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The Effect of Cover Crops to Soil Erosion in Olive Orchards

Zeytin Bahçesindeki Örtü Bitkilerinin Toprak Erozyonuna Etkisi

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Key Words:

Cover Crop, Erosion, *Olea europaea* L., Rainfall Simulation.

ABSTRACT

This research work was conducted in an olive orchard (in Kilitbahir, name of a village in Eceabat Town, Canakkale) with six different plant covers namely horse bean, field pea, vetch, vetch + wheat, field pea + wheat along with a control plot. The experiments were laid out in 24 plots with 4 replications. A total of 24 rainfall simulations were performed to investigate the effects of different cover crops on soil erosion. While the differences in time to runoff values of the plots have been found significant (p=0.012), but the differences between runoff, maximum runoff and runoff coefficient of the plots were seen nonsignificant. Sediment concentration, sediment peak and total soil loss values of the plots also significantly varied. The highest sediment concentration (55.15 g lt-1) and sediment peak (81.37 g lt-1) were observed in control plot while the lowest sediment concentration (5.86 g lt-1) and sediment peak (17.46 g lt-1) have been seen in field pea + wheat plot. Sediment concentration and peak values of the other plots were in between them. Total soil loss of the control plot was almost 12 times higher than the loss in field pea + wheat plot. Further long-term studies can be conducted for properly and better understanding of the effects of cover crops on erosion process.

Anahtar Sözcükler:

Erozyon, Örtü Bitkisi, Yapay Yağmurlama, Zeytin.

ÖZET

Zeytin bahçesinde (Çanakkale'nin Eceabat İlçesinin Kilitbahir köyü) 6 farklı örtü bitkisi (bakla, yem bezelyesi, fiğ, fiğ+buğday, yem bezelyesi+buğday, kontrol) ve 4 tekerrürden oluşan 24 parsellik deneme kurulmuştur. Farklı örtü bitkilerinin toprak erozyonuna etkisini belirlemek için toplamda 24 yapay yağmurlama yapılmıştır. Yüzey akışın başlaması için geçen süre parseller arasında istatistik olarak önemli çıkarken (p=0.012), yüzey akış, maksimum yüzey akış, yüzey akış katsayısı istatistik olarak önemsiz çıkmıştır. Parseller arasında sediment konsantrasyonu, sediment piki ve toplam toprak kaybı değerleri bakımından istatistik olarak önemli farklılıklar çıkmıştır. En fazla sediment konsantrasyonu (55.15 g lt-1) ve sediment piki (81.37 g lt-1) kontrol parselinde çıkmışken en az sediment konsantrasyonu (5.86 g lt-1) ve sediment piki (17.46 g lt-1) yem bezelyesi+ buğday parselinde görülmüştür. Diğer parsellerdeki sediment konsantrasyonu ve sediment piki değerleri bu rakamlar arasında değişme göstermiştir. Kontrol parselindeki toplam toprak kaybı yem bezelyesi+ buğday parselinden 12 kat daha fazla bulunmuştur. Örtü bitkilerinin erozyon sürecine etkilerini daha iyi anlamak için farklı çevre koşullarında uzun süreli araştırmalar yapılmalıdır.

INTRODUCTION

Olive is native to Eastern Mediterranean and accepted as the gift of God to humanity. Throughout the history, it has been the scepter of kings, holy oil of reverends and the symbol of peace and honor. It has been the resource of several legends and accepted as the symbol of peace for centuries. The olive (*Olea europaea* L.) is a species of small tree in the family of

Oleaceae. The motherland of olive is Upper Mesopotamia including Southeastern Anatolia Region of Turkey and Southern Near Asia (Sakar and Unver, 2011). Olive has a significant place in social and economic lives of several countries like Spain, Italy, Greece, Turkey and Tunisia. Turkey has a significant olive production potential with suitable climatic and soil conditions for olive cultivation. Olive orchards cover about 4.1% of the entire agricultural lands of Turkey. The abundance of olive cultivation has been reported especially in Marmara, Aegean, Mediterranean and Southeastern Anatolia Regions of Turkey. Aegean (75%), Mediterranean (14%) and Marmara (10%) taking the place of top three regions with regard to number of olive trees and its production (Tepecik et al. 2011).

Cover crops play a significant role in agricultural systems. Considering the research site of the present study (Eceabat Town of Canakkale), cover crops were brought into agenda for better use of olive cultivated lands in that region. Canakkale Province meets about 6% of total olive production of the country and 11% of the agricultural lands of the province is covered by olive groves. Eceabat Town, where the experiments were conducted, has 1574 ha olive cultivation land and olive culture has 10.8% share in total agricultural activities of the province (Anonymous, 2012).

