T.R.
NIGDE OMER HALISDEMIR UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
DEPARTMENT OF PLANT PRODUCTION AND TECHNOLOGIES

CHARACTERIZATION OF A WILD POPULATION OF *HIPPOPHAE RHAMNOIDES* IN ÇAMARDI, CENTRAL ANATOLIA, TURKEY

AYŞE HAYRİYE SAYGI

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Master Thesis

Supervisor

Prof. Dr. Ian Timothy RILEY

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The study titled "**Characterization of A Wild Population of *Hippophae Rhamnoides* In Çamardi, Central Anatolia, Turkey**" and presented by Ayşe Hayriye SAYGI under the supervision of **Prof. Dr. Ian Timothy Riley** has been accepted as Master thesis by the jury at the **Department of Plant Production and Technologies** of Nigde Omer Halisdemir University, Graduate School of Natural and Applied Sciences.

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CONFIRMATION

This thesis has been found appropriate at the date of ..... / /2022 by the jury mentioned above who have been designated by the board of Directors of Graduate School of Natural and Applied Sciences and has been confirmed with the resolution of Board of Directors dated ..... /..... /2022 and numbered .....

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DIRECTOR

THESIS CERTIFICATION

This is to certify that this research paper is my original work. I declare that this thesis has been duly written by me in accordance with the thesis writing rules, and any contributions involved by others, with whom I have worked together at Niğde Ömer Halisdemir University have acknowledged precisely in the thesis.

Ayşe Hayriye SAYGI

ÖZET

HİPPOPHAE RHAMNOIDES'İN ÇAMARDI, ORTA ANADOLU, TÜRKİYE'DEKİ YABANİPOPÜLASYONUNUN KARAKTERİZASYONU

SAYGI, Ayşe Hayriye
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Halk arasında yalancı iğde olarak adlandırılan *Hippohae rhamnoides*, ılıman bölge çalısı olup, olumsuz çevre koşullarına dayanıklıdır ve önemli yabani yenilebilir meyvelerden biridir. Bu çalışmada, *H. rhamnoides*'in Orta Anadolu, Çamardı'daki en güneydeki yabani popülasyonu kullanılarak etnobotanik inceleme ve morfolojik karakterizasyon yapılmıştır. Etnobotanik çalışma, Çamardı'da yaşayan yaşlı nüfus ile yarı yapılandırılmışgörüşme şeklinde gerçekleştirilmiş ve bitki halk tarafından daha çok "Karaçalı" olarak adlandırılmıştır. *H. rhamnoides*'in morfolojik karakterizasyonu için ImageJ görüntü işleme yazılım programı kullanılmıştır. Sonuçlar, Çamardı'dan örneklenen 18 katılımın ağaç analizinde genel olarak klonal bir yapı sergilendiğini göstermiştir. Meyve analizlerinde sahalar arası en büyük farklılık AR parametresinde 1.30 -1.85 aralığında iken, tohum analizlerinde ise 1.71-2.15 olarak bulunmuştur. Sınırlı sayıdaki verilerden elde edilen sonuçlar gelecekte daha fazla katılım dikkate alınarak değerlendirildiğinde, ülke ekonomisine daha faydalı olacaktır.

Anahtar Kelimeler: *Hippohae rhamnoides*, yabani popülasyon, etnobotanik, morfolojik karakterizayon, ImageJ

SUMMARY

CHARACTERIZATION OF A WILD POPULATION OF *HIPPOPHAE RHAMNOIDES* IN ÇAMARDI, CENTRAL ANATOLIA, TURKEY

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Hippohae rhamnoides commonly named as sea buckthorn, is a temperate bushes and and resistant to adverse environmental conditions. It is one of the important wild edible fruits that naturally grown in some part of the Turkey. In this stuıdy, ethnobotanical investigation and morphological characterzation were done with using the most southerly wild population of *H. rhamnoides* in Çamardı, Central Anatolia, Turkey. The ethnobotanical study was conducted in the form of a semi-structured interview with the elderly population living in Çamardı and the plant was mostly called as "Karaçalı" by the people. In order to morphological characterization of *H. rhamnoides* image processing software program ImageJ was used. Results showed that, tree analysis of 18 accessions sampled from Çamardı generally exhibited a clonal structure. In fruit analysis, the greatest variationamong sites was in the AR parameter in the range of 1.30 -1.85 while in seed analysis it was 1.71-2.64. The results obtained from a limited number of data are evaluated by considering more genotypes in the future, has the potential to provide even greater benefits to the economy of the country.

Keywords: *Hippohae rhamnoides*, wild population, ethnobotany, morphologic characterization, ImageJ

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SYMBOLS AND ABBREVIATIONS

Symbols	Descriptions
%	Percentage
℃	Celsius
Cm	Centimeter
G	Gram
L	Liter
M	Meter
Mg	Milligram
Ml	Milliliter
Mm	Millimeter
mm^2	Square millimeter

Abbreviations	Descriptions
CVAR	Coefficient of Variation Aspect Ratio
Min	Minute
RH	Relative Humidity

CHAPTER I

INTRODUCTION

Hippophae rhamnoides which is commonly named as sea buckthorn, belongs to the *Elaeagnaceae* family. It is a temperate bush and native for Europe and Asia (Gao et al., 2000). The generic Latin name, *Hippophae*, translates to shiny horse because of sea buckthorn was used as a fodder crop for horses in ancient Greece in history.

The distribution of *H. rhamnoides* varies between Himalayan regions including India, Nepal, Bhutan, from Pakistan and Afghanistan to China, Mongolia, Russia, Kazakhstan, Hungary, Romania, Switzerland, Germany, France and England and Finland, Sweden to the northwards to Finland, Sweeden and Norway (Rousi, 1971; Zeb, 2004a). It is cultivated or naturally grown in the various parts of the world.

Turkey is one of the countries that *H. rhamnoides* is native. The plant, can grow in the most parts of the country in the form of shrubs. It is generally wild and distributed throughout North and East Anatolia, and central regions of Turkey. It is known locally as "Yalancı iğde" or "Karga dikeni" (Baytop, 1999; Çakır, 2004).

Hippophae rhamnoides which naturally found on slopes, riverbanks and seashores, exists as a pioneer plant with significant value for water and soil conservation. The optimum pH for the plant is between 6 to 7 (Li and Schroeder, 1996).

Hippophae rhamnoides has an actinorhizal root nodules on their root system. The plants which belong to the Elaeagnaceae family have the ability to fixing the atmospheric nitrogenon their root nodules by the symbiotic relationship with the *Frankia* bacteria which is an actinomycetic, nitrogen fixing, nodule forming endophyte of woody trees and shrubs (Kato et.al, 2007).

Considering the plant characteristics, *H. rhamnoides* is in the form of a decidious shrub or tree that typically in the range of 0.5 to 6 m in height but may reach up to 18 m in central Asia. The male trees are more erect than the spreading female trees. The branches are dense, stiff, and very thorny with both terminal and axillary twig spines. The linear or

lanceolate shaped leaves, which are 3 to 8 cm long and less than 7 mm wide, are dark grey-green on the upper surface and a distinct pale, silvery-grey on the lower surface. The sex of the wind cross-pollinated dioecious plant is evaluated according to the bud forms on the branches before fruiting (Bernath and Földesi, 2010). *Hippophae rhamnoides* fruit can vary in both shape and colour, but are typically globular to egg-shaped berries ranging from yellow to bright orange in colour. Different fruit shape and size, together with the contrast between fruit and leaf colour, add to the ornamental value of this plant.

Hippophae rhamnoides fruits and leaves are used in medical purposes, in the food and cosmetics industries, in traditional medicine, as animal fodder, in horticulture, and for ecological purposes. The versatile uses of this plant make it inevitable to evaluate local populations as genetic resources in the future. Therefore, the sustainability of gene resources depends on the protection of wild populations of this plant. Crop wild relatives provide the largest reservoir of genetic diversity that helps develop crops that are resistant to or can tolerate major gene diseases, pest resistance, and abiotic stress conditions (Wettberg et al., 2020).

Plants have been used for various purposes for centuries and people have benefited from plants to meet their various needs. As a result of the bond between humankind and plant, which has been going on for centuries, the science of ethnobotany, in which the whole world accepts its importance and where serious researches are carried out, was born.

Hippophae rhamnoides is in the structure of a classical clonal plant and it naturally propogates by suckers which is a shoot arising from the underground root and produces large quantities of sucker plants during propagation (Bai et al., 2021). Due to developing an extensive root system, *H. rhamnoides* is used for preventing soil erosion in agricultural ecosystem. In addition to preventing soil erosion, it also plays an important role in land reclamation by growing in almost all kinds of edaphic conditions, providing very high protection to the soil and colonizing barren lands (Bolea and Chira 2012). The shrub suckers are appropriately fill in space quickly and can be used in shelterbelts and conservation plantings to capture agri-environmental benefits (e.g. control soil erosion, trap snow, maintain pollinator and wildlife habitats).

Plant morphological characters are important for the identification and classification of

plants. Morphological comparison gives an idea about the similarities and differences between plants. Plant morphology observes not only the vegetative (somatic) structures such as shoot and root system of plants, but also their reproductive structures such as flower and fruit in angiosperms.

The creation of some software programs with technological developments has contributed to scientific research. ImageJ is one of the software programs that can be used to view, annotate, edit, calibrate, measure, analyze, manipulate, print and save raster (row and column) image data. ImageJ software used in Science and Engineering for material analysis has also been used more recently to determine fruit characteristics (Shiddiq et al., 2017.

CHAPTER II

REVIEW OF LITERATURE

2.1 Wild Population of Fruit Crops

Wild fruit crops are undomesticated trees or shrubs that can grow spontaneously in natural or semi-natural ecosystems without direct human influence. About 20.000 of the plant species among 750,000 to 1,000,000 in the world used for the medical purposes (Ozbek, 2005).

Wild edible fruits (WEFs) are among the most widely used non-timber forest products as well as being important sources of nutrition, medicine and income for consumers. WEFs, which is also used as food, is capable of providing fiber, fuel and some processed products. They also thrive in a variety of environments such as agroforestry and urban landscapes, deserts and natural areas (Sardeshpande and Shackleton, 2019).

Wild population of crops often reflect greater diversity and nutritional quality than those derived from cultivated plants (Rasmussen et al., 2017). Some WEFs have medicinal properties and contain antioxidants, minerals and vitamins beneficial to the body, and some are used in the treatment of diseases (Deshmukh et al., 2010). Natural with the consumption of fruits, which are a source of antioxidants, by preventing oxidation events that may occur, free oxidative damage of DNA by radicals are prevented or possible damage is reduced (Tüysüz et al., 2021).

2.1.1 Wild population of fruit crops in Turkey

Wild fruits have an important place in terms of plant diversity in Turkey, which is a country rich in flora (Ercisli et al., 2009). A center of origin (or center of diversity) is a geographic area where a group of domesticated or wild organisms first developed their distinctive features. They are also considered centers of diversity.

Centers of origin were first described by Nikolai Vavilov in 1924. Two of Vavilov's centers of origin (Near East and Mediterranean Centers) also include Turkey (Tan, 2010).

Mediterannean, Black Sea, Middle East, North East and South Anatolia regions are the regions where the wild fruit population are heavily found (Ercişli, 2004). About 500 of 9,000 plants growing for medicinal purposes in Turkey (Ozbek, 2005).

Some of the fruit families that also including the wild species are, Juglandaceae, Berberidaceae, Saxifragaceae, Rosaceae, Rhamnaceae, Elaeagnaceae, Grossulariaceae, Anarcadidaceae, Cornaceae, Coryllaceae, Ericaceae, Caprifoliaceae, Moraceae (Ercişli et al., 2009).

The greater diversity and species richness of Turkey is explained by

- Three plant geographies meeting point of the region,
- Center of origin and diversity of many crops/plant species
- The center of cultivation of many products,
- High endemism in species,
- It is due to the bridge and migration route between Europe and Asia (Tan, 2010).

Due to having topographically rocky areas, steep lands, excess of stream edges, in some regions wild fruits come to the fore rather than cultivated fruits. The presence of wild fruits is also important in terms of rural landscape.

In our country, which has an important place in terms of plant population diversity, besides the cultivated fruits, there are also many wild fruit species, most of which are recognized by our producers but not cultivated (Kökosmanlı and Keleş, 2000).

Rosehip, hawthorn, blackberry, quince, persimmon, cranberry, raspberry, barberry, wild cherry, mahaleb, black mulberry, wild apple, wild pear, pomegranate and olive are some wild fruits to be given as examples

2.1.2 Wild population of selected fruit crops in Turkey

Some well-known examples of wild population of fruit crops in Turkey are cranberry and hawthorn.

2.1.2.1 Cranberry (*Cornus mas* L.)

Cranberry is a drupe wild fruit belonging to the Cornaceae family. It is native to Anatolia, the Caucasus and Europe, and it grows widely in the coastal regions, mountainous and forested areas of Turkey (Didin et al., 2000). It started to be grown commercially in newly established orchards in provinces such as Karabük, Bursa, Yalova, Malatya and Istanbul. Fruits, leaves, flowers and the barks of the cranberry tree are used to cure many diseases. Fresh fruit is a very important source of vitamin C that draws attention with its vitamin C content which is twice as much as oranges and also berries contain antioxidant, anti-inflammatory, flavonoids and anthocyanidins (Hassanpour et al., 2012)

2.1.2.2 Hawthorn (*Crataegus* spp.)

The most important wild fruit species that has spread naturally in our country is hawthorn. Hawthorn (*Crataegus* spp.) belonging to the Rosaceae family and that has been used medicinally since ancient times. Europe, Asia and North America are the regions where hawthorn tree populations are seen in the world. Hawthorn which is one of the cultivated species in Hatay, also have the potential to be cultivated and spread in Mersin (Gülnar and Silifke), Aksaray, Osmaniye (Bahçe), Adıyaman and Malatya districts (Çalıkan et al., 2018). It is a wild plant with high nutritional properties and potential to be cultivated. It is natural in various regions of Turkey such as Aegean, Eastern Anatolia, Southern, Central and Northern Anatolia.

The hawthorn plant grown as recipient of diversity by eating birds or mammals, and forms still undescribed may be reported. (Bektaş et al., 2017).

2.1.3 Wild population of *Hippophae rhamnoides* in the world

Hippophae rhamnoides is the species which naturally grow in the cold climatic regions in the world. The low rainfall areas of Asia and Europe have suitable conditions for this plant to grow. Although *H. rhamnoides* is a plant that grows in cold regions, it grows better with full sun. The temperature requirement of 15-25°C during active growth is proof of this.

Hippophae rhamnoides grows in North and South America, apart from 30 Asian and European countries. It is seen that 80-90% of the world's resources are in China. Russia, India and Mongolia are also countries rich in *H. rhamnoides* plant resources (Singh et al., 2003). In the other terms, genus *Hippophae* originated in the Himalayas then it spread throughout China and to the west (Rajchal, 2009). Sea buckthorn fruit, named *H. rhamnoides* by the taxonomist Linnaeus in 1753, described three more species in 1971, namely the Finnish taxonomist Rousi, *H. rhamnoides*, *H. salicifolia* D. Don and H. tibetana. In 1978, Chinese taxonomists Liu Shengwu and He Tinnong, reported a new species called *H. neurocarpa*. Lian Yongshan who is a Chinese taxonomist, found another new species and two subspecies in 1995: *H. goniacarpa*, *H. goniacarpa* subsp. *litangensis* and *H. neurocarpa* subsp. *stellatopilosa*. Additionally, *H. rhamnoides wolongensis* were described as a new subspecies by Lian et al in 2003 (Rajchal, 2009).

Therefore, according to Germplasm Resource Information Network (GRIN, 2007) and the taxonomical studies, genus *Hippophae* has seven species with eleven subspecies. Some species of sea buckthorn berries are shown in Figure 2.1.

Figure 2.1. Fruit samples from seven species and subspecies of *Hippophae* collected from China (Liu et al., 2017).

Table 2.1. Distribution of *Hippophae* species and subspecies (Mir et al., 2018)

***Hippophae* taxons**	**Occurrence**
Rhamnoides ssp. *Rhamnoides*	Scandinavian countries, Baltic Sea countries,Germany, Belgium, Netherlands, Ireland,Poland, U.K. France, Russia
Rhamnoides ssp. *Sinensis*	The North, Northwest, Southwest of China
Rhamnoides ssp. *yunnanensis*	Sichuan, Yunnan and Tibet, China
Rhamnoides ssp. *Mongolica*	Siberia,Russia, Mongolia, Xinjiang of China
Rhamnoides ssp. *Turkestanica*	Pakistan, Afkhanistan, Turkmenistan, Kirghizstan, Uzbekistan, Kazakhstan, Iran, Turkey, Xinjiang and Tibet, China
Rhamnoides ssp. *Fluviatilis*	Alps Mountains: Germany, France, Switzerland, Austria, Czech, Slovakia, Italy,
Rhamnoides ssp. *Carpatica*	The Capathinan Mountains, Transsylvanian Alps,the valley and the mouths of the Donube and its tributary.
Rhamnoides ssp. *Caucasica*	The Caucasus Mountains, Georgia, Azerbaijan, Armenia, Ukraine, Romania, Turkey, Bulgaria, Iran,Russia.
Goniocarpa	Sichuan, Qinghai, China
goniocarpa ssp. *Litangensis*	Sichuan, Qinghai, China
Neurocarpa	Sichuan, Qinghai and Gansu, China
Neurocarpa ssp. *stellatopilosa*	Sichuan, Qinghai and Tibet, China
Tibetana	Sichuan, Qinghai, Gansu and Tibet, China, Nepal, India
Gyantsensis	Tibet, China
Salicifolia	The southern slope of Himalayan Mt. Tibet, China,Bhutan, Nepal, India

* Source: Sea buckthorn (*Hippophae* spp.): A Unique high altitude multipurpose plantspecies growing in cold regions

Figure 2.2. Distribution of *Hippophae* spp. in Europe and Asia (Lu, 1992)

2.1.4 Wild population of *Hippopahe rhamnoides* in Turkey

Hippophae spp., which is extremely resistant to adverse environmental conditions, is among the most important edible wild fruits that can be grown in Turkey without any chemical intervention. Aras-Tayhan (1995) reported that this species naturally grows on stream banks, dry streams, sandy and gravelly soils at very different latitudes and elevations in Turkey. Aras-Tayhan (1997) (with reference to Bottema, 1995), in pollen analyzes made in Anatolia by drillings in Yeniçağ Lake, Abant Lake, Tatlıgöl, Ladik Lake and Demiryurt Lake *Hippophae* spp. reports that they included pollen (Figure 2.3). The presence of *Hippophae* spp. pollen even in earlier periods shows the taxon is naturally found in Anatolia.

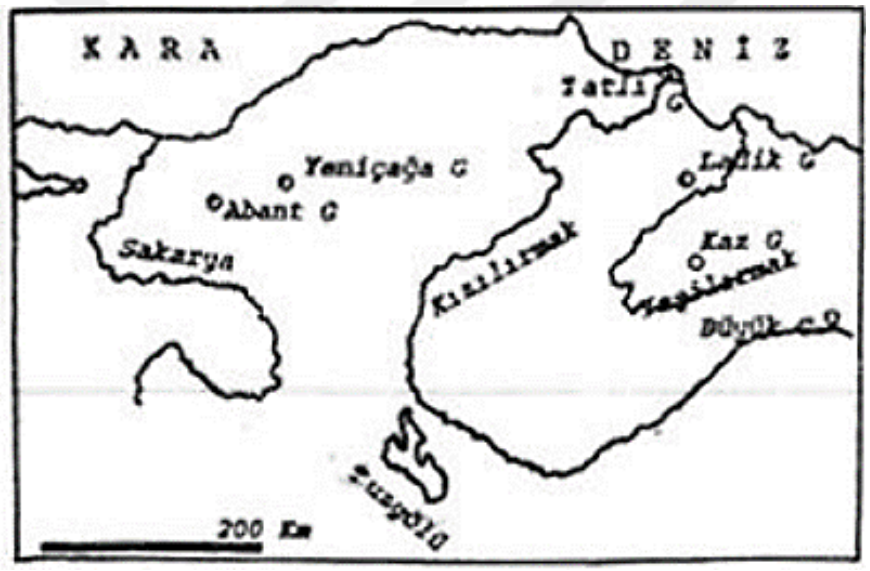

Figure 2.3. Areas of distribution of *Hippophae* L. species in Anatolia in the Late Quaternary (Bottema et al., 1995)

As indicated in Table 1, *H. rhamnoides* ssp. *caucasica* Rousi is the taxon of the*Hippophae* spp. in Turkey (Figure 2.4). In studies on *H. rhamnoides* in Turkey, it has beenreported that species belonging to different climatic regions have different characteristicsin plant morphology (1971; McKean, 1982; Bottema et al. (1995); Aras-Tayhan, 1995a, 1995b, 1997; Merev, 1998; Süleyman et al., 2001, 2002; Gumustekin, 2003). Forexample, some Turkish specimens likewise the *H. rhamnoides* subsp. *turkestanica*, due to their drought adaptation, have unusually silvery small leaves but *H. rhamnoides* ssp. *caucasica* from the Bulgarian coast of the Black Sea represent the transition to the *H. rhamnoides* subsp.

carpatica (Aras et al., 2007).

Figure 2.4. Natural distribıition of *Hippophae rhamnoides* ssp. *caucasica* (Aras and Tayhan, 1995)

The taxonomic classification of the species is quite difficult due to the clinical nature of the *Hippophae* species. In addition, Rousi (1971) indicated that, fruit characteristics such as the shape and size of the fruit also differ between and within the species (Aras et al., 2007).

Dindaroğlu and Alan (2015) indicated, *H. rhamnoides* grows in the north, north east or north west directions, at elevations between 1,600 m and 1,970 m, especially on the riverbanks, in their research areas in Erzurum and its surroundings. In addition, they reported that this species spread over on the brown soils, colluvial soils and alluvial soils which organic matter is between 0.7 and 3% and the pH range of this soils is between 6.6-7.1.

Ercişli et al. (2007) researched on comparison of *H. rhamnoides* genotypes which the samples were found in the town of Uzundere (lat 40°33′ N, long 41°35′ E, and 1,025 m asl) in Erzurum province in Eastern Anatolia, Turkey. Beside this, in order to investigate the biochemical content of *H. rhamnoides*, Yıldız et al. (2012) analyzed the samples they collected from the Erzurum and its surroundings (Ispir and Pazaryolu districts) Northeast

part of the Turkey. In addition, in a thesis study, it is explained that the samples used in

H. rhamnoides show natural distribution in Tosya, Kastamonu 41°02′ N-34°03′E, Ilgaz, Çankırı 40°36′ N-33°37′ E and Kargı, Çorum 40°33′ N-34°57′ E and its surroundings. Aras et al. (2007) the fact that the samples used in their studies on fruit and seed characterization of *H. rhamnoides* belong to natural populations taken from Sivas Sincan stream 39°54' N-37°59' E, Trabzon (Esiroglu Town) 40°52' N-39°45' E, Ilgaz Bolu-Kastamonu Çamkur junction 40°56' N-33°36' E and Ürgüp 38°40' N-34o56' E can be shown as proof that the plant grows in these regions.

In 2012, Sezen et al. investigated the biodiversity of *H. rhamnoides* trees/shrubs, fruit and leaves characterization of the wild natural population, Uzundere town 40°33′ N- 41°35′ E and altitude 1,025 m in the Çoruh Valley which has the important plant diversity in Turkey.

2.1.5 Preservation of wild population

Herbal medicines have been widely used and continues to be used all over the world since the prehistoric period. People living in Anatolia since then from the Paleolithic Age, have benefited from plants for therapeutic purposes and have been using plants in various ways for about 50,000 years (Özbek, 2005).

Continuous and irresponsible collection of plants from nature, excessive and uncontrolled grazing causes the deterioration of the natural structure. This also applies to endemic plant species. Therefore, plants grown in the flora of our country face various problems (Nohutçu et al., 2019).

The genetics contained in the gene pool for the long-term use of mankind the process of storing resources is expressed as the preservation of genetic resources (Nohutçu et al., 2019). These protection methods are of two types, ex-situ and in-situ. Ex-situ conservation means the protection of biodiversity elements outside their natural habitat. In-situ, on-site conservation means the protection of natural habitats and ecosystems, the protection and production of cultured species in the environments where they develop their distinctive characteristics means conservation and production in their

natural environment (Karagöz et al., 2010). Appropriate actions of in situ approaches for the preparation and implementation of conservation management or monitoring plans can be carried by a wide variety of organizations such as various government departments, national or regional environmental agencies, other government services, forestry, institutes, university departments, botanical gardens, national or local environmental or conservation associations, intergovernmental organizations, non-governmental organizations, the armed forces and civil society (Heywood, 2015).

2.2 Uses of *Hippophae rhamnoides*

Hippophae rhamnoides is a multipurpose species which has many advantages for its nutritional, medicinal, ornamental, theuropatic and environmental properties (Enescu, 2014). The medicinal and nutritional value of *H. rhamnoides* has been confirmed in many countries with clinical studies and scientific studies conducted in the 20th century (Zeb, 2004). Vegetative and generative parts of the plant are generally used asfolk remedy in the treatment of diseases such as burns/injuries, wounds and ulcers, hypertension, eczema, inflammation, tissue regeneration, treatment of skin grafts (Pundir et al., 2021). Phytochemical studies carried out that *H. rhamnoides contain* flavonoids, carotenoids, polyunsaturated fatty acids, minerals, vitamins, omega 3, 6, 9 and the rarest omega 7 and about 190 bioactive compounds in its structure. When examined pharmacologically, *H. rhamnoides* oil showed antibacterial,anti-sebum, antifungal, anti-atopic dermatitis and wound healing activities by promoting regeneration of tissues (Li, 1999). The different features of *H. rhamnoides*were gathered under one roof and the purpose of the different parts of the plant was shown schematically in the Figure 2.5.

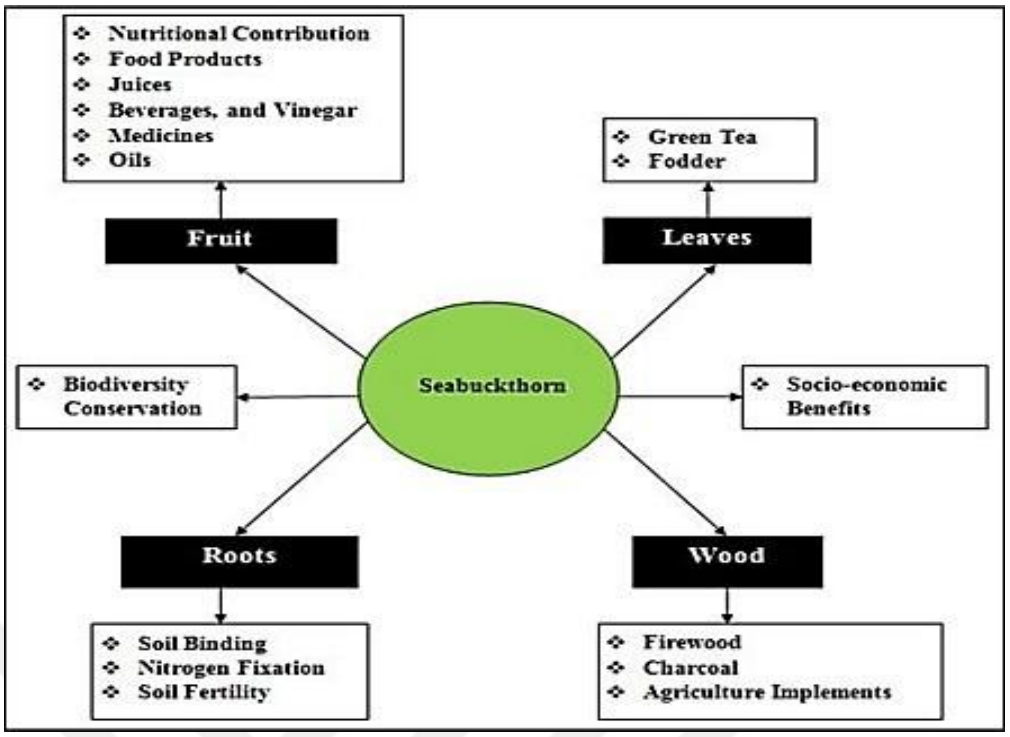

Figure 2.5. Different features of *Hippophae rhamnoides* (Sharma et al., 2019)

Due to these benefits to humanity, *H. rhamnoides* has become one of the research and development topics of the pharmaceutical industry (Letchamo et al., 2018) and has received great attention from scientists and engineers for its intense ecological and socio-economic benefits all over the world (Rajchal, 2009).

Among all other uses, *Hippophae* spp. due to its silvery leaves and flamboyant orange fruits, it can be used alone or as an ornamental shrub planted on hedges (Li and Schroeder 1996).

2.2.1 Agroecosystem and environmental uses of *Hippophae rhamnoides*

Agroforestry is the deliberate integration of trees and shrubs into crop and livestock systems to provide environmental, economic and social benefits. *Hippophae rhamnoides* is one of the agroforestry plants that prevents soil erosion, is used for land reclamation, windbreak and soil nitrogen fixer, increases biodiversity and adjusts the microclimate of the ecosystem (Chengjiang and Daiqiong, 2002). It is also an important agroforestry tree which are used for alley cropping. Meanwhile Bi and Zhang reported (2014) that, the activity of invertase, urease, acid phosphatase which are the soil

enzymes, effectively enhance by cultivating of Hippophae spp. in the soil that this is especially important in terms of rehabilitating the soil in the mining field. In addition, *H.rhamnoides* increases its water holding capacity due to its developmental root system (Chengjiang and Daiqiong, 2002). Additionally, the plantation of *H. rhamnoides*, with its lush crown, rich bushes, accumulates precipitation, and a thicker substrate that redistributes precipitation makes the air and soil moisture in the forest more stable (Chengjiang and Daiqiong, 2002). Other specific benefits are described in the subheadings below.

2.2.1.1 Nitrogen fixation and soil fertility

Hippophae rhamnoides is a species that fixes atmospheric nitrogen. This species has been proven to have an active symbiotic relationship with a bacterium of the genus Frankia, which forms nodules in the root of woody trees and shrubs without showing any signs of disease in living plant tissues, fixes nitrogen and generally improves soil fertility (Jike and Xiaoming 1992; Brasovan and Codrea 2008). Frankia bacteria belongs to the class of Actinomycetes that enhance the soil biodiversity by enriching more organic matter, more oxygen and soil organisms (Small et al., 2002). By the simbiotic relationship with Frankia bacteria, even under nitrogen-free conditions, *H. rhamnoides* plants with root nodules grew normally and is reduced need to utilize fertilizers (Small et al., 2002). Thus, input costs that do not require fertilizer addition and ecological problems caused by chemical fertilizers are reduced (Rajchal, 2009). Li (1992) mentioned the nitrogen fixing capacity of *H. rhamnoides* forest as 180 kg nitrogen/ha/year for 8-10 years old plant (Lu, 1992). In addition, having caduceus leaves, the annual leaf-litter represents an important source of organic elements for soils (Brasovan et al. 2009). *H. rhamnoides* produces biomass through the leaf litter and dead roots. This biomass is converted into organic minerals by microorganism activities in the soil and hence increases soil fertility in a fragile and marginal area (Sharma et al., 2019).

2.2.1.2 Soil erosion control and land reclamation projects

Human impact is effective on the mountain ecosystems. Conservation and rehabilitation is required to maintain human impact curative effects on downstream ecosystems, freshwater resources and social conditions (Acharya et al., 2010).

Hippophae rhamnoides is used for soil protection purposes in the control of soil erosion and in land reclamation projects, as it has the ability to grow in almost any soil condition and colonize bare lands (Enescu, 2014). Figure 2.6 explained that *H. rhamnoides* plants can be grown even the opencast mining in the background of field. It proves the plants can be grown any edaphic conditions and can be colonized under the bare terrains.

Strong functions such as ecological adaptation, fast growth, suckering habit and nitrogen fixation promote to improving the soil, preventing soil permeability and soil erosion. Extensive root system of the plant provides soil enhancer characteristics especially on fragile slopes on soil conservation (Rajchal, 2009).

Figure 2.6. *Hippophae rhamnoides* plantation in the foreground, opencast mining in the background

2.2.1.3 Wildlife habitat enhancement and farm stand protection

Hippophae rhamnoides bushes, beside their land reclamation and other uses, can provide

an excellent habitat to several wildlife species (Acharya et al. 2010), being both shelter and winter food for several bird or small mammals species (Binggeli et al. 1992). In addition, its leaves which have considerable amount of proteins, can be used as livestock and pet food (Suryakumar and Gupta 2011). Thorny structure of plants help to protect various bird species and small rodents (Sharma et al, 2019).

Figure 2.7. A small bird nest found within the *Hippophae rhamnoides* shrubs

2.2.1.4 Combating the desertification

Some of the case studies shows that the frequency and severity of subsequent sandstorms were greatly diminished by growing the *H. rhamnoides*. Figure 2.8 indicated that in the Kubuqi desert which is the the seventh largest desert in China, has in famous sandstorms overthere. The Chinese government implemented a number of ecological initiatives to reduce the sandstorms. One such project was planting *H. rhamnoides* to stabilise the sand dunes. After that it is realized that, the frequency and severity of subsequent sandstorms were greatly diminished.

Figure 2.8. *Hippophae rhamnoides* scrub in the Kubuqi desert

2.2.2 Agricutural uses of *Hippophae rhamnoides*

2.2.2.1 Alley cropping

Alley cropping can be defined as, planting of trees or shrubs in two or more sets of single or multiple rows with agronomic, horticultural, or forage crops cultivated in the alleys between the rows of woody plants. *Hippophae rhamnoides* can be used as an agroforestry shrub or tree for growing the other crops between them in the field. So that, the crops can be grown using the nitrogen which fixing by the Frankia that are found the root nodules of the *H. rhamnoides*.

Figure 2.9. Different varieties of *Hippophae rhamnoides* were planted in the field and harvest of oats which were grown with alley cropping

2.2.2.2 Windbreak

Using as a windbreak of *H. rhamnoides* in the field, can reduce the soil erosion,nutrient leaching and offer some protection from extreme weather events. When the trees are planted in the direction of the wind, the crops are protected from the harsh effect of the wind. Plants that act as windbreaks must be resistant to drying effects and physical injuries caused by wind and *H. rhamnoides* are well suited for this task. *Hippophae rhamnoides* is one of the plant which are effectively use as a windbreaks in an open areas to protect the soil from the wind erosion. In addition, it controls the snow accumulation and prevents the snowslide (Rajchal, 2009).

2.2.3 Medicinal uses of *Hippophae rhamnoides*

Diminishing inflammation, disinfecting bacteria, relieving pain and promoting regeneration of tissue can be evaluated as the most important medicinal properties of *H. rhamnoides*. Thus, 10 *Hippophae* spp. varieties have been improved into liquid, powder, plaster, paste, pill, ointment, aerosol drug form to treat diseases (Chandra et al., 2018). *Hippophae rhamnoides* fruit is traditionally used as raw material and food ingradient with their high content vitamin C berries (up to 20 g/kg fresh berries). The fruit and the seed include oil, tocopherols and plant sterols (Kallio et al., 2002). Having high level of vitamin C and E content help to reduce the lipid peroxidation (Porkkala-Sarataho et al., 2000). The content of vitamin C and tocopherols varies within and between natural populations based on plant genetics, weather conditions and harvest time. (Kallio et al., 2002).

A high-quality medicinal oil is made from the fruit which include vitamin E, carotenoids, phytosterols and essential fatty acids. It is used in the treatment of cardiovascular disorders. For example, total flavonoids of *H. rhamnoides* were given to 128 patients at 10 mg three times a day for 6 weeks and it was observed to lower their cholesterol levels without any adverse effects (Zeb, 2004).

Figure 2.10. *Hippophae rhamnoides* medicinal oil

The other importance of the fruit oil is, capable of reducing the incidence of cancer. Lifestyle and dietary measures are important for preventing 30-40% of all cancers. Food with antioxidant contains great duties in this regard. *Hippophae rhamnoides* has this ability due to having antioxidant properties although the positive medicine (phosphamide) much more effective than *Hippophae* oil on the cancer cells (Chandra et al., 2018).

Hippophae rhamnoides seed oil from which include the hexan extract, has successful findings in curing gastrointestinal disorders such as ulcer disease (Khan et al., 2010, Krejcarová et al., 2015).

In addition, skin damage including burns, bedsores, eczema, and radiation injury has been treated by using bioactive oil which obtained from the young branches and leaves of *Hippophae* spp. For example, in 1986, many of the Chernobyl nuclear disaster victims were treated with *H. rhamnoides*. The oil is also taken internally for diseases of the stomach and intestine (Small et. al., 2011).

Hippophae rhamnoides helps to protect the immune system at the cellular level with the nutrients it contains as well (Chandra et al., 2018). Indigestion, cough and blood sepsis have traditionally treated by *H. rhamnoides* in many parts of the world (Khan et al., 2010). Besides, it has positive effects on mental health. It has been observed to prevent memory loss, especially in elderly people (Krejcarová et al., 2015).

2.2.4 Industrial uses of *Hippophae rhamnoides*

The mature fruit of the *H. rhamnoides* consume as a juice, jam, wine and nutritional tea in food industry (Chandra et al., 2018). *Hippophae rhamnoides* prefers on food industry due to its nutritional value such as high levels of beta-carotene (provitamin A), alpha-tocopherol (vitamin E), high levels of L-ascorbic acid (vitamin C) and organic acids as well (Kanayama et al., 2009). Juice from *H. rhamnoides* berries is a common drink in many parts of Asia and Europe (Kallio et al., 2002) (Figure 2.11).

Figure 2.11. *Hippophae rhamnoides* consumed as a juice

Hippophae rhamnoides leaves, either fresh or dried, can be steeped to yield a nutritional tea in after washed from the dust particles. The leaves, young branches and fruit pulp can be used as an animal fodder. In addition, it has been observed that *H. rhamnoides* increases egg production and body weight of laying hens (Krejcarová et al., 2015).

Figure 2.12. *Hippophae rhamnoides* consumed as a tea from fresh leaves or fruits *Hippophae rhamnoides* oil is an effective biodiesel (Shankar et al., 2010).

Due to its tough, hard, very durable, fine-grained structure, it is utilized for fine carpentry. Colorful fruit of the plant give the opportunities to use it as a dye in the industry. While yellow dye is obtained from stem, root and leaves, blackish brown dye is obtained from young leaves and shoots (Figure 2.13).

Figure 2.13. Golden yellow to pale orange wool dyed with *Hippophae rhamnoides* extract

Hippophae rhamnoides has also been tested in the cosmetic industry. Its extracts have been proven to improve metabolism and delay skin aging. Because of its positive therapeutic effects, is used in beauty creams (Rajchal, 2009).

2.3 Morphological Characterization of Fruit Crops

Plant morphology is the science that describes the external structure or physical form of plants by interpreting plants on the basis of plan and origin similarity. Morphology forms the basis of taxonomic definitions. It has an important place in the containment and limitation of taxa (Simpson, 2010). It is used to make general or detailed comparisons of plant species belonging to any species with similar structures. Therefore, the species can be determined and the varieties found in each classification can be easily identified (Borrelli et al., 2009). Morphology knowledge in breeding programs and data on the biology of the species, plays an important role in determining strategies (Rego et al., 2020).

Plant morphology deals with both vegetative and reproductive part of the plants.

Vegetative structures consist of the stem, leaves and roots of the plant, while reproductive structures consist of fruits, flowers and seeds.

Plant characterization has several definitions or explanations given by scientists. They use plant characterization for hereditary characters and evaluate it as an account ranging from morphology to molecular markers. Morphological or visible descriptors, although limitations such as limited number of traits, insignificant hereditary trait variations, environmental conditions, age and breeding systems, important for improving selection and identifying local species. Of course, genetic characterization techniques such as RAPD (random-amplified polymorphic DNA), AFLP (amplified fragment length polymorphism), SSR (simple sequence repeat, microsatellite), ISSR (inter simple sequence repeat) and gene-based EST-SSR (expressed sequence tags-simple sequence repeat) is more reliable than morphologic characterization but morphologic characterization will be used until molecular markers are economically accessible in developing countries (Luta et al., 2020; Nawaz et al., 2018).

For the classification of fruits and vegetables in the agricultural sector, morphological characteristics (size and shape) are often used, which also affect the price in the commercial sense. Projected area, perimeter, length, width, major and minor axis are the properties of fruits and vegetables that can be measured by computer vision. Area is calculated as the actual number of pixels in an image. The distance between zone boundaries is expressed as the perimeter, which is a scaling quantification measure, major axis is the longest line across of every two boundry pixels while minor axis is the longest line drawn across the object perpendicular. Measuring of the similarities between the shape is difficult to identifying the fruits. Therefore, shape descriptors which are region based (based on integral area of object) and contour based (boundary segment edusing local features), play an important role to describe the fruit shape. Roundness, aspect ratio and compactness are described as a shape feature of the fruits and vegies (Bhargava et al., 2019).

2.3.1 Vegetative characterization of fruit crops

Stems, roots and leaves are three main parts of a vegetative structure of a plant. These structures broadly support the plant growth and they are essential for maintaining the life

of a plant.

2.3.1.1 Leaf characterization of fruit crops

One of the main components of species and morphotype identification is morphologic characterization of the leaf. Leaf type, shape, margin, apex, and base of the leaves are evaluated as a main morphologic characteristic of leaves. These characteristics can be differed among the morphotypes even in the same species. There are many studies that use leaf characters such as leaf ratio, petiole length, and micromorphological characters to determine intraspecific variation. The leaf characteristics of the Vitex negundo length, width and petiole length was done using a ruler or dial caliper (Salvaña et al., 2019).

The other study conducted by Yaman and Turan (2021), for "Some Fruit and Leaf Characteristics of Different Apricot Cultivars in Kayseri". In this research, leaf length and leaf width, petiole length and thickness and chlorophyll density have been characterized. Leaf length and width, petiole length and thickness measured by in mm with the help of digital caliper, chlorophyll density measured by with SPAD device (502 Plus Konica Minolta).

Image analysis can also be used to describe the leaf characteristics. Maeda et al. (2018) were analyzed the persimmon leaves based on EFDs and a PCA using the SHAPE program package for evaluating biological contour shapes developed by Iwata and Ukai (2002).

2.3.1.2 Stem characterization of fruit crops

Stem is the above ground part of the plants that develops buds and shoots. The main functions of the stem are to support the leaves, delivering water and minerals to the leaves and the transportation of the photosynthetic products from leaves to other parts of the plant, including roots.

Nodes, internodes, leaves, axillary buds, and axillary shoots are the primary structures of the stem. Botanical quality control for the marketing process and/or pharmaceutical industry, as for other morphological characterization of plant parts of a particular crop, is

also important for the stem characterization (Sapio et al., 2012).

Pseudo-stem and fruit-bunch-stem of the banana researched by Abdullah et al. (2014) research can be given as an example for the proximate analysis, elemental analysis, heating value, chemical and thermal analysis. By using these techniques, the fixed carbon, the carbon, hydrogen, nitrogen and sulfur content of the samples; higher heating values; the extractives, lignin, holocellulose, alpha-cellulose, and ash content, thermal behavior of the samples were characterized and the biomass of the banana stem compare with the other products.

2.3.1.3 Root characterization of fruit crops

Root is the plant organ that hold the plant and absorb the nutrient and water from the soil. To understanding the mechanism of the plant growth, physical factors between the soil and root should be evaluated (Ozoe et al., 2015).

Ali et al. (2020) studied on root anatomical characteristics of pomegranate genotypes. Selective genotypes were taken and preservation, sectioning, staining, and mounting process were done, respectively. For preservation, some of the chemical treatment applied to the root section of pomegranate plant. Sectioning process were done by using free-hand sectioning technique and some fine sections were picked and washing with series of different concentration of ethanol before staining. Xylem vessels and sclerenchyma tissues were used for staining and the washed section dip into the safranin. After that, sections were mounted on Canadian balsam by placing a drop of resin on a slide and placed on slides and photographed with a digital camera attached to a compound microscope. So that, 115 wild and domesticated pomegranate genotypes clustered based on morpho-molecular and biochemical analyze.

2.3.2 Reproductive characterization of fruit crops

Flowers are the reproductive structures of angiosperms for all living organisms. The reproduction of flowering plants, which beginning with flower induction and ends with the germination of the seed, involves a complex series of events (Ornduff, 1978).

2.3.2.1 Fruit characterization

Undoubtedly, supply/demand as a requirement of modern fruit growing that production plans should be made according to consumer preferences. The fact that, market preferences are mobile as opposed to static allows for the introduction of new varieties. Maturation time, total quality and preservation ability of fruit is important in choosing varieties. Vurgun and Aslantas (2014) studied on the morphological apple characterization in the East Anatolia region of Turkey. Vernier caliper were used forthe measurement of the morphologic parameters such as fruit length and width, petiole length and width of the fruits. In round-shaped fruits, the width of the fruit is measured as in the Figure 2.14. Fruit flesh weight and seed weight parameters measured by precision balance after the seeds of the fruits were removed.

Figure 2.14. Round- shape fruit width measurement (Laboratory services,National Educational Ministry of Turkey)

One of the other important quality criteria parameters of fruits is the color that affects its appeal. Natural pigments, chlorophylls, carotenoids and anthocyanins form the chemical basis of color. In the analysis, color cards are used for the standards and darker, lighter, etc. comparisons are made in subjective terms

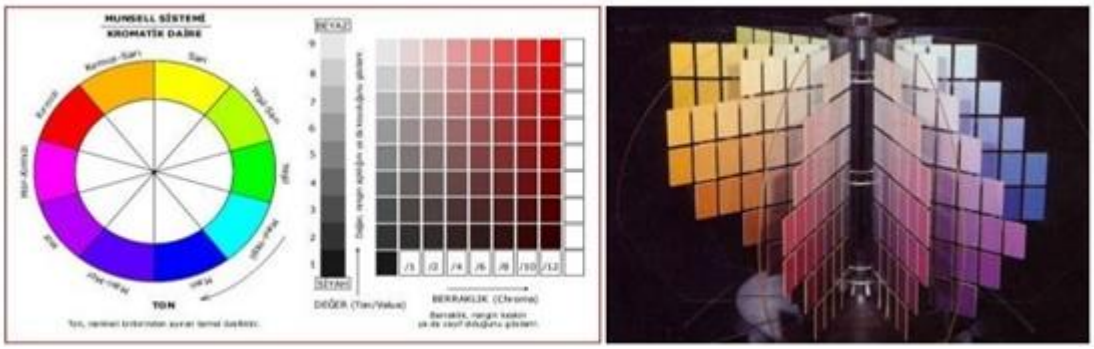

Figure 2.15. Munsell color scale (Laboratory services, National Educational System)

The wide diversity detected in fruit crops is a unique treasure for the new variety development program. Beside traditional characterization methods, image analysis also sheds light on the automatically characterization of fruit using new technologies with more accurate, fast and objective quality determination (Kodagali et al., 2012). It is not only useful for the morphological characterization but also useful for detection of the diseases on fruit. For example, Karhan et al. (2011), morphological image processing techniques were used to detect the spots on apricots due to *Coryneum beijerinckii* (leaf piercing) disease and to interpret the apricot quality as a result of this detection. It has been observed that the accuracy rate obtained as a result of this study is sufficiently successful. Without the need for different more complex methods, only morphological operations and stain detection with the help of a filter have been successfully applied.

2.3.2.2 Seed characterization

A seed is an embryonic plant enclosed in a protective outer covering. It is formed by the development of the fertilized seed ovule.

Seed size is a very important factor in identifying the seed according to its shape and texture. Length, width and thickness are also considered as morphological characterization parameters in the seed. As in fruit characterization, seed characterization is of two types, manual and image analysis. Calibrated rulers, calipers and eye piece micrometer devices used for manual measurement of seed. Gokturk et al. (2017) used the manual characterization technique to identified the hawthorn (Crateagus sp.) species and realised that there were inter spesific differences in terms of seed characteristics. Likewisethe fruit characterization, image analysis a number of software program can be

used to characterizing seeds (Figure 2.16).

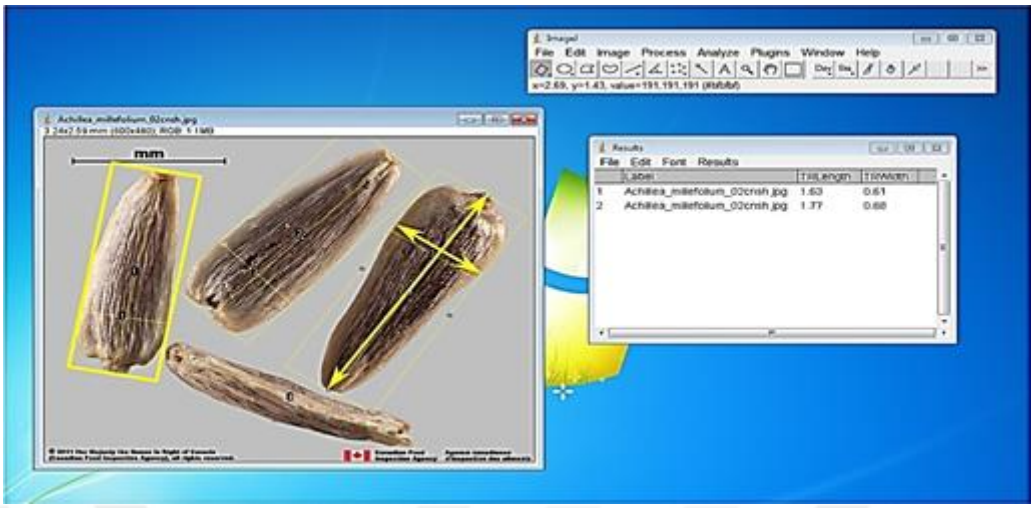

Figure 2.16. Measurement of Achillea millefolium by using ImageJ software programme (International Seed Morphology Association)

2.4 Characterization of Fruit Crops by Using ImageJ Software Program

Image processing is a field that covers all operations performed with the help of computer on any image file saved in electronic media. This area covers the processes of changing the features such as light, color, contrast, sharpness or clarity on the image. It also includes operations to remove noise, roughness or distortion in the image. Apart from these, extracting meaningful data from image files and obtaining different information about the objects in that image are also included in the field of image processing (Balcı et al., 2016).

With the rapid development of technology, image processing has gained great importance. It is seen that especially these applications are widely used in security systems, vehicle interior-exterior automation, military field applications, robot applications, agriculture-based applications, medicine and biomedical fields, manufacturing and design applications, geographic information systems (Samtas and Gulesin, 2011).

It has been observed that computer vision has been successfully applied to objectively determine the visual properties of foodstuffs such as color intensity, color distribution, visual defects, size and shape (Omid et al., 2011).

ImageJ is one of the powerful software programs which can be freely downloaded, has recently found use in various sciences such from the medicine to astronomy. It is developed at the National Institutes of Health and installers are suitable for Windows, MacOS and OSX, and Linux. ImageJ can view, edit, analyze, process, display and print 8-bit, 16 bit and 32 bit and most formats like TIFF, GIF, JPEG, BMP, DICOM, FITS and raw.

ImageJ has many different buttons on the tool bar (Figure 2.17) that give the opportunities to analysis of images (Aboukarima et al, 2018).

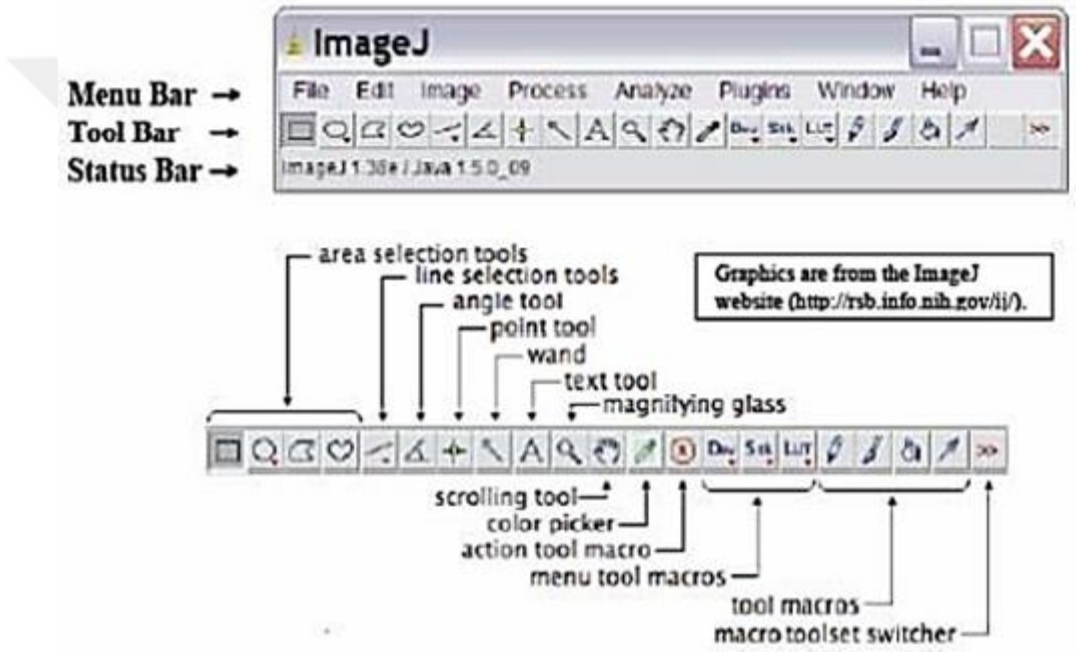

Figure 2.17. Main menu window of ImageJ software (Aboukarima et al., 2017)

Solak and Altınısık aimed to classify products by using hazelnut fruit in their studies. In the experimental study, hazelnut images in the environment were recorded by the camera, then processed using some image processing techniques, size and area calculations were made on the hazelnut images and the hazelnut fruits in the environment were detected with a 100% success rate.

Image processing techniques not only used for the fruit analysis but also used for assessment of flowering intensity and growth of fruit trees. For example, Treder et al., (2021) to assessed flowering intensity of pear trees, manual counting of inflorescences

and photographs of trees in full bloom were taken.

In addition, ImageJ has many advantages comparing with manual analysis on seeds. For instance, it accelerates the analysis process, minimizes distortions caused by natural light and microscope and allows some features to be defined automatically based on image pixel values (Vale et al., 2020).

2.5 Ethnobotany and an Overview of Ethnobotanical Studies of *Hippophae rhamnoides*

Ethnobotany is a scientific study that deals with the human-plant interactions in their historical and geographical totality and includes traditional knowledge of people and customs regarding plants (Alexiades, 2018).

According to archaeological findings from ancient times, humans primarily used plants to obtain nutrients and overcome health problems. This information, obtained through trial and error, has reached the present day with some changes and developments in usage patterns throughout the ages (Pei et al., 2020).

Turkey is quite rich in terms of endemism. Total in all European countries while the number of endemic taxa is approximately 2,750, the number of endemic species in our country is 2,891, the number of taxa is more than 3,750 (Kadıoğlu et al., 2020). Considering all this information, extensive work on this appears to have potential. Identifying and updating local plant names is an important part of community-integrated ethnobotanical studies (Kendir and Guvenc, 2000).

Our country, which has a rich cultural heritage, also has a rich knowledge in terms of ethnobotany. However, in parallel with the migration from rural areas to cities and developing technology, new generations do not know the value of this treasure and this information is at risk of being lost because it is not used. Therefore, it is necessary to putthis very valuable information in writing and contribute for our country's economy. The determination of which plants can be used in which regions can only be determined in thelight of ethnobotanical studies and in this way, the information received from the public will be returned to contribute to the economy of the people (Sadıkoğlu, 1998).

Local knowledge of plant identification in a particular area can be made using semi-structured interviews, a qualitative research method that combines a predetermined set of open questions and the opportunity of the interviewer to further explore specific themes or answers (Silva et al., 2014). For example, Gurdal and Kultur (2013) collected the information via semi-structured interviews with people for research the medicinal plants in Marmaris, Muğla. They reported that 64 plant species belonging to 35 families including the uses of nine essential oils for medicinal purposes.

According to the ethnobotanical studies in Turkey, the Black Sea and Central Anatolian regions have been explored more. Ethnobotanical Studies carried out in Niğde (west of Aladağlar) according to this study 200 plant samples were collected and it was determined that 126 species were used. It has been determined that 125 species are used in the production of medicinal, 39 species of food, 7 species of animal feed, 5 species of honey, 14 types of materials, and 5 species have environmental uses (Uzun, 2014).

2.5.1 Overview of ethnobotanical studies of *Hippophae rhamnoides*

The fact that, *Hippophae rhamnoides* has been used for many purposes for many years has made it inevitable to carry out ethnobotanical studies on this plant in its natural habitat. Özgen et al (2004) conducted on an ethnobotanical study Ilıca, Erzurum. *Hippophae rhamnoides* is one of the species that is used by the local people who called it as “Sincan”, “Karaçalı” and “Ekşi”, consumed as a fresh fruit in Ilıca village.

Karakaya et al (2019) used structured and semi-structured interviews to identify medicinal plants in Aziziye district of Erzurum, Turkey. As a result of the study, they informed that the leaves and fruits of *H. rhamnoides* is used by the local people for diabetes.

As it is mentioned in the usage of *H. rhamnoides*, the oil of the fruit and seed effectively combat for skin diseases, utilized in a cosmetic industry as an anti-aging cream and lotion. Fahad and Bano (2012) conducted a survey in various locations from Kargha and Naltar Gilgit, Baltistan. As a result of interview with the local people, *H. rhamnoides* locally named as “Buru” and fruit of the plant are used for cytoprotective, antistress, immunomodulatory, anti-tumor, atherogenic, anti-microbial, radioprotective,

hepatoprotective and tissue regeneration.

Shahzadi et al (2021) made an ethnobotanical study on *H. rhamnoides* subsp. turkestanica from Oshikhandas and Bagrot valleys of district Gilgit, Gilgit-Baltistan, Pakistan. Local people named it as “Buro” (65%), “Chanxo” (35%) and they are agreed with that there are two types according to color.

2.6 Aim of Study

This project aimed to evaluate the morphological characteristics of trees, buds, leaves, fruits and seeds of *H. rhamnoides* in Çamardı district Niğde, Turkey and to assessed from that to make judgment about its genetic diversity, regeneration and threatened that mightbe there. This population from Çamardı has not previously been reported and it is currently uncharacterized. Also, it is possibly the most southerly population of *H. rhamnoides* in Turkey and it is a percentral source of genetic diversity. Therefore, it allows the development of genetic resources and the characterization of the unreported population of *H. rhamnoides*. In addition, it is an important target for the protection of the wild population, which hold the essential genes for disease and insect resistance. Additionally, to do more research on the characteristics of this species, which is not widely grown although it is a plant native to Turkey, to provide the people recognizing of the plant and bring this species to the economy of the country and to shed light on the scientists who is working on this plant.

CHAPTER III

MATERIALS AND METHODS

The research was conducted on a naturally occurring population of *H. rhamnoides* such that to determine the distribution and population structure and experimental methodologies to vegetative and reproductive morphologies and ethnobotanical investigation of *H. rhamnoides* in Çamardı, Niğde.

3.1 Distribution

In order to determine the distribution of *H. rhamnoides* shrubs/trees in the Çamardı region, GPS coordinates were noted where the samples were taken. Although these did not show 100% of the entire population in the valley, it provided an information about the presence of the wild population of *H. rhamnoides* in the valley.

3.2 Population Structure and Morphology

The population structure which included males and females, were evaluated according to the size of plants such as big/small bushes, multi stems or single trunk trees as well. In order to measuring the height of the shrubs/trees at each location, one of the scale bar were used.

All the photos of the trees and samples which were used to determine the plant morphology, were taken by Xiomi Mi Note 10, 6.47" 1080 x 2340 pixels, 108MP 2160p mobile phone camera and measurement of the height of the trees were determined by using ImageJ software program.

Figure 3.1. *Hippophae rhamnoides* male tree photo by using scale bar to determine its height

3.3 Sampling Area and Design

The sampling for this research were done 18 sites (at arbitrary intervals down the Çamardı district, so these were a mixture of all male, all female and mixed.) collecting sampling from five plants within the clumps at each site in Çamardı in the end-October and mid-November 2021. This was completed three trips to the Çamardı 1 week apart and each trip was evaluated as a block. *Hippophae rhamnoides* populations from eighteen sites and their GPS coordinates are shown in Table A1.

Wild populations of *H. rhamnoides* was assessed according to their vegetative and reproductive characteristics.

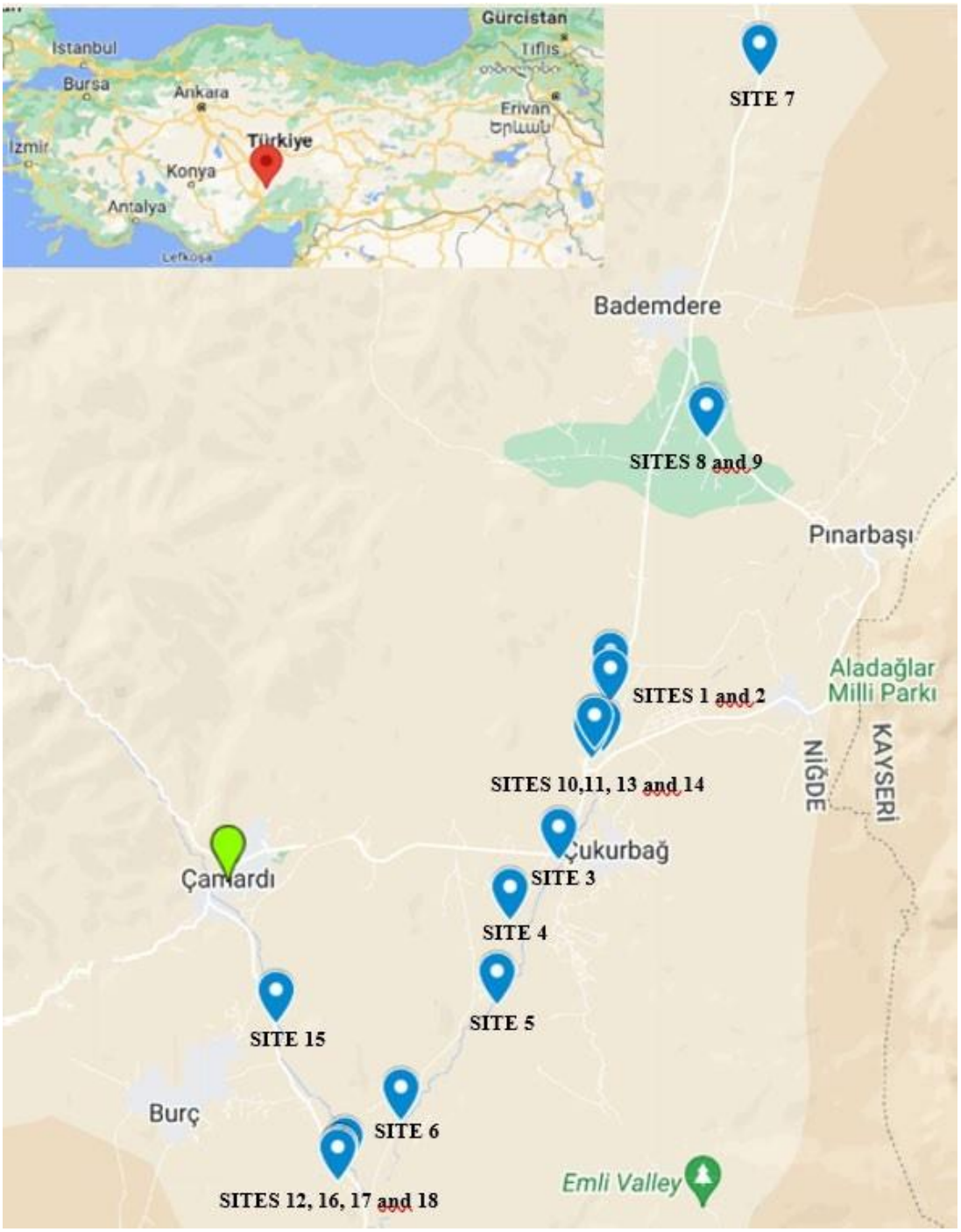

Figure 3.2 Map showing the GPS coordinates of the *Hippopahe rhamnoides* 18 sampling sites in Çamardı, Niğde

Morpho-physiological traits included plant height (m), trunk diameter (mm), leaves, fruits and seeds length and width (mm), fresh fruit weight, dry fruit weight (g) and 10 buds weight (g).

For each accession, approximate size of each plant such as height and main stem diameter

were measured. About 400 mm long four branches/shoots were taken from each for vegetative characteristics diagnosis.

For the reproductive characterization of *H. rhamnoides*, fruit samples were taken from the four branches of each five clumps of nine sites.

Figure 3.3. *Hippophae rhamnoides* female tree with its orange berries

3.4 Morphological Characterization of *Hippophae rhamnoides* in Çamardı, Niğde

Six sites with *H. rhamnoides* populations were identified in the Çamardı valley for each trip, and four fresh branches/shoots from each of the five trees within the clumps by *H. rhamnoides* were collected and placed in a plastic container. These process were done for each subsequent trip and the samples taken from a total of 18 sites, nine of which were male and nine of which were female, were evaluated recording for the seed, bud, fruit and

leaf properties.

3.4.1 Vegetative characterization of *Hippophae rhamnoides*

Vegetative characterization of *H. rhamnoides* is based on the evaluation of trees, branches, buds and leaves characteristics of the population using the ImageJ software program.

3.4.1.1 Vegetative characterization of *Hippophae rhamnoides* trees

With three visits to Çamardı in end-October and mid-November, a total of 90 *H. rhamnoides* trees, male and female, from 18 sites, were evaluated on the sex of the plant, plant type, trunk diameter and tree height (see Table A2 *H. rhamnoides* tree data). Trunk diameter of trees were estimated visually but tree height analyzed by using a software program. Therefore, each tree photograph was taken at a specific scale using a 1.50 m scale bar and then tree heights were measured by using ImageJ software.

The image analysis of tree heights was performed as follows: 1) opening the image and scaling it by using the set scale and entering the settings to the scaled bar 2) mark the distance between the top of the tree and the last point where it touched the ground. Before the analysis of *H. rhamnoides* trees were performed, aberrant points and data were examined.

3.4.1.2 Vegetative characterization of *Hippophae rhamnoides* buds

Vegetative parts of *H. rhamnoides* were collected as mentioned above. Ten buds from each of four branches of each male and female trees were taken from the middle of the branch and placed in a labeled plastic container (Figure 3.4). Each container was weighed with a five significant figures digital balance and the results were noted (Figure 3.5).

Figure 3.4. Ten male buds from each of four branches of *Hippophae rhamnoides* trees

Figure 3.5. Ten male buds of *Hippophae rhamnoides* weighed on a digital balance

3.4.1.3 Vegetative characterization of *Hippophae rhamnoides* leaves

Leaves is an important vegetative part of the plant which have several essential functions likewise photosynthesis, transpiration, storage and defense. Different genotypes within the same species may differ in leaf shape and size, affecting plant growth and productivity (Cosmelescu et al., 2020). In order to characterize *H. rhamnoides* leaves the experiment was carried out by collecting leaves from the branches of male and female trees from different parts of Niğde Çamardı district.

Hippopahe rhamnoides leaves were analyzed after examined and cleaning the data according to solidity, roundness, circularity, perimeter, perimeter ellipse, aspect ratio,

major and minor, feret and minferet.

Area, circularity and roundness were not many useful parameters due to the flat shape ofthe leaves.

Circularity, calculated by ImageJ using this formula

$$4\pi \times [Area]/[Perimeter]^2 \quad (3.1)$$

with a value of 1.0 indicating a perfect circle. As the value approaches 0.0, it indicates anincreasingly elongated shape.

Aspect ratio, The aspect ratio of the particle's fitted ellipse, and calculated by ImageJ using this formula

$$[Major\ Axis]/[Minor\ Axis] \quad (3.2)$$

Roundness calculated by ImageJ using this formula

$$4 \times [Area]/\pi \times [Major\ axis]^2 \quad (3.3)$$

Solidity calculated by ImageJ using this formula

$$[Area]/[Convex\ area] \quad (3.4)$$

Solidity was only giving the idea about how goodness of the image. Feret was an ImageJ measurement that equavelent to calipers. The minor and the minferet were giving the idea about the width of the leaf and the major and feret were giving the idea about the length of the leaf. Perimeter which was driven mostly by the major length of the leaves, calculated by ImageJ that was fix the calipers from the longest length to the narrow ones and from those two values the estimated perimeter was calculated. Perimeter ellipse were created by ImageJ which fix the best ellipse to the image.

3.4.1.3.1 Using materials

A total of 3,348 leaf samples were taken for all areas, 10 leaves from each 4 branches of each *H. rhamnoides* tree sample. After data analysis and cleaning, 3,303 of 3,348 samples were used for the characterization of the leaves. These leaves were placed on a damp yellow cloth and rehydrated for 20 minutes to give the leaves a flat appearance.

3.4.1.3.2 Image acquisition

Rehydrated flat leaf samples were labeled and placed on a 300 mm high flat stand and photographed (Figure 3.6) To increase accuracy, the photo was taken using a round-ring daylight source.

Figure 3.6. Forty rehydrated flat *Hippophae rhamnoides* leaves image

3.4.1.3.3 Image processing

By using these images, features such as area, perimeter, length, width, Feret dimensions, aspect ratio, roundness and solidity of the *H. rhamnoides* leaves were analyzed by using ImageJ software program.

The Image analysis was performed as follows: 1) Open the leaves images with ImageJ 2) duplication of image by selecting only the area where the leaves were located and labelling the file 3) go through the process of Adjust a brightness and contrast 4) conversion of the adjusted image to the binary image range type gray (8 bit) (Figure 3.7) and fill holes 5) analyzing the particles without scaling and measure the images in pixels, size in 10.000-infinity pixel^2 by using the set measurements (area, center of mass, bounding rectangle, shape descriptors, centroid, perimeter, fit ellipse, Feret's diameter)

Figure 3.7. Example of binary image of *Hippophae rhamnoides* leaves in the ImageJ program

3.4.2 Reproductive characterization of *Hippophae rhamnoides*

This experiment conducted by using totally 45 samples (*H. rhamnoides* trees) from nine female sites to diagnosis the reproductive characteristics of *H. rhamnoides*.

3.4.2.1 Characterization of *Hippophae rhamnoides* fruting branches

Hippophae rhamnoides fruits collected from four branch samples of each tree were placed in labeled plastic boxes, and fresh fruit samples were weighed with digital balance and noted. The samples were then left to dry. Dried fruit samples were weighed with a digital

balance after waiting until the dry fruit weight stabilized and the moisture in its structure was lost.

In addition, in order to estimate how vigorous the tree was, the length from the last fruit on each branch to the tip of the branch was measured with the metal ruler and noted. (see Table A3. *H. rhamnoides* branch data).

3.4.2.2 Characterization of *Hippophae rhamnoides* fruits by using ImageJ

3.4.2.2.1 Using materials

For the experiment, 12,873 fruit samples were taken from 45 tree samples from 9 female sites. After data analysis and cleaning, 12,852 of a total of 12,873 samples were used for fruit characterization.

3.4.2.2.2 Image acquisition

Each fruit samples for the certain tree were laid on a white background A4 paper and put on a 300 mm high flat stand. During this time, care was taken not to let the fruits touch each other (Figure 3.8). The ring supplement lamp was used for taking the more quality photos with the more brightness.

Figure 3.8. Example of image of *Hippophae rhamnoides* fruits which taken under the ring supplement

3.4.2.2.3 Image processing

The Image analysis was performed as follows: 1) opening the image and scaling it by using the set scale and entering the settings to the scaled bar. 2) duplication of image by selecting only the area where the fruits were located 3) eliminating the shadows by adjusting the brightness and contrast of the image 4) conversion of the adjusted image to the binary image range type gray (8 bit) (Figure 3.9) 5) filling the holes and applying a watershed to separate fruit that touches each other 6) analyzing the particles by using the set measurements (area, center of mass, bounding rectangle, shape descriptors, centroid, perimeter, fit ellipse, Feret's diameter) scaled photo and noted the results.

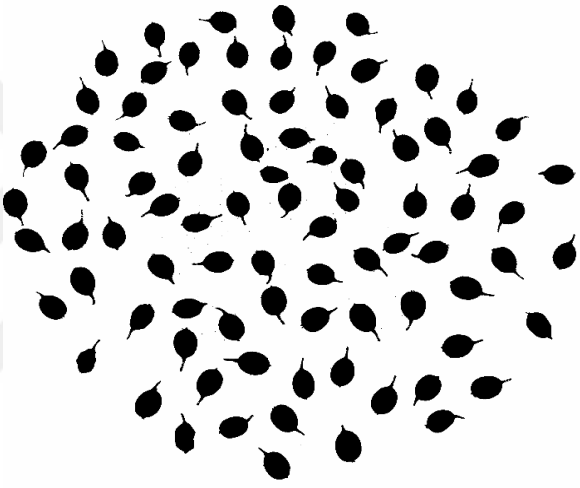

Figure 3.9. Example of binary image of *Hippophae rhamnoides* fruits in the ImageJ program

3.4.2.3 Characterization of *Hippophae rhamnoides* seeds by using ImageJ

Image Analysis provides a new tool for classifying plant species according to the morphological and colorimetric properties of seeds and makes an important contribution to systematic studies (Vale et. all., 2020).

3.4.2.3.1 Using materials

Forty-five samples totally with 1,975 *H. rhamnoides* seeds were used for the experiment.

About 40 *H. rhamnoides* seeds belonging to a particular region and tree were stripped from its fruits and put into a labelled small plastic container.

3.4.2.3.2 Image acquisition

About 40 seeds per images were laid on a white background A4 paper and put on a 300 mm high flat stand. During this time, care was taken not to let the seeds touch each other (Figure 3.10). The ring supplement lamp was used for taking the more quality photos with the more brightness.

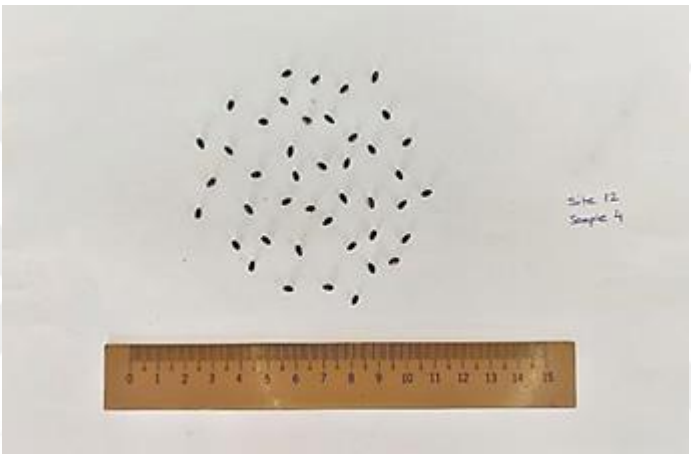

Figure 3.10. Example of image of about 40 *Hippophae rhamnoides* seeds which were at Site 12, Sample 4

3.4.2.3.3 Image processing

The Image analysis was performed as follows: 1) opening the image and scaling it by using the set scale and entering the settings to the scaled bar. For this image 150 mm ruler were used as a scale bar 2) duplication of image by selecting only the area where the seeds were located 3) eliminating the shadows by adjusting the brightness and contrast of the image 4) conversion of the adjusted image to the binary image range type gray (8 bit) (Figure 3.11) 5) analyzing the particles by using the set measurements (area, center of mass, bounding rectangle, shape descriptors, centroid, perimeter, fit ellipse, Feret's diameter).

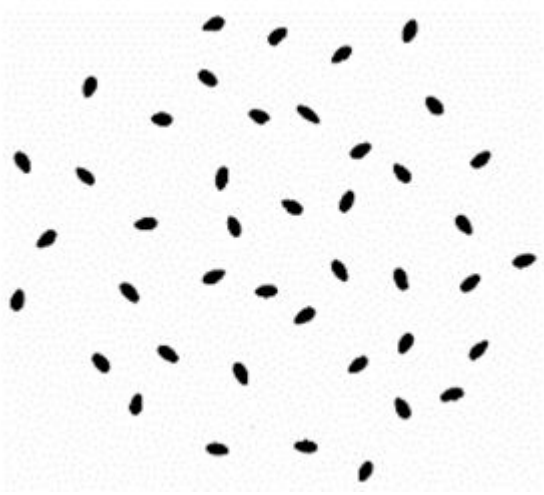

Figure 3.11. Example of binary image of *Hippophae rhamnoides* seeds in the ImageJ program

3.5 Germination of *Hippophae rhamnoides* Seeds at a Room Temperature After1 and 5 °C Stratification

Morphological characterization of the fruits and also the structure of the trees in the field gave some clues that they resemble clonal clusters. Based on this assumption, fruit samples taken separately from 4 branches of 5 trees for each site were combined as a single branch. About 40 seeds stripped from the pulp and they put in small plastic containers (Figure 3.12).

Figure 3.12. Combined *Hippophae rhamnoides* fruits and seeds stripped from pulp in small containers

Forty- five germination tests were performed with two replicates and 18 trays used for the experiment. Each 20 seeds from certain sites and trees randomly distributed to the trays. Moistured peat were used and the experiment set up was created by dividing the single-ply towel paper into five, with 20 seeds in each compartment (Figure 3.13).

Figure 3.13. Germination test set up using *Hippophae rhamnoides* seeds After set up the experiment, 18 trays were stayed in a 1.5 °C with 92% RH cold room fora week to cold requirement of the *H. rhamnoides* seeds (Figure 3.14). At the end of a week, the trays were moved to 5°C cold room to stay there for a week. In order to maintainsoil moisture balance, water was sprayed on the trays at intervals.

Figure 3.14. *Hippophae rhamnoides* seeds exposed to 1.5°C with 92% RH cold room for a week

Two weeks stratified seeds were brought to the lab condition at a room temperature which close to 25°C and germination number of seeds were counted three days intervals.

3.5.1 Development of the model

The germination experiment was done by following log-logistic function time to event model reported (Onofri et al., 2022). Three parameters were fitted in a model which were Gmax (response) [coef-d], G50 (days) [coef-e] and Slope (response/day) [coef-b]. G50 was fitted the coef-e which representing the 50% germination at a certain day. Gmax was fitted to coef-d in the function and representing the proportion of the maximum germination. Slope was the fitted the coef-b and representing the speed of the germination.

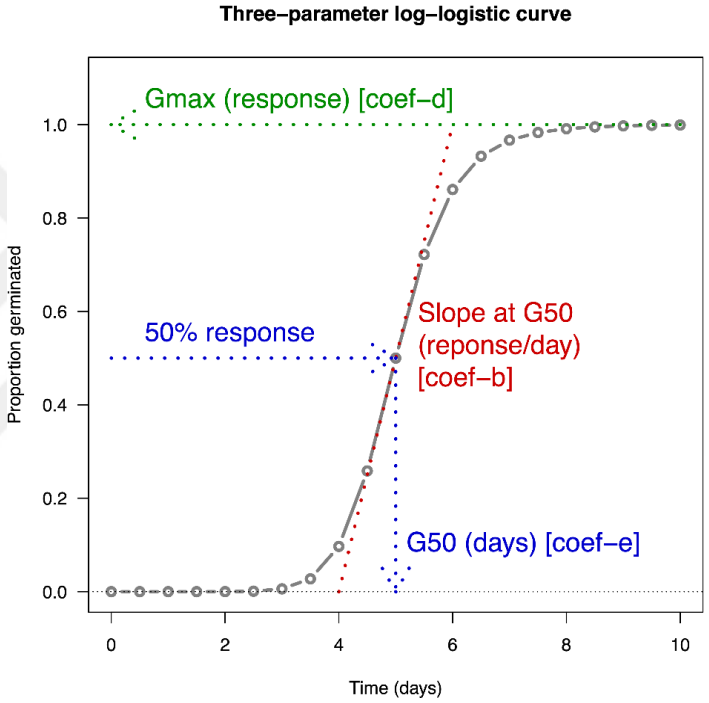

Figure 3.15. Three-parameter (Gmax, G50 and Slope) log- logistic curve of proportion of germinated seeds to time

Apart from three parameters, Germ and Gday were taken from the data set. Germ was shown as the proportion of germinated seed and Gday was the number of days for maximum germination.

3.6 Ethnobotanical Research of *Hippophae rhamnoides* in Çamardı, Niğde

The study was carried out in Çamardı district of Niğde in August, 2022. Information about *H. rhamnoides* was obtained from 21 people through semi-structured interviews in an

open market. Name, age and occupation of the interviewees, local name of *H. rhamnoides*, part of the plant that was being used, purpose of usage, place of growing was asked to the local people by showing fresh plant material and photos of the plant and answers were sought to the above questions about the plant.

Figure 3.16. Semi-structured interview about ethnobotanical investigation of *Hippophae rhamnoides* with the local people in Çamardı, Niğde

CHAPTER IV

RESULTS

4.1 Vegetative Characterization of *Hippopahe rhamnoides* in Çamardı, Niğde

Vegetative characterization analysis of *H. rhamnoides* were done by using R statistics.

4.1.1 *Hippophae rhamnoides* tree analysis

4.1.1.1 Tree size

Coefficient variation (CV%) for the two parameters used to asses tree size within and between the sites is shown in Figure 4.1. According to the figure *H. rhamnoides* trunk diameter was more variable than the treeheight.

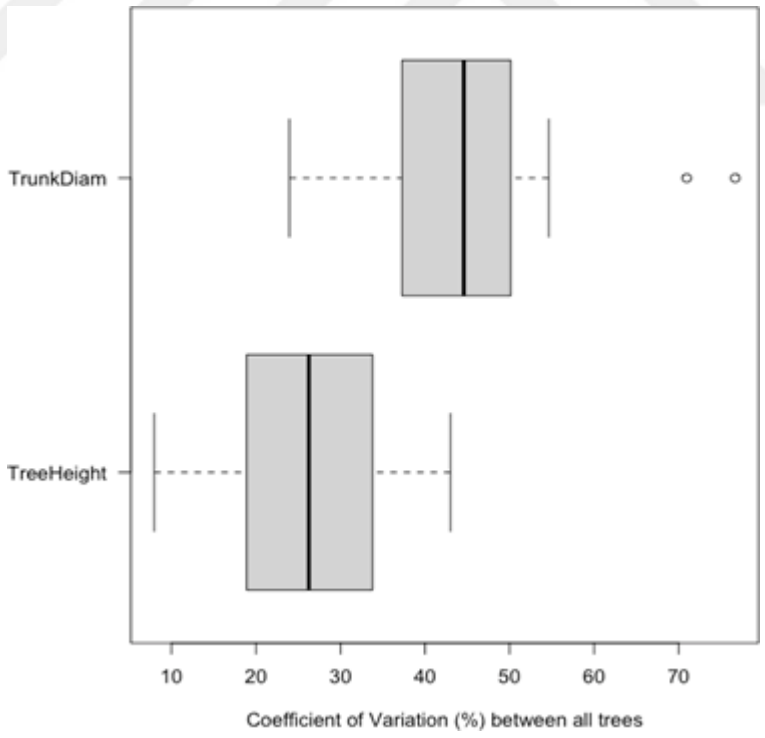

Figure 4.1. Coefficient variation (CV%) for trunk diameter and tree heightbetween all trees at site level

Figure 4.2. shows that, tree heights had a highly variable pattern between and within the

sites. Site 9 had the highest variation within the sites, followed by Sites 1 and 5, respectively. Site 13 had the lowest variation and indicated the most clonal structure within the clusters. It was seen that the height of the mean values of *H. rhamnoides* trees between the sites were in the range of 1.77-4.86 m.

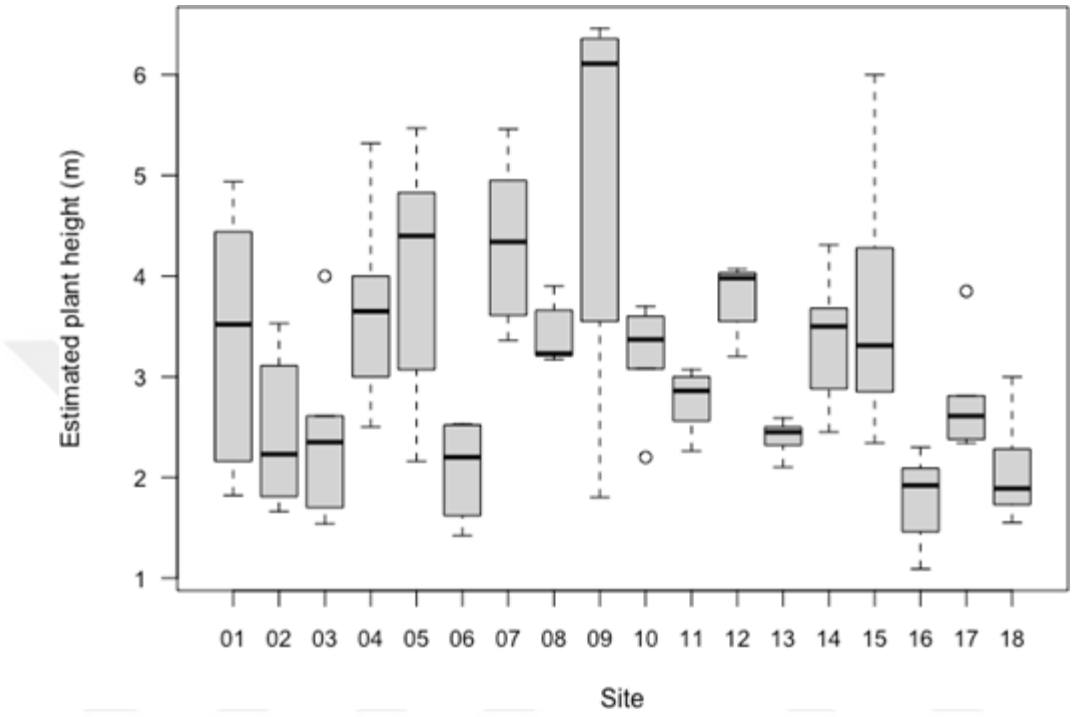

Figure 4.2. Estimated plant height (m) diagram of the *Hippophae rhamnoides* trees between18 sites

Figure 4.3 indicates the estimated plant height (m) of the *H. rhamnoides* female trees of nine sites. Although some sites showed minor changes (Sites 8 and 12) within the site, some had quite large variations (Sites 2, 4 and 15).

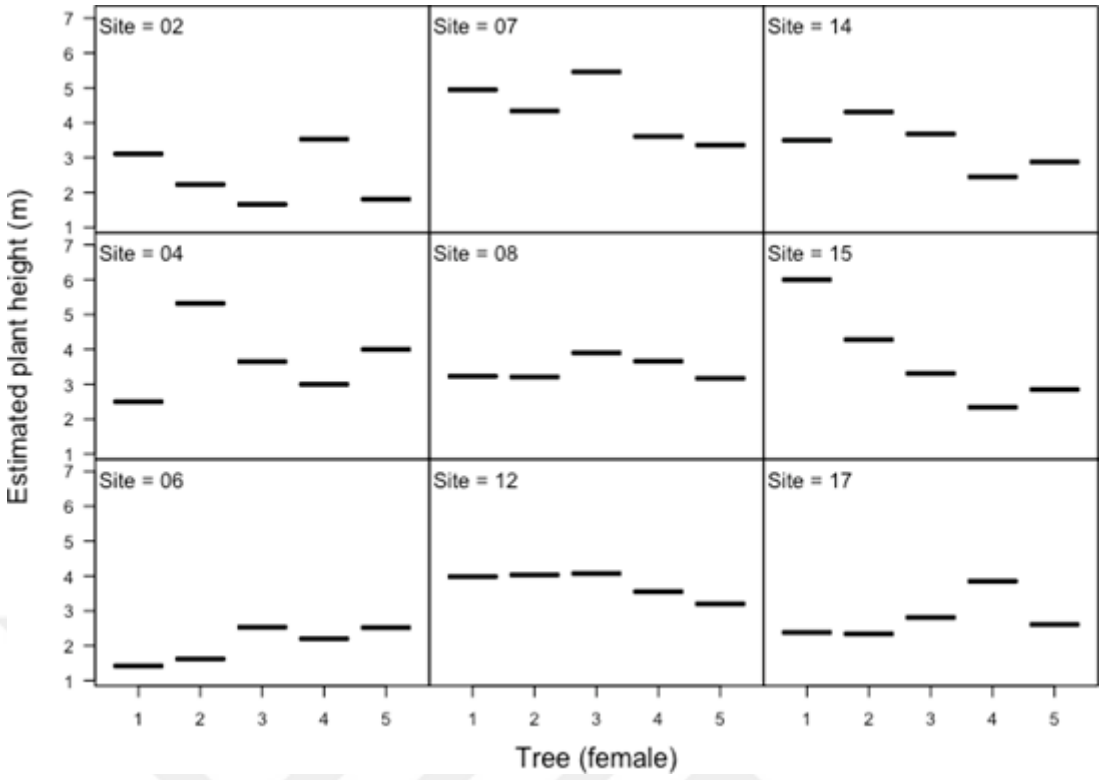

Figure 4.3. Estimated plant height (m) diagram of the *Hippophae rhamnoides* female trees of nine sites

Figure 4.4 shows the estimated height of *H. rhamnoides* male trees in tree and site level. Some of the sites had short trees and showed small differences within the sites such as Sites 13 and 18. However, Sites 1, 5 and 9 had substantial variation between the trees within the sites.

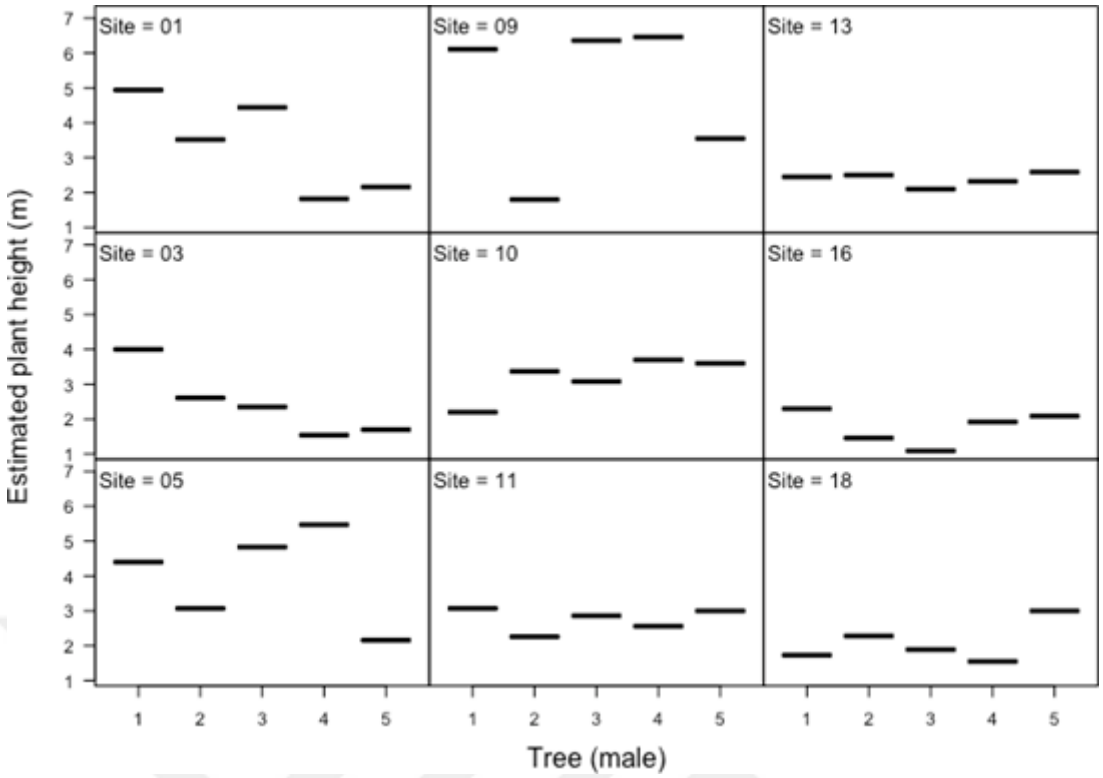

Figure 4.4. Estimated plant height (m) diagram of the *Hippophae rhamnoides* male trees ofnine sites

4.1.1.2 Trunk diameter

The estimated trunk diameter (mm) of *H. rhamnoides* trees is shown in Figure 4.5. There were moderate differences in estimated trunk diameters between sites. Although Site 9 had the largest trunk diameter trees, it was the site with the greatest variation within the site. However, Site 18 interpreted as having shrub kind of trees with the smallest trunk diameter. The trunk diameter of the mean values of *H. rhamnoides* trees between the sites were in the range of 11-70 mm.

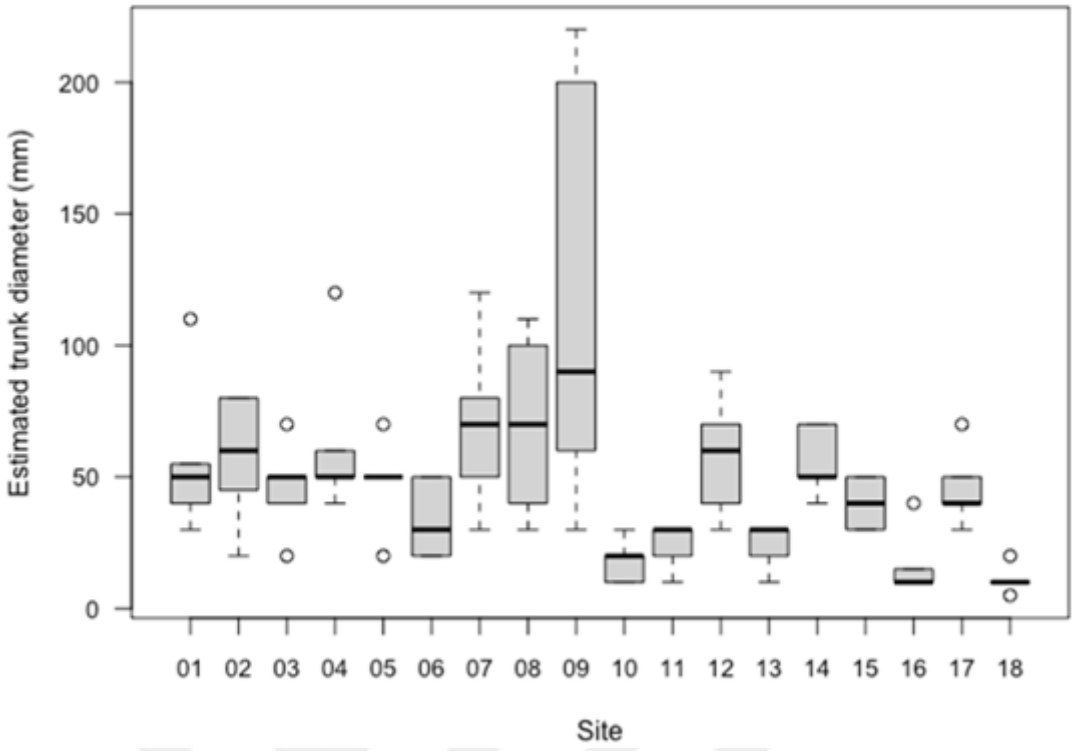

Figure 4.5. Estimated trunk diameter (mm) diagram of the *Hippophae rhamnoides* trees between 18 sites

Figure 4.6 indicates the estimated trunk diameter (mm) of the *H. rhamnoides* female trees of nine sites. Although there was moderate variation between the sites, considerable variations observed between the trees within the sites. Site 7 had both small and large trunk diameter trees within the sites but Site 15 had the stable structure.

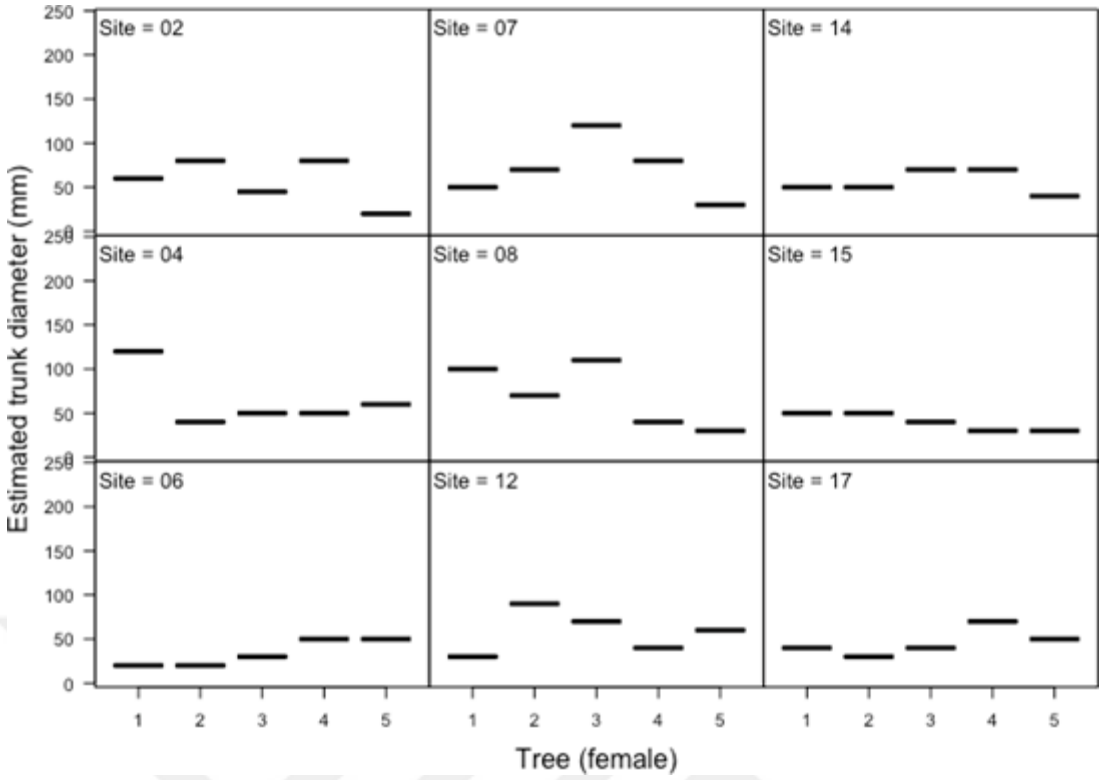

Figure 4.6. Estimated trunk diameter (mm) diagram of the *Hippophae rhamnoides* female trees of nine sites

Figure 4.7 shows the estimated trunk diameter (mm) of the *H. rhamnoides* male trees of nine sites. Many sites had the less variation of estimated trunk diameter (Sites 10, 11, 13,16 and 18) but Site 9 had the substantial variation in the particular trees within the sites. A particular tree at Site 1 also had a different trunk diameter than the other trees within the sites.

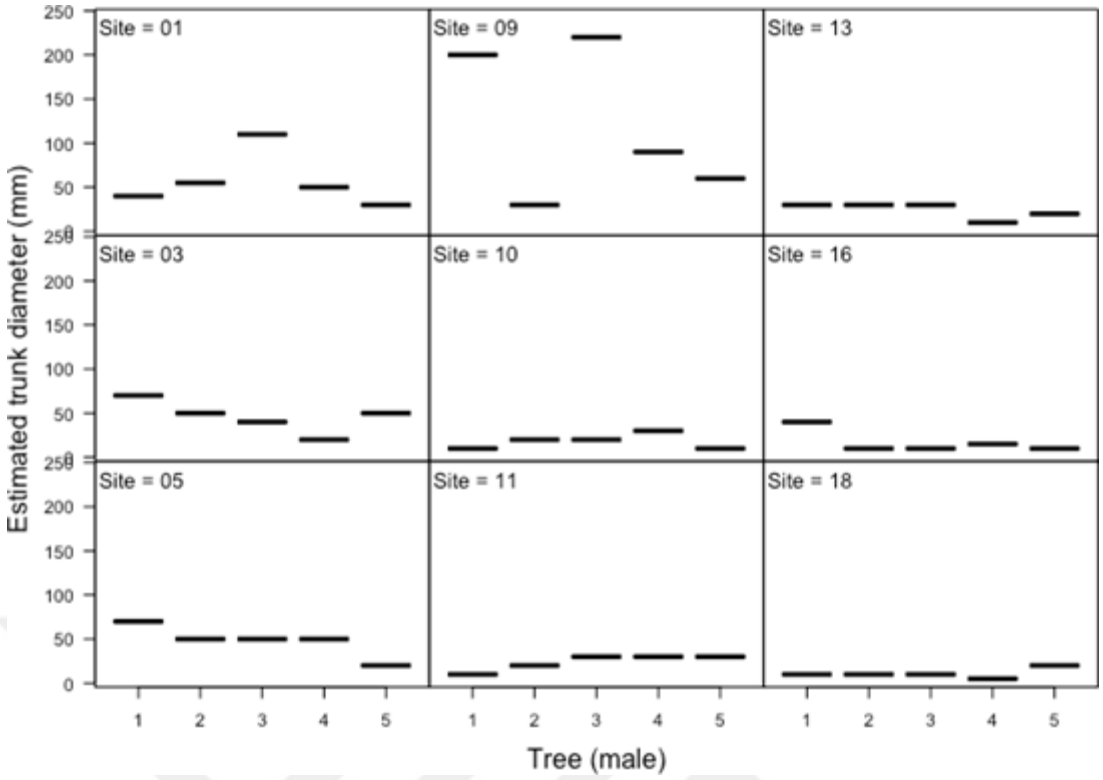

Figure 4.7. Estimated trunk diameter (mm) diagram of the *Hippophae rhamnoides* male trees of nine sites

Coefficient variation (CV%) and effect size for two parameters, tree height and trunk diameter, used to assestree size within and between the sites shows in Figure 4.8. The CV% for trunk diameter was 24.9% and the CV% for the tree height was 40.4% in site level. The detailed analysis are shown in Table A4. (see *H. rhamnoides* tree analysis)

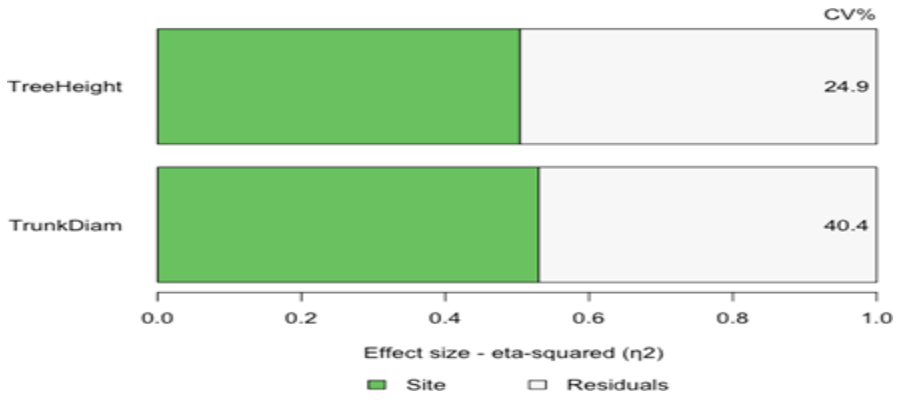

Figure 4.8. Coefficient variation (CV%) and effect size, eta-square (η2), graphshowing tree height and trunk diameter of *Hippophae rhamnoides* trees

4.1.2 Hippophae rhamnoides buds analysis

Coefficient variation (CV%) for *H. rhamnoides* male and female tree branches used to assess bud dry weights is shown in Figure 4.9.

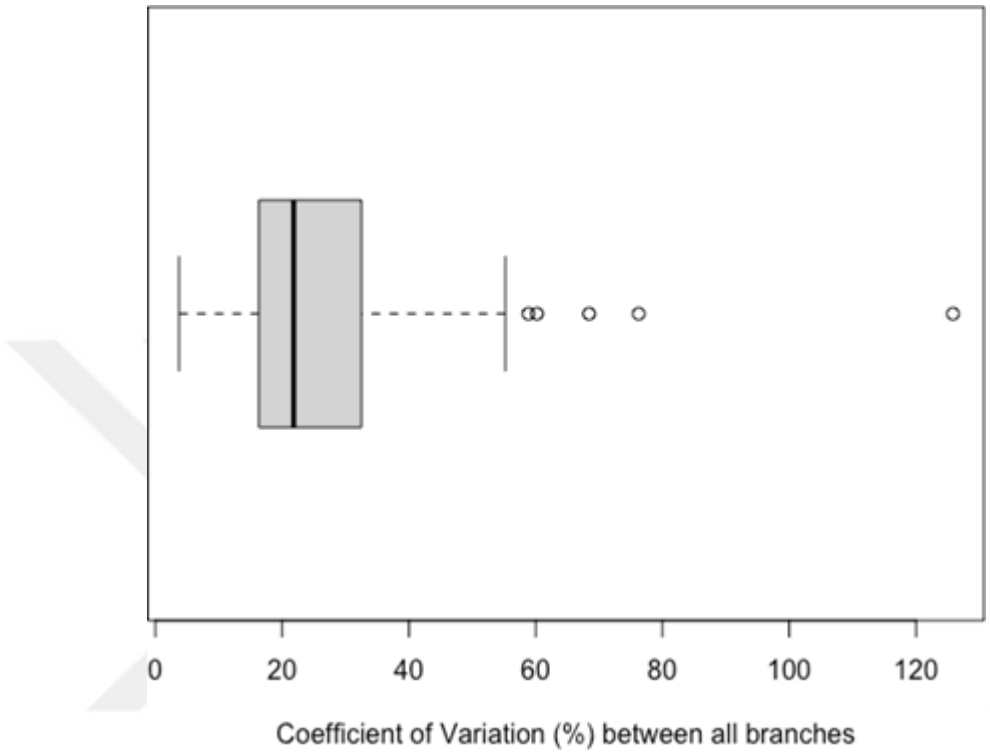

Figure 4.9. Coefficient variation (CV%) of between all *Hippohae rhamnoides* trees

Dry weights of buds taken from the same positions of male and female tree branches are compared on tree and site level. Comparing data and analysis are shown on Table A5 (see. *H. rhamnoides* bud analysis). According to the analyzed data, there was very small variation between and within the sites of the dry weights of the female buds but the malebuds had greater variation than the females.

4.1.2.1 Bud dry weight

Figure 4.10 shows the variation of dry bud weights of *H. rhamnoides* branches at tree and site level for eighteen sites. The last three sites (Sites 16, 17 and 18) had the minimum variation and quite lower bud dry weight between the sites. Two sites had the larger variation with the higher bud dry weight (Sites 3 and 5). The variation within the sites for the female trees were pretty minimal so it indicated the variation between the sites were

mostly driven by the male sites of the *H. rhamnoides* trees. The male trees were at Sites 1, 3 and 5 had the substantial variation between the trees with in the sites. Although there were differences between trees at Site 1, there were slight differences in particular trees at sites. Additionally, Site 5 had marked differences between trees within sites, with certain trees with the highest bud dry weight above 30 mg.

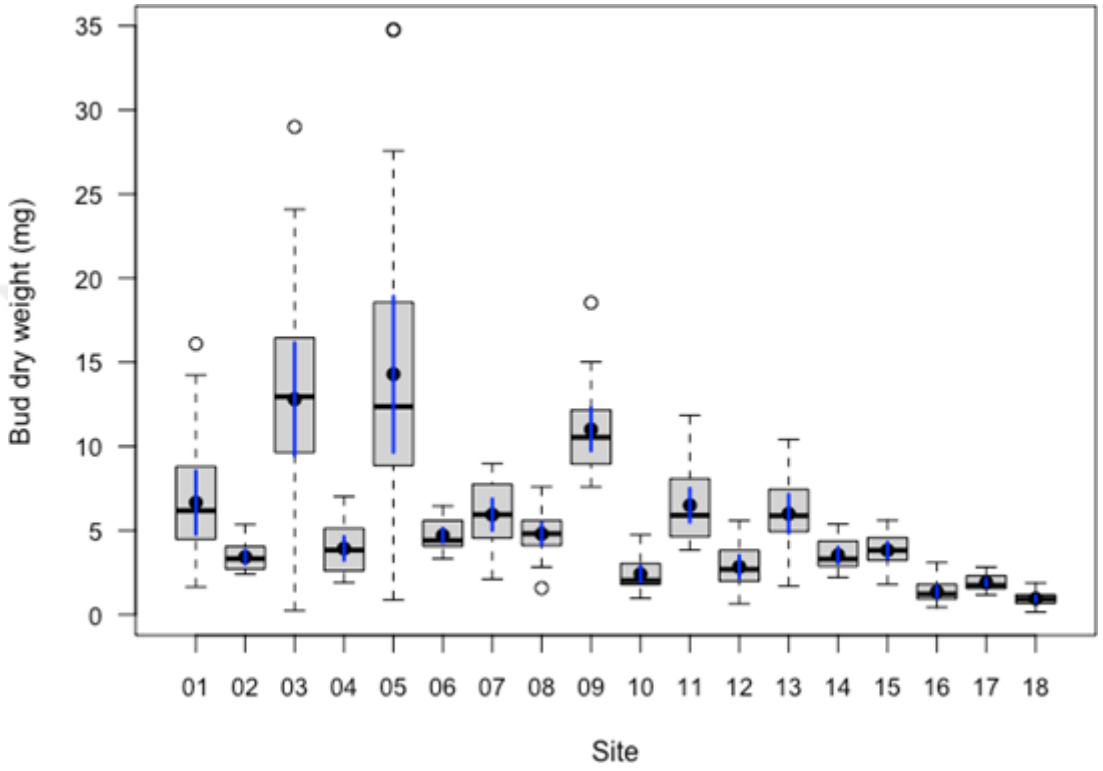

Figure 4.10. Bud dry weight (mg). Site: overall for 18 sites of *Hippophae rhamnoides*

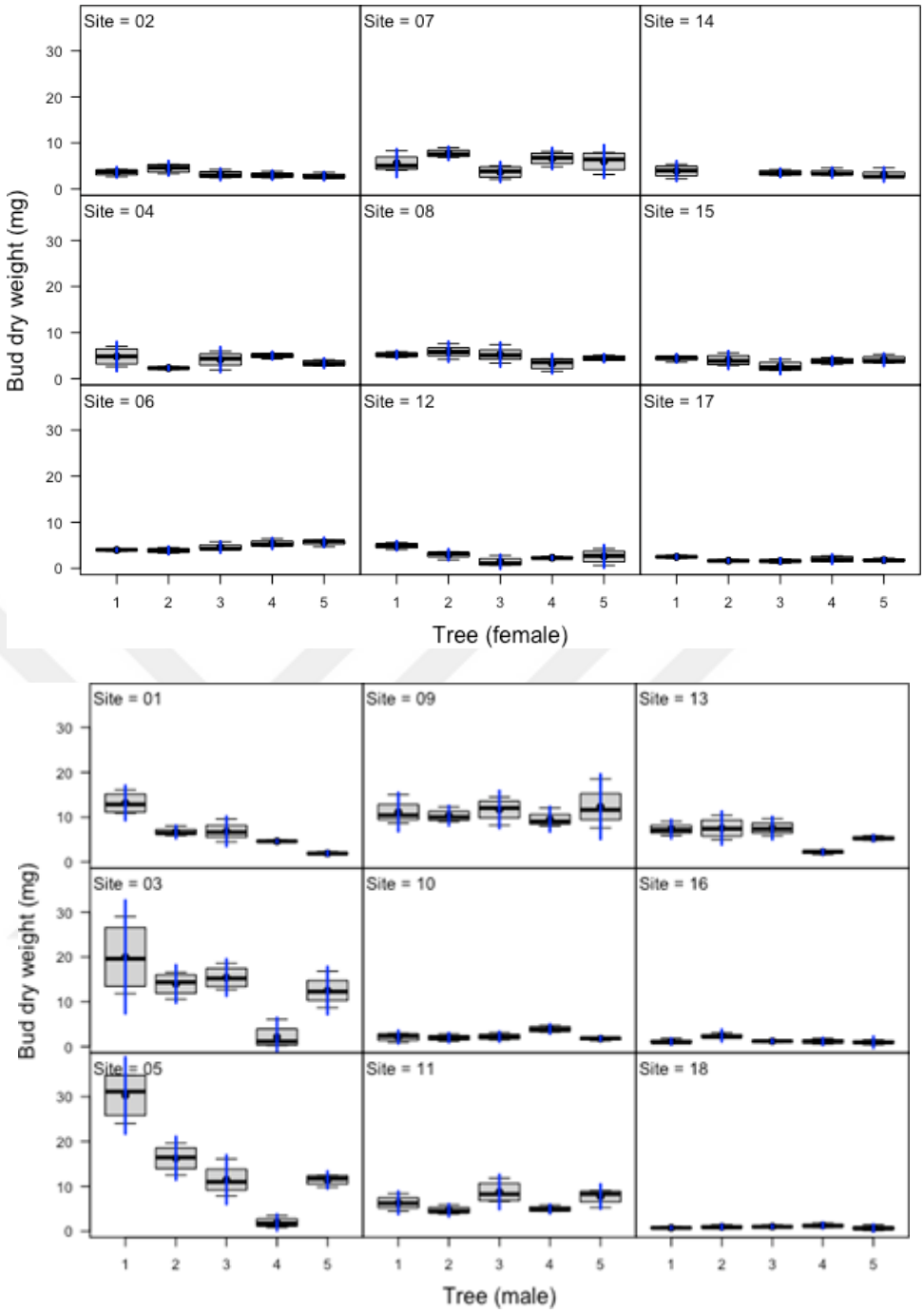

Figure 4.11. Bud dry weight (mg). Tree: Each of five male/female trees of *Hippophae rhamnoides* within eachsite

Figure 4.12 shows the variation between the sites and between the trees within the sites ofthe bud dry weight of *H. rhamnoides* trees. Site variation of the buds of *H. rhamnoides* was higher than the bud variation between trees. The highest variation with 74%, was variation in tree levels.

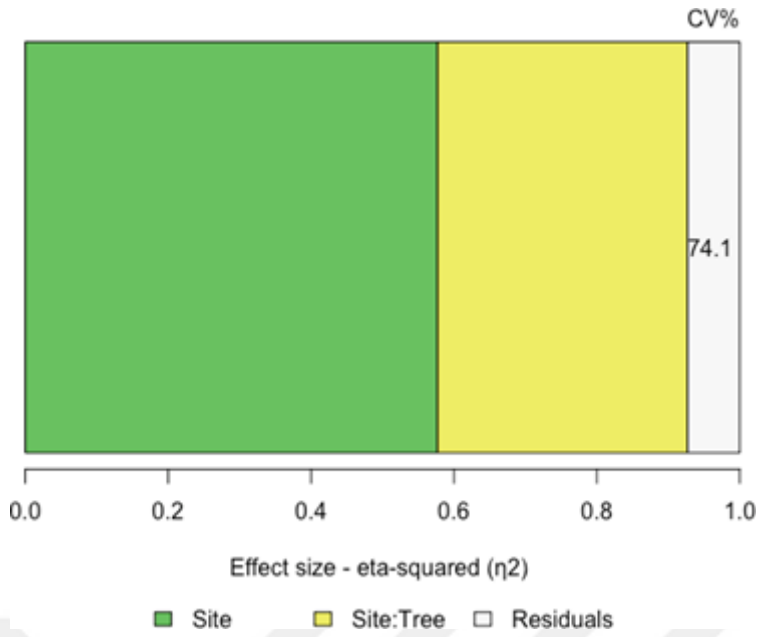

Figure 4.12. Coefficient variation **(**CV%) and effect size, eta-square (η2), graph showing budsof *Hippophae rhamnoides* trees

4.1.3 *Hippophae rhamnoides* leaves analysis

Coefficient variation (CV%) for the 11 parameters used to asses *H. rhamnoides* leaves is shown in Figure 4.13.

Figure 4.13 shows that, the first three parameters were highly variable among the others. Leaf area was the most variable and the feret length was the least variable parameters.

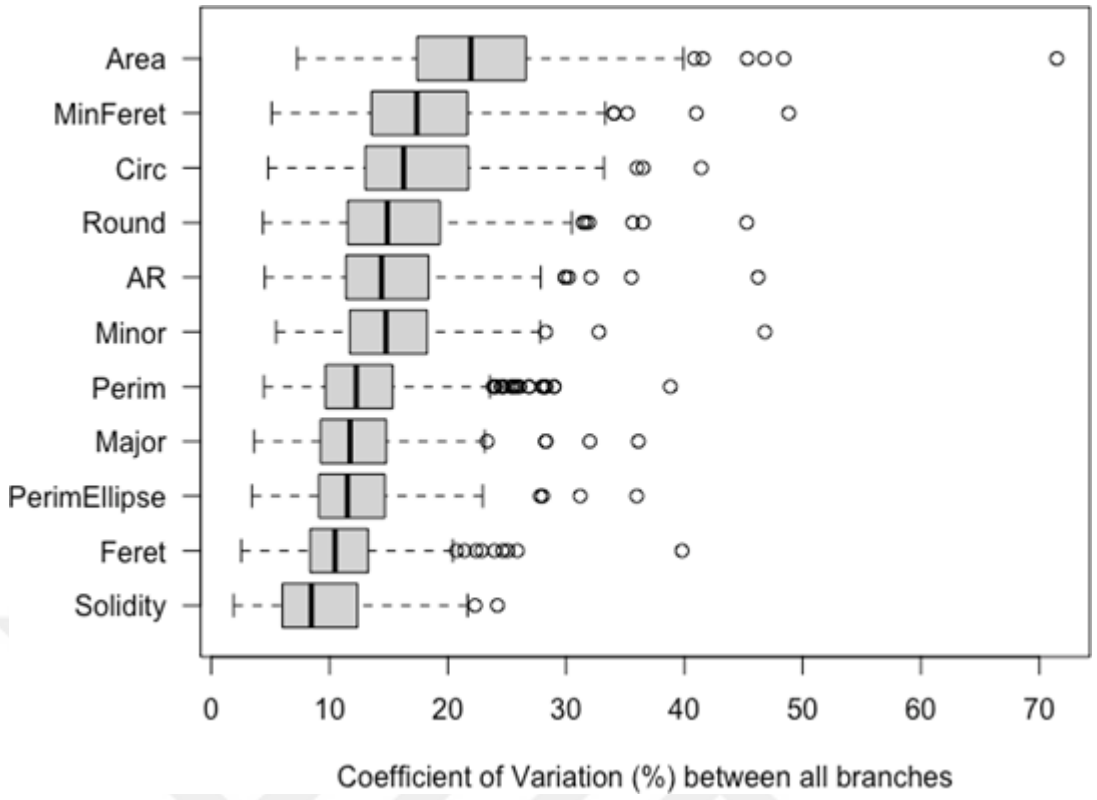

Figure 4.13. Coefficient variation **(**CV%) of area, minimum feret (MinFeret), circularity (Circ),roundness (Round), aspect ratio (AR), minor, perimeter (Perim),major, perimeter ellipse (PerimEllipse), feret, and solidity between all *Hippohae rhamnoides* branches

4.1.3.1 Solidity

Solidity is the measure of how good the image is. There was moderate variation betweenthe sites of the solidity of the leaves (Figure 4.14). Some sites had the higher variation (Site 3) within the sites but some had the lowest variation with the highest mean value (Site 17). Figure4.15 shows that, although female sites had the higher variation among the trees within the sites, Site 3 in male sites had the greatest variation for each particulartrees.

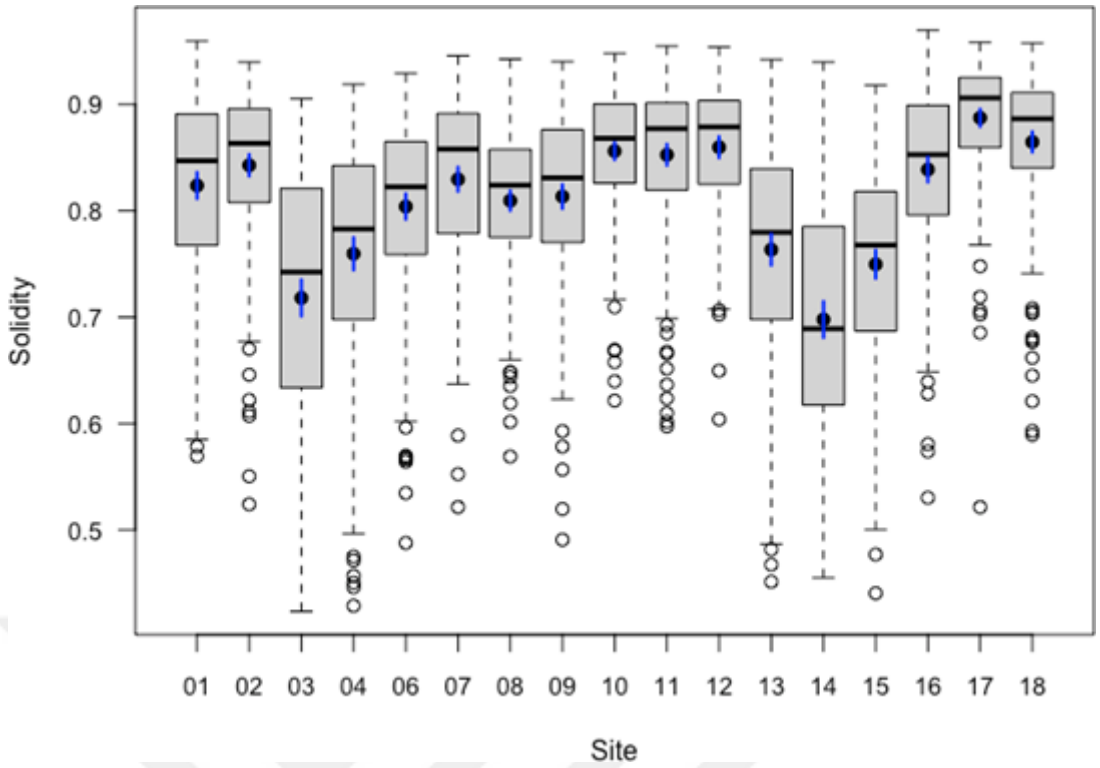

Figure 4.14. Solidity. Site: overall for 18 sites of *Hippophae rhamnoides*

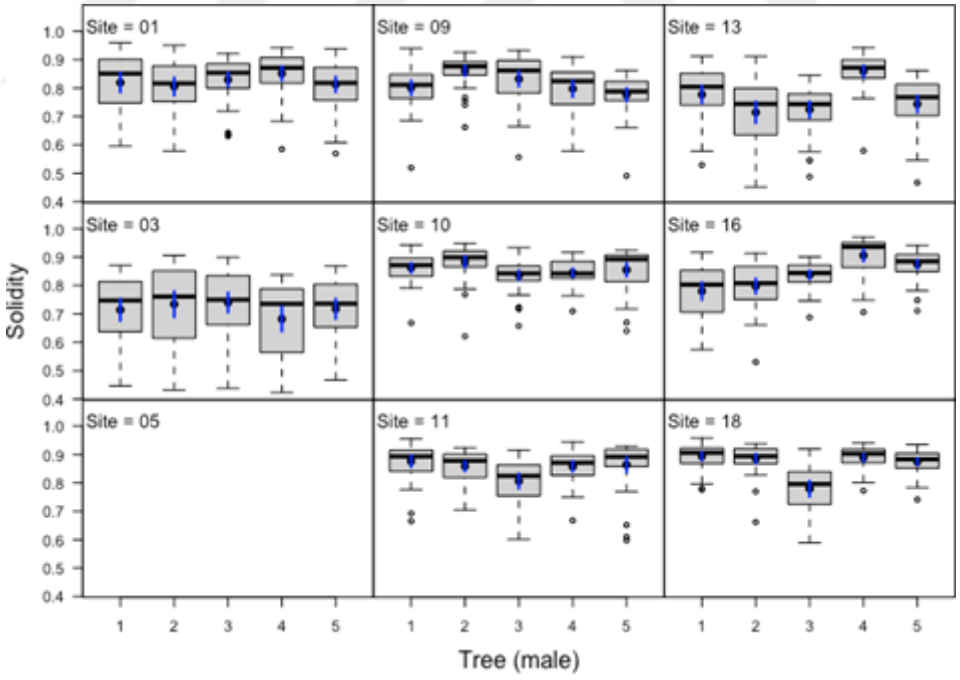

Figure 4.15. Solidity Tree: Each of five male/female leaves of *Hippophae rhamnoides* within each site

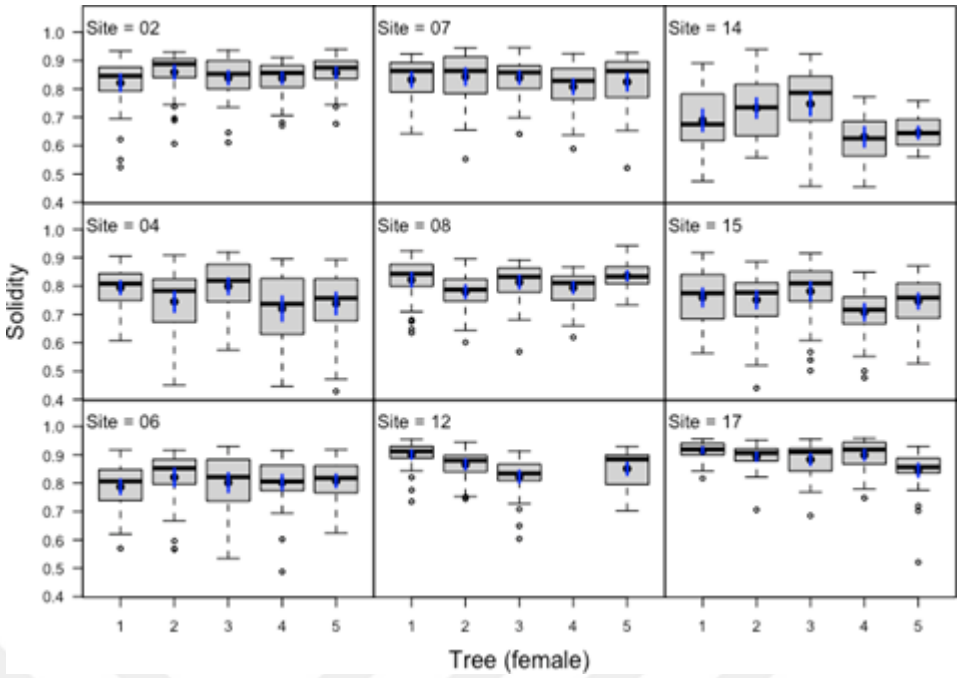

Figure 4.15. (Continue) Solidity Tree: Each of five male/female leaves of *Hippophae rhamnoides* within each site

4.1.3.2 Feret length

Figure 4.16 shows the feret length (mm) of the *H. rhamnoides* leaves between the site levels. While some sites were fairly close in feret length, Site 4 had the longest feret length with a median of over 60 mm. When the male and female sites compared, the feret length followed a stable pattern between the trees within the sites (Figure 4.17).

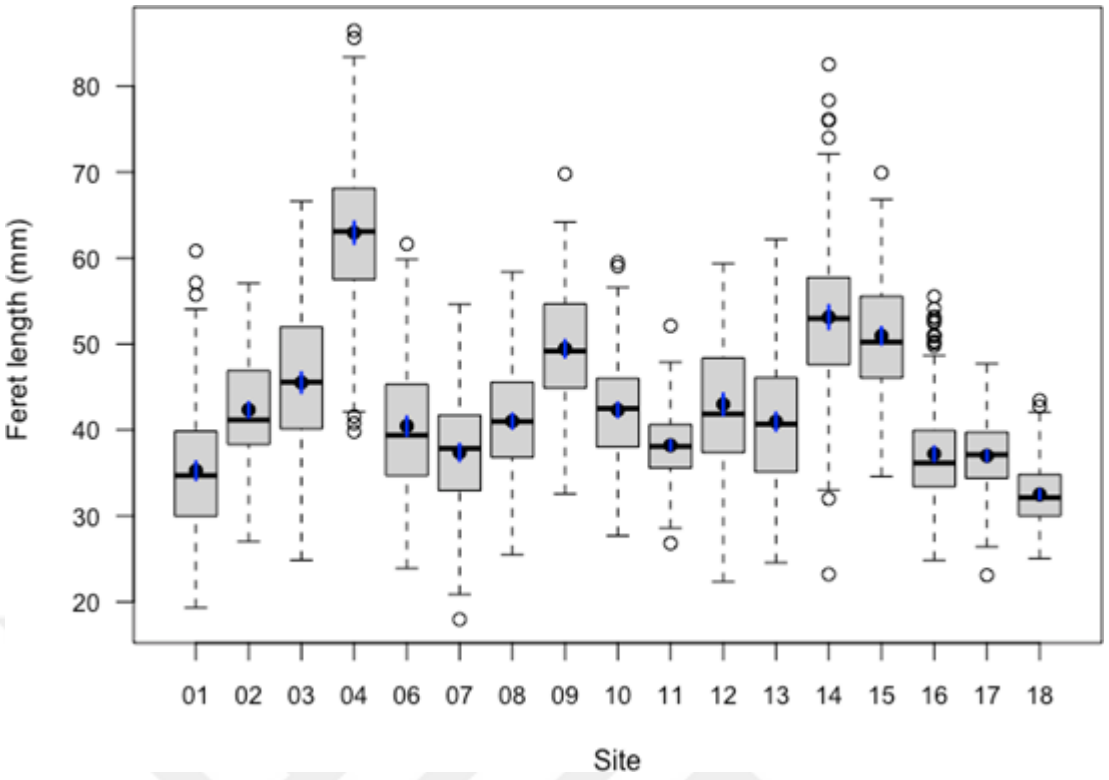

Figure 4.16. Feret length (mm). Site: overall for18 sites of *Hippophae rhamnoides*

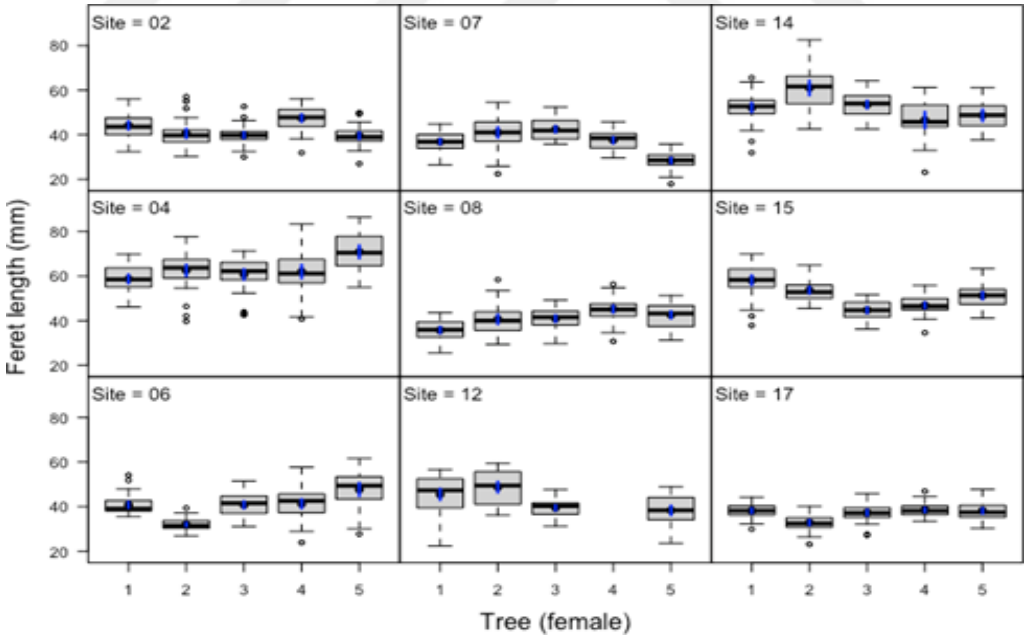

Figure 4.17. Feret length (mm). Tree: Each of five male/female leaves of *Hippophae rhamnoides* within each site

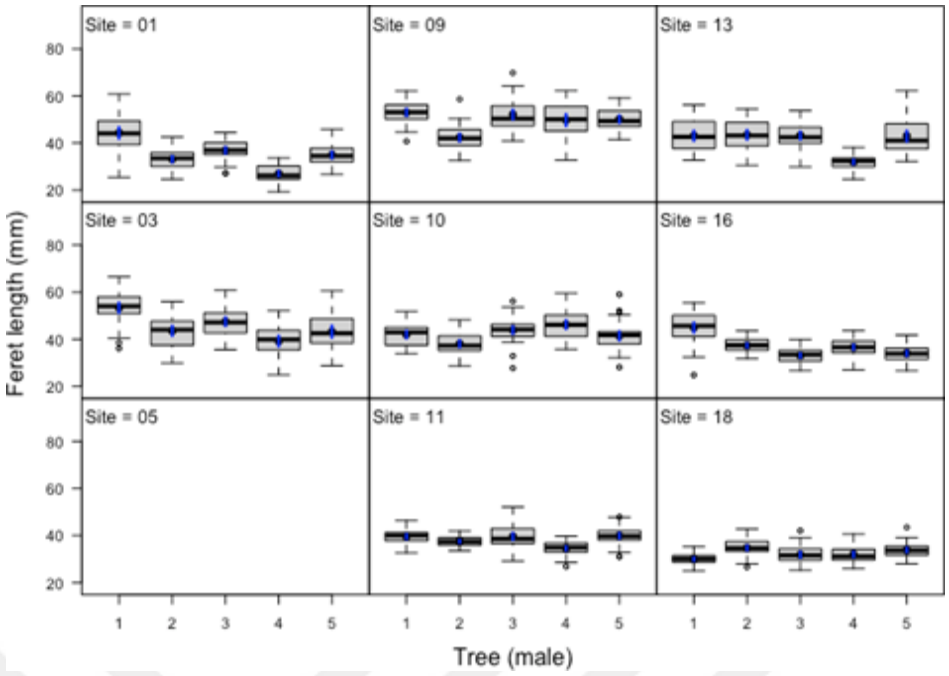

Figure 4.17. (Continue) Feret length (mm). Tree: Each of five male/female leaves of *Hippophaerhamnoides* within each site

4.1.3.3 Ellipse perimeter

Ellipse perimeter is a measure of the circumference of the leaves that fit into the ellipse and the moderate variation between sites is shown in Figure 4.18. The highest ellipse perimeter median value was the leaves on Site 4 which was close to 120 mm and the lowest one was the leaves on Site 18 with over 60 mm. Differences were also observed between trees within the sites in terms of ellipse perimeter (Site 15). Site 17 had the least variable ellipse perimeter (mm) between the female sites with the lowest median value. Variation in male trees within the sites was less than in female trees.

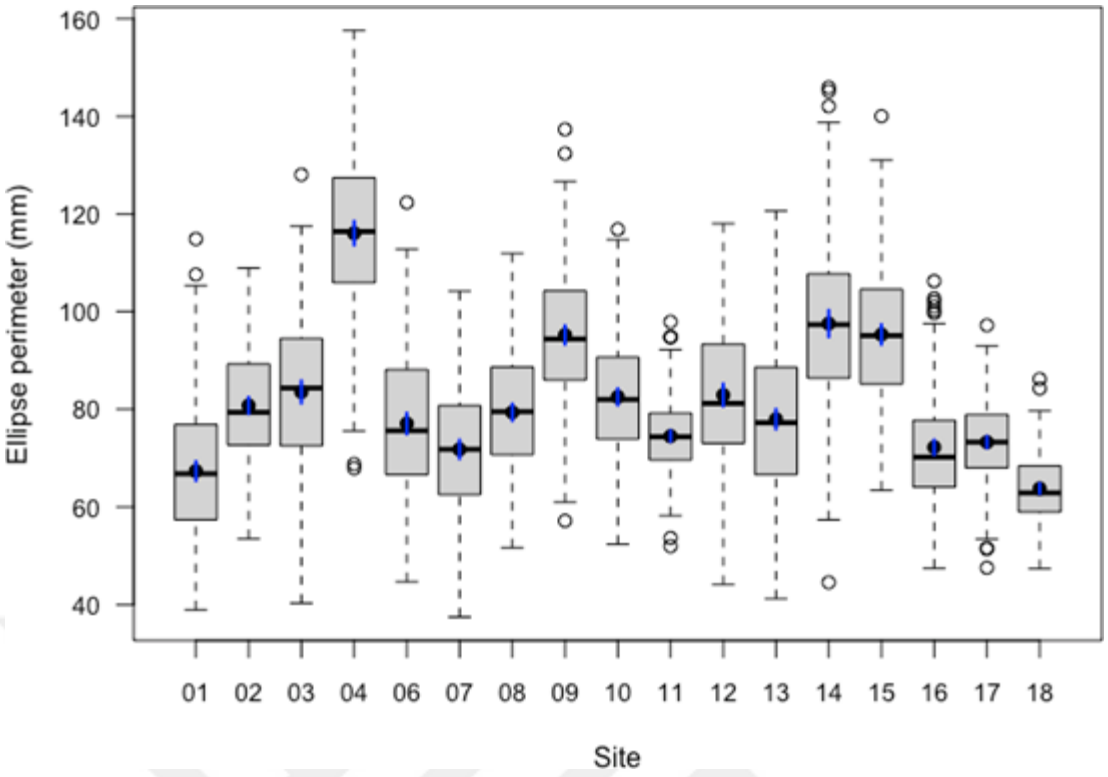

Figure 4.18. Ellipse perimeter (mm). Site: overall for 18 sites of *Hippophae rhamnoides*

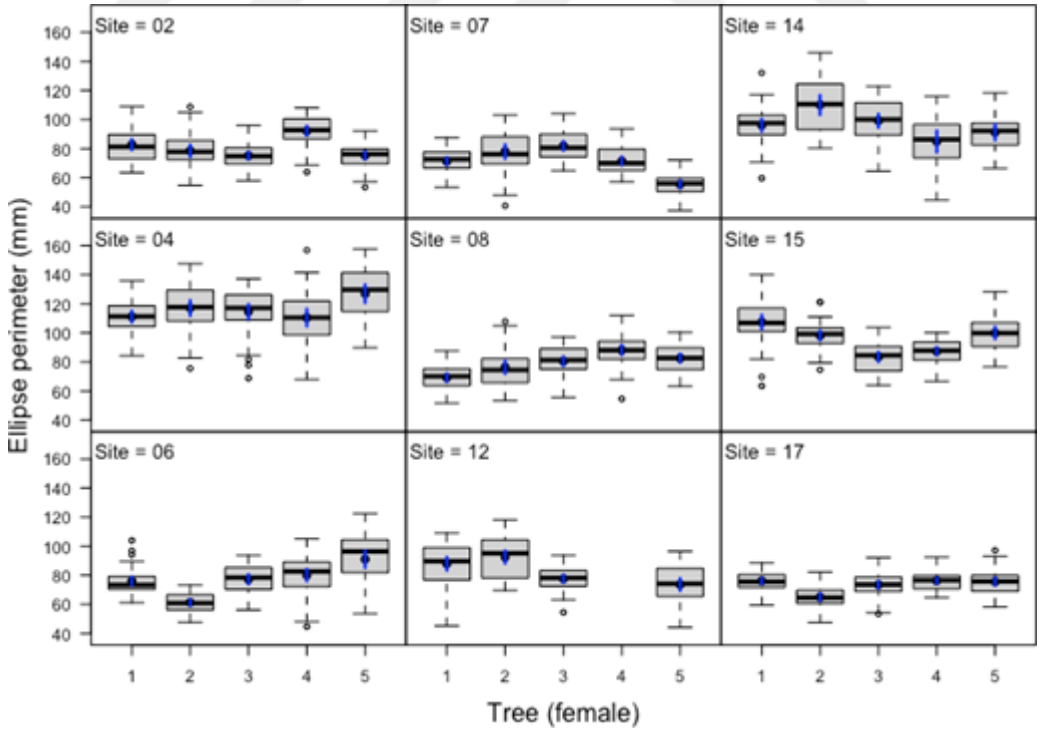

Figure 4.19 Ellipse perimeter (mm). Tree: Each of five male/female leaves of *Hippophae rhamnoides* within each site

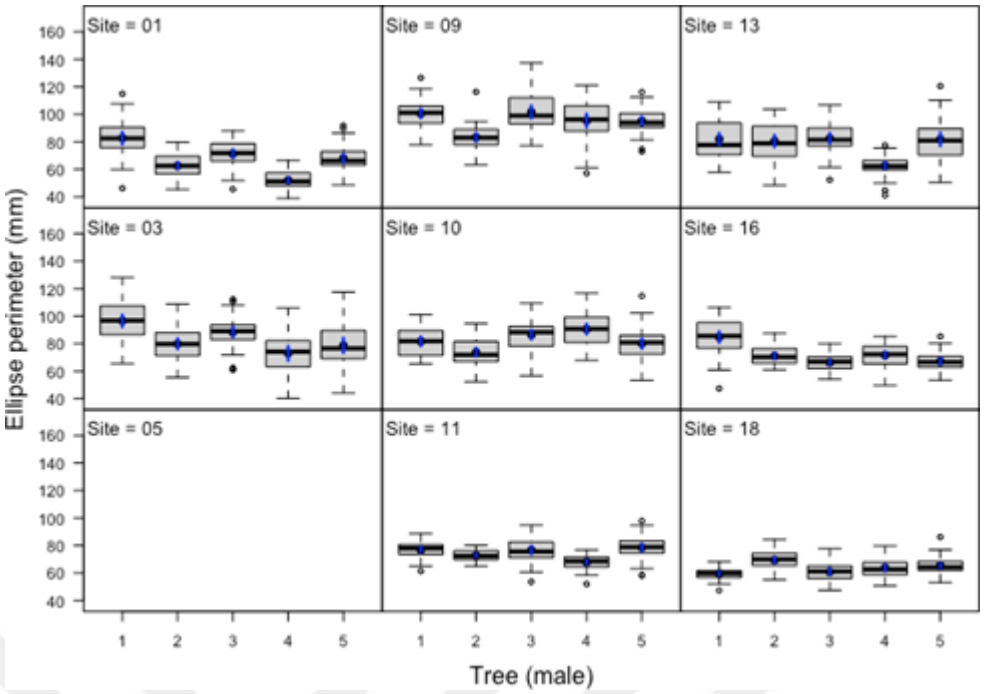

Figure 4.19. (Continue) Ellipse perimeter (mm). Tree: Each of five male/female leaves of *Hippophae rhamnoides* within each site

4.1.3.4 Major ellipse axis

The major ellipse axis is the measured of the longest diameter of the leaves. Figure 4.20 shows the highest major ellipse median value was the leaves on Site 4 which was close to 60 mm and the lowest one was the leaves on Site 18 with over 30 mm. Differences were also observed between trees within the sites in terms of the major ellipse (Site 15). Site 17 had the least variable ellipse perimeter (mm) between the female sites with the lowest median value. The variation in male trees within the sites was less than in femaletrees (Figure 4.21).

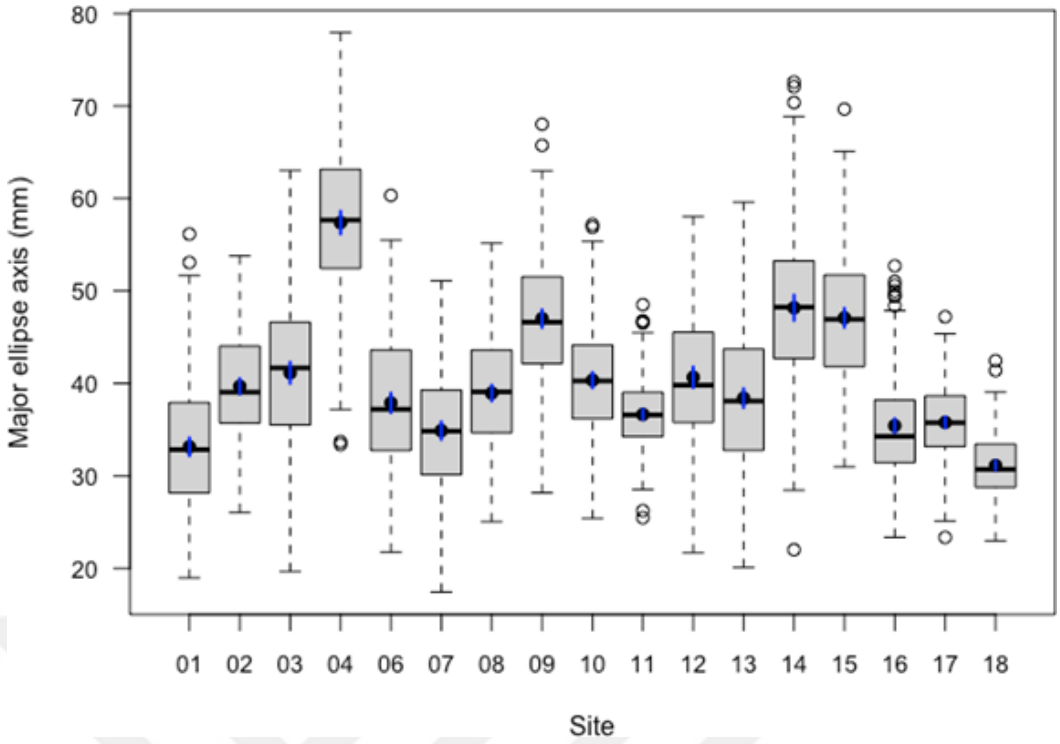

Figure 4.20. Major ellipse axis (mm). Site: overall for eighteen sites of *Hippophae rhamnoides*

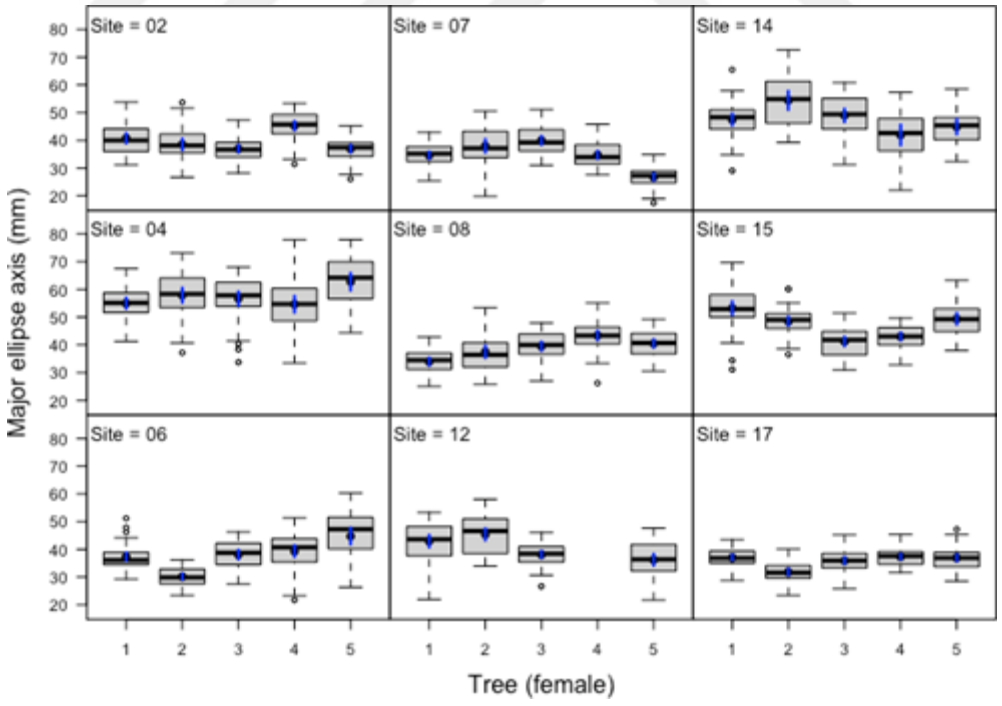

Figure 4.21. Major ellipse axis (mm). Tree: Each of five male/female leaves of *Hippophae rhamnoides* within each site

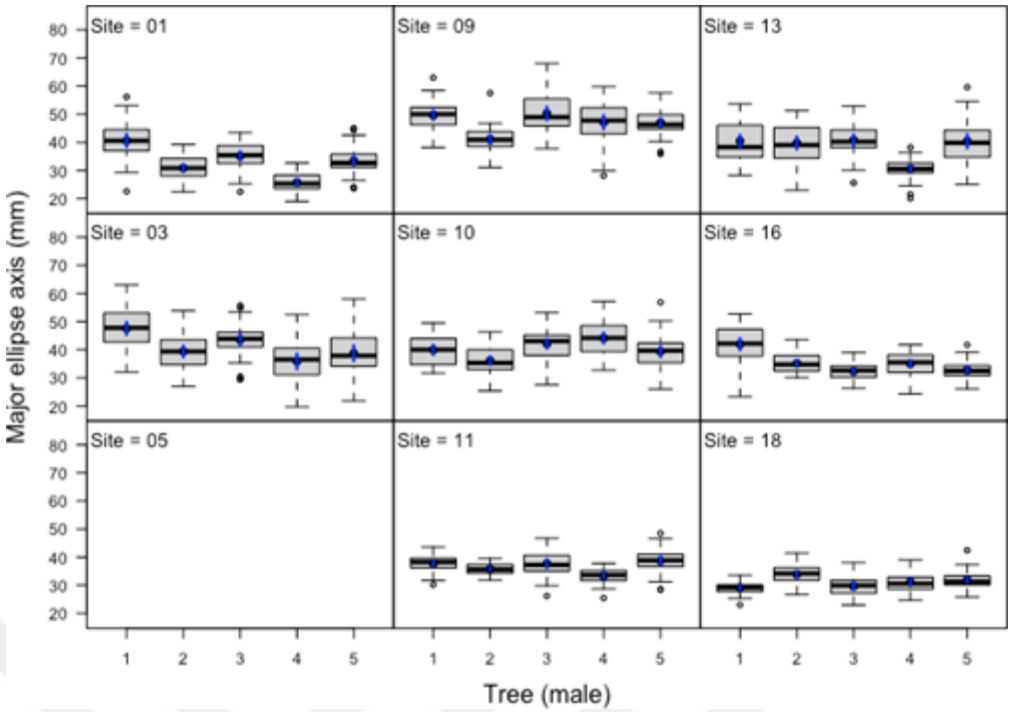

Figure 4.21. (Continue) Major ellipse axis (mm). Tree: Each of five male/female leaves of *Hippophae rhamnoides* within each site

4.1.3.5 Perimeter

The perimeter is the length of an outline of the *H. rhamnoides* leaves. The variation among some sites was similar as group (Sites 8 and 9; Sites 12 and 13; Sites 16, 17 and 18) but there was high variation among some sites (Sites 14 and 18) (Figure 4.22). The pair of particular trees at Site 14 had the highest variation within the site. Also, Site 6 had greater variation between the trees within the site. There was no high variation between the sites in male trees. Site 11 had the lowest variation between the sites and between the trees within thesite (Figure 4.23).

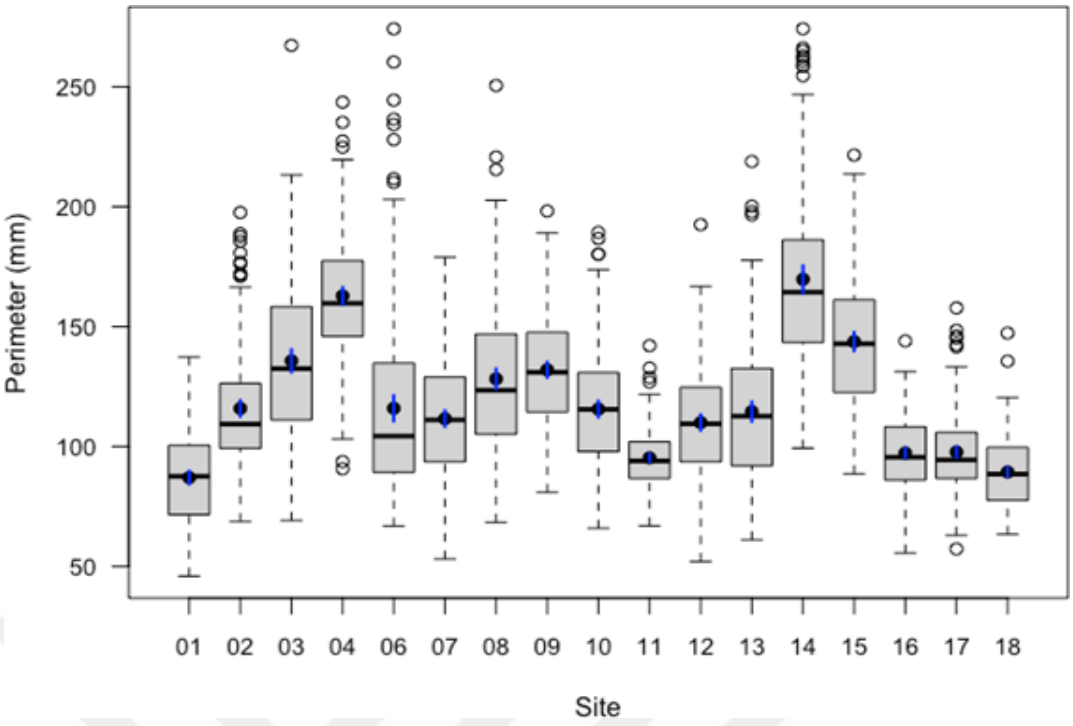

Figure 4.22. Perimeter (mm). Site: overall for 18 sites of *Hippophae rhamnoides*.

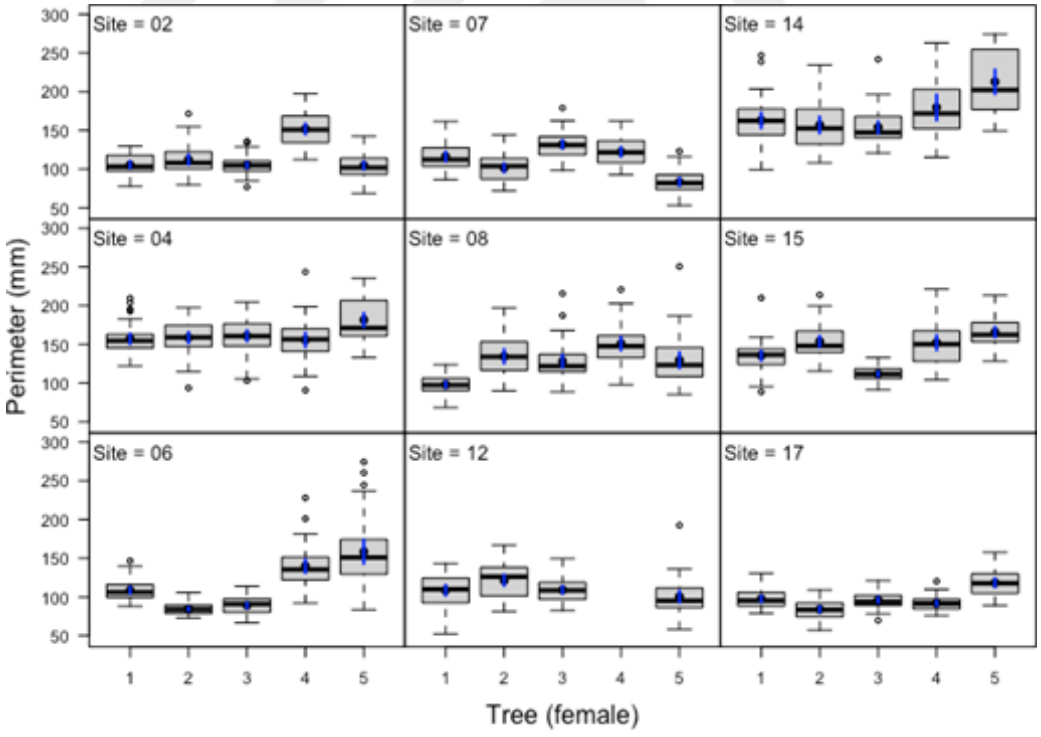

Figure 4.23. Perimeter (mm). Tree: Each of five male/female leaves of *Hippophae rhamnoides* within each site

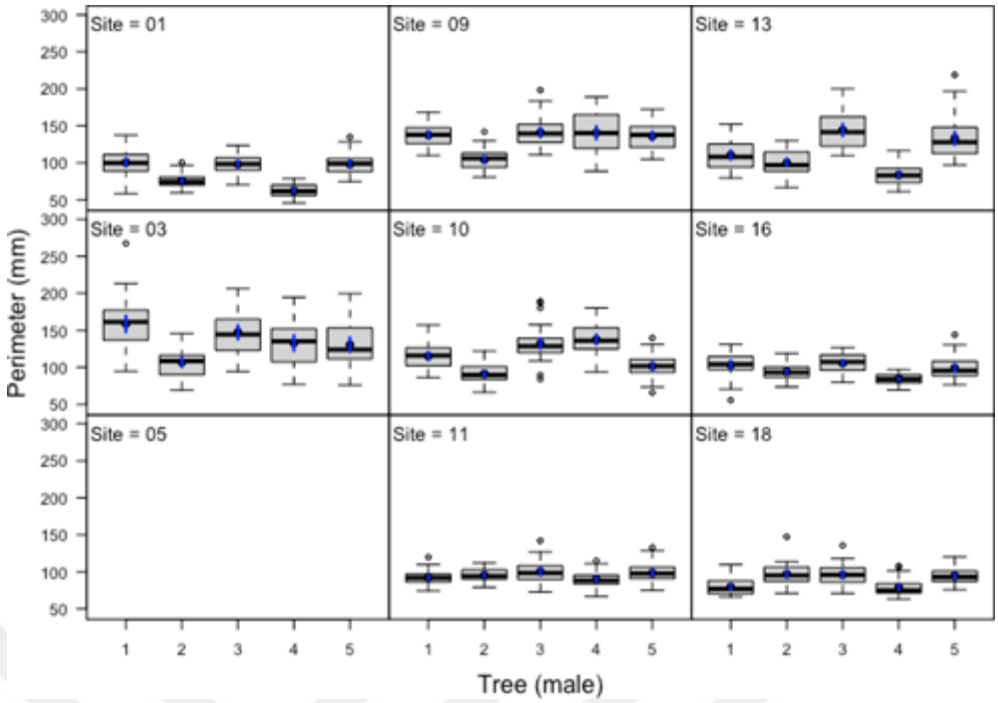

Figure 4.23. (Continue) Perimeter (mm). Tree: Each of five male/female leaves of *Hippophae rhamnoides* within each site

4.1.3.6 Minor ellipse axis

The minor ellipse axis (mm) is the measured of the shortest diameter of the leaves that fitted in ellipse. Figure 4.24 shows the highest minor ellipse median value was the leaves on Site 10 which was close to 5 mm and the lowest one was the leaves on Site 1 with over 3 mm. The highest differences between female trees were at Site 12, while the within-site variation at Sites 1, 10, and 16 with male sites was greater than the others (Figure 4.25).

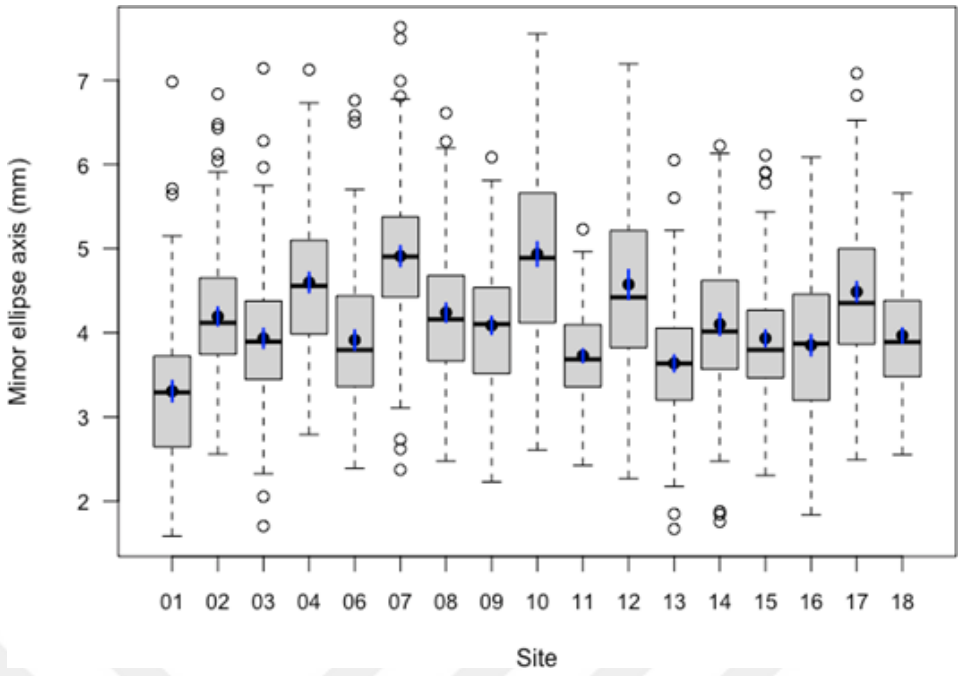

Figure 4.24. Minor ellipse (mm). Site: overall for 18 sites of *Hippophae rhamnoides*

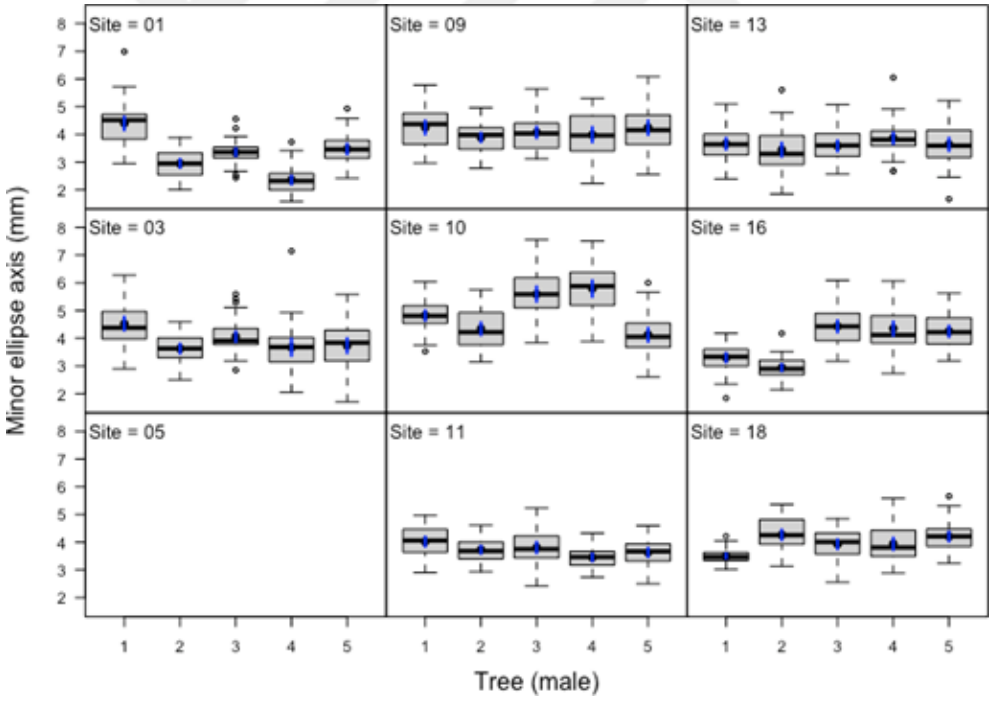

Figure 4.25. Minor ellipse (mm). Tree: Each of five male/female leaves of *Hippophae rhamnoides* within each site

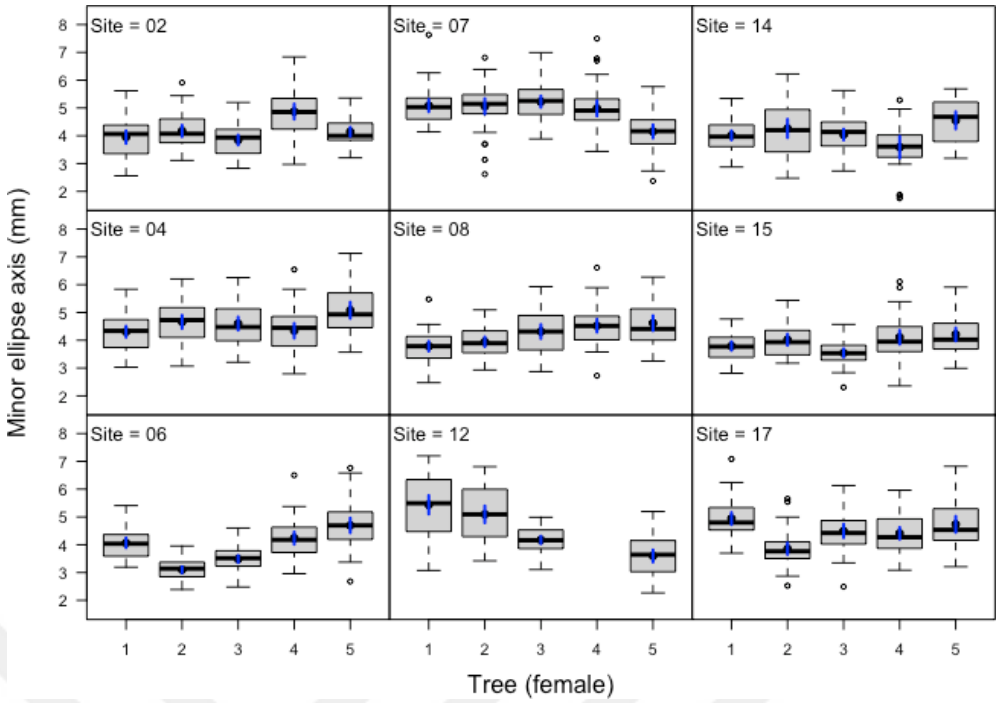

Figure 4.25. (Continue) Minor ellipse (mm). Tree: Each of five male/female leaves of *Hippophae rhamnoides* within each site

4.1.4 Aspect ratio

The aspect ratio (AR) is the ratio of the length to the width of the leaves of *H. rhamnoides*. Figure 4.26 shows moderate differences between sites. While some sites had very close AR (Sites 14 and 15; Sites 17 and 18), the difference between some was high. (Sites 4 and 18). AR among trees on female sites had a fairly stable pattern but some sites with male trees had slight variation (Sites 13 and 16) (Figure 4.27)

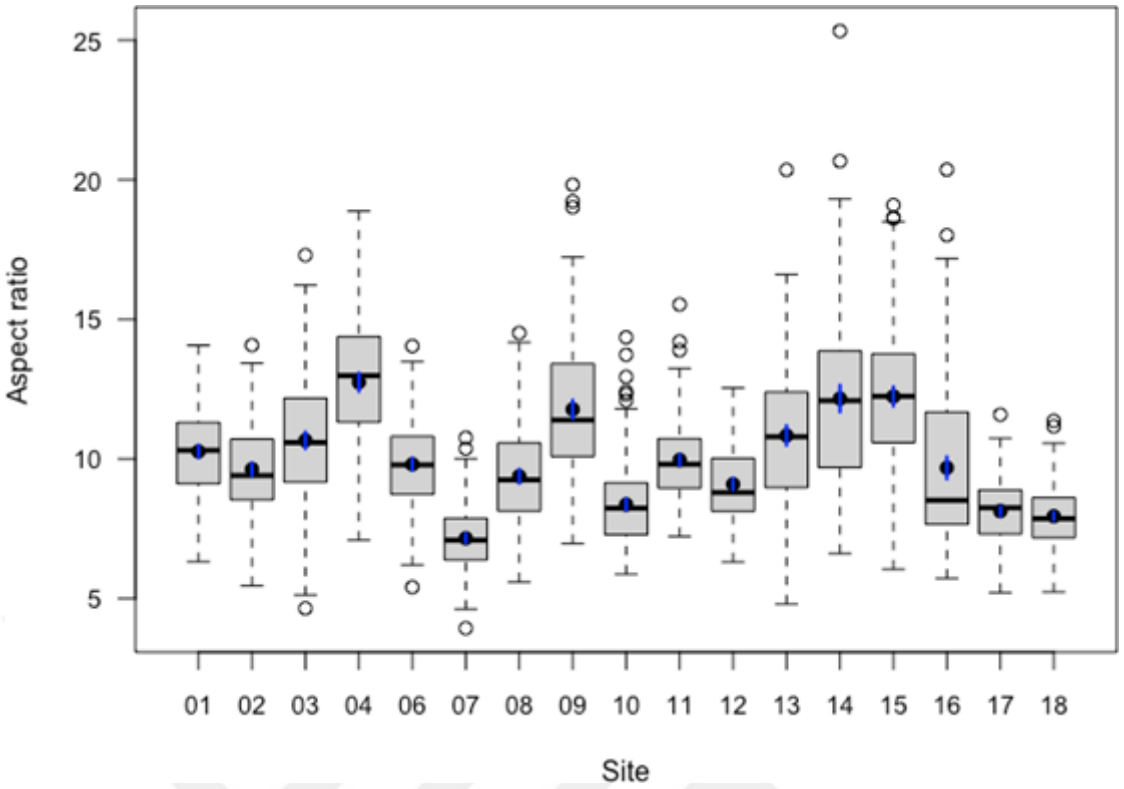

Figure 4.26. Aspect Ratio (AR). Site: overall for 18 sites of *Hippophae rhamnoides*

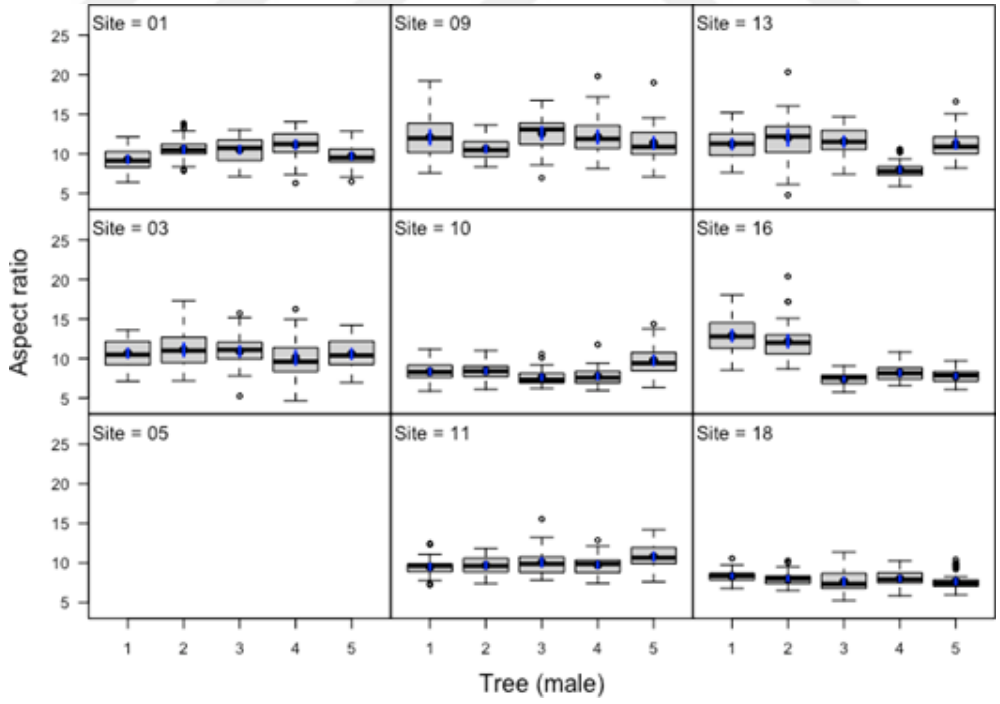

Figure 4.27. Aspect ratio Tree: Each of five male/female leaves of *Hippophae rhamnoides* within each site

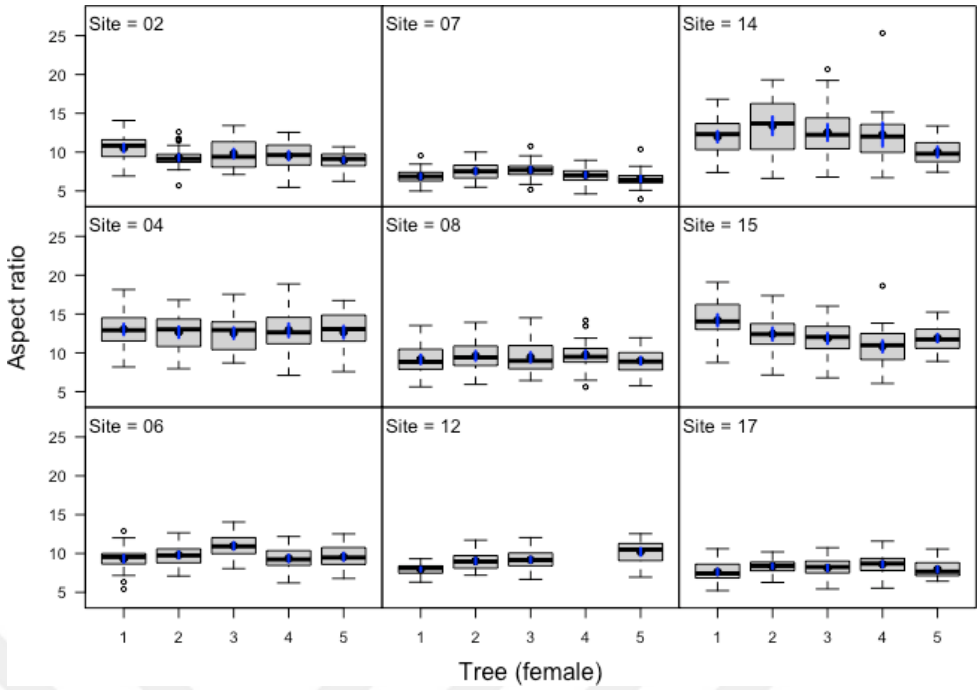

Figure 4.27. (Continue) Aspect ratio Tree: Each of five male/female leaves of *Hippophae rhamnoides* within each site

4.1.4.1 Roundness

Figure 4.28 shows that there were moderate differences of the roundness between the sites of *H. rhamnoides.* The highest roundness median value was close to 0.15 with Site 7. The less rounded shape leaves were at Site 4 with the lowest median value over 0.05. Overall, the leaf roundness measure within the 18 sites showed a regular pattern at tree level. However, there were slight differences between certain trees at some sites (Sites 13 and 16) (Figure 4.29).

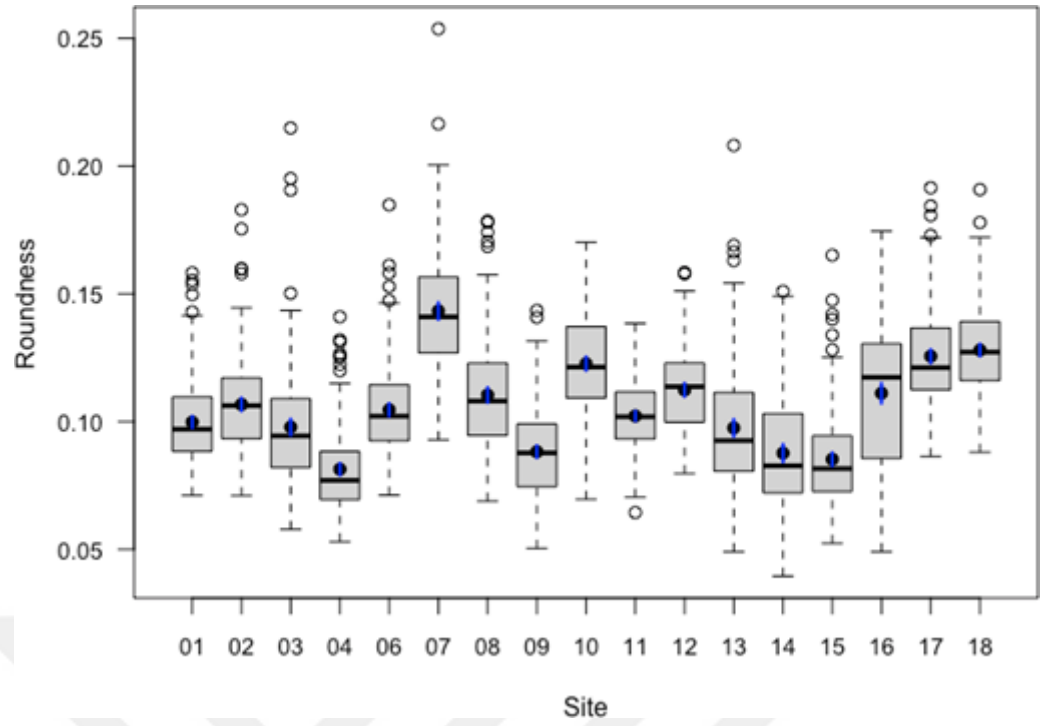

Figure 4.28. Roundness Site: overall for 18 sites of *Hippophae rhamnoides*

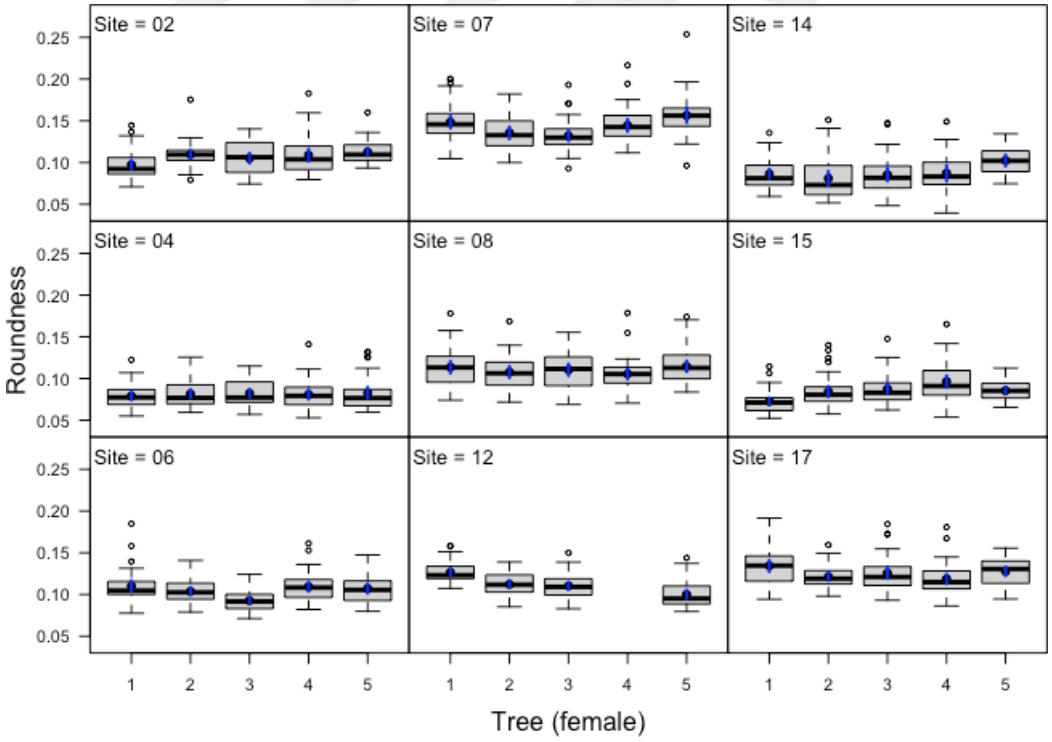

Figure 4.29. Roundness Tree: Each of five male/female leaves of *Hippophae rhamnoides* within each site

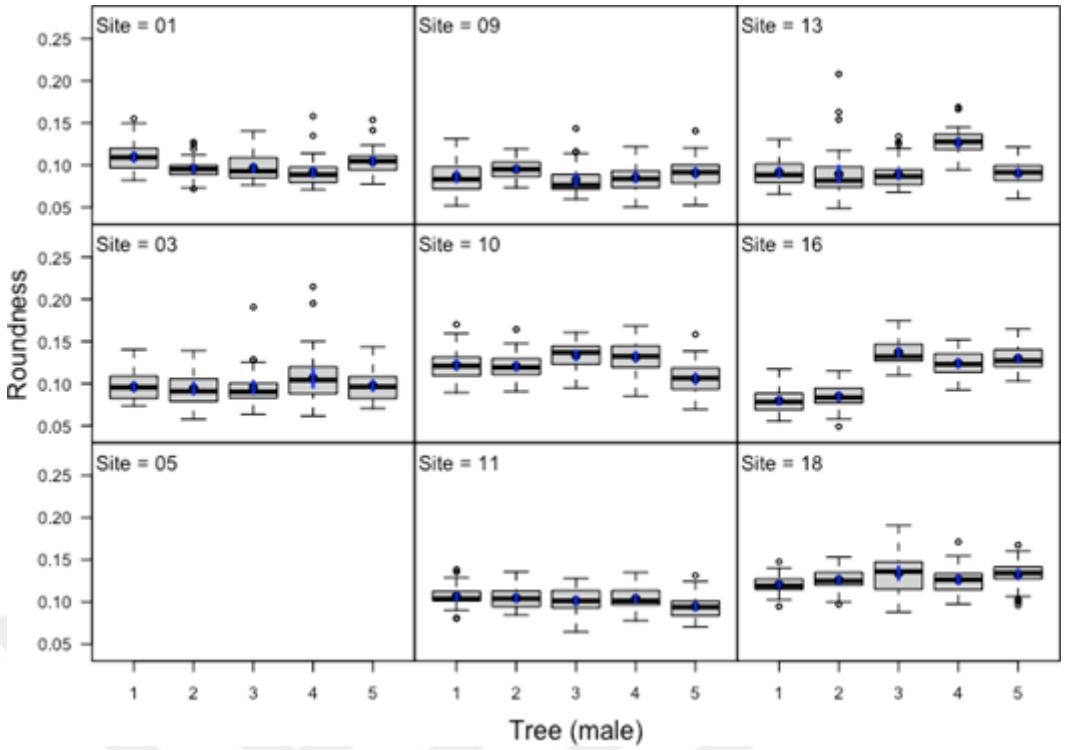

Figure 4.29. (Continue) Roundness Tree: Each of five male/female leaves of *Hippophae rhamnoides* within each site

4.1.4.2 Circularity

Figure 4.30 indicates the circularity were moderately different between the sites of *H. rhamnoides.* If the value is one, it indicates of perfect circle. The highest circularity median value was close to 0.15 at Site 12. The less circular shape leaves were at Site 4 with the lowest median value close to 0.1. Overall, the circularity measure within the 18 sites did not show a regular pattern at the tree level, such as the roundness. The variation in female trees at Site 7 was higher than at other sites and had more variation within itself. Site 13 was the more variable sites among the male tree sites (Figure 4.31).

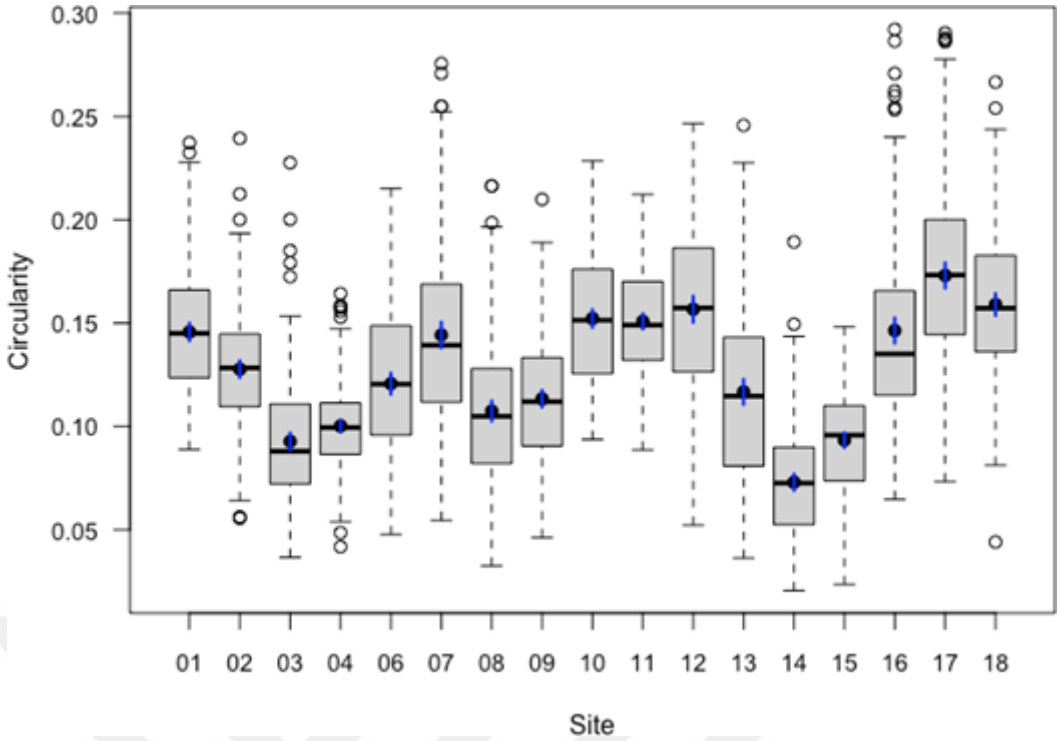

Figure 4.30. Circularity Site: overall for18 sites of *Hippophae rhamnoides*

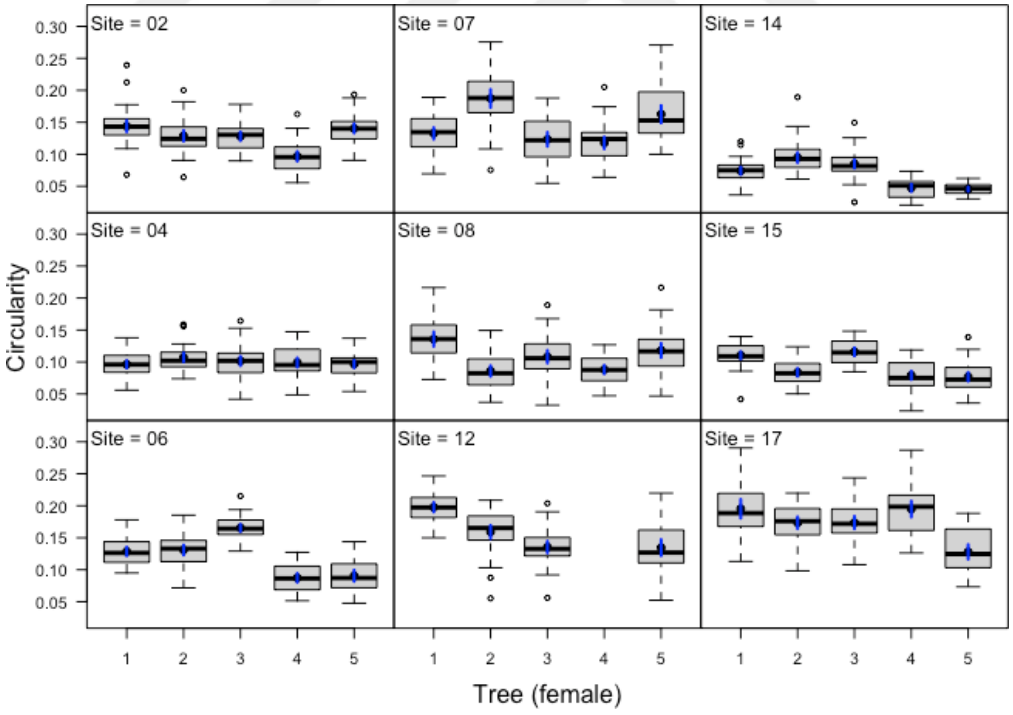

Figure 4.31. Circularity Tree: Each of five male/female leaves of *Hippophae rhamnoides*

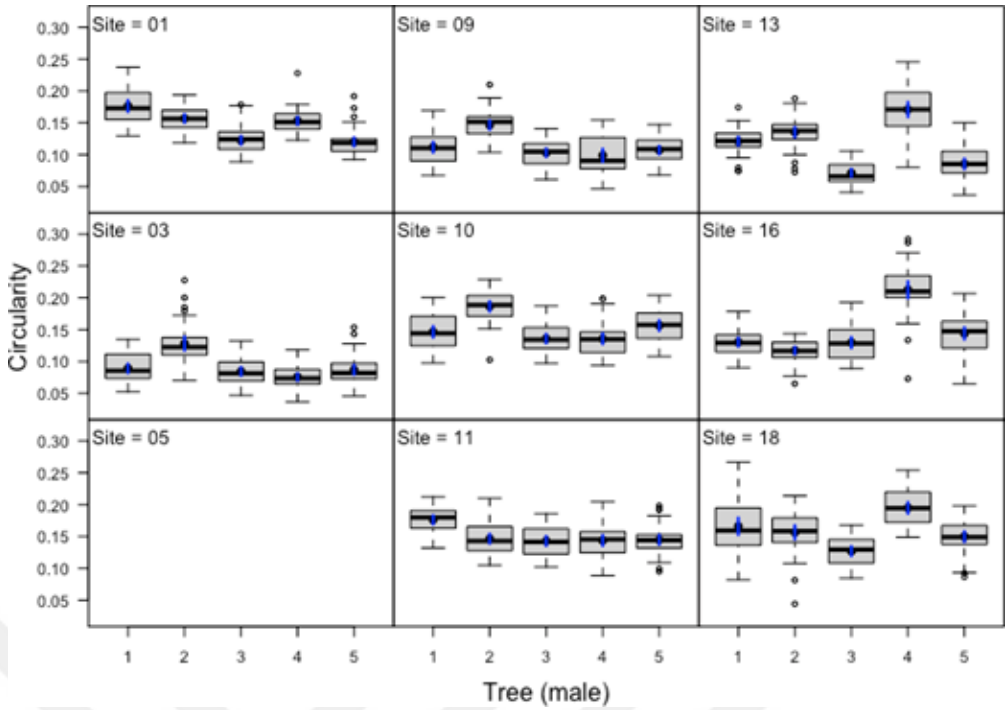

Figure 4.31. (Continue) Circularity Tree: Each of five male/female leaves of *Hippophae rhamnoides*

4.1.4.3 Feret width

Figure 4.32 shows the differences between the Feret width (mm) of the *H. rhamnoides* leaves of 18 sites. Although leaf Feret widths had generally close median values between sites, there were sites with great variation within the site (Site 14). The highest median value was leaves at Site 10, close to 6 mm, and the lowest leaves median value was above 3 mm at Site 1. Sites 12 and 14 showed greater variation among trees within the site, as well as particularly within the individual trees but other sites had consistent pattern (Figure 4.33).

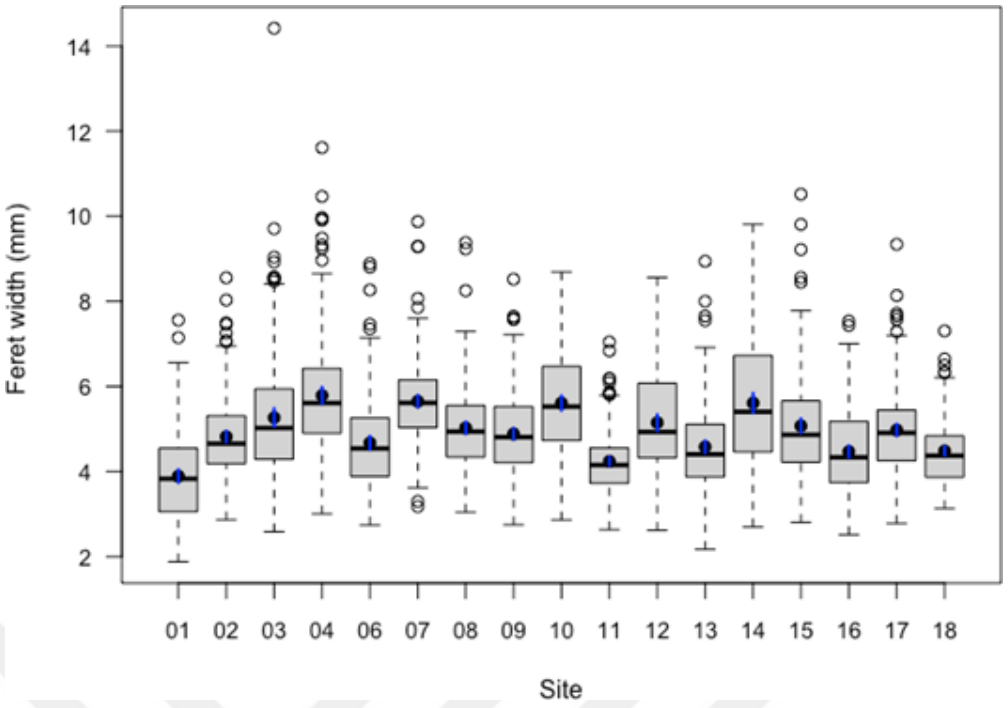

Figure 4.32. Feret width (mm). Site: overall for18 sites of *Hippophae rhamnoides*

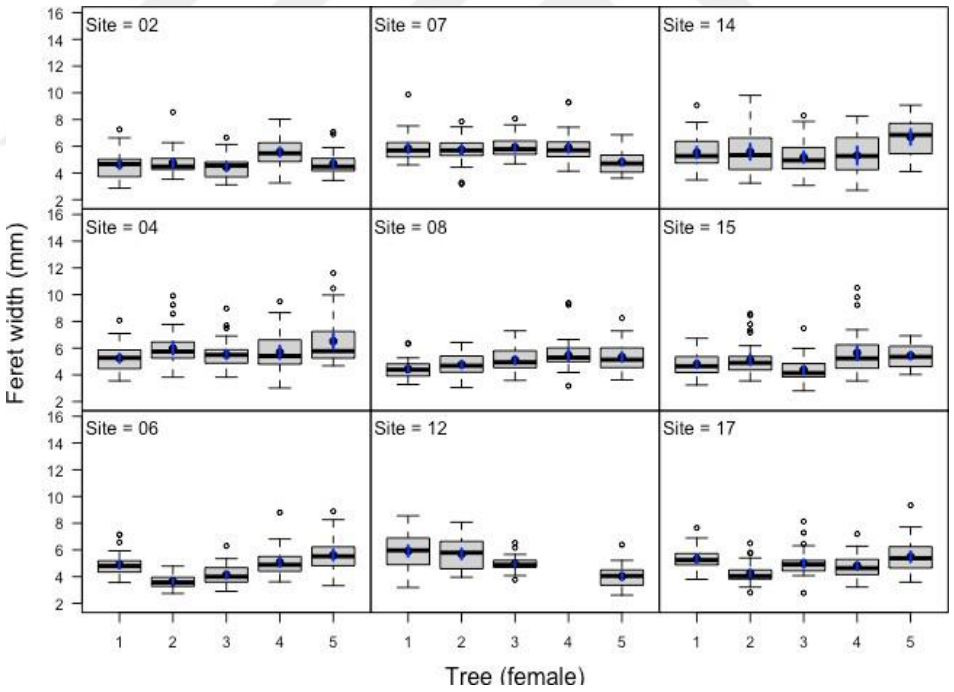

Figure 4.33. Feret width (mm). Tree: Each of five male/female leaves of *Hippophae rhamnoides* within each site

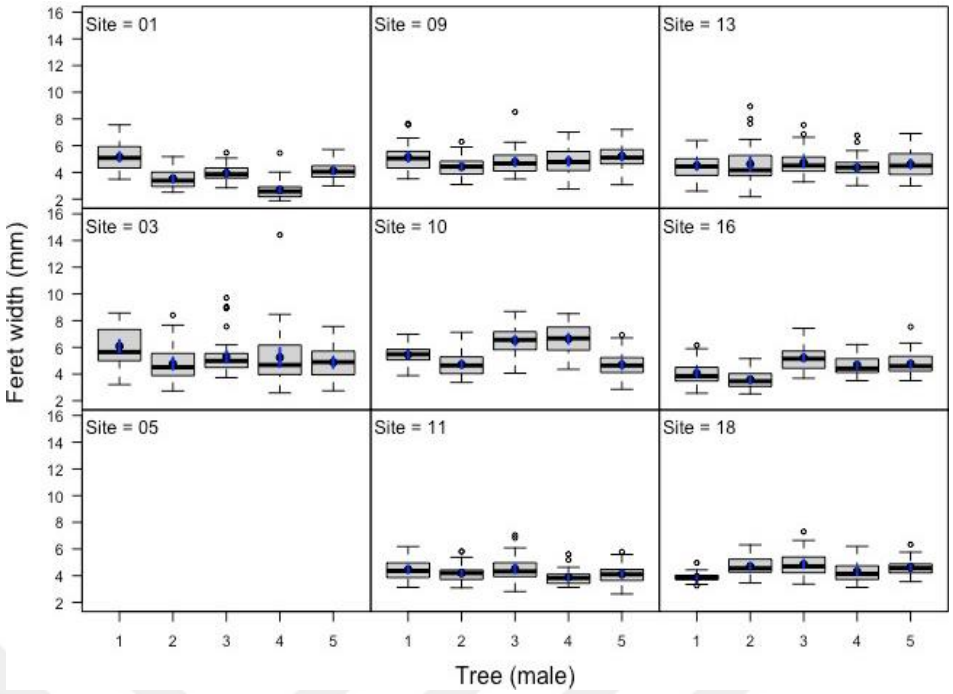

Figure 4.33. (Continue) Feret width (mm). Tree: Each of five male/female leaves of *Hippophaerhamnoides* within each site

4.1.5 Area

Figure 4.34 shows the variation of the area (mm^2) of the *H. rhamnoides* leaves. There were moderately differences between the sites and Site 4 had the highest median value between the sites with over 200 mm^2. Site 12 had the higher variation between the trees within the female sites but the median value was low. Site 1 was the lowest area median value with below 100 mm^2. Sites 1, 3 and 10 had substantial variation between male trees within sites.

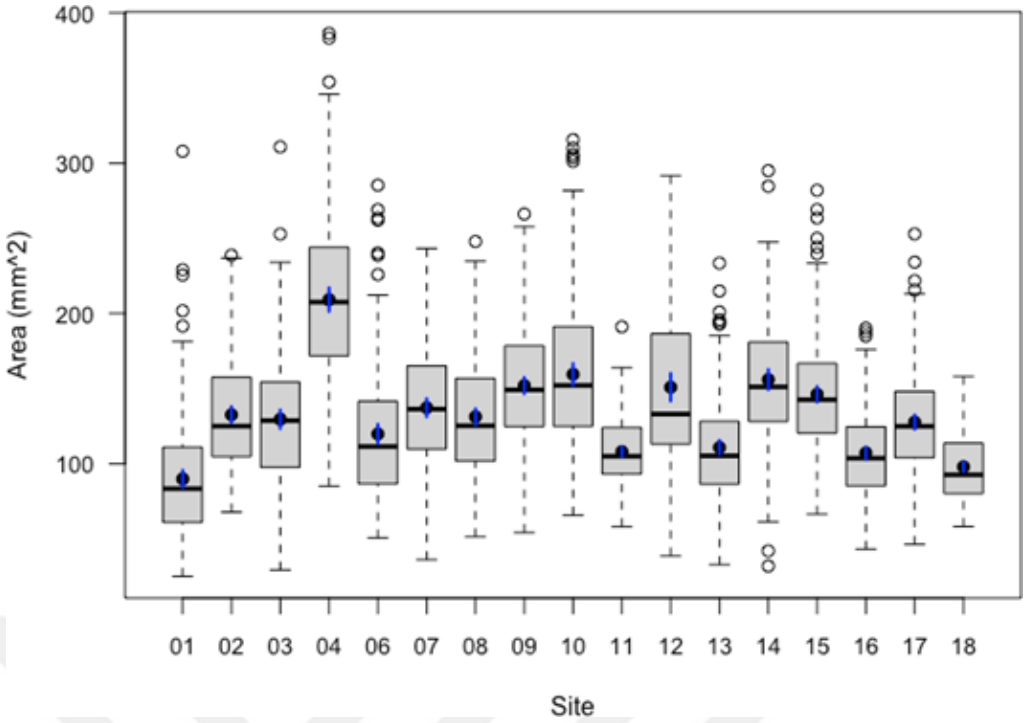

Figure 4.34. Area (mm^2). Site: overall for18 sites of *Hippophae rhamnoides*

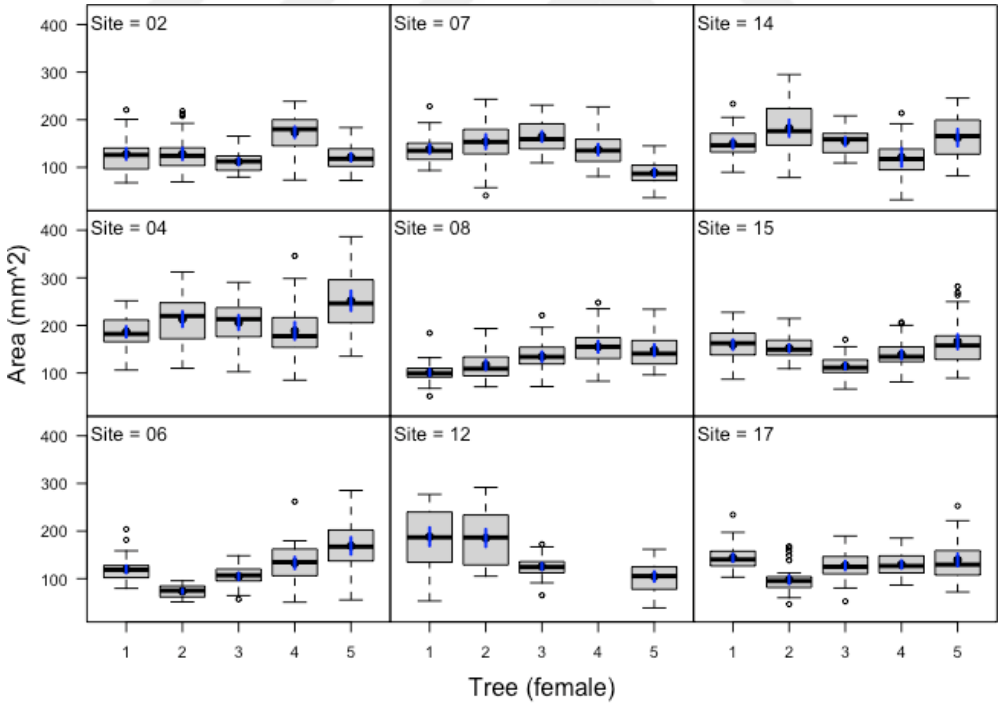

Figure 4.35. Area (mm^2). Tree: Each of five male/female leaves of *Hippophae rhamnoides* within each site

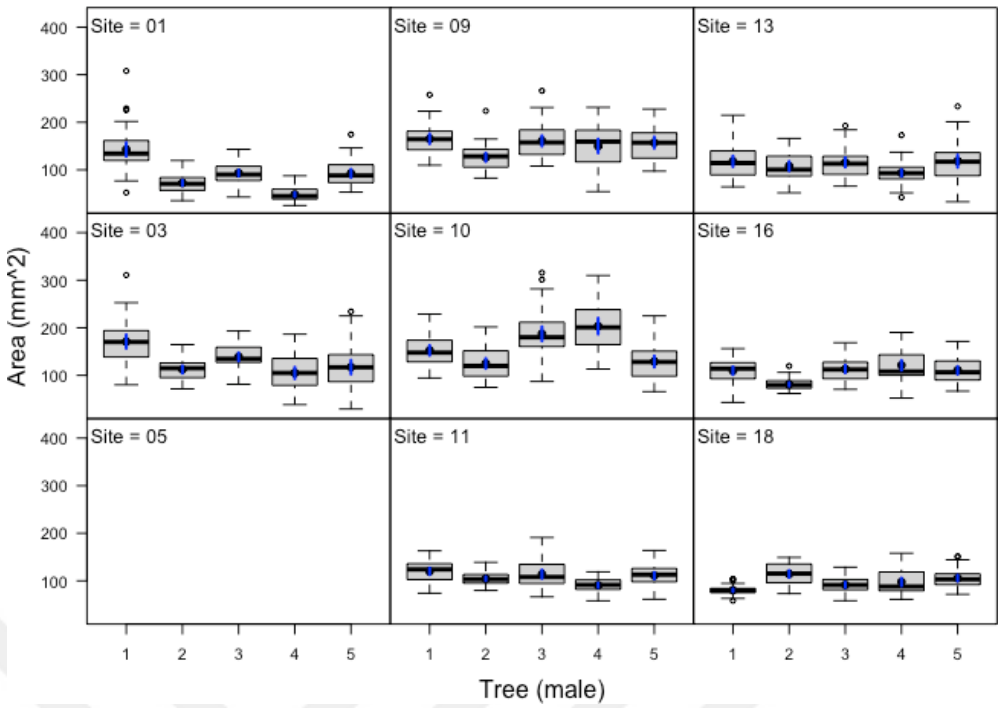

Figure 4.35. (Continue) Area (mm^2). Tree: Each of five male/female leaves of *Hippophae rhamnoides* within each site

The 11 parameters of *H. rhamnoides* leaves evaluated at tree, site and branch levels (Figure 4.36). Detailed analyzed data are shown in Table A6. (see *H. rhamnoides* leaf analysis).

According to Figure 4.36, there were a lot of variation for perimeter ellipse, major, feret and perimeter for the site level but slight variation at tree and branch level. Coefficient variation (CV%) for these three paramaters at tree levels were 21.6, 22.0 and 26.7%, respectively.

The variation at the site level for the minferet and minor width parameters was not very high. All these parameters were also examined in branch levels and very small variation observed within the site of the branches.

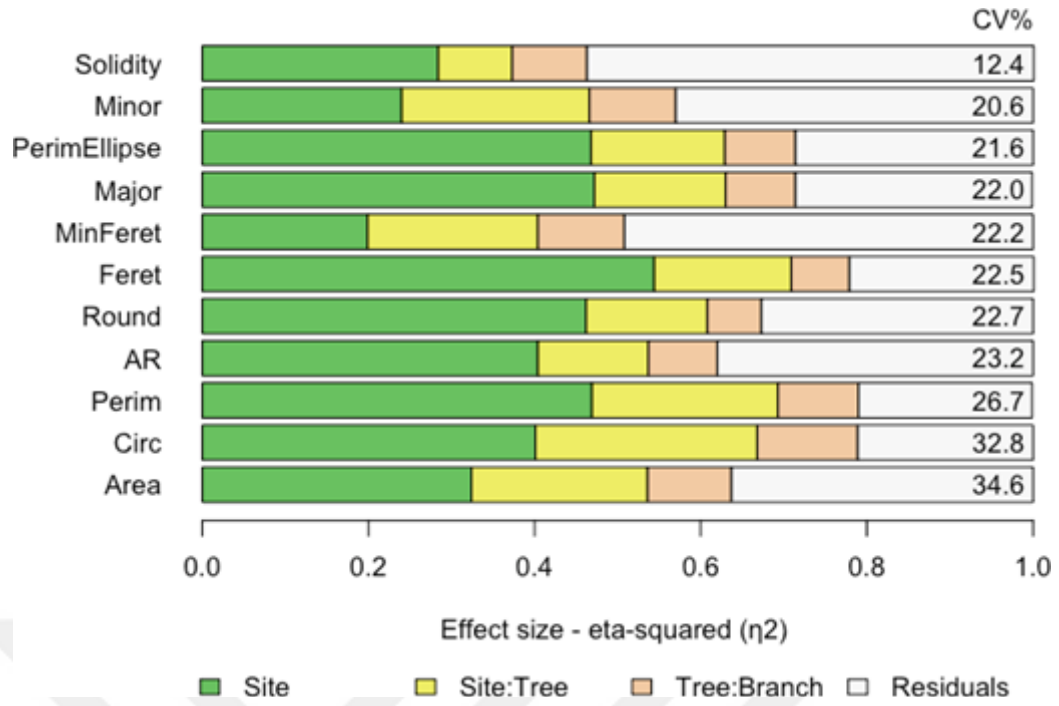

Figure 4.36. Coefficient variation (CV%) and effect size, eta-squared (η2), graph showing solidity, minor, perimeter ellipse (PerimEllipse), major, minimum feret (MinFeret), feret, roundness (round), aspect ratio (AR), perimeter (Perim), circularity (Circ) and area of the leaves of *Hippophae rhamnoides* in site, tree and branch levels

4.2 Reproductive Characterization of *Hippopahe rhamnoides* in Çamardı, Niğde

Reproductive characterization analysis which were included fruiting branches, fruits, seeds and germination analysis of *H. rhamnoides* were done by using R statistics.

4.2.1 *Hippophae rhamnoides* fruiting branches analysis

Coefficient variation (CV%) for the eight parameters used to asses fruiting branches is shown in Figure 4.37. Figure 4.37 shows that, there were four highly variable parameters and three parameters had less than 20% variation. Among them, fruit density was the most variable and the fruit moisture was the least variable parameters.

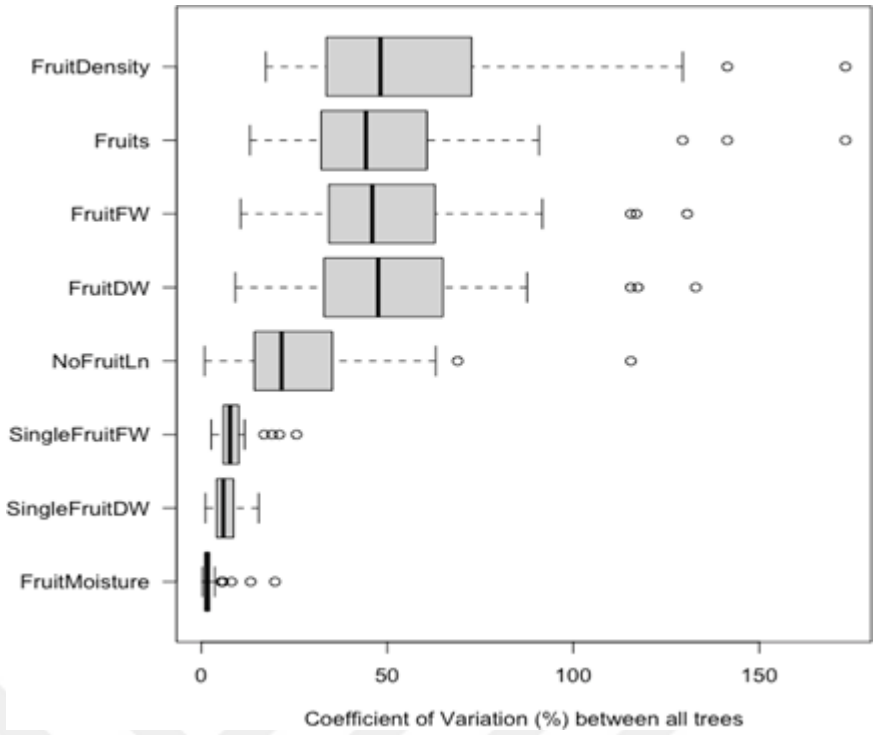

Figure 4.37. Coefficient variation (CV%) of fruit moisture content, single fruit dry weight, single fruit fresh weight, none fruit length, fruit dry weight, fruit fresh weight and total number of fruit andfruit density between all *Hippohae rhamnoides* trees

These parameters were also compared within and between the sites and the analysis are shown in Table A7 (see *H. rhamnoides* fruiting branch analysis).

4.2.2 Fruit moisture contents

The fruit moisture contents between sites and between trees within sites is presented in Figure 4.38 and 4.39, respectively. The moisture content was approximately around 70% across the sites. However, two sites (Sites 8 and 14) had lower moisture contents of below 65%. Mostly trees withinthe sites were consisted however Sites 14 and 15 showed the most variability between treeswithin sites. In Site 15, there were some moderate variation on two trees within the site.

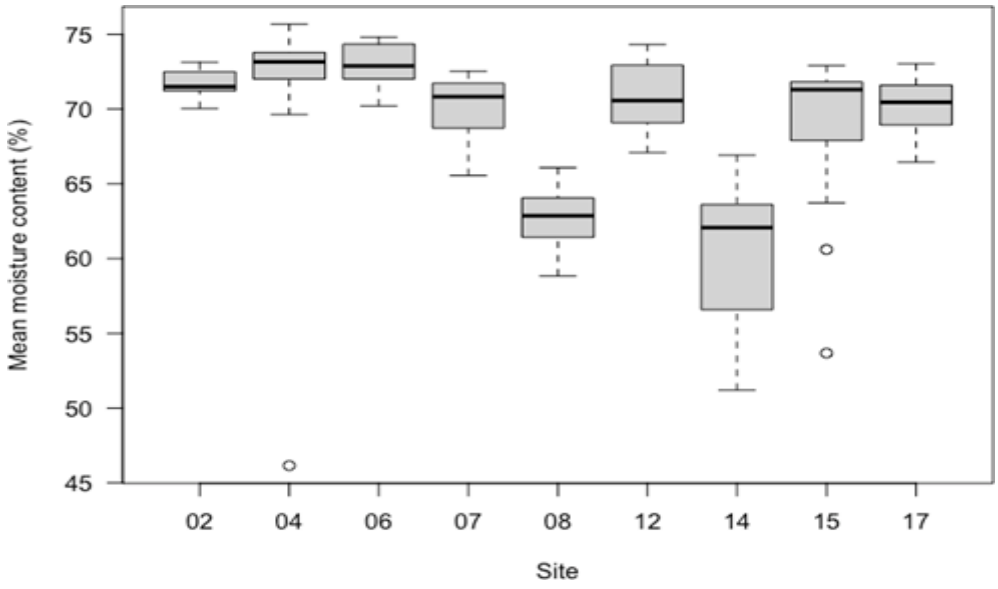

Figure 4.38. Mean moisture content (%). Site: overall for nine female sites of *Hippophae rhamnoides*

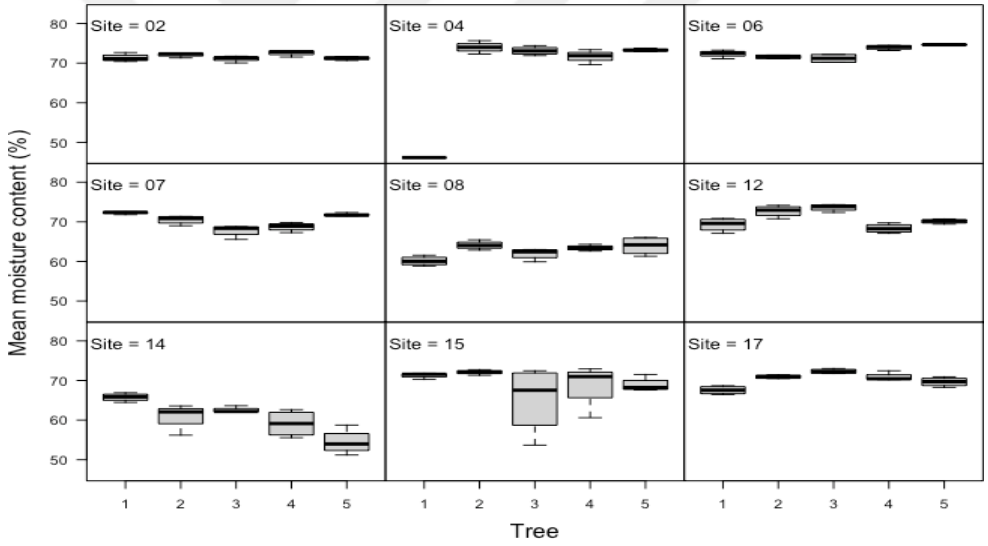

Figure 4.39. Mean moisture content (%). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.2.3 Single fruit dry weight

Single fruit dry weight is calculated by dividing the dry fruit weight of a sample by the number of fruits in that sample. Figure 4.40 and Figure 4.41 indicates the single fruit dryweight of the *H. rhamnoides* for site and tree levels, respectively. According to the meanfruit dry weight, there was more variation between the sites. Site 8 had the lowest single fruit dry weight of about 0.02 g while Site 7 had the highest single fruit dry

weight of about 0.05 g. Overall, Site 12 was the site which had the substantial variation between thesites. In tree levels, therewere limited variation in Site 8 but Site 12 and 7 had the highervariation which could be driven by the genetics or environment.

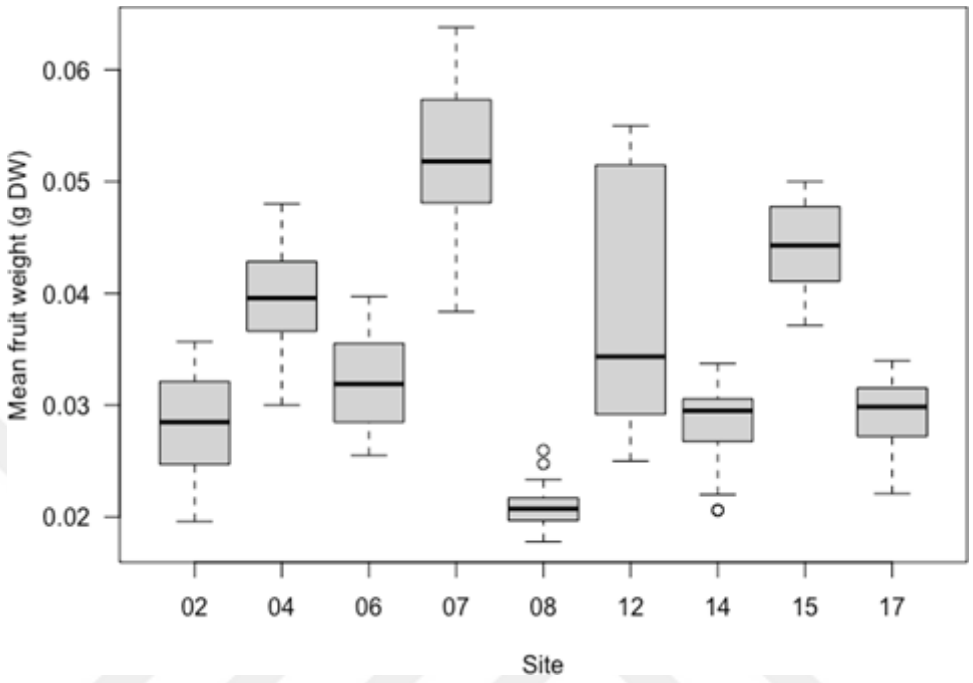

Figure 4.40. Single fruit dry weight (g DW). Site: overall for nine female sites of *Hippophae rhamnoides*

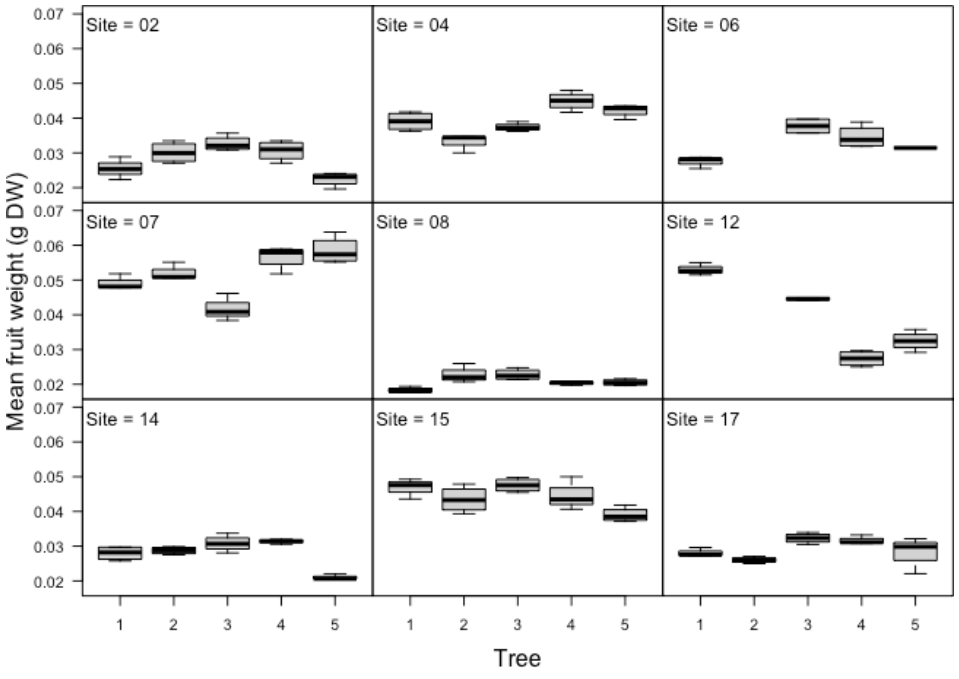

Figure 4.41. Single fruit dry weight (g DW). Tree: each of five trees of *Hippophae hamnoides* within each site

4.2.4 Single fruit fresh weight

Single fruit fresh weight is calculated by dividing the fresh fruit weight of a sample by the number of fruits in that sample. Fresh fruit weight (g FW) between sites and between trees within sites are shown in Figure 4.42 and 4.43, respectively. Similar to single dry fruit weight, there was more variation between sites. Site 8 had the lowest fresh fruit weight, about 0.05 g. Sites 8 and 14 also had lower variation between sites and between trees within sites suggestingthat the trees in both sites were clonal. However, Site 12 had the most variability betweenthe sites and also between the sites within the trees. Sites 7 and 15 had higher fresh fruit weight between sites but were moderately variable within sites between trees.

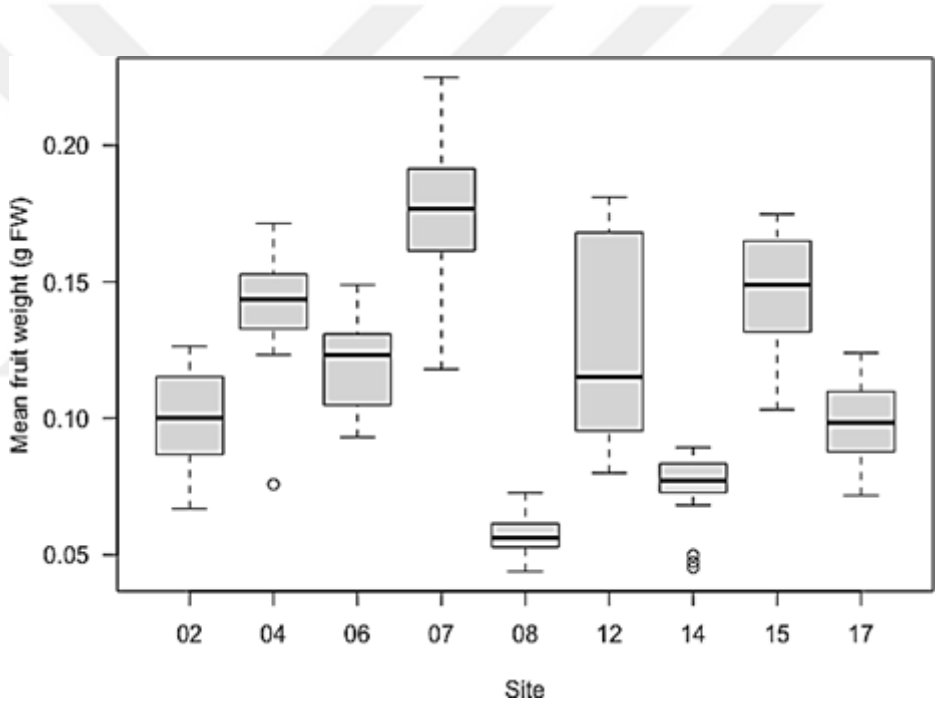

Figure 4.42. Single fruit fresh weight (g FW). Site: overall for nine female sites of *Hippophae rhamnoides*

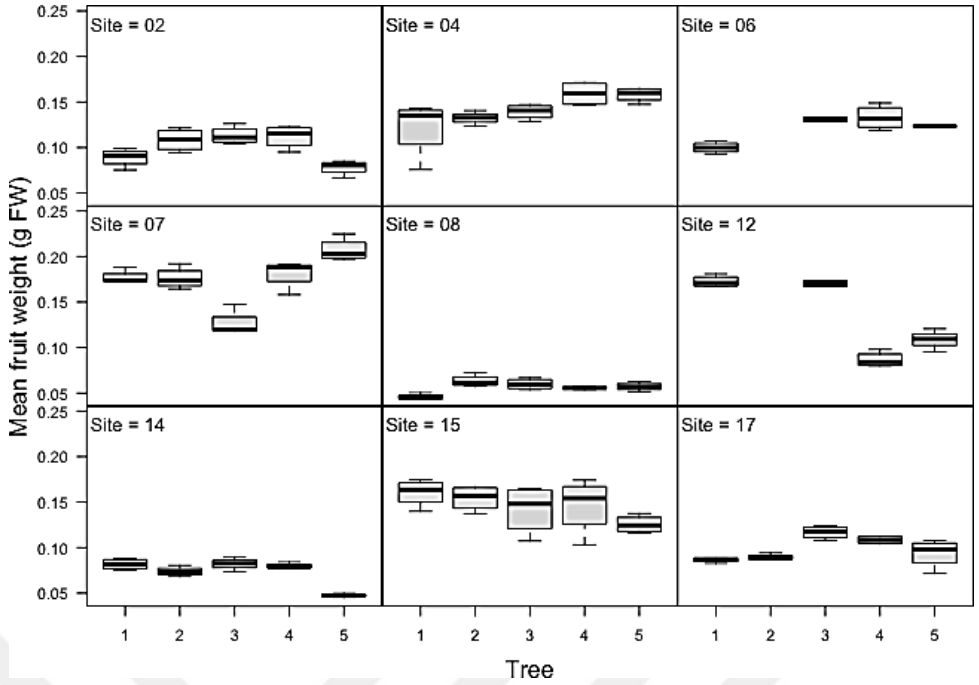

Figure 4.43. Single fruit fresh weight (g FW). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.2.5 None fruiting length

None fruiting length of *Hippophae* branches is a kind of a measure of the new growth/vigor of the fruit on 2nd year wood. Figure 4.44 shows the none fruiting length across the nine sites of *H. rhamnoides* female trees were sampled. There were some differences between the sites. Four sites had a longer none fruiting length which were approximately 300 in mm, while the others were shorter. The ones with the longest fruiting lengths were Site 6 and the one with the shortest none fruiting length was the Site 8. Sites 14 and 15 had the more variability between the particular trees (Figure 4.45).

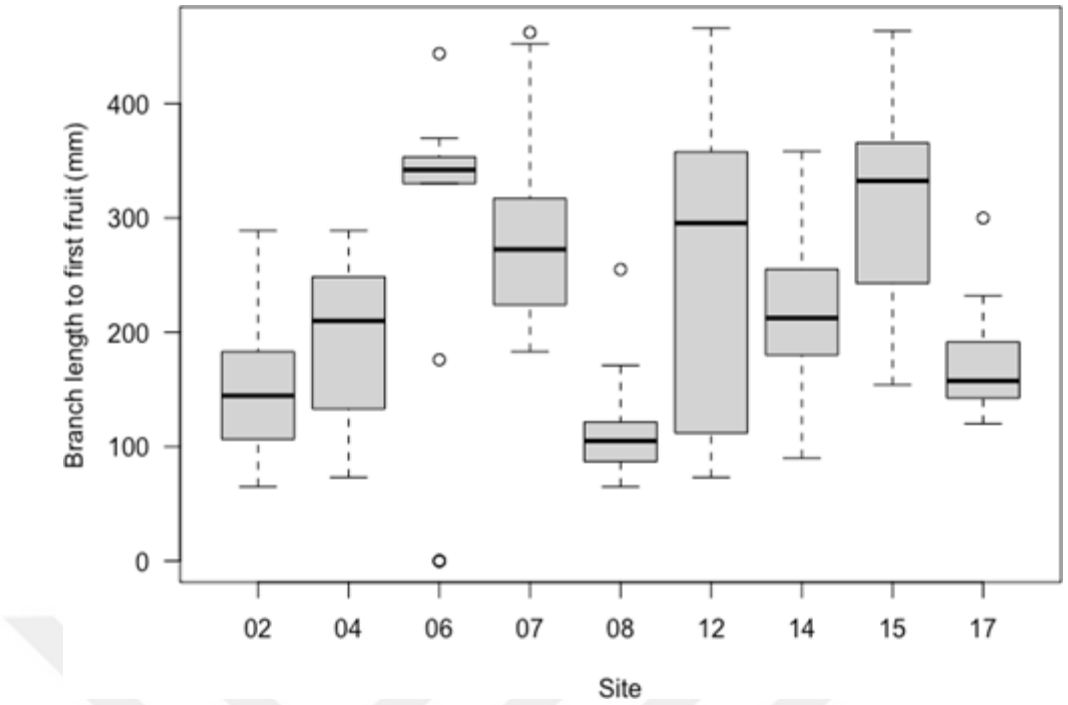

Figure 4.44. Brunch length to first fruit (NoFruitLn in mm). Site: overall for nine female sites of *Hippophae rhamnoides*

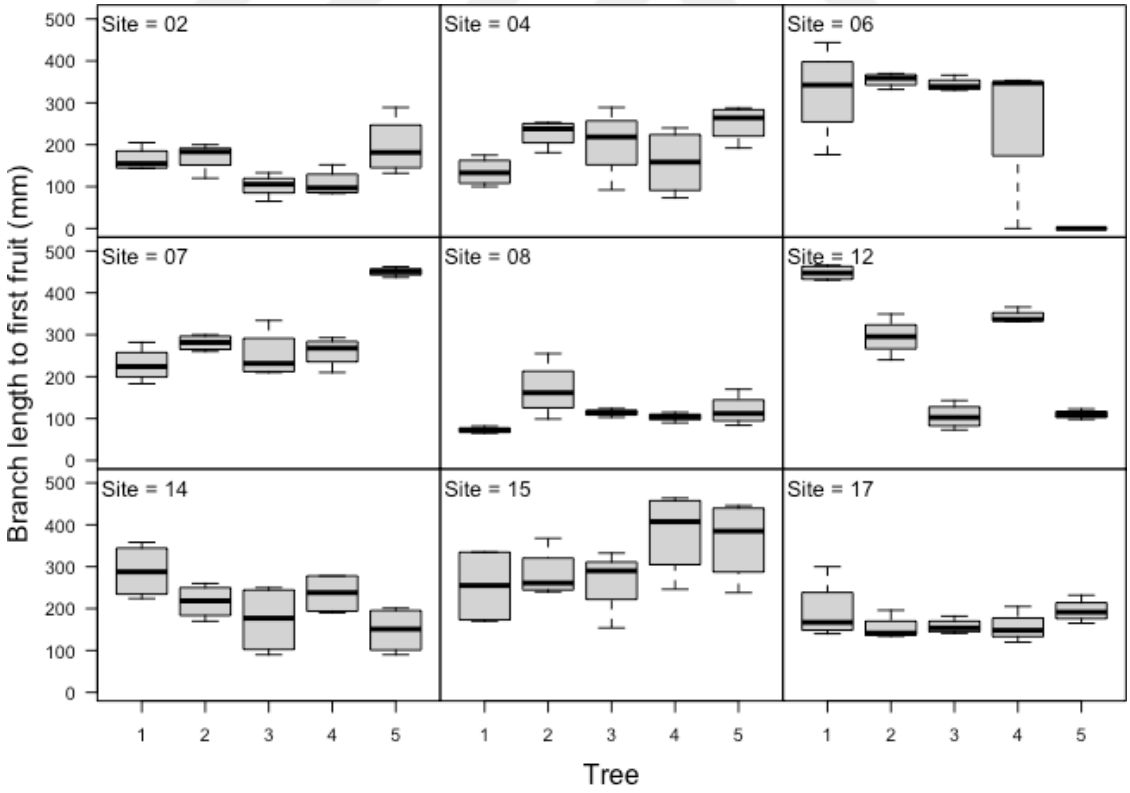

Figure 4.45. Brunch length to first fruit (NoFruitLn in mm). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.2.6 Fruit dry weight

Figure 4.46 shows that, two sites (Sites 2 and 8) had the considerable variation across the overall. Site 8 had the highest fruit dry weight with approximately 4 g. More differences were seen in trees at Sites 2, 8 and 12 compared to the other sites. However, the trees on Sites 15 and 17 were more consistent than the others.

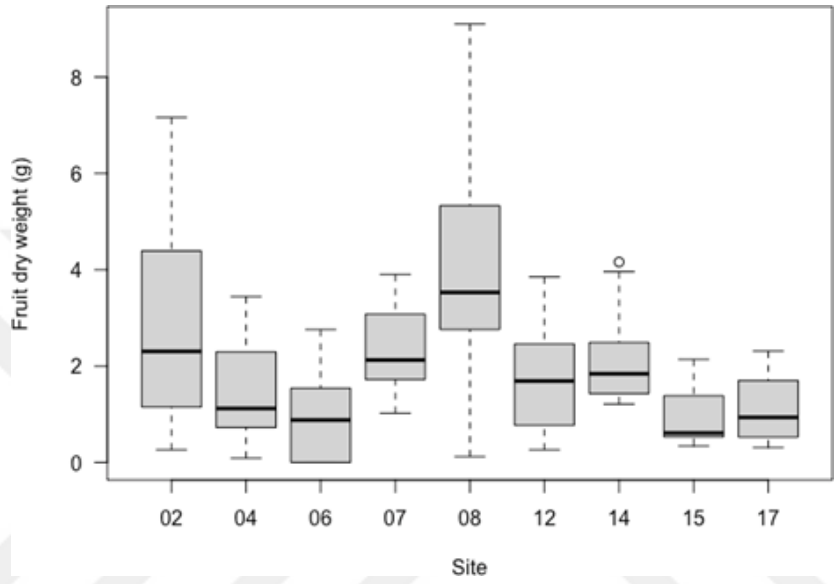

Figure 4.46. Fruit dry weight (g). Site: overall for nine female sites of *Hippophae rhamnoides*

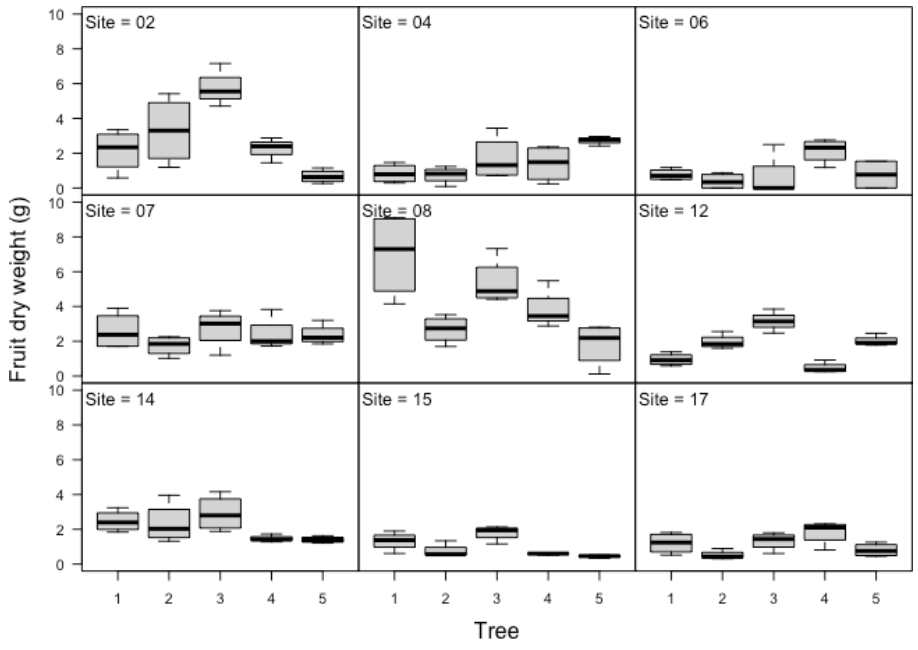

Figure 4.47. Fruit dry weight (g). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.2.7 Fruit fresh weight

Fresh fruit weight refers to the water content present in the fruit. Figure 4.48 shows the fresh fruit weight of *H. rhamnoides* between the sites and tree level. The highest water content with the largest value at about 10 g, was at Site 8. The lowest water content was at Site 15 of 3 g. The tree variation within the sites was mostly driven by Sites 2, 8 and 12. The variation between trees at Site 12 was moderately high, but the variation of the particular trees within the site was low. In contrast, Site 8 had the larger variation between trees.

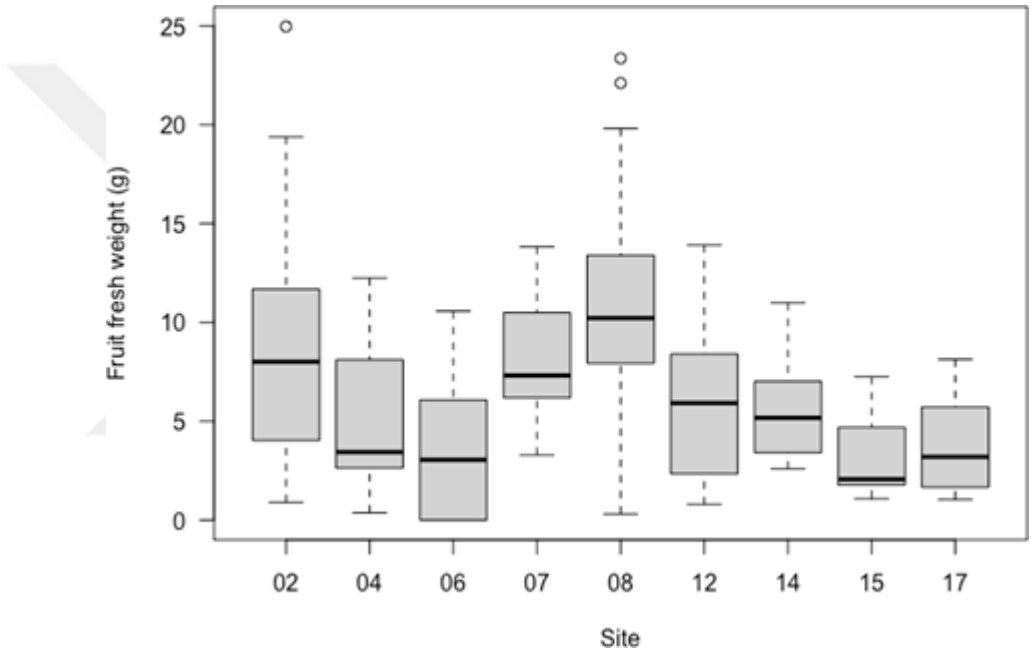

Figure 4.48. Fruit fresh weight (g). Site: overall for nine female sites of *Hippophae rhamnoides*

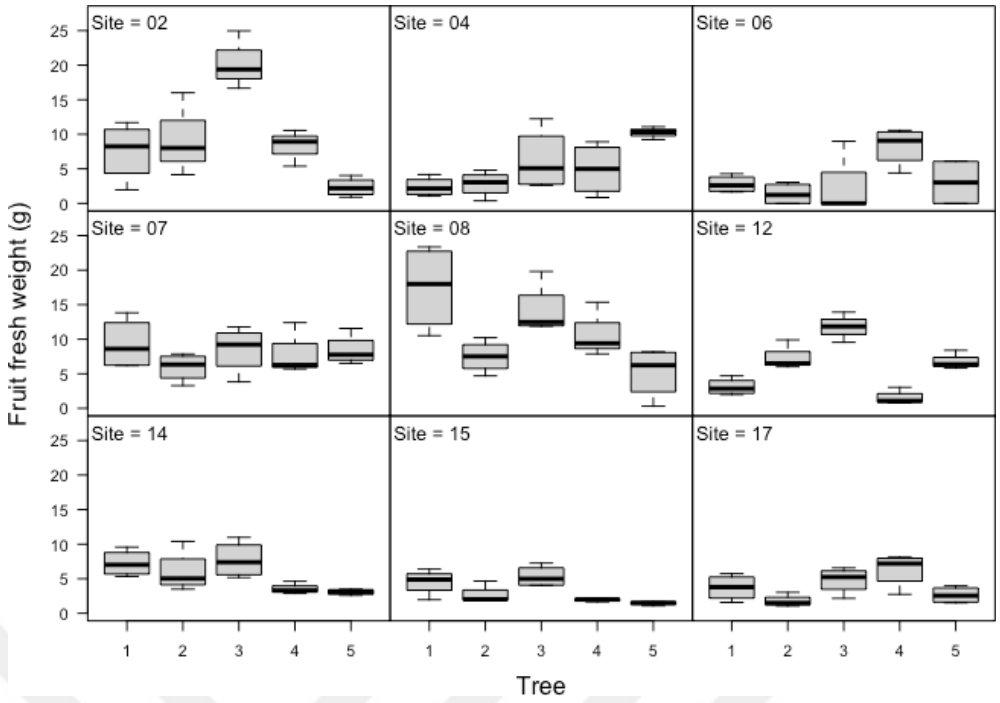

Figure 4.49. Fruit fresh weight (g). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.2.8 Number of fruit

Figure 4.50 shows that, total number of fruits in Site 8 considerably larger than the other sites and it had the highest variation between sites and between trees within sites. Each of five trees of *H. rhamnoides* within each site nearly same except from the Site 8 (Figure 4.51).

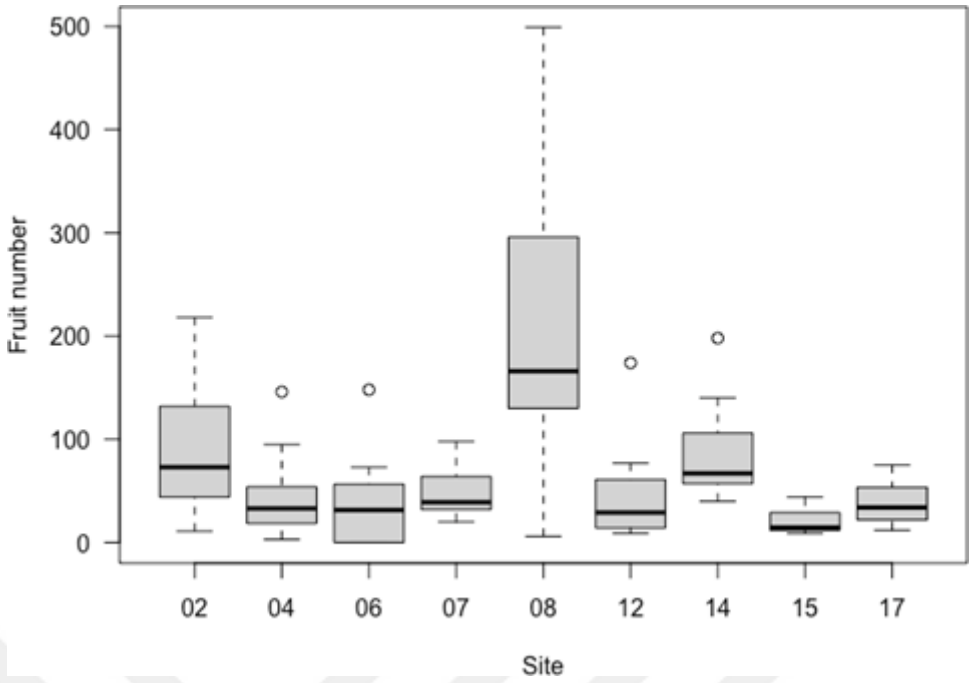

Figure 4.50. Total number of fruits. Site: overall for nine female sites of *Hippophae rhamnoides*

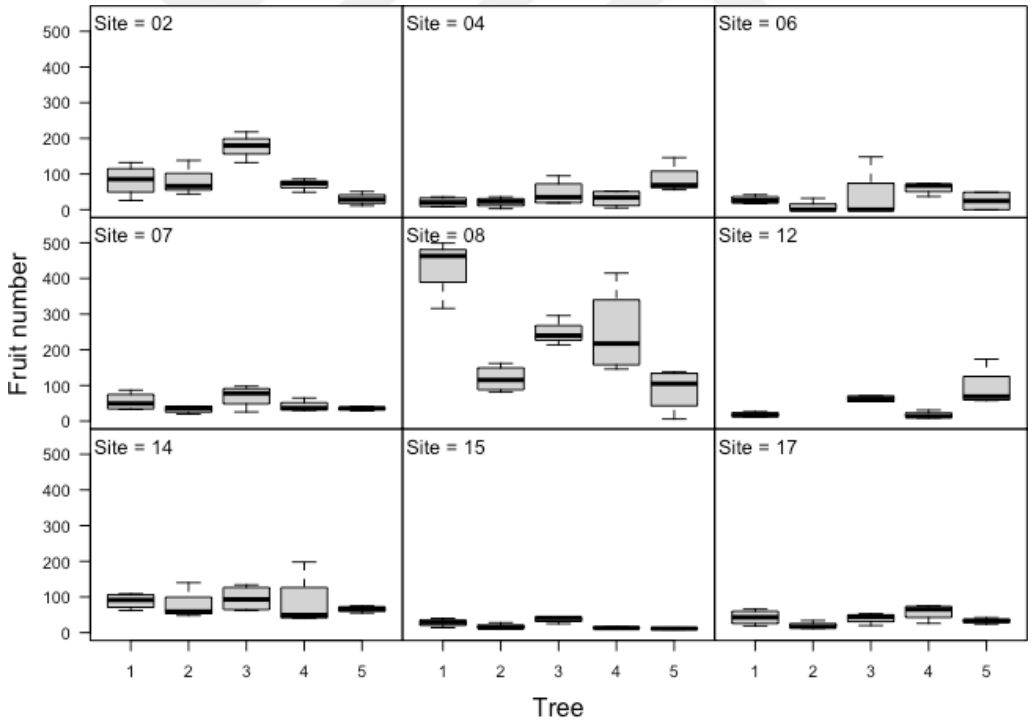

Figure 4.51. Total number of fruits. Tree: each of five trees of *Hippophae rhamnoides* within each site

4.2.9 Fruit density

Fruit density was the number of fruits per mm of the *H. rhamnoides* branches. Figure 4.52

shows the fruit density of *H. rhamnoides* between the sites and tree level. Maximum fruit density was at the Site 8 with the substantial median value while the lowest fruit density was at the Site 4 between the sites. Site 6 and 8 had the larger variation between the trees within the sites. Although Site 17 had the lowest variation, fruit density on each tree wasroughly the same, indicative of the sites being clonal (Figure 4.53).

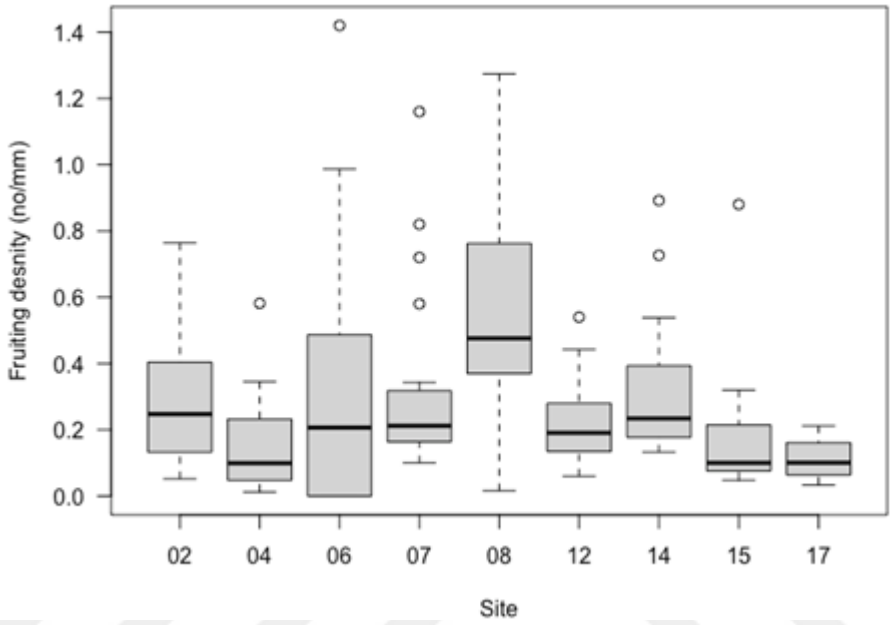

Figure 4.52. Fruit density (no/mm). Site: Overall for nine female sites of *Hippophae rhamnoides*

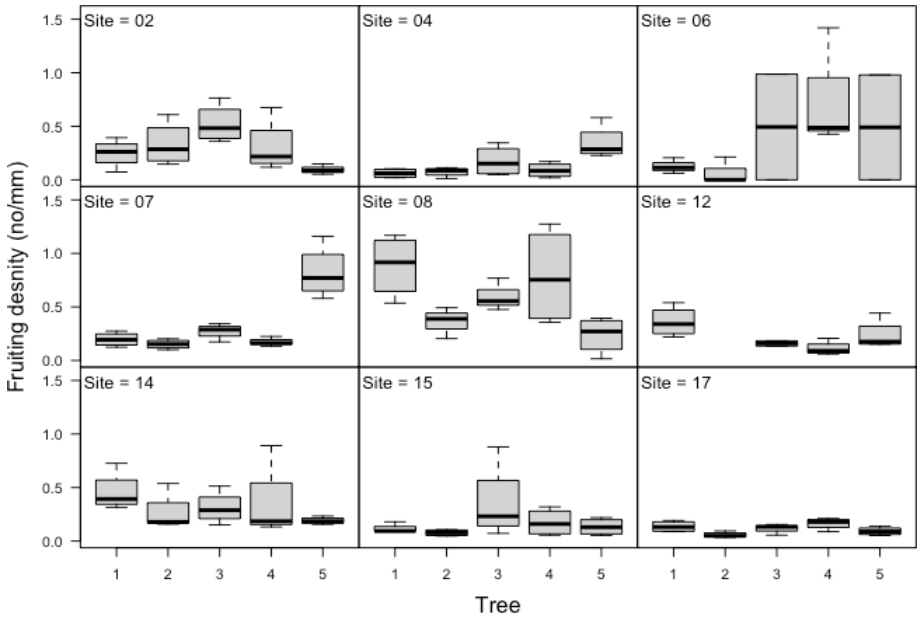

Figure 4.53. Fruit density (no/mm). Tree: Each of five trees of *Hippophae rhamnoides* within each site

Figure 4.54 indicated the effect sizes across for the eight parameters used to assess fruting tree branches in *H. rhamnoides*. Coefficient variation (CV%) in the figure refers to the variation percentage within the sites. The effect sizes which were higher than 60%, were quite larger for the first three parameters. The following three parameters were moderately variable for whicheta squared were in the range of 30-40% between the sites but highly variable within the sites. The high variability within sites is due to genetic or environmental factors. Thelowest effect size belongs to the last parameter which was thefruit density with 24% but the variation within the sites was considerably higher from theothers.

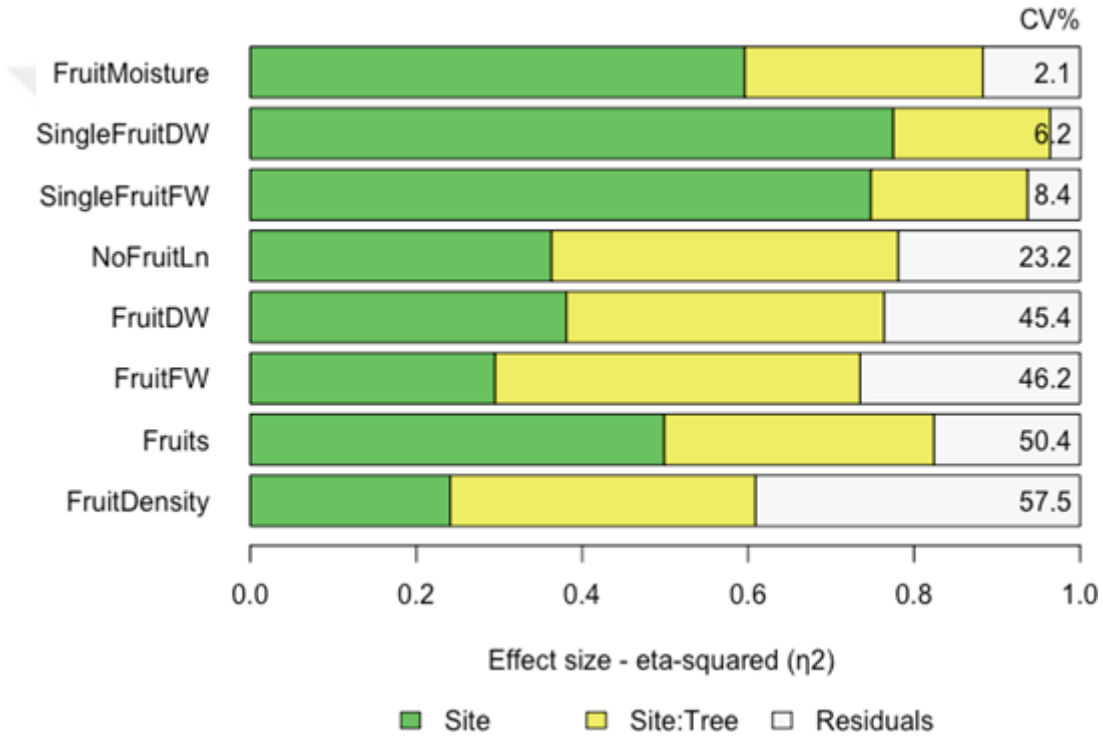

Figure 4.54. Coefficient variation (CV%) and effect size, eta-squared (η2), graph showingfruit fresh weight (FruitFW), single fruit fresh weight (SingleFruitFW), fruit dry weight (FruitDW), single fruit dry weight (SingleFruitDW), fruit moisture content and fruitless length (NoFruitLn) of *Hippohae rhamnoides* branches at tree and site level

4.3 *Hippophae rhamnoides* Fruits Analysis

Coefficient variation (CV%) for the 12 parameters used to asses *H. rhamnoides* fruits is shown in Figure 4.55 and it shows that, the estimated peduncle was highly variable parameter among the others with nearly 50% variation. The least variable parameter wasthe solidity close to 3% variation.

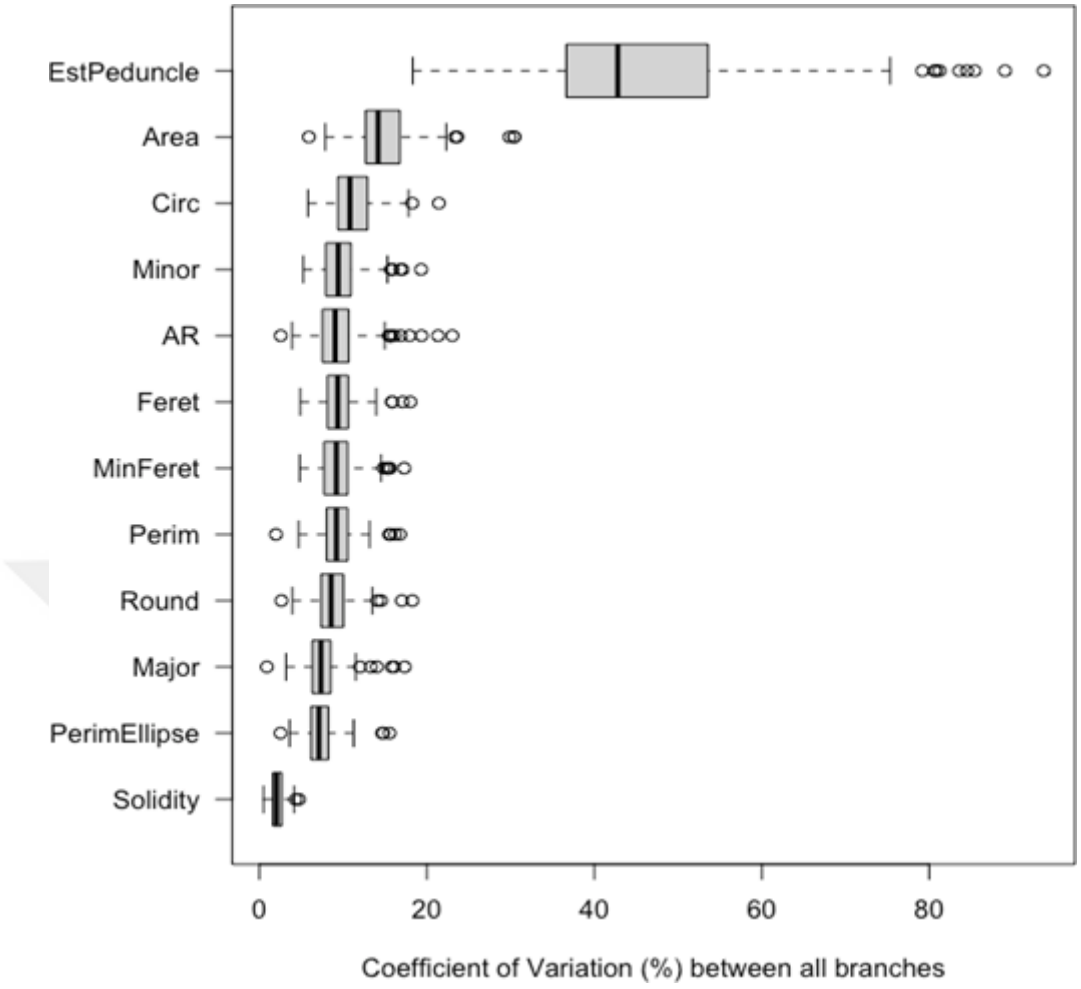

Figure 4.55. Coefficient variation (CV%) of estimated peduncle, area, circularity, minor, aspect ratio, feret, minimum ferret (Minferet), perimeter, roundness, major, perimeter ellipse (PerimEllipse) and solidity between all *Hippohae rhamnoides* branches

4.3.1 Solidity

Figure 4.56 shows that, there were slight differences of the solidity due to the tidied up theimages of *H. rhamnoides* fruits between nine female sites. The largest variation within the site was Site 2, while the lowest variation but the highest median value was the fruitsin Site 7. Sites except from Sites 2 and 12, had a constant pattern within the sites betweeneach five trees. There were four trees on site 12, as one sample was removed due to estimated fruiting results.

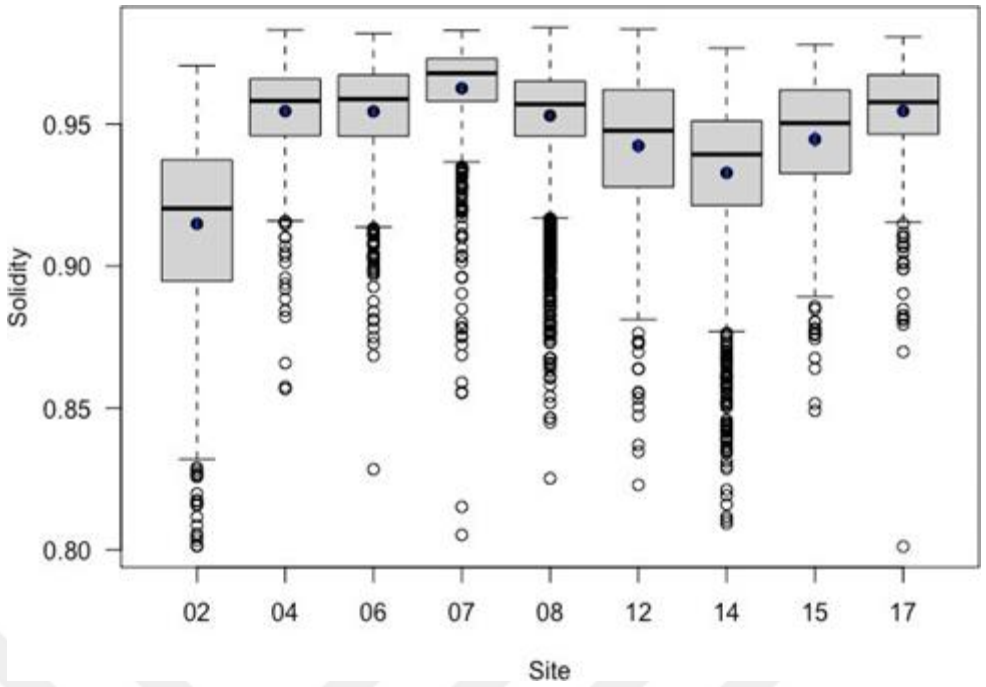

Figure 4.56. Solidity. Site: overall for nine female sites of *Hippophae rhamnoides*

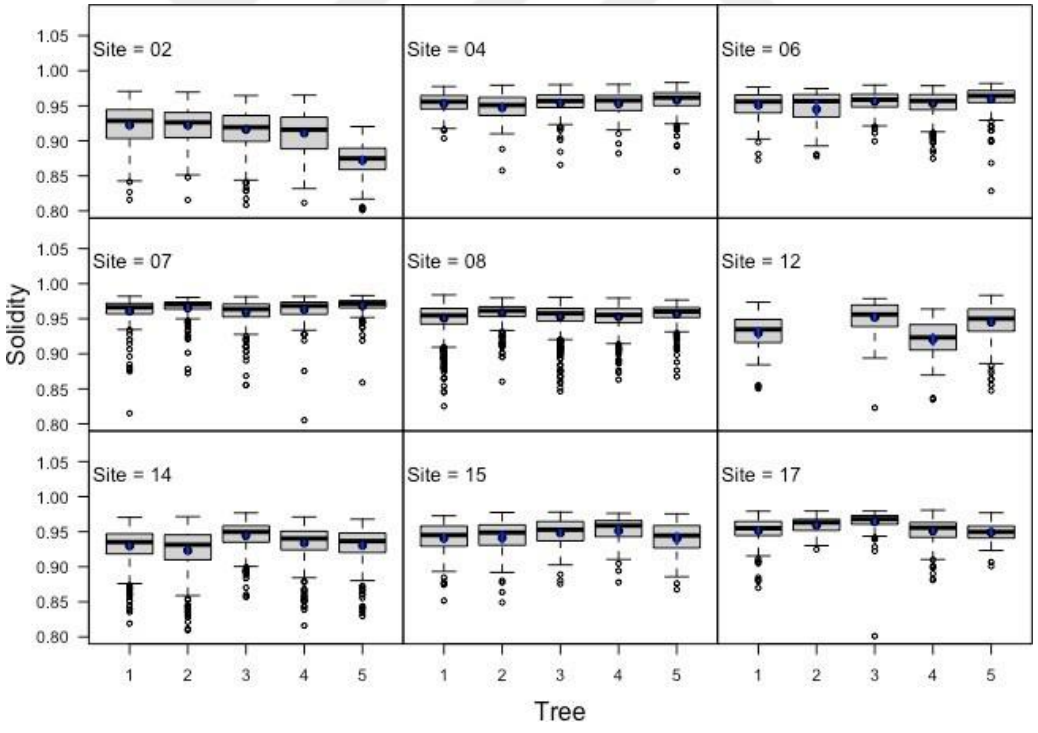

Figure 4.57. Solidity. Tree:each of five trees of *Hippophae rhamnoides* within each site

4.3.2 Ellipse perimeter

Ellipse perimeter is a measure of the length of the fruits that fit into the ellipse and the

moderate variation between some sites (Sites 8, 12, 14, 15 and 17) is shown in Figure 4.58. The highest ellipse perimeter median value was the fruits on Site 15 which was close to 30 mm and the lowest one was the leaves on Site 8 with over 15 mm. Three of the five trees in Site 14 had the higher variation within the site. Site 15 had the larger fruit perimeter with lowest variation between and within the sites.

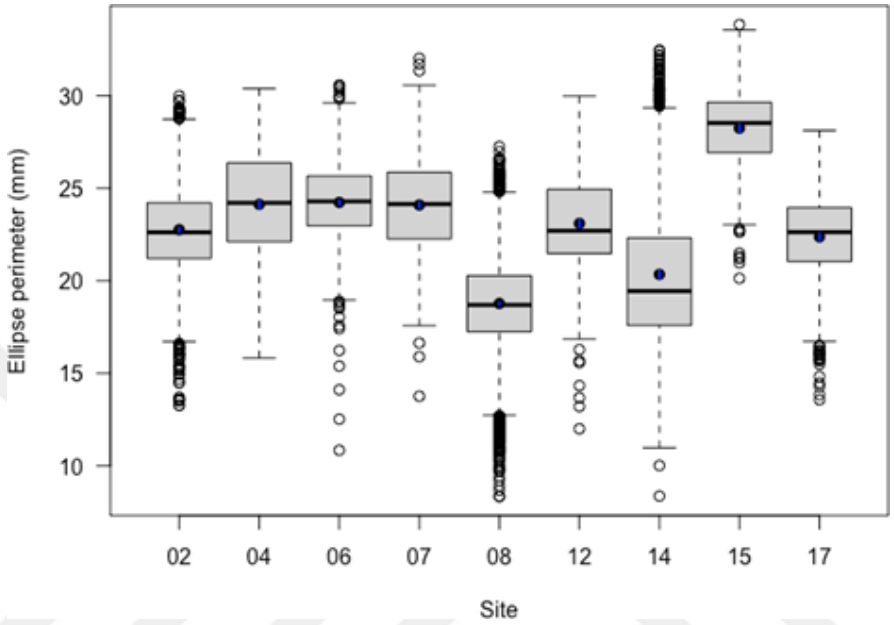

Figure 4.58. Ellipse perimeter (mm). Site: overall for nine female sites of *Hippophae rhamnoides*

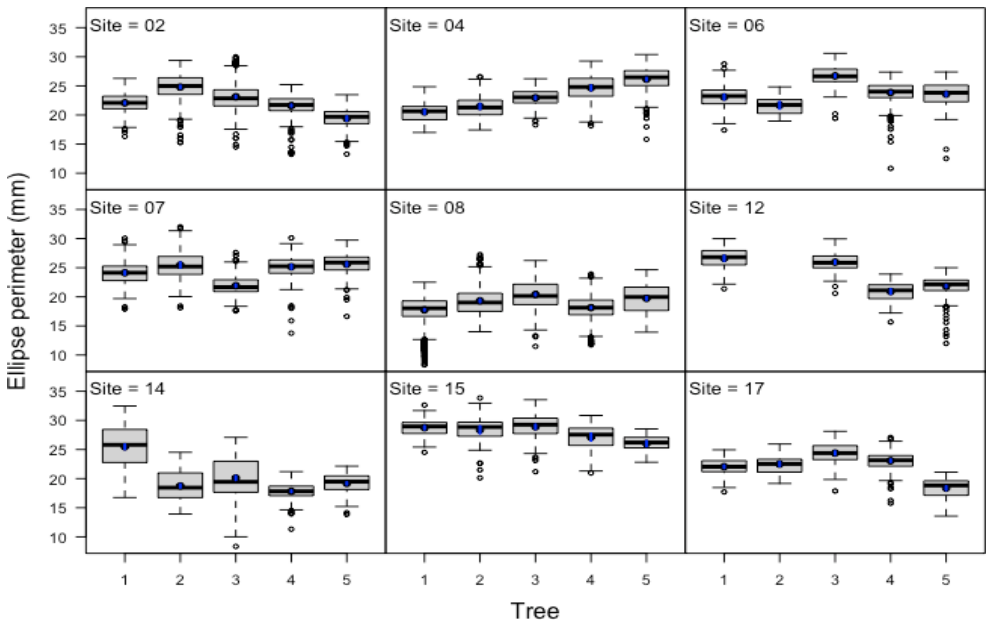

Figure 4.59. Ellipse perimeter (mm). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.3.3 Major ellipse axis

The major ellipse axis is the measured of the longest diameter of the fruit. Figure 4.60 shows the highest major ellipse median value was the fruits on Site 15 which was close to 12 mm and the lowest one was the leaves on Site 8 with over 6 mm. There were differences of the major ellipse of Site 14 among the trees within the site. Three of the five trees in Site 14 had the higher variation within the site (Figure 4.61).

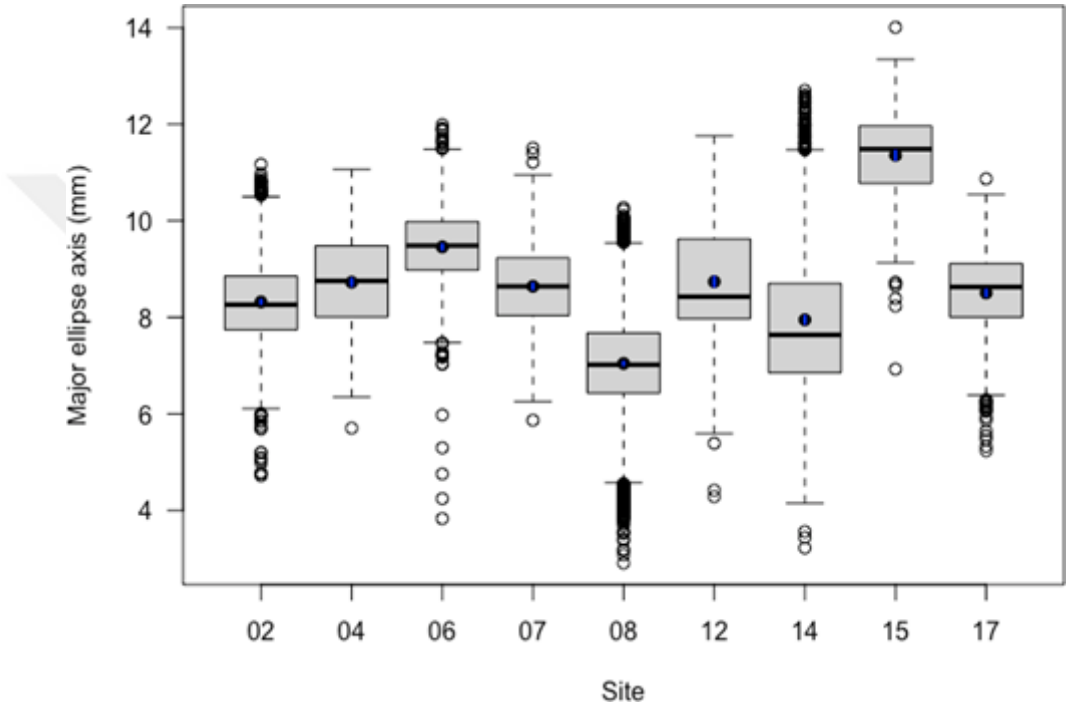

Figure 4.60. Major ellipse axis (mm). Site: overall for nine female sites of *Hippophae rhamnoides*

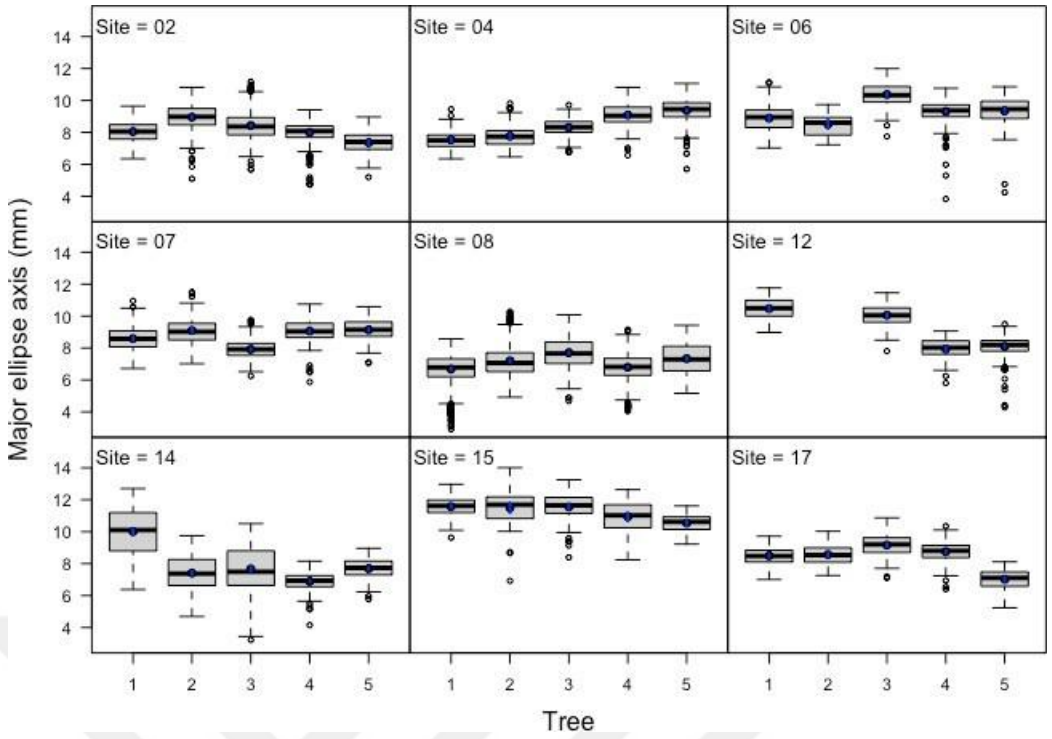

Figure 4.61. Major ellipse axis (mm). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.3.4 Roundness

Figure 4.62 shows that there was moderate variation on the roundness of *H. rhamnoides* fruits between the sites. However, there were slight variation between trees within each site. The more rounded fruits were at Site 7 close to 0.8 and the least variable site was Site 15 with more elongated fruit close to 0.6 (Figure 4.63).

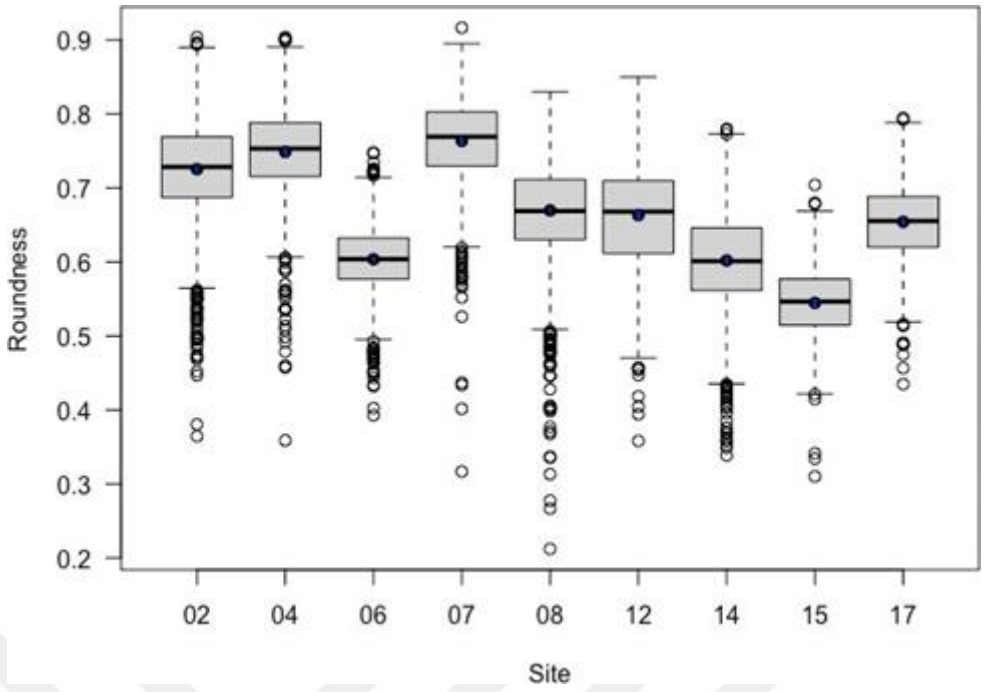

Figure 4.62. Roundness. Site: overall for nine female sites of *Hippophae rhamnoides*

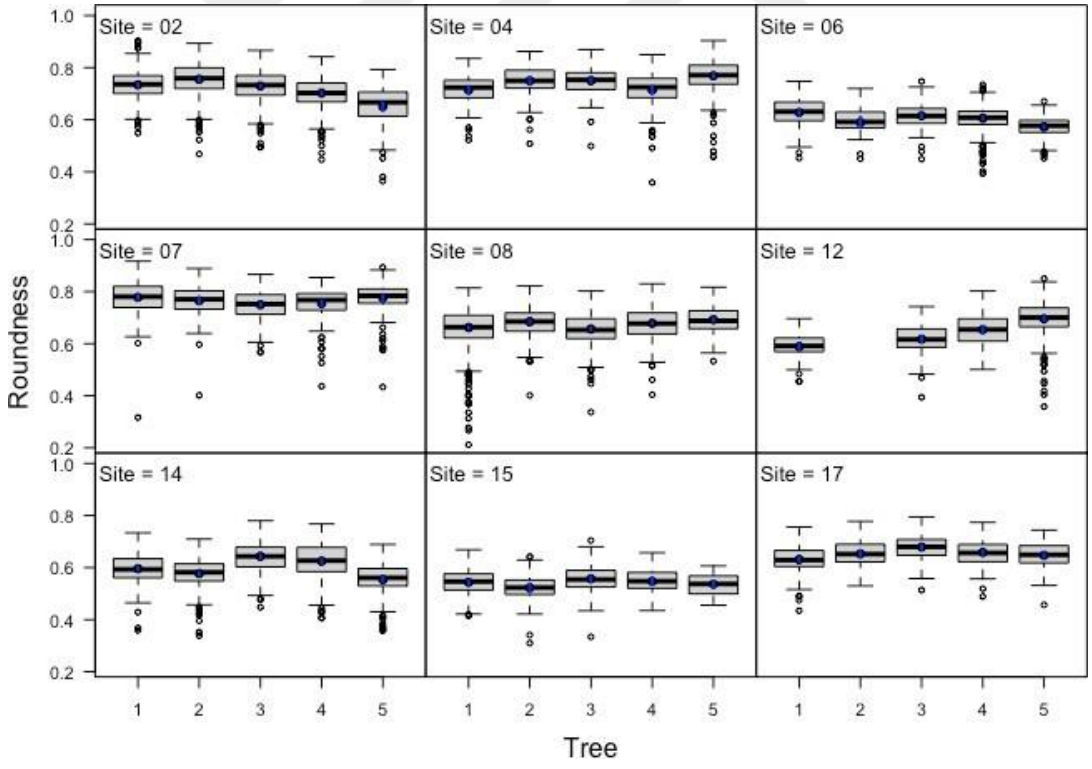

Figure 4.63. Roundness. Tree:each of five trees of *Hippophae rhamnoides* within each site

4.3.5 Perimeter

The variation of the circumference was quite similar to that of the elliptical circumference, since here they were calculating the same thing using different lengths, feret lengths. Figure 4.64 and 4.65 shows the variation of the perimeter of the *H. rhamnoides* fruitsbetween for each nine sites and between the trees within the sites, respectively. According to this, some sites had very close perimeter median value (Sites 2, 4, 6 and 7) between sites but some had quite variation (Sites 8, 12, 14, 15 and 17). The highest perimeter was the fruitin Site 15 and the lowest perimeter median value was the fruit at Site 8. The higher variation observed the between the first three trees within the Site 14. This was an indication that there were more large and small fruits on the Site 14 within the trees.

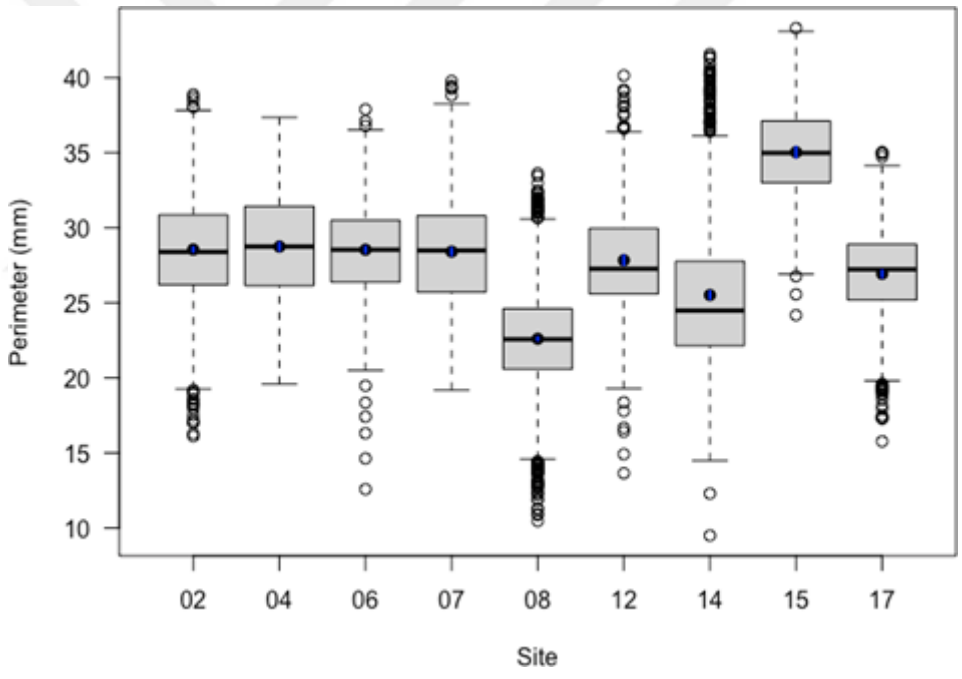

Figure 4.64. Perimeter (mm). Site: overall for nine female sites of *Hippophae rhamnoides*

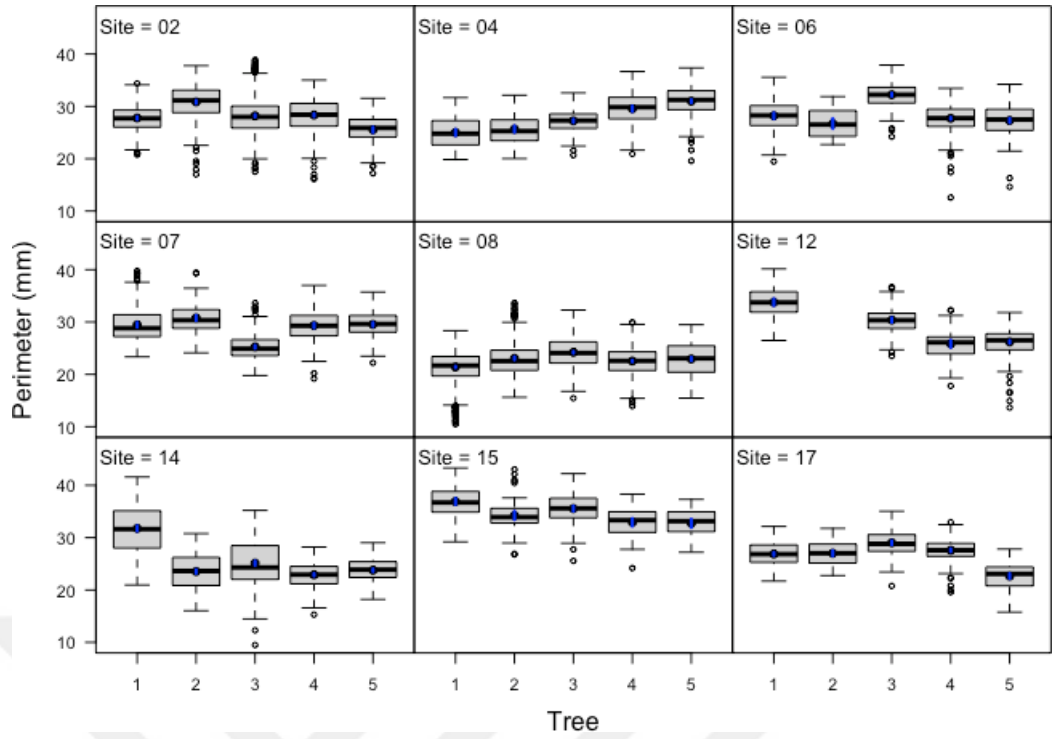

Figure 4.65. Perimeter (mm). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.3.6 Feret width

Figure 4.66 shows the variation between the feret width of the *H. rhamnoides* fruits between the site and tree levels. There was moderate variation of feret width of *H. rhamnoides* fruits between the sites. Sites 2, 4 and 7 had wider fruits than the other sites. Site 14 had the highest variation between the sites. The variation of fruit feret width within the first three trees at Site 14, was greater than the others. Other trees on the sites followed a constant pattern.

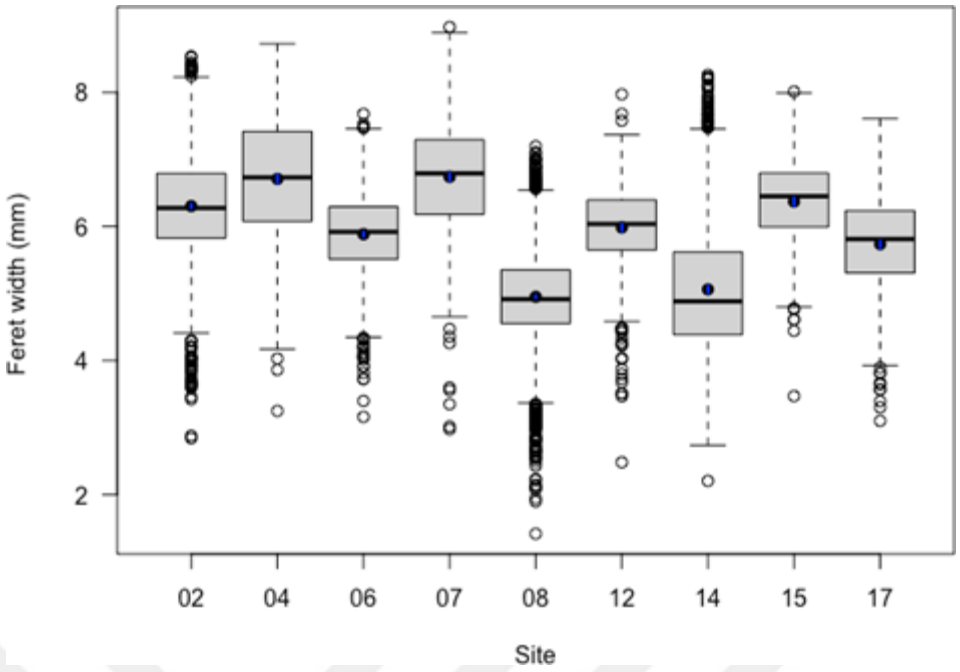

Figure 4.66 Feret width (mm). Site: overall for nine female sites of *Hippophae rhamnoides*

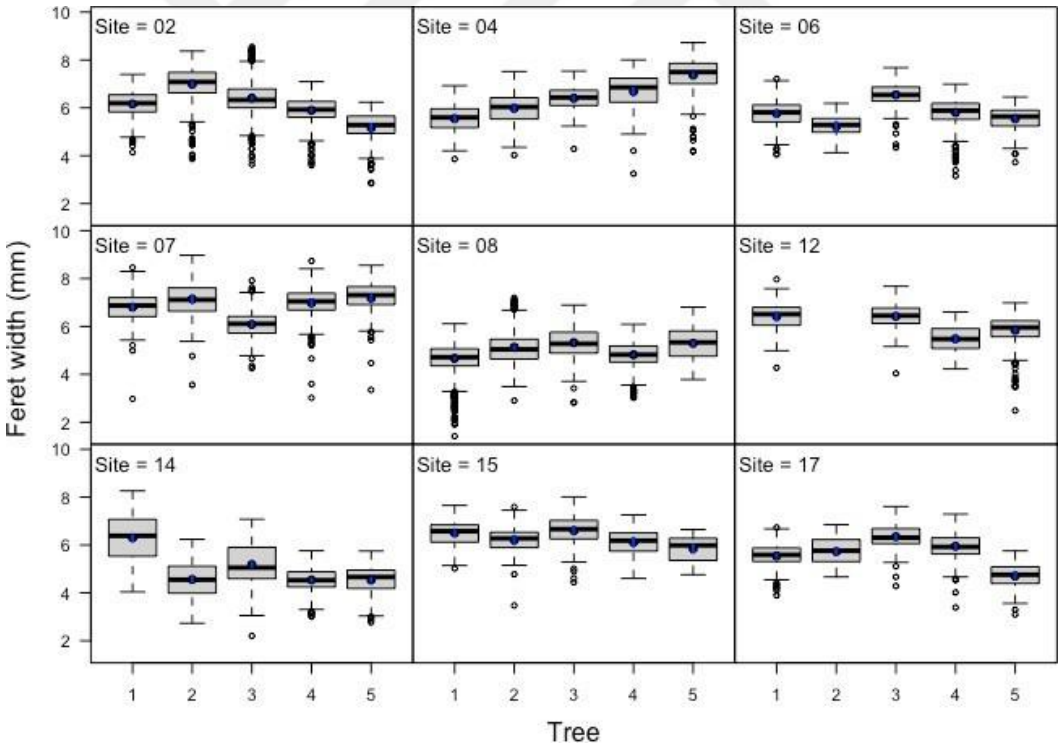

Figure 4.67. Feret width (mm). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.3.7 Feret length

Figure 4.68 shows the variation between the feret length of the *H. rhamnoides* fruits between the site and tree levels. There was moderate variation of feret length of *H. rhamnoides* fruits between the sites. Sites 2, 4 and 7 had the closest median feret length value than the other sites. Site 14 had the highest variation between the sites. The highest feret length was the fruits at Site 15. The variation of fruit feret length within the first three trees at Site 14, was greater than the others. Other trees on the sites nearly followed a constant pattern. (Figure 4. 69).

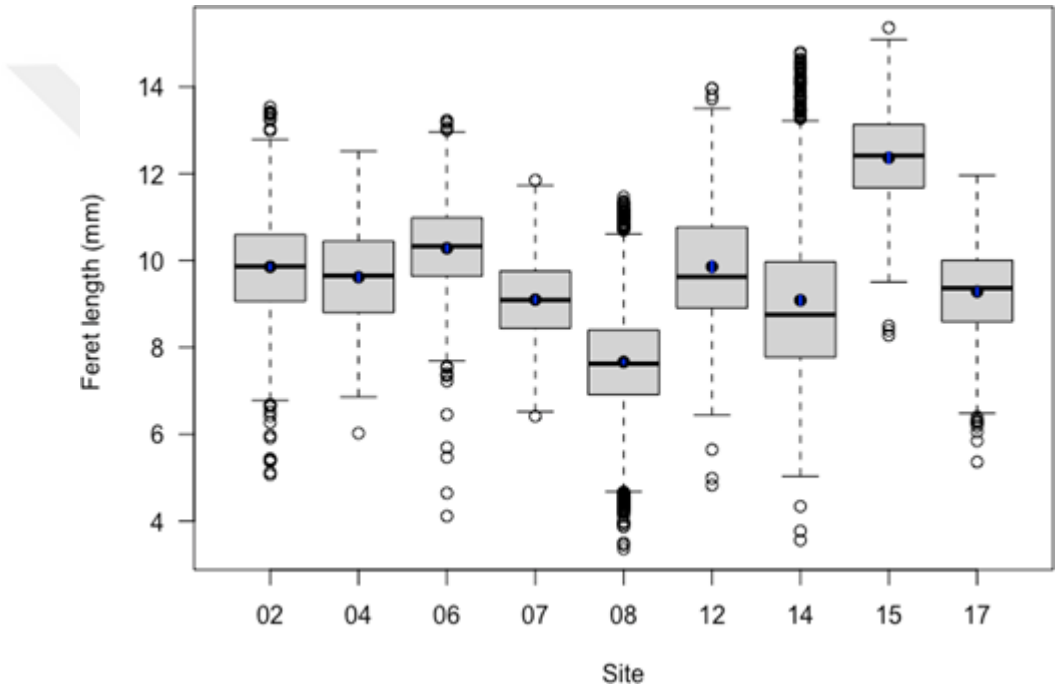

Figure 4.68. Feret length (mm). Site: overall for nine female sites of *Hippophae rhamnoides*

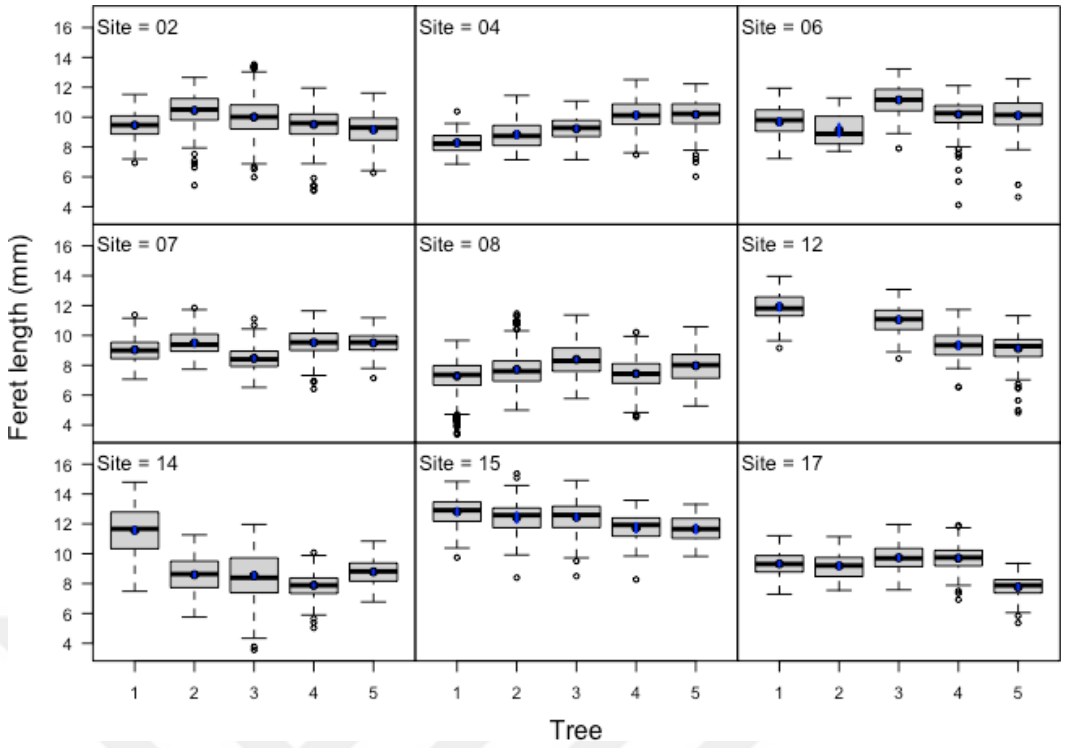

Figure 4.69. Feret length (mm). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.3.8 Aspect ratio

The aspect ratio (AR) is the ratio of the length to the width of the fruit of *H. rhamnoides*. Figure 4.70 shows moderate differences on AR between sites but had fairly stable pattern in tree levels. While some sites had very close AR (Sites 2, 4 and 7; Sites 8, 12, and 17), the difference between some was high. (Sites 7 and 15). There was slight difference between the trees within each site (Figure. 4.71)

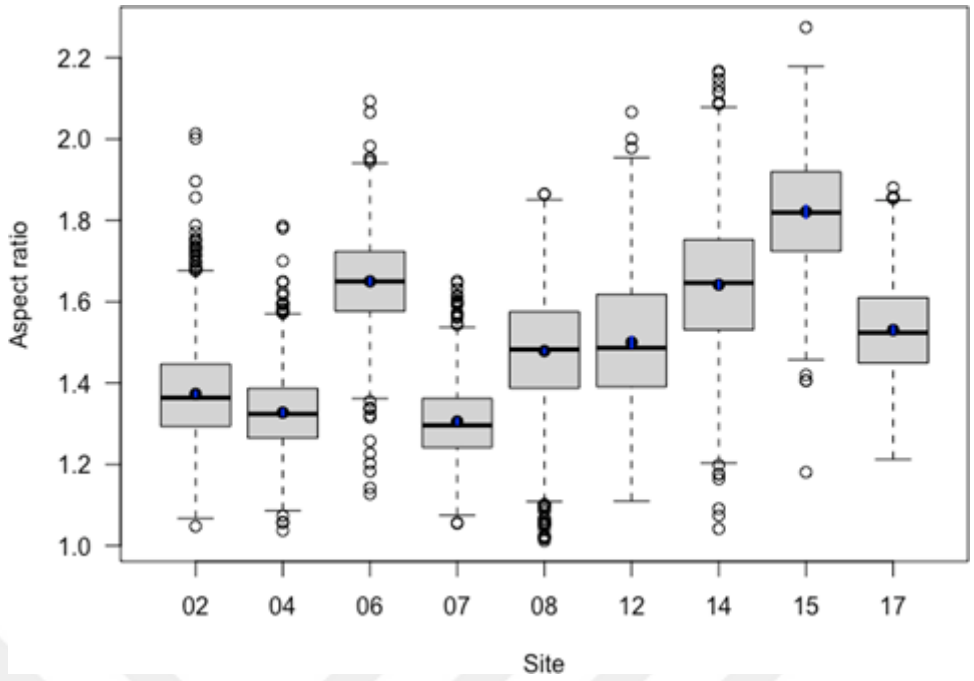

Figure 4.70. Aspect ratio. Site: overall for nine female sites of *Hippophae rhamnoides*

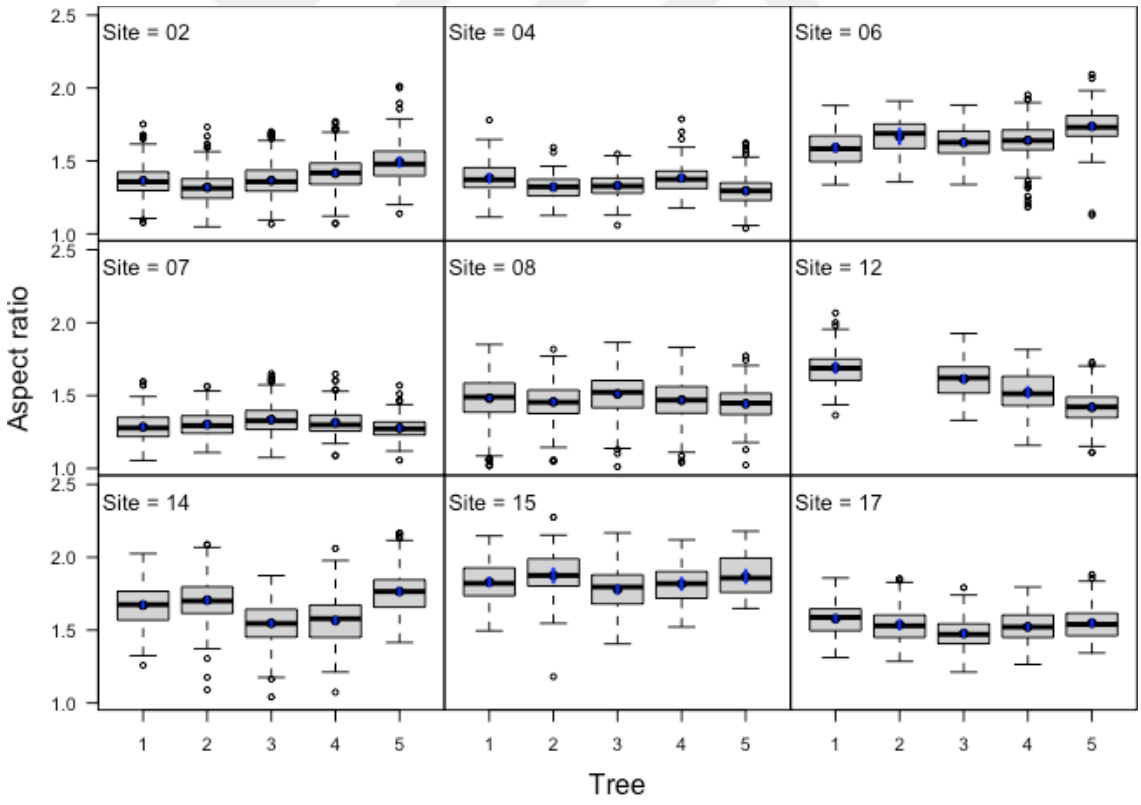

Figure 4.71. Aspect ratio. Tree: each of five trees of *Hippophae rhamnoides* within each site

4.3.9 Minor ellipse axis

The minor ellipse axis (mm) is the measured of the shortest diameter of the fruit that fitted in ellipse. Figure 76 shows the highest minor ellipse median value was the fruits onSite 7 which was over 6 mm and the lowest one was the fruits on Site 14 with over 4 mm.The highest differences between female trees were at Site 4, while the within-site variation atSites 4, 7, and 14 with was greater than the others.

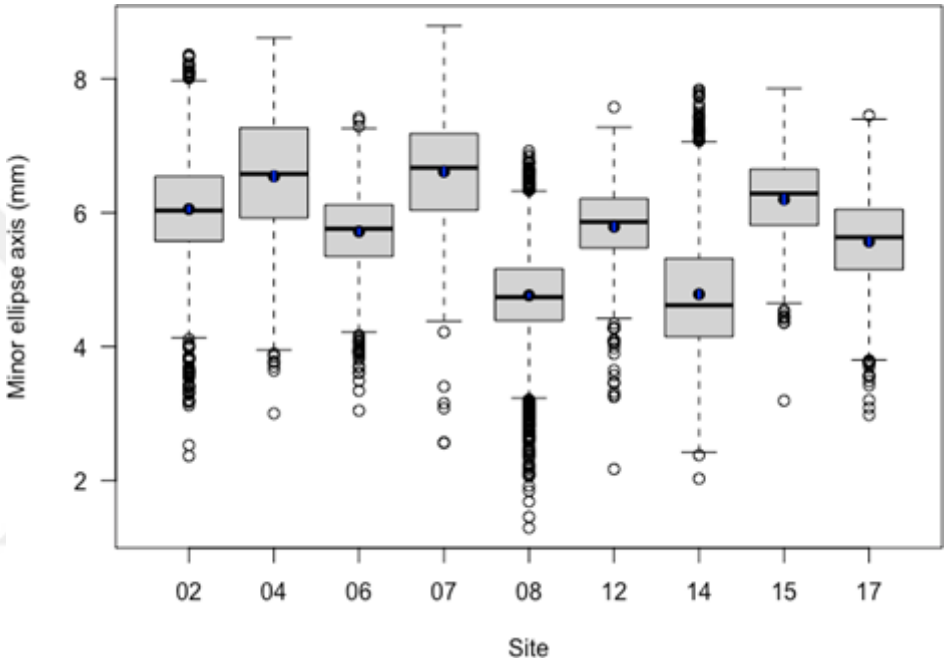

Figure 4.72. Minor ellipse axis (mm). Site: overall for nine female sites of *Hippophae rhamnoides*

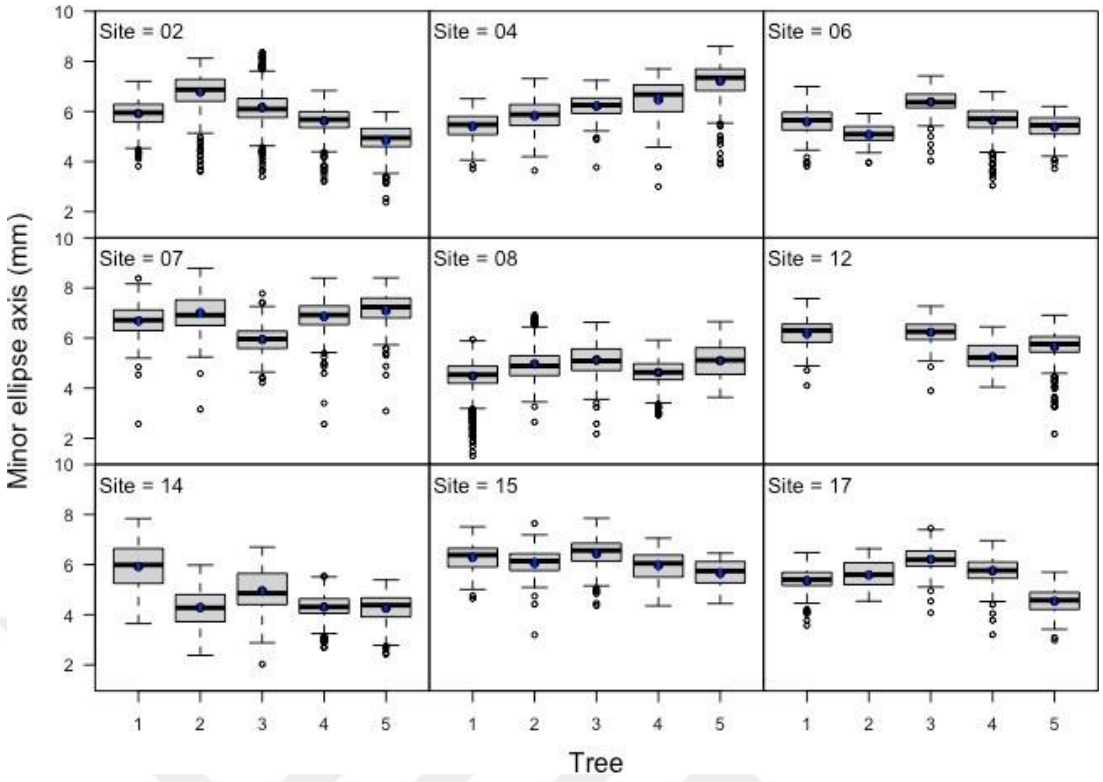

Figure 4.73. Minor ellipse axis (mm). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.3.10 Circularity

Figure 4.74 indicates the circularity was moderately different between the sites of *H. rhamnoides.* The highest circularity median value was close to 0.7 at Site 7. The lowest median value which indicates elongated fruits, was above 0.5 at Site 15. Overall, the circularity within the nine sites showed a regular pattern at the tree level (Figure 4.75).

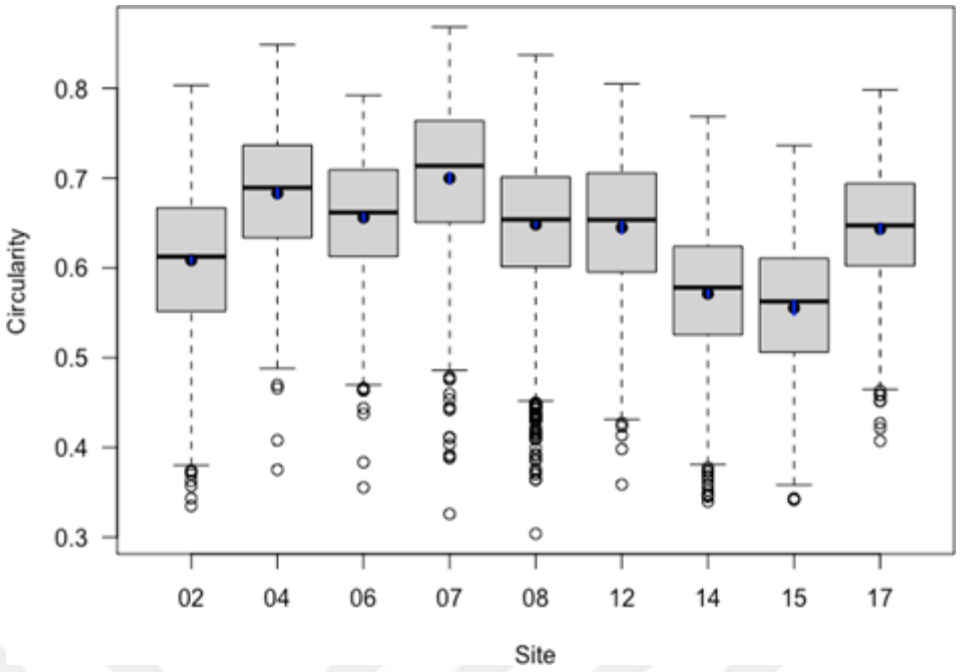

Figure 4.74. Minor ellipse axis (mm). Site: overall for nine female sites of *Hippophae rhamnoides*

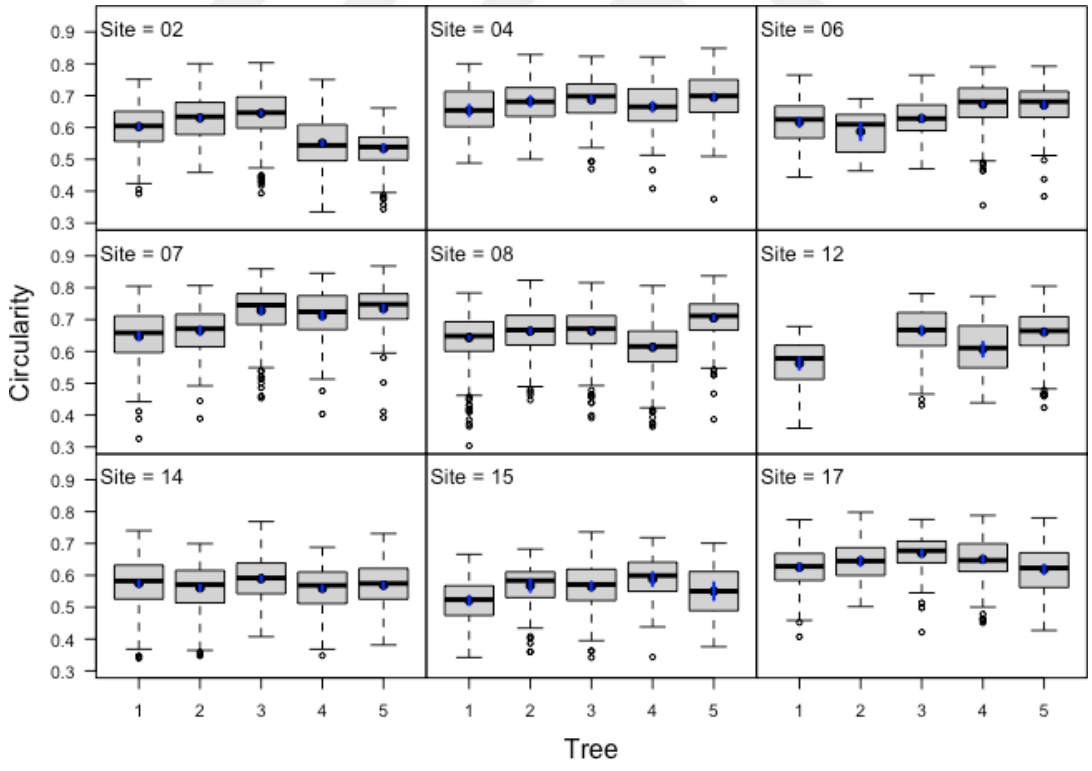

Figure 4.75. Minor ellipse axis (mm). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.3.11 Area

Figure 4.76 shows the variation of the area (mm^2) of the *H. rhamnoides* fruits. There were moderately differences between some sites (Sites 8, 12, 14, 15 and 17) but slight differences between Sites 2, 4, 6, and 7. Site 15 had the highest median value between the sites close with 60 mm^2. Site 4 had the higher variation between the trees within the site (Figure 4.77).

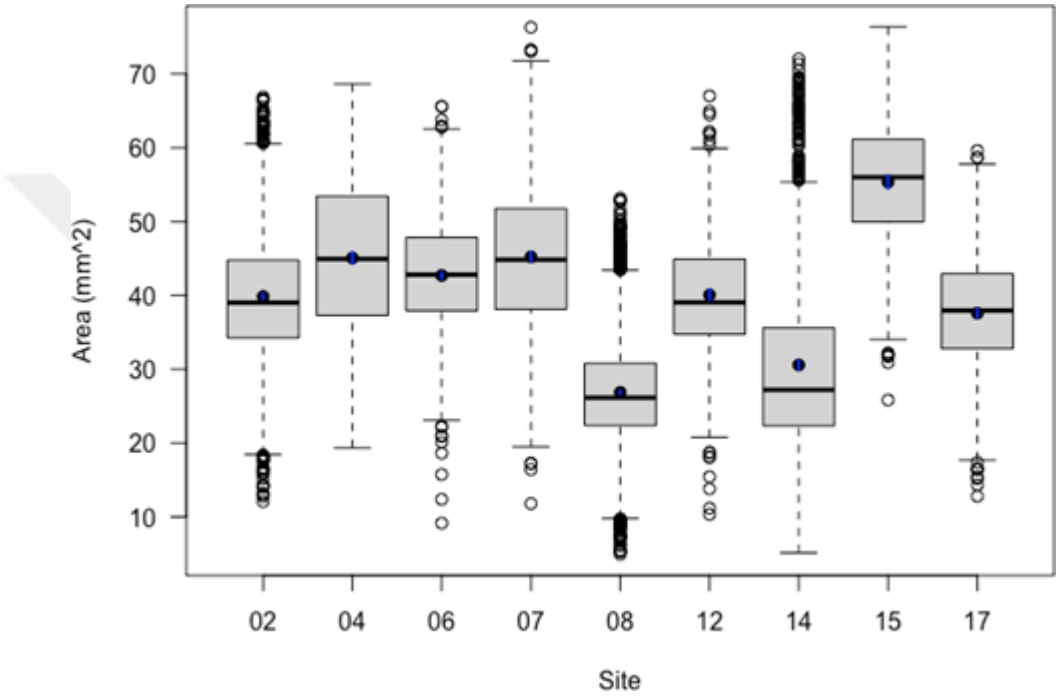

Figure 4.76. Area(mm^2). Site: overall for nine female sites of *Hippophae rhamnoides*. Tree:each of five trees of *Hippophae rhamnoides* within each site

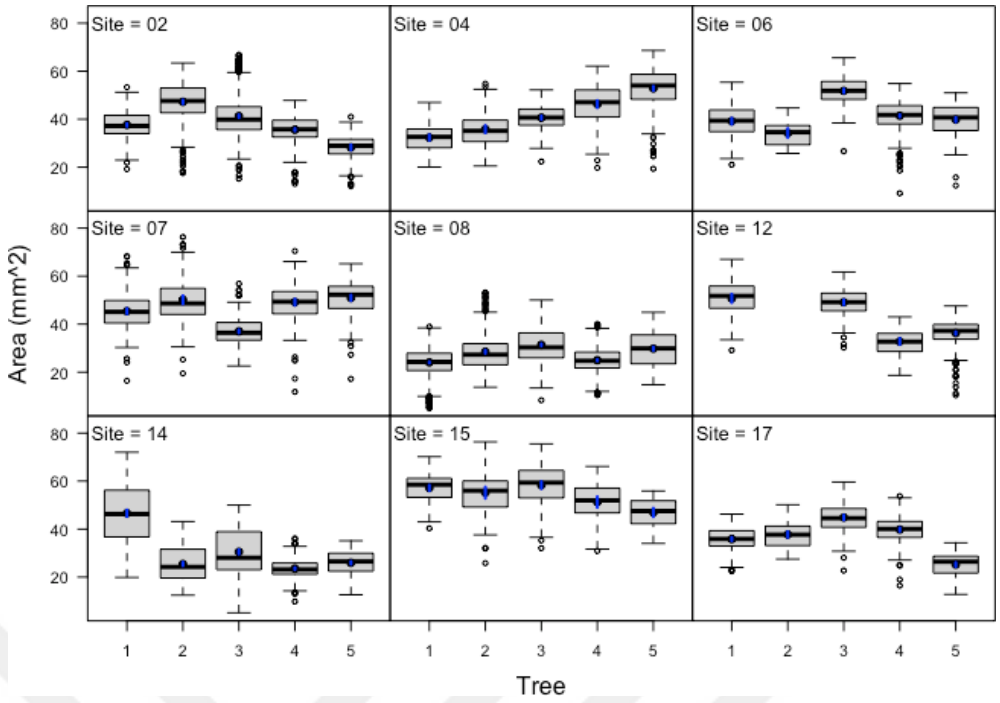

Figure 4.77. Area (mm^2). Tree:each of five trees of *Hippophae rhamnoides* within each site

4.3.12 Estimated peduncle

Figure 4.78 shows the variation of the estimated peduncle (mm) of the *H. rhamnoides* fruits. The difference of elliptical measurements from feret measurements was used in the estimated peduncle calculation. Some sites (Sites 12, 14, 15 and 17) had slight differences between each other. Site 2 had higher estimated peduncle length but the fruits at Site 7 had lower. The more variation within sites were the fruits at Site 12. Even Site 12 had the most variation between trees within the site and between individual trees, Site 2 had more variation due to the individual tree itself (Figure 4.79)

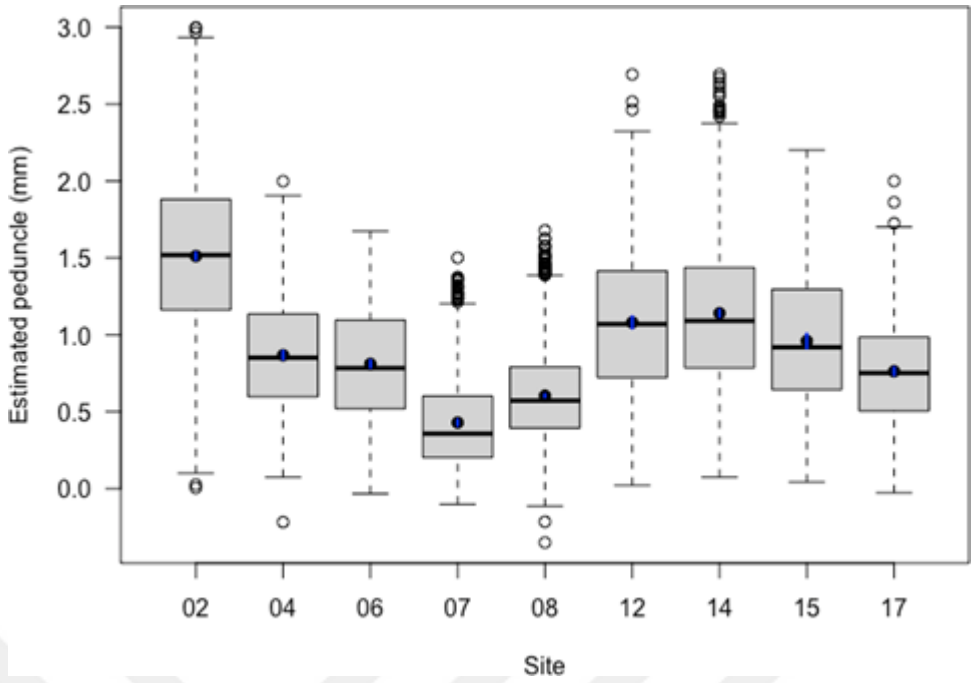

Figure 4.78. Estimated peduncle (mm). Site: overall for nine female sites of *Hippophae rhamnoides*. Tree: each of five trees of *Hippophae rhamnoides* within each site

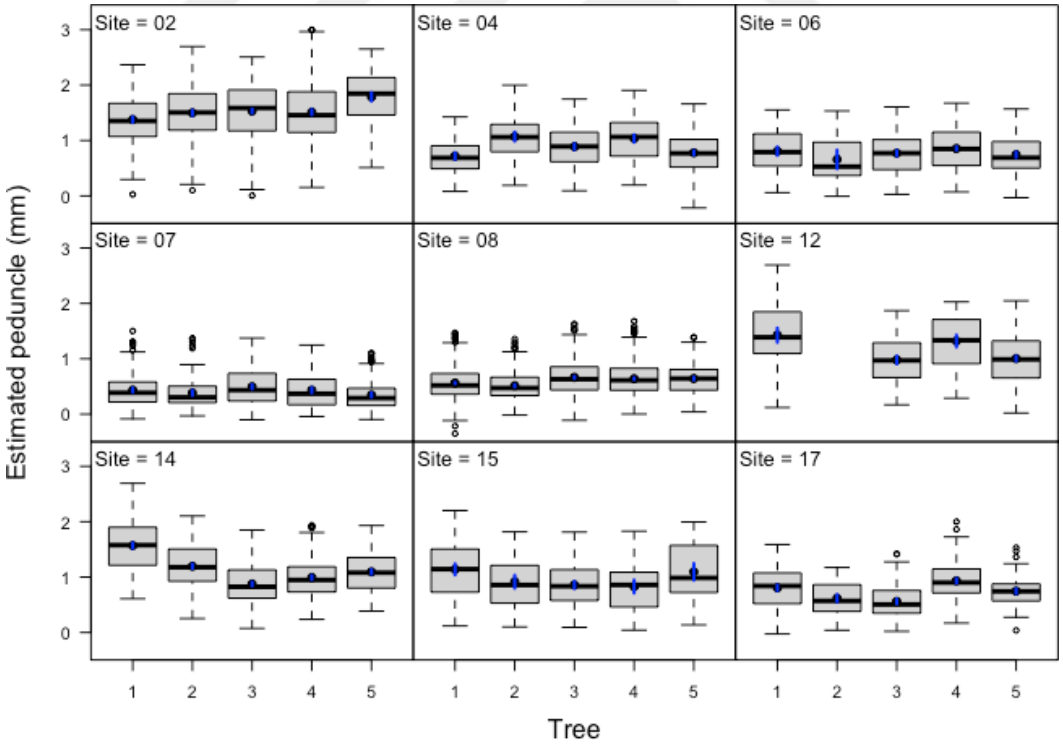

Figure 4.79. Estimated peduncle (mm). Tree: each of five trees of Hippophae rhamnoideswithin each site

Figure 4.80 indicated the effect sizes across for the 12 parameters used to assess fruit analysis in *H. rhamnoides*. Coefficient variation (CV%) in the figure refers to the

variation percentage within the sites. There were a lot of variation in terms of solidity, AR, roundness and estimated peduncle for the site level but slight variation at tree and branch level. There was a lot variation in terms of perimeter ellipse, major, minor, feret, minferet and area atsite level but also moderate variation in terms of tree and branch levels.

The certain data analysis for each parameter such as mean value, CV% and effect size, eta-squared (η2), are shown in Table A8. (See *H. rhamnoides* fruit analysis).

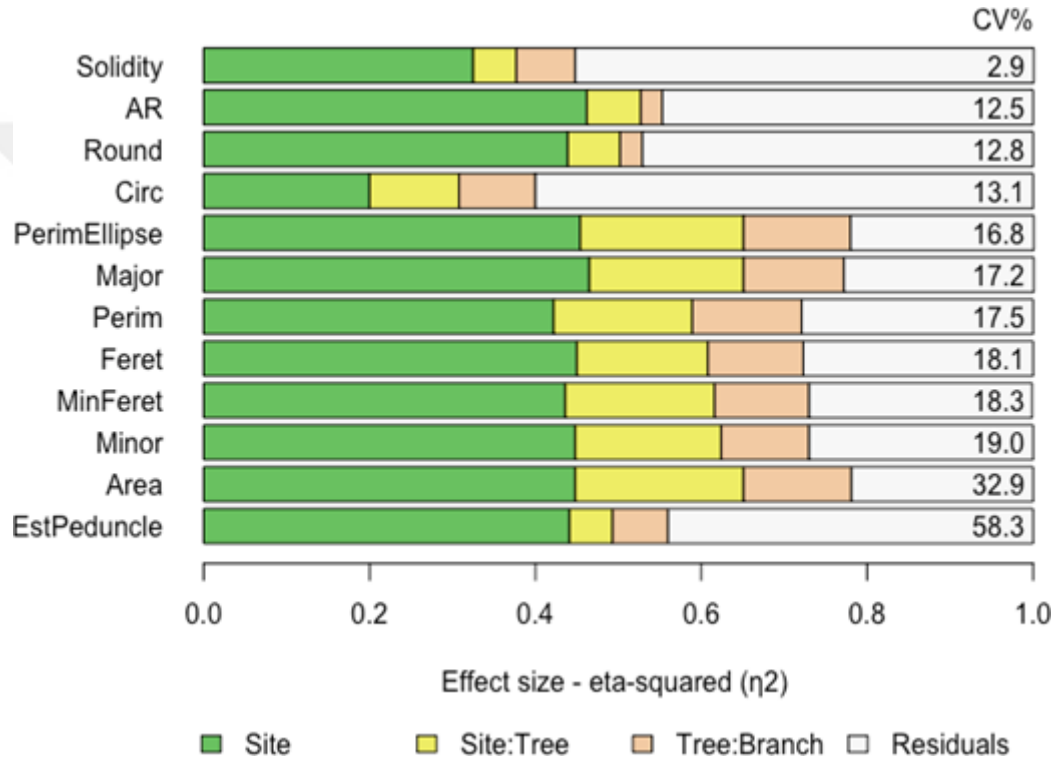

Figure 4.80. Coefficient variation (CV%) and effect size- eta-squared (η2) graph showing solidity, aspect ratio (AR), roundness (Round), circularity (Circ), perimeter ellipse (PerimEllipse), major, perimeter (Perim), feret, minimum ferret (MinFeret), minor, area and estimated peduncle (EstPeduncle)of the fruits of Hippophae rhamnoides in site, tree and branch levels

4.4 *Hippophae rhamnoides* Seeds Analysis

Coefficient variation (CV%) for the 11 parameters used to asses *H. rhamnoides* seeds is shown in Figure 4.81.

Figure 4.81 shows that, the area was highly variable parameter among the others with nearly

10% variation. The least variable parameter was the solidity close to 1% variation. For the other parameters the variation between all trees were close to each other.

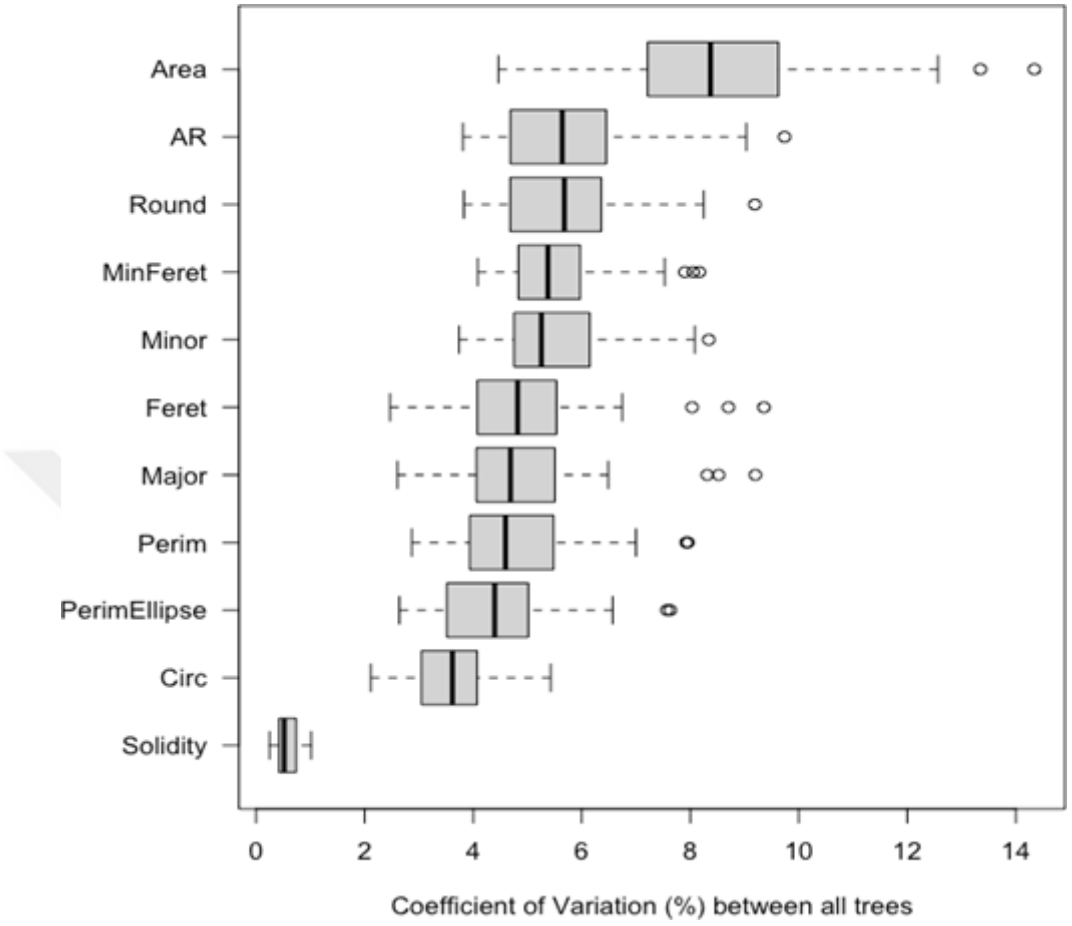

Figure 4.81. Coefficient variation (CV%) of area, aspect ratio (AR), roundness (Round), minimum ferret(Minferet), minor, feret, major, perimeter (Perim),perimeter ellipse, (PerimEllipse), circularity (Circ) andsolidity between all *Hippohae rhamnoides* trees

4.4.1 Solidity

Figure 4.82 shows that, there were slight differences of the solidity due to the tidied up theimages of *H. rhamnoides* seeds between nine female sites. The largest variation within the site was Site 6, while the lowest variation was the seeds in Site 2. All the sites had a pretty much constant pattern between each five trees within the sites (Figure 4.83).

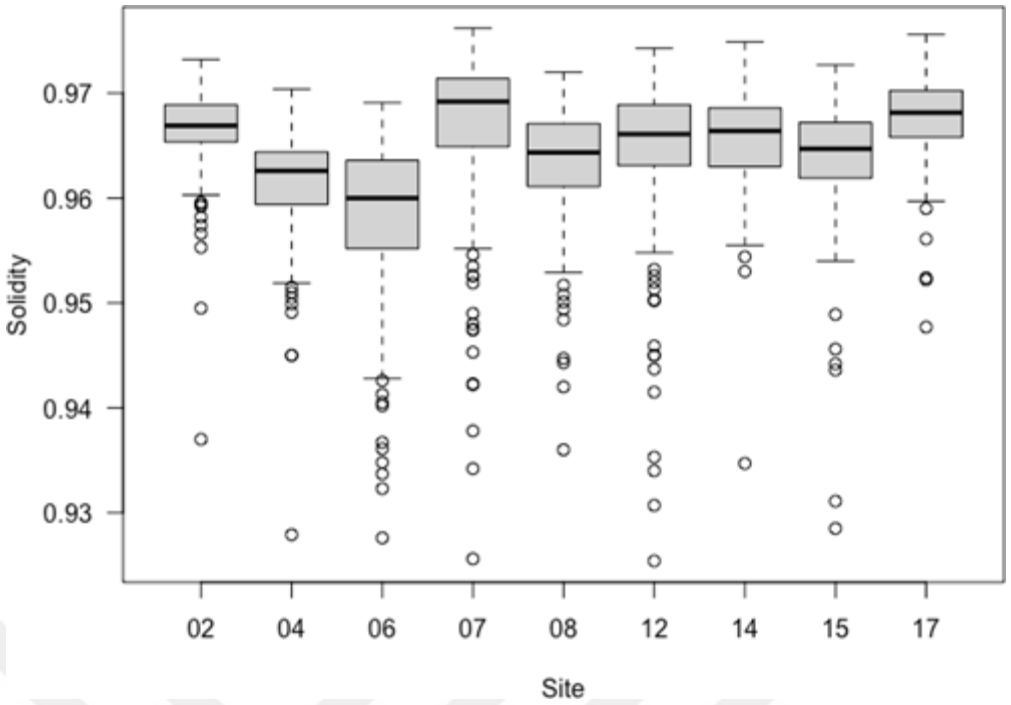

Figure 4.82. Solidity. Site: overall for nine female sites of *Hippophae rhamnoides*

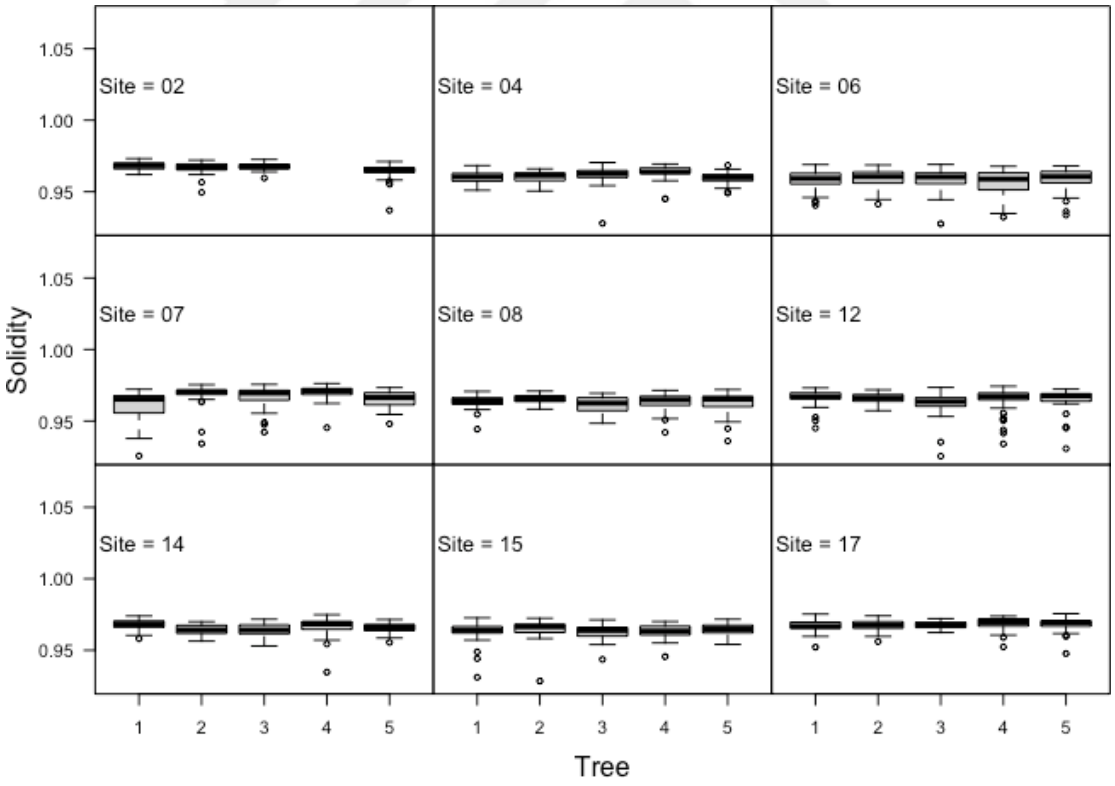

Figure 4.83. Solidity. Tree: each of five trees of *Hippophae rhamnoides* within each site

4.4.2 Circularity

Figure 4.84 indicates the circularity was moderately different between the sites of *H. rhamnoides.* The highest circularity median value was close to 0.8 which means the seeds were more rounded at Site 2. The lowest median value which indicated elongated seeds, was over 0.6 at Site 15. Overall, the circularity within the nine sites showed a regular pattern at the tree level except from the Site 12. Three of the five trees had elongated shape seeds but two of the trees had more rounded seeds than the others. Therefore, Site 12 had higher variation between the sites (Figure 4.85).

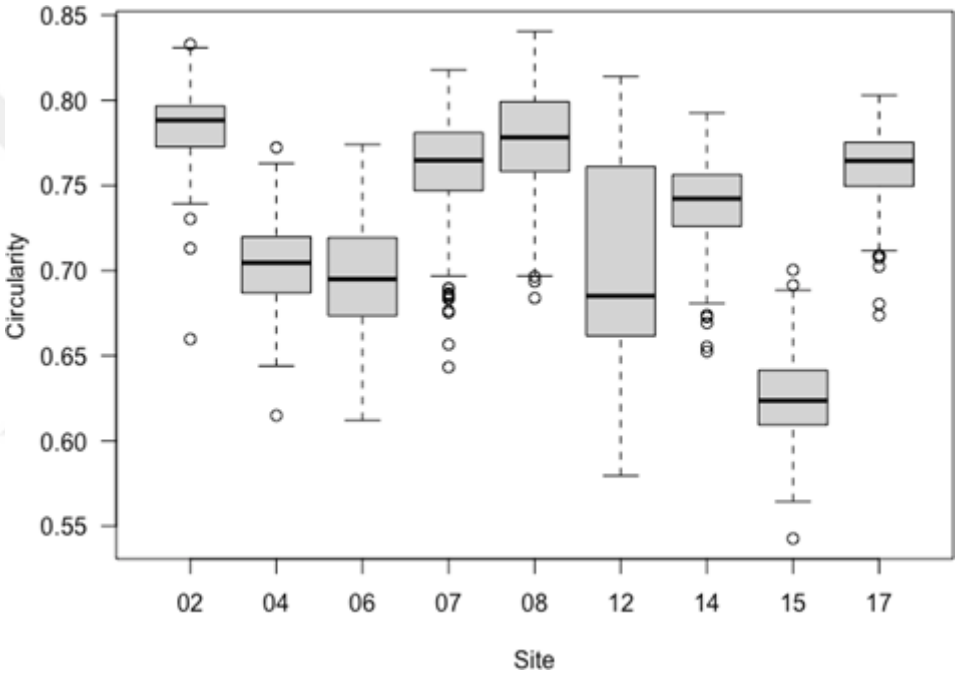

Figure 4.84. Circularity. Site: overall for nine female sites of *Hippophae rhamnoides*

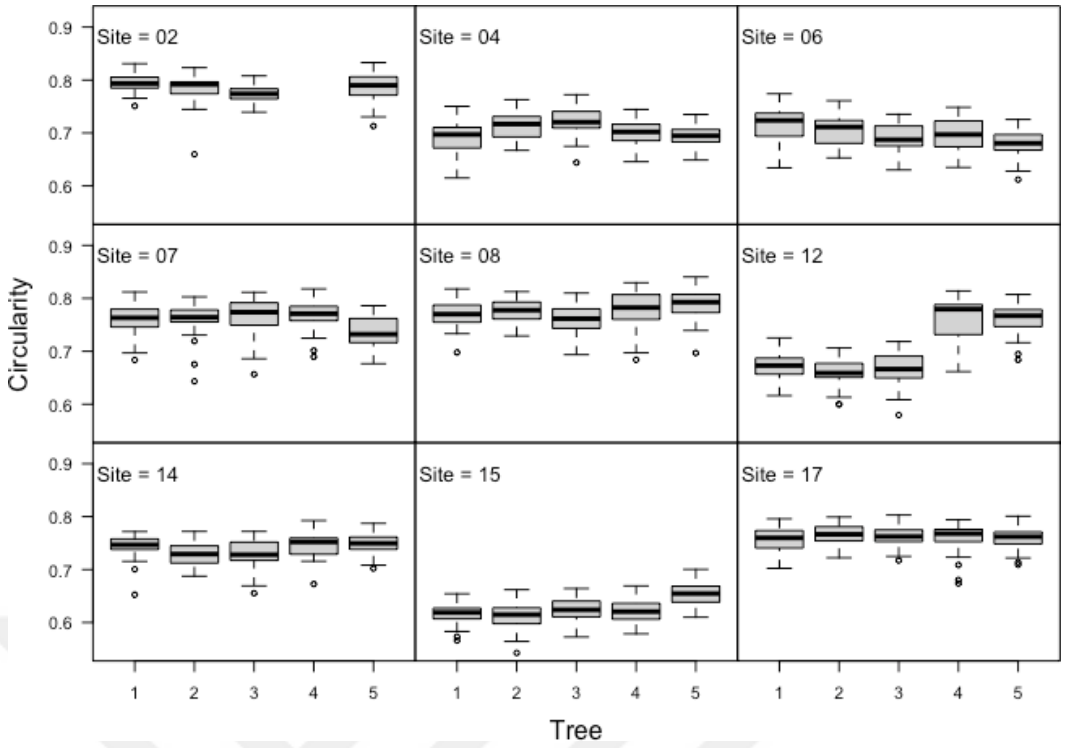

Figure 4.85. Circularity. Tree: each of five trees of *Hippophae rhamnoides* within each site

4.4.3 Ellipse perimeter

Ellipse perimeter is a measure of the circumference of the seeds that fit into the ellipse and the moderate variation between the sites is shown in Figure 4.86. The highest ellipseperimeter median value was the seeds on Site 7 which was close to12 mm and the lowestone was the seeds on Site 8 with over 8 mm. Site 12 had larger variation between and within the sites.

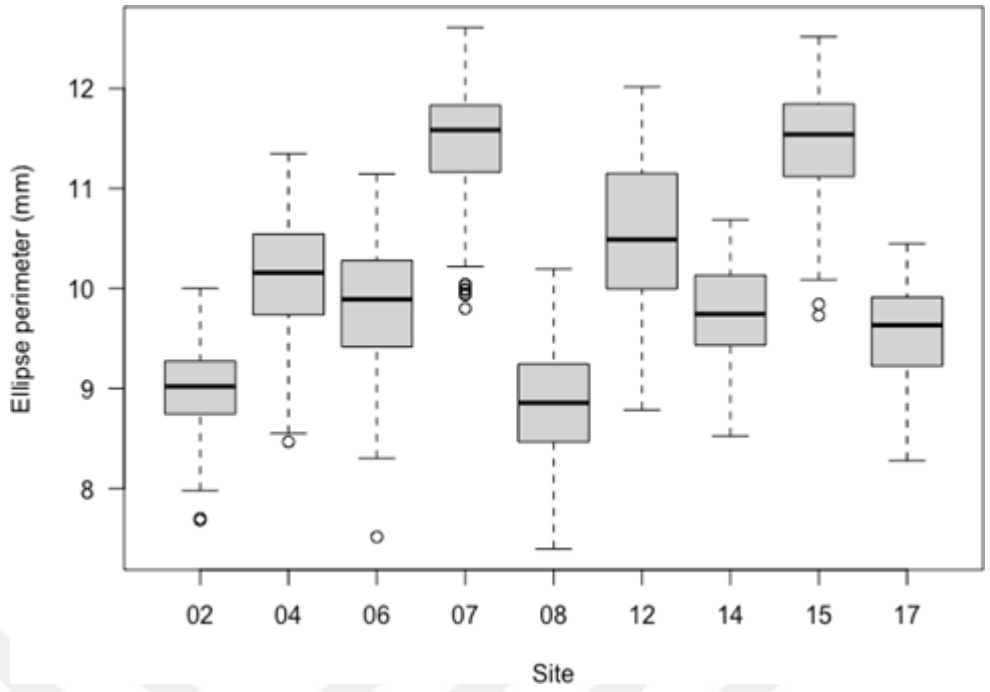

Figure 4.86. Ellipse Perimeter (mm). Site: overall for nine female sites of *Hippophae rhamnoides*

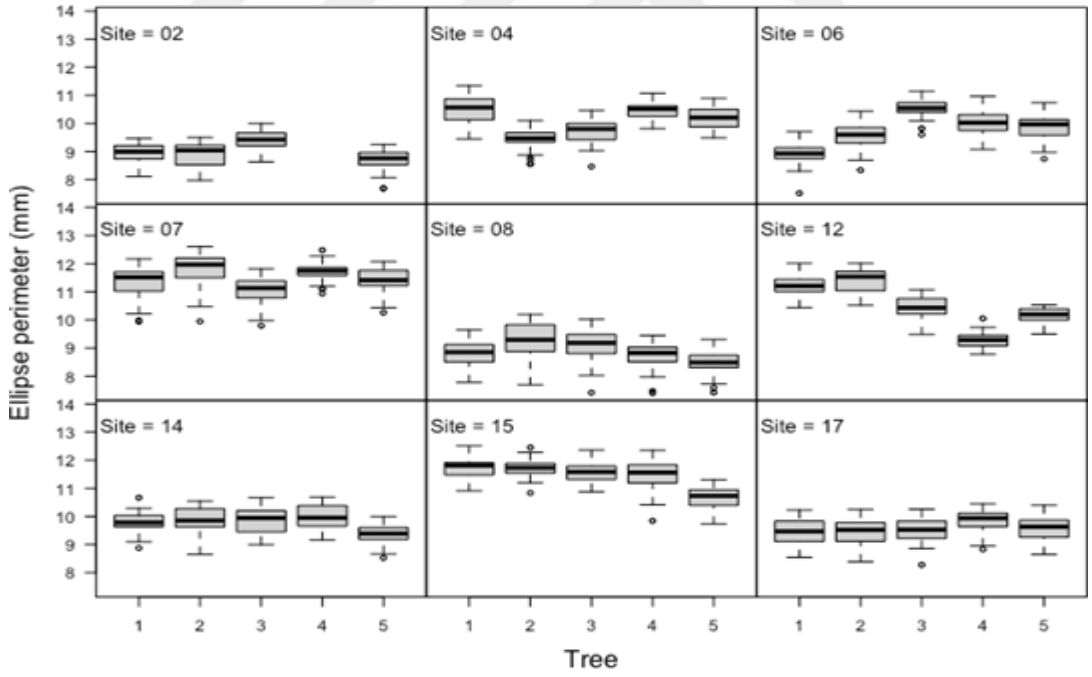

Figure 4.87. Ellipse Perimeter (mm). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.4.4 Perimeter

The variation between the perimeter is a measure of the circumference of the seeds that

fit into the ellipse and the moderate variation between the sites is shown in Figure 4.88. The highest ellipse perimeter median value was the seeds on Site 7 which was close to 12 mm and the lowest one was the seeds on Site 8 with over 9 mm. Site 12 had larger variation between and within the sites (Figure 4.89).

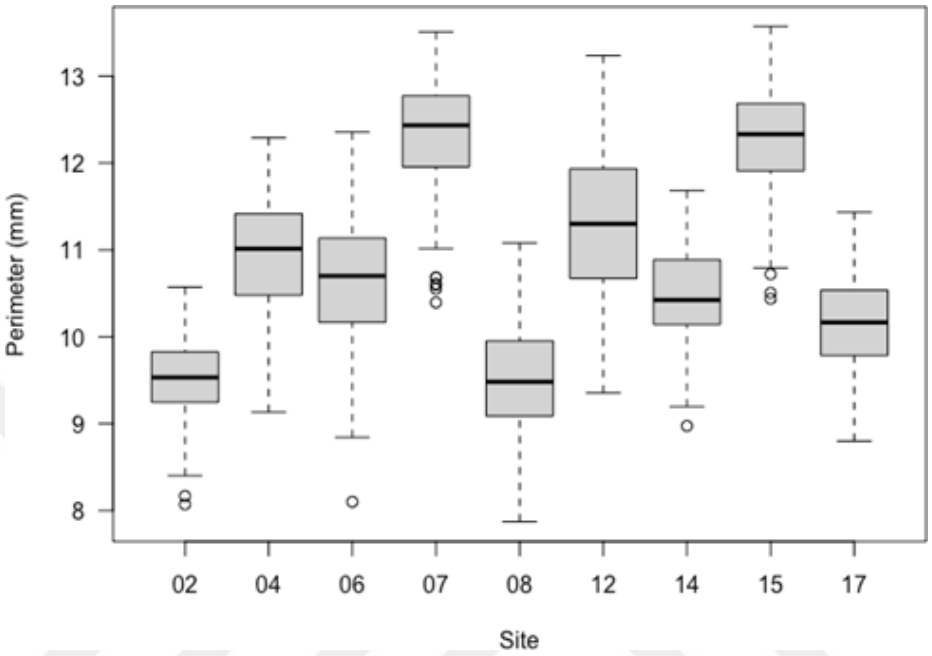

Figure 4.88. Perimeter (mm). Site: overall for nine female sites of *Hippophae rhamnoides*

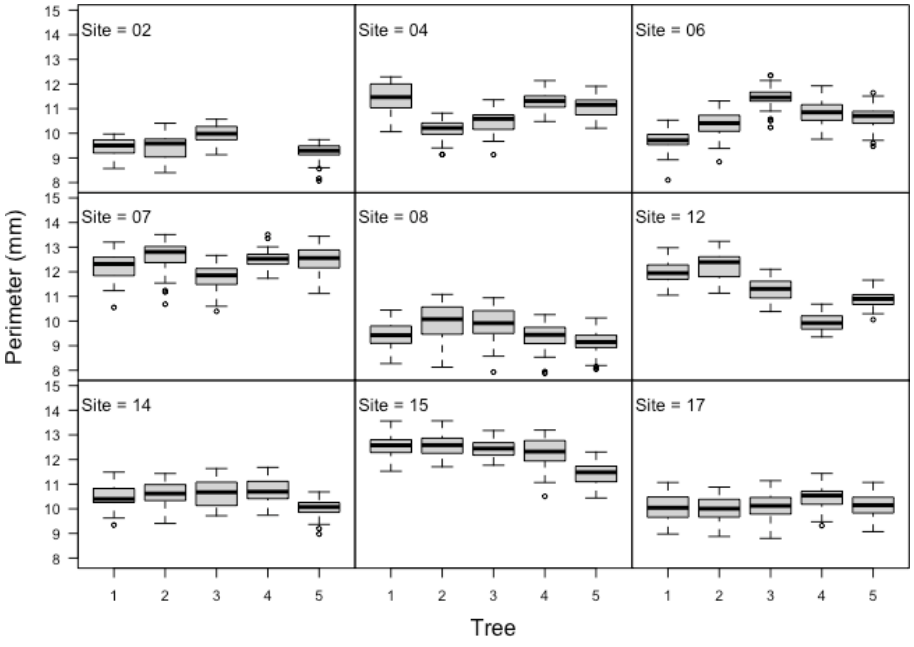

Figure 4.89. Perimeter (mm). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.4.5 Major ellipse axis

The moderate variation between nine sites of major ellipse axis of *H. rhamnoides* seeds is shown in Figure 4.90. The longest seeds were at Site 15 with the highest median valuewith over 5 mm while the smallest seeds were at Site 8 of 3.5 mm median value. Some sites had pretty much constant pattern at tree level within the sites (Sites 8, 14 and 17) however there was more fluctuation in some sites (Sites 4, 6, 7 and 12). The second tree sample at Site 8 had the most variation in within the trees (Figure 4.91).

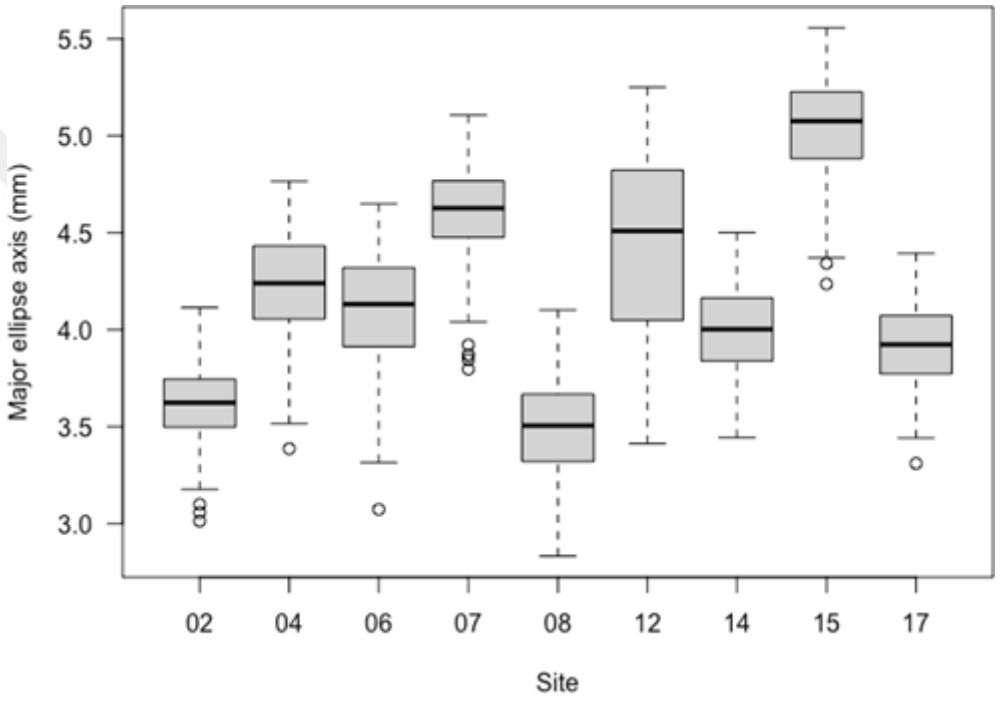

Figure 4.90. Major ellipse axis (mm). Site: overall for nine female sites of *Hippophae rhamnoides*

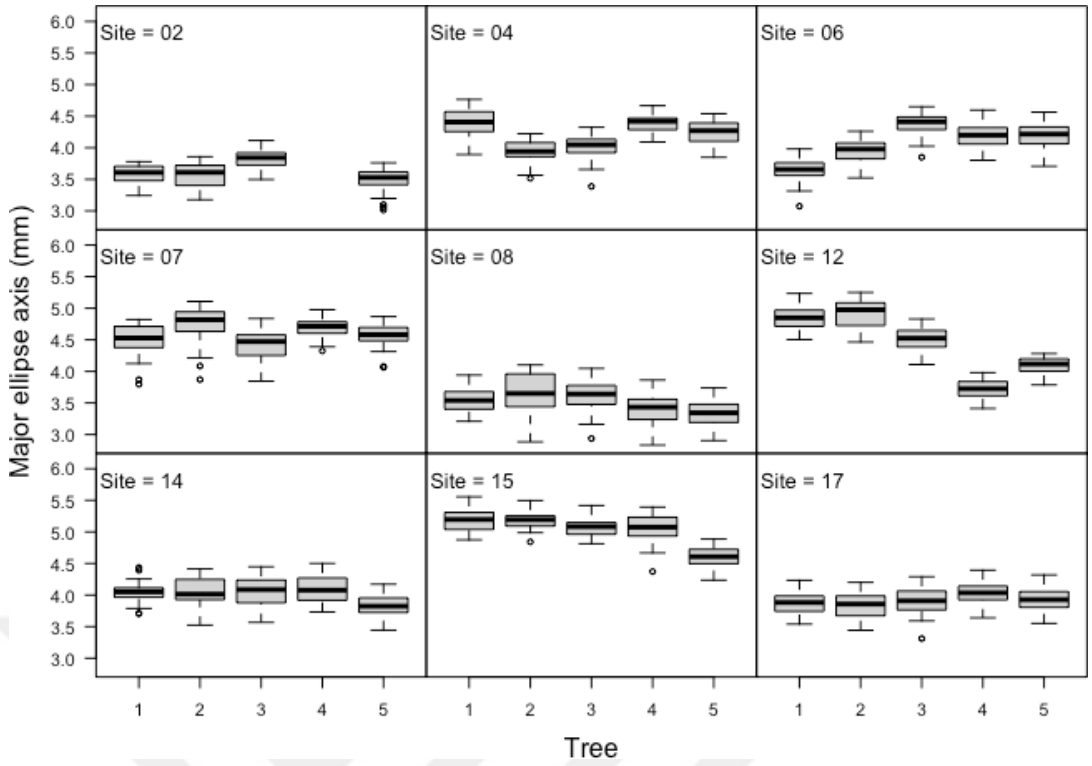

Figure 4.91. Major ellipse axis (mm). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.4.6 Feret length

Feret length showed a very similar structure with the major ellipse axis in seed analysis. The moderate variaiton between nine sites of major ellipse axis of *H. rhamnoides* seeds is shown in Figure 4.92. The longest seeds were at Site 15 with the highest median value with over 5 mm while the smallest seeds were at Site 8 of over 3.5 mm median value. Thelargest variation was at Site 12 between the sites. Some sites had pretty much constant pattern at tree level within the sites (Sites 8, 14 and 17). However, there was more fluctuation in some sites (Site 4, 6, 7 and 12). The second tree sample at Site 8 had the most variation within the trees (Figure 4.93).

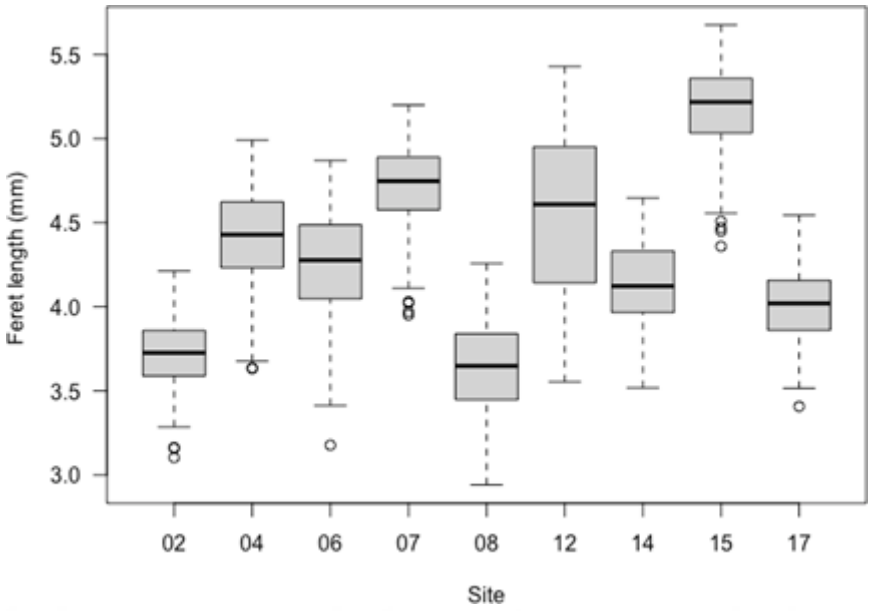

Figure 4.92. Feret length (mm). Site: overall for nine female sites of *Hippophae rhamnoides*

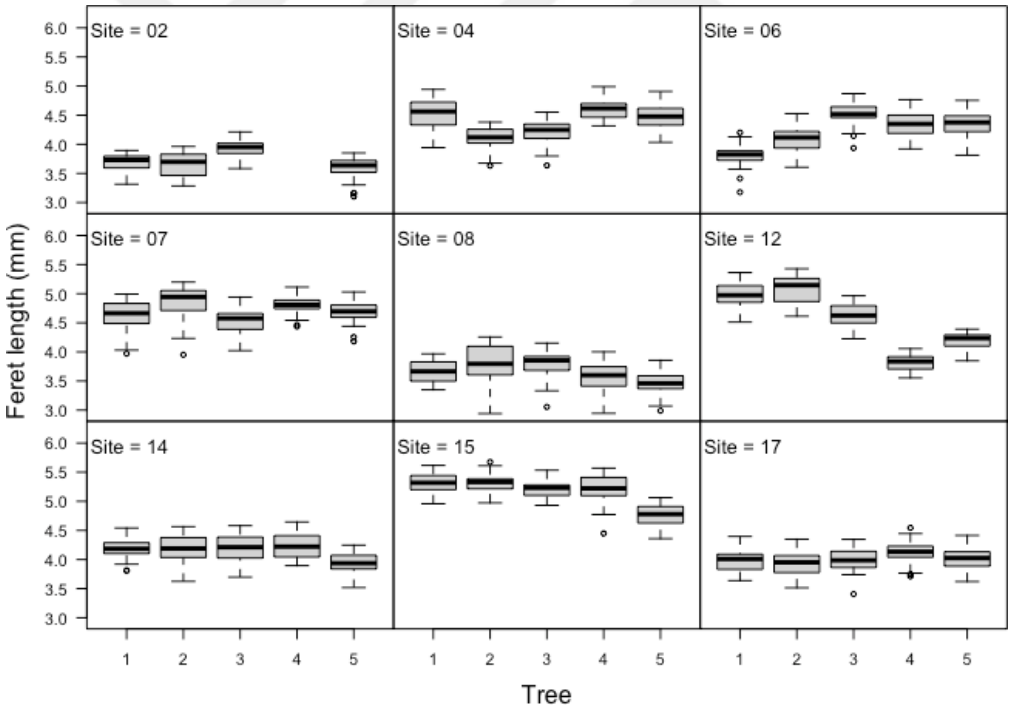

Figure 4.93. Feret length (mm). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.4.7 Minor ellipse axis

The slight variaiton (except Site 7) between nine sites of major ellipse axis of *H.*

rhamnoides seeds is shown in Figure 4.94. The widest seeds were at Site 7 with the highest median value close to 2.6 mm, while the narrow shaped seeds were at Site 15 with a median value of over 1.8 mm. Generally the sites had pretty much constant pattern at tree level within the sites. However, Sites 6 and 12 had more variation between the trees within the sites (Figure 4.95).

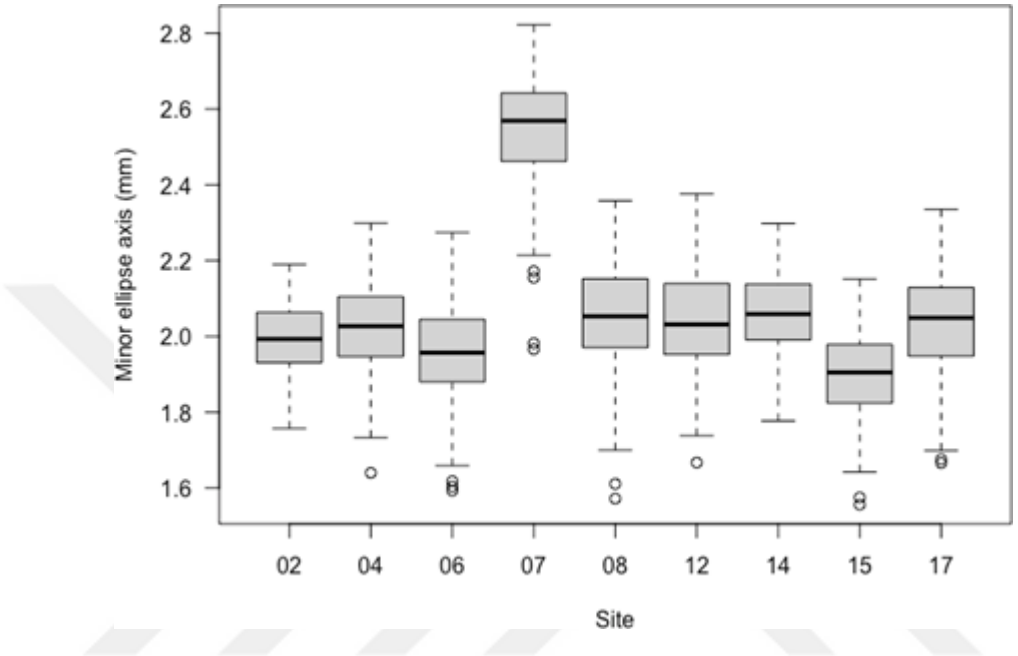

Figure 4.94. Minor ellipse axis (mm) Site: overall for nine female sites of *Hippophae rhamnoides*

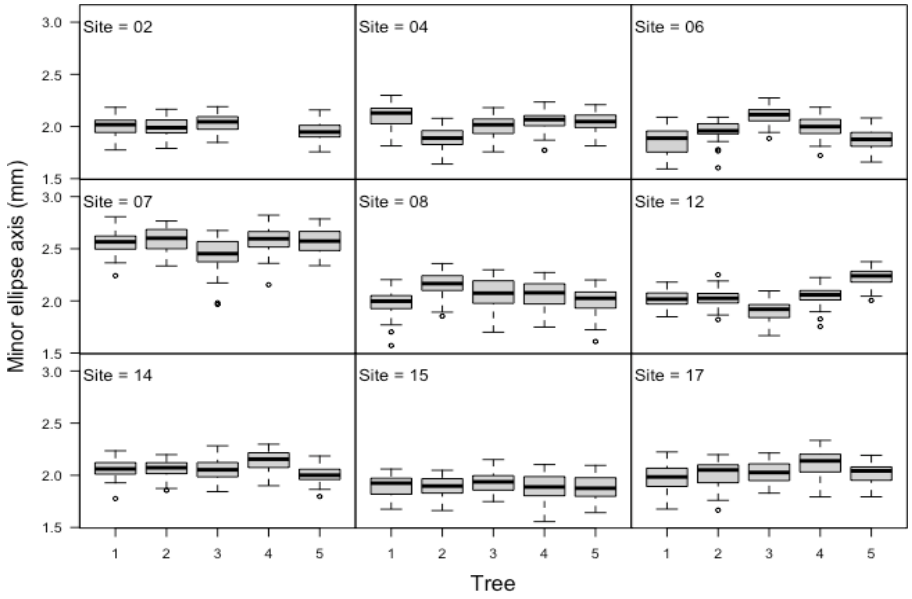

Figure 4.95. Minor ellipse axis (mm). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.4.8 Feret width

Feret width showed a very similar structure to the minor ellipse axis in seed analysis. The slight variation (except Site 7) between nine sites of major ellipse axis of *H. rhamnoides* seeds is shown in Figure 4.96. The widest seeds were at Site 7 with the highestmedian value over 2.6 mm, while the narrow shaped seeds were at Site 15 with a medianvalue of close to 2 mm. Generally, the sites had pretty much constant pattern at tree levelwithin the sites. However, Sites 6 and 12 had more variation between the trees within the sites (Figure 4.97).

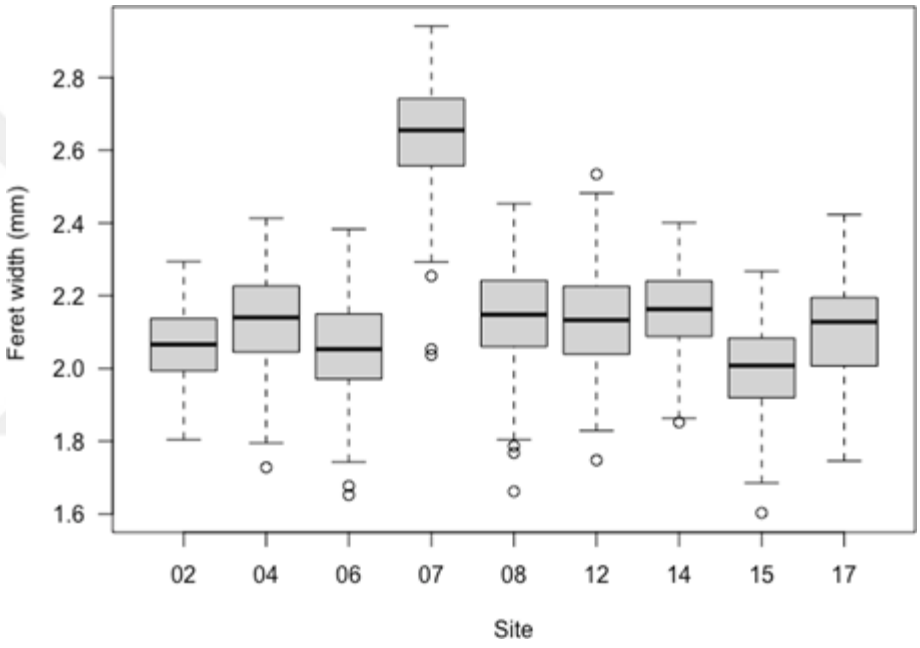

Figure 4.96. Feret Width (mm). Site: overall for nine female sites of *Hippophae rhamnoides*

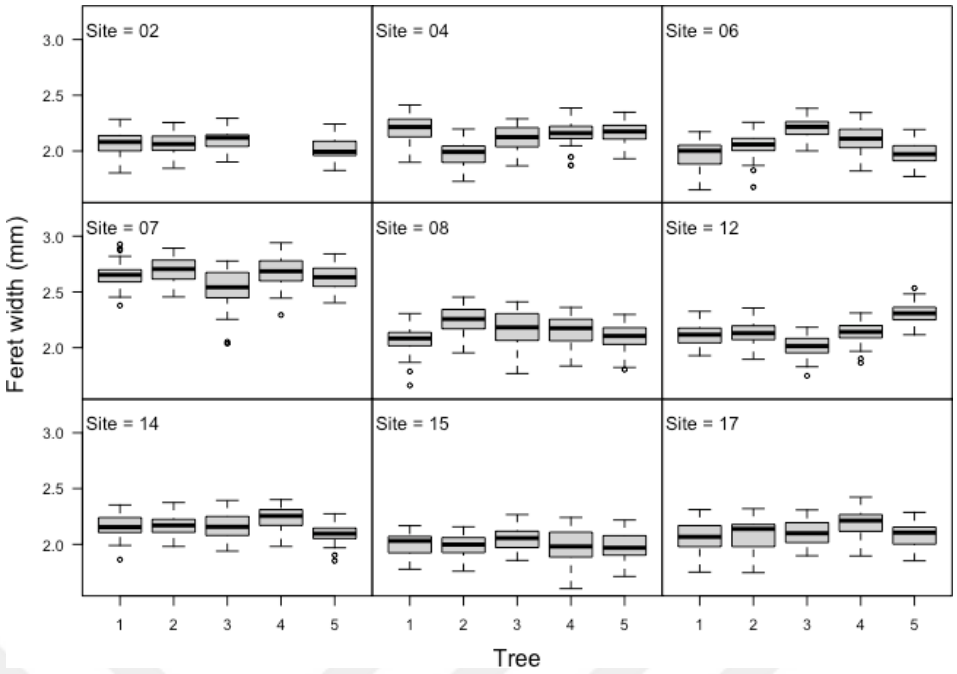

Figure 4.97. Feret Width (mm). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.4.9 Roundness

Figure 4.98 shows that there was moderate variation on the roundness of *H. rhamnoides* seeds between the sites. However, there were slight variation between trees within each site. The more rounded shape seeds were at Site 8 close to 0.60 and the least variable site was Site 15 with more elongated seeds close to 0.40. The larger variation was at Site 12 between the trees within the sites. While the first three trees had elongated seeds, the other two of them had more rounded seeds within the site (Figure 4.99).

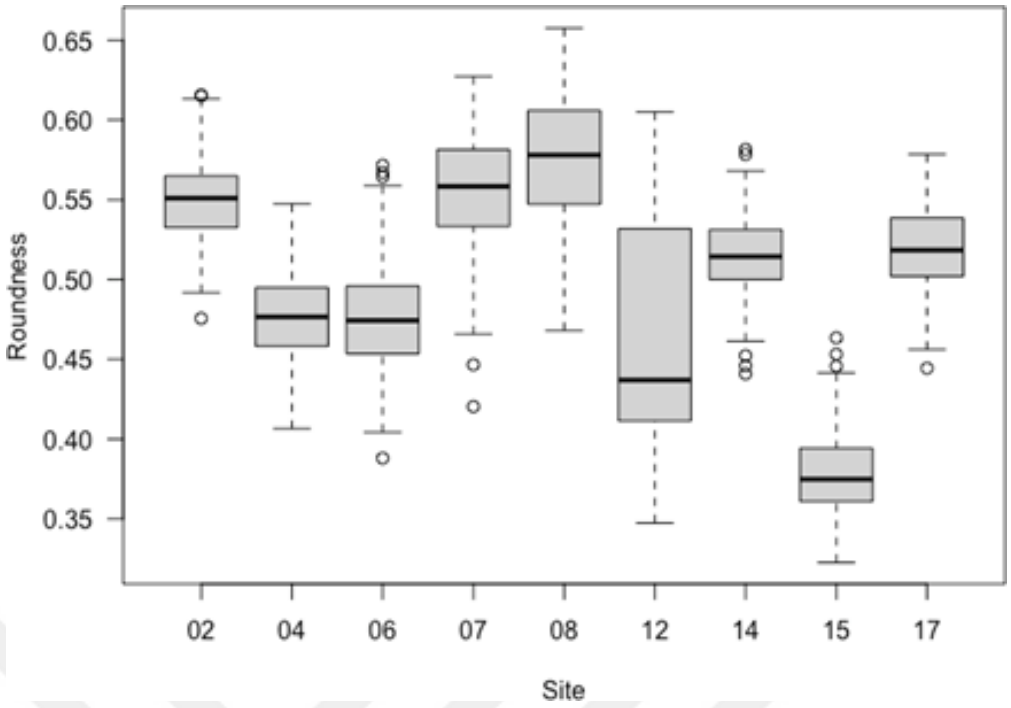

Figure 4.98. Roundness. Site: overall for nine female sites of *Hippophae rhamnoides*

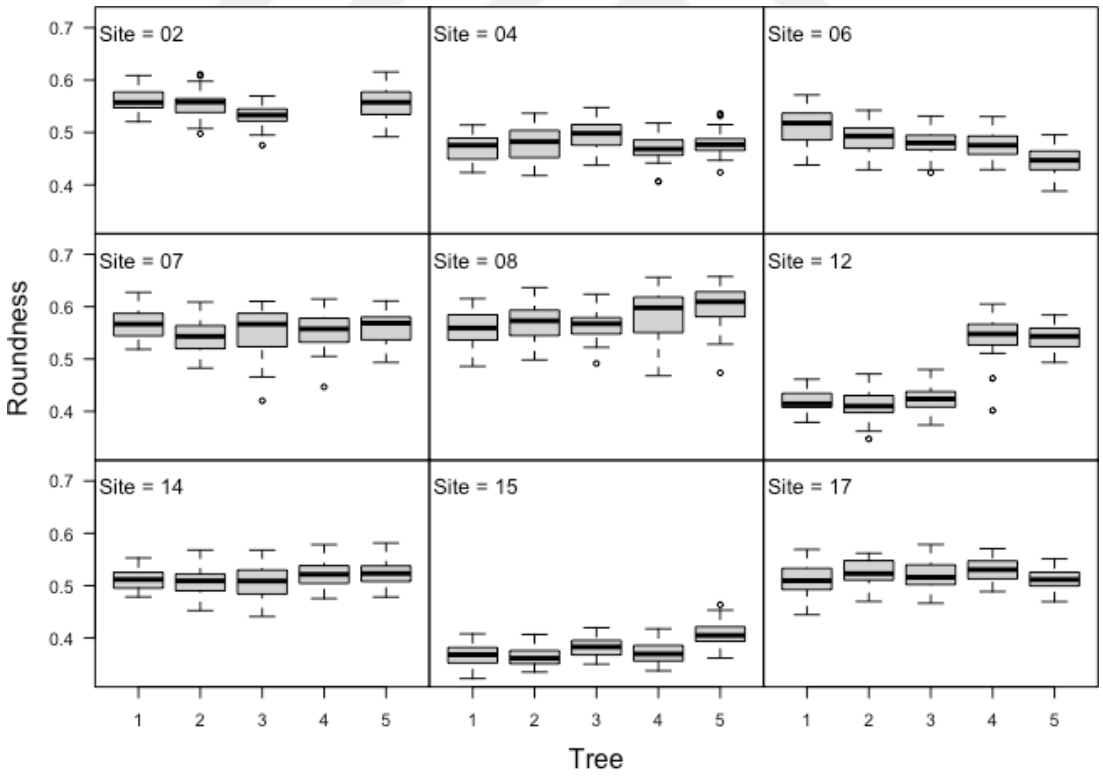

Figure 4.99. Roundness. Tree:each of five trees of *Hippophae rhamnoides* within each site.

4.4.10 Aspect ratio

The aspect ratio (AR) is the ratio of the length to the width of the seeds of *H. rhamnoides*. Figure 4.100 shows moderate differences on AR between sites but had fairly stable pattern in Figure 4.101 in tree levels. While some sites had very close AR (Sites 4 and 6; Sites 7 and 8; Sites 14and 17), the difference between some was high. (Sites 8 and 15). There was slight difference between the trees within each site. the highest variation between the trees within the sites was at Site 12 (Figure 4.101).

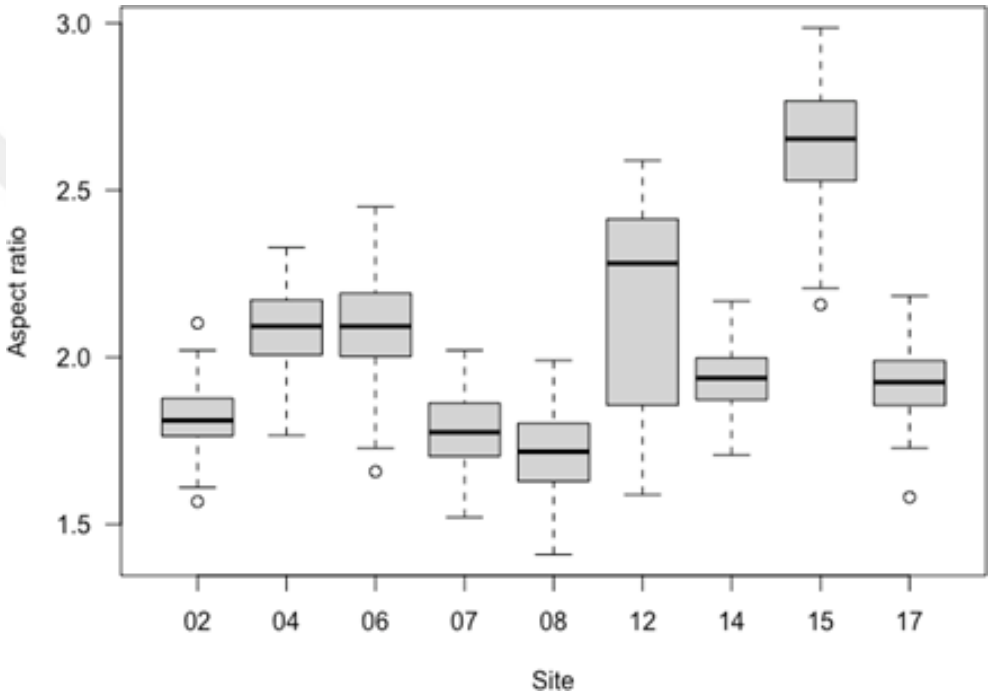

Figure 4.100. Aspect ratio. Site: overall for nine female sites of *Hippophae rhamnoides*

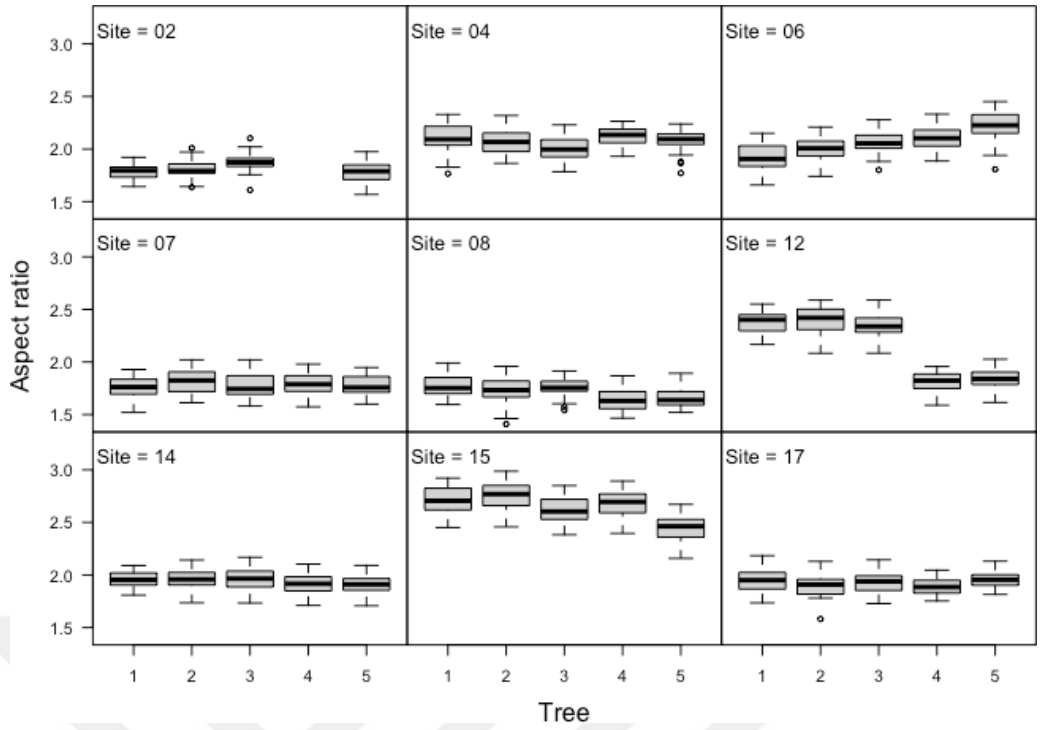

Figure 4.101. Aspect ratio. Tree: each of five trees of *Hippophae rhamnoides* within each site

4.4.11 Area

Figure 4.102 shows the variation of the area (mm^2) of the *H. rhamnoides* seeds. There weremoderately differences between the sites. Site 7 had the largest area median value with over 9 mm^2 while Site 8 had the lowest area with over 5 mm^2. Sites 4, 6, 7 and 12 had more variation between the trees within the sites. Within tree variation was mostly driven by Sites 4 and 8 (Figure 4.103).

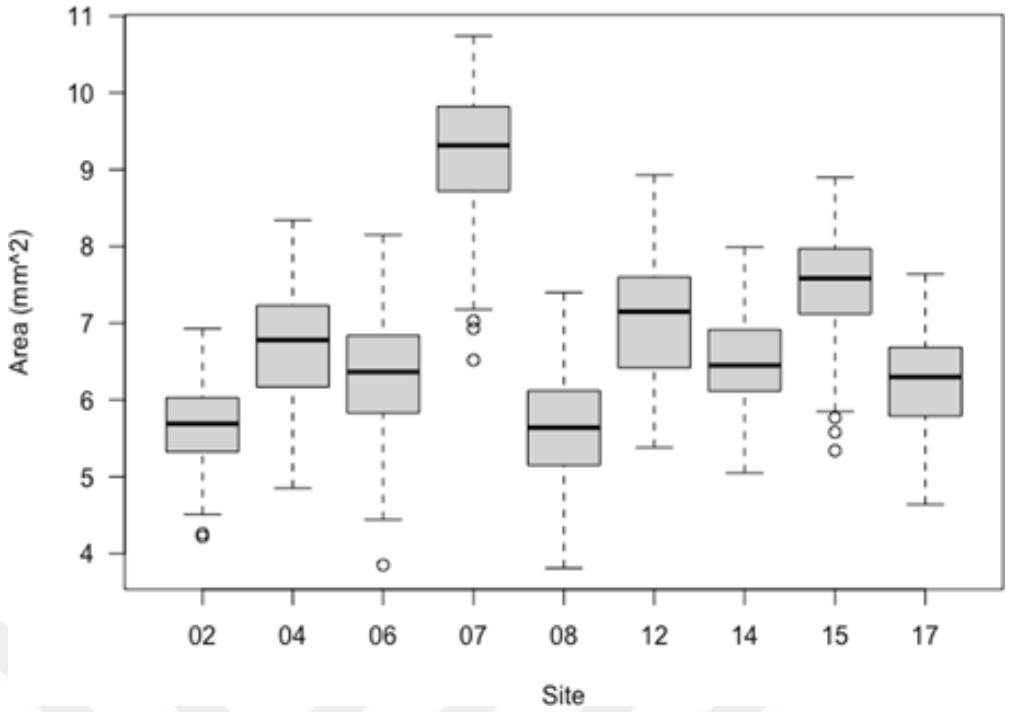

Figure 4.102. Area. Site: overall for nine female sites of *Hippophae rhamnoides*

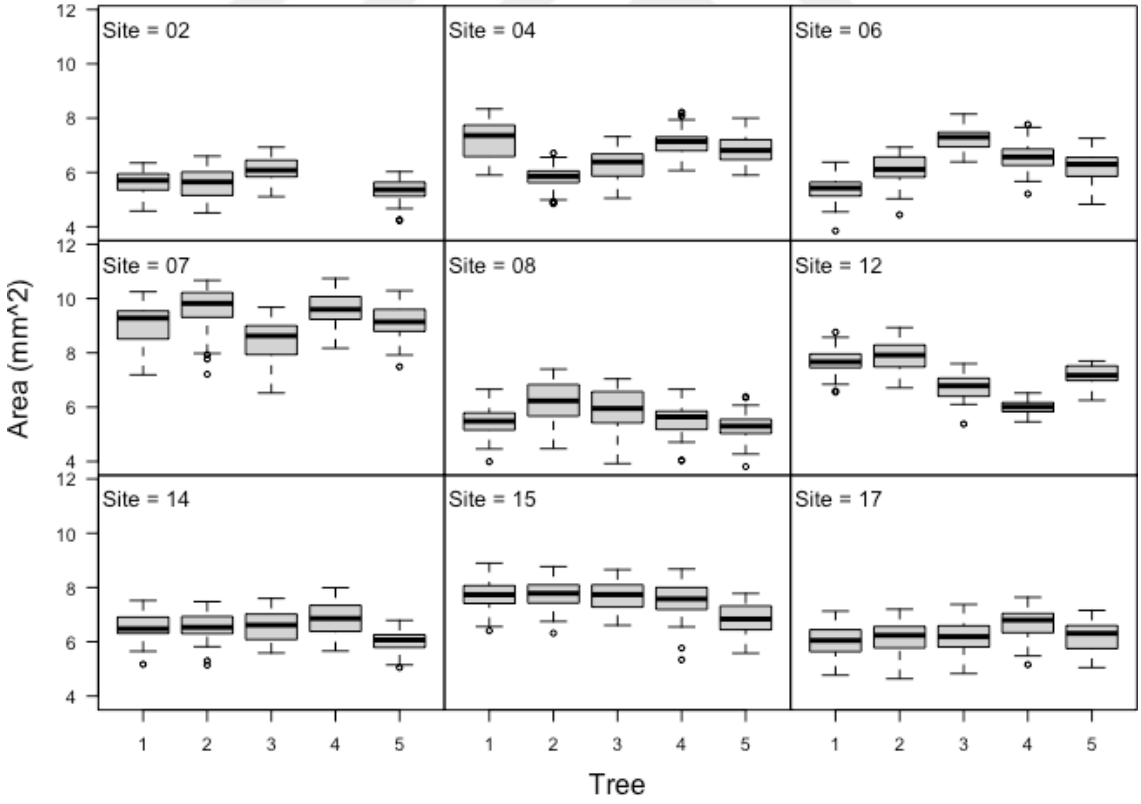

Figure 4.103. Area. Tree: each of five trees of *Hippophae rhamnoides* within each site

Seed analysis was evaluated at the site and tree level (not branch level), unlike fruit and

leaf analysis. Figure 4.104 indicated the effect sizes across for the 11 parameters used to assess seed analysis in *H. rhamnoides*. Coefficient variation (CV%) in the figure below refers to the variation percentage within the sites. The variation in seed analysis was largely driven by variationbetween the sites. There was small variation in terms of solidity at tree and site level. Minor, min feret and area had nearly same variation at site level. However, the variationof area was a little bit higher than those. AR had the highest variation at site level but didnot have much variation at tree level. The other parameters showed pretty similar variation between the sites and between the trees within the sites. For each parameters the certain data such as mean value, CV% and effect size, eta-squared (η2), were seen in Table A9. (see *H. rhamnoides* seed analysis).

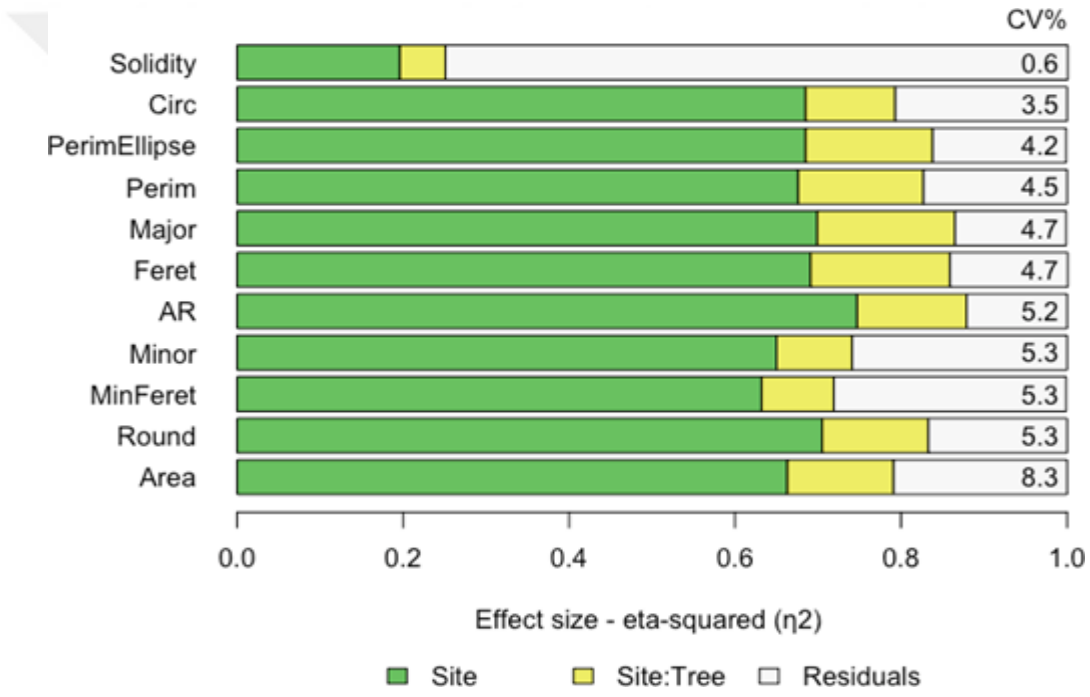

Figure 4.104. Coefficient variation (CV%) and effect size, eta-squared (η2), graph showing solidity, circularity (Circ), perimeter ellipse (PerimEllipse), perimeter (Perim), major, feret, aspect ratio (AR), minor, minimum feret (MinFeret), feret, roundness (Round) and area of Hippophae rhamnoides seeds in site and tree levels

4.5 *Hippophae rhamnoides* Germination Analysis

Coefficient variation (CV%) for the five parameters used to asses *H. rhamnoides* seeds germination is shown in Figure 4.105. The highest CV% value was on Gday with nearly 25% variation while the lowest CV% was on G50 between all trees with nearly 7% variation.

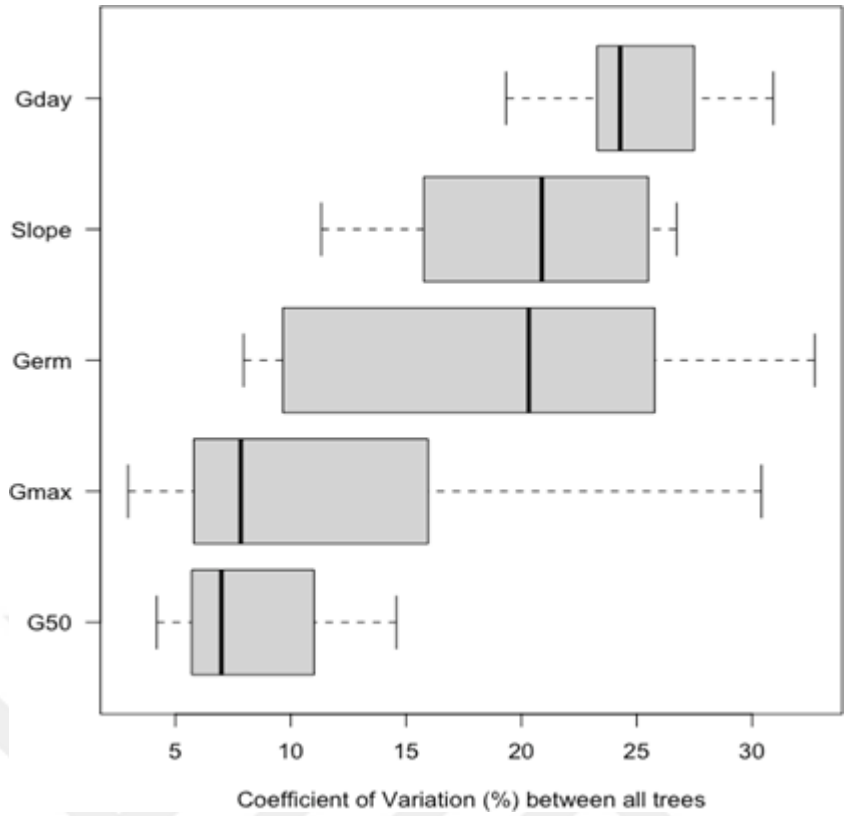

Figure 4.105. Coefficient variation (CV%) of Gday, Slope, Germ, Gmax and G50 between all *Hippophae rhamnoides* trees

4.5.1 G50

The moderate variation between the sites on G50 that was the time of 50% germination of *H. rhamnoides* seeds is shown in Figure 4.106. Site 15 had the higher variation median value with close to 8 but Site 17 had the lowest variation median value with below 5. The highest variation between the trees within the sites were at Site 12. However, there was low variation between the trees at Site 14.

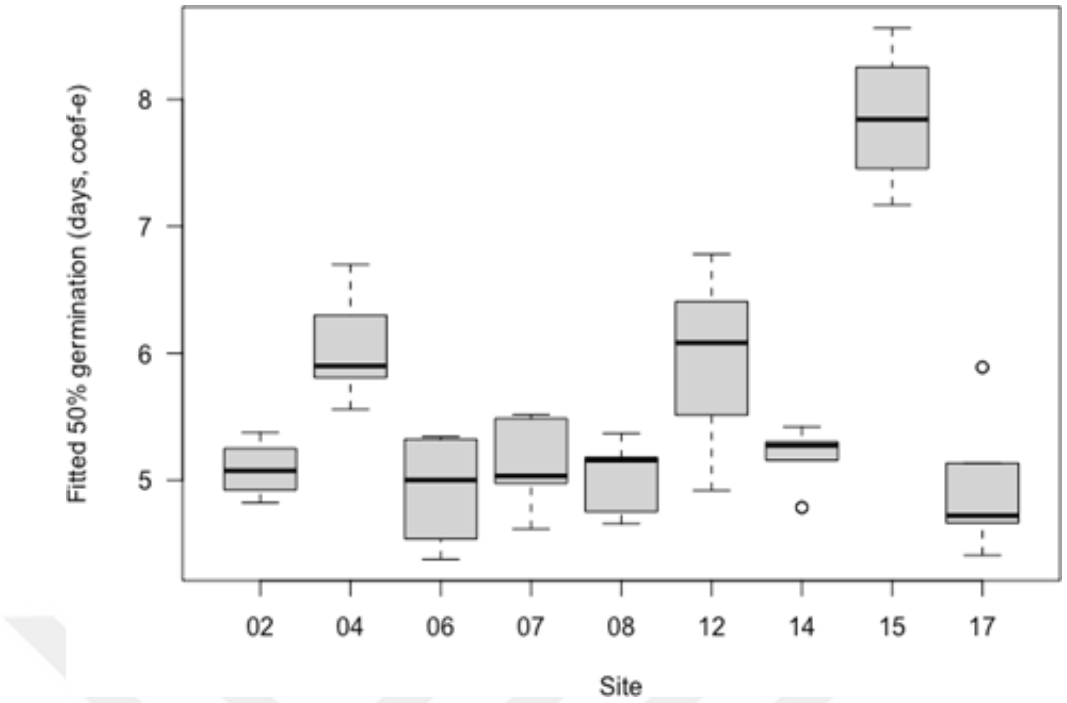

Figure 4.106. Fitted 50% germination (days, parameter Gday, coef-e). Site: overall for nine female sites of *Hippophae rhamnoides*

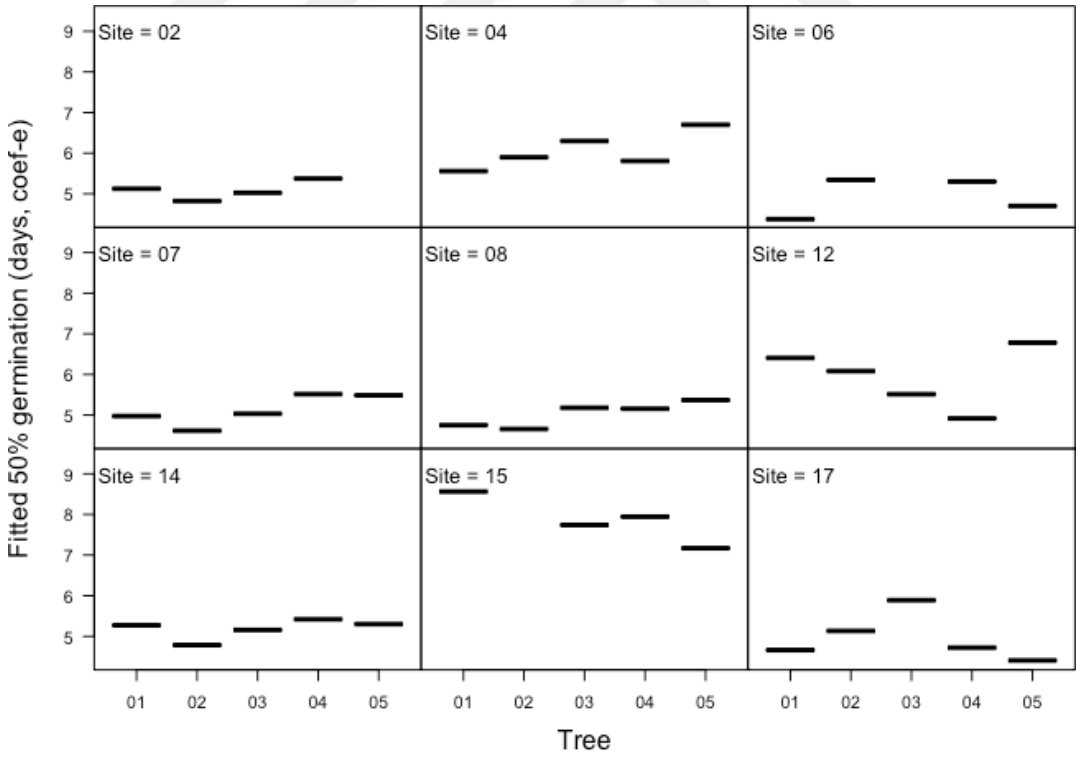

Figure 4.107. Fitted 50% germination (days, parameter G50, coef-e). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.5.2 Gmax

The variation between the sites on Gmax that was fitted the log-logistic function (coef-d) between the eight sites of *H. rhamnoides* seeds is shown in Figure 4.108. The highest maximum germination proportion was at Site 8 while the lowest one was the Site 17. Sites 12 and 17 had higher variation between the trees within the sites.

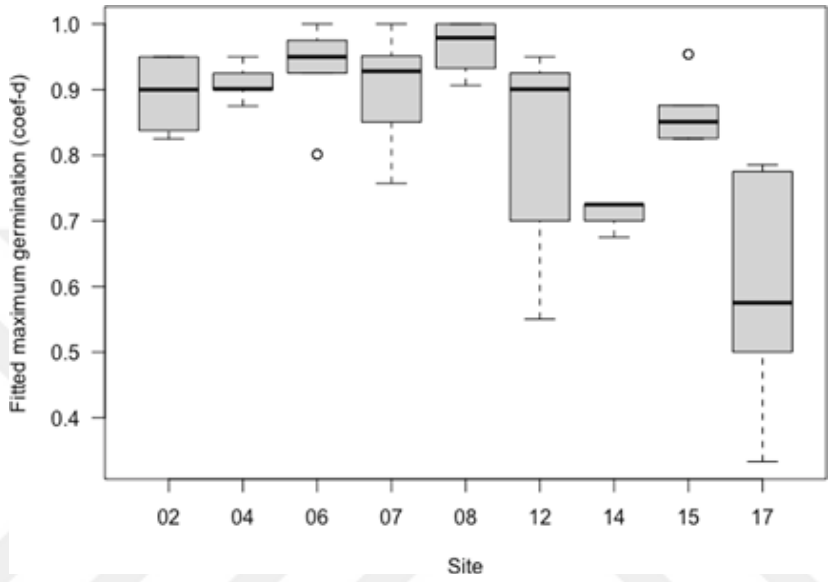

Figure 4.108. Fitted maximum germination (days, parameter Gmax, coef-d). Site: overall for nine female sites of *Hippophae rhamnoides*

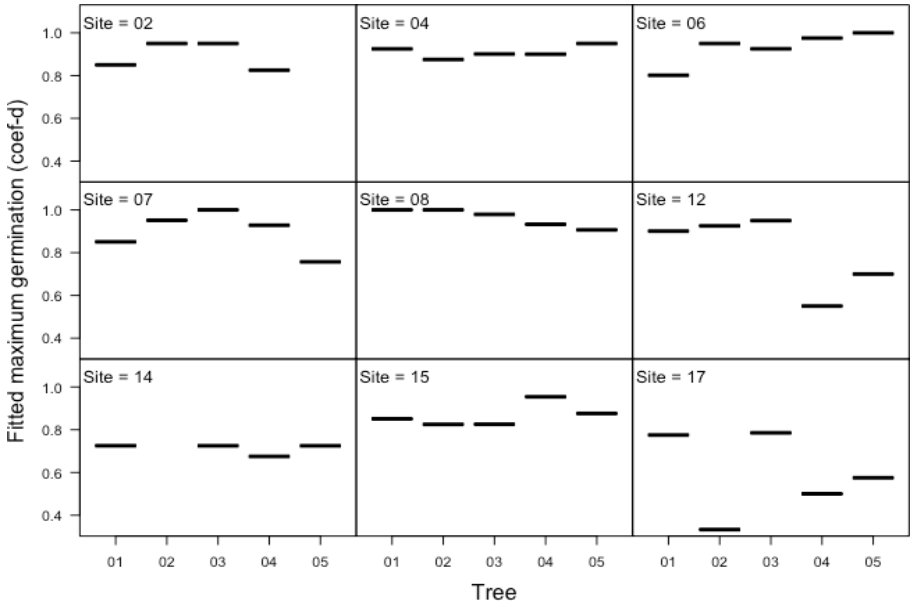

Figure 4.109. Fitted maximum germination (days, parameter Gmax, coef-d). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.5.3 Germ

The variation between the eight sites on Germ that was consisted of the data set of *H. rhamnoides* seeds is shown in Figure 4.110. The highest germination proportion was at Site 2 while the lowest one was the Site 17. The variation of proportion of the germination wasquite high in some individual trees within some sites (especially at Sites 4, 8 and 17). Sites 12 and 17 had the higher variation between the trees within the sites. However, Sites 2 and 14 had more constant pattern between the sites (Figure 4.111).

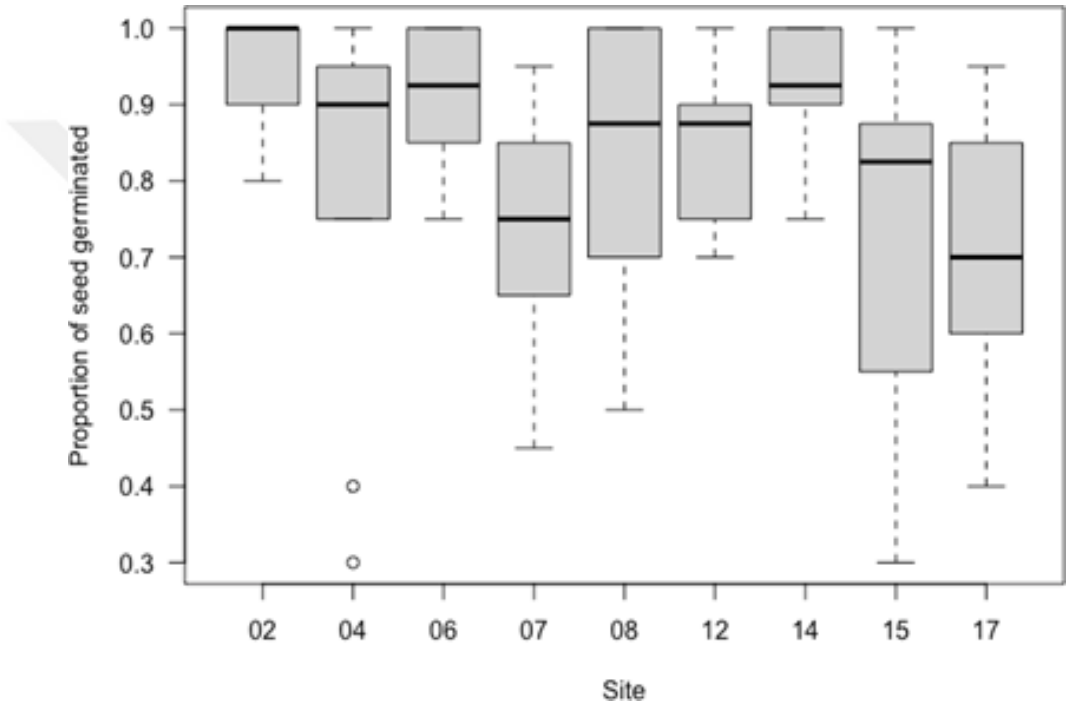

Figure 4.110. Proportion of seed germinated (parameter Germ). Site: overall for nine female sites of *Hippophae rhamnoides*

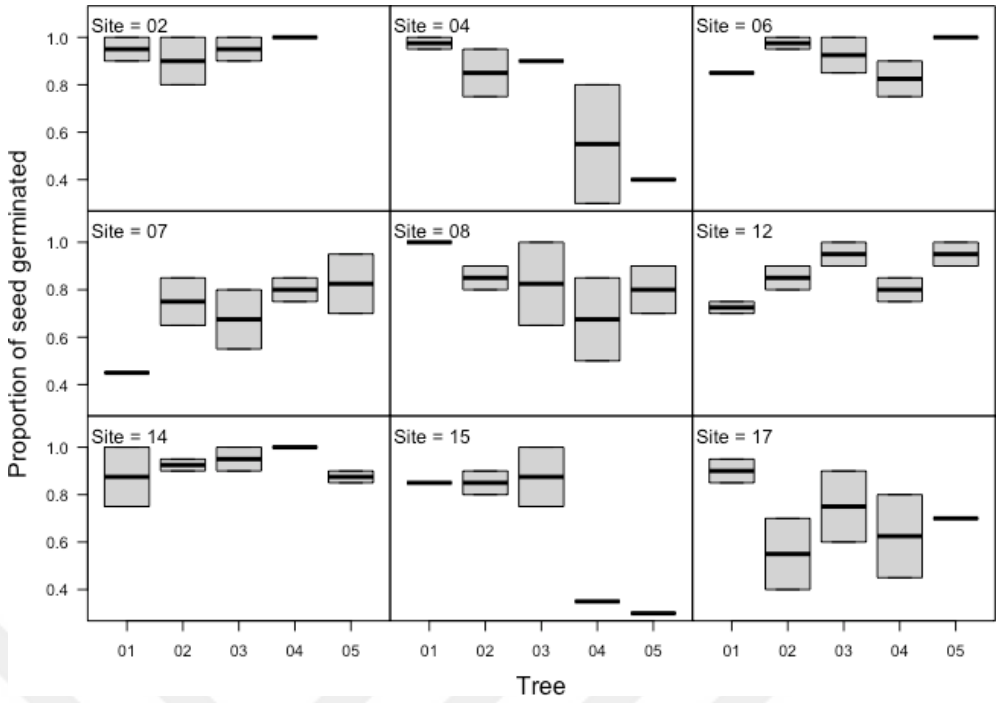

Figure 4.111. Proportion of seed germinated (parameter Germ). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.5.4 Slope

The variation between the sites on fitted slope to maximum germination that was fitted the log-logistic function (coef-b) between the eight sites of *H. rhamnoides* seeds is shown in Figure 4.112. The highest slope variaition to maximum germination was at Site 4 while the lowest one was the Site 8. Sites 12 and 17 had higher variation between the trees within the sites. The smallest variation between the individual trees and between the sites was at Site 7.

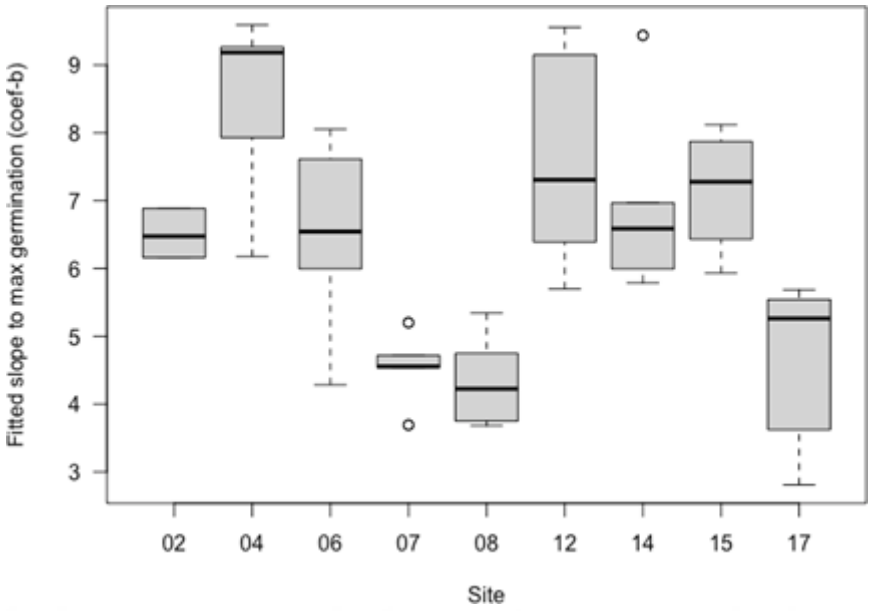

Figure 4.112. Fitted slope to maximum germination (parameter Slope, coef-b). Site: overall for nine female sites of *Hippophae rhamnoides*

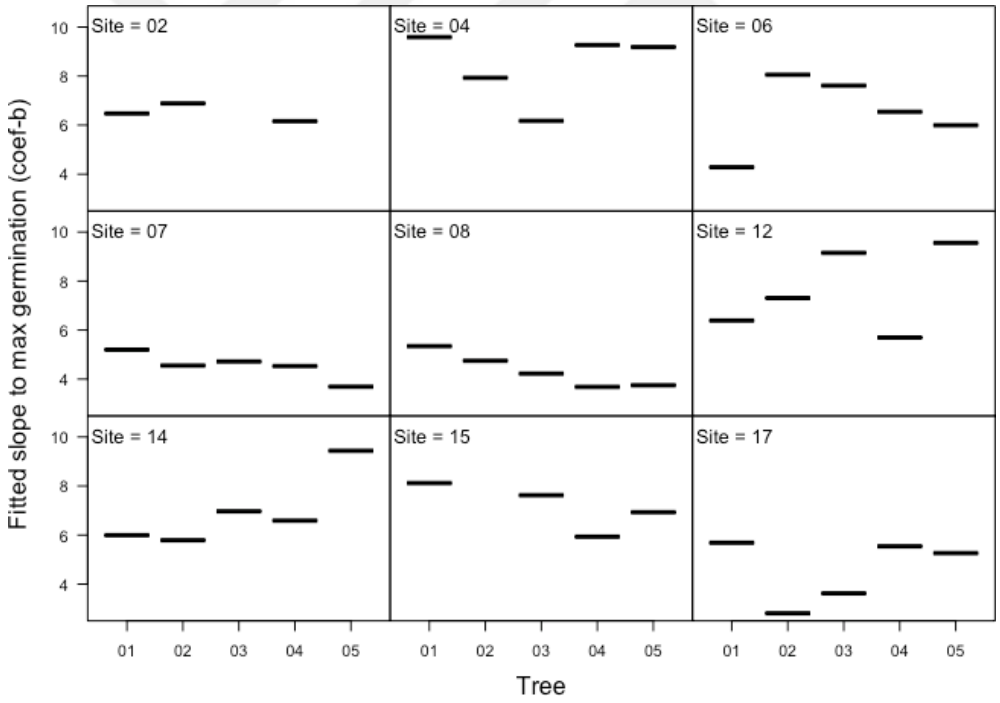

Figure 4.113. Fitted slope to maximum germination (Slope, coef-b). Tree: each of five trees of *Hippophae rhamnoides* within each site

4.5.5 Gday

The moderate variation of Gday between the eight sites of *H. rhamnoides* seeds is shown in Figure 4.114. The highest variation on days to maximum germination was at Site 14

while the lowest one was the Site 2. There was substantial variation some individual trees nearlyfor all sites. Site 4 had the highest variation between the individual trees within the site (Figure 4.115).

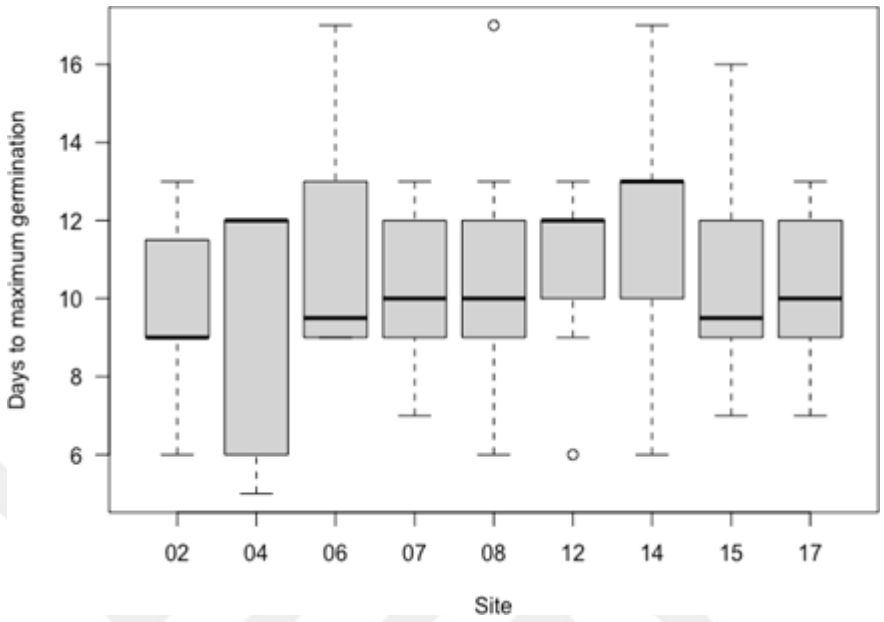

Figure 4.114. Days to maximum germination (parameter Gday). Site: overall for nine female sites of *Hippophae rhamnoides*

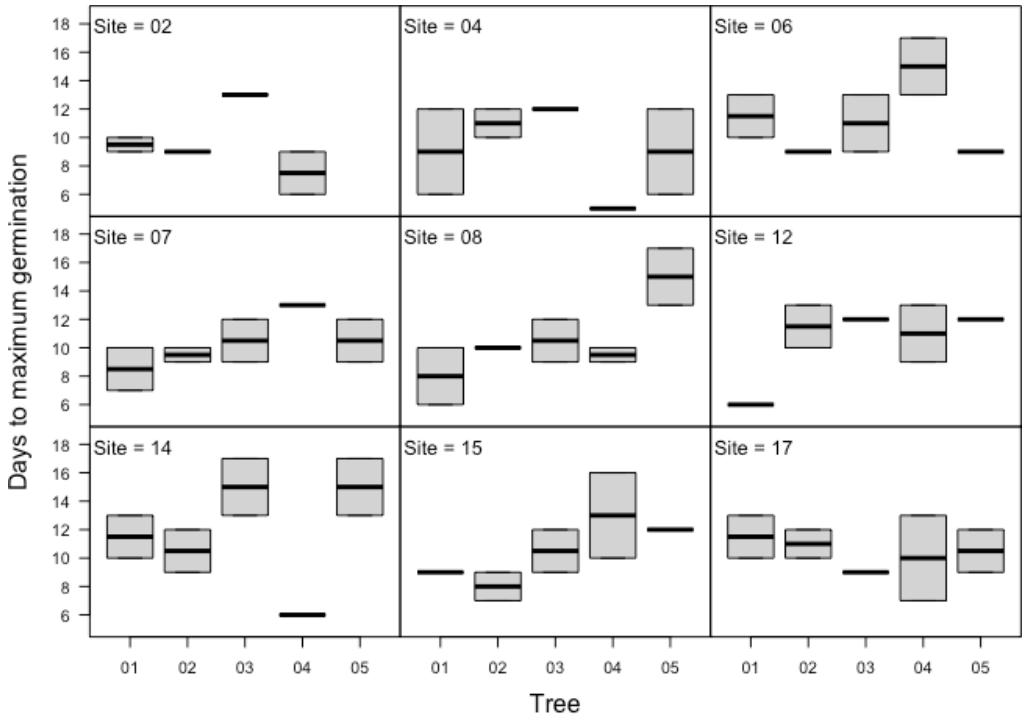

Figure 4.115. Days to maximum germination (parameter Gday). Tree: each of five trees of *Hippophae rhamnoides* within each site

Figure 4.116 indicated the effect sizes across for the five parameters used to assess germination of *H. rhamnoides* seeds. Coefficient variation (%CV) in the figure refers to the variation percentage between the sites. G50, Gmax and Slope were the parameters which fitted thelog-logistic function but Germ and Gday was the measured data set and calculated by astaken the median across all samples. G50 had the larger variation between all the parameters at site level. There was small variation in terms of Gday, at site level while, there was substantial variation at tree level. The variation between Gmax and Slope was quite similar between the sites.

For each parameters the certain data such as mean value, CV% and effect size, eta-squared (η2), were seen in Table A10. (see *H. rhamnoides* germination analysis).

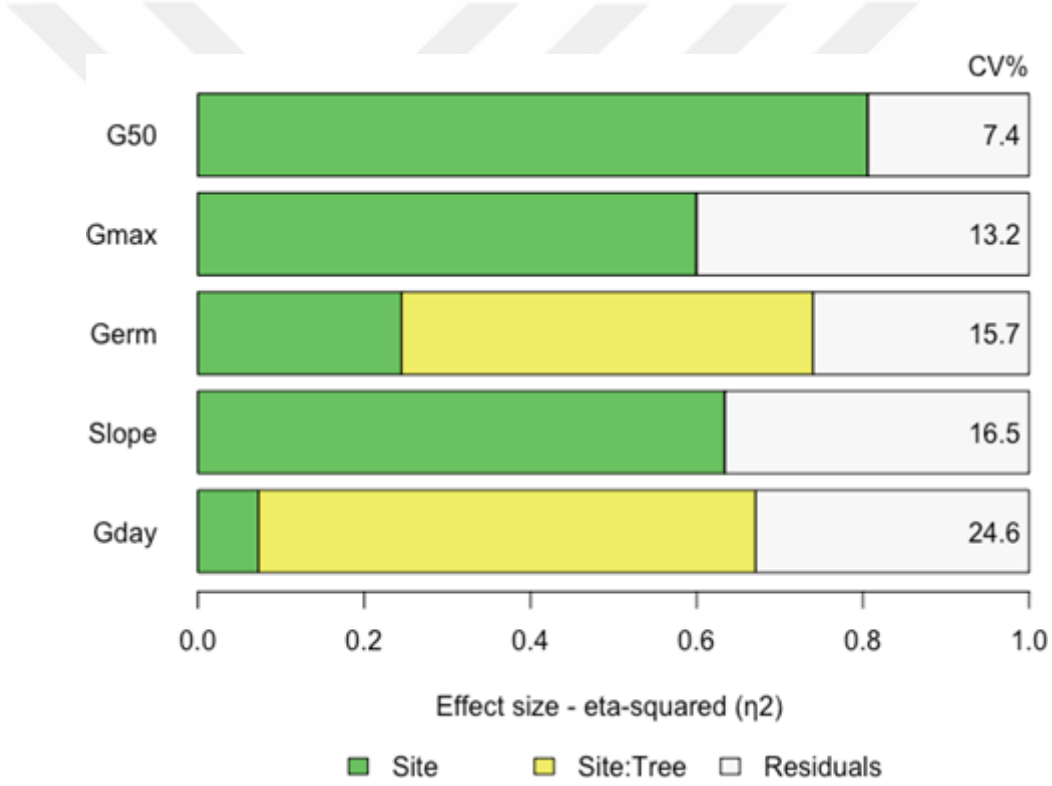

Figure 4.116 Coefficient variation (%CV) and effect size, eta-squared (η2), graph showing G50, Gmax, Germ, Slope and Gday of *Hippophae rhamnoides* seeds

4.6 Ethnobotanical Study Results of *Hippophae rhamnoides* in Çamardı, Niğde

In the ethnobotanical study of *H. rhamnoides*, a total of 25 respondent aged 50-80 were interviewed, 47% male and 53% female. Most of the occupations consisted of housewifes and farmers. Of the 25 people that was questioned, there was only four did not recognize

this plant. Except two of them, all the interviewees were native and living in Çamardı, Niğde since from their childhood. The plant is often called as “Kara çalı”, but is rarely called as “Domuz çalısı”, “Kör iğde” and “Yalancı iğde” by the local people. A total of the 21 interviewees, only four of them consume this as a fresh fruit when they were child. In addition, it was used as fencing, firewood, teeth cleaning and animal feed especially for the birds in a wild habitat. Although the plant generally used for these purposes, parts of the plant such as leaves and seeds were not used by the local people for anything specifically. Even they knew the plant, they did not place high value to it.

This plant is the outlier population of the *H. rhamnoides* and it clonally propagated. Due to its thorniness plant structure local people wanted to remove the plant from their field or garden. Removing the clonal propagated plant from the environment, get threatened the wild population of the *H. rhamnoides* and gene resources of it as well.

Raising awareness by explaining the numerous benefits and uses of this plant to the public will contribute both to the protection of the natural population and to the use of a new agricultural product by the public by introducing less thorny varieties of the plant to the region.

The local name and usage of *H. rhamnoides* in Çamardı, Niğde, and the demographic characteristics of the respondents are shown in the Table 2.

Table 4.1. The local name and usage of *H. rhamnoides* in Çamardı, Niğde and the demographic characteristics of the interviewees

Interviewees	F/M	Age	Occupation	Local Name	Usage of *H. rhamnoides*
1	F	50	Housewife	Kara çalı	Firewood
2	F	53	Housewife	Kara çalı	Fresh fruit
3	M	53	Self-employment	Kuş üzümü	Animal feed
4	M	75	Butcher	Kara çalı	Fresh fruit
5	F	70	Housewife	Kör iğde	Fencing
6	F	67	Housewife	Dikenli iğde	Nothing
7	M	70	Housewife	Kara çalı	Nothing
8	F	65	Housewife	Kara çalı	Nothing
9	F	75	Housewife	Kara çalı	Fresh fruit
10	M	62	Retired	Kara çalı	Firewood
11	M	72	Farmer	Kara çalı	Nothing
12	M	60	Merchant	Kara çalı	Nothing
13	F	63	Housewife	Kara çalı	Fresh fruit
14	F	64	Housewife	Kara çalı	Firewood
15	M	64	Retired	Kara çalı	Fencing
16	F	50	Housewife	Kara çalı	Nothing
17	M	58	Self-Employment	Kör iğde	Fencing
18	F	52	Housewife	Yalancı iğde	Fresh fruit
19	M	66	Retired	Domuz çalısı	Teeth cleaning
20	F	67	Housewife	Kara çalı	Fencing
21	M	79	Restaurateur	Kara çalı	Fencing

CHAPTER V

DISCUSSION

5.1 *Hippophae rhamnoides* Tree Sizes

As with all other plants, trees need water, nitrogen compounds, mineral salts and growth regulators to carry out their vital activities. The habitat and type of the tree, the cultural interventions that have been made or are being made in the past are among the factors that affect the increment and growth.

Findings of the southernmost known population of *H. rhamnoides* in Çamardı district of Niğde province showed that the tree characteristic was in the form of shrub or tree. Although the bush form was generally dominant in arid areas far from a water source, the bush form had left its place to the multi-stem tree form in the populations in the areas close to streams and water. Since the plant was easy to propagate clonal, especially plants in the form of bushes that expand laterally have been encountered on the roadsides in the form of clusters.

In this study, differences were observed between and within the sites in terms of tree trunk diameter and tree length. These differences may be caused by environmental or genetic factors as mentioned above.

5.2 *Hippophae rhamnoides Buds*

According to results of the dry weights of buds taken from the same positions of male and female trees branches there was very small variation between and within the sites of the dry weights of the female buds but the male buds had greater variation than the females. While some sites had larger buds, some had the smaller bud structure. The variation between the sites was mostly driven by the male sites of the *H. rhamnoides* trees. The fact that two male tree sites had large buds in particular suggests that this may be caused by some kind of disease such as genetic, viral disease, insect infestation, or due to the environmental factors.

5.3 *Hippophae rhamnoides* Leaves

Leaf samples taken from 18 sites in Çamardı district of *H. rhamnoides* showed moderate differences in leaf morphological parameters in general.

Solidity was a parameter related to the quality of the photograph taken, and more reliable results could be obtained by improving the features such as light and contrast in the photographs taken.

Length and width was a good example of a genetic trait that can be influenced by environmental factors. While a plants genetic code may provide instructions for the length, the expression of this length might be suppressed if the plant had poor growing conditions or effected from the pathogen such as fungi, viral diseases or insect infestation. In this study, the length parameters of the ferret length and major ellipse axis were almost close to each other and the average of the length of the leaves were 42.6 and 39.9 mm, for all sites, respectively. The minor difference was that the feret length corresponds to the top and bottom of the leaf, while the length of the main ellipse indicates the main length that the leaf fits into the optimal ellipse. Site 4, which differed markedly from the others, was the site with an elongated leaf length. When Site 4 was examined in terms of location, it was observed that it had the most green environment compared to other sites and had fertile soil structure around which there were agricultural lands. The shortest leaves were in Sites 16, 17, and 18, located away from the water flow and on bare land. So it could be said that growing conditions were highly effective on the leaf length.

Tree structure also played an important role in growing conditions, as the deep root structure of the plant means that it takes more minerals from the soil and affects the vigor of the tree. Therefore, the other plant organs such as leaves, fruits can grown better. Although genetic differences also affected this situation, it was impossible to say anything about the certainty of genetics by looking at their morphology.

The width of the leaves was also the parameters that were more environmentally determined. The width parameters were described as feret width and minor ellipse axis, and the average leaf widths for all regions are 4.85 and 4.09 mm, respectively. As mentioned in the leaf length, the small difference was due to the fact that one was the

shortest elliptical length and the other was the ferret length.

Aspect ratio was highly variable between the sites but was pretty flat across the trees within each site. Due to the trees within the clump had dry location or in contrast wet location and having high moisture content and different aspect to the sun could be effective on the growing of the trees differently within a clump even if they genetically identical. Therefore, the aspect ratio might be genetically driven in some way, the clusters might be genetically different or alternatively the site might somehow driven that phenotype.

According to the research carried out in Çamardı, while the aspect ratio of the leaves is between 7.93-11.6, Rousi (1971) reported that *H. rhamnoides* ssp. caucasica had 9.6±0.21, *H. rhamnoides* turkestenica 8.2±0.15 and H. salicifolia 6.7±0.14 aspect ratios. Rousi (1971) reported that Turkey had *H. rhamnoides ssp. caucasica* and *H. rhmanoides turkestenica* subspecies and it can be said that the sampled sites may be in the same subspecies in overlapping values at the same aspect ratio.

Perimeter and elliptical perimeter gave an information about the circumference of the leaf and since it was a parameter somehow dependent on the length, Site 4 has a larger perimeter such as the leaf length parameters than the other sites. The properties mentioned for length were applied to some extent in this case as well.

5.4 *Hippophae rhamnoides* Fruiting Branches

Ecological factors effect the growing condititons of the fruit crop. In this study, it was seen that the moisture content of the fruits in Site 14 was lower than the other sites and the moisture content of the fruits in the branches in Sites 4 and 6 was higher.

Sites 4 and 6 were close to each other in terms of location and these areas located on fertile lands close to agricultural lands. When both the location and tree structures of Site 4 were examined, it was observed that the trees in Sites 4 and 6 were generally in the form of a single tree rather than a bush. Therefore, the physiological mechanism may have

facilitated the transport of nutrients and water to the fruits found in the trees and may have increased the moisture content of the fruit.

Considering the structure of the trees in Site 14, they had a multi-stem form, so the nutrients taken from the soil and the water need to be transported to more organs of the plant, and therefore the moisture requirement per fruit may be reduced. In addition, Site 14 was far from the water source compared to Sites 4 and 6 may also have affected this. Branch length to the first fruit was a kind of a measure of the new growth/vigor of the fruit on 2nd year wood. The tree branches in Site 4 had the greatest length value of this parameter, supporting the comments on fruit moisture content.

The graphs containing the fresh and dry fruit weights were similar to each other, which means that the moisture in the fruit was removed in a proportionally close amount depending on the moisture content they contain.

The fact that, Site 8 had the highest number of fruits, did not mean that it was good in terms of fruit quality. The high number of fruits may be due to partial periodicity. Therefore, the trees in this region carry a lot of fruit load and spend all their energy on ripening these fruits.

Parallel to the number of fruits, the fruit density on the branches was also seen at the highest level in Site 8. Since the number of fruits was low in Sites 15 and 17, fruit density was lower than in other sites.

5.5 *Hippophae rhamnoides* Fruits

The length, width, perimeter, aspect ratio and roundness parameters were evaluated in fruit as well as in leaves, and moderate differences were observed in nine sites in general. Unlike the leaf analysis, the estimated fruit peduncle length was also calculated for the fruit characterization. As a result of the analyzes made, it was seen that the longest fruits in terms of major length and feret length, which are the length parameters, were at Site 15. The proximity of Site 15 to water resources may have positively affected fruit development, and a genetic trait may be expressed phenotypically by the influence of environmental factors. However, the number of fruits on the trees in this region was low,

added a contrast to the event. This may be related to the earliness tree variety and fruiting earlier than other sites and dropped their fruits.

The width of the fruit also determined by environmentally. The smallest and narrowest fruits was at Site 8. As it mentioned on fruiting branches, Site 8 had the most fruits and therefore the fruits may not grow any further individually.

Peduncle length and aspect ratio were more likely genetically determined. The difference of elliptical measurements from feret measurements was used in the estimated peduncle calculation. Feret length includes the bottom and top points, while elliptical length only aims to measure the length of the fruit that was limited to the elliptical area. Considering the difference between these two parameters, the greatest peduncle length was of the fruits at Site 2 among the sites, Although the fruits in Site 4 have better ecological conditions than Site 2, the shorter peduncle lengths compared to this region may indicate that it was related with the genetic feature of the plant.

Aspect ratio of the plant gave an idea about the shape descriptive of the *H. rhamnoides* fruits. According to the values for length of the berries and fresh fruit width were given in Rousi (1971) elliptical shape of fruits were in the range of 7; 6-7 mm for ssp. caucasica and 7-8; 6-7 mm for ssp. turcestenica in length to width, respectively. For example, Site 15 which had the largest AR with elliptical fruits, while Site 8 had an oblong fruit structure and fruits in other sites were among these values. According to the comparisons in the Rousi table of the *H. rhamnoides* subspecies, *H. rhamnoides ssp. caucasica* and *H. rhamnoides ssp. turcestenica* increased the likelihood of the species found in Çamardı district. In addition, the samples with the lowest median aspect ratio show the characteristics of H. salicifolia in terms of fruit colour and shape in Site 7, suggesting the possibility of this subspecies being found in the region. Sezen et al (2014) reported that the berry diameter was 5.48 to 7.18 mm and the berry length was at the range of 6.64 to 9.14 mm, respectively in the Coruh valley of Turkey. There was high variation in terms of berry characteristics when compared to the study conducted in Çamardı district. Although there was not as much diversity as in the Coruh valley, a moderate difference was observed in terms of fruit characteristics in Çamardı, Niğde.

5.6 *Hippophae rhamnoides* Seeds

Seed analysis of *H. rhamnoides* was similar to leaf and fruit analysis and it was seen that the variation was driven between the sites.

Solidity variation was quite low when it compared with the leaf and fruit analysis. It can be said that this should be close to solid since it was taken better quality photos than fruit and leaf analysis and the seeds did not have a convex area.

Circularity, perimeter, ellipse perimeter, aspect ratio and roundness gave an idea about the shape characteristics of the seeds and there were moderate differences between the sampling sites of *H. rhamnoides* in Çamardı. However, there were slight differences within some sites. For example, Site 12 had the strongest differences within the sites and it could be said that those trees were phenotypically different but for the other sites the phenotypic differences were less pronounced so it could be said that Site 12 had two clonal structure. This differences might be by genotypic or environmental bases but the only way if there was any genetical differences were shown on the plant was the DNA sequences.

The major elliptical axis and feret length were the length parameters of the seeds. According to the analysis, the longest seeds were found in Site 15 and when compared with fruit length parameters, it was seen that there was a direct proportionality between fruit and seed lengths of *H. rhamnoides* in this site.

The minor elliptical axis and feret width was the width parameters of *H. rhamnoides*. Although the seed width was generally almost constant at all sites, the seeds in Site7 had a wider seed structure than the others. This may be due to that Site 7, which was different from other sites in terms of fruit shape and fruit color, may belong to a different subspecies of *H. rhamnoides* in Çamardı.

According to the study report of Aras and Tayhan (1995), the average values of the seeds originating from Trabzon were determined as 4.273 to 2.060 for the length and width, and 4.200 to 2.084 for the seeds originating from Sivas of the *H. rhamnoides ssp. Caucasica* Rousi fruits, respectively. The length of the seeds taken from nine sites in

Çamardı district were between 3.65 to 4.71 mm while the width of the seeds were found between 2 to 2.64mm. According to these results, it was seen that the seeds in our study were not much different from the seeds of Trabzon and Sivas origin in terms of seed size and width. Although there were similarities, it was not possible to say with certainty that they werethe same subspecies without using molecular detection methods.

5.7 *Hippophae rhamnoides* Germination

According to germination analysis *H. rhamnoides* seeds were investigated under five basic parameters in which three of them were fitting the log-logistic function model while two of them was analyzed by using the data getting from the experiment.

G50 was one of the parameters which was fitting the model and showed how many days needed to get 50% germination of the seeds. Site 15 required the highest days to got 50% germination. This could be related with the genetic or the environmental factors. In general, even if uniform laboratory conditions were provided for seed germination, germination may have taken place later due to the impermeability of the seed coat, mechanical inhibition of embryo development by the seed coat, and the presence of inhibitors against germination in the seed coat.

Gmax was the other parameters that fitted to the log- logistic function. Although there was a moderate variation between sites in general, the highest germination was observedat Site 8. This may be due to the permeability of the seed coat in Site 8 was higher than in other regions. In addition, genetic factors may have affected the germination of the seed.

Slope was also the parameter that was fitted the function and showed the how the germination faster rise. The larger slope had the faster germination and G50 was quickly happened. In this study, the highest slope was at Site 4, and the G50 parameter was expected to be the fastest at Site 4, whereas it belonged to Site 17, indicating a slight variation between the experimental data and the fitted function.

Gday refers to the days to maximum germination and in this study Site 4 had the highest variation within the sites. This may be due to the branches effect coming together of seeds belonging to different branches, even on the same tree.

Germ is done by arithmetically and it was measured parameters. There was a moderate variation between sites in general. Of the sites, six of them were quite fast (Sites 2,4,6, 8,12 and14), two of them a little bit slower (Sites 7 and 15) and one site was much slower (Site17). According to germ maximum propotion of the germination was at Site 2 while for Gmax, maximum proportion of germination was at Site 8. These differences were happened due to germ was the measured parameter and Gmax was the fitted parameter to the curve. Although they were not identical, was a little bit variation and close each other.

5.8 *Hippophae rhamnoides* Ethnobotanical Study in Çamardı

The scientific discipline of ethnobotany is the study of human interactions with plants. *H. rhamnoides* is one of the multipurpose plant in many parts of the world although the usage of the plant are not common in Turkey. This may be due to the high variety of fruits in Turkey and the low requirement for this species.

In our study which conducted in Çamardı, *H. rhamnoides* was commonly named as "Karaçalı" by the local people. Although they knew the plant, nearly 30% of them did not use it for any purposes. 15% of the 21 people used it as a firewood, nearly 24% of them used as a fresh fruit when they were child. 5% of them used as animal feed and other purposes but many of them used this plant as a fencing to protect their field. Due to its thorny structure, people called this plant poisonous. However, the thorny nature of the plant provided an advantage to protect the garden from wild animals and future dangers. Local people, who did not know the beneficial properties of the plant, thought it as a threat in agricultural lands due to the rapid proliferation of the plant and removed it from the field. In addition to its invasive characters, raising public awareness about that it was an important nitrogen source for the soil when used under controlled, gains importance in associating the plant with agriculture.

5.9 ImageJ Advantages and Disadvantages on *Hippophae rhamnoides* Characterization

Precise and accurate measurements of morphological features through image analysis are essential to obtain reliable data. The first premise for image processing analysis is to set the environment in which the image will be taken. Correct setting of ambient lighting contributes to obtaining reliable results. In the study, images were tried to be obtained by using a three-pod light camera system. It was also important to adjust the camera settings and distance settings, and to adjusted the camera height equally for each photo shoot. Otherwise there can be quite difference between the measured results and the actual result. It was essential to use a reference with a certain measurement other than the sample while taking the image. Otherwise, the image can only be processed in pixel size.

By using ImageJ, many features such as length, width, perimeter, roundness, circularity could be analyzed with a single photo frame by analyzing a large number of leaves, fruits and seeds. However, at this stage, especially in fresh fruit analysis, the soft texture of the fruit and the small fruit size made the image acquisition process difficult and time consuming but it is a much more useful method compared to manual measurement for soft texture fruit analysis. Another important issue was that the samples in the image to be taken should not touch each other. Since these objects would be counted as whole in determining the number of fruits, this may affect the distribution negatively. For example, the high number of fruits was at Site 8, made both image acquisition and analysis difficult.

In the leaf analysis, the fact that some leaves had a curved structure in shape required leaf rehydration and pretreatment before the image was obtained.

Seeds were the smallest part of the plant during the analysis. Therefore, ImageJ contributed of doing analysis by the smallest samples without using any caliper or other measurement instrument.

CHAPTER VI

CONCLUSION

The study indicated that there is a moderate biodiversity on most of trees, buds, leaves fruits, seeds morphological characteristics of sea buckthorns. According to Rousi (1971) morphologic characteristics of the subspecies within the populations of *H. rhamnoides* are highly variable but fruit length parameters and shape are characteristic. In addition, Rousi (1971) reported that, *H. rhamnoides ssp. rhamnoides* has the larger and cylindirical shape fruit however, *H. rhamnoides ssp. caucasica* has very small fruit. According to the comparisons in the Rousi (1971) table of the fruit and seed parameters data of *H. rhamnoides* subspecies, *H. rhamnoides ssp. caucasica* and *H. rhamnoides ssp. turcestenica* overlapped with the given data belong to the subspecies and it increased thelikelihood of the same subspecies found in Çamardı district.

Actually, the status of the plant population is look safe at the moment but it is under threat due to people do not value with it such as using the plants as burning or firewood and cutting it out. In our study, there was some diversity on the plant and this diversity might be useful as a wild resource of genes for agricultural plants in the future but appears that most of the propagation clonal which means that diversity can be easily lost. There was not a lot of seedling propagation if so the trees in the clumps were different from each other, the trees would not be alike. Therefore, the clonal nature of this plant may result in loss of genetic material.

This is the outlier population of the plant and represented the potential value for agriculture and to the ecosystem also the plant nesting for birds which are the important part of the ecosystem. Çamardı is a district where the apple farming is done, so that these trees providing some birds to a life and the birds eating the bugs that effect the apple trees. The fact that this plant grows naturally in the region is an indication that it can be cultivated. Breeding with different thornless varieties brought from other regions may also contributed to the cultivation of a new product in the district and thus to employment by opening different branches of industry for Niğde.

In addition, using of the plant in recreation studies, from the positive features of its

invasive character, helps to protect the soil against erosion by transforming bare soils into natural vegetation.

This study also highlights the use of image processing and computer vision technology in agriculture. Morphological characters which are the most important quality characteristics of agricultural products, were examined with a computer vision system that provides more real, high accuracy and reliability, and non-destructive grading, instead of manually inspecting size, color and shape. Although the photographing process is time consuming, image processing techniques can be easily used instead of manual measurements, especially of products with soft structure.

As a conclusion, considering the deficiencies in the implementation of the studies, it is inevitable that the contribution of image processing techniques in agriculture to sustainable agriculture will increase gradually.

REFERENCES

Acharya, S., Tsering S. ve S. Singh. "Seabuckthorn (*Hippophae* sp. L.): New crop opportunity for biodiversity conservation in cold arid trans-Himalayas." ***Journal of Soil and Water Conservation***, 201-204, 2010

Akodagali, J. ve S Balaji. "Computer vision and image analysis based techniques for automatic characterization of fruits a review". ***International Journal of Computer Applications*** 50 (6), 2012.

Alexiades, M., The international encyclopedia of anthropology, 1st ed., ***Wiley Blackwell,*** London, 2018

Ali, T., M. Nafees, A. Maqsood, S. Naqvi, U. Shahzad, H. M. Salman and M. A. Malghani. "Contribution of root anatomical characteristics in fruit profile of pomegranate genotypes to expand productionarea in Pakistan". ***Agronomy*** 810, 2020.

Amiryousefi, M.R., Mohebbi, M. and Tehranifar, A., 2018. Pomegranate seed clustering by machine vision. ***Food Science & Nutrition***, 6(1), 18-26, 2018.

Aras-Tayhan, A. "*Hippophae rhamnoides* ssp. *caucasica* Rousi Tohumlarinin morfolojisi"***, İstanbul Üniversitesi Orman Fakültesi Dergisi***, 45, 97-106, 2014.

Aslan, B. G. ve Yazıcı, K. "Doğanın bize sunduğu görsel şölen: yabani meyveler", ***Türkiye Tohumcular Birliği Dergisi***, 74-79,2018.

Bai, S., K. Nie, S. Ji, S. Chen, Z. Yao, G. Li, C. Tang, and F. Guo. "Response of Chinese seabuckthorn clonal growth and photosynthetic physiological mechanisms toward a soil moisture gradient". ***Iforest - Biogeosciences and Forestry*** 14(4), 2021.

Balduzzi, M., B. M. Binder, A. Bucksch, C. Chang, L. Hong, A. S. Iyer-Pascuzzi, C. Pradal and E. E. Sparks. "Reshaping plant biology: Qualitative and quantitative descriptors for plant morphology". ***Frontiers in PlantScience*** 8, 2017.

Bartish, I. V., N. Jeppsson, G. I. Bartish, R. Lu and H. Nybom. "Inter- and intraspecific genetic variation in *hippophae* (elaeagnaceae) investigated by rapd markers". ***Plant Systematics and Evolution*** 225(1), 85-101, 2000.

Bektaş, M., Ş. B. Bükücü, Akide Ö. ve M. Sütyemez. "Akçadağ ve Hekimhan ilçelerinde yetişen alıç (*Crataeugus* spp.) genotiplerinin bitki ve pomolojiközellikleri", ***Türk Tarım ve Doğa Bilimleri Dergisi*** 4(4): 484–490, 2017

Bhargava, A. and A. Bansal. "Fruits and vegetables quality evaluation using computer vision: a review". ***Journal of King Saud University - Computer and Information Sciences*** 33(3), 243-57, 2021.

Bhattacharjee, P. "Seabuckthorn: a fruit for future", ***Nature Protocols***, 4(1): 19-20, Nisan, 2019.

Gokturk, A., S. Güner and F. Yıldırım. "Seed properties of hawthorn (***Crateagus*** sp.) species and effects of sulfuric acid pretreatments on seed coat thickness", ***VIII International Scientific Agriculture Symposium***, 733-738, 2017.

Bi, Y. ve Y. Zhang. "Role of the different planting age of seabuckthorn forests tosoil amelioration in coal mining subsidence land**". *International Journal of Coal Science & Technology*** 1(2), 192-97, 2014.

Bottema, S., H. Woldring, and B. Aytuğ. "Late quaternary vegetation history of northern Turkey". ***Palaeohistoria***, 13-72, 1995.

Çalişkan, O., K. Gündüz ve S. Bayazit. "Sarı alıç" (*Crataegus azarolus* L.) genotipinin morfolojik, biyolojik ve meyve kalite özelliklerinin incelenmesi". ***Journal of Agricultural Faculty of Gaziosmanpaşa University*** *(JAFAG)* 35, 69-74,2018.

Canada Agriculture and Agri-Food Canada. Seabuckthorn propagation. **Ottawa: Agriculture and Agri-Food Canada**, 2018.

Chandra, S., R. Zafar, P.Dwivedi, P. Borkar and L Shinde. "Pharmacological and nutritional importance of sea buckthorn (*Hippophae)*". ***Innovation Journal***, 2018.

Chen, D., X. Chen, J. Wang, Z. Zhang, Y. Wang, C. Ji, and X. Hu. "Estimation of thermal time model parameters for seed germination in15 Species: The Importance of Distribution Function". ***Seed Science Research*** 31(2), 83- 90, 2021.

Ciesarová, Z., M. Murkovic, K. Cejpek, F. Kreps, B. Tobolková, R. Koplík and E. Belajová. "Why is sea buckthorn (*hippophae rhamnoides* l.) so exceptional? a review". ***Food Research International*** 133, 2020.

Deshmukh, B. S. and V. Shinde. "Fruits in the wilderness: A potential of local food resource." ***International Journal of Pharma and Bio Sciences*** 1(2), 2010.

Dhyani, D., R. K. Maikhuri, S. Misra, and K. S. Rao. "Endorsing the declining indigenous ethnobotanical knowledge system of sea buckthorn in central Himalaya, India". ***Journal of Ethnopharmacology*** 127(2) 329-34, 2010.

Dindaroğlu, T. ve M. Önal. "Yalancı iğde bitkisinin (*Hippophae rhamnoides* L.) bazı ekstrem yayılış alanı özellikleri", ***III. Uluslararası Odun Dışı Orman Ürünleri Sempozyumu***, Kahramanmaraş, Türkiye, 951-957, 2014

Elford, E. "Introduction to sea buckthorn". ***Onspecialtycrops***, 2013.

Emre, G., M. Haznedaroğlu, A. Doğan, H. Koyu and E. Tuzlacı. "Anethnobotanical study of medicinal plants in Acipayam (Denizli-Turkey)". ***Journal of Herbal Medicine***, 2017.

Enescu, C. "Sea-buckthorn: A species with a variety of uses, especially in land reclamation". ***Dendrobiology*** 72**,** 41-46, 2014.

Erc, S. “Comparison of sea buckthorn genotypes (hippophae rhamnoides L.) based onRAPD and FAME Data”, ***Turkish Journal of Agriculture and Forestry***,363-368, 2008.

Ercisli, S. “A short review of the fruit germplasm resources of Turkey”. ***Genetic Resources and Crop Evolution*** 51 (4), 419-35, 2004.

Fahad, S. “Ethnobotanical and physiological studies of some endangered plant species collected from two different altitudes in Gilgit Baltistan”. https://www.academia.edu/81111632/

Gao, X., M. Ohlander, N. Jeppsson, L. Björk and V. Trajkovski. “Changes in antioxidant effects and their relationship to phytonutrients in fruits of sea buckthorn (*Hippophae rhamnoides* l.) during maturation”. ***Journal of Agriculturaland Food Chemistry*** 48(5), 1485-90, 2000.

Gassmann, M., B. Grenacher, B. Rohde and J. Vogel. “Quantifying western blots: pitfalls of densitometry”. ***Electrophoresis*** 30(11), 1845-55, 2009.

Gül, V. “Rize yöresine ait tıbbi ve aromatik bitkilere genel bir bakış”, ***Iğdır Üniversitesi Fen Bilimleri Enstitüsi Dergisi***, 97-107, 2014

Güleryüz, M., E. Orhan, Y. Erturk and H. Karlidag. “The use of wildedible fruits in sustainable fruit production in turkey”, ***1st International Symposium on Sustainable Development***, 78-82, 2009.

Güneş, F. and N. Ozhatay. “An ethnobotanical study from Kars (Eastern) Turkey”. ***Biological Diversity and Conservation*** 4, 30-41, 2011.

Gürdal, B. and Ş. Kültür. “An ethnobotanical study of medicinal plants in Marmaris (Muğla, Turkey)”. ***Journal of Ethnopharmacology*** 146(1), 113-26, 2013.

Hassanpour, H., Y. Hamidoghli and H. Samizadeh. “Some fruit characteristics of iranian cornelian cherries (Cornus Mas L.)”. ***Notulae Botanicae Horti Agrobotanici Cluj-Napoca*** 40 (1), 247-52, 2012.

Hayit, T., H. Erbay ve F. Hayit. “Gıda sektöründe uygulanan görüntü işleme çalışmalarının ve tekniklerinin incelenmesi”. ***Electronic Letters on Science and Engineering*** 14 (1), 12-22, 2018.

Hazarika, T. and T. Singh. “Wild edible fruits of manipur, india: associated traditional knowledge and implications to sustainable livelihood”. ***Genetic Resources and Crop Evolution*** 65, 2018.

Ilhan, G., M. Gundogdu, K. Karlović, V. Židovec, A. Vokurka and S. Ercişli. “Main agro-morphological and biochemical berry characteristics of wild- grown sea buckthorn (hippophae rhamnoides l. ssp. caucasica rousi) genotypes in Turkey”. ***Sustainability*** 13(3), 1198, 2021.

Iwata, H. and Y. Ukai. “SHAPE: A computer program package for quantitative evaluation of biological shapes based on elliptic fourier descriptors”. ***The Journal of heredity*** 93, 384-85, 2002.

Jaganathan, A. and S. M. Kumar. “A study on image based techniques for fruits and meat”. *International* ***Journal for Innovative Research in Science & Technology*** 3,233-38,2017.

Jaroszewska, A., W. Biel, A. Jaroszewska and W. Biel. “Chemical composition and antioxidant activity of leaves of mycorrhized sea-buckthorn (*Hippophae rhamnoides* L.)”. ***Chilean Journal of Agricultural Research*** 77(2) 155-62 , 2017.

Jman R. S.. “Wild edible plants and their traditional use in the human nutritioninbosnia-herzegovina”. ***Ecology of Food and Nutrition*** 45(3) 189- 232, 2006..

Kadioğlu, Z., K. Çukadar, A. Kandemir, N. N. Kalkan, H. Vurgun ve V. Dönderalp. "Kars ilinde sebze olarak tüketilen yabani bitki türlerinin tespiti ve kullanım şekilleri". ***Anadolu Ege Tarımsal Araştırma Enstitüsü Dergisi,*** 11-32, 2020.

Kallio, H., B. Yang and P. Peippo. "Effects of different origins and harvesting time on vitamin C, tocopherols, and tocotrienols in sea buckthorn (*hippophae rhamnoides*) berries". ***Journal of Agricultural and Food Chemistry*** 50(21), 2002.

Kanayama, Y., W. Ohkawa, E. Chiba, K. Sato, K. Kanahama and J. Ofosu-Anim. "Nutritional components and nitrogen fixation in sea buckthorn (*Hippophae rhamnoides* L.)". ***Acta Horticulturae,*** 806, 309-14, 2009.

Karagöz, A., N. Zencirci, A. Tan, T. Taskin, H. Köksel, M. Sürek, C. Toker ve K. Ozbek. "Bitki genetik kaynaklarinin korunmasi ve kullanimi". ***Türkiye Ziraat Mühendisligi VII Teknik Kongresi*** 1, 155-77, 2010.

Karakaya, S., A. Polat, Ö. Aksakal, Y. Z. Sümbüllü and Ü. İncekara. "Ethnobotanical study of medicinal plants in aziziye district (Erzurum, Turkey)".***Turkish Journal of Pharmaceutical Sciences*** 17(2), 211-20, 2020.

Kato, K., Y. Kanayama, W. Ohkawa and K. Kanahama. "Nitrogen fixation in sea buckthorn (*Hippophae rhamnoides*) root nodules and effect of nitrate on nitrogenase activity". ***Engei Gakkai Zasshi*** 76, 185-90, 2007.

Kendir, G. ve A. Güvenç. "Etnobotanik ve Türkiye'de yapılmış etnobotanik çalışmalara genel bir bakış". ***Hacettepe University Journal of the Faculty of Pharmacy,*** **sy** 1, 49-80, 2010.

Klimešová, J., J. Martínková, J. G. Pausas, M. G. de Moraes, T. Herben, F. H. Yu and J. Puntieri. "Handbook of standardized protocols for collecting plant modularity traits". ***Perspectives in Plant Ecology, Evolution andSystematics*** 40, 125485, 2019.

Krejcarová, J., E. Straková, P. Suchý, I. Herzig and K. Karásková. "Sea buckthorn (hippophae rhamnoides l.) as a potential source of nutraceutics and its therapeutic possibilities - a review". ***Acta Veterinaria Brno*** 84(3), 257-68, 2015.

Kültür, Ş. "An ethnobotanical study of Kırklareli (Turkey)". ***Phytologia Balcanica*** 14, 279-89, 2008.

Letchamo, W., M. Ozturk, V. Altay, M. Musayev, N. A. Mamedov and K. R. Hakeem. "An alternative potential natural genetic resource: sea buckthorn [*elaeagnus rhamnoides* (Syn.: *Hippophae rhamnoides*)]". İçinde Global Perspectives on Underutilized Crops, ***Springer International Publishing***, 2018.

Li, H., C. Ruan, J. Ding, J. Li, L. Wang and X. Tian. "Diversity in sea buckthorn (*Hippophae rhamnoides* L.) accessions with different origins based on morphological characteristics, oil traits, and microsatellite markers". EditörShailendra Goel. ***PLOS ONE*** 15(3), e0230356, 2020.

Li, T. S. C. and W. R. Schroeder. "Sea buckthorn (*Hippophae rhamnoides* L.): a multipurpose plant". ***HortTechnology*** 6(4), 370-80, 1996.

Li, T. S. C. "Sea Buckthorn: New Crop Opportunity", ***Journal of Soil and Water Conservation***, 9(3), 201-204, 2010

Luta, D., G. Msalya and E. Mtengeti. "A review of plant characterization: First step towards sustainable forage production in challenging environments". ***African Journal of Plant Science*** 14, 350-57, 2020.

Maeda, H., T. Akagi and R. Tao. "Quantitative Characterization of Fruit Shape and Its Differentiation Pattern in Diverse Persimmon (*Diospyros kaki*) Cultivars". ***Scientia Horticulturae*** 228, 41-48, 2018.

Mathew, D., P.n Thangaraj, S. Gomez and Z. Ahmed. "Characterizationof seabuckthorn (*Hippophae* spp.) genetic resources in India using morphological descriptors". ***Plant genetic resources newsletter*** *(Rome, Italy: 1979)* 149, 2007.

Mir, N., S. M. Geelani, R. Bhat, H. Qadri and B. Beigh. "Seabuckthorn (*Hippophae* spp.): A Unique high altitude multipurpose plant species growing in cold regions", ***International Journal of Advance Research in Science and Engineering***, 1941-1952, 2018

Mussadiq, Z., B. Laszlo, L. Helyes and C. Gyuricza. "Evaluation andcomparison of open source program solutions for automatic seed counting on digital images". ***Computers and Electronics in Agriculture*** 117, 194-99 2015.

Nazir, N., M. Zahoor and M. Nisar. "A review on traditional uses and pharmacological importance of genus elaeagnus species". ***The BotanicalReview*** 86(3), 247-80, 2020.

Nohutçu, L., M. Tunçtürk ve R. Tunçtürk. "Yabani bitkiler ve sürdürülebilirlik", ***Yüzüncü Yıl Üniversitesi Fen Bilimleri Enstitüsü Dergisi*** 24(2), 142-151, 2019

Oliveira, A. D.. Sustainability of Agroecosystems. ***BoD – Books on Demand***, 2018.

Omid, M., M. Khojastehnazhand and A. Tabatabaeefar. "Estimating volume and mass of citrus fruits by image processing technique." ***Journal of Food Engineering*** 100(2), 315-21, 2010.

Ornduff, R. "Reproductive characters and taxonomy". ***Systematic Botany*** 3(4), 420-27, 1978.

Özbek, H. "Cinsel ve jinekolojik sorunların tedavisinde bitkilerin kullanımı", ***Van Tıp Dergisi***: 12 (2):170-174, 2005

Özbek, H. "Omaloplia spireae spireae (pallas) (Coleoptera: Scarabaeidae), A newpestof sea buckthorn, *Hippophae rhamnoides* L., in Turkey", ***Turkish Journal of Zoology*** 35(3):437-440, 2011

Özgen, U., Y. Kaya and M. Coşkun. "Ethnobotancal studies in the villages ofthedistrict of Ilıca (province Erzurum), Turkey". ***Economic Botany*** 58(4), 691- 96 2004.

Rajchal, R. “Seabuckthorn (Hippophae Salicifolia) Management Guide”, t.y., 45. Rasmussen, Laura Vang, Cristy Watkins, ve Arun Agrawal. “Forest contributions to livelihoods in changing agriculture forest landscapes”. ***Forest Policy and Economics*** 84, 1-8, 2017.

Regina, S., P. P. Silva, F. d. S. Araújo, F. Fernandes and W. Nascimento. “Tomato seed image analysis during the maturation”. ***Journal of Seed Science*** 41, 22-31, 2019.

Rêgo, M. D. C. A., A. C. D. A. Lopes, R. F. M. D. Barros, A. M. Lamas, M. F. Costa and R. L. F. Gomes. “Morphological characterization and genetic diversityin ornamental specimens of the genus sansevieria”. ***Revista Caatinga*** 33(4), 985-92, 2020.

Rongsen, L. and H Ahani. “The genetic resources of hippophae genus and its utilization”, ***Advance in Agriculture and Biology*** 1 (2) 27-31, 2013

Rop, O., S. Ercişli, J. Mlcek, T. Jurikova and I. Hoza. “Antioxidant and radical scavenging activities in fruits of 6 sea buckthorn (*Hippophae rhamnoides* L.) cultivars”. ***Turk J Agric For***, t.y., 9.

Rousi, A.. “The genus hippophaë l. a taxonomic study”. ***Annales Botanici Fennici*** 8(3), 177-227, 1971.

Saied, A. S., J. Gebauer, K. Hammer and A. Buerkert. “Ziziphus spina- christi (l.) willd.: A multipurpose fruit tree”. ***Genetic Resources and Crop Evolution***55 (7), 929-37, 2008.

Salvaña, F. R., K. Eco, N. Madarcos and N. Bautista. “Leaf morphological characterization and cluster analysis of vitex negundo morphotypes”. ***Environmental and Experimental Biology*** 17, 75-83, 2019.

Samtaş, G. and M. Gülesin. “Sayısal görüntü işleme ve farklı alanlardaki uygulamaları**”.** ***Ejovoc*** 2(1), 85-97 2012.

Sapio, O. di, M. Bueno, H. Busilacchi, M. Quiroga and C. Severin. "Morphoanatomical characterization of salvia hispanica l. (lamiaceae) leaf, stem, fruit and seed." ***Boletín Latinoamericano y del Caribe de Plantas Medicinales y Aromáticas*** 11(3), 249-68 2012.

Sardeshpande, M. and C. Shackleton. "Wild edible fruits: a systematic review of an under researched multifunctional ntfp (Non-Timber Forest Product)". ***Forests*** 10(6), 467, 2019.

Sargın, S. A., E. Akçicek and S. Selvi. "An ethnobotanical study of medicinal plants used by the local people of Alaşehir (Manisa) in Turkey". ***Journal of Ethnopharmacology*** 150(3), 860-74, 2013.

Sezen, I., S. Ercisli, O. Cakir, A. Koc, E. Temim and A. Hadziabulic. "Biodiversity and landscape use of sea buckthorn (*Hippophae rhamnoides* L.) in the coruh valley of Turkey". ***Erwerbs-Obstbau*** 57(1), 23-28, 2015.

Shahzadi, N. ve T. K. Noor. "Morphological characterization and ethnobotanical studies of *hippophae rhamnoides sub sp. Turkestanica* from oshikhandas and bagrot valleys of district Gilgit, Pakistan." ***Journal of Interdisciplinary Biosciences***1, 7-10, 2017.

Shajahan, S., Agricultural Field Applications of Digital Image Processing Using an Open-Source ImageJ Platform, Yüksek Lisans Tezi, ***North Dakota State University***, Kuzey Dakota 2019.

Sharma, A., V. Singh, A. Sharma and N. Negi. "Sea buckthorn a newapproach in ecological restoration of Himalayan ecosystem: a review", ***International Journal of Chemical Studies*** 7(1): 1219-1226, 2019

Shiddiq, M., R. Salambue, R. Poja and A. Trianov Solistio. "Analysis ofphysical properties of oil palm fresh fruit bunches using imagej". ***Applied ScienceandTechnology*** 1(1), 388-94, 2017.

Silva, H. C. H., R. L. F. Caraciolo, L. C. Marangon, M. A. Ramos, L. L. Santos ve U. P. Albuquerque. "Evaluating different methods used in ethnobotanical and ecological studies to record plant biodiversity". ***Journal of Ethnobiology and Ethnomedicine*** 10, 48, 2014.

Singh, V. "Geographical adaptation and distribution of sea buckthorn (*Hippophae*L.) Resources", ***A Multipurpose Wonder Plant***, 21-34 ,2003.

Small, E., P. Catling and T.S.C. Li. "Blossoming treasures of biodiversity: sea buckthorn (*Hippophae rhamnoides*)-an ancient crop with modern virtues". ***Biodiversity*** 3, 25-27, 2002.

Sun, K., W. C., R. Ma, X. Chen, A. Li and S. Ge. "Genetic variation in*hippophae rhamnoides ssp. sinensis (Elaeagnaceae)* revealed by RAPD markers". ***Biochemical Genetics*** 44(5), 186-97, 2006.

Suryakumar, G. ve A. Gupta. "Medicinal and therapeutic potential of sea buckthorn (*Hippophae rhamnoides* L.)". ***Journal of Ethnopharmacology*** 138(2), 268-78, 2011.

Tan, A. "Türkiye bitki genetik kaynaklari ve muhafazasi", ***Anadolu Journal of AARI***, 9-37, 2010

Pei, S., H. Alan and Y. Wang. "Vital roles for ethnobotany in conservationand sustainable development". ***Plant Diversity*** 42(6), 399-400, 2020.

Treder, W., K. Klamkowski, A. Tryngiel-Gać and K. Wójcik. "Application of imagej software in the assessment of flowering intensity and growth Vigor of Pear Trees", ***Journal of Horticultural Research***, 20-30, 2021

Tüysüz, B., Ö. Çakir ve E. Dertli. "Bazı yabani meyve türlerinin antioksidanpotansiyeli ve fenolik asit profilinin belirlenmesi". ***European Journal of Science and Technology***, 2020.

URL1, Morfolojik görüntü işleme yöntemleri ile kayısılarda yaprak delen (çil) hastalığı sonucu oluşan lekelerin tespiti. https://docplayer.biz.tr/19573325-Morfolojik goruntu isleme yontemleri ile kayisilarda yaprak delen çil hastaligi sonucu olusan lekelerin tespiti.

Vale, A. M. P. G., M. Ucchesu, C. Di Ruberto, A. Loddo, J. M. Soares, and G. Bacchetta. "Anew automatic approach to seed image analysis: From acquisition to segmentation", https://arxiv.org/abs/2012.06414, 11 Aralık 2020

Vinson, J. A., X. Su, L. Zubik and P. Bose. "Phenol antioxidant quantity andquality in foods: fruits". ***Journal of Agricultural and Food Chemistry*** 49(11), 5315-21 2001.

Yaman, M. ve S. Turan. "some fruit and leaf characteristics of different apricot cultivars in Kayseri". ***Erzincan Üniversitesi Fen Bilimleri Enstitüsü Dergisi*** 14, 962- 69, 2021.

Yildiz, H., M. Şengül, F. Celik and B. Duralija. "Bioactive content of sea buckthorn (*Hippophae rhamnoides* L.) berries from Turkey". ***Agriculturae ConspectusScientificus (ACS)*** 77, 53-55, 2012.

APPENDICES

Table A1. GPS coordinates of *Hippophae rhamnoides* populations from 18 Sites.

Site	N	E	Latitude	Longitude	Altitude
1	37°51'35.9442"	35°03’29.4203"	37.8600	35.0582	1491
2	37°51’37.8778"	35°03'29.7662"	37.8600	35.0582	1501
3	37°50'10.4834"	35°02’54.8970"	37.8362	35.0486	1441
4	37°49’38.0482"	35°02'21.3223"	37.8272	35.0393	1441
5	37°48’52.0499"	35°02’11.9753"	37.8145	35.0367	1409
6	37°47'47.9292"	35°01'06.0463"	37.7966	35.0183	1396
7	37°57'17.8585"	35°05'12.6146"	37.9550	35.0868	1755
8	37°54'01.8630"	35°04'38.6893"	37.9005	35.0774	1559
9	37°54’01.3453"	35°04’37.0240"	37.9004	35.0770	1543
10	37°51'10.6765"	35°03'25.2475"	37.8530	35.0570	1463
11	37°51’06.7360"	35°03'17.6054"	37.8519	35.0549	1466
12	37°47'21.9372"	35°00’27.6491"	37.7894	35.0077	1413
13	37°51'11.7025"	35°03'19.7082"	37.8533	35.0555	1479
14	37°51'11.6042"	35°03’19.7194"	37.8532	35.0555	1479
15	37°48'41.9706"	34°59'40.6158"	37.8117	34.9946	1426
16	37°47’17.5600"	35°00'24.2244"	37.7882	35.0067	1413
17	37°47’17.4510"	35°00'23.7373"	37.7882	35.0066	1413
18	37°47'15.9342"	35°00’21.8365"	37.7878	35.0061	1437

TableA2. *Hippophae rhamnoides* tree data

Unit	Site	Tree	TreeeNo	Sex	PlantType	TrunkDiam	TreeHeight
1	1	1-1	1	M	Shrub	40	4.94
2	1	1-2	2	M	Shrub	55	3.52
3	1	1-3	3	M	Shrub	110	4.44
4	1	1-4	4	M	Shrub	50	1.82
5	1	1-5	5	M	Shrub	30	2.16
6	2	2-1	1	**F**	Shrub	60	3.11
7	2	2-2	2	**F**	Shrub	80	2.23
8	2	2-3	3	**F**	Shrub	45	1.66
9	2	2-4	4	**F**	Shrub	80	3.53
10	2	2-5	5	**F**	Shrub	20	1.81
11	3	3-1	1	M	Shrub	70	4.00
12	3	3-2	2	M	Tree	50	2.61
13	3	3-3	3	M	Tree	40	2.35
14	3	3-4	4	M	Shrub	20	1.54
15	3	3-5	5	M	Shrub	50	1.70
16	4	4-1	1	**F**	Multistem	120	2.50
17	4	4-2	2	**F**	Tree	40	5.32
18	4	4-3	3	**F**	Tree	50	3.65
19	4	4-4	4	**F**	Tree	50	3.00
20	4	4-5	5	**F**	Multistem	60	4.00
21	5	5-1	1	M	Tree	70	4.40
22	5	5-2	2	M	Tree	50	3.07
23	5	5-3	3	M	Tree	50	4.83
24	5	5-4	4	M	Tree	50	5.47
25	5	5-5	5	M	Multistem	20	2.16
26	6	6-1	1	**F**	Shrub	20	1.42
27	6	6-2	2	**F**	Shrub	20	1.62
28	6	6-3	3	**F**	Shrub	30	2.53
29	6	6-4	4	**F**	Tree	50	2.20
30	6	6-5	5	**F**	Tree	50	2.52
31	7	7-1	1	**F**	Multistem	50	4.95
32	7	7-2	2	**F**	Multistem	70	4.34
33	7	7-3	3	**F**	Multistem	120	5.46
34	7	7-4	4	**F**	Multistem	80	3.61
35	7	7-5	5	**F**	Shrub	30	3.36
36	8	8-1	1	**F**	Shrub	100	3.23
37	8	8-2	2	**F**	Multistem	70	3.21
38	8	8-3	3	**F**	Multistem	110	3.90
39	8	8-4	4	**F**	Multistem	40	3.66
40	8	8-5	5	**F**	Multistem	30	3.17
41	9	9-1	1	M	Multistem	200	6.11
42	9	9-2	2	M	Shrub	30	1.80
43	9	9-3	3	M	Tree	220	6.36
44	9	9-4	4	M	Tree	90	6.46

45	9	9-5	5	M	Tree	60	3.55
46	10	10-1	1	M	Shrub	10	2.20
47	10	10-2	2	M	Tree	20	3.37
48	10	10-3	3	M	Multistem	20	3.08
49	10	10-4	4	M	Multistem	30	3.70
50	10	10-5	5	M	Tree	10	3.60
51	11	11-1	1	M	Multistem	10	3.07
52	11	11-2	2	M	Multistem	20	2.26
53	11	11-3	3	M	Shrub	30	2.86
54	11	11-4	4	M	Multistem	30	2.56
55	11	11-5	5	M	Tree	30	3.00
56	12	12-1	1	**F**	Multistem	30	3.98
57	12	12-2	2	**F**	Tree	90	4.03
58	12	12-3	3	**F**	Tree	70	4.07
59	12	12-4	4	**F**	Multistem	40	3.55
60	12	12-5	5	**F**	Tree	60	3.20
61	13	13-1	1	M	Shrub	30	2.45
62	13	13-2	2	M	Shrub	30	2.50
63	13	13-3	3	M	Multistem	30	2.10
64	13	13-4	4	M	Shrub	10	2.32
65	13	13-5	5	M	Shrub	20	2.59
66	14	14-1	1	**F**	Multistem	50	3.50
67	14	14-2	2	**F**	Multistem	50	4.31
68	14	14-3	3	**F**	Multistem	70	3.68
69	14	14-4	4	**F**	Multistem	70	2.45
70	14	14-5	5	**F**	Multistem	40	2.88
71	15	15-1	1	**F**	Multistem	50	6.00
72	15	15-2	2	**F**	Tree	50	4.28
73	15	15-3	3	**F**	Tree	40	3.31
74	15	15-4	4	**F**	Tree	30	2.34
75	15	15-5	5	**F**	Multistem	30	2.85
76	16	16-1	1	M	Shrub	40	2.30
77	16	16-2	2	M	Shrub	10	1.46
78	16	16-3	3	M	Shrub	10	1.09
79	16	16-4	4	M	Shrub	15	1.92
80	16	16-5	5	M	Shrub	10	2.09
81	17	17-1	1	**F**	Shrub	40	2.38
82	17	17-2	2	**F**	Shrub	30	2.34
83	17	17-3	3	**F**	Shrub	40	2.81
84	17	17-4	4	**F**	Shrub	70	3.85
85	17	17-5	5	**F**	Shrub	50	2.61
86	18	18-1	1	M	Shrub	10	1.73
87	18	18-2	2	M	Shrub	10	2.28
88	18	18-3	3	M	Shrub	10	1.89
89	18	18-4	4	M	Shrub	5	1.55
90	18	18-5	5	M	Shrub	20	3.00

Table A3. *Hippophae rhamnoides* branch data

Uni	Site	Tree	TreeNo	Branch	BranchNo	FruitFW	FruitFW.old	FruitDW	FruitDW.old	NoFruitLn	Fruits	Fruits.old
1	2	2-1	1	2-1-1	1	11.69	NA	3.35	NA	165	132	NA
2	2	2-1	1	2-1-2	2	9.72	NA	2.83	NA	145	98	NA
3	2	2-1	1	2-1-3	3	1.96	NA	0.58	NA	144	26	NA
4	2	2-1	1	2-1-4	4	6.77	NA	1.85	NA	205	73	NA
5	2	2-2	2	2-2-1	1	8.01	NA	2.21	NA	183	66	NA
6	2	2-2	2	2-2-2	2	4.15	NA	1.19	NA	200	44	NA
7	2	2-2	2	2-2-3	3	16.01	NA	4.39	NA	120	138	NA
8	2	2-2	2	2-2-4	4	19.54	NA	5.42	NA	183	193	NA
9	2	2-3	3	2-3-1	1	19.39	NA	5.55	NA	65	180	NA
10	2	2-3	3	2-3-2	2	31.41	NA	9.41	NA	106	301	NA
11	2	2-3	3	2-3-3	3	16.67	NA	4.71	NA	133	132	NA
12	2	2-3	3	2-3-4	4	24.97	NA	7.16	NA	105	218	NA
13	2	2-4	4	2-4-1	1	10.56	NA	2.88	NA	152	86	NA
14	2	2-4	4	2-4-2	2	8.93	NA	2.40	NA	107	74	NA
15	2	2-4	4	2-4-3	3	5.38	NA	1.45	NA	84	49	NA
16	2	2-4	4	2-4-4	4	26.52	NA	7.55	NA	87	279	NA
17	2	2-5	5	2-5-1	1	72.00	NA	0.77	NA	132	32	NA
18	2	2-5	5	2-5-2	2	0.90	NA	0.26	NA	289	11	NA
19	2	2-5	5	2-5-3	3	1.67	NA	0.49	NA	205	25	NA
20	2	2-5	5	2-5-4	4	4.03	NA	1.15	NA	158	51	NA
21	4	4-1	1	4-1-1	1	1.05	NA	0.29	NA	100	8	NA
22	4	4-1	1	4-1-2	2	2.73	NA	1.47	NA	150	36	NA
23	4	4-1	1	4-1-3	3	4.17	NA	1.12	NA	175	30	NA
24	4	4-1	1	4-1-4	4	1.57	NA	0.46	NA	116	11	NA
25	4	4-2	2	4-2-1	1	4.80	NA	1.24	NA	181	36	NA
26	4	4-2	2	4-2-2	2	3.44	NA	0.90	NA	228	26	NA
27	4	4-2	2	4-2-3	3	0.37	NA	0.09	NA	248	3	NA
28	4	4-2	2	4-2-4	4	2.67	NA	0.74	NA	253	19	NA
29	4	4-3	3	4-3-1	1	12.24	NA	3.44	NA	225	95	NA
30	4	4-3	3	4-3-2	2	2.94	NA	0.78	NA	92	20	NA
31	4	4-3	3	4-3-3	3	7.23	NA	1.85	NA	289	50	NA
32	4	4-3	3	4-3-4	4	2.60	NA	0.71	NA	212	19	NA
33	4	4-4	4	4-4-1	1	0.85	NA	0.24	NA	240	5	NA
34	4	4-4	4	4-4-2	2	8.91	NA	2.37	NA	73	52	NA
35	4	4-4	4	4-4-3	3	7.31	NA	2.22	NA	208	50	NA
36	4	4-4	4	4-4-4	4	2.68	NA	0.75	NA	109	18	NA
37	4	4-5	5	4-5-1	1	9.23	NA	2.42	NA	288	56	NA
38	4	4-5	5	4-5-2	2	11.10	NA	2.96	NA	279	68	NA
39	4	4-5	5	4-5-3	3	10.32	NA	2.77	NA	192	70	NA
40	4	4-5	5	4-5-4	4	22.89	NA	6.20	NA	249	146	NA
41	6	6-1	1	6-1-1	1	1.86	NA	0.51	NA	176	20	NA
42	6	6-1	1	6-1-2	2	4.29	NA	1.18	NA	> 400	42	NA
43	6	6-1	1	6-1-3	3	3.33	NA	0.89	NA	> 300	31	NA
44	6	6-1	1	6-1-4	4	1.66	NA	0.48	NA	> 300	17	NA

46	6	6-2	2	6-2-2	2	2.43	NA	0.68	NA	> 300	NA	NA
47	6	6-2	2	6-2-3	3	NA	NA	NA	NA	> 300	NA	NA
48	6	6-2	2	6-2-4	4	NA	NA	NA	NA	> 300	NA	NA
49	6	6-3	3	6-3-1	1	8.99	NA	2.50	NA	> 300	70	NA
50	6	6-3	3	6-3-2	2	19.74	NA	5.88	NA	> 300	148	NA
51	6	6-3	3	6-3-3	3	NA	NA	NA	NA	> 300	NA	NA
52	6	6-3	3	6-3-4	4	NA	NA	NA	NA	> 300	NA	NA
53	6	6-4	4	6-4-1	1	10.57	17.93	2.76	4.7	> 400	71	132
54	6	6-4	4	6-4-2	2	10.11	20.54	2.58	5.63	> 300	73	147
55	6	6-4	4	6-4-3	3	8.03	6.4	2.06	1.71	> 300	64	49
56	6	6-4	4	6-4-4	4	4.40	NA	1.18	NA	NA	37	NA
57	6	6-5	5	6-5-1	1	6.11	13.67	1.54	3.6	> 400	NA	104
58	6	6-5	5	6-5-2	2	6.04	16.76	1.54	4.22	> 400	49	NA
59	6	6-5	5	6-5-3	3	NA	4.84	NA	1.25	NA	NA	38
60	6	6-5	5	6-5-4	4	NA	NA	NA	NA	NA	NA	NA
61	7	7-1	1	7-1-1	1	13.83	NA	3.90	NA	183	87	NA
62	7	7-1	1	7-1-2	2	6.26	NA	1.72	NA	282	36	NA
63	7	7-1	1	7-1-3	3	6.21	NA	1.71	NA	233	33	NA
64	7	7-1	1	7-1-4	4	10.96	NA	3.03	NA	215	63	NA
65	7	7-2	2	7-2-1	1	3.29	NA	1.02	NA	300	20	NA
66	7	7-2	2	7-2-2	2	7.19	NA	2.13	NA	293	42	NA
67	7	7-2	2	7-2-3	3	7.87	NA	2.26	NA	260	41	NA
68	7	7-2	2	7-2-4	4	5.48	NA	1.57	NA	270	31	NA
69	7	7-3	3	7-3-1	1	3.83	NA	1.20	NA	> 300	26	NA
70	7	7-3	3	7-3-2	2	11.77	NA	3.76	NA	214	98	NA
71	7	7-3	3	7-3-3	3	10.03	NA	3.13	NA	210	85	NA
72	7	7-3	3	7-3-4	4	8.42	NA	2.90	NA	249	71	NA
73	7	7-4	4	7-4-1	1	6.35	NA	1.99	NA	293	34	NA
74	7	7-4	4	7-4-2	2	12.41	NA	3.83	NA	210	65	NA
75	7	7-4	4	7-4-3	3	6.17	NA	2.02	NA	261	39	NA
76	7	7-4	4	7-4-4	4	5.70	NA	1.72	NA	275	30	NA
77	7	7-5	5	7-5-1	1	8.08	NA	2.29	NA	> 400	41	NA
78	7	7-5	5	7-5-2	2	7.44	NA	2.12	NA	> 400	36	NA
79	7	7-5	5	7-5-3	3	6.52	NA	1.85	NA	> 400	29	NA
80	7	7-5	5	7-5-4	4	11.57	NA	3.20	NA	> 400	58	NA
81	8	8-1	1	8-1-1	1	10.52	NA	4.15	NA	65	233	NA
82	8	8-1	1	8-1-2	2	13.87	NA	5.62	NA	82	316	NA
83	8	8-1	1	8-1-3	3	22.11	NA	9.10	NA	73	499	NA
84	8	8-1	1	8-1-4	4	23.36	NA	8.98	NA	70	463	NA
85	8	8-2	2	8-2-1	1	6.83	NA	2.44	NA	255	94	NA
86	8	8-2	2	8-2-2	2	10.22	NA	3.53	NA	171	162	NA
87	8	8-2	2	8-2-3	3	4.70	NA	1.70	NA	99	82	NA
88	8	8-2	2	8-2-4	4	8.21	NA	3.05	NA	152	137	NA
89	8	8-3	3	8-3-1	1	19.81	NA	7.33	NA	115	296	NA
90	8	8-3	3	8-3-2	2	12.92	NA	5.18	NA	124	240	NA
91	8	8-3	3	8-3-3	3	12.04	NA	4.58	NA	114	214	NA
92	8	8-3	3	8-3-4	4	11.88	NA	4.41	NA	103	189	NA

93	8	8-4	4	8-4-1	1	15.36	NA	5.48	NA	292	265	NA
94	8	8-4	4	8-4-2	2	9.41	NA	3.45	NA	105	170	NA
95	8	8-4	4	8-4-3	3	23.00	NA	8.60	NA	115	415	NA
96	8	8-4	4	8-4-4	4	7.88	NA	2.88	NA	90	146	NA
97	8	8-5	5	8-5-1	1	4.48	NA	1.67	NA	84	80	NA
98	8	8-5	5	8-5-2	2	8.18	NA	2.81	NA	170	130	NA
99	8	8-5	5	8-5-3	3	7.99	NA	2.71	NA	105	138	NA
100	8	8-5	5	8-5-4	4	0.31	NA	0.12	NA	119	6	NA
101	12	12-1	1	12-1-1	1	2.34	NA	0.77	NA	> 400	14	NA
102	12	12-1	1	12-1-2	2	3.36	NA	1.05	NA	> 400	20	NA
103	12	12-1	1	12-1-3	3	1.99	NA	0.58	NA	> 400	11	NA
104	12	12-1	1	12-1-4	4	4.70	NA	1.39	NA	> 400	27	NA
105	12	12-2	2	12-2-1	1	6.02	NA	1.60	NA	> 300	NA	NA
106	12	12-2	2	12-2-2	2	6.50	NA	1.79	NA	240	NA	NA
107	12	12-2	2	12-2-3	3	9.91	NA	2.56	NA	298	NA	NA
108	12	12-2	2	12-2-4	4	9.25	NA	1.90	NA	293	NA	NA
109	12	12-3	3	12-3-1	1	13.92	NA	3.85	NA	73	NA	NA
110	12	12-3	3	12-3-2	2	11.85	NA	3.14	NA	113	71	NA
111	12	12-3	3	12-3-3	3	32.91	NA	8.45	NA	143	NA	NA
112	12	12-3	3	12-3-4	4	9.56	NA	2.47	NA	92	55	NA
113	12	12-4	4	12-4-1	1	0.96	NA	0.30	NA	> 300	12	NA
114	12	12-4	4	12-4-2	2	1.21	NA	0.39	NA	> 300	15	NA
115	12	12-4	4	12-4-3	3	3.04	NA	0.92	NA	> 300	31	NA
116	12	12-4	4	12-4-4	4	0.79	NA	0.26	NA	> 300	9	NA
117	12	12-5	5	12-5-1	1	6.36	NA	1.91	NA	123	58	NA
118	12	12-5	5	12-5-2	2	5.82	NA	1.78	NA	98	61	NA
119	12	12-5	5	12-5-3	3	8.40	NA	2.46	NA	111	77	NA
120	12	12-5	5	12-5-4	4	21.00	NA	6.22	NA	107	174	NA
121	14	14-1	1	14-1-1	1	6.02	NA	2.14	NA	245	80	NA
122	14	14-1	1	14-1-2	2	8.01	NA	2.65	NA	224	103	NA
123	14	14-1	1	14-1-3	3	9.58	NA	3.24	NA	> 300	109	NA
124	14	14-1	1	14-1-4	4	5.34	NA	1.84	NA	> 300	62	NA
125	14	14-2	2	14-2-1	1	4.75	NA	1.73	NA	170	59	NA
126	14	14-2	2	14-2-2	2	3.49	NA	1.32	NA	197	48	NA
127	14	14-2	2	14-2-3	3	5.32	NA	2.33	NA	260	78	NA
128	14	14-2	2	14-2-4	4	10.41	NA	3.96	NA	240	140	NA
129	14	14-3	3	14-3-1	1	8.79	NA	3.34	NA	115	119	NA
130	14	14-3	3	14-3-2	2	5.98	NA	2.26	NA	250	67	NA
131	14	14-3	3	14-3-3	3	10.99	NA	4.16	NA	239	134	NA
132	14	14-3	3	14-3-4	4	5.17	NA	1.88	NA	90	62	NA
133	14	14-4	4	14-4-1	1	4.63	NA	1.73	NA	190	55	NA
134	14	14-4	4	14-4-2	2	3.30	NA	1.42	NA	278	43	NA
135	14	14-4	4	14-4-3	3	2.88	NA	1.28	NA	198	40	NA
136	14	14-4	4	14-4-4	4	15.63	NA	6.05	NA	278	198	NA
137	14	14-5	5	14-5-1	1	3.49	NA	1.44	NA	201	70	NA
138	14	14-5	5	14-5-2	2	2.60	NA	1.21	NA	190	55	NA
139	14	14-5	5	14-5-3	3	3.34	NA	1.63	NA	112	75	NA

140	14	14-5	5	14-5-4	4	2.90	NA	1.32	NA	90	64	NA
141	15	15-1	1	15-1-1	1	6.39	NA	1.90	NA	170	40	NA
142	15	15-1	1	15-1-2	2	5.03	NA	1.43	NA	176	30	NA
143	15	15-1	1	15-1-3	3	1.96	NA	0.61	NA	> 300	14	NA
144	15	15-1	1	15-1-4	4	4.72	NA	1.33	NA	> 300	27	NA
145	15	15-2	2	15-2-1	1	2.06	NA	0.59	NA	> 300	15	NA
146	15	15-2	2	15-2-2	2	4.98	NA	0.54	NA	249	12	NA
147	15	15-2	2	15-2-3	3	1.94	NA	0.54	NA	273	13	NA
148	15	15-2	2	15-2-4	4	4.67	NA	1.34	NA	240	28	NA
149	15	15-3	3	15-3-1	1	7.26	NA	2.00	NA	290	44	NA
150	15	15-3	3	15-3-2	2	5.90	NA	2.14	NA	> 400	44	NA
151	15	15-3	3	15-3-3	3	7.05	NA	1.16	NA	154	25	NA
152	15	15-3	3	15-3-4	4	4.08	NA	1.89	NA	> 300	38	NA
153	15	15-4	4	15-4-1	1	2.90	NA	0.60	NA	> 400	12	NA
154	15	15-4	4	15-4-2	2	1.92	NA	0.52	NA	> 300	12	NA
155	15	15-4	4	15-4-3	3	1.65	NA	0.65	NA	> 400	16	NA
156	15	15-4	4	15-4-4	4	2.08	NA	0.61	NA	246	14	NA
157	15	15-5	5	15-5-1	1	1.62	NA	0.52	NA	238	14	NA
158	15	15-5	5	15-5-2	2	1.65	NA	0.47	NA	> 300	12	NA
159	15	15-5	5	15-5-3	3	1.42	NA	0.46	NA	> 400	11	NA
160	15	15-5	5	15-5-4	4	1.08	NA	0.34	NA	> 400	9	NA
161	17	17-1	1	17-1-1	1	4.77	NA	1.60	NA	177	54	NA
162	17	17-1	1	17-1-2	2	1.57	NA	0.52	NA	300	19	NA
163	17	17-1	1	17-1-3	3	2.81	NA	0.88	NA	140	32	NA
164	17	17-1	1	17-1-4	4	5.73	NA	1.82	NA	157	66	NA
165	17	17-2	2	17-2-1	1	1.60	NA	0.46	NA	196	17	NA
166	17	17-2	2	17-2-2	2	3.03	NA	0.89	NA	144	34	NA
167	17	17-2	2	17-2-3	3	1.40	NA	0.40	NA	134	16	NA
168	17	17-2	2	17-2-4	4	1.05	NA	0.31	NA	139	12	NA
169	17	17-3	3	17-3-1	1	2.16	NA	0.61	NA	141	20	NA
170	17	17-3	3	17-3-2	2	4.77	NA	1.34	NA	182	42	NA
171	17	17-3	3	17-3-3	3	5.71	NA	1.54	NA	149	47	NA
172	17	17-3	3	17-3-4	4	6.57	NA	1.80	NA	158	53	NA
173	17	17-4	4	17-4-1	1	2.74	NA	0.81	NA	205	26	NA
174	17	17-4	4	17-4-2	2	6.58	NA	1.96	NA	150	59	NA
175	17	17-4	4	17-4-3	3	7.81	NA	2.31	NA	146	75	NA
176	17	17-4	4	17-4-4	4	8.13	NA	2.24	NA	120	72	NA
177	17	17-5	5	17-5-1	1	1.72	NA	0.53	NA	165	24	NA
178	17	17-5	5	17-5-2	2	3.97	NA	1.26	NA	196	42	NA
179	17	17-5	5	17-5-3	3	1.51	NA	0.45	NA	232	14	NA
180	17	17-5	5	17-5-4	4	3.37	NA	0.98	NA	187	33	NA

Table A4. *Hippophae rhamnoides* tree analysis

TreeHeight	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	17	59.5166	0.504	24.91	1	1.11
2	Residuals	71	58.5377	0.496	NA	1	1.11
3	Total	88	118.054	1	37.26	1	1.11

Means	1	2	3	4	5	6	7	8	9
$\bar{x}$	3.38	2.47	2.44	3.69	3.99	2.06	4.34	3.43	4.86

10	11	12	13	14	15	16	17	18	$\bar{x}$
3.19	2.75	3.77	2.39	3.36	3.2	1.77	2.8	2.09	3.11

TrunkDiam	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	17	27178.5	0.53	40.4	4	4.44
2	Residuals	68	24108.8	0.47	NA	4	4.44
3	Total	85	51287.2	1	57.88	4	4.44

Means	1	2	3	4	5	6	7	8	9
$\bar{x}$	43.8	57	46	50	48	34	70	70	60

10	11	12	13	14	15	16	17	18	$\bar{x}$
18	24	58	24	56	40	17	46	11	42.9

Table A5. *Hippophae rhamnoides* bud analysis

BudWt	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	17	2889.644	0.577	37.41	14	3.93
2	Site:TreeNo	71	1754.634	0.35	74.09	14	3.93
3	Residuals	253	367.14	0.073	NA	14	3.93
4	Total	341	5011.418	1	78.32	14	3.93

Means	1	2	3	4	5	6	7	8	9	10
1	13.16	3.62	13.453	4.82	25.79	3.99	5.63	5.21	9.84	2.14
2	6.7	4.49	13.95	2.3	15.14	3.89	7.74	5.84	10.33	1.98
3	6.85	3.17	14.363	4.14	9.96	4.6	3.7	5.24	11.7	2.21
4	4.62	3.02	0.847	5	1.95	5.39	6.63	3.24	9.54	3.92
5	1.93	2.8	11.074	3.37	11.44	5.63	5.97	4.45	10.28	1.77
6	6.6	5 3.4	2 10.73	7 3.9	3 12.8	6 4.7	0 5.9	3 4.8	0 10.3	4 2.4

11	12	13	14	15	16	17	18	$\bar{x}$
6.33	4.9	7.33	3.89	4.42	1.157	2.49	0.758	6.61
4.67	2.96	7.55	NA	4.04	2.467	1.65	0.975	5.69
7.73	1.42	7.55	3.52	2.71	1.208	1.59	1.032	5.15
4.96	2.28	2.23	3.55	3.82	1.15	2.01	1.284	3.64
7.74	2.59	5.31	3.14	4.11	0.964	1.81	0.698	4.73
0 6.2	8 2.8	3 5.9	9 3.5	3 3.8	2 1.38	9 1.9	1 0.949	5.14

Table A6. *Hippophae rhammoides* leaf analysis

Solidity	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	16	9.306947	0.284	10.52	32	0.97
2	Site:TreeNo	67	2.916552	0.089	12.36	32	0.97
3	Tree:BranchNo	252	2.948592	0.09	12.36	32	0.97
4	Residuals	2935	17.63377	0.538	NA	32	0.97
5	Total	3270	32.80586	1	12.36	32	0.97

Means	1	2	3	4	6	7	8	9	10
1	0.819	0.822	0.705	0.794	0.787	0.832	0.822	0.801	0.862
2	0.802	0.859	0.714	0.737	0.82	0.843	0.78	0.86	0.883
3	0.83	0.839	0.735	0.799	0.802	0.84	0.814	0.832	0.836
4	0.851	0.838	0.679	0.699	0.803	0.808	0.794	0.797	0.845
5	0.81	0.857	0.718	0.739	0.808	0.825	0.836	0.776	0.855
$\bar{x}$	0.82	0.84	0.71	0.75	0.8	0.83	0.8	0.81	0.85

11	12	13	14	15	16	17	18	$\bar{x}$
0.876	0.9	0.778	0.675	0.756	0.78	0.916	0.894	0.813
0.859	0.866	0.7	0.721	0.752	0.798	0.893	0.886	0.81
0.806	0.822	0.724	0.744	0.781	0.837	0.884	0.779	0.806
0.858	NA	0.859	0.631	0.708	0.906	0.899	0.889	0.804
0.864	0.851	0.744	0.646	0.747	0.874	0.845	0.874	0.804
0.85	0.86	0.76	0.68	0.74	0.83	0.89	0.86	0.81

Feret	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	16	162352.9	0.544	15.11	73	2.21
2	Site:TreeNo	67	49180.34	0.165	22.51	73	2.21
3	Tree:BranchNo	252	20780.77	0.07	22.64	73	2.21
4	Residuals	2894	66108.88	0.222	NA	73	2.21
5	Total	3229	298422.9	1	22.67	73	2.21

Means	1	2	3	4	6	7	8	9	10
1	43.9	43.6	52.5	58.7	40.2	36.9	35.8	53	42
2	33.2	40.2	43.1	62.3	32	40.3	39.7	41.9	38.1
3	36.9	39.5	47.5	60.5	40.8	42.5	40.9	51.7	43.9
4	27	47.5	38.3	59.6	40.7	37.6	45.2	49.2	45.7
5	34.9	39.6	41.4	69	46.6	28.4	42.6	50.1	41
$\bar{x}$	35.2	42.1	44.5	62	40	37.1	40.8	49.2	42.1

11	12	13	14	15	16	17	18	$\bar{x}$
39.5	45.2	43.1	51.6	58.2	44.7	38.1	30	44.5
37.5	48	43.5	59.8	53.4	37.4	32.9	34.7	42.2
39.6	39.5	43.2	53.2	44.7	33.1	37.3	31.9	42.7
34.5	NA	32	45.1	46.9	36.6	38.5	32	41
39.9	38.1	41.5	48.2	50.9	34	38.1	33.9	42.3
38.2	42.7	40.6	51.6	50.8	37.2	37	32.5	42.6

PerimEllipse	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	16	463249.9	0.468	15.59	77	2.33
2	Site:TreeNo	67	159569.9	0.161	21.57	77	2.33
3	Tree:BranchNo	252	83862.02	0.085	21.63	77	2.33
4	Residuals	2890	282579.7	0.286	NA	77	2.33
5	Total	3225	989261.5	1	21.68	77	2.33

Means	1	2	3	4	6	7	8	9	10
1	81.9	81.5	94.7	111	75.4	71.3	69.2	99.9	81.7
2	62.6	78.5	78.6	116	61.3	76.4	73.6	82.4	73.8
3	71.3	75.3	88.3	114	77.2	81.9	80.5	99.9	86.5
4	52.1	92.2	70.6	106	79.5	71.5	87.8	94.8	90
5	67.4	75.3	74.6	123	89.7	55.3	82.1	95.2	79.2
$\bar{x}$	67.1	80.6	81.4	11.4	76.6	71.3	78.6	94.4	82.2

11	12	13	14	15	16	17	18	$\bar{x}$
76.8	87.6	81.6	94.1	105.3	84.4	76.1	59.6	84.2
72.7	91.3	80.6	108.3	97	71.1	65	69.4	79.9
76.7	77.7	82.5	98.5	82.9	66.4	73.5	60.8	82
67.8	NA	62.6	81.5	87.3	71.6	76.2	63.8	78.5
78.5	73.6	79.4	91.2	99.3	67.2	75.1	65.3	80.7
74.5	82.6	77.3	94.7	94.4	72.1	73.2	63.8	81.1

Major	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	16	117112.9	0.472	15.81	75	2.27
2	Site:TreeNo	67	39270.03	0.158	21.96	75	2.27
3	Tree:BranchNo	252	20902.04	0.084	22.03	75	2.27
4	Residuals	2892	70599.16	0.285	NA	75	2.27
5	Total	3227	247884.1	1	22.07	75	2.27

Means	1	2	3	4	6	7	8	9	10
1	40.2	40.1	46.7	54.7	37	34.6	33.9	49.3	40
2	30.8	38.5	38.7	57.5	30.1	37.2	36.1	40.6	36.1
3	35.1	37	43.5	56.4	38.1	39.9	39.5	49.4	42.2
4	25.7	45.3	34.7	52.4	39	34.7	43.1	46.8	43.9
5	33.1	36.9	36.7	60.8	44.1	26.8	40.2	46.9	38.9
$\bar{x}$	33	39.6	40.1	56.3	37.7	34.6	38.6	46.6	40.2

11	12	13	14	15	16	17	18	$\bar{x}$
37.7	42.8	40.2	46.5	52.2	41.7	37.1	29.1	41.4
35.7	45	39.8	53.6	47.9	35.1	31.8	33.9	39.3
37.7	38.1	40.7	48.7	40.9	32.3	35.9	29.6	40.3
33.3	NA	30.6	40.2	43	35	37.3	31.1	38.5
38.7	36.2	39.2	44.9	49	32.8	36.9	31.8	39.6
36.6	40.5	38.1	46.8	46.6	35.4	35.8	31.1	39.9

Perim	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	16	1468771	0.469	19.18	98	2.97
2	Site:TreeNo	67	702373.8	0.224	26.67	98	2.97
3	Tree:BranchNo	252	304541.3	0.097	26.56	98	2.97
4	Residuals	2869	653644.7	0.209	NA	98	2.97
5	Total	3204	3129330	1	26.95	98	2.97

Means	1	2	3	4	6	7	8	9	10
1	100.6	106	149	157	108.6	113.9	98.1	138	115.2
2	75.8	111	107	159	84.6	100.6	129.9	103	91.4
3	98.2	105	147	160	89.2	129.9	122	140	129.1
4	62.4	151	124	151	135.9	122.3	147.1	139	136.8
5	98.1	105	123	177	143.3	83.5	124.9	136	101.7
$\bar{x}$	87	115	130	161	112.3	110	124.4	131	114.8

11	12	13	14	15	16	17	18	$\bar{x}$
92.4	108.6	109.6	158	134	103.2	97.6	79.6	116
95.4	119.3	100.3	155	151	94	84.1	95.9	109
100.2	109.3	140.8	152	112	105.4	96.1	96.1	119
89.8	NA	83.6	169	143	84.4	92	79.1	119
98.4	98.1	128.3	201	164	97.9	118.3	94.7	123
95.2	108.8	112.5	167	141	97	97.7	89.1	117

Minor	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	16	545.0079	0.24	17.95	107	3.24
2	Site:TreeNo	67	512.6836	0.226	20.6	107	3.24
3	Tree:BranchNo	252	235.8782	0.104	20.69	107	3.24
4	Residuals	2860	974.5122	0.43	NA	107	3.24
5	Total	3195	2268.082	1	20.69	107	3.24

Means	1	2	3	4	6	7	8	9	10
1	4.26	3.87	4.45	4.31	4.03	4.98	3.74	4.18	4.82
2	2.95	4.13	3.63	4.56	3.1	4.94	3.95	3.89	4.32
3	3.36	3.81	4.02	4.53	3.49	5.18	4.16	4.03	5.54
4	2.35	4.69	3.54	4.24	4.18	4.78	4.43	3.96	5.72
5	3.44	4.14	3.69	4.88	4.59	4.16	4.45	4.11	4.08
$\bar{x}$	3.27	4.13	3.87	4.5	3.88	4.81	4.15	4.03	4.9

11	12	13	14	15	16	17	18	$\bar{x}$
4.02	5.31	3.66	3.98	3.79	3.3	4.82	3.5	4.18
3.73	5	3.36	4.24	4.02	2.94	3.76	4.26	3.93
3.81	4.17	3.54	4	3.54	4.39	4.41	3.92	4.11
3.45	NA	3.8	3.52	3.97	4.35	4.37	3.82	4.07
3.63	3.55	3.56	4.51	4.18	4.25	4.5	4.17	4.11
3.73	4.51	3.58	4.05	3.9	3.85	4.37	3.94	4.09

AR	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	16	6815.74	0.404	17.25	86	2.6
2	Site:TreeNo	67	2247.41	0.133	23.16	86	2.6
3	Tree:BranchNo	252	1398.96	0.083	23.3	86	2.6
4	Residuals	2881	6409.22	0.38	NA	86	2.6
5	Total	3216	16871.3	1	23.31	86	2.6

Means	1	2	3	4	6	7	8	9	10
1	9.32	10.44	10.67	12.7	9.23	6.88	8.93	11.5	8.34
2	10.58	9.29	10.59	12.5	9.81	7.56	9.28	10.6	8.41
3	10.54	9.83	10.67	12.3	10.98	7.72	9.18	12.5	7.62
4	11.17	9.46	9.54	12.3	9.37	7.08	9.55	11.8	7.63
5	9.74	8.98	10.56	12.6	9.58	6.44	8.98	11.2	9.45
$\bar{x}$	10.27	9.6	10.41	12.5	9.79	7.14	9.18	11.5	8.29

11	12	13	14	15	16	17	18	$\bar{x}$
9.51	7.97	11.07	11.7	13.8	12.75	7.63	8.36	10.05
9.71	9.04	11.53	13	12.1	11.68	8.35	8.03	10.12
9.93	9.19	11.48	11.8	11.7	7.38	8.13	7.59	9.91
9.75	NA	8.02	11.5	10.6	8.18	8.61	8.02	9.54
10.8	10.21	10.94	10	11.9	7.78	7.96	7.66	9.69
9.94	9.1	10.61	11.6	12	9.55	8.14	7.93	9.86

Round	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	16	0.83327	0.462	16.76	119	3.6
2	Site:TreeNo	67	0.26394	0.146	22.68	119	3.6
3	Tree:BranchNo	252	0.11656	0.065	22.79	119	3.6
4	Residuals	2848	0.58886	0.327	NA	119	3.6
5	Total	3183	1.802622	1	22.8	119	3.6

Means	1	2	3	4	6	7	8	9	10
1	0.1086	0.0954	0.0951	0.078	0.107	0.144	0.111	0.0846	0.121
2	0.0961	0.1079	0.0914	0.0806	0.1029	0.132	0.106	0.0952	0.119
3	0.0957	0.1036	0.092	0.0824	0.0927	0.131	0.107	0.0811	0.133
4	0.0889	0.1041	0.0984	0.0793	0.108	0.141	0.102	0.0837	0.131
5	0.1033	0.1115	0.0952	0.0773	0.1046	0.153	0.112	0.0887	0.104
$\bar{x}$	0.0985	0.1045	0.0944	0.0795	0.103	0.14	0.108	0.0867	0.122

11	12	13	14	15	16	17	18	$\bar{x}$
0.1065	0.127	0.0898	0.085	0.0706	0.0798	0.131	1.121	0.103
0.1047	0.112	0.0827	0.0781	0.0793	0.0848	0.12	0.126	0.101
0.1014	0.109	0.0868	0.0802	0.0861	0.1364	0.122	0.129	0.104
0.1039	NA	0.1247	0.0845	0.0934	0.1234	0.116	0.125	0.107
0.0927	0.1	0.0907	0.1025	0.0855	0.1298	0.128	0.132	1.106
0.1018	0.112	0.0949	0.0861	0.083	0.1108	0.123	0.127	0.104

Circ	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	16	2.29188	0.401	25.99	89	2.69
2	Site:TreeNo	67	1.52837	0.267	32.79	89	2.69
3	Tree:BranchNo	252	0.69107	0.121	32.79	89	2.69
4	Residuals	2878	1.20421	0.211	NA	89	2.69
5	Total	3213	5.71552	1	33.46	89	2.69

Means	1	2	3	4	6	7	8	9	10
1	0.175	0.1397	0.088	0.0964	0.1286	0.13	0.1257	0.1117	0.147
2	0.157	0.1241	0.1216	0.1046	0.1308	0.184	0.0845	0.1447	0.186
3	0.121	0.1269	0.0844	0.0999	0.1642	0.119	0.1062	0.103	0.136
4	0.151	0.0951	0.0756	0.0992	0.0873	0.115	0.0882	0.0976	0.134
5	0.118	0.1393	0.0837	0.0968	0.0906	0.156	0.1138	0.1064	0.156
$\bar{x}$	0.144	0.125	0.0907	0.0994	0.1203	0.141	0.1037	0.1127	0.152

11	12	13	14	15	16	17	18	$\bar{x}$
0.176	0.198	0.1198	0.0741	0.1106	0.13	0.182	0.163	0.135
0.145	0.155	0.1327	0.0908	0.0838	0.117	0.172	0.155	0.135
0.143	0.133	0.0713	0.0832	0.116	0.13	0.17	0.127	0.12
0.142	NA	0.1689	0.0475	0.0793	0.208	0.189	0.195	0.123
0.145	0.123	0.0838	0.0456	0.077	0.141	0.125	0.15	0.115
0.15	0.152	0.1153	0.0682	0.0933	0.145	0.168	0.158	0.126

MinFeret	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	16	733.263	0.199	19.85	117	3.54
2	Site:TreeNo	67	755.876	0.205	22.18	117	3.54
3	Tree:BranchNo	252	383.819	0.104	22.3	117	3.54
4	Residuals	2850	1814.179	0.492	NA	117	3.54
5	Total	3185	3687.137	1	22.3	117	3.54

Means	1	2	3	4	6	7	8	9	10
1	5.04	4.45	5.78	5.17	4.78	5.73	4.44	4.94	5.45
2	3.53	4.66	4.47	5.71	3.65	5.63	4.76	4.43	4.73
3	3.94	4.38	4.98	5.43	4.14	5.86	5.04	4.69	6.52
4	2.61	5.4	4.81	5.35	4.98	5.71	5.27	4.84	6.59
5	4.13	4.58	4.75	5.96	5.48	4.82	5.21	5.22	4.64
$\bar{x}$	3.8	4.7	4.96	5.52	4.61	5.55	4.94	4.82	5.59

11	12	13	14	15	16	17	18	$\bar{x}$
4.43	5.73	4.48	5.32	4.8	4.01	5.27	3.88	4.92
4.2	5.64	4.29	5.3	4.81	3.6	4.19	4.71	4.61
4.39	4.95	4.62	4.92	4.29	5.23	4.84	4.81	4.88
3.89	NA	4.31	5.18	5.29	4.69	4.75	4.23	4.87
4.11	3.96	4.52	6.59	5.43	4.69	5.27	4.63	4.94
4.2	5.07	4.44	5.46	4.92	4.44	4.87	4.45	4.85

Area	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	16	2073734	0.324	28.33	108	3.27
2	Site:TreeNo	67	1354044	0.212	34.65	108	3.27
3	Tree:BranchNo	252	645036	0.101	34.67	108	3.27
4	Residuals	2859	2322134	0.363	NA	108	3.27
5	Total	3194	6394948	1	34.69	108	3.27

Means	1	2	3	4	6	7	8	9	10
1	133.7	122	167	186	117.5	136.2	98.7	163	150
2	72.5	128	112	205	73.6	149.1	115	124	125
3	93.3	112	139	202	105	164.8	132.2	158	181
4	48.2	172	103	174	129.7	130.9	152.8	145	191
5	90.6	121	107	232	160.2	88.8	146	154	124
$\bar{x}$	87.6	13.1	12.6	20	117.2	134	128.9	14.9	15.4

11	12	13	14	15	16	17	18	$\bar{x}$
119.8	181	117.9	148	158	110	140.2	80.3	137
104.7	171	107.9	175	152	81	95.8	114.3	124
112	125	113.7	154	115	113	127.7	91.5	132
90.7	NA	91.5	109	135	121	129.8	96.1	126
110.9	105	111	156	158	111	127.8	105.6	130
107.6	14.6	108.4	14.8	14.3	10.7	124.3	97.6	130

Table A7. *Hippophae rhamnoides* fruiting branch analysis

FruitMoisture	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	2777.4273	0.596	4.35	5	2.78
2	Site:TreeNo	36	1335.0467	0.287	2.12	5	2.78
3	Residuals	124	544.5577	0.117	NA	5	2.78
4	Total	168	4957.0316	1.000	7.67	5	2.78

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	0.0255	0.0391	0.0276	0.0492	0.0183	0.0529	0.028	0.047	0.028	0.0351
2	0.0301	0.033	NaN	0.0519	0.0227	NaN	0.0287	0.0434	0.026	0.0337
3	0.0327	0.0374	0.0377	0.0418	0.0228	0.0446	0.0308	0.0476	0.0323	0.0364
4	0.0306	0.0449	0.0346	0.0566	0.0204	0.0274	0.0313	0.0444	0.0316	0.0358
5	0.0225	0.0422	0.0314	0.0584	0.0205	0.0325	0.0211	0.039	0.0285	0.0329
6	0.0283	0.0393	0.0328	0.0516	0.0209	0.0393	0.028	0.0443	0.0293	0.0349

SingleFruitDW	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	0.014098503	0.775	13.98	6	3.33
2	Site:TreeNo	34	0.003431109	0.189	6.25	6	3.33
3	Residuals	117	0.000664709	0.037	NA	6	3.33
4	Total	159	0.018194321	1	30.83	6	3.33

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	0.0255	0.0391	0.0276	0.0492	0.0183	0.0529	0.028	0.047	0.028	0.0351
2	0.0301	0.033	NaN	0.0519	0.0227	NaN	0.0287	0.0434	0.026	0.0337
3	0.0327	0.0374	0.0377	0.0418	0.0228	0.0446	0.0308	0.0476	0.0323	0.0364
4	0.0306	0.0449	0.0346	0.0566	0.0204	0.0274	0.0313	0.0444	0.0316	0.0358
5	0.0225	0.0422	0.0314	0.0584	0.0205	0.0325	0.0211	0.039	0.0285	0.0329
6	0.0283	0.0393	0.0328	0.0516	0.0209	0.0393	0.028	0.0443	0.0293	0.0349

SingleFruitFW	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	0.21059852	0.748	17.26	3	1.67
2	Site:TreeNo	34	0.05331726	0.189	8.45	3	1.67
3	Residuals	119	0.01773844	0.063	NA	3	1.67
4	Total	161	0.28165421	1	36.36	3	1.67

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	0.089	0.122	0.1	0.179	0.046	0.1725	0.0818	0.161	0.0864	0.115
2	0.1082	0.132	NaN	0.176	0.0632	NaN	0.0739	0.155	0.0896	0.114
3	0.1132	0.139	0.131	0.126	0.06	0.1704	0.0821	0.142	0.1168	0.12
4	0.1121	0.159	0.133	0.181	0.0557	0.0866	0.08	0.146	0.1085	0.118
5	0.0782	0.158	0.123	0.207	0.0571	0.1087	0.0475	0.126	0.094	0.111
6	0.1001	0.142	0.122	0.174	0.0564	0.1346	0.0731	0.146	0.099	0.116

NoFruitLn	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	731595.5	0.355	37.12	5	2.78
2	Residuals	130	438106.5	0.212	NA	5	2.78
3	Total	174	2062330.4	1	49.43	5	2.78

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	165	135	326	228	72.5	448	289	254	194	235
2	172	228	355	281	169.2	295	217	282	153	239
3	102	204	343	252	114	105	174	259	158	190
4	108	158	233	260	103.3	343	236	381	155	220
5	196	252	0	450	119.5	110	148	363	195	204
$\bar{x}$	148	195	252	294	115.7	260	213	308	171	217

FruitDW	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	164.9469	0.381	62.31	8	4.44
2	Site:TreeNo	36	165.6625	0.383	45.43	8	4.44
3	Residuals	127	102.227	0.236	NA	8	4.44
4	Total	171	432.8363	1	82.14	8	4.44

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	2.152	0.835	0.765	2.59	6.96	0.948	2.47	1.317	1.205	2.14
2	3.302	0.742	0.39	1.74	2.68	1.962	2.33	0.753	0.515	1.6
3	5.807	1.695	0.833	2.75	5.38	3.153	2.91	1.797	1.323	2.85
4	2.243	1.395	2.145	2.39	3.94	0.468	1.48	0.595	1.83	1.83
5	0.667	2.717	0.77	2.37	1.83	2.05	1.4	0.448	0.805	1.45
$\bar{x}$	2.834	1.477	0.981	2.37	4.16	1.716	2.12	0.982	1.135	1.97

FruitFW	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	1088.502	0.295	63.56	9	5
2	Site:TreeNo	36	1620.59	0.44	46.17	9	5
3	Residuals	126	977.8492	0.265	NA	9	5
4	Total	170	3686.941	1	76.51	9	5

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	7.54	2.38	2.79	9.31	17.46	3.1	7.24	4.53	3.72	6.45
2	9.39	2.82	1.37	5.96	7.49	7.23	5.99	2.66	1.77	4.96
3	20.34	6.25	3	8.51	14.16	11.78	7.73	5.32	4.8	9.1
4	8.29	4.94	8.28	7.66	10.88	1.5	3.6	1.94	6.32	5.93
5	2.33	10.22	3.04	8.4	5.24	6.86	3.08	1.44	2.64	4.81
$\bar{x}$	9.58	5.32	3.69	7.97	11.05	6.09	5.53	3.18	3.85	6.2

Fruits	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	497662.5	0.499	69.75	10	5.56
2	Site:TreeNo	35	324335.5	0.325	50.36	10	5.56
3	Residuals	118	176101.2	0.176	NA	10	5.56
4	Total	161	998099.2	1	116.08	10	5.56

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	82.2	21.2	27.5	54.8	426	18	88.5	27.8	42.8	87.6
2	82.7	21	10.7	33.5	118.8	NaN	82.3	17	19.8	48.2
3	176.7	46	49.3	70	250	63	95.5	37.8	40.5	92.1
4	69.7	31.2	61.2	42	249	16.8	84	13.5	58	69.5
5	29.8	85	24.5	35.3	88.5	92.5	66	11.5	33	51.8
$\bar{x}$	88.2	40.9	34.6	47.1	226.4	47.6	83.3	21.5	38.8	69.8

FruitDensity	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	2.985676	0.241	80.56	7	3.89
2	Site:TreeNo	35	4.556413	0.368	57.53	7	3.89
3	Residuals	120	4.838009	0.391	NA	7	3.89
4	Total	163	12.3801	1	98.09	7	3.8

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	0.2476	0.061	0.1272	0.196	0.884	0.36	0.457	0.122	0.1359	0.288
2	0.3317	0.0743	0.0711	0.152	0.369	NaN	0.292	0.0782	0.0571	0.178
3	0.5223	0.1744	0.4933	0.273	0.6	0.159	0.31	0.3538	0.1192	0.334
4	0.3072	0.0896	0.7778	0.171	0.785	0.112	0.349	0.1738	0.1645	0.325
5	0.0932	0.3452	0.49	0.82	0.238	0.237	0.19	0.1334	0.0919	0.293
$\bar{x}$	0.3004	0.1489	0.3919	0.322	0.575	0.217	0.32	0.1722	0.1137	0.285

Table A8. *Hippophae rhamnoides* fruit analysis

Solidity	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	2.954361	0.325	2.29	143	1.11
2	Site:TreeNo	35	0.469805	0.052	2.86	143	1.11
3	Tree:BranchNo	124	0.641636	0.071	2.83	143	1.11
4	Residuals	12541	5.035257	0.553	NA	143	1.11
4	Total	12708	9.101059	1	2.83	143	1.11

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	0.922	0.953	0.951	0.961	0.951	0.93	0.93	0.941	0.952	0.943
2	0.922	0.947	0.945	0.965	0.958	NA	0.923	0.941	0.959	0.945
3	0.916	0.954	0.956	0.959	0.953	0.952	0.945	0.948	0.964	0.95
4	0.911	0.953	0.953	0.963	0.953	0.92	0.934	0.951	0.951	0.943
5	0.872	0.958	0.96	0.968	0.956	0.945	0.93	0.94	0.949	0.942
$\bar{x}$	0.909	0.953	0.953	0.963	0.954	0.937	0.932	0.944	0.955	0.945

PerimEllipse	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	78632.33	0.454	11.74	150	1.17
2	Site:TreeNo	35	34051.76	0.197	16.79	150	1.17
3	Tree:BranchNo	124	22290.13	0.129	16.9	150	1.17
4	Residuals	12534	38307.22	0.221	NA	150	1.17
5	Total	12701	173281.5	1	17.08	150	1.17

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	22.1	20.5	23.1	24.1	17.8	26.6	25.5	28.7	22	23.4
2	24.8	21.5	21.7	25.5	19.3	NA	18.7	28.4	22.5	22.8
3	23.1	23	26.7	21.9	20.4	26	20.1	28.9	24.4	23.8
4	21.6	24.7	23.9	25.2	18.1	20.9	17.8	27.1	23.1	22.5
5	19.4	26.1	23.6	25.6	19.7	21.8	19.2	26	18.4	22.2
$\bar{x}$	22.2	23.2	23.8	24.4	19.1	23.8	20.3	27.8	22.1	23.0

Major	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	12240.29	0.465	11.93	207	1.61
2	Site:TreeNo	35	4895.334	0.186	17.22	207	1.61
3	Tree:BranchNo	124	3185.116	0.121	17.49	207	1.61
4	Residuals	12477	6022.718	0.229	NA	207	1.61
5	Total	12644	26343.46	1	17.74	207	1.61

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	8.05	7.54	8.89	8.59	6.68	10.47	10	11.6	8.49	8.92
2	8.96	7.77	8.51	9.1	7.19	NA	7.41	11.5	8.57	8.62
3	8.43	8.31	10.37	7.92	7.71	10.05	7.67	11.6	9.16	9.02
4	7.99	9.08	9.31	9.07	6.8	7.93	6.89	10.9	8.75	8.53
5	7.36	9.36	9.35	9.14	7.33	8.1	7.69	10.5	7.02	8.43
6	8.1	8.4	9.2	8.7	7.1	9.1	7.9	11.2	8.4	8.72

Round	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	39.15596	0.439	9.28	339	2.64
2	Site:TreeNo	35	5.60567	0.063	12.76	339	2.64
3	Tree:BranchNo	124	2.399602	0.027	12.51	339	2.64
4	Residuals	12345	42.02965	0.471	NA	339	2.64
5	Total	12512	89.19088	1	12.58	339	2.64

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	0.734	0.714	0.628	0.778	0.662	0.589	0.596	0.543	0.631	0.653
2	0.756	0.749	0.59	0.765	0.684	NA	0.577	0.522	0.653	0.662
3	0.73	0.75	0.616	0.75	0.656	0.617	0.643	0.557	0.679	0.666
4	0.703	0.714	0.606	0.754	0.678	0.654	0.625	0.547	0.658	0.66
5	0.651	0.769	0.573	0.776	0.692	0.696	0.554	0.536	0.647	0.655
$\bar{x}$	0.714	0.739	0.602	0.765	0.675	0.639	0.599	0.541	0.654	0.659

Perim	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	115754.2	0.422	12.82	291	2.26
2	Site:TreeNo	35	45785.98	0.167	17.5	291	2.26
3	Tree:BranchNo	124	36136.98	0.132	17.66	291	2.26
4	Residuals	12393	76656.31	0.279	NA	291	2.26
5	Total	12560	274333.5	1	17.79	291	2.26

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	27.8	25	28.2	29.5	21.4	33.8	31.8	36.9	26.9	29
2	30.9	25.7	26.7	30.8	23.1	NA	23.5	34.2	27	27.7
3	28.2	27.2	32.2	25.3	24.2	30.4	25.1	35.5	29	28.6
4	28.4	29.6	27.7	29.3	22.6	25.8	22.9	32.9	27.6	27.4
5	25.5	31	27.3	29.5	22.9	26.2	23.8	32.7	22.7	26.9
$\bar{x}$	28.1	27.7	28.4	28.9	22.8	29.0	25.4	34.5	26.6	28.0

MinFeret	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	5932.502	0.436	13.09	171	1.33
2	Site:TreeNo	35	2447.044	0.18	18.26	171	1.33
3	Tree:BranchNo	124	1555.605	0.114	18.15	171	1.33
4	Residuals	12513	3660.874	0.269	NA	171	1.33
5	Total	12680	13596.02	1	18.27	171	1.33

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	6.16	5.55	5.76	6.81	4.67	6.41	6.3	6.5	5.55	5.97
2	6.99	5.99	5.22	7.14	5.13	NA	4.56	6.21	5.73	5.87
3	6.41	6.4	6.54	6.09	5.32	6.43	5.18	6.6	6.35	6.15
4	5.9	6.68	5.81	6.98	4.82	5.48	4.54	6.11	5.95	5.81
5	5.17	7.36	5.54	7.18	5.29	5.84	4.54	5.85	4.71	5.72
$\bar{x}$	6.12	6.40	5.77	6.84	5.04	6.04	5.03	6.25	5.66	5.91

Feret	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	16291.54	0.45	12.78	259	2.02
2	Site:TreeNo	35	5731.47	0.158	18.13	259	2.02
3	Tree:BranchNo	124	4145.796	0.115	18.52	259	2.02
4	Residuals	12425	10012.99	0.277	NA	259	2.02
5	Total	12592	36181.79	1	18.75	259	2.02

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	9.46	8.28	9.68	9.04	7.28	11.93	11.56	12.8	9.33	9.93
2	10.45	8.84	9.14	9.5	7.72	NA	8.59	12.4	9.19	9.48
3	10.01	9.23	11.15	8.47	8.39	11.05	8.54	12.4	9.73	9.89
4	9.51	10.14	10.19	9.53	7.44	9.33	7.89	11.7	9.71	9.5
5	9.16	10.17	10.12	9.5	7.97	9.14	8.79	11.7	7.77	9.36
$\bar{x}$	9.7	9.3	10	9.2	7.7	10.3	9	12.2	9.1	9.65

AR	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	192.7574	0.462	8.58	373	2.9
2	Site:TreeNo	35	27.07202	0.065	12.52	373	2.9
3	Tree:BranchNo	124	10.84686	0.026	12.21	373	2.9
4	Residuals	12311	186.265	0.447	NA	373	2.9
5	Total	12478	416.9413	1	12.28	373	2.9

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	1.36	1.38	1.59	1.28	1.48	1.69	1.67	1.83	1.58	1.54
2	1.32	1.32	1.67	1.3	1.46	NA	1.71	1.87	1.54	1.52
3	1.37	1.33	1.63	1.33	1.51	1.61	1.55	1.78	1.48	1.51
4	1.42	1.38	1.64	1.31	1.47	1.52	1.57	1.82	1.52	1.52
5	1.49	1.29	1.74	1.28	1.44	1.42	1.77	1.87	1.55	1.54
$\bar{x}$	1.3	1.3	1.6	1.3	1.4	1.5	1.6	1.8	1.5	1.53

Minor	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	6141.296	0.448	13.5	158	1.23
2	Site:TreeNo	35	2413.75	0.176	19.01	158	1.23
3	Tree:BranchNo	124	1457.364	0.106	18.89	158	1.23
4	Residuals	12526	3704.748	0.27	NA	158	1.23
5	Total	12693	13717.16	1	19.01	158	1.23

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	5.92	5.4	5.58	6.68	4.49	6.17	5.92	6.29	5.36	5.76
2	6.77	5.83	5.07	7.01	4.97	NA	4.29	6.06	5.59	5.7
3	6.16	6.22	6.38	5.94	5.12	6.22	4.95	6.44	6.21	5.96
4	5.62	6.47	5.64	6.86	4.63	5.24	4.31	5.97	5.76	5.61
5	4.84	7.21	5.38	7.09	5.1	5.67	4.27	5.65	4.54	5.53
$\bar{x}$	5.8	6.2	5.6	6.7	4.8	5.8	4.7	6	5.4	5.71

Circ	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	17.94861	0.2	11.96	169	1.31
2	Site:TreeNo	35	9.73254	0.108	13.08	169	1.31
3	Tree:BranchNo	124	8.270822	0.092	13.16	169	1.31
4	Residuals	12515	53.81941	0.6	NA	169	1.31
5	Total	12682	89.77138	1	13.25	169	1.31

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	0.603	0.653	0.617	0.647	0.643	0.562	0.575	0.521	0.625	0.605
2	0.63	0.682	0.587	0.665	0.664	NA	0.561	0.568	0.645	0.625
3	0.645	0.687	0.628	0.728	0.664	0.665	0.589	0.565	0.669	0.649
4	0.55	0.665	0.673	0.713	0.613	0.607	0.559	0.589	0.65	0.624
5	0.534	0.695	0.671	0.734	0.705	0.661	0.569	0.55	0.619	0.638
$\bar{x}$	0.59	0.67	0.63	0.69	0.65	0.62	0.57	0.55	0.64	0.628

Area	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	793265.6	0.448	23.27	215	1.67
2	Site:TreeNo	35	359226.5	0.203	32.92	215	1.67
3	Tree:BranchNo	124	230330.2	0.13	32.94	215	1.67
4	Residuals	12469	388207.7	0.219	NA	215	1.67
5	Total	12636	1771030	1	33.16	215	1.67

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	37.6	32.4	39.2	45.4	24.1	50.7	46.6	57.2	35.9	41
2	47.2	35.8	34.2	50.2	28.5	NA	25.5	55.2	37.7	39.3
3	41.3	40.6	51.8	37	31.4	49.1	30.5	58.3	44.8	42.8
4	35.6	46.3	41.4	49.2	25	32.8	23.5	51.3	39.8	38.3
5	28.2	52.8	39.8	50.9	29.8	36.3	26	46.9	25.2	37.3
$\bar{x}$	38	41.6	41.3	46.5	27.8	42.2	30.4	53.8	36.7	39.8

EstPeduncle	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	1487.211	0.441	46.48	449	3.49
2	Site:TreeNo	35	173.9539	0.052	58.32	449	3.49
3	Tree:BranchNo	124	224.1225	0.067	58.5	449	3.49
4	Residuals	12235	1483.734	0.44	NA	449	3.49
5	Total	12402	3369.021	1	58.55	449	3.49

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	1.38	0.72	0.808	0.435	0.562	1.43	1.569	1.14	0.806	0.983
2	1.5	1.071	0.659	0.384	0.513	NA	1.195	0.915	0.618	0.857
3	1.53	0.889	0.771	0.495	0.664	0.98	0.876	0.858	0.561	0.847
4	1.51	1.036	0.856	0.432	0.641	1.32	0.993	0.83	0.933	0.95
5	1.79	0.778	0.744	0.348	0.643	1.01	1.095	1.095	0.746	0.916
$\bar{x}$	1.5	0.89	0.76	0.41	0.6	1.1	1.14	0.96	0.73	0.918

Table A9. *Hippophae rhamnoides* seed analysis

Solidity	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	0.01618	0.196	0.59	4	0.21
2	Site:TreeNo	35	0.00451	0.055	0.56	4	0.21
3	Residuals	1846	0.06198	0.75	NA	4	0.21
4	Total	1889	0.08267	1	0.69	4	0.21

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	0.968	0.96	0.958	0.962	0.964	0.966	0.968	0.963	0.967	0.964
2	0.967	0.96	0.959	0.969	0.966	0.966	0.964	0.965	0.967	0.965
3	0.968	0.962	0.959	0.967	0.962	0.962	0.964	0.963	0.968	0.964
4	NA	0.964	0.957	0.97	0.964	0.964	0.966	0.963	0.969	0.965
5	0.964	0.96	0.959	0.965	0.963	0.965	0.966	0.965	0.968	0.964
$\bar{x}$	0.967	0.961	0.958	0.967	0.963	0.965	0.966	0.964	0.968	0.964

Circ	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	4.07685	0.685	4.16	28	1.48
2	Site:TreeNo	35	0.64386	0.108	3.51	28	1.48
3	Residuals	1822	1.22855	0.207	NA	28	1.48
4	Total	1865	5.94926	1	7.79	28	1.48

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	0.795	0.693	0.715	0.761	0.772	0.672	0.744	0.616	0.756	0.725
2	0.784	0.713	0.707	0.762	0.777	0.66	0.731	0.613	0.767	0.724
3	0.773	0.72	0.691	0.765	0.761	0.666	0.728	0.625	0.762	0.721
4	NA	0.699	0.697	0.771	0.781	0.763	0.746	0.622	0.76	0.73
5	0.787	0.695	0.681	0.736	0.79	0.762	0.75	0.655	0.759	0.735
$\bar{x}$	0.785	0.704	0.698	0.759	0.776	0.705	0.74	0.626	0.761	0.728

PerimEllipse	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	1374.46	0.685	5.66	39	2.06
2	Site:TreeNo	35	307.636	0.153	4.19	39	2.06
3	Residuals	1811	323.243	0.161	NA	39	2.06
4	Total	1854	2005.34	1	10.31	39	2.06

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	8.93	10.5	8.9	11.3	8.83	11.23	9.84	11.7	9.41	10.08
2	8.89	9.45	9.58	11.8	9.27	11.41	9.85	11.7	9.42	10.15
3	9.44	9.7	10.5	11	9.07	10.48	9.86	11.6	9.52	10.13
4	NA	10.46	10.06	11.7	8.71	9.28	9.99	11.5	9.83	10.2
5	8.7	10.19	9.89	11.4	8.47	10.15	9.38	10.7	9.58	9.83
$\bar{x}$	8.99	10.06	9.79	11.5	8.87	10.51	9.78	11.4	9.55	10.05

Perim	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	1643.48	0.676	5.91	42	2.22
2	Site:TreeNo	35	366.656	0.151	4.47	42	2.22
3	Residuals	1808	421.932	0.173	NA	42	2.22
4	Total	1851	2432.06	1	10.6	42	2.22

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	9.42	11.4	9.67	12.2	9.46	11.97	10.5	12.6	10.04	10.8
2	9.43	10.1	10.35	12.6	9.99	12.24	10.6	12.6	9.96	10.9
3	9.98	10.4	11.46	11.8	9.86	11.28	10.6	12.5	10.12	10.9
4	NA	11.3	10.85	12.5	9.35	9.94	10.7	12.3	10.43	10.9
5	9.22	11.1	10.66	12.5	9.1	10.88	10	11.4	10.14	10.6
$\bar{x}$	9.51	10.9	10.6	12.3	9.55	11.26	10.5	12.3	10.14	10.8

Major	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	354.146	0.699	6.58	36	1.9
2	Site:TreeNo	35	84.2586	0.166	4.69	36	1.9
3	Residuals	1814	68.1021	0.134	NA	36	1.9
4	Total	1857	506.506	1	12.53	36	1.9

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	3.57	4.39	3.64	4.51	3.54	4.84	4.05	5.18	3.87	4.18
2	3.56	3.94	3.94	4.74	3.66	4.92	4.05	5.19	3.83	4.2
3	3.83	4.01	4.38	4.42	3.62	4.5	4.04	5.07	3.9	4.2
4	NA	4.38	4.19	4.69	3.4	3.72	4.09	5.06	4.02	4.19
5	3.48	4.25	4.19	4.56	3.33	4.09	3.82	4.61	3.93	4.03
$\bar{x}$	3.61	4.2	4.07	4.59	3.51	4.41	4.01	5.02	3.91	4.15

Feret	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	362.371	0.691	6.55	37	1.95
2	Site:TreeNo	35	87.9199	0.168	4.74	37	1.95
3	Residuals	1813	74.4245	0.142	NA	37	1.95
4	Total	1856	524.716	1	12.35	37	1.95

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	3.68	4.52	3.81	4.64	3.66	4.99	4.18	5.31	3.97	4.31
2	3.66	4.11	4.09	4.86	3.8	5.07	4.18	5.32	3.94	4.34
3	3.92	4.22	4.52	4.54	3.78	4.63	4.19	5.22	3.99	4.33
4	NA	4.6	4.34	4.81	3.55	3.82	4.23	5.22	4.12	4.34
5	3.58	4.47	4.34	4.68	3.46	4.19	3.94	4.77	4.02	4.16
$\bar{x}$	3.71	4.38	4.22	4.71	3.65	4.54	4.15	5.17	4.01	4.28

Minor	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	54.4063	0.65	6.01	37	1.95
2	Site:TreeNo	35	7.60249	0.091	5.26	37	1.95
3	Residuals	1813	21.7061	0.259	NA	37	1.95
4	Total	1856	83.7149	1	10.31	37	1.95

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	2	2.09	1.87	2.57	1.98	2.02	2.06	1.9	1.97	2.05
2	1.99	1.89	1.96	2.58	2.15	2.03	2.06	1.89	2.01	2.06
3	2.04	2	2.11	2.44	2.07	1.91	2.06	1.94	2.03	2.06
4	NA	2.05	2	2.59	2.06	2.05	2.14	1.88	2.12	2.11
5	1.95	2.04	1.88	2.56	2	2.23	2	1.88	2.02	2.06
$\bar{x}$	1.99	2.01	1.96	2.55	2.05	2.05	2.06	1.9	2.03	2.07

MinFeret	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	54.358	0.632	5.98	39	2.06
2	Site:TreeNo	35	7.49809	0.087	5.31	39	2.06
3	Residuals	1811	24.0913	0.28	NA	39	2.06
4	Total	1854	85.9474	1	9.99	39	2.06

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	2.07	2.19	1.97	2.66	2.06	2.11	2.17	2.01	2.05	2.14
2	2.06	1.98	2.05	2.69	2.24	2.13	2.17	1.99	2.09	2.15
3	2.11	2.12	2.2	2.53	2.17	2.01	2.17	2.05	2.1	2.16
4	NA	2.16	2.11	2.69	2.15	2.13	2.23	1.98	2.19	2.21
5	2.01	2.17	1.98	2.63	2.09	2.31	2.1	1.98	2.08	2.15
$\bar{x}$	2.6	2.12	2.06	2.64	2.14	2.14	2.17	2	2.1	2.16

Round	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	5.76505	0.705	6.85	49	2.59
2	Site:TreeNo	35	1.04703	0.128	5.34	49	2.59
3	Residuals	1801	1.36171	0.167	NA	49	2.59
4	Total	1844	8.17379	1	13.35	49	2.59

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	0.562	0.471	0.512	0.568	0.56	0.419	0.511	0.367	0.511	0.498
2	0.555	0.479	0.49	0.546	0.572	0.412	0.509	0.363	0.526	0.495
3	0.531	0.497	0.48	0.552	0.563	0.424	0.507	0.383	0.523	0.496
4	NA	0.471	0.476	0.556	0.584	0.544	0.522	0.373	0.529	0.507
5	0.558	0.478	0.447	0.56	0.601	0.543	0.523	0.408	0.512	0.514
$\bar{x}$	0.551	0.479	0.481	0.556	0.576	0.46	0.514	0.379	0.52	0.503

AR	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	122.221	0.747	6.72	58	3.06
2	Site:TreeNo	35	21.6213	0.132	5.21	58	3.06
3	Residuals	1792	19.8785	0.121	NA	58	3.06
4	Total	1835	163.721	1	14.76	58	3.06

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	1.78	2.11	1.92	1.75	1.78	2.38	1.96	2.72	1.95	2.04
2	1.81	2.08	2.01	1.82	1.72	2.39	1.96	2.76	1.9	2.05
3	1.88	2	2.06	1.77	1.76	2.35	1.96	2.61	1.92	2.03
4	NA	2.12	2.11	1.79	1.64	1.8	1.91	2.67	1.89	1.99
5	1.78	2.08	2.22	1.78	1.66	1.84	1.91	2.44	1.96	1.96
$\bar{x}$	1.81	2.08	2.06	1.78	1.71	2.15	1.94	2.64	1.92	2.01

Area	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	1818.18	0.663	10.38	40	2.11
2	Site:TreeNo	35	351.382	0.128	8.29	40	2.11
3	Residuals	1810	571.624	0.209	NA	40	2.11
4	Total	1853	2741.18	1	17.99	40	2.11

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	5.63	7.21	5.38	9.03	5.51	7.68	6.55	7.73	5.98	6.74
2	5.61	5.84	6.13	9.62	6.23	7.86	6.56	7.73	6.08	6.85
3	6.15	6.3	7.24	8.44	5.88	6.74	6.55	7.7	6.21	6.8
4	NA	7.11	6.6	9.63	5.53	6	6.86	7.49	6.65	6.98
5	5.33	6.85	6.22	9.15	5.25	7.17	6.02	6.82	6.22	6.56
$\bar{x}$	5.68	6.66	6.31	9.17	5.68	7.09	6.51	7.5	6.23	6.76

Table A10. *Hippopahe rhamnoides* germination analysis

G50	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	60.63856	0.806	7.4	4	4.55
2	Residuals	75	14.64071	0.194	0	4	4.55
3	Total	83	75.27927	1	17.17	4	4.55

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	5.13	5.56	4.38	4.98	4.75	6.41	5.27	8.56	4.66	5.52
2	4.82	5.9	5.34	4.62	4.66	6.08	4.79	NA	5.13	5.17
3	5.02	6.3	NA	5.03	5.18	5.51	5.16	7.74	5.89	5.73
4	5.38	5.81	5.3	5.52	5.16	4.92	5.42	7.94	4.72	5.57
5	NA	6.7	4.7	5.49	5.37	6.78	5.3	7.17	4.41	5.74
$\bar{x}$	5.09	6.05	4.93	5.13	5.02	5.94	5.19	7.8	4.96	5.57

Gmax	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	1.093712	0.6	10.16	2	2.27
2	Residuals	77	0.727793	0.4	0	2	2.27
3	Total	85	1.821505	1	17.36	2	2.27

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	0.85	0.925	0.801	0.851	1	0.901	0.725	0.851	0.775	0.853
2	0.95	0.875	0.95	0.952	1	0.925	NA	0.825	0.333	0.851
3	0.95	0.901	0.925	1	0.979	0.95	0.725	0.826	0.786	0.893
4	0.825	0.9	0.975	0.928	0.933	0.55	0.675	0.954	0.5	0.805
5	NA	0.95	1	0.757	0.906	0.7	0.725	0.876	0.575	0.811
$\bar{x}$	0.89	0.91	0.93	0.89	0.96	0.8	0.71	0.86	0.59	0.842

Germ	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	0.64927	0.245	19.42	4	4.55
2	Site:TreeNo	35	1.310611	0.495	13.16	4	4.55
3	Residuals	40	0.6875	0.26	NA	4	4.55
4	Total	83	2.647381	1	21.68	4	4.55

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	0.95	0.975	0.85	0.45	1	0.725	0.875	0.85	0.9	0.842
2	0.9	0.85	0.975	0.75	0.85	0.85	0.925	0.85	0.55	0.833
3	0.95	0.9	0.925	0.675	0.825	0.95	0.95	0.875	0.75	0.867
4	1	0.55	0.825	0.8	0.675	0.8	1	0.35	0.625	0.736
5	NA	0.4	1	0.825	0.8	0.95	0.875	0.3	0.7	0.731
$\bar{x}$	0.95	0.73	0.91	0.7	0.83	0.85	0.92	0.64	0.7	0.807

Slope	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	171.7873	0.634	16.49	4	4.55
2	Residuals	75	99.06353	0.366	0	4	4.55
3	Total	83	270.8509	1	28.85	4	4.55

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	6.47	9.59	4.28	5.2	5.35	6.39	5.99	8.12	5.69	6.34
2	6.89	7.93	8.05	4.55	4.75	7.31	5.79	NA	2.81	6.01
3	NA	6.18	7.61	4.72	4.23	9.15	6.97	7.62	3.62	6.26
4	6.16	9.27	6.54	4.53	3.68	5.7	6.59	5.93	5.54	5.99
5	NA	9.18	5.99	3.69	3.75	9.56	9.44	6.93	5.26	6.73
$\bar{x}$	6.51	8.43	6.5	4.54	4.35	7.62	6.95	7.15	4.58	6.29

Gday	Stratum	Df	Sum.Sq	Eta.Sq	CV	Outliers	OutlierPC
1	Site	8	42.03856	0.073	24.55	3	3.41
2	Site:TreeNo	35	344.1556	0.598	15.74	3	3.41
3	Residuals	41	189.5	0.329	NA	3	3.41
4	Total	84	575.6941	1	24.62	3	3.41

Means	2	4	6	7	8	12	14	15	17	$\bar{x}$
1	9.5	9	11.5	8.5	8	6	11.5	9	11.5	9.39
2	9	11	9	9.5	10	11.5	10.5	8	11	9.94
3	13	12	11	10.5	10.5	12	15	10.5	9	11.5
4	7.5	5	15	13	9.5	11	6	13	10	10
5	NA	9	9	10.5	15	12	15	12	10.5	11.62
$\bar{x}$	9.75	9.2	11.1	10.4	10.6	10.5	11.6	10.5	10.4	10.45

CURRICULUME VITAE

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