THE EFFECT OF PLANT DIVERSITY AND GROUND COVER ON SEEDLING ESTABLISHMENT OF *DIPLOTAXIS TENUIFOLIA* (L.) DC. IN THE CENTRAL ANATOLIAN STEPPE

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ABSTRACT

THE EFFECT OF PLANT DIVERSITY AND GROUND COVER ON SEEDLING ESTABLISHMENT OF *DIPLOTAXIS TENUIFOLIA* (L.) DC. IN THE CENTRAL ANATOLIAN STEPPE

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Invasive exotic plants increasingly pose a threat to native biodiversity in many parts of the world. However, they have rarely become successful in Turkey. One hypothesis suggests a highly diverse native flora avoids establishment of any potential invaders through intense competition. This hypothesis was tested through an experimental setup where a native plant, the Perennial Wall-rocket (*Diplotaxis tenuifolia*) was used to emulate an invasion at its early stages. *D. tenuifolia* is a cosmopolitan flowering plant native to parts of North Africa, West Asia and Europe, and considered to be invasive in regions such as Australia, Argentina and North America. The study took place at METU where ungrazed pockets of typical of Central Anatolian Steppe remain. The experimental setup involved varying levels of reduced species richness and/or ground cover through manipulation of the local vegetation, followed by transplanting the "invader" species and then recording its fate as a function of native plant diversity. Survival rates of *D. tenuifolia* seedlings were found to be significantly different, but showed weak effects for plots with varied levels of species richness and ground cover. At the end of the experiment, survival rates of *D. tenuifolia* seedlings in low, middle and high species richness categories was observed as %15.74, %18.83, and %16.36, respectively; and survival rates of low, middle and high cover categories was observed as %17.90, %20.68, and %12.34, respectively. This is the first study that explores conditions for invasiveness in Turkey. While this study does not confirm our main hypothesis, it paves the way for future research on explaining why invasive plant species are not successful in Turkey.

Keywords: Central Anatolian Steppe, Invasive Species, Biodiversity

ÖZ

İÇ ANADOLU BOZKIRINDAKİ BİTKİ ÇEŞİTLİLİĞİ VE TOPRAK ÖRTÜSÜNÜN *DIPLOTAXİS TENUIFOLIA* (L.) DC.'NIN FİDE YERLEŞİMİNE ETKİSİ

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İstilacı yabancı bitkiler dünyanın birçok farklı bölgesinde yerel biyoçeşitliliği tehdit etmekte, ancak bu bitkiler Anadolu'da nadiren başarılı olabiliyor. Bir hipoteze göre, çeşitliliği fazla olan yerel floralar, potansiyel istilacılarla yoğun bir rekabete girerek yerleşmelerini önlemekte. Bu hipotez, istilanın erken safhalarını taklit etmesi amacıyla yerel bir tür olan *Diplotaxis tenuifolia*'yı kullanarak, deneylerle test edilmiştir. *D. tenuifolia* kozmopolit ve çiçekli bir bitkidir. Kuzey Afrika, Batı Asya ve Avrupa'nın çeşitli kısımlarında yerli tür olarak tanınır. Bu tür, kuvvetli rekabetçi özelliklere sahiptir. Ayrıca Avustralya, Arjantin ve Kuzey Amerika bölgelerinde istilacı olarak kabul edilirler. Çalışma ODTÜ arazisinde, tipik İç Anadolu Bozkırının otlatılmamış bölgelerinde gerçekleşmiştir. Deney kurulumu, lokal vejetasyonun tür zenginliğinin ve/veya toprak örtüsünün farklı seviyelerde azaltılmasından sonra, "istilacı" türün fidelerinin dikilmesini ve yerel bitki çeşitliliğinin, istilacının geleceğini işlevsel anlamda nasıl etkilediğinin kaydedilmesini kapsamaktadır. *D. tenuifolia* fidelerinin canlı kalma oranı, farklı seviyelerde tür zenginliği ve toprak örtüsüne sahip parsellerde, anlamlı ölçüde farklılık göstermiştir ancak etki büyüklüğü düşüktür. Deneyin sonunda, *D. tenuifolia*'nın canlı kalma oranları düşük, orta ve yüksek tür zenginliği kategorilerinde, sırasıyla %15.74, %18.83 ve %16.36; düşük, orta ve yüksek toprak örtüsü kategorilerinde, sırasıyla %17.90, %20.68 ve %12.34 olarak belirlenmiştir. Bu çalışma Türkiye'deki istilacılık koşullarını araştıran ilk çalışmadır. Bu çalışma ana hipotezimizi onaylar nitelikte olmasa da istilacı bitki türlerinin neden Türkiye'de başarılı olamadığını açıklamak adına gelecekte yapılacak çalışmaların yolunu açmaktadır.

Anahtar Kelimeler: İç Anadolu Bozkırı, İstilacı Türler, Biyoçeşitlilik

Dedicated to Güliz and Erdoğan

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GLM	Generalized Linear Model
GAM	Generalized Additive Model
METU	Middle East Technical University

CHAPTER 1

INTRODUCTION

Invasive alien species, which can be described as non-native, exotic or introduced species, meaning that they are in an ecosystem where they were not evolved, are the major drivers of biodiversity loss around the globe, also affecting the economy and human health, and often share common traits such as rapid growth, fast seed production, and a high tolerance for the environment (Colautti & MacIsaac, 2004; Ehrenfeld, 2010; Fath, 2018). After the 16th century, alongside with increased travel of humans around the globe, invasive species thrived, causing the displacement and extinction of native species (Fath, 2018). There are 340 taxa in the alien flora in Turkey, and some of them are considered as invasive alien plant species, alongside with undiscovered ones (TiBK, 2015; Uludağ et al., 2017). Invasive alien plant species such as *Abutilon theophrasti*, *Amaranthus retroflexus*, *Conyza canadensis* (L.), *Xanthium spinosum* L., *Xanthium strumarium* L. can be found in Ankara, where this experiment took place (TiBK, 2015). However, there are no recordings of invasive alien plant species that invaded ungrazed and natural habitats of Central Anatolian Steppe, and this creates a gap in knowledge on why invasive alien plant species cannot establish, grow, and invade such habitats. One hypothesis suggests that a highly diverse native flora prevents the establishment of any potential invaders through intense competition (Levine et al., 2004). This study aims to test this hypothesis through an experimental setup in which a native plant, *Diplotaxis tenuifolia*, would emulate an invasion at its early stages. The study design involves varying levels of reduced species richness and ground cover through manipulating the local vegetation followed by planting the "invader" species and then recording its fate as a function of native plant diversity. The study took place at Middle East Technical University, where ungrazed pockets of typical of Central Anatolian Steppe remain. This will be the first study that explores conditions for invasiveness in Turkey.

1.1 Invasion Process

The invasion process, otherwise known as the invasion pathway, aims to explain sequential series of stages, or barriers, that all alien species transit (Cassey et al., 2018). This so-called invasion process is made of four sequential stages that are event-level effects: transport, introduction, establishment, and spread (Cassey et al., 2018). For a species to become an invasive alien species, it must successfully overcome all the biogeographical, social, demographic, environmental, and dispersal barriers through the invasion stages (Blackburn et al., 2011).

1.1.1 Transport

The network of transportation vectors (e.g., trains, trucks, ships, and planes) have expanded exponentially in the last century and along with technological advancement of transportation and globalization of trade, opened up new spatial opportunities for invasive alien species (Essl et al., 2015; Seebens et al., 2015). With these advancements, commodities such as nutrients, live animals, and plants can be transported around the globe relatively quickly, and these commodities carry along transmissible tests and diseases along with smaller species that transported through the commodity, its packaging, or the mode of transportation (Cassey et al., 2018).

1.1.2 Introduction

After a species is transported to a new area, they are not counted as introduced until the species can find its way into a recipient environment, as they might not survive the transportation or contained after they are off-loaded (Cassey et al., 2018). The introduction stage is an under-researched area and is sometimes considered to be the same as the transportation stage (Cassey et al., 2018). Furthermore, the research on the introduction stage suggests that propagule supply and traits (e.g., body mass) of the potential invasive species do effect the success of the introduction (Cassey et al., 2018; Su et al., 2016).

1.1.3 Establishment

The establishment stage is generally related to the survival of initially introduced individuals that form reproducing and expanding populations, that are influenced by characteristics of the invader species and the recipient ecosystem (Crooks & Rilov, 2009). In order to establish, species have to survive in a certain new environment, for invasive alien species, a certain new environment that they are considered as non-native (Lockwood et al., 2007). After the introduction, some traits, such as traits related to tolerance to harsh environmental conditions, are known to increase the success of survival and reproduction of invasive alien species in a new area (Crooks & Rilov, 2009). Furthermore, the introduced species must pass two environmental filters, abiotic and biotic filters. Invasive species must show tolerance to the physical and chemical properties of the environment that is caused by the habitat and the climate in order to establish successfully, and invaders are known to be more successful in degraded or disturbed habitats (Crooks & Rilov, 2009). Successful invasive species might capitalize on the fact that they left behind their co-evolved predators and parasites due to transportation (enemy release hypothesis), and factors such as species diversity and redundancy of the introduced area may influence the success of the invasive species (Crooks & Rilov, 2009).

1.1.4 Spread

Only some invasive species can manage to spread widely across their available range after they establish (Cassey et al., 2018). Hypotheses on the subjects such as the role of landscape-level habitat patterns, the strength of interspecific interactions, and species traits that promote dispersal explain some aspects of the invasive species spread (Cassey et al., 2018).

1.2 Invasion Hypotheses

There are many hypotheses about the mechanics of invasion and how invasive species establishes in new locations.

The preemption hypothesis suggests that the introduced species cannot establish in the new location due to the presence of native species, since these native species physically occupy the empty spaces and excludes the introduced species (Fath, 2018).

Enemy release hypothesis suggests that invasive species, different from native species, might be less affected by “enemies” such as herbivores and parasites; thus, they are more successful in competing with native species (Fath, 2018).

Resource hypothesis is based on the availability of resources, and as the resources are relatively higher, habitats are more prone to invasions. Resource-enrichment hypothesis and fluctuating resources hypothesis are based on the availability of unused resources, as these resources are relatively higher, habitats are more prone to invasions (Fath, 2018). Within the fluctuating resource hypothesis, disturbance and enrichment are seen as the main factors that increase resources. Still, natural fluctuations caused by weather conditions and drought can also cause invaders to access the resources (Radford, 2013).

The diversity-resistance hypothesis suggests that as the diversity of communities is higher, their proneness to invasion is lower. As there are fewer niches to be filled, it is more likely for the invasive species to be excluded from the habitat. On the contrary, there are field studies that support with increased diversity, habitats are more prone to invasive species. On another note, for large regional scales, increased diversity results in proneness to invasive species (Fath, 2018).

The geographical range hypothesis suggests that the range of the introduced species can be predicted through its climatic range in its native habitat, and after it establishes in a new continent, the species is likely to spread the entire climatic range over the decades (Fath, 2018).

1.3 Invasion Resistance

The best-known reasons for high invasibility are the high rate of disturbances in habitats and the high rate of propagule supply (Crawley et al., 1999). The theory that suggests diverse communities at small spatial scales resists invasions through competition has shown its validity through large numbers of research (Kennedy et al., 2002). Biotic factors of invasion resistance of ecosystems such as predation, presence of herbivores, pests and diseases; and abiotic factors such as high temperature or salinity can decrease the chance of the ecosystems colonization against invasive exotic plant species, and additionally, may constrain their spread and impact (Levine et al., 2004). Species identity may alter the invasion resistance of an ecosystem as invasive species with similar traits to the native plants would lower the chance of the invasive species establishment, as suggested by limiting similarity concept (Funk et al., 2008). Community ecology perspective suggests that resource opportunities arise for invasive alien species when native species do not reduce available resources and escape opportunities arise for invasive alien species when natural enemies such as diseases, predators, and parasites are not effective against invasive species (Shea & Chesson, 2002). Niche differentiation of a community does alter the invasion resistance as higher niche opportunities provide more invasion chances for invasive species (Shea & Chesson, 2002).

1.4 Plant Strategies

When studying the invasive plants or interactions between invasive plants and native plants, theories such as Universal Adaptive Strategy Theory and Resource - Ratio Theory, provides an insight on why invasive plants succeed or fail to establish and spread in different habitats.

1.4.1 Universal Adaptive Strategy Theory

According to Grime's "Universal Adaptive Strategy Theory," plants are evolved with three different forms of strategy to overcome natural selection: Competitive strategy, which is characterized by maximal vegetative growth in low stress and low disturbance conditions; Stress-tolerant strategy, which is characterized by reduced vegetative and reproductive vigor and increased endurance to environmental stress; and ruderal strategy which is characterized by short life span and high seed production to endure both disturbed and stressful environments (Grime, 1977).

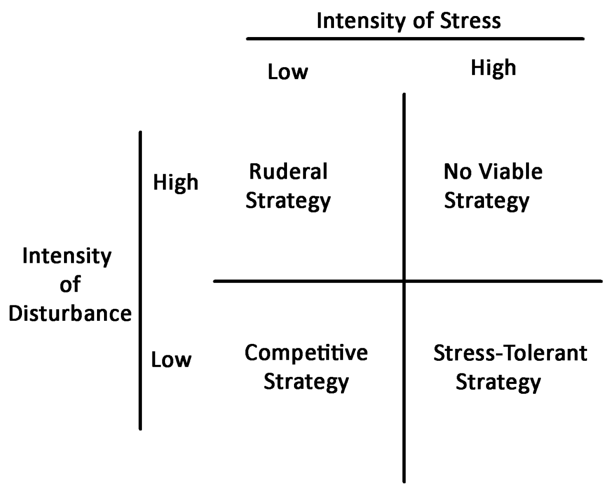

Figure 1.1: Parameters of Universal Adaptive Strategy Theory.

1.4.1.1 External Factors

There are two external factors which affect plant biomass in a defined area, stress and disturbance, which; in this case, stress factor consists of elements such as shortage of light, water, mineral, and sub-optimal climate, and disturbance factor consists of elements such as herbivore pressure, pathogens, human-induced disturbance, soil erosion, and fire (Grime, 1977). Plants with competitive strategy are best established in low stress and low disturbed habitats, plants with stress-tolerant strategy are best established in high stress and low disturbed habitats, and plants with ruderal strategy are best established in low stress and highly disturbed habitats (Grime, 1977).

1.4.1.2 Competitive Strategy

Using the definition of “the tendency of neighboring plants to utilize the same quantum of light, ion of a mineral nutrient, molecule of water, or volume of space” for plant competition is beneficial when discussing this strategy, as this definition argues that discussing competition with relation to its mechanism and not its effects allows us to differentiate such impacts as abiotic factors (e.g., physiochemical environment) or biotic effects (e.g., selective predation) (Grime, 1977). Nonetheless, when plants exist nearby, as neighbors, whether they are the same species or different species, properties such as growth, seed production, and mortality show differences to their stand-alone properties, but as it is indicated, changes in the performance of plants cannot be all attributed to competition, as these differences may be due to factors such as the capacity to exploit the resources (Grime, 1977). In order to determine the strategy of plants, characteristics such as lateral spread, canopy height and litter accumulation can be taken into account (Hodgson et al., 1999). Studying the competition mechanism may prove some difficulties as plants show variation in their competitive ability with different environments due to their responses to stress and disturbance and their genetic variations (Gadgil & Solbrig, 1972; Grime, 1977). Therefore, a plant may show strong competition traits in one site but may be weak in other environments. When we set aside the noncompetitive effects, it can be seen that mechanism of competition branches out as within the environments as there are different resources (e.g., space, water, minerals, etc.), different availability of those resources, and different ability to compete for those resources (Grime, 1977).

1.4.1.3 Stress Tolerant Strategy

When discussing this theory, defining stress as ”the external constraints which limit the rate of dry-matter production of all or part of the vegetation” would allow us to discuss different forms of stress (Grime, 1977). Stress tolerant species have the capacity to retain resources in different habitats that are poor in terms of resources, and are able to repair celular components of their dense and persistent tissues (Pierce et al., 2017). Plant growth and survival are closely related to abiotic resources, which was mentioned in the competitive strategy section, but also optimal climatic conditions and toxins or pollutants in the environment as plant species or different populations that contain different genetic variations may differ in susceptibility to some forms of stress, thus resulting in different plant compositions in different environments (Grime, 1977). Furthermore, some of this stress may be induced or originated by neighboring plants. Some of the most important types of plant induced stress are shading and reduction of nutrient levels in the soil (Grime, 1977). Among the stress types, there are abiotic stresses such as drought, salinity, heat, cold, chilling, freezing, nutrient, high light intensity, ozone and anaerobic stresses, and biotic stresses such as pathogens and herbivores (Suzuki et al., 2014). Apart from identifying stress characteristics of habitats, determining which type of stress is causing the limitation in the primary production of plants is also essential to understand this phenomenon (Grime, 1977). The best-known effect of stress is to weaken the species with high competitive ability and cause them to be replaced by stress-tolerant species (Grime, 1977). This effect might raise suspicion as tolerance to stress may differ according to the type of stress, but there is enough evidence to indicate that there are common aspects of tolerance to stress concerning its mechanism (Grime, 1977). Vascular plants that are adapted to different types of stress may have different mechanisms of coping, but the adaptations that have been shown against limited productivity are highly similar (e.g., evergreen habit, low phenotypic plasticity, shy flowering) (Grime, 1977).

1.4.1.4 Ruderal Strategy

Before discussing the ruderal strategy, a definition of disturbance should be given as “mechanisms which limit the plant biomass by causing its destruction” (Grime, 1977). Ruderal species invest their resources on their propagules, rather than the individuals, in order to regenerate the population when faced with repeated disturbance (Pierce et al., 2017). Environmental stress or unproductive habitats is not the sole reason for the low vegetation density. The partial or total destruction of the vegetation may also result in low densities as a balance between the processes of production and destruction determines the amount of vegetation and the ratio between living and dead material (Grime, 1977). There are numerous disturbance mechanisms such as natural catastrophes, human impact, and more isolated effects such as pathogens and seasonal shifts in climate; nonetheless, there are some distinctions between the forms of disturbance that consist of immediate removal of plants and remaining dead plant materials in habitats (Grime, 1977). While disturbance processes with low severity favor competitive species, disturbance processes with high severity favor ruderals, which are species highly adapted to exploit the disturbed environments, such as annual or perennial species with short life cycles (Grime, 1977). Two of the main characteristics of ruderal plants is a high rate of dry-matter production, which facilitate directing the energy sources from photosynthesis to seed production, that sometimes pursued even at times of severe stress and the cost of vegetative development; and a high rate of survivability of their seeds which is achieved through the ability to bury their seed in the soils for long periods of time and germinate rapidly when the disturbance takes effect (e.g., when disturbance results in light exposure to the seed or removes the insulating material (Grime, 1977).

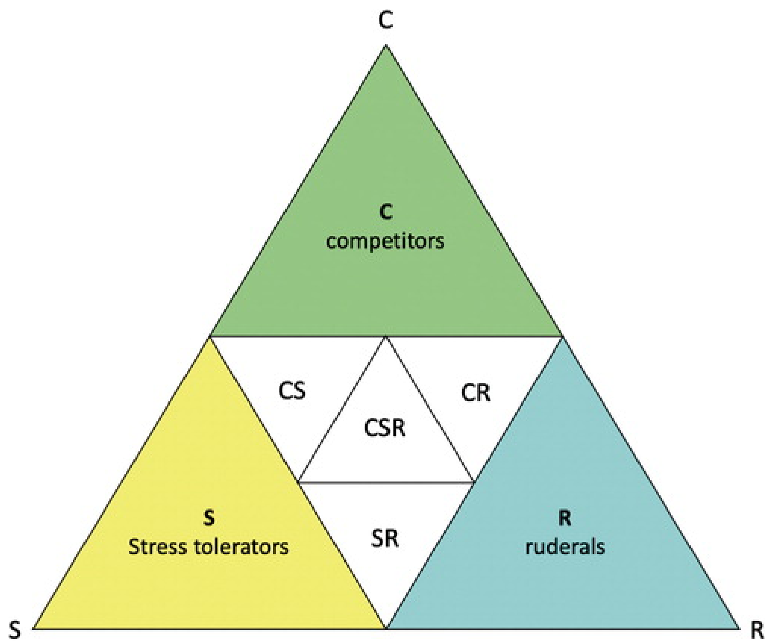

Figure 1.2: Grime's CSR Triangle.

1.4.2 Resource - Ratio Theory

David Tilman's "Resource - Ratio Theory" or R* rule, which was based on Robert MacArthur's work in 1972, was formed with the intention of explaining the interactions between competing species through analyzing their use and effect on mutually utilized resources (Miller et al., 2005).

This theory (which will be referred to as R* Rule from here on out) characterizes a dynamic interaction between consumers and limiting sources; as populations increase in size with the presence of abundant resources, they will start to compete with other species when resource levels drop and become limiting, and according to Tilman, the populations that can decrease resource levels to that degree should outcompete other species (Miller et al., 2005). Notwithstanding, while more than one resource constrains the population sizes, trade-offs in the ability to utilize different sources may allow the co-existence of competitor species (Miller et al., 2005).

1.4.2.1 Resource in R* Rule

Tilman describes resource as “a consumable factor for which increases in its availability lead to increased per capita reproductive rates through at least some range of its availability” and categorizes resources into substitutable, essential, or hemi-essential (Tilman, 1982).

1.4.2.2 Competition for resources

R* rule foresees that in the case of various species compete with each other for a singular limiting resource, the species that has the lowest requirement for the limiting resource should displace the rest of the species with the competition (Tilman, 1982). Furthermore, in the case of various species competing with each other for two resources, if one species has the lowest requirement for both of the resources, it displaces all other species through competition, disregarding the initial conditions (Tilman, 1982). In the case that one species does not have the lowest requirement for both resources but only one, a co-existence opportunity arises for another species that has the lowest requirement for the other resource, and whether these species can co-exist depends on the abundance and the rate of consumption of the limiting resources (Tilman, 1982).

1.4.2.3 Resource and Plant Diversity

Tilman's theory states that plants that differ in their requirements for the optimal ratio of resources can make up rich and stable communities, thus plant diversity should be maximal in habitats that are moderately poor in resources, and the diversity should decrease in the case of increased or decreased resource richness of the habitat (Tilman, 1982).

1.4.3 Plant Strategies and Invasive Plants

Vascular plants that adopt competitor and ruderal strategies are generalized with characters such as rapid growth, shortleaf life span, higher photosynthetic rate, and high flowering frequency, which coincides with invasive plant characteristics (Guo et al., 2018). There are previous studies at the regional and global scale for the C-S-R strategies of invasive plants, which emphasizes that established alien plants mostly adopt competitive and competitive-ruderal strategies (Guo et al., 2018). Alien plants that adopt stress-tolerant strategy do not show success relative to the other strategies either at the regional or global scale. Furthermore, alien plants that adopt ruderal strategy (excluding herbs that have a short life span) show relative success in naturalization (Guo et al., 2018; Pyšek et al., 2003). As it was mentioned, Tillman's R* Rule states that when there is a limiting resource, the species with the lowest requirement (or higher acquisition rate) for that resource eliminates the other species through competition. In the context of invasive species, if there is a limiting resource, the invasion would occur if the invasive species R* is lower than the native species according to the R* Rule (Ren & Zhang, 2009; Shea & Chesson, 2002). *D. tenuifolia* is a ruderal species, and while it is not considered a competitive-ruderal species, it was noted that they possess competitive traits to some extent (Erik, 2012; Masson et al., 2015). Nevertheless, *D. tenuifolia* can not invade natural, ungrazed, and unplowed habitats since the extent of its competitiveness are not enough to establish; and this would also suggest that *D. tenuifolia* has a higher requirement for the limiting resources in habitats as their competitive characteristics are quite limited (Erik, 2012).

1.5 Central Anatolian Steppe

Central Anatolia, which is the central region of Turkey, harbors Tuz Gölü (Salt Lake), and branches of Kızılırmak and Sakarya rivers, is an area that comprises plains, plateaus, rolling hills, and mountains of sedimentary or volcanic origin, and consists of soft bedrock–chalk, clay and marl (Ambarlı et al., 2016).

1.5.1 Climate

In Central Anatolia, summers are hot and dry, and winters are cold, especially on the East side. The coldest month is January with a mean temperature of -0.7°C and the hottest month is July with a mean temperature of 22°C, the annual mean temperature is 10.8°C. Annual precipitation is 413.8 mm, and rains mostly fall in spring and winter (Sensoy et al., 2008).

1.5.2 Vegetation

Steppes are primary climatogenic grasslands on dry habitats; they are very diverse and, in general, rich in forbs (Török et al., 2020). They are natural or semi-natural (transformed due to human interference) and present in arid or semi-arid regions in Eurasia and North Africa (Ambarlı, 2017). Trees and shrubs cover less than %10 and %25 of the steppe vegetation, respectively (Ambarlı, 2017). Ecologically, steppes are separated into five subregions due to different climate and soil properties: Europe, Central Asia, Mongolia, Tibet, and Mediterranean (Wesche et al., 2016).

The Central Anatolian Steppe is largely treeless due to its dry and harsh climate. The vegetation generally consists of dwarf-shrubs, herbs, geophytes, and annuals (Wit et al., 2012).

1.6 Diplotaxis tenuifolia

Diplotaxis tenuifolia (Perennial wall-rocket) is a perennial, ruderal plant from the Brassicaceae family that grows on empty fields around residential areas, roadsides, and tillages (Erik, 2012). While *D. tenuifolia* is considered a native species in the Mediterranean and western Asia, it is a cosmopolitan plant (Nicoletti et al., 2007). This plant's distinct features include brochidrodromous yellow petals and siliques with a seedless beak (Nicoletti et al., 2007). Furthermore, they are well adapted to rough and calcareous environments; they have high adapting, high competing, and easy propagation properties along with allelopathic substance production (S-glucopyranosyl thiohydroximate), thus considered to be an invasive species in countries such as Australia, Argentina, and United States of America (Eschmann-Grupe et al., 2003; Giordano et al., 2005; Padulosi & Pignone, 1996).

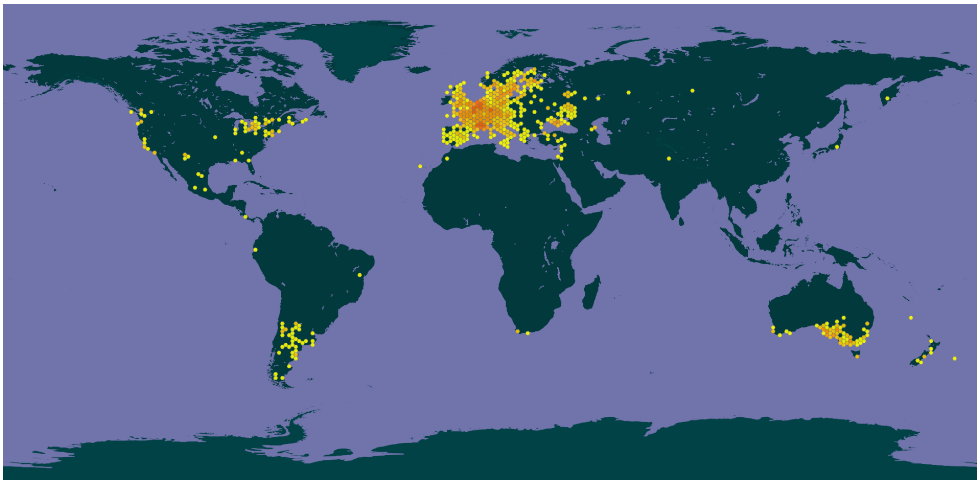

Figure 1.3: Global occurrence records of *Diplotaxis tenuifolia* on Global Biodiversity Information Facility (GBIF, 2020).

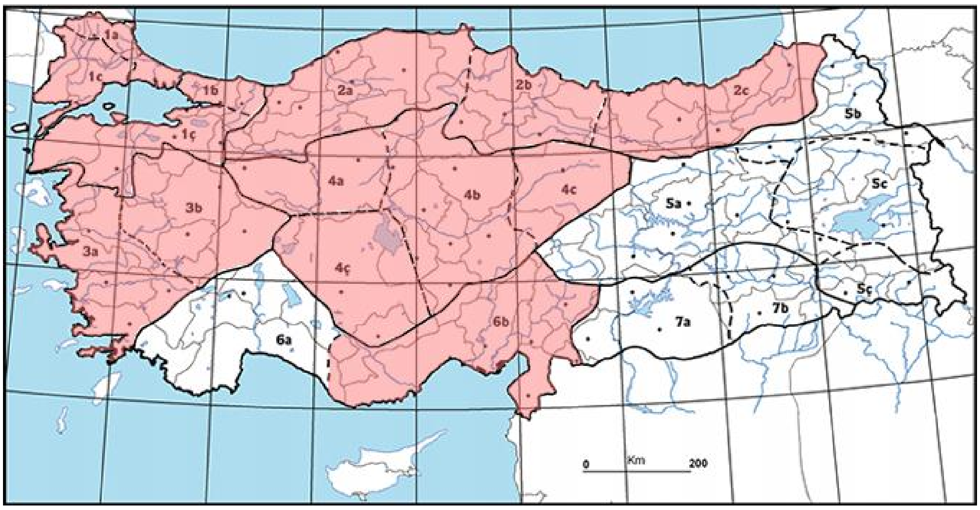

Figure 1.4: Distribution of *Diplotaxis tenuifolia* in Anatolia from Bizimbitkiler database (Mutlu, 2012).

1.7 Nurse Effect

Nurse effect is an aspect of plant facilitation, which explains that some perennial species such as shrubs, trees, and cushion plants can provide advantages to other plants through mechanisms such as increasing the seed output and promoting seed dispersal, functioning as a seed trap and promoting seed arrival, modification of the substrate and promoting the seedling establishment, reducing competition and abiotic stresses thus promoting plant growth, and lastly increasing survival and reproductive output (Filazzola & Lortie, 2014). It is also known that native species facilitate some invasive species with such mechanisms, and this phenomenon was investigated through the relation between survival rate of seedlings and ground cover in this study (Cavieres et al., 2008; Cavieres et al., 2005).

CHAPTER 2

MATERIALS AND METHODS

2.1 Study Area

2.1.1 Seed Collection Sites

Diplotaxis tenuifolia seeds were gathered at Middle East Technical University Campus (39°53’48.98"N, 32°46’51.08"E) (in front of METU Architecture Department) and İncek district (39°49’26.50"N, 32°43’28.17"E) (near Incek Taxi garage) in Ankara and Burdur (37°42’38.23"N, 30°13’58.22"E) (behind Burkent Market). These seeds were preserved in a glass jar and fridges at +4 C°.

Figure 2.1: Seed Collection Site in METU Campus (in front of METU Architecture Department)

Figure 2.2: Seed Collection Site in İncek (near Incek Taxi garage)

Figure 2.3: Seed Collection Site in Burdur (behind Burkent Market)

2.1.2 Experiment Site

An ungrazed patch of steppe with typical Central Anatolian Steppe vegetation was selected within the Middle East Technical University campus's borders (39°53'7.75"N, 32°46'11.24"E) (behind Aysel Sabuncu Care Center).

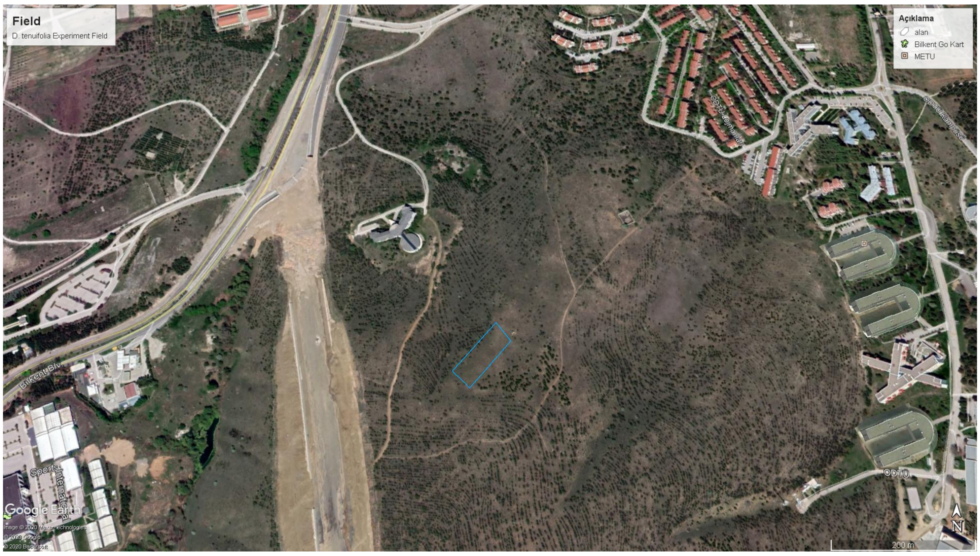

Figure 2.4: Experimental Field in METU Campus (behind Aysel Sabuncu Care Center)

2.2 Experimental Plots

2.2.1 Constructing the Plots

A total of 60, 1-meter square (1m x 1m) experimental plots were built systematically, 2 meters apart from each other. These experimental plots were placed as six columns and ten rows. Columns were coded with letters "A" through "F" and rows were coded with numbers "1" through "10". Four metal sticks that are 40 centimeters long were bent from one side and were nailed to the ground and bound together with a thread to form a square indicated the location of experimental plots. Every plot was marked with a unique code that contained a letter and a number.

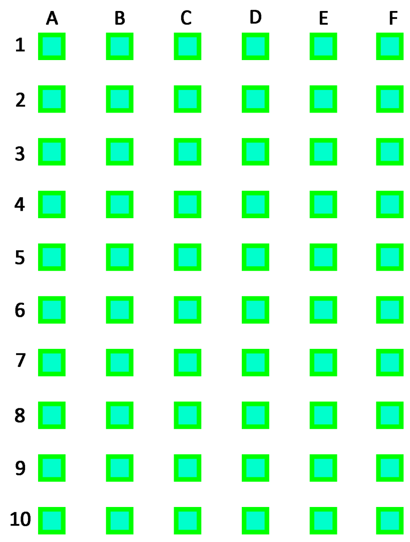

Figure 2.5: Layout of experimental plots in the field.

Figure 2.6: A constructed experimental plot

Figure 2.7: Special code of the experimental plots

2.2.2 Plot Measurements

2.2.2.1 Species Richness Measurements

After the plots were built, ground cover and plant species richness of each plot was measured. To determine the species richness of the plots, the plant species were first coded and photographed. Some of the plant species were identified at the experiment site. For plants that could not be identified at the site, samples were taken from outside the plots and identified in the laboratory by a qualified expert.

2.2.2.2 Ground Cover Measurements

To determine the ground cover, Point Intercept Method was used. To use this method, a 1-meter square plastic frame that contained ten equally distanced horizontal and vertical holes with threads was built, thus creating a "Cross-Hair Point Frame" with 100 cross-hairs. Ground cover of plots was measured through placing the point frame on to the plots and putting a metal stick on the ground at every cross-hair. The places where the stick hit the soil were recorded as empty, and the places the stick hit a plant were recorded alongside the name of the plant species that were present. After the recording, the ground cover was determined by dividing the number of plant recording to 100, thus identifying the ground cover in percentages.

Figure 2.8: Cross-hair Point Frame

2.2.3 Manipulating the Values of Experimental Plots

2.2.3.1 Determining the Categories for Ground Cover and Species Richness

To create varying levels of cover and richness, three levels for each category were created as low, medium, and high, thus when combined, create nine cover and richness plots. In 60 experimental plots, the mean and median values for species richness was found as 12,65 and 12; for ground cover it was found as 91,25 and 92. To form a gradient; low cover, medium cover, and high cover levels were determined as less than %39, between %40 and %69, and more than %70, respectively. Low richness, medium richness, and high richness levels were determined to be less than four species, between five and eight species, and more than nine species, respectively.

2.2.3.2 Assigning the Categories for Ground Cover and Species Richness

A semi-randomized technique was used to assign the cover and richness categories to plots, as completely randomizing the process was not possible due to non-manipulated species richness and ground cover values were not compatible with the assigned values. The plots with the highest cover and richness were assigned to high cover - high richness plots, and plots with the lowest cover and richness were assigned to low cover – low richness plots. Moreover, from remaining plots, the ones with the lowest cover and highest richness were assigned to low cover – high richness plots. After that, all the remaining plots were randomly assigned to the rest of the categories.

2.2.3.3 Manipulating the Ground Cover and Species Richness

After all the plots were assigned to cover and richness categories, the cover and plant richness values of the plots were reduced according to their assigned categories, and the reduced values were randomly appointed within the limits of each category's values. After that, ground cover and plant richness of the plots was reduced by removing the plants with their roots. To reduce the plant species richness, rarest species with respect to the total abundance of the plots were determined and removed from the plots, according to the randomly appointed values. To reduce the ground cover, the most abundant species with respect to the total abundance of the plots were determined and removed from the plots according to the randomly appointed values. For the removal, plots were divided into four hypothetical and equally sized subplots, and one plant was removed in order at every subplot to ensure an equal reduction in ground cover within the plots, starting from the South-Western subplot and continuing clockwise. After a plant was removed, Cross-Hair Point Frame was placed, and the ground cover was measured. This process was done until the assigned random value was reached. Lastly, all plots were disturbed at the ground level with a shovel to ensure that every plot was highly disturbed.

2.3 Seed Assays

2.3.1 Cut Test

To conduct a seed viability test, a total of 160 *D. tenuifolia* seeds were cut into half with a sharp razor blade and were examined under a microscope. 82 out of 160 seeds

(%51.25) were determined as viable, and the rest of the seeds were either dead or empty.

2.3.2 Seed Sowing

D. tenuifolia seeds were sown into the experimental plots after the manipulations took place, in June 2019 and December 2019, with approximately 2000 and 6000 seeds, respectively. For the process of sowing the seeds, experimental plots were divided into four hypothetical subplots, seeds were mixed with soil that was taken from outside of the experimental plots but from experimental sites, and the soil was scattered equally among the subplots. After 15 days, experimental plots were observed every week to determine any seedling emergence.

2.4 Seedling Preparation

Diplotaxis tenuifolia seeds were cultivated in a laboratory setup. The medium in which the seeds were planted contained well-mixed peat, vermiculite and perlite mixture, the ratio of the mixture was 4:1:1, respectively. This mixture was put in seedling trays and soaked in water. After that, 5 mg of *D. tenuifolia* seeds were planted in every cell of the total six seedling trays. After the plantation, seedling trays were placed under a light source that provided light for 12 hours, every day; and room temperature was approximately at 24.5 °C. The seedling trays were watered every two days. After *D. tenuifolia* seeds grew into seedlings, they were transplanted into bigger pots, and they were moved to a greenhouse.

Figure 2.9: Laboratory setup for seed cultivation

2.5 Seedling Transplants

Cultivated seedlings were transplanted into the experimental plots. All the transplanted seedlings had second set of leaves and eighteen seedlings were transplanted to every plot. Before the transplantation, every plot was divided into 18 hypothetical subplots (16,7 cm by 33,3 cm). Furthermore, holes that were around 3 cm deep were opened at the center of the subplots, and seedlings were transplanted into these holes on May 6. Dead plants were renewed with new ones the following two days to mitigate the effect of transplant. Seedlings was watered after the transplantation and after the renewals were done using 500 ml of tap water, and five days after the renewals using 1 liter of tap water for every plot to reduce the transplant effect. Moreover, plots were watered with 1 liter of tap water on May 15, May 18, and May 25 to normalize below seasonal normals of precipitation.

2.6 Data Recording

The survival of the seedlings in each plot was recorded every day for 92 days, starting from 9 May 2020. Climate data such as temperature, precipitation, humidity, cloud cover and wind speed were acquired from Turkish State Meteorological Service for stations TBMM, Ankara Guvercinlik Airport, and Etimesgut Airport. Mean values of these three stations was used in statistical analyses.

2.7 Statistical Methods

Statistical analyses were carried out to assess the relation between the survival rate (the number of living seedlings divided by the total number of transplanted seedlings in a plot) of the *D. tenuifolia* seedlings and species richness, ground cover, and climate values (daily values of maximum temperature, humidity, precipitation, cloud cover, maximum wind speed). These analyses were conducted within Linear Mixed-Effects Model with data observed over 92 days and time as a random factor (days since transplantation). R Studio was used for all the statistical analyses. R packages' stats', 'lme4' and 'mgcv' was used for Linear Mixed-Effects Model and Generalized Additive Model analyses, respectively. Linear Mixed-Effects Model was conducted using the 'lmer' function, and Generalized Additive Model analyses were conducted using the 'gam' function (Bates et al., 2015; R Core Team, 2020; Wood, 2017).

CHAPTER 3

RESULTS

A total of 76 taxa was found within the 60 experimental plots. While 10 of them could not be taxonomically identified and only coded, one was identified at division level (Bryophyta), 11 were identified at family level, 24 were identified at genus level, and 30 were identified at the species level (Appendix B).

Both for *D. tenuifolia* seeds that were sown to experimental plots in June 2019 and December 2019, there were no determined emergence of seedlings. For the seeds that were sown in June 2019, out of total 120.000 seeds that were sown, only four seedlings were found that may be potentially *D. tenuifolia* seedlings, but these could not be identified since these seedlings died before they grew enough to identify.

Linear mixed-effects model analyses showed that the effect of species richness, temperature, precipitation, humidity, maximum wind speed, and cloud cover show statistically significant results with the survival rate of *D. tenuifolia* seedlings, but they only explained a very small proportion of the total variation, which restrains us from concluding that manipulated values and climate values have an effect on the survival rate of transplanted seedlings.

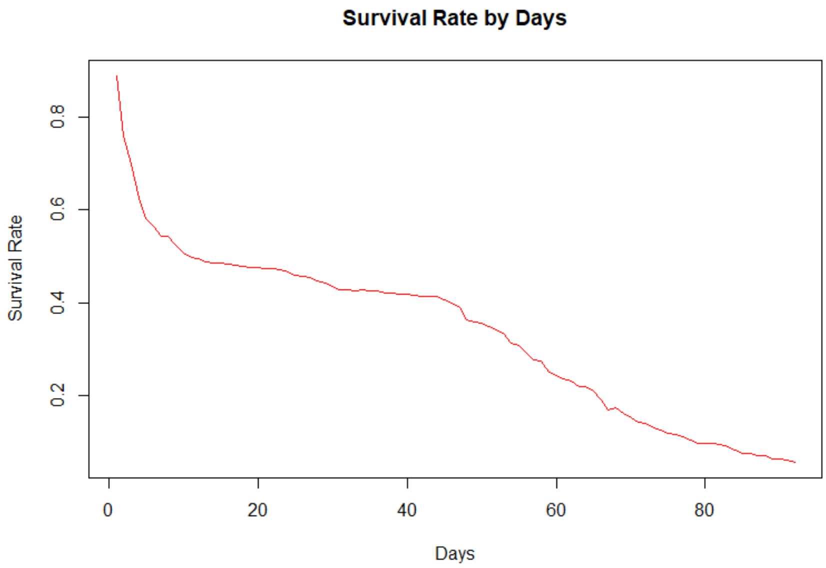

Figure 3.1: Survival rate of *D. tenuifolia* by days passed

3.1 Manipulated Values

3.1.1 Species Richness

While the Linear mixed-effects model analysis of species richness (as a fixed factor) and time (as a random factor) suggests a statistically significant correlation between species richness and survival rate, when compared to a null model (that only time is added as a random factor), species richness does not provide improvement for the model in terms of likelihood ratio and R-squared values; which would suggest that species richness as a variable produce a weak effect size and does not explain much of the total variance.

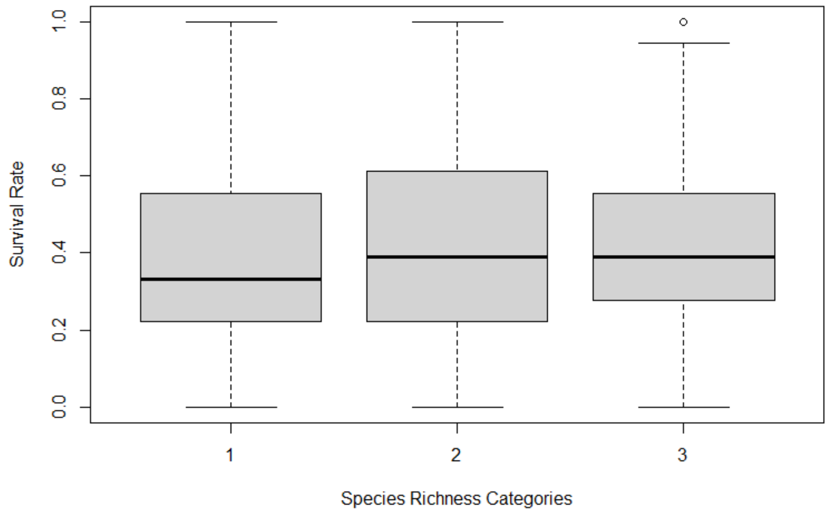

Figure 3.2: Survival rate of *Diplotaxis tenuifolia* in species richness categories. Species Richness Categories 1, 2, and 3 represents low, medium and high categories

Table 3.1: Linear Mixed Model Analysis of Survival Rate by Species Richness

	Value	Std.Error	DF	t	p	R-square
(Intercept)	0.3132	0.0198	4875	15785613	0	
Species Richness	0.0109	0.003	4875	3543602	0,0004	0.465
Time (Random)						0.4636

Table 3.2: ANOVA of Null Model and Species Richness Model

Model	AIC	BIC	logLik	deviance	Chisq	Pr(>Chisq)
Null	-2700.1	-2680.6	1353.1	-2706.1		
Spp. Richness	-2710.7	-2684.6	1359.3	-2718.7	12.543	0.0003

3.1.2 Ground Cover

Linear mixed-effects model analysis of ground cover (as a fixed factor) and time (as a random factor) does not suggest a statistically significant correlation between ground cover and survival rate. Also, when compared to a null model (that only time is added as a random factor), ground cover does not provide any significant improvement for the model in terms of likelihood ratio and R-squared values.

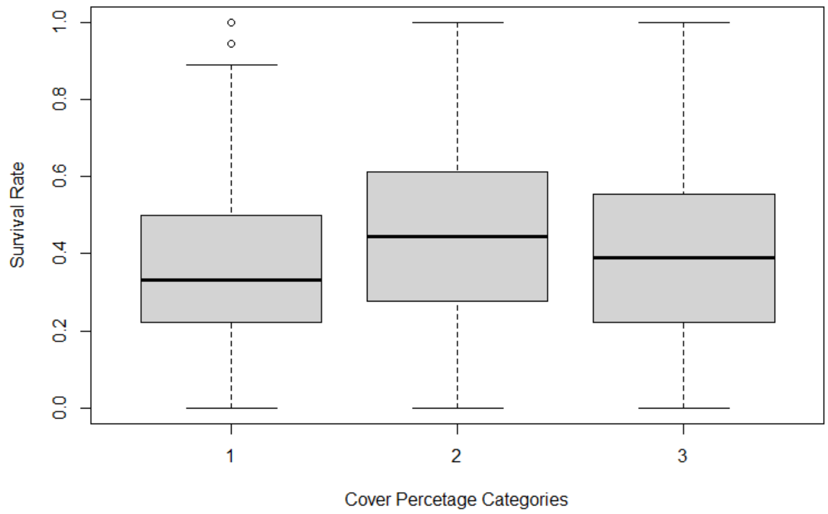

Figure 3.3: Survival rate of *Diplotaxis tenuifolia* in ground cover categories. Cover Percentage Categories 1, 2, and 3 represents low, medium and high categories

Table 3.3: Linear Mixed Model Analysis of Survival Rate by Ground Cover

	Value	Std.Error	DF	t	p	R-square
(Intercept)	0.3318	0.0198	4875	16720203	0.000	
Cover	0.0016	0.0031	4875	0.527338	0.598	0.4637
Time (Random)						0.4636

Table 3.4: ANOVA of Null Model and Ground Cover Model

Model	AIC	BIC	logLik	deviance	Chisq	Pr(>Chisq)
Null	-2700.1	-2680.6	1353.1	-2706.1		
Cover	-2698.4	-2672.4	1353.2	-2706.4	0.2781	0.5979

3.1.3 Interaction Effect of Species Richness and Ground Cover

While the Linear mixed-effects model analysis of the interaction of species richness and ground cover (as a fixed factor) and time (as a random factor) suggests a statistically significant correlation between this interaction and survival rate when compared to a null model (that only time is added as a random factor), species richness and ground cover do not provide improvement for the model in terms of likelihood ratio and R-squared values; which would suggest that the interaction of species and ground cover as a variable produce a weak effect size and does not explain much of the total variance.

Table 3.5: Linear Mixed Model Analysis of Survival Rate by Species Richness and Ground Cover

	Value	Std.Error	DF	t	p	R-square
(Intercept)	0.2443	0.0256	4873	9522133	0	
SpeciesRichness	0.0437	0.0081	4873	5373071	0	
Cover	0.0344	0.0081	4873	4231267	0	
SpeciesRichness x Cover	-0.0164	0.0037	4873	-4354354	0	0.467
Time (Random)						0.4636

Table 3.6: ANOVA of Null Model and Interaction (Species Richness and Ground Cover) Model

Model	AIC	BIC	logLik	deviance	Chisq	Pr(>Chisq)
Null	-2700.1	-2680.6	1353.1	-2706.1		
Interaction	-2725.9	-2686.8	1368.9	-2737.9	31758	5,89E-04

3.2 Climate Values

3.2.1 Maximum Temperature

While the Linear mixed-effects model analysis of maximum temperature (as a fixed factor) and time (as a random factor) suggests a statistically significant correlation between maximum temperature and survival rate, when compared to a null model (that only time is added as a random factor), maximum temperature does not provide improvement for the model in terms of likelihood ratio and R-squared values; which would suggest that maximum temperature as a variable produce a weak effect size and does not explain much of the total variance.

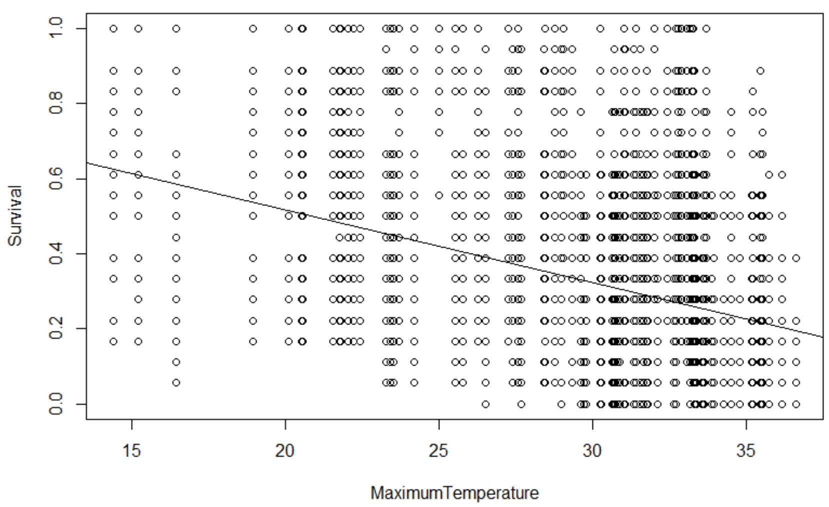

Figure 3.4: Scatterplot of the relation between Survival Rate and Maximum Temperature. Horizontal axis represents recorded temperatures in celsius

Table 3.7: Linear Mixed Model Analysis of Survival Rate by Maximum Temperature

	Value	Std.Error	DF	t	p	R-square
(Intercept)	0.9025	0.0944	4876	9551937	0	
MaximumTemperature	-0.019	0.0031	90	-6093186	0	0.467
Time (Random)						0.4636

Table 3.8: ANOVA of Null Model and Maximum Temperature Model

Model	AIC	BIC	logLik	deviance	Chisq	Pr(>Chisq)
Null	-2700.1	-2680.6	1353.1	-2706.1		
Max Temp.	-2729.9	-2703.9	1369.0	-2737.9	31775	1,73E-05

3.2.2 Cloud Cover

Linear mixed-effects model analysis of cloud cover (as a fixed factor) and time (as a random factor) suggests a statistically significant correlation between cloud cover and survival rate, but when compared to a null model (that only time is added as a random factor), cloud cover does not provide improvement for the model in terms of likelihood ratio and R-squared values; which would suggest that cloud cover as a variable produce a weak effect size and does not explain much of the total variance.

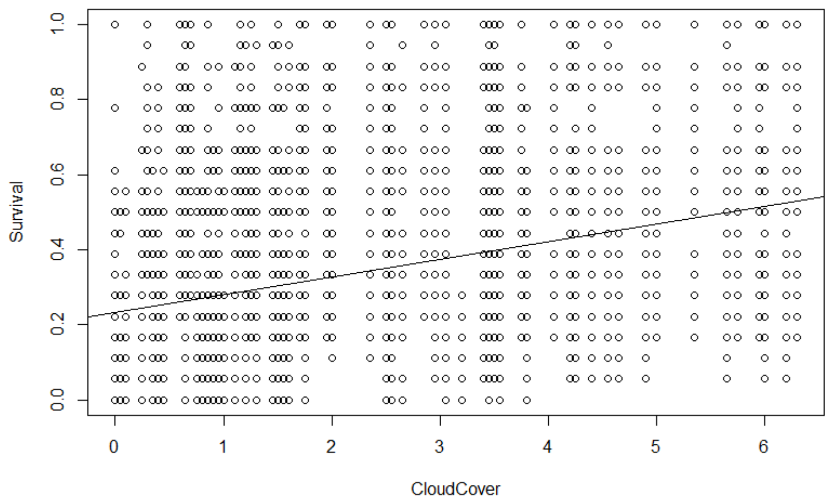

Figure 3.5: Scatterplot of the relation between Survival Rate and Cloud Cover. Horizontal axis represents recorded cloud cover in oktas

Table 3.9: Linear Mixed Model Analysis of Survival Rate by Cloud Cover

	Value	Std.Error	DF	t	p	R-square
(Intercept)	0.2336	0.0262	4876	8921677	0	
Cloud Cover	0.0471	0.009	90	5036417	0	0.4661
Time (Random)						0.4636

Table 3.10: ANOVA of Null Model and Cloud Cover Model

Model	AIC	BIC	logLik	deviance	Chisq	Pr(>Chisq)
Null	-2700.1	-2680.6	1353.1	-2706.1		
Cloud Cover	-2721.0	-2694.9	1364.5	-2729.0	22843	0,001758

3.2.3 Humidity

Linear mixed-effects model analysis of humidity (as a fixed factor) and time (as a random factor) suggests a statistically significant correlation between humidity and survival rate, but when compared to a null model (that only time is added as a random factor), humidity does not provide improvement for the model in terms of likelihood ratio and R-squared values; which would suggest that humidity as a variable produce a weak effect size and does not explain much of the total variance.

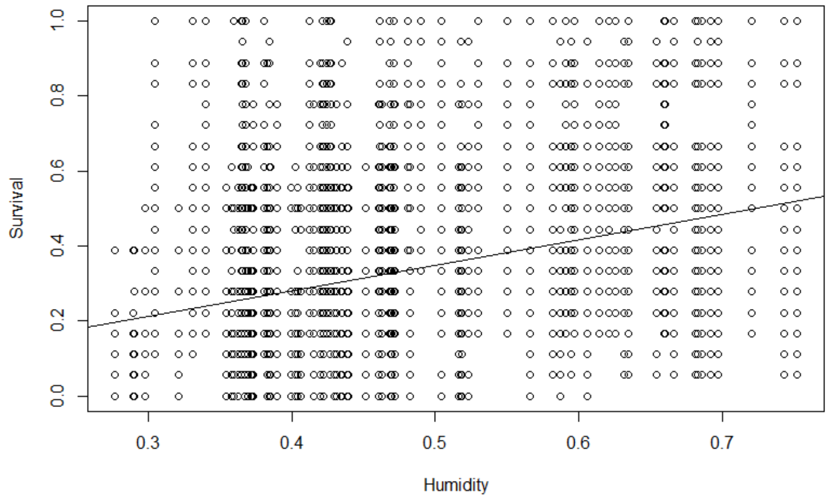

Figure 3.6: Scatterplot of the relation between Survival Rate and Humidity. Horizontal axis represents recorded humidity percentage

Table 3.11: Linear Mixed Model Analysis of Survival Rate by Humidity

	Value	Std.Error	DF	t	p	R-square
(Intercept)	0.00543	0.0709	4876	0.0765	0.939	
Humidity	0.6845	0.143	90	4785886	0.000	0.4660
Time (Random)						0.4636

Table 3.12: ANOVA of Null Model and Humidity Model

Model	AIC	BIC	logLik	deviance	Chisq	Pr(>Chisq)
Null	-2700.1	-2680.6	1353.1	-2706.1		
Humidity	-2719.0	-2692.9	1363.5	-2727.0	20.86	0,0049

3.2.4 Precipitation

Linear mixed-effects model analysis of precipitation (as a fixed factor) and time (as a random factor) suggests a statistically significant correlation between precipitation and survival rate, but when compared to a null model (that only time is added as a random factor), precipitation does not provide improvement for the model in terms of likelihood ratio and R-squared values; which would suggest that precipitation as a variable produce a weak effect size and does not explain much of the total variance.

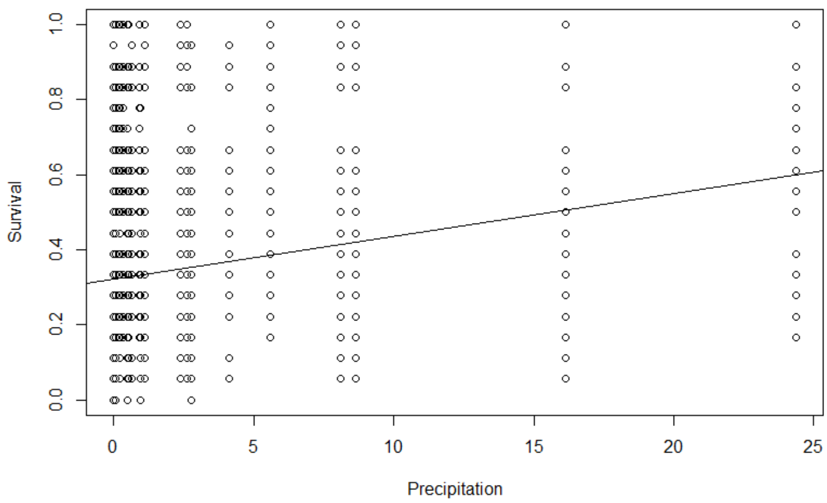

Figure 3.7: Scatterplot of the relation between Survival Rate and Precipitation. Horizontal axis represents recorded precipitation in millimeters

Table 3.13: Linear Mixed Model Analysis of Survival Rate by Precipitation

	Value	Std.Error	DF	t	p	R-square
(Intercept)	0.3218	0.0195	4876	16503235	0.0000	
Precipitation	0.0114	0.00534	90	2147239	0.0345	0.4641
Time (Random)						0.4636

Table 3.14: ANOVA of Null Model and Precipitation Model

Model	AIC	BIC	logLik	deviance	Chisq	Pr(>Chisq)
Null	-2700.1	-2680.6	1353.1	-2706.1		
Precipitation	-2702.7	-2676.7	1355.4	-2710.7	45963	0.03204

3.2.5 Maximum Wind Speed

Linear mixed-effects model analysis of maximum wind speed (as a fixed factor) and time (as a random factor) does not suggest a statistically significant correlation between maximum wind speed and survival rate. Also, when compared to a null model (that only time is added as a random factor), maximum wind speed does not provide any significant improvement for the model in terms of likelihood ratio and R-squared values.

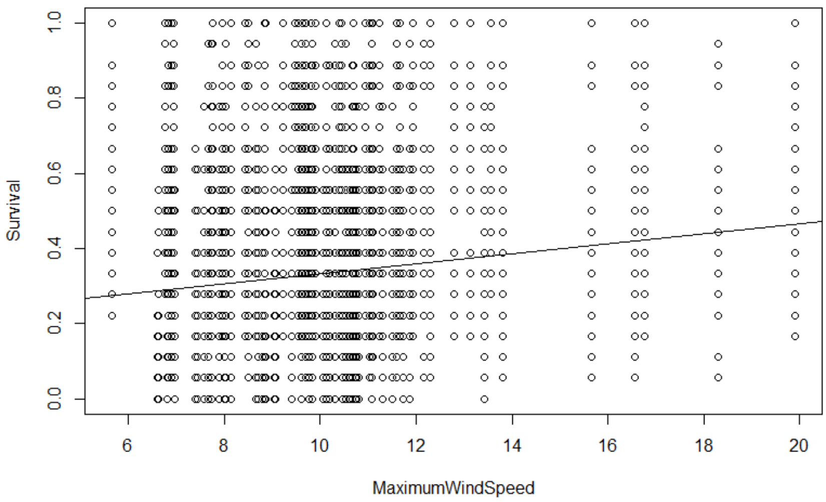

Figure 3.8: Scatterplot of the relation between Survival Rate and Maximum Wind Speed. Horizontal axis represents recorded maximum wind speed in meters/seconds

Table 3.15: Linear Mixed Model Analysis of Survival Rate by Maximum Wind Speed

	Value	Std.Error	DF	t	p	R-square
(Intercept)	0.1996	0.0784	4876	2544859	0.0110	
MaximumWindSpeed	0.0133	0.0075	90	1777119	0.0789	0.464
Time (Random)						0.4636

Table 3.16: ANOVA of Null Model and Maximum Wind Speed Model

Model	AIC	BIC	logLik	deviance	Chisq	Pr(>Chisq)
Null	-2700.1	-2680.6	1353.1	-2706.1		
Max. Wind.	-2701.3	-2675.3	1354.7	-2709.3	3173	0.07487

3.3 Manipulated Values and Climate Values

For the Linear mixed-effects model analysis of ground cover, species richness, precipitation, maximum temperature, humidity, maximum wind speed, cloud cover (as a fixed factor) and time (as a random factor); ground cover, species richness, and maximum temperature suggests a statistically significant correlation with survival rate, and precipitation, humidity, maximum wind speed, and cloud cover does not show a does not suggest a statistically significant correlation with survival rate. When this model is compared to a null model (that only time is added as a random factor), none of the fixed factors provides improvement for the model in terms of likelihood ratio and R-squared values; which would suggest that manipulated and climate as variables produce a weak effect size and do not explain much of the total variance.

Table 3.17: Linear Mixed Model Analysis of Survival Rate by Manipulated and Climate Values

	Value	Std.Error	DF	t	p	R-square
(Intercept)	0.6763	0.2430	4873	2783624	0.0054	
Species Richness	0.0437	0.0081	4873	5373071	0.0000	
Cover	0.0344	0.0081	4873	4231267	0.0000	
Max. Temperature	-0.0161	0.0053	86	-3051143	0.0030	
Cloud Cover	0.0174	0.0166	86	1050718	0.2963	
Humidity	-0.063	0.2592	86	-0.243258	0.8084	
Precipitation	-0.001	0.0053	86	-0.151888	0.8796	
Max. Wind Speed	0.0037	0.0077	86	0.486778	0.6277	
SpeciesRichness:Cover	-0.0164	0.0037	4873	-4354354	0.0000	0.4707
Time (Random)						0.4636

Table 3.18: ANOVA of Null Model and All Factors Model

Model	AIC	BIC	logLik	deviance	Chisq	Pr(>Chisq)
Null	-2700.1	-2680.6	1353.1	-2706.1		
All Factors	-2750.6	-2678.9	1386.3	-2772.6	66426	2.52e-11

CHAPTER 4

DISCUSSION

Due to its vital management component, invasion biology is generally considered a topic on the intersection of ecology and conservation biology, as it is both a research field and a field of action (Courchamp et al., 2017).

The dominant paradigm in invasion biology is successful invaders must overcome biotic resistance, such as competition (Levine et al., 2004). The main interest in biotic resistance against invasive species is due to possible benefits such as predicting which communities are more susceptible to invasions and dealing with invasive species, as it causes great harm to global biodiversity and the global economy (Levine et al., 2004).

Many researchers studied the effect of competition on invasive plant species with different invader species, habitats, manipulation types, and response variables. The dominant outcome is that competition does form a barrier against invasive plant species. One meta-analysis revealed strong and significant effects of resident competitors on both the establishment and individual performance of exotic invaders (Levine et al., 2004). Additionally, the same meta-analysis studied the effect of species diversity on invasive plant species and stated only one paper by Lyons & Schwartz in 2001 utilized a non-native species as the invader; thus, the findings were cluttered, and Lyons & Schwartz found that species diversity actually facilitated the invader (Levine et al., 2004). Nonetheless, it is speculated for the Lyons & Schwartz paper that with less plant diversity, much more invaders could establish on the experiment site (Levine et al., 2004).

The main hypothesis of this research was that the reason invasive plants can not invade natural Central Anatolian Steppe vegetation is due to plant diversity. This hypothesis was produced due to observations that invasive plants were not recorded in Central Anatolian Steppe, which are highly diverse in terms of plant species, and there are numerous empirical studies on plant diversity contributes to invasion barrier through intense competition. The expectation when testing this hypothesis through the experiments was that experimental plots with higher species richness would show a quicker or higher death rate compared to experimental plots with low species richness. Furthermore, the field observation that *D. tenuifolia* seedlings that were near or under another bigger plant had a higher survival rate led this research to investigate nurse effect of the vegetation. Therefore, after these observations and before the statistical analyses, the hypothesis was enhanced by stating that higher species richness in experimental plots would result in lower survival rates, and high ground cover in experimental plots would result in higher survival rates.

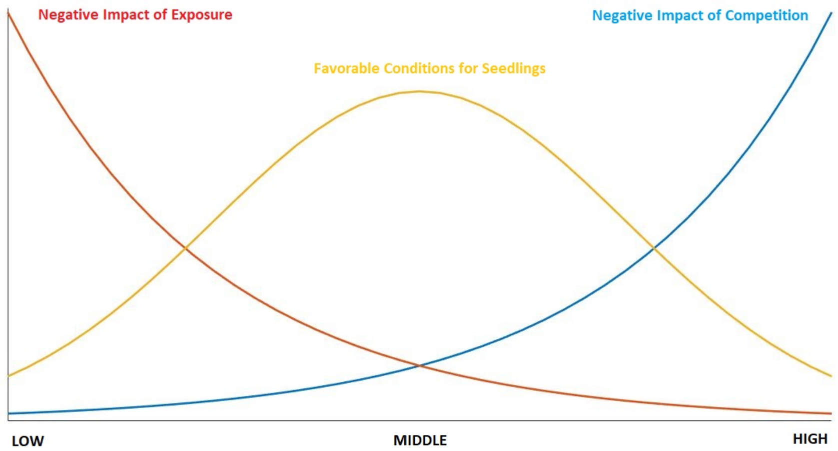

Figure 4.1: This graphic visualize the hypothesis that levels of nurse effect and species richness effects negative impact of exposure (due to low ground cover) and negative impact of competition (due to high species richness), respectively. Favorable conditions for *D. tenuifolia* seedlings can occur when the negative impact of exposure and negative impact of competition levels are not too high

While the analyses do not approve the hypothesis that plant diversity is the main reason why invasive species can not colonize the natural and ungrazed pockets of Central Anatolian Steppe, it paves the way for future research for determining the reasons for this phenomenon. Some potential reasons for this phenomenon might be due to resource availability, soil composition, identity, and traits of the native species, niche differentiation, and predation by insects. *D. tenuifolia* is known for its success in colonizing the fields on roadsides and around residential areas, which are highly disturbed and this could suggest that highly competitive plants that reside in experimental plots are better in terms of utilizing the limited resources in the soil. There are also few observations on the ants that inhabit the experiment area were feeding on the *D. tenuifolia* leaves, which could suggest that herbivores may alter the invasion resistance of the experimental area. Furthermore, trait differentiation and diversity could be another reason for the invasion resistance, as this experimental setup did not measure or analyzed any plant traits.

Figure 4.2: A photograph of an ant that carry a pulled out *D. tenuifolia* leaf

4.1 Selection of Invader Species

One of the reasons why the statistical analyses did not validate the hypothesis might be due to the selection of the "invader" species, *D. tenuifolia*. In the summer of 2019 and the fall of 2019, approximately 2000 and 6000 *D. tenuifolia* seeds, respectively, were planted into each experimental plot. While it is expected that the introduction of such seed supply would result in a number of established *D. tenuifolia* plants, there were no instances of any established *D. tenuifolia*. Furthermore, in the case of any unnoticed seed germination, there were not any observations or recordings of *D. tenuifolia* seedlings.

For the prior and the current experiment, the low survival rate of the *D. tenuifolia* seeds and seedlings in all the ground cover and species richness categories also indicate that this species might not be suitable for this type of experiment. While *D. tenuifolia* is a ruderal plant and considered to be an invasive species in different parts of the earth, it still is a native plant for the selected region. Therefore, this species is exempted from any "enemy-release" advantages, meaning that it does not escape from its natural predators, pathogens, or competitors.

When the applications of Universal Adaptive Strategy Theory and R* Rule to the invasive plant ecology are taken into account, competitive characteristics of *D. tenuifolia* might be insufficient in order to establish in the natural, ungrazed, unplowed pockets of Central Anatolian Steppe habitat. Furthermore, the process of disturbance that was applied to the experiment field through reducing species richness and ground cover might not be enough for *D. tenuifolia* to establish, since this species is considered to be a ruderal species (Erik, 2012).

4.2 Nurse Effect

Different ground cover categories provide an opportunity to inquire about the supposed "nurse effect" that took place in the experimental plots. The facilitation of the so-called invader by the native plants in experimental plots was observed in the first 43 days of the experiment. In this time frame, seedlings in the low ground cover experimental plots showed a much lower survival rate when compared to the experimental plots that were appointed to the medium ground cover and high ground cover categories. A couple of different reasons can explain this phenomenon. First, facilitation provided by the native species might have reduced the transplantation shock that took place in the first days of the experiment. While this might explain some portion of the phenomenon, it would not explain what took place in the remaining of the time frame. It is possible that native species facilitated *D. tenuifolia* seedlings through providing some form of protection and cover it from the climatic effects such as high temperatures. As for the rest of the experiment time frame, the effect of the facilitation was not enough in July and August, and possibly the effect of drought and high temperatures were too high.

4.3 Unusual Climate

Unusual levels of high temperature were seen in the summer of 2020 in the northern hemisphere and in Ankara, where this experiment took place. This might be another reason why the statistical analyses did not validate the hypothesis, as harsh climatic conditions most probably affected the survival rate of the *D. tenuifolia*. National Oceanic and Atmospheric Administration (NOAA) states that, for the northern hemisphere, this summer, global land and ocean surface temperature was the second highest in the 141-year record at 14.85 degrees Celcius and 1.05 degrees Celcius above the 20th-century average. It was the hottest year-to-date on record across a large portion of northern Asia, parts of Europe, China, Mexico, northern South America as well as the Atlantic, northern Indian and Pacific oceans.

Turkish State Meteorological Service (MGM) states that, in the summer of 2020, for provinces of Eskişehir and Ankara, and counties Aksaray, Akşehir, Ereğli, Kulu, Yunak, Pınarbaşı, mean temperature values were above the seasonal normals, for the rest of the Central Anatolia region, mean temperature values were around the seasonal normals. In Central Anatolia, the lowest temperature was in Kangal province with 1.9 degrees Celcius, and the highest mean temperature was in the city of Kırıkkale and Çiçekdağı province with 39.9 degrees Celcius.

In the summer of 2020, precipitation levels for Turkey were lower than the seasonal precipitation levels, which was higher than seasonal normals. Across Turkey, the mean precipitation value for summers was 65.7 mm between the years of 1981 and 2010; it was 68.0 mm for the summer of 2020 and 89.3 mm for the summer of 2019. These findings explain that for the summer of 2020, seasonal precipitation was %8 higher but %26 lower than the summer of 2019. For Central Anatolia, the mean precipitation value between the years of 1981 and 2020 is 53.7 mm, 53.3 mm for the summer of 2020, and 105.9 mm for the summer of 2019. Precipitation levels were normal when compared to seasonal normals, but were %49 lower when compared to the summer of 2019.

The climate data that was compiled from "National Oceanic and Atmospheric Administration" (NOAA) and "Turkish State Meteorological Service" (MGM) suggests that temperature values for the summer of 2020, when this experiment took place, was higher than seasonal normals. Furthermore, in the summer of 2020, while precipitation levels were close to seasonal normals, it was intensely lower than in 2019. This would suggest that one reason for the statistical analyses could not validate the hypothesis in question might be due to intensely different climatic values of this year affecting the survival rate of the *D. tenuifolia* seedlings and meddle with the results. Although statistical analyses did not validate the effect of the climatic values on the survival rate of the invader seedlings, it still should be considered as a factor, as the climatic data suggests a drastic change from the seasonal normals and high temperature is known to make ecosystems harder to invade (Levine et al., 2004).

4.4 Transplant Shock

Another reason for the statistical findings are not supporting the hypothesis might be due to a possible transplant shock that took place at the beginning of the field experiment. Seedling transplant shock can be defined as a certain spectrum of planting conditions such as seedling mortality or impaired growth after planting the seedlings (Close et al., 2005). Transplant shock is used for describing a number of distinct physiological responses to stress as it can result in the death of the seedling or impairment of the performance of seedling (Close et al., 2005). The reason why transplanted seedlings suffer some consequences is related to limited and confined root systems and imperfect root-soil contact (Burdett, 1990). This process reduces the effective root area of the seedlings and eliminates the root hairs, so even under favorable abiotic conditions, transplanted seedlings do subsist through the stress (van Bavel, 1996). Furthermore, some climatic extremes, such as drying wind, low precipitation, high temperature, amplify the effect of this shock (Sharma et al., 2006).

An observation in the experiment area might indicate that transplant shock took effect when the experiment began. Two long and large flower pots that contained *D. tenuifolia* seedlings were left at the experiment area on the same day of transplantation. While the seedlings in the pots grew, there were no instances of growing within the experimental plots. However, this very well might be due to other factors such as competition and resource availability in the soil. Nevertheless, if any transplant shock took place within the experimental plots, it might have interfered with the statistical analyses.

Figure 4.3: A photograph of *D. tenuifolia* in the flower pot

Figure 4.4: A photograph of *D. tenuifolia* in the experimental plot

In conclusion, there are many possible reasons (e.g., high temperature levels, transplantation shock, selection of the invader species, traits of the native plants, resource availability, herbivores, soil composition, facilitation by native plants) why this experiment did not produce a direct causality relation between plant diversity and the survival rate of the *D. tenuifolia* seedlings. Some future considerations for understanding this phenomenon that takes place in Central Anatolian Steppe could involve studying the soil salinity and composition as the literature suggests that it directly affects the success of the invader plants' success. Furthermore, the identity of the native plant species should be studied as it is highly possible that while some plants facilitate the invasive plants, some plants compete with them through a number of mechanisms.

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Appendix A

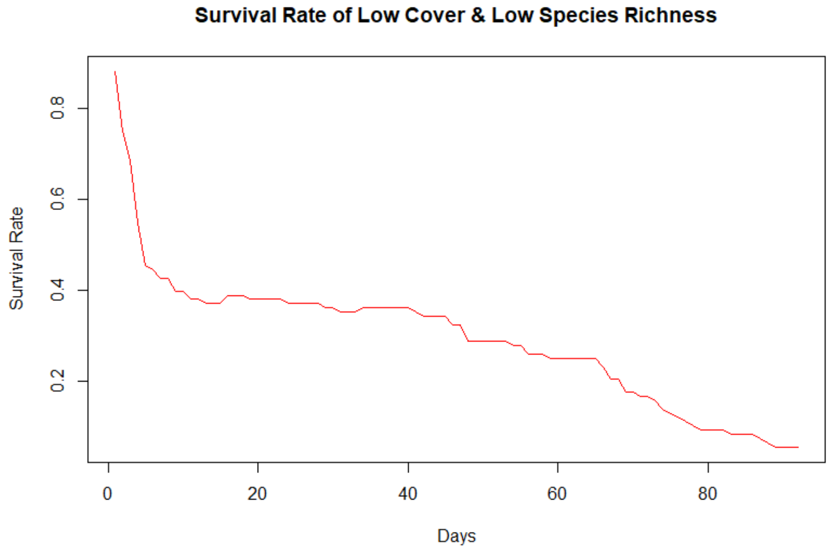

Figure A.1: Survival rate of Low Cover, Low Species Richness plots

Table A.1: Regression Analysis of "Survival Rate" by factors for Low "Ground Cover" and Low "Species Richness" categories.

Dep. Var.	Factor I	Factor II	F-statistic	t-value	Adj. R-sqr
Survival	Days		415.6	10-16	0.4294
Survival	Days	Max. Temp.	208.1	10-16 & 0.378	0.4292
Survival	Days	Precipitation	207.9	10-16 & 0.473	0.4289
Survival	Days	Humidity	207.7	10-16 & 0.624	0.4286
Survival	Days	Max. Wind	208.5	10-16 & 0.272	0.4296
Survival	Days	Cloud Cover	209.1	10-16 & 0.168	0.4303

Table A.2: Generalized Additive Model of "Survival Rate" by factors for Low "Ground Cover" and Low "Species Richness" categories

Dep. Var.	Factor I	Factor II	GCV	t-value	Dev. Exp.
Survival	Days		0.02312	10-16	43%
Survival	Days	Max. Temp.	0.022864	10-16 & 0.0116	44.1%
Survival	Days	Precipitation	0.023183	10-16 & 0.473	43.1%
Survival	Days	Humidity	0.023194	10-16 & 0.685	43.1%
Survival	Days	Max. Wind	0.023151	10-16 & 0.358	43.2%
Survival	Days	Cloud Cover	0.023125	10-16 & 0.168	43.2%

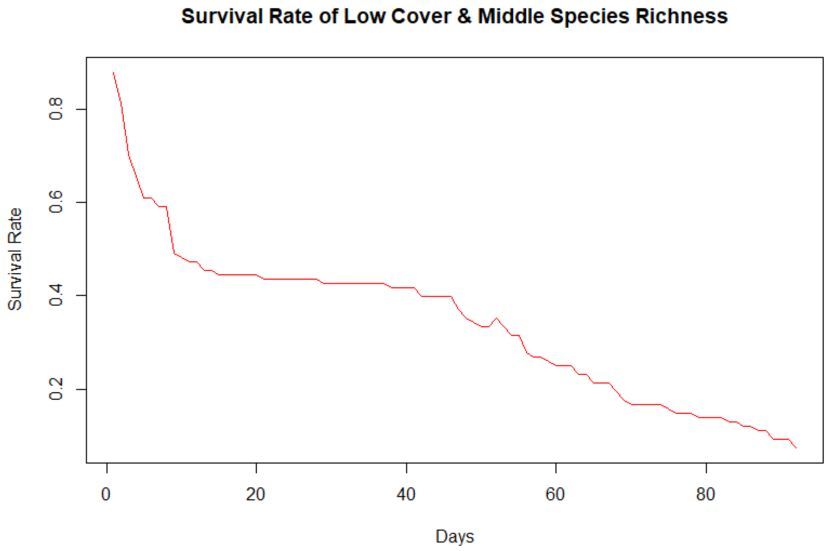

Figure A.2: Survival rate of Low Cover, Medium Species Richness plots

Table A.3: Regression Analysis of "Survival Rate" by factors for Low "Ground Cover" and Medium "Species Richness" categories.

Dep. Var.	Factor I	Factor II	F-statistic	t-value	Adj. R-sqr
Survival	Days		205.6	10-16	0.2708
Survival	Days	Max. Temp.	103.3	10-16 & 0.334	0.2707
Survival	Days	Precipitation	102.7	10-16 & 0.717	0.2697
Survival	Days	Humidity	102.6	10-16 & 0.95	0.2695

Table A.3 continued from previous page

Survival	Days	Max. Wind	103	10-16 & 0.491	0.2701
Survival	Days	Cloud Cover	103.3	10-16 & 0.325	0.2708

Table A.4: Generalized Additive Model of "Survival Rate" by factors for Low "Ground Cover" and Medium "Species Richness" categories

Dep. Var.	Factor I	Factor II	GCV	t-value	Dev. Exp.
Survival	Days		0.067187	10-16	27.2%
Survival	Days	Max. Temp.	0.067213	10-16 & 0.324	27.6%
Survival	Days	Precipitation	0.067416	10-16 & 0.717	27.2%
Survival	Days	Humidity	0.067432	10-16 & 0.95	27.2%
Survival	Days	Max. Wind	0.067374	10-16 & 0.491	27.3%
Survival	Days	Cloud Cover	0.067313	10-16 & 0.325	27.3%

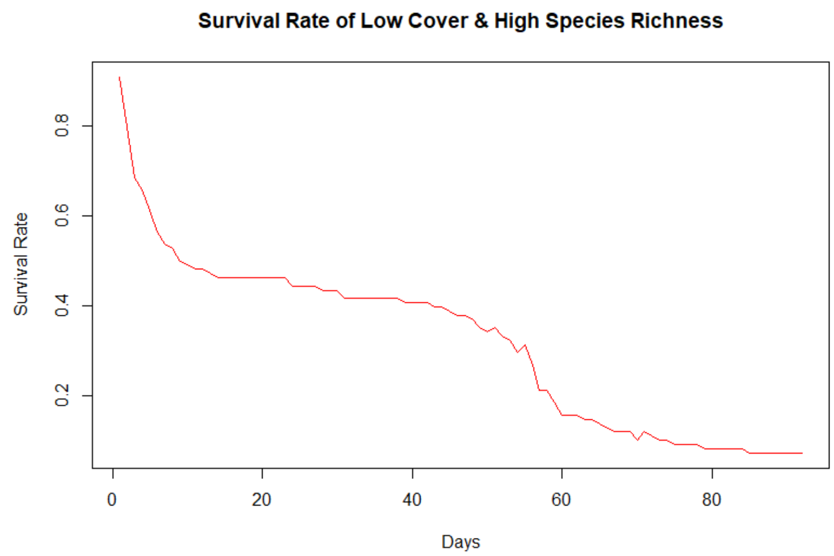

Figure A.3: Survival rate of Low Cover, High Species Richness plots

Table A.5: Regression Analysis of "Survival Rate" by factors for Low "Ground Cover" and High "Species Richness" categories.

Dep. Var.	Factor I	Factor II	F-statistic	t-value	Adj. R-sqr
Survival	Days		1218	10-16	0.6884
Survival	Days	Max. Temp.	608.4	10-16 & 0.615	0.688
Survival	Days	Precipitation	608.1	10-16 & 0.838	0.6878
Survival	Days	Humidity	608.6	10-16 & 0.56	0.688
Survival	Days	Max. Wind	609.9	10-16 & 0.278	0.6885
Survival	Days	Cloud Cover	609.4	10-16 & 0.346	0.6883

Table A.6: Generalized Additive Model of "Survival Rate" by factors for Low "Ground Cover" and High "Species Richness" categories

Dep. Var.	Factor I	Factor II	GCV	t-value	Dev. Exp.
Survival	Days		0.014686	10-16	68.9%
Survival	Days	Max. Temp.	0.014528	10-16 & 0.0118	69.5%
Survival	Days	Precipitation	0.014738	10-16 & 0.838	68.9%
Survival	Days	Humidity	0.014704	10-16 & 0.39	69%
Survival	Days	Max. Wind	0.014708	10-16 & 0.278	69%
Survival	Days	Cloud Cover	0.014716	10-16 & 0.346	68.9%

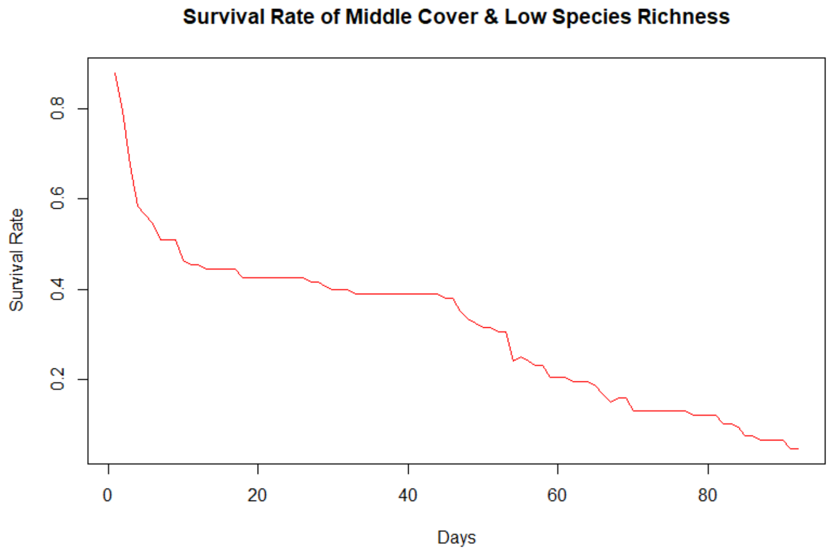

Figure A.4: Survival rate of Medium Cover, Low Species Richness plots

Table A.7: Regression Analysis of "Survival Rate" by factors for Medium "Ground Cover" and Low "Species Richness" categories.

Dep. Var.	Factor I	Factor II	F-statistic	t-value	Adj. R-sqr
Survival	Days		305.9	10-16	0.3563
Survival	Days	Max. Temp.	152.9	10-16 & 0.638	0.3553
Survival	Days	Precipitation	152.8	10-16 & 0.699	0.3553
Survival	Days	Humidity	152.7	10-16 & 0.794	0.3552
Survival	Days	Max. Wind	152.9	10-16 & 0.591	0.3554
Survival	Days	Cloud Cover	153.1	10-16 & 0.47	0.3557

Table A.8: Generalized Additive Model of "Survival Rate" by factors for Medium "Ground Cover" and Low "Species Richness" categories

Dep. Var.	Factor I	Factor II	GCV	t-value	Dev. Exp.
Survival	Days		0.047684	10-16	35.7%
Survival	Days	Max. Temp.	0.047645	10-16 & 0.212	36.2%
Survival	Days	Precipitation	0.047845	10-16 & 0.699	35.8%
Survival	Days	Humidity	0.047852	10-16 & 0.794	35.8%

Table A.8 continued from previous page

Survival	Days	Max. Wind	0.047832	10-16 & 0.591	35.8%
Survival	Days	Cloud Cover	0.047812	10-16 & 0.47	35.8%

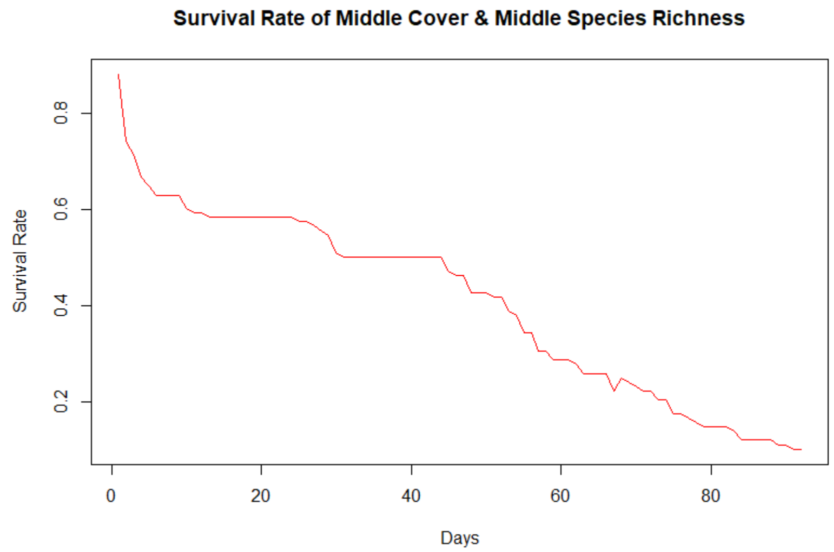

Figure A.5: Survival rate of Medium Cover, Medium Species Richness plots

Table A.9: Regression Analysis of "Survival Rate" by factors for Medium "Ground Cover and Medium "Species Richness" categories

