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Original Article

Potential Usage of Some of the Ground-Cover Vegetation for Ecosystem Restoration Practices in Central Anatolian Region of Turkey

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ABSTRACT

Long-term animal grazing and agricultural practices in the Central Anatolian Region have disturbed the vegetation cover and rendered the sites prone to erosion. Plantation practices have been carried out for about six decades in the region. However, tree-oriented plantation practices have not shown promising results. Thus, experimental data gathered in the region using new approaches with different plant species are urgently needed. The aim of the current study is to evaluate the potential usage of some of the ground-cover species for ecosystem restoration in the region. The seeds of 16 local species were collected during extensive field surveys in the summer and early fall of 2012 and 2013. Five sites scattered on the basin were chosen as experimental blocks. The area covers the driest part of the region, with less than 300 mm annual precipitation and 11°C average temperature. Soil texture for the first 20 cm of soil depth in the experimental units ranges from clay to sandy clay loam, with a high lime content. In October 2012, April 2013, October 2013, and April 2014 seeds of these 16 species were sown on three 40 cm × 600 cm beds. In the spring and summer of 2013 and 2014, sites were visited, and field emergence rates and seedling growth were recorded. Based on the results of the experiment, *Atriplex hortensis*, *Glaucium corniculatum*, *Marrubium parviflorum*, *Onobrychis tournefortii*, *Peganum harmala*, *Reseda lutea*, *Stachys cretica*, *Teucrium polium* and *Vicia cappadocica* appear to be the most promising ground-cover species for ecosystem restoration in the region.

Keywords: Arid land, ground cover, restoration, Turkey

Introduction

The Central Anatolian closed basin extends between the North Anatolian Mountain line in the North and the Taurus Mountains in the South, and has a continental climate. Due to low precipitation and low biological activity, soils in the region remain at the early development stages, and their properties are largely determined by parent material (Atalay, 2002; Kapur et al., 2002; Özhatay et al., 2003; Tunçdilek, 1987; Uslu, 1971). Shallow soils and persistent summer drought lead to steppe, the typical vegetation formation in the region. These drylands are environmentally fragile and thus very susceptible to degradation. Long-term animal grazing and conversion of marginal sites into agricultural land have disturbed the vegetation cover, rendering the sites prone to erosion. These disturbed or degraded ecosystems are characterized by poor soil fertility, shortage of water, and deteriorated microenvironment, which would severely restrict their productivity (Day & Detling, 1994; Varnamkhasti et al., 1995). The recurrent disturbance of ground cover leads to significant loss of productive topsoil and the associated microorganisms. Thus, plant cover composition has changed dramatically. The remaining plant communities consist mainly of herbs and shrub species, which can resist long-term drought and are often unpalatable (Atalay, 2002; Özhatay et al., 2003; Tunçdilek, 1987; Uslu, 1971).

The lack of natural vegetation as windbreaks has resulted in an increased evaporation and water deficiency due to the constantly blowing winds in the vast plains. During dry periods, fine-grained and loose soil particles are easily mobilized and transported over long distances (Balcı, 1978; Birkman,

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1976; Brady & Weil, 1999; Hillel, 1998; Richards, 1954). As a result, about half of Central Anatolia is under the influence of wind and water erosion (T.C. Çevre ve Orman Bakanlığı, 2005, 2008).

In the 1960s, the Turkish government launched an afforestation action program to reclaim these degraded lands. According to the Ministry of Forestry and Water Affairs, by 2010, nearly 900 000 ha of land were afforested for soil protection (T.C. Çevre ve Orman Bakanlığı, 2008). There still are more than five million hectares of potential land that are technically, socially, and ecologically feasible for afforestation in Turkey (T.C. Çevre ve Orman Bakanlığı, 2005, 2008). A significant part of these areas is in arid and semi-arid regions. Afforestation success in these infertile soils is limited, since seedlings cannot acquire enough water and their survival and growth rates are very low (Irmak, 1963; T.C. Çevre ve Orman Bakanlığı, 2005, 2008; Uslu, 1971).

Soil protection, erosion control, and greenbelt plantation practices have been commonly utilized for nearly six decades in the region. Since the main focus of these practices is the establishment of trees, the success rate was assessed by tree survival and growth. Long-practiced tree planting has not shown significant success. Restoration practices on these marginal sites should not be limited to planting trees to prevent soil erosion but also aim to establish microbial communities, their interactions, and the other natural processes in the rhizosphere. Therefore, the first step of restoration programs in these degraded lands should be the establishment of an herbaceous and shrub cover to improve soil organic matter (OM) and nutrient content. Beginning with species of early seral stages may increase subsequent afforestation success (Heske, 1952).

The restoration of these marginal sites should start with choosing the plant species that can germinate and thrive in limy and salty soils, are adapted to aridity, and which will disseminate a large number of seeds and enrich the soil with OM and nutrients, rather than putting the trees of the later seres in place (Balcı, 1978; Çepel, 1995; Çetik, 1985; Irmak, 1963; Kapur et al., 2002; Thirgood, 1982).

Information on soil and nutrient cycling at different seral stages in these limy, salt-affected, and alkaline soils is very limited. Experimental data gathered in the region using new approaches with different plant species are urgently needed.

Thus, the aim of the current study is to survey some of the ground-cover vegetation and to evaluate their potential usage for the restoration of degraded land, and conducting field trials.