Olive cultivated lands of Turkey are generally sloping sites with shallow soil depths. Usually they are exposed to water erosion and such exposures most of the time have negative impacts on yields. To prevent such negative impacts, effective soil and water preservation measures able to hold available moisture and to prevent nutrient leaching should be taken in consideration (Unal et al. 2007). Conservation tillage is an alternative practice to overcome those problems. Open row spaces are covered with a plant cover (cover crops-ground crops) with the help of this practice.

Cover crops have been shown to provide a variety of benefits within agroecosystems. These include reduced soil erosion, increased biological diversity (e.g., microbes, insects, and birds), increased nutrient cycling and biological nitrogen fixation, increased soil organic matter, improved weed control, and increased crop yields (Wortman et al. 2012). Gomez et al. (2004) carried out a research on soil management with cover crops on runoff plots and reported the total annual soil loss as 1.2 t ha^{-1} yr^{-1} and average annual runoff coefficient as 2.5%. Such results were directly related to preservative impact of cover crops and consequent improved soil aggregate stability. Ordonez-Fernandez et al. (2007) conducted a research work on ecologic olive orchards of Southern Spain with 1 m^2 runoff plots aimed to investigate the effects of cover crops and then reported a significant reduction in available phosphorus losses, soil losses and runoff. Many other studies which investigating the relationships between plant cover and erosion were performed in Turkey by Yonter and Geren, 2006; Geren and Yonter, 2007; and Parlak 2012.

The present study was conducted in Eceabat Town of Canakkale aimed to investigate the impacts of different cover crops on runoff and soil loss in olive orchards.

MATERIALS and METHODS

Eceabat Town is located between 26-27° east longitudes and 40-41° north latitudes by covering an area of 426.6 km^2 (42661 ha). The district is located in Southern Marmara Section within the borders of Canakkale Province north of Gallipoli Peninsula. The district is also surrounded by the sea on three sides and has a "National Historical Park" within its borders.

As far as the climate is concerned, Canakkale Province is located in a transition zone between actual seasonal Mediterranean climate and humid-warm Black Sea climate. So the climate of the region is classified as "sub-humid Marmara transition climate" (Turkes et al. 2011). Climatic data of Gallipoli have been taken from the meteorology station to put for the climatic characteristics of the research site. Trial area with having an annual average temperature of 14.8 °C along with an annual average precipitation of 656 mm. Due to the impacts of Mediterranean macroclimate, significant portion of the precipitations is occurred in winter but the low level of rainfall is observed in summer with intensive agricultural practices.

The experimental site is situated in Canakkale which formed by Middle-Young Miocene-aged shoreline (river, lagoon) and offshore depositions. The Bayraktepe unit, one of the four members of Canakkale texture, was renamed later on as Kilitbahir formation. This formation exhibits horizontal and vertical transitions between shoreline and offshore environmental conditions, and intercalated depositions from place to place which dominantly consist of sandstone, limestone, sandy limestone, pebble stone and siltstones (Atay and Tunoğlu, 2002). Since the research site is located within Mediterranean climatic zone then the zone-specific species are dominant over there. Stone pine (*Pinus pinea*), *Quercus brandii* and maquis shrublands widely spreads around olive groves (Atalay, 1994).

Experiments were carried out in an area of 2400 m^2 of olive orchard (with 12-15% slopes) in Kilitbahir village of Eceabat Town shown in Figure 1. The olive trees, already present in experimental area, were 5 years old at the time of research started. Cover crops namely common vetch – local variety (Vetch) (*Vicia sativa*), field pea – local variety (*Pisum arvense* L.) – field bean – local variety (*Vicia faba* L.) and wheat (*Ttriticum aestivum*)- Bereket cultivar have been used as materials in experimental trials. All experiments were conducted in Randomized Complete Block Design (RCBD) using 4 replications in each treatment. There were a total of 24 plots [6 different crop covers (field bean, field pea, vetch, vetch + wheat, field pea + wheat, control (fallow) x 4 replications)] established in olive orchard. Sowings have been done in between two rows of trees in 2nd October, 2011. Each plot consisted of two inter-rows and a row in between of all plots. Each plot size was 20 m x 5 m = 100 m^2. A total of three olive trees were taken from each plot into consideration for research purpose.

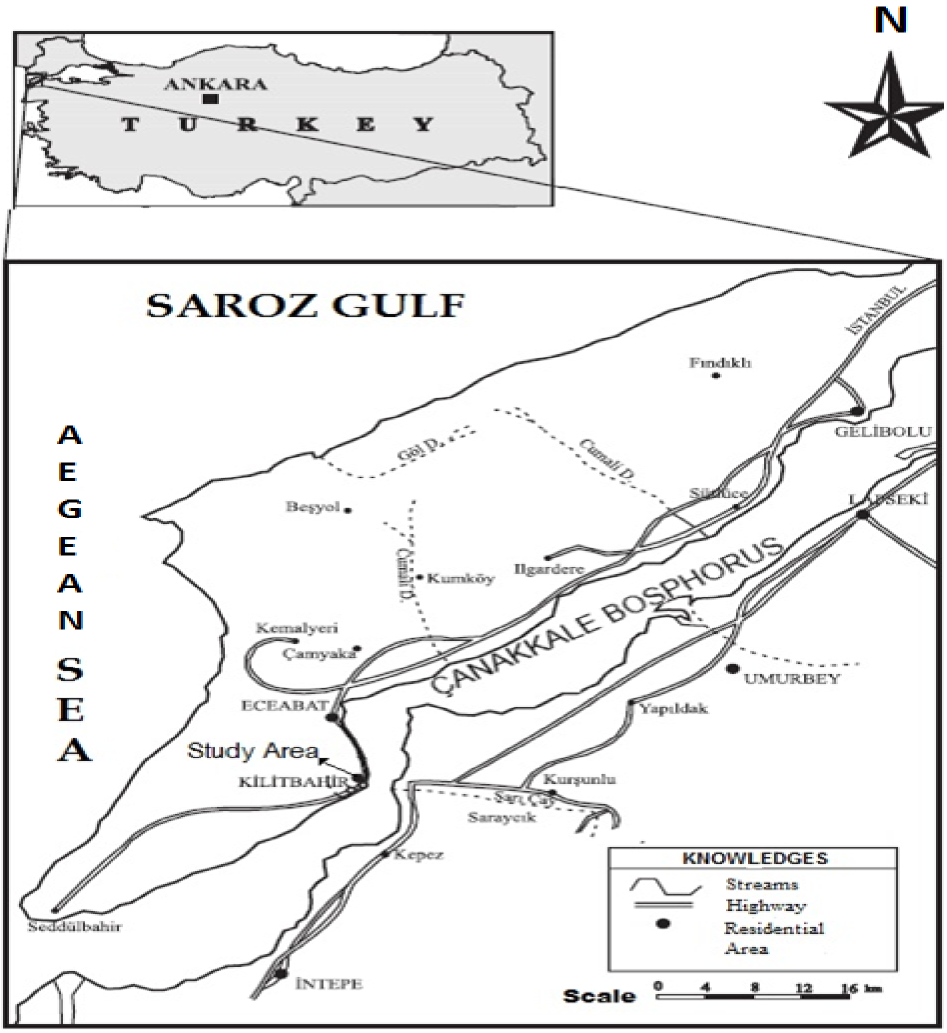

Figure 1. Location of the study area.

Before the rainfall simulations, 4 soil samples were taken from control plot of research site at 0-30 cm depth for determining soil characteristics. The soil samples were kept air-dried then sieved using a 2 mm sieve. Hydrometer method (Gee and Bauder,1986) has been used to determine the distribution of soil particles size. The pH and electrical conductivity (EC) of soil samples were measured into a suspension of soil: water (1:2.5) using digital pH–EC meter (Mclean,1982; Rhoades, 1982). Lime content of soil samples was determined with the help of "Scheibler Calcimeter" as described by Nelson (1982). Smith–Weldon method (Nelson and Sommers, 1982) was used to investigate the soil organic matter. According to the results of above analyses, the soil of research site has been found as sandy loam containing 55.1% sand, 24.49% silt and 20.41% clay. The soil was also found with a texture of slightly alkaline (pH = 7.24), unsaline (EC = 0.51 dS m^{-1}), medium lime ($CaCO_3$ = 7.29%) and having low organic matter contents (1.55%).

Rainfall simulation tests: A portable Kamphorst rainfall simulator, shown in Figure 2, has been used for this purpose (Kamphorst, 1987). Mini rainfall simulator, specifically designed for soil erosion studies, was obtained from Eijkelkamp, Netherland, and then standardized according to the conditions of research site. This type of mini simulator is preferred to use in field as well as laboratory because of its small size, easy to carry and easily operation. A total of 24 rainfall simulations (1 for each plot) were performed over the experimental site. The runoff plot of the mini rainfall simulator covers an area of 0.0625 m^2 and surrounded with a metal frame that is why all runoff water is collected at the lowest point. The raindrops were observed to fall from an average height of 0.4 m on soil surface. Rain intensity was 1.2 mm min^{-1} and kinetic energy has been noted 3.92 J m^{-2} (Kamphorst, 1987; Martinez et al. 2003; Romero et al. 2007). The simulated rainfall intensity portrayed a 5-yr return period for study region. Rainfