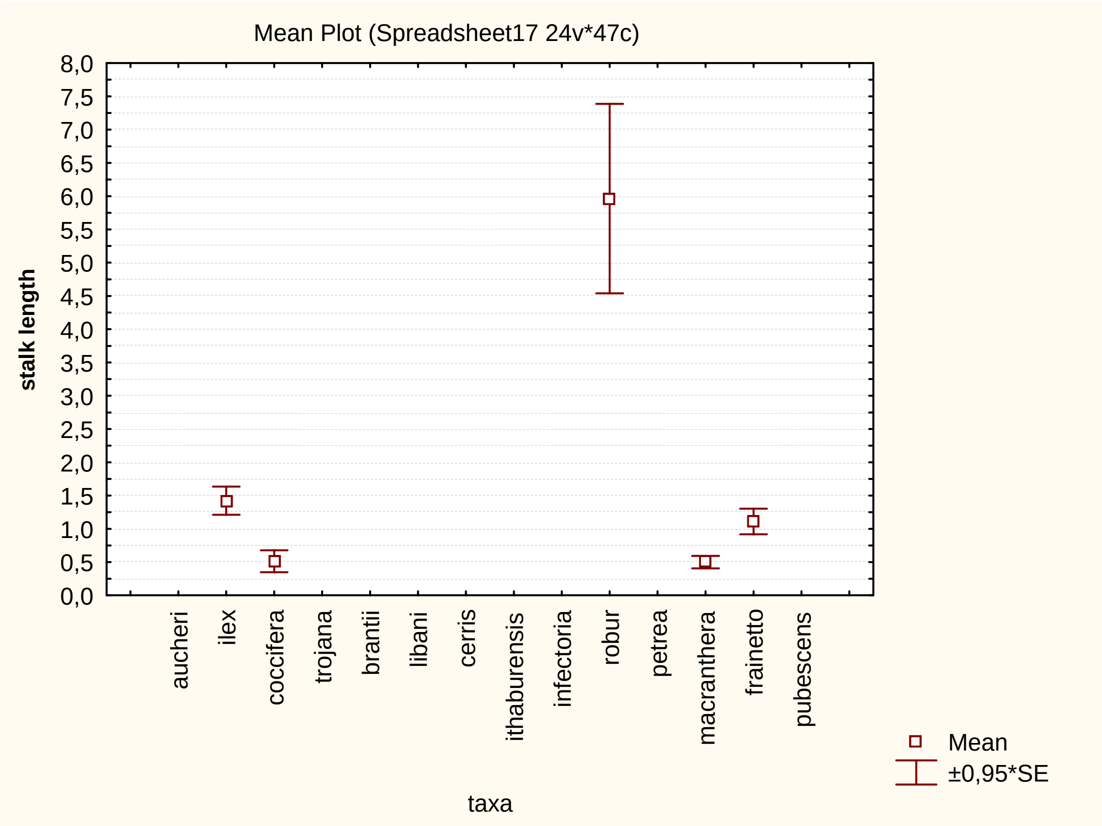


Figure 31 – Means with standard error plots for stalk length

Table 28 – Scoring character states for stalk length stalk length

| Group number | Group range | Coding range | Character state |
|---|---|---|---|
| 1 | 0,348 | - ∞ | 1 |
| | 0,678 | 0,797 | |
| 2 | 0,916 | | 2 |
| | 1,635 | 3,087 | |
| 3 | 4,539 | | 3 |
| | 7,388 | + ∞ | |

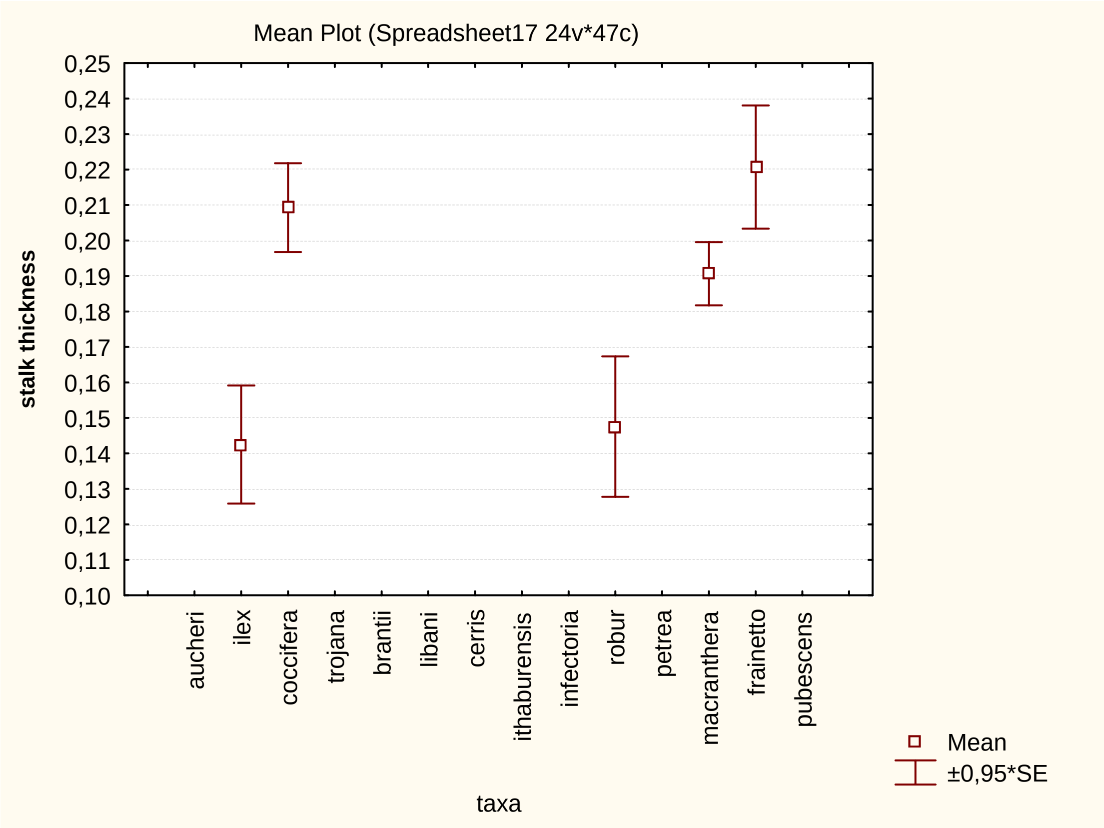


Figure 32 – Means with standard error plots for stalk thickness

Table 29 – Scoring character states for stalk thickness stalk thickness

| Group number | Group range | Coding range | Character state |
|---|---|---|---|
| 1 | 0,126 | - ∞ | 1 |
| | 0,167 | 0,174 | |
| 2 | 0,181 | | 2 |
| | 0,238 | + ∞ | |