Methods

Site Description

The study was carried out in the Acıpınar, Incesu, Emirgazi, Sazlıpınar, and Karapınar municipalities, scattered over about 3000 km^2 in the Central Anatolian Basin and designated as afforestation sites by the General Directorate of Forestry. A randomized block design with five replications was employed for the study. One of the study sites is located in the Acıpınar region at 1080 m elevation (33°51’41.05” E, 38°32’35.64” N). The site is facing the south aspect. The soil texture between the 0 and 20 cm soil depth is loamy to silty clay loam. One of the sites located in the Incesu region (33°46'50.47" E, 38°11'52.78"N) is located at a 1000 m elevation. The soil texture is sandy loam to clay loam. Another site, Emirgazi, is located in a region with an elevation of 1180 m elevation (33°51'41.53" E, 37°54'54.54" N), with 0–20% slope. Soil texture ranges from sandy clay to loamy. One of the sites, located in the Sazlıpınar region (33°11'52.46" E, 37°42'16.33" N), is at a 980 m elevation. The Sazlıpınar site has clay loam in 0–20 cm of soil depth. One of the sites is located at 970 m elevation in the Karapınar region (33°28'52.34"E, 37°43'48.95" N). The soil texture for this site is sandy loam to clay loam.

The areas present varying geological conditions. Limestone, marn, claystone, conglomerate, sandstone, and gypsum are commonly distributed in the plain (Kapur et al., 2002; Tunçdilek, 1987). Due to the climate and poor soil development, the water storage capacity of the soil is limited. Low precipitation and poor leaching have caused the accumulation of ions and carbonates in the upper soil profile (Brady & Weil, 1999; Buol et al., 1989; Dregne, 1976; Fanning & Fanning, 1989). Thus, alkaline salty and sodic soils cover large areas. The soil bulk density in the first 20 cm soil depth averages 1.2 g/cm^3 across all the sites. All of the sites have high lime content. The soil salinity in all sites is considered below the critical value (Table 1). Soil OM and nutrient content are very low, with no significant variation among the sites (Tables 1 and 2).

There are two meteorological stations in the vicinity of the experimental sites. The Acıpınar site is located 25 km northwest of the Aksaray meteorological station, whereas the Incesu experimental site is located 22 km south of the same station. The Emirgazi site is located 15 km north of the Karapınar meteorological station. The Karapınar and Sazlıpınar experimental sites are located 15 km and 40 km west of the Karapınar meteorological station, respectively. The prevailing continental climate results in moisture deficiency throughout the growing season in the region (Atalay, 2002; Özyuvacı, 1999). Ceylan et al. (2009) stated that the region is the driest part of Turkey and is considered “very dry.” This area covers the driest part of the region, with annual precipitation of less than 300 mm and average temperatures of 11°C. The Walter diagrams constructed based on 60 years of climatic data gathered from these two stations indicate that the area where the experimental plots are located experience a water deficiency from May to October (Walter, 1970; Figure 1a and b).

Field Study

The seeds of 16 species (*Allium myrianthum* Boiss., *Alyssum strigosum* Banks & Sol., *Atriplex hortensis* L., *Glaucium corniculatum* (L.) Curtis, *Globularia orientalis* L., *Marrubium parviflorum* Fisch. & C. A. Mey., *Nepeta congesta* Fisch. & C. A. Mey., *Onobrychis*

Table 1.
Mean ± Stderr of the Soil pH, CEC (Cmol$_c$/kg), Total Lime (%), EC (dS/m), and OM (%) for the First 20 cm Soil Depth Sampled From Experimental Plots Conducted to Study the Potential Usage of Some of the Ground-Cover Vegetation for Ecosystem Restoration Practices in the Central Anatolian Region of Turkey

Sites	pH	CEC (cmol$_c$/kg)	Total Lime (%)	EC (dS/m)	OM (%)
Acıpınar	7.9 ± 0.25	36 ± 5	24 ± 7	2.29 ± 0.45	1.2 ± 0.3
İncesu	8.1 ± 0.18	37 ± 7	25 ± 6	0.27 ± 0.02	0.2 ± 0.2
Sazlıpınar	7.8 ± 0.30	22 ± 7	15 ± 4	0.29 ± 0.02	1.3 ± 0.1
Emirgazi	7.9 ± 0.23	30 ± 11	9 ± 2	0.30 ± 0.01	0.8 ± 0.2
Karapınar	7.9 ± 0.22	33 ± 8	45 ± 10	0.32 ± 0.01	2.1 ± 0.1

Table 2.
Mean ± Stderr of the Soil Nutrient Concentrations for the First 20 cm Soil Depth Sampled From Experimental Plots Conducted to Study the Potential Usage of Some of the Ground-Cover Vegetation for Ecosystem Restoration Practices in the Central Anatolian Region of Turkey

