

Determination of the growth performance and soil protection ability of the Caper (Capparis sp.) in eroded site in semi-arid region of Artvin, Turkey^[*]**Turan YÜKSEK^{1*} Filiz YÜKSEK² Mehmet ÖZALP³ Zafer ÖLMEZ³**¹ Recep Tayyip Erdogan University, Department of Landscape Architecture, Rize, Turkey² Forestry and Water Affairs, Directorate of Eastern Black Sea Forestry Research Institute, Trabzon, Turkey³ Artvin Coruh University, Department of Forestry Engineering, Artvin

Abstract: In this study, the growth performance and soil protection ability of the Caper (*Capparis sp.*) in eroded site in semi-arid region of Artvin, Turkey were investigated. For this purpose, the experimental plot at the site included a randomized complete block with four replicates (a total of 8 experimental plots: 2 treatments × 4 replicates). Each plot was 20-m long×5-m wide, which is wide enough to minimize edge effects and large enough for downslope rills to develop. Between 2006 - 2008, water and sediment accumulated in sediment deposited tanks were measured. Then, with the help of these values, the runoff, the amount of transported sediment and the concentration of transported sediment were calculated. In addition, the development of the caper seedlings has been observed and recorded. As a result of the research, the average survival percent of caper sapling in 2006 was found to be 21%. While, the mean height of caper seedlings varied between 4.6 cm and 6.1 cm in 2006, it has been varied between 5.2 cm and 8.18 cm in 2007. As a result of the statistical analysis, there were significant differences in terms of runoff, sediment yield and sediment concentration according to season and years, but no significant differences were observed between bare area and caper experimental sites. It has been determined that the adaptation of the caper in the eroded soil and its development is not at the desired level. It is thought that severe summer drought during the growing season negatively affects the survival and development of the caper saplings in the first years of planting. The survival rate of the caper and its low development could not prevent the erosive effect of the rain. It can be said that severe summer drought and soil characteristics (e.g: soil texture, soil water content, etc...) have significant effects on growing and survival rates of caper saplings.

It can be more useful to use combination with additional erosion control techniques (e.g., soil protection techniques) to make erosion control in this kind of sites where there is irregular and inadequate rainfall.

Keywords: Caper, eroded site, semi-arid, runoff, sediment, sediment concentration, Artvin.

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Artvin (Türkiye)'nin Yarı Kurak Erozyonlu Alanlarında Kapari'nin Toprak Koruma Yeteneği ve Büyüme Performansının Belirlenmesi

Öz: Bu çalışmada Artvin'de yarı-kurak sahalarda kaparinin gelişimi ve toprak koruma yeteneği araştırılmıştır. Bu amaçla her bir işlem için rastlantılı tam bloklar deneme desenine göre, her biri 4 yinelemeli (4 x 100 m²) 4 adet kalıcı blok oluşturulmuştur. Bu boklarda her bir işlem için yüzeysel akış ölçüm parselleri oluşturulmuştur. 2006-2008 yılları arasında meydana gelen yüzeysel akış sonucu tanklarda biriken su ve taşınan sediment miktarı ölçülmüştür. Daha sonra bu değerler yardımıyla yüzeysel akış yüksekliği, taşınan sediment miktarı ve taşınan sediment konsantrasyonu hesaplanmıştır. Ayrıca parsellere dikilen kaparinin gelişimi izlenmiştir. Araştırma sonucunda kapari parsellerinde 2006 yılında ortalama yaşam yüzdesi % 21 olarak bulunmuştur. 2006 yılında kapari parsellerindeki boy gelişimi 2.7-6.9 cm arasında iken; 2007 yılında ise bu değer 16.3-68.7 cm olmuştur. Yapılan istatistik analiz sonucunda yüzeysel akış yüksekliği, taşınan sediment miktarı ve sediment konsantrasyonu bakımından mevsimlere göre ve yıllara göre istatistiksel anlamda önemli farklılıklar gözlenirken, çıplak parsellere göre kapari ile erozyon kontrolü yapılmış parselde anlamlı farklılıklar gözlenmemiştir. Kaparinin araştırma sahası erozyona uğramış topraklardaki adaptasyonunun ve gelişmesinin arzulanan seviyede olmadığı tespit edilmiştir. Büyüme mevsimi boyunca yaşanan yaz kuraklığı dikimin ilk yıllarında bitkinin hayatta kalmasını ve gelişimini olumsuz etkilediği düşünülmektedir. Kaparinin hayatta kalma oranının ve gelişiminin az olması yağmurun erosiv etkisinin engelleyecek kapalılığın oluşmamasıyla sonuçlanmıştır. Şiddetli yaz kuraklığı ve toprak özelliklerinin (toprak tekstürü, toprak su sabitleri, vb.) türün gelişimi ve türün yaşam yüzdesi üzerinde etkili olduğu söylenebilir. Erozyona uğramış ve vejetasyon döneminde düzensiz ve yetersiz yağışların olduğu yerlerde; bu türün ilave erozyon kontrolü teknikleri (toprak koruma teknikleri) ile kombine edilerek kullanılması erozyon kontrolünün daha başarılı olmasını sağlayabilir.

Anahtar sözcükler: Kapari, erozyon, yüzeysel akış, sediment, sediment konsantrasyonu, Artvin

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GİRİŞ

Erosion is a very important environmental problem both in Turkey and worldwide (Yüksek and Yüksek, 2015). Soil erosion by water has been considered to be the major cause for loss of soil nutrients and reduced plant productivity (Zhou et al., 2008). Although many methods are used to prevent erosion; using of shrub and grass species in different ways to fight against the impact of water erosion is a widely used practice (Andreu et al., 1998). It is expressed in many studies that plant cover was an effective method of preventing soil and nutrient loss (Zhang et al., 2010). The vegetation cover reduces the effect of rain erosivity, especially on the ground, and keeps the soil in place by covering its roots with the soil, improving the physical and chemical properties of the soil (Angima et al., 2002; Kothiyari et al., 2004; Babalola et al., 2007; Mohammad and Adam, 2010; Nunes et al., 2011; Yüksek and Yüksek, 2015). However, in semi-arid areas and in delicate ecosystems damaged, it is difficult to develop effective plant species in order to improve the existing vegetation cover and prevent erosion. In addition, this eroded areas has a negative effect on the plant development, because the rain is inadequate when plant is needed the most. In order to achieve the desired success in erosion control studies in semi-arid areas, choice of species suitable for the field in eroded sites is very important (Yüksek and Yüksek, 2007). Therefore, in such erosion areas, species that are high abiotic stress tolerance and grow fast to cover the land easily and thus reduce the erosive effect of rain are foreground. The caper plant belonging to the family of Capparaceae is also stated to be able to be used easily in erosion control by covering and protecting the soil surface with deep root descent system, embrace, climber and spreader form (Kelkit ve Müftüoğlu, 2001). It is stated that the caper is naturally found in this region, it is characterized by xerophyte, it can easily reach to rainy spring and dry summers over 40 °C and 350 mm of annual rainfall and can be used for soil protection in erosion control works (Ölmez, 2001). Although there are many studies on the use of some species to prevent plant growth and erosion in semi-arid areas (Andreu et al., 1998; Chirino et al., 2006; Li et al., 2006; Martinez Raya et al., 2006; Zhou et al., 2008; Xu et al., 2009; Zhang et al., 2010; Mohammad and Adam 2010; P. Garcia-Estringana et al., 2013; Yüksek and Yüksek, 2015). The development of this plant in soil in eroded sites in semi-arid lands and detailed data on erosion prevention ability are insufficient.

The aim of this study is to assess plant development of *Capparis ovata* Desf. and to determine runoff, sediment yield and sediment concentration at different time periods in semi-arid area.

METHODOLOGY

Research area is situated in the Yusufeli district of Artvin (40° 46'35 " north, 41° 49'03" east) northeast of Turkey, with an average elevation of 1050 meters a.s.l. According to observation values between 1974 and 2000, Yusufeli district has an average temperature of 14.2 °C and an annual total precipitation of 289.2 mm. 1974–2000 record of Yusufeli meteorological station, 40 km far away from the study area, which is the nearest station to Pamukçular watershed, annual precipitation was 350 mm. According to the data of the Yusufeli meteorological station 22.41% of the annual precipitation occurs in spring, 18.45% occurs in summer, 25.77% occurs in fall and 33.37% occurs in winter. According to the climate diagram of the study area by Thornthwaite, there was strongly a water deficiency from May 15th to November 15th (See Fig. 1) (Yüksek and Yüksek, 2011). The annual average temperature was 15.40 °C, average temperature in summer (June–July–August period) varied between 23 and 27 °C, average highest temperature varied between 29 and 34 °C As can be seen from Figure 1, after April the water is approached and there is severe drought from May to June to the middle of October. The geological formation in the study area consists of two strati-graphic units: (i) a lower unit of pillowed and massive basalt and basaltic andesite intercalated with some thin-bedded silts and shales, and (ii) an upper unit of shallow-water sedimentary rocks with some interbedded basic volcanic rocks (Lower–Middle Jurassic shales and sandstones (Hamurkesen formation), Upper–Lower Cretaceous lime-stones (Berdiga formation), (Dokuz, 2000).

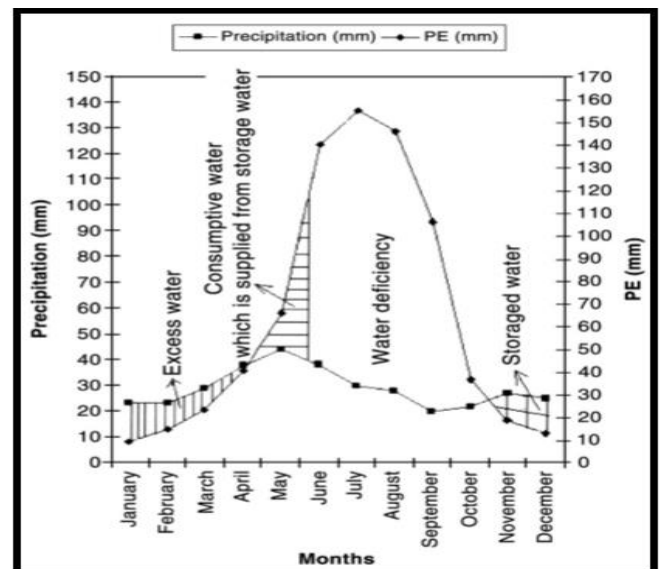


Figure 1. Climate diagram of Yusufeli area by Thornthwaite (period 1974–2000) (Yüksek and Yüksek, 2011).

The average land slope of the study area is 20%. The soil characteristics of the study area were given in Table 1 (Yüksek et al., 2009). The natural vegetation covered in the area is sparse due to extreme destructiveness and drought, and even the soil remains bare. There are mostly bush and herbaceous taxa in the research area. The main

woody and herbaceous taxa found in the alanda are *Quercus petraea* (Matt.) Liebl. *Juniperus oxycedrus* L., *Paliurus spina-christi* Mill, *Eleagnus angustifolia* L., *Capparis ovata* Desf., *Crataegus monogyna* Jacq., *Rosa canina* L., *Lotus corniculatus* L., *Dactylis glomerata* L., *Astragalus ssp.*, *Bromus ssp.*, *Poa ssp.*, *Carex ssp.*, *Paspalum ssp.* The experimental plots were established as "a randomized complete block design with four replications".

Table 1. Soil characteristics of experimental plots in research area (Yüksek et al., 2009).

Soil Properties	Soil Depth (cm)	Bare Plot	Caper Plot
Sand (%)	0-10	43.46	46.22
	10-30	49.88	50.79
	30-50	39.78	43.70
Clay (%)	0-10	32.10	29.11
	10-30	25.23	25.72
	30-50	37.86	33.50
Silt (%)	0-10	24.23	24.67
	10-30	24.90	23.49
	30-50	22.35	22.80
Bulk density (g/cm ³)	0-10	0.96	0.90
	10-30	1.18	1.28
	30-50	1.23	1.26
Particle density (g/cm ³)	0-10	2.50	2.52
	10-30	2.67	2.61
	30-50	2.62	2.58
Total porosity (%)	0-10	61.52	64.17
	10-30	55.81	50.65
	30-50	52.86	51.12
Soil organic matter (%)	0-10	2.58	2.62
	10-30	2.41	1.85
	30-50	1.82	1.73
N (%)	0-10	0.11	0.14
	10-30	0.04	0.08
	30-50	0.02	0.04
Available Phosphorus (ppm)	0-10	48.97	45.54
	10-30	21.18	37.14
	30-50	19.21	25.41
Ca ⁺⁺ (me/100g)	0-10	21.28	21.19
	10-30	21.93	21.51
	30-50	21.43	21.45
Mg ⁺⁺ (me/100g)	0-10	1.13	1.17
	10-30	1.18	1.19
	30-50	1.20	1.21
CaCO ₃ (%)	0-10	35.89	36.60
	10-30	35.83	36.10
	30-50	36.91	39.89
K ⁺ (me/100g)	0-10	0.33	0.32
	10-30	0.30	0.30
	30-50	0.28	0.28
Cation exchange capacity (me/100g)	0-10	25.65	25.90
	10-30	24.90	26.10
	30-50	25.10	26.05
pH (1/2.5 H ₂ O)	0-10	7.65	7.61
	10-30	7.69	7.65
	30-50	7.72	7.73

For this purpose, runoff plots of 20 m length (in the direction of slope) and 5 m width, each with four repetitions in the same parent material, same aspect, same soil type,

same elevation and same slope group were set up in the study area. The edges of the generated test plots were isolated so that they are not affected by the surrounding superficial flow and similar hydrological events.

In the plots where the capers planted, the land was destroyed as little as possible and mechanically cleaned the entire area. Then, on October 27, 2005, 2 + 0 potted caper seedlings originating from Artvin were planted by a distance of 1.5 m x 2 m distance. Thus, a total of 30 caper seedlings were planted in each of the plots and a total of 120 caper seedlings were planted in experimental plots. Growing media of potted caper seedling consisted of a mixture of forest soil, stream sand and cow manure (1:1:1).

The average shoot length measured in caper plots. The measurements were repeated monthly in the vegetation period basis during research. The plant cover was removed using herbicide in the bare plots and no soil treatment was done on the bare plots. A rainfall gauge was placed in the study area to determine the precipitation of the plots. Surface runoff and sediment sampling were carried out for 3 years after erosive rainfall. The results of the study were evaluated using the SPSS statistical package program.

The effects of different treatments on runoff, sediment yield and sediment concentration on caper and bar plots were analyzed by T test. Soil conservation ability of caper according to years and seasons was analyzed with ANOVA.

RESULTS AND DISCUSSION

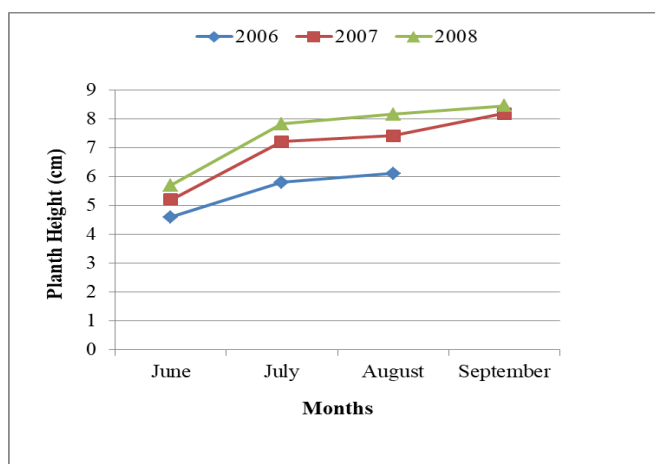
The distribution of the amount of rainfall during the study period was presented in Table 2. When the rainfall values are examined, it is determined that rainfall decreases linearly with years. Monthly variation of precipitation during the year is quite different from the years. According to average values, the highest rainfall occurred in April.

The periods when the temperature is high and the plant needs the most water are June, July and August in the research area. However, only 23.7 % of annual total rainfall falls in this period. In addition, the level of evaporation in this period is at the top of the year. These negative factors are thought to negatively affect plant development in the field of research. In caper plots, the average life percentage of 21% in 2006 is thought to be caused by inadequate and irregular rainfall in summer and severe evapotranspiration.

It is emphasized that in order to complete the development of caper, regular irrigation should be done especially in the first years (Özturan 2007; Ölmez, 2001). The average plant height development of the caper during the observation years was given in Figure 2.

Table 2. Monthly rainfall (mm) and mean annual rainfall for the study period 2006–2008.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual Rainfall (mm)
2006	16.6	9.8	33.8	80.6	60.4	33.2	57.8	12.4	23.8	76.4	54.4	10.0	469.2
2007	34.8	9.4	35.0	60.2	36.4	46.2	15.6	70.0	0.0	30.2	95.8	14.8	448.8
2008	30.8	12.5	41.0	78.0	45.0	36.0	18.6	26.6	27.6	26.0	60.5	12.3	414.9
Mean	27.4	10.6	36.6	72.9	47.3	38.5	30.7	36.3	17.1	44.2	70.2	12.4	444.2

**Figure 2.** Average plant height development of the caper over the years.

When Figure 2 is examined, it is seen that caper does not show the desired plant development. As a matter of fact, it is stated in the survey made by Özturan 2007 that the plant height of caper reached 65.30 cm in June in the first year following planting, and 98.33 cm in August. On the other hand, after June, the caper seedlings was irrigated once in a week in order to improve the adaptation mechanism and plant growth against hot and dry temperature (Özturan, 2007). Study area was established in eroded site. Considering the general soil characteristics of the research area, it can be said that the high clay content in the area and the low amount of sand have an adverse effect on the adaptation and development of caper seedlings in the area. Therefore, it was thought that soil characteristic of the study area had negative effects on plant growth. The soil texture of research plots is clay or clay loam. Therefore, it can be concluded that this high clay content negatively affect the development of caper seedlings in the research area. It was reported that the caper is best developed in the pH ratio between 6.3 and 8.3 (Kara et al., 1996) in sandy loam soils which has high lime and organic matter content (Özdemir and Öztürk, 1996). The insufficient of the protective vegetation in the area and the continuous destruction of the bare soil surface, especially by short-term heavy rainfall, negatively affected the soil aggregate structure, especially the top soil. The aggregate structure was deteriorated due to the inadequacy of the vegetation and especially by the short time heavy rain. The deterioration of the soil aggregate

structure and the high level of clay in the soil texture may have affected negatively the aeration of the soil, the drainage conditions and the hydrophobic properties of the soil. These changes in the soil characteristics have probably affected the development of caper saplings in the negative direction. For as much as it is stated that soil airflow and the amount of oxygen in the soil air are very important for the saplings during the growing (Brady and Weil, 1999; Yüksek et al., 2009). Although the total annual amount of rainfall in the research area is sufficient for capari development, the large irregularities in the monthly distribution of rainfall, the slow growth of caper root development in the early days of growth, clay fractions in the soil and inadequate soil water may had been a negative effect on the growth of caper seedlings. The highest sediment yield was measured in caper plots; while the lowest runoff was measured in bare plots (Table 3).

Table 3. Average runoff, sediment yield and sediment concentration in experimental plots (Values represent the mean \pm standard deviation).

Treatment	Runoff (mm)	Sediment Yield (g m^{-1})	Sediment Concentration (g l^{-1})
Bare	0.49 \pm 0.73a	8.76 \pm 17.70a	8.09 \pm 8.34a
Caper	0.48 \pm 0.71a	9.84 \pm 19.91a	9.78 \pm 11.98a
Sig. Level	0.922	0.694	0.259

If the same letter appears within-column, differences are not significant at the 5% level.

There was no statistical difference in surface flow, sediment yield and sediment concentration between the bare plots and and caper plots. The clusters in the research parcels have not developed a development that could protect against the erosion of the land. Acar et al., (2002) studied on the erosion areas in Manisa-Sarıgöl region; it was found that caper did not directly affect the top soil loss during the study period because it gave life struggle in the first two years and tried to strengthen the root system. However, from the third year onwards, it has been determined that the plants grow horizontally by giving long shoots and can make up to three meters of peak diameter, and that the plant residue accumulated on the soil surface of the caper can make an erosion preventive effect from the third year onwards.

The changes in surface runoff, sediment yield and sediment concentration according to years and seasons are given in Table 4 and Table 5.

Table 4. Average runoff, sediment yield and sediment concentration in experimental plots according to years. (Values represent the mean \pm standard deviation).

Year	Runoff (mm)	Sediment Yield (g m ⁻¹)	Sediment Concentration (g l ⁻¹)
2006	0.68 \pm 0.88a	16.81 \pm 25.02a	13.52 \pm 15.22a
2007	0.31 \pm 0.33ab	2.29 \pm 2.66b	6.26 \pm 2.24a
2008	0.10 \pm 0.09b	0.36 \pm 0.25c	3.78 \pm 1.43b
Sig. Level	0.000	0.000	0.000

If the same letter appears within-column, differences are not significant at the 5% level.

Table 5. Table Average runoff, sediment yield and sediment concentration from experimental plots according to seasons (Values represent the mean \pm standard deviation).

Season	Runoff (mm)	Sediment Yield (g m ⁻¹)	Sediment Concentration (g l ⁻¹)
Spring	0.03 \pm 0.03c	0.09 \pm 0.12c	3.09 \pm 2.18b
Summer	0.94 \pm 0.84a	21.04 \pm 25.25a	17.11 \pm 14.51a
Autumn	0.22 \pm 0.19b	0.95 \pm 0.95b	4.64 \pm 1.14b
Sig. Level	0.000	0.000	0.000

If the same letter appears within-column, differences are not significant at the 5% level.

As seen in both Tables 4 and 5, the runoff, sediment yield and sediment concentration change with years and seasons is a statistically significant level. It is also stated that the superficial flow of the monthly and seasonal distribution of rain influences the sediment yield and the sediment coefficient (Yüksek and Yüksek, 2015). Chirino et al. (2006), reported that rainfall characteristics (such as frequency, duration, quantity and intensities) are also influential in rainfall flow relations as well as vegetation characteristics (closure, root and body structure). Andreu et al. (1998) reported that evolution of the rain regime which affected the development of vegetation also greatly influenced erosion parameters.

CONCLUSIONS and RECOMMENDATIONS

It has been determined that the adaptation and development of the caper seedlings in the clayey soil in eroded site not in the desired level. Percentage of survival rate of caper seedlings was found to be quite low (24%) in the first years following planting. Therefore, during the first season of planting, the texture of soil and summer drought during the growing season had adversely affected the development and survival percentage of caper saplings. Throughout the research period, the development of the caper saplings was not at the desired level. As a result, the plant did not protect the soil from erosive rain. In addition, it has been determined that the effect of rain erosivity changes with the season and years. Both soil properties and rain characteristic (such as: the amount of rainfall, type of

rainfall and the distribution of rainfall) are quite effective on plant growth in eroded sites. Therefore, the combination of erosion control techniques such as mulching, terracing and irrigation might be increased the survival percentage of caper saplings and soil conservation ability in eroded sites. It is very well known that mulching the soil surface with a layer of plant residue conserves water and soil because mulch reduces surface runoff, increases water infiltration into the soil and retards soil erosion (Ghawi and Battikhi, 1986; Adekalu et al., 2007; Smets et al., 2008). But it should not be forgotten that the plant material for mulching was only available and efficient after the wet years. For this reason, the plants to be used in mulching should be carefully selected.

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