Dep. Var.	Factor I	Factor II	F-statistic	t-value	Adj. R-sqr
Survival	Days		696.1	10-16	0.5578
Survival	Days	Max. Temp.	348.2	10-16 & 0.398	0.5576
Survival	Days	Precipitation	347.4	10-16 & 0.886	0.557
Survival	Days	Humidity	350.8	10-16 & 0.0824	0.5594
Survival	Days	Max. Wind	347.4	10-16 & 0.96	0.557
Survival	Days	Cloud Cover	348.2	10-16 & 0.397	0.5576

Table A.10: Generalized Additive Model of "Survival Rate" by factors for Medium "Ground Cover" and Medium "Species Richness" categories

Dep. Var.	Factor I	Factor II	GCV	t-value	Dev. Exp.
Survival	Days		0.027234	10-16	56.2%
Survival	Days	Max. Temp.	0.027257	10-16 & 0.308	56.4%
Survival	Days	Precipitation	0.027333	10-16 & 0.994	56.2%
Survival	Days	Humidity	0.027282	10-16 & 0.189	56.2%
Survival	Days	Max. Wind	0.027328	10-16 & 0.811	56.2%
Survival	Days	Cloud Cover	0.027329	10-16 & 0.701	56.2%

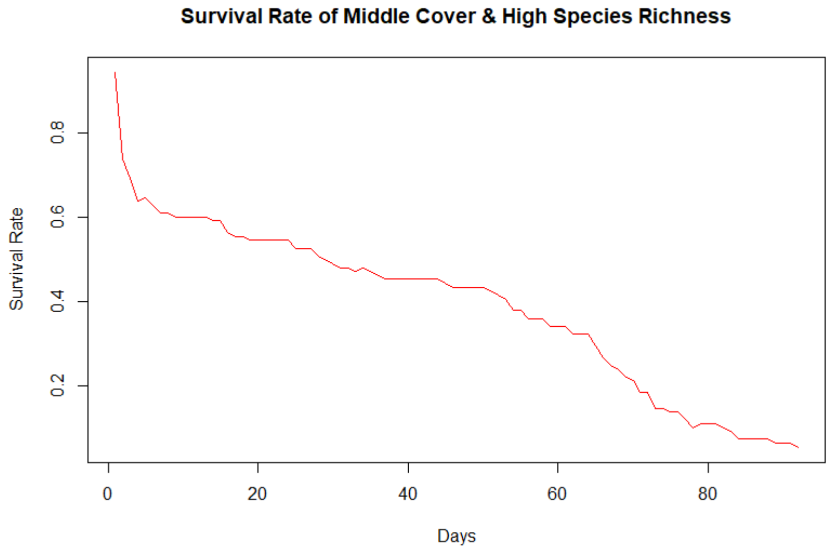

Figure A.6: Survival rate of Medium Cover, High Species Richness plots

Table A.11: Regression Analysis of "Survival Rate" by factors for Medium "Ground Cover and High "Species Richness" categories

Dep. Var.	Factor I	Factor II	F-statistic	t-value	Adj. R-sqr
Survival	Days		822.5	10-16	0.5985
Survival	Days	Max. Temp.	410.5	10-16 & 0.818	0.5978
Survival	Days	Precipitation	411.3	10-16 & 0.432	0.5983
Survival	Days	Humidity	411.8	10-16 & 0.299	0.5986

Table A.11 continued from previous page

Survival	Days	Max. Wind	410.5	10-16 & 0.933	0.5978
Survival	Days	Cloud Cover	410.5	10-16 & 0.979	0.5978

Table A.12: Generalized Additive Model of "Survival Rate" by factors for Medium "Ground Cover" and High "Species Richness" categories

Dep. Var.	Factor I	Factor II	GCV	t-value	Dev. Exp.
Survival	Days		0.023825	10-16	60.7%
Survival	Days	Max. Temp.	0.023891	10-16 & 0.52	60.7%
Survival	Days	Precipitation	0.023857	10-16 & 0.276	60.8%
Survival	Days	Humidity	0.023889	10-16 & 0.715	60.7%
Survival	Days	Max. Wind	0.0239	10-16 & 0.643	60.7%
Survival	Days	Cloud Cover	0.023858	10-16 & 0.445	60.8%

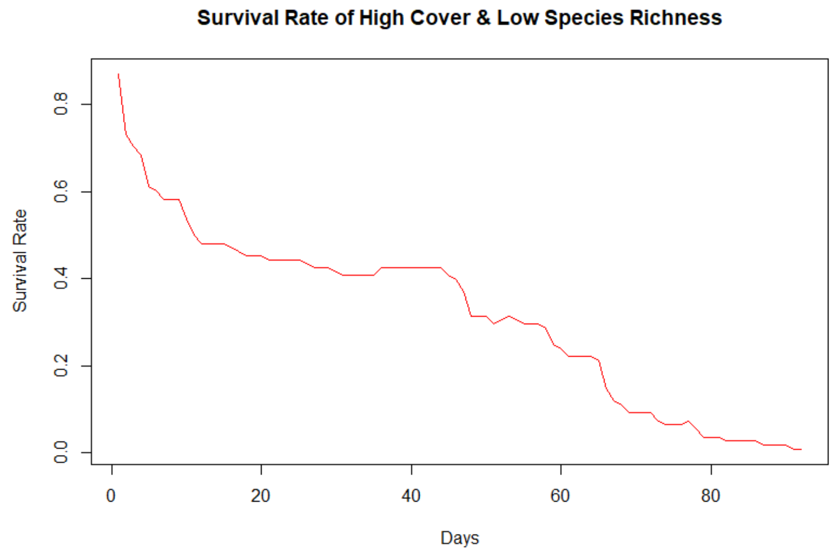

Figure A.7: Survival rate of High Cover, Low Species Richness plots

Table A.13: Regression Analysis of "Survival Rate" by factors for High "Ground Cover and Low "Species Richness" categories

Dep. Var.	Factor I	Factor II	F-statistic	t-value	Adj. R-sqr
Survival	Days		1051	10-16	0.6558
Survival	Days	Max. Temp.	527.4	10-16 & 0.159	0.6564
Survival	Days	Precipitation	524.6	10-16 & 0.851	0.6552
Survival	Days	Humidity	525.8	10-16 & 0.345	0.6558
Survival	Days	Max. Wind	524.9	10-16 & 0.625	0.6554
Survival	Days	Cloud Cover	525	10-16 & 0.56	0.6554

Table A.14: Generalized Additive Model of "Survival Rate" by factors for High "Ground Cover" and Low "Species Richness" categories

Dep. Var.	Factor I	Factor II	GCV	t-value	Dev. Exp.
Survival	Days		0.019762	10-16	65.8%
Survival	Days	Max. Temp.	0.01955	10-16 & 0.0136	66.4%
Survival	Days	Precipitation	0.019806	10-16 & 0.53	65.9%
Survival	Days	Humidity	0.01983	10-16 & 0.692	65.8%
Survival	Days	Max. Wind	0.01981	10-16 & 0.456	65.9%
Survival	Days	Cloud Cover	0.019782	10-16 & 0.271	65.9%

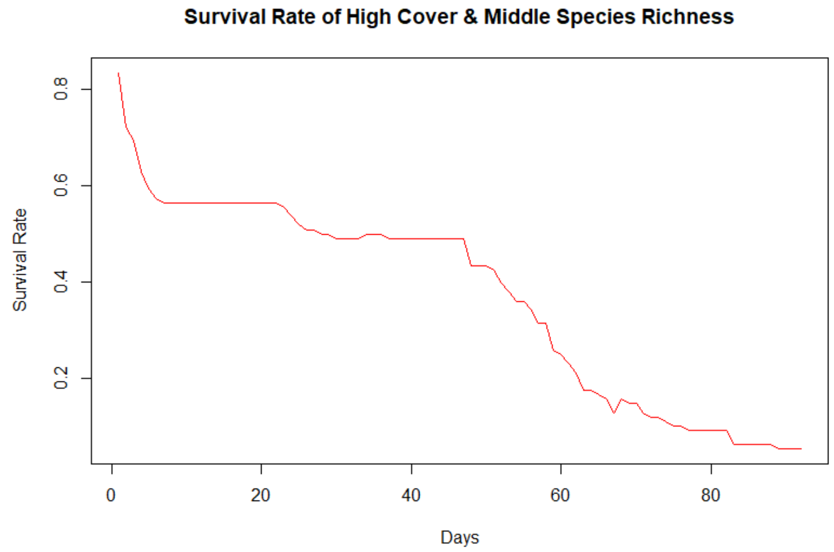

Figure A.8: Survival rate of High Cover, Mid Species Richness plots

Table A.15: Regression Analysis of "Survival Rate" by factors for High "Ground Cover and Medium "Species Richness" categories

Dep. Var.	Factor I	Factor II	F-statistic	t-value	Adj. R-sqr
Survival	Days		473.7	10-16	0.4617
Survival	Days	Max. Temp.	238	10-16 & 0.185	0.4625
Survival	Days	Precipitation	236.7	10-16 & 0.581	0.4611
Survival	Days	Humidity	242.2	10-16 & 0.0126	0.4668
Survival	Days	Max. Wind	236.6	10-16 & 0.613	0.461
Survival	Days	Cloud Cover	238.6	10-16 & 0.123	0.4631

Table A.16: Generalized Additive Model of "Survival Rate" by factors for High "Ground Cover" and Medium "Species Richness" categories

Dep. Var.	Factor I	Factor II	GCV	t-value	Dev. Exp.
Survival	Days		0.045241	10-16	47.2%
Survival	Days	Max. Temp.	0.045324	10-16 & 0.411	47.4%
Survival	Days	Precipitation	0.045401	10-16 & 0.781	47.2%
Survival	Days	Humidity	0.045287	10-16 & 0.302	47.4%

Table A.16 continued from previous page

Survival	Days	Max. Wind	0.045406	10-16 & 0.991	47.2%
Survival	Days	Cloud Cover	0.045378	10-16 & 0.495	47.2%

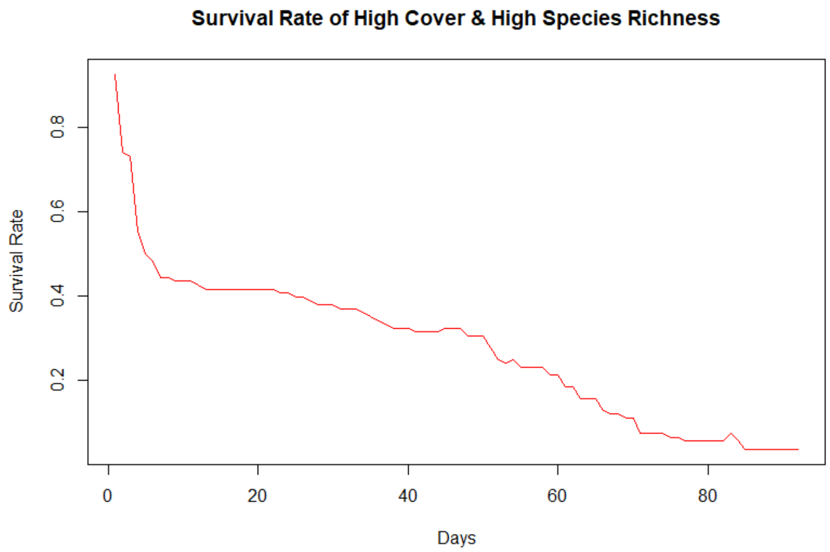

Figure A.9: Survival rate of High Cover, High Species Richness plots

Table A.17: Regression Analysis of "Survival Rate" by factors for High "Ground Cover and High "Species Richness" categories

Dep. Var.	Factor I	Factor II	F-statistic	t-value	Adj. R-sqr
Survival	Days		1324	10-16	0.706
Survival	Days	Max. Temp.	661.6	10-16 & 0.507	0.7057
Survival	Days	Precipitation	662.8	10-16 & 0.294	0.7061
Survival	Days	Humidity	661.1	10-16 & 0.704	0.7055
Survival	Days	Max. Wind	664.4	10-16 & 0.15	0.7066
Survival	Days	Cloud Cover	665.2	10-16 & 0.113	0.7068

Table A.18: Generalized Additive Model of "Survival Rate" by factors for High "Ground Cover" and High "Species Richness" categories

Dep. Var.	Factor I	Factor II	GCV	t-value	Dev. Exp.
Survival	Days		0.011581	10-16	70.7%
Survival	Days	Max. Temp.	0.011442	10-16 & 0.00774	71.3%
Survival	Days	Precipitation	0.0116	10-16 & 0.294	70.7%
Survival	Days	Humidity	0.01162	10-16 & 0.704	70.7%
Survival	Days	Max. Wind	0.01158	10-16 & 0.15	70.8%
Survival	Days	Cloud Cover	0.01157	10-16 & 0.113	70.8%

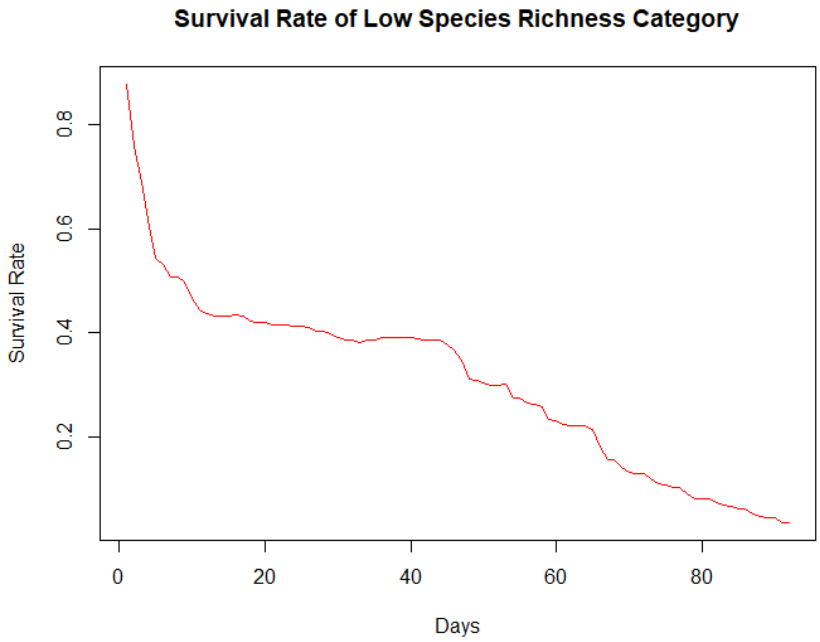

Figure A.10: Survival rate of Low Species Richness plots

Table A.19: Regression Analysis of "Survival Rate" by factors for Low "Species Richness" category

Dep. Var.	Factor I	Factor II	F-statistic	t-value	Adj. R-sqr
Survival	Days		1465	10-16	0.4693
Survival	Days	Max. Temp.	733.9	10-16 & 0.141	0.4697
Survival	Days	Precipitation	732.3	10-16 & 0.463	0.4692

Table A.19 continued from previous page

Survival	Days	Humidity	732.7	10-16 & 0.352	0.4693
Survival	Days	Max. Wind	733.1	10-16 & 0.246	0.4694
Survival	Days	Cloud Cover	733.8	10-16 & 0.153	0.4696

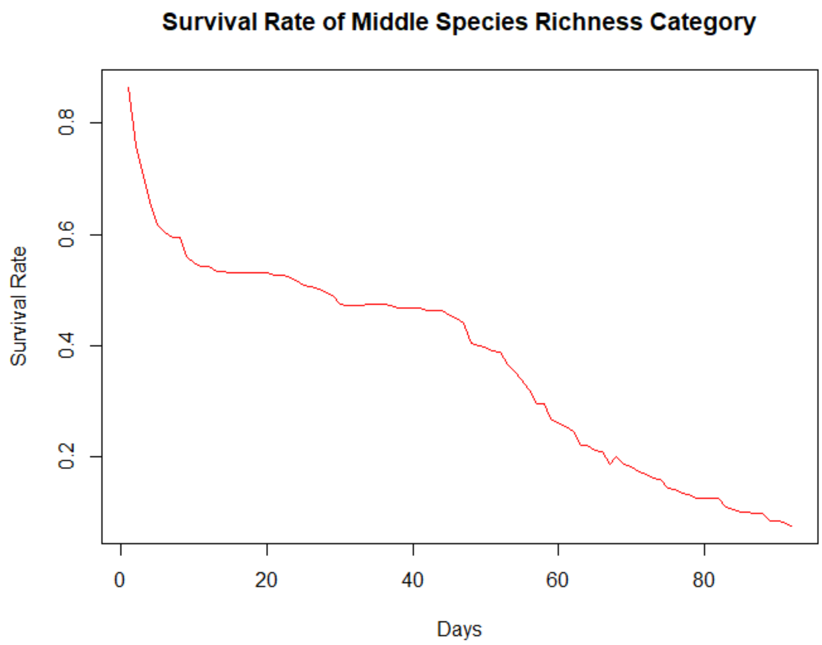

Figure A.11: Survival rate of Medium Species Richness plots

Table A.20: Regression Analysis of "Survival Rate" by factors for Medium "Species Richness" category

Dep. Var.	Factor I	Factor II	F-statistic	t-value	Adj. R-sqr
Survival	Days		1136	10-16	0.4068
Survival	Days	Max. Temp.	567.8	10-16 & 0.644	0.4065
Survival	Days	Precipitation	567.6	10-16 & 0.899	0.4064
Survival	Days	Humidity	571.4	10-16 & 0.0336	0.408
Survival	Days	Max. Wind	567.6	10-16 & 0.875	0.4064
Survival	Days	Cloud Cover	567.9	10-16 & 0.57	0.4065

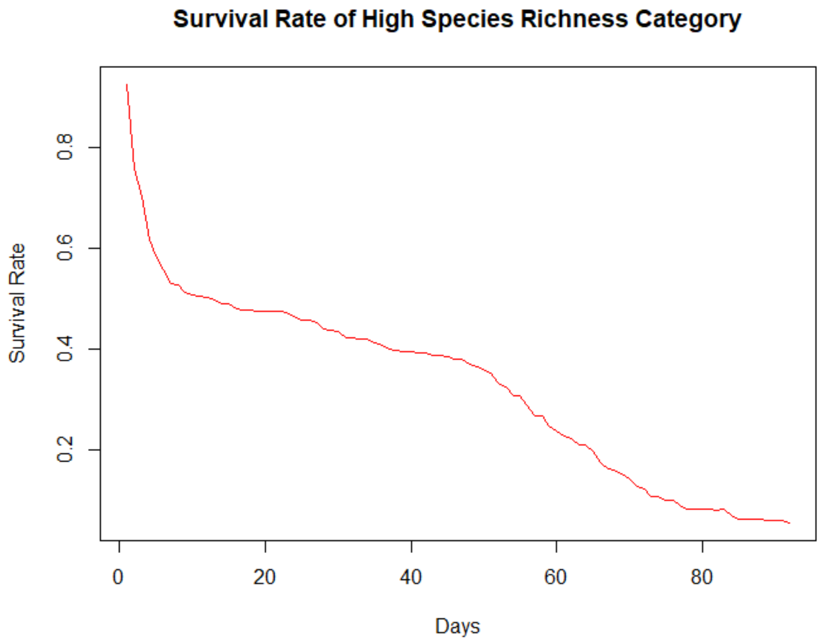

Figure A.12: Survival rate of High Species Richness plots

Table A.21: Regression Analysis of "Survival Rate" by factors for High "Species Richness" category

Dep. Var.	Factor I	Factor II	F-statistic	t-value	Adj. R-sqr
Survival	Days		2784	10-16	0.6271
Survival	Days	Max. Temp.	1392	10-16 & 0.485	0.627
Survival	Days	Precipitation	1393	10-16 & 0.276	0.6271
Survival	Days	Humidity	1392	10-16 & 0.419	0.627
Survival	Days	Max. Wind	1393	10-16 & 0.254	0.6272
Survival	Days	Cloud Cover	1393	10-16 & 0.237	0.6272

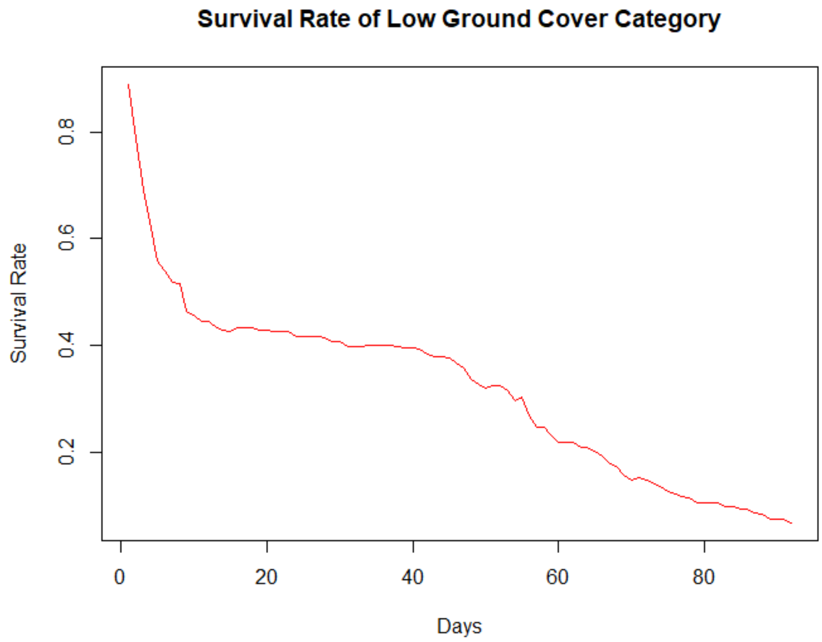

Figure A.13: Survival rate of Low Ground Cover plots

Table A.22: Regression Analysis of "Survival Rate" by factors for Low "Ground Cover" category

Dep. Var.	Factor I	Factor II	F-statistic	t-value	Adj. R-sqr
Survival	Days		1169	10-16	0.4138
Survival	Days	Max. Temp.	585.9	10-16 & 0.168	0.4141
Survival	Days	Precipitation	584.7	10-16 & 0.48	0.4136
Survival	Days	Humidity	584.4	10-16 & 0.648	0.4135
Survival	Days	Max. Wind	586	10-16 & 0.15	0.4142
Survival	Days	Cloud Cover	586.8	10-16 & 0.0848	0.4145

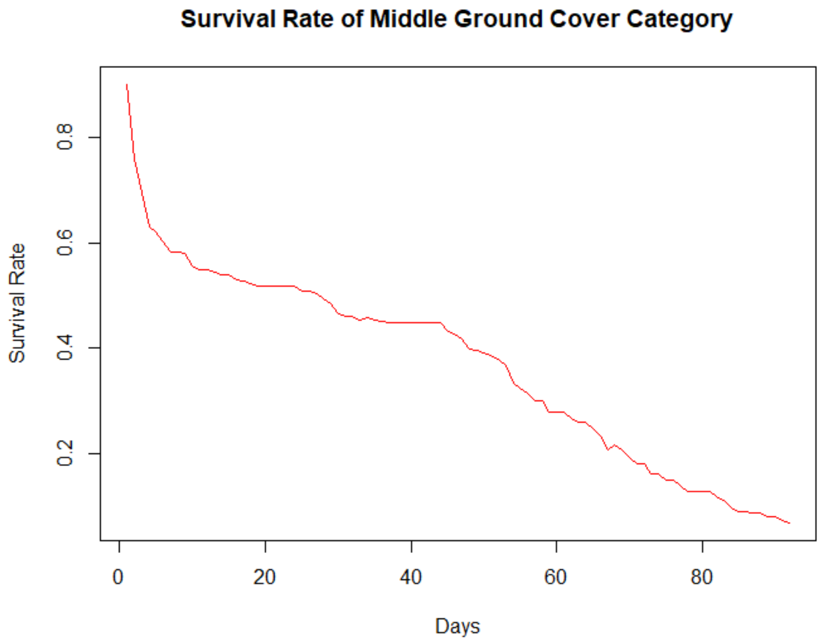

Figure A.14: Survival rate of Medium Ground Cover plots

Table A.23: Regression Analysis of "Survival Rate" by factors for Medium "Ground Cover" category

Dep. Var.	Factor I	Factor II	F-statistic	t-value	Adj. R-sqr
Survival	Days		1532	10-16	0.4806
Survival	Days	Max. Temp.	765.7	10-16 & 0.995	0.4803
Survival	Days	Precipitation	766	10-16 & 0.571	0.4804
Survival	Days	Humidity	768.1	10-16 & 0.119	0.4811
Survival	Days	Max. Wind	765.8	10-16 & 0.766	0.4803
Survival	Days	Cloud Cover	765.7	10-16 & 0.964	0.4803

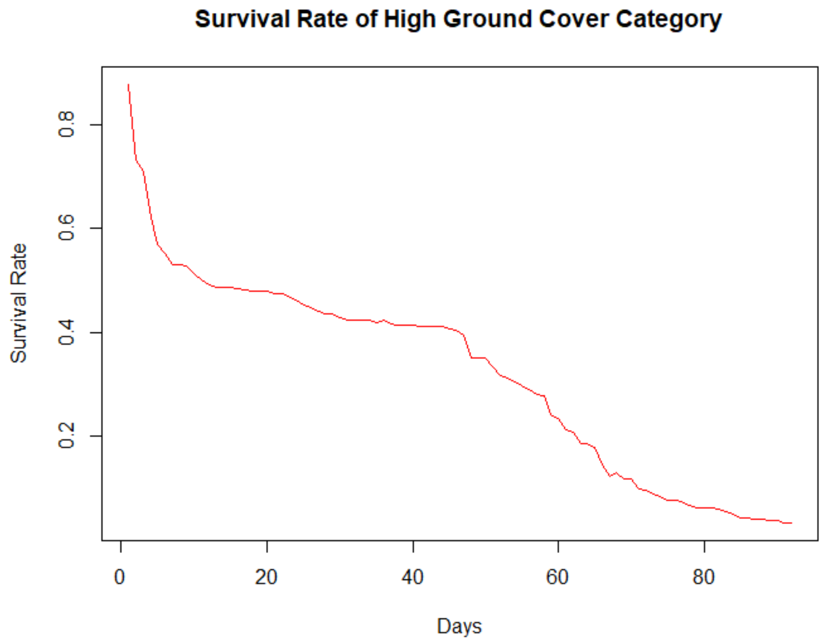

Figure A.15: Survival rate of High Ground Cover plots

Table A.24: Regression Analysis of "Survival Rate" by factors for High "Ground Cover" category

Dep. Var.	Factor I	Factor II	F-statistic	t-value	Adj. R-sqr
Survival	Days		2107	10-16	0.56
Survival	Days	Max. Temp.	1053	10-16 & 0.962	0.5597
Survival	Days	Precipitation	1053	10-16 & 0.941	0.5597
Survival	Days	Humidity	1058	10-16 & 0.0289	0.561
Survival	Days	Max. Wind	1053	10-16 & 0.68	0.5597
Survival	Days	Cloud Cover	1053	10-16 & 0.792	0.5597

Appendix B

Table B.1

Taxon Name	Frequency
Achillea sp.1	1
Adonis aestivalis L.	4
Ajuga salicifolia	7
Alyssum sp. 1	6
Allium sp. 1	13
Allium sp. 2	4
Angiospermae sp. 1	9
Anthemis sp. 1	1
Asperula arvensis L.	7
Asteraceae sp. 1	1
Asteraceae sp. 2	8
Asteraceae sp. 3	9
Asteraceae sp. 4	3
Asteraceae sp. 5	2
Astragalus micropterus	2
Astragalus plumosus	37
Astragalus sp. 1	1
Bryophyta sp. 1	19
Cerinthe minor	1
Chenopodium sp.1	7
Coronilla scorpioides L.	2

Table B.1 continued from previous page

Crupina crupinastrum	1
Dipsacaceae sp1.	1
Echinaria capitata (L.) Desf.	3
Echium sp.1	1
Eryngium campestre L.	1
Euforbia sp.1	6
Euphorbia sp.2	1
Festuca sp.1	57
Galium verum	2
Genista sessilifolia	11
Helianthemum ledifolium	42
Helianthemum sp.2	9
Heracleum sp.1	1
Marrubium parviflorum	1
Marrubium sp. 1	1
Marrubium sp.2	13
Medicago rigidula	4
Onosma sp. 1	4
Ornithogalum sp. 1	16
Perricum sp. 1	1
Phlomis sp. 1	36
Pilosella sp. 1	6
Pilosella sp. 2	1
Pimpinella tragium	4
Plantago lanceolata	7
Poaceae sp. 1	2
Poaceae sp. 2	1
Poaceae sp. 3	8
Poaceae sp. 4	13
Poaceae sp.5	11
Poligonium sp.1	1

Table B.1 continued from previous page

Potentilla recta	7
Ranunculus ficaria	8
Salvia cryptantha	5
Salvia tchihatcheffii	37
Salvia sp. 1	4
Sanguisorba minor	45
Teucrium polium L.	43
Teucrium sp. 1	10
Thesium procombens	25
Thlaspi perfoliatum L.	3
Thymus longicaulis	5
Verbascum sp. 1	7
Veronica sp. 1	1
Viola occulta	4
Unidentified sp. 1	1
Unidentified sp. 2	1
Unidentified sp. 3	1
Unidentified sp. 4	18
Unidentified sp. 5	22
Unidentified sp. 6	1
Unidentified sp. 7	1
Unidentified sp. 8	6
Unidentified sp. 9	1
Unidentified sp. 10	4