			Ca	Mg	K	Na
Sites	Total *N* (%)	P_2O_5 (ppm)	(cmolc/kg)			
Acıpınar	0.06 ± 0.001	16 ± 5	22 ± 4	10 ± 4	0.8 ± 0.3	0.06 ± 0.01
İncesu	0.01 ± 0.001	11 ± 3	15 ± 5	18 ± 6	0.32 ± 0.2	0.08 ± 0.01
Sazlıpınar	0.06 ± 0.001	20 ± 4	17 ± 7	2.6 ± 1	0.87 ± 0.3	0.03 ± 0.01
Emirgazi	0.04 ± 0.001	30 ± 8	24 ± 8	3.3 ± 1	0.29 ± 0.3	0.08 ± 0.01
Karapınar	0.10 ± 0.002	60 ± 21	26 ± 5	4.2 ± 1	1.7 ± 0.6	0.14 ± 0.01

tournefortii (Willd.) Desv., *Peganum harmala* L., *Reseda lutea* L., *Salsola kali* L. subsp. *Ruthenica* (Iljin) Soo, *Salvia absconitiflora* Greuter & Burdet., *Stachys cretica* L., *Teucrium polium* L., *Vicia cappadocica* Boiss. & Balansa) were collected during extensive field surveys in the summer and early fall of 2012 and 2013 (Table 3). The sites where the seeds were collected from are afforestation sites and have been excluded from herding for more than 10 years. The seeds were dried naturally and kept in a cool place in the laboratory until they were sown.

The soil has a hardpan at about 70–80 cm profile depth. Therefore, using a ripper to break up the hardpan constitutes the main part of the site preparation work for securing successful afforestation in the region. In the summer of 2012, the sites were ripped using a caterpillar tractor (135 HP) equipped with a three-shank ripper. Then the topsoil was tilled with a 4 × 4 rubber-tired tractor to prepare seeding beds.

In October 2012, April 2013, October 2013, and April 2014, for each species, three 40 cm × 600 cm beds were leveled using agricultural rakes. In mid-October 2012, after the first rains supplied enough moisture to the soil (about field capacity), depending on the thousand-seed weights, equal amounts of seeds were uniformly distributed on the beds with the help of a wooden frame (Table 3). Following sowing, the seeds were covered manually. The same procedures were repeated in adjacent beds on each site in the early spring of 2013 (1st week of April). The experiment was repeated in the fall of 2013 fall and the spring of 2014 for *A. hortensis*, *G. corniculatum*, *M. parviflorum*, *O. tournefortii*, *P. harmala*, *R. lutea*, *S. cretica*, *T. polium,* and *V. cappadocica* species, which showed field emergence success for the previous year. From the third week of April 2014, the plots were visited three times at seven-day intervals to observe the field emergence. The field emergence rate was obtained by counting the number of seedlings that had attained the two-leaf stage.

A 20 × 50 cm wooden frame consisting of 20 equal quadrants, each of 5 × 10 cm dimension, was placed on each plot at the end of April. The number of seedlings in each quadrant was counted and ground-cover estimation was recorded (Marsdena et al., 2002).

Sampling and Analysis
To determine soil properties, two sets of soil samples were taken from the first 20 cm soil depth from each site in October 2012. The first set of soil samples were taken with 100 cm^3 soil core samplers (AMS Soil Core Sampler) and used to determine bulk density. Soil bulk density was calculated through the known volume of core and oven-dry weight of soil. The other set of soil samples (taken at about 1.5 kg) was air-dried and sieved (<2 mm) for analysis. Soil particle-size distribution was analyzed with the Bouyoucos hydrometer method, thus enabling soil texture determinations (Gee & Bauder, 1986). Soil pH and electrical conductivity (EC) were estimated using water suspension (Rhoades, 1996; Thomas, 1996). The total lime content was measured with a Scheibler calcimeter. Total C concentrations were

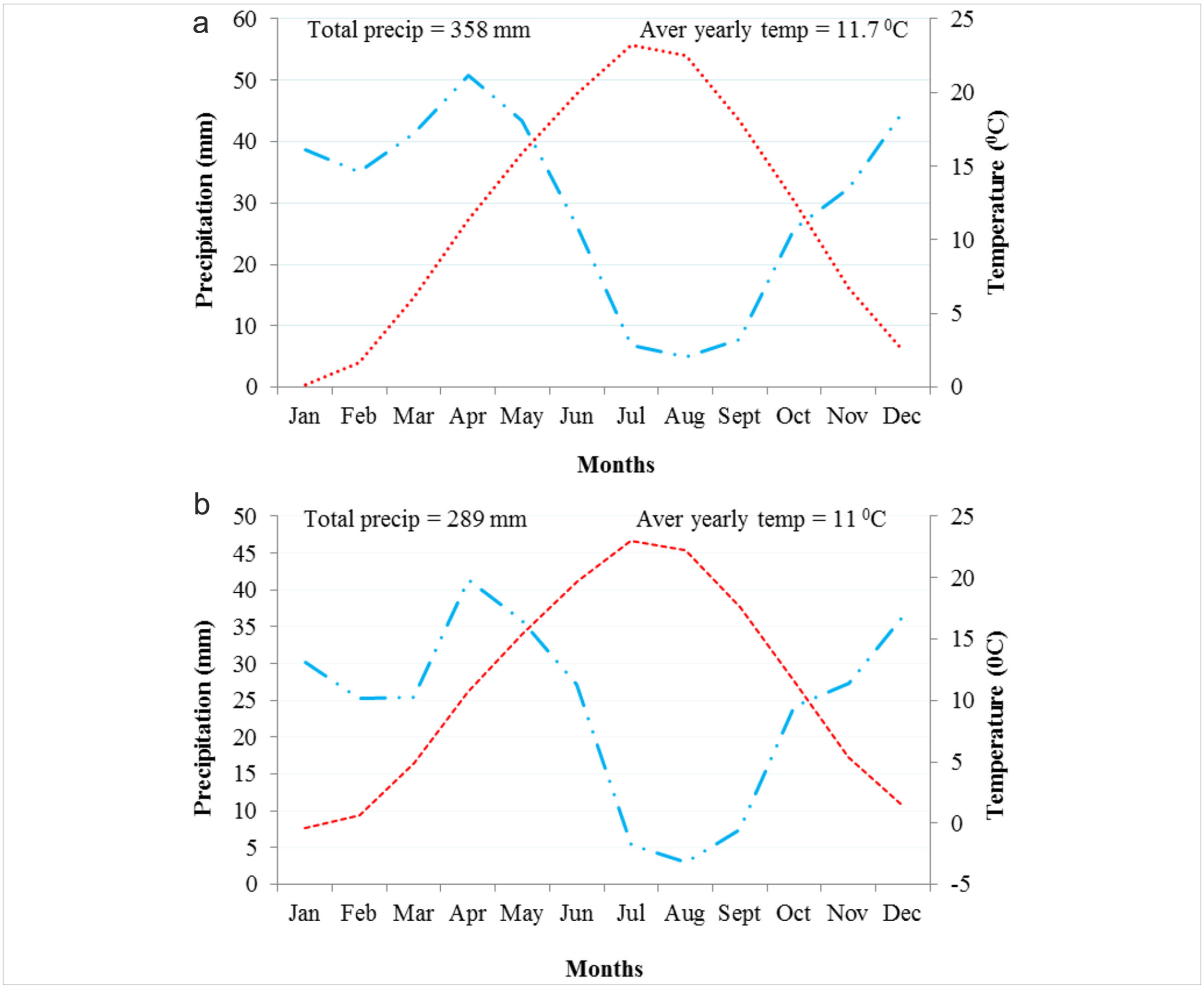

Figure 1.
(a) Walter Diagram for the Acıpınar and Incesu Experimental Sites Established to Study the Potential Usage of Some of the Ground-Cover Vegetation for Ecosystem Restoration Practices in the Central Anatolian Region of Turkey. (b) Walter Diagram for Karapınar, Emirgazi, and Sazlıpınar Experimental Sites Established to Study the Potential Usage of Some of the Ground-Cover Vegetation for Ecosystem Restoration Practices in the Central Anatolian Region of Turkey.

analyzed using a dry combustion method in a LECO CNS 2000 Carbon Analyzer (Nelson & Sommers, 1996). Total soil *N* was analyzed after samples were digested using the micro-Kjeldahl method (Kjeltec Auto 1030 Model) (Bremner, 1996; Nelson & Sommers, 1996). Total soil *p* was determined using a Spectronic 20D Colorimeter after the samples were first digested in nitric and perchloric acid (Kuo, 1996). Exchangeable cations (K, Ca, and Mg) were extracted with ammonium acetate (Suarez, 1996). Calcium and Mg were determined using a Perkin–Elmer 3110 Atomic Absorption Spectrometer (Wright & Stuczynski, 1996). Potassium was determined using a Jenway Flame Photometer. Cation exchange capacity (CEC) was determined from NH_4OAc extraction (Sumner & Miller, 1996).

In mid-summer of 2014 when the plants reached the highest growth, five plants from each plot were uprooted using a shovel, placed in paper bags, and carried to the lab to determine biomass accumulations. Upon returning to the lab, the plant samples were gently immersed in a water bucket to remove the soils attached to the root surface. The samples were dried to constant weight (about 48 hours) at 65°C. Then the above-ground and below-ground parts of the plants were weighed separately. The projected specific leaf area was measured in the lab with a portable leaf area meter (LI-3100C Area Meter from Li-Cor).

The volumetric water content of the soil was recorded at a 20 cm soil depth for ten randomly located spots on beds using a time-domain reflectometer (TDR) (Soil moisture Equipment Corp. Time Domain Reflectometry 6050X3K5B; Rhoades & Oster, 1986), several times from May till September, in both years.

Statistical Analysis
The field emergence rate and biomass growth were tested with an analysis of variance (ANOVA) procedure for a randomized

Table 3.
Mean ± Stderr of Thousand-Seed Weight of the Collected Species to Study the Potential Usage of Some of the Ground-Cover Vegetation for Ecosystem Restoration Practices in the Central Anatolia Region of Turkey

Family	Species	Thousand-Seed Weight (g)
Alliaceae	*Allium myrianthum*	30.246 ± 3.4
Amaranthaceae	*Salsola kali* subsp. *ruthenica*	10.258 ± 2.1
Amaranthaceae	*Atriplex hortensis*	63.3 ± 2.5
Brassicaceae	*Alyssum strigosum*	3.57 ± 0.7
Brassicaceae	*Brassica nigra*	8.21 ± 1.3
Fabacaceae	*Onobrychis tournefortii*	23.7 ± 0.62
Fabaceae	*Vicia cappadocica*	43.5 ± 0.5
Globulariaceae	*Globularia orientalis*	2.43 ± 0.1
Lamiaceae	*Nepeta congesta*	13.81 ± 2.6
Lamiaceae	*Marrubium parviflorum*	2.56 ± 0.1
Lamiaceae	*Salvia absconitiflora*	38.45 ± 4.1
Lamiaceae	*Teucrium polium*	2.18 ± 0.1
Lamiaceae	*Stachys cretica*	3.83 ± 0.1
Resedaceae	*Reseda lutea*	1.08 ± 0.05
Papaveraceae	*Glaucium corniculatum*	4.25 ± 0.1
Zygophyllaceae	*Peganum harmala*	3.11 ± 0.7

block design. To investigate the relationship among plant variables and soil variables, the Pearson correlation procedure was used. SAS was used for all statistical analyses (SAS Institute Inc. 1996). The results for ANOVA were considered significant at $p < .05$. Tukey's HSD test with $\alpha = 0.05$ was performed to compare the total biomass means.

Results

Out of 16 species, only *P. harmala* seeds showed field emergence from the sowing in the fall of 2012. For the spring 2013 sowing, *A. hortensis*, *G. corniculatum*, *M. parviflorum*, *O. tournefortii*, *P. harmala*, *R. lutea*, *S. cretica*, *T. polium,* and *V. cappadocica* species had successful field emergence rates. For the next year's trials, the species that showed successful field emergence rates in the previous year were used. For the following years, October of 2013, and April of 2014, the seeds of *A. hortensis*, *G. corniculatum*, *M. parviflorum*, *O. tournefortii*, *P. harmala*, *R. lutea*, *S. cretica*, *T. polium,* and *V. cappadocica* were sown again on the beds. Field control in May of 2014 showed that *A. hortensis*, *G. corniculatum*, *M. parviflorum*, *O. tournefortii*, *P. harmala*, *R. lutea*, *S. cretica*, *T. polium,* and *V. cappadocica* had successful field emergence rates. The field emergence and ground-cover rates of the species varied between 15–24% and 60–70%, respectively. The field emergence rates and ground-cover percentages were not significantly different among these species (Table 4).

The results of the data indicate no relations of seed germination with soil CEC, pH, and nutrient variables. All of the sites have high lime content. EC values in all sites are considered below the critical value (4 dS/m). Soil OM and nutrient content are very low. Due to higher variation within sites, no significant variation was measured among the sites for any of the soil variables. The field emergence values for each germinated species were not significantly different among the sites. However, some of the species' seedlings with successful emergence rates did not survive during the summer drought. The seedlings were desiccated on certain spots on each bed. TDR measurements showed that the volumetric water content of soils on the first 20 cm depth dropped to around 10% in all treatments by mid-May.

Statistical analysis showed that the growth of the species also was not related to soil variables. For each species,

Table 4.
Mean ± Stderr of the Seed Germination Rate (%) and Ground-Cover Rate of the Germinating Seeds on the Experimental Plots Conducted to Study the Potential Usage of Some of the Ground-Cover Vegetation for Ecosystem Restoration Practices in Central Anatolian Region of Turkey

Family	Species	Field Emergence Rate (%)	Ground Cover (%)
Amaranthaceae	*Atriplex hortensis*	19 ± 6^{a}	58 ± 15^{a}
Fabacaceae	*Onobrychis tournefortii*	17 ± 6^{a}	64 ± 10^{a}
Fabaceae	*Vicia cappodicica*	23 ± 5^{a}	70 ± 12^{a}
Lamiaceae	*Marrubium parviflorum*	19 ± 5^{a}	70 ± 16^{a}
Lamiaceae	*Teucrium polium*	18 ± 7^{a}	62 ± 9^{a}
Lamiaceae	*Stachys cretica*	16 ± 5^{a}	65 ± 11^{a}
Resedaceae	*Reseda lutea*	24 ± 6^{a}	70 ± 8^{a}
Papaveraceae	*Glaucium corniculatum*	15 ± 7^{a}	68 ± 12^{a}
Zygophyllaceae	*Peganum harmala*	23 ± 5^{a}	65 ± 10^{a}

Note: The results of variance (ANOVA) procedure for randomized block design were considered significant at $p < .05$. Means with a common lowercase letter are not significantly different at $\alpha = 0.05$ according to Tukey's HSD test.

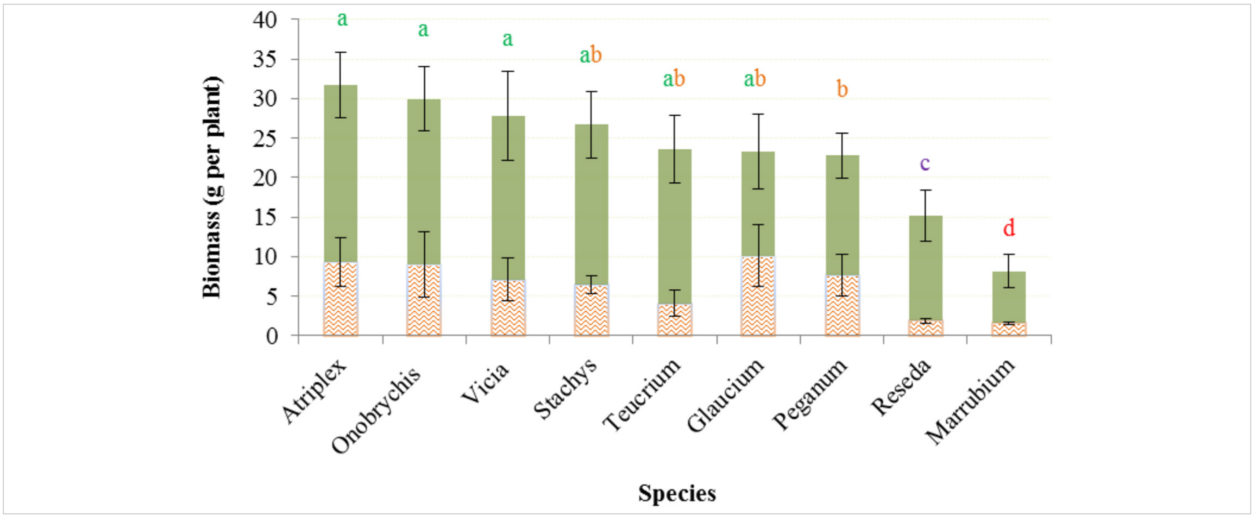

Figure 2.
Mean and SE of Biomass for Different Species Sampled from Experimental Plots Conducted to Study the Potential Usage of Some of the Ground-Cover Vegetation for Ecosystem Restoration Practices in Central Anatolian Region of Turkey. Mean Values With a Common Lowercase Letter Are Not Significantly Different. For Each Species, the Upper Part of the Column Represents Above-Ground Biomass and the Lower Part of the Column Represents the Root Biomass.

biomass measurements did not show significant differences among the sites. *A. hortensis*, *O. tournefortii* and *V. cappadocica* showed the best growth rates in all sites. These species produced about two times more biomass compared to the mean biomass of the *M. parviflorum*, *P. harmala* and *R. lutea* (Figure 2). Biomass and ground cover per seedling for *A. hortensis* ($p = .0001$), *M. parviflorum* ($p = .0007$), *P. harmala* ($p = .001$), *R. lutea* ($p = .0021$) and *T. polium* ($p = .0002$) were significantly related (Figure 3).

Individual seedling weight ($p = .0001$), ground-cover area ($p = .0001$), and SLA values ($p = .0021$) were significantly different among the emerged species. *A. hortensis* and *P. harmala* had the highest biomass and largest ground-cover area per seedling. On the other hand, *V. cappadocica* had almost three times SLA than the other species (Table 5).

Discussion, and Conclusion and Recommendations

In addition to climatic and edaphic constraints to plant growth, clearing for the cultivation of cereals, firewood collection from dwarf shrubs, and heavy overgrazing have dramatically degraded the Irano-Turanian phytogeographic provinces of Turkey. Even though plantation practices have been carried out for about six decades in the region, tree-oriented plantation practices have shown limited success. Naeem (2006) stated that if nutrient cycling or productivity is adversely influenced, it might hinder restoration. Therefore, in these severely degraded ecosystems, restoration projects might aim to restore different functional groups for the ramping up of species and increasing the diversity. If herb species are used as part of an overall restoration strategy, they may modify microclimate and edaphic conditions in ways that favor the establishment of woody species (Rhoades et al., 1998).

However, the low rainfall and its poor distribution, together with prolonged hot and dry periods have caused difficult environmental conditions for germination, field emergence, and the natural establishment of species. On the other hand, if the disturbance is removed, the degraded ecosystems may initiate a progressive succession to the primitive community, and the restoration process can then be considered as a progressive succession (Zerga, 2015). Early seral vegetation grows through different stages, while it is improving the function of the ecosystem by providing physical soil protection against erosion by reducing the velocity of runoff and by its decomposition, and this contributes to nutrient cycling. However, when insufficient plant populations have remained on the site, natural revegetation is slow in many areas. An enclosure usually permits the restoration and biological recovery of vegetation structure, composition, biomass, and productivity in a time span of 3–5 years or more in steppic ecosystems (Le Houerou, 2000). Therefore, species adapted to sowing are often desirable for a successful restoration (Vallentine, 1989). Enclosing the site and applying some cultural practices such as tilling may create favorable microsites to enable seeds to germinate and establish more successfully (Gebremeskel & Pieterse, 2008).

Over the years, thousands of hectares of restoration sites similar to the current one have been established artificially in Morocco, Iran, Australia, Tunisia, and Algeria (Koocheki, 1996; Rhoades et al., 1998). For the current study, 16 species were collected from fenced afforestation sites. Out of 16 species, *A. hortensis*, *G. corniculatum*, *M. parviflorum*, *O. tournefortii*, *P. harmala*, *R. lutea*, *S.*

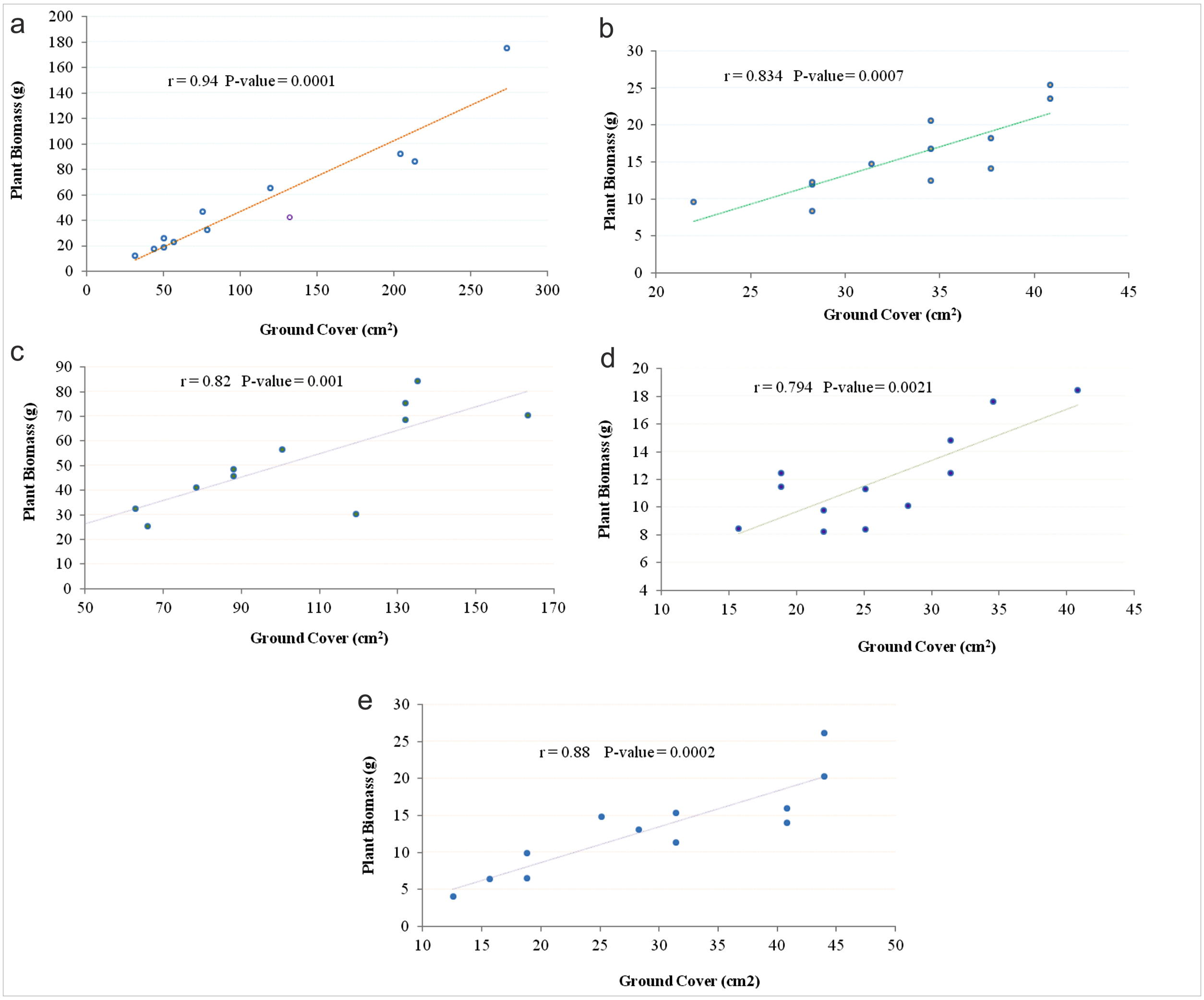

Figure 3.
(a) Correlation Between Plant Biomass (g) and Its Ground-Cover Area (cm²) of Atriplex hortensis Sampled From Experimental Plots Conducted to Study the Potential Usage of Some of the Ground-Cover Vegetation for Ecosystem Restoration Practices in the Central Anatolian Region of Turkey. (b) Correlation Between Plant Biomass (g) and Its Ground-Cover Area (cm²) of Marrubium parviflorum Sampled From Experimental Plots Conducted to Study the Potential Usage of Some of the Ground-Cover Vegetation for Ecosystem Restoration Practices in the Central Anatolian Region of Turkey. (c) Correlation Between Plant Biomass (g) and Its Ground-Cover Area (cm²) of Peganum harmala Sampled From Experimental Plots Conducted to Study the Potential Usage of Some of the Ground-Cover Vegetation for Ecosystem Restoration Practices in the Central Anatolian Region of Turkey. (d) Correlation Between Plant Biomass (g) and Its Ground-Cover Area (cm²) of Reseda lutea Sampled From Experimental Plots Conducted to Study the Potential Usage of Some of the Ground-Cover Vegetation for Ecosystem Restoration Practices in the Central Anatolian Region of Turkey. (e) Correlation Between Plant Biomass (g) and Its Ground-Cover Area (cm²) of Teucrium polium Sampled From Experimental Plots Conducted to Study the Potential Usage of Some of the Ground-Cover Vegetation for Ecosystem Restoration Practices in the Central Anatolian Region of Turkey.

cretica, *T. polium,* and *V. cappadocica* had successful field emergence rates.

The results of the data indicate no relations of seed germination with soil chemical variables. All of the sites have high lime content. Even though the EC value in Acıpınar sites is almost ten times more than the value for the other sites, the soil salinity in all sites is considered below the critical value (Richards, 1954). Soil OM and nutrient content are very low. Since the variations on seed size, root length, SLA, etc. are very high among the species, such plant traits do not seem to explain field emergence and survival rates. Therefore, it is assumed that the main factor on seedling growth in this region is the available moisture in the rooting depth. The seedlings were desiccated on certain spots on each bed in a couple of weeks after emergence. The reason for the desiccation of seedlings can be partially attributed to germination in the fixed soil depth for moisture uptake. When this soil layer gets dry at the beginning of the summer, the

Table 5.
Mean ± Stderr of Biomass (g), Individual Seedling Ground-Cover Area (cm²) and Specific Leaf Area (SLA, cm²/g) of the Species Sampled From Experimental Plots Conducted to Study the Potential Usage of Some of the Ground-Cover Vegetation for Ecosystem Restoration Practices in Central Anatolian Region of Turkey

Species	Plant Weight (g)	Cover Area (cm²)	SLA (cm²/g)
*Atriplex hortensis*L.	53.3 ± 13.5[a]	111 ± 23[a]	437 ± 5[e]
Peganum harmala L.	50.5 ± 6[a]	101 ± 10[a]	858 ± 12[b]
Glaucium corniculatum (L.)	2.7 ± 0.3[b]	13.6 ± 0.5[b]	473 ± 32[d]
Marrubium parviflorum Fisch. & C.A.Mey	15.7 ± 1.5[b]	32.2 ± 1.7[b]	685 ± 4[c]
Onobrychis tournefortii (Willd.) Desv.	11.2 ± 1[b]	24.9 ± 1.6[b]	396 ± 8[e]
Reseda lutea L.	12 ± 1[b]	26.2 ± 2.1[b]	673 ± 12[c]
Stachys cretica L.	9.5 ± 1.1[b]	20.4 ± 1.1[b]	435 ± 3[ed]
Teucrium polium L.	13.2 ± 1.8[b]	29.2 ± 3.2[b]	367 ± 5[e]
Vicia cappodicica Boiss. & Bal.	17.3 ± 2.2[b]	32.9 ± 3.3[b]	1077 ± 13[a]

Note: The results of variance (ANOVA) procedure for randomized block design were considered significant at $p < .05$. Means with a common lowercase letter are not significantly different at $\alpha = 0.05$, according to Tukey's HSD test.

roots, which explore the deeper soil horizon, may have better soil moisture availability, but when the roots do not explore the lower soil horizons, the plants may experience severe drought stress. TDR measurements showed that the volumetric water content of soils in the first 20 cm depth drops to around 10% in all treatments by mid-May. This value is much below the available water content needed for plant growth in these soils.

However, in nature, the seeds fall on different soil layers and many of them deteriorate, but only those that find the best microclimate for that season can thrive. Harper et al. (1965) claimed that seed germination and establishment of natural and artificial revegetation is a result of the number of seeds favorable in microsites or safe sites in the seedbed. Thus, varied micro-environments provided on a soil surface act selectively on seed populations and determine the numbers of safe germination sites (Harper et al., 1965).

Because of the yearly variations in the precipitation patterns and soil warming, it is not possible to provide a practical suggestion to the practitioners. Many of the species not grown in open areas grow successfully in the fenced and tilled experimental sites. Thus even natural recovery of the vegetation can still contribute significantly to the early restoration process of the sites providing enough protection and soil condition. Therefore, tilling and fencing large areas may start the natural restoration of the plant communities. However, it may take several years for these species to have enough coverage on the ground. The process can be accelerated artificially and modified according to the restoration program in the region. The results of the current study indicate that leveling the surface for seedbeds may reduce the diversity of the soil microclimate, and it is risky for germination and growth. Thus, instead of having a smooth soil surface, rough surfaces may provide uneven depth and secure enough germination and growth success by simulating the natural distribution of the seeds in different layers of the soil.

A. hortensis, *O. tournefortii,* and *V. cappadocica* showed the best growth rates in all sites. These species produced about two times more biomass compared to the mean biomass of *M. parviflorum*, *P. harmala,* and *R. lutea* (Figure 2). In addition, *A. hortensis* produced plenty of seeds by the mid-summer and it was infested by wild animals (especially rabbits). The results of this experiment are similar to the others reported from different arid regions for *Atriplex* species. *Atriplex* species are used extensively in different regions for arid land and rangeland restoration. Mohebbi et al. (2014) reported that *Atriplex* species have been used extensively due to the high palatability and high forage value in Iran. *Atriplex canesence* provides excellent browse for wildlife and is highly palatable for most livestock and big game (Mohebbi et al., 2013, 2014).

The results of the experiment imply that *A. hortensis*, *G. corniculatum*, *M. parviflorum*, *O. tournefortii*, *P. harmala*, *R. lutea*, *S. cretica*, *T. polium,* and *V. cappadocica* are the most promising species to use as ground-cover for ecosystem restoration practices in the region. Since *A. hortensis* holds the soil strongly and provides food for animals, this species can be used in restoration practices for both soil protection and wildlife promotion services.

Further studies are needed about the species which showed germination success. Experiments should be conducted to measure the performance of the seed germination and growth rate for different seeding depths. Using varying seeding depth may guarantee enough seedlings on the ground. Those plowing should create different clumps on the surface and these clumps should not be broken up to create a more homogeneous surface.

Field observations showed that fencing the sites to protect them from grazing pressure promoted the germination and growth of some of the ground-cover vegetation. Certain manipulations such as adding seeds of species that are not naturally present in the site and that have shown emergence success and also removing some of the more competitive species already on the site may accelerate the restoration process. Enriching the soil OM and nutrient content through establishing early seral stages may facilitate the subsequent afforestation practices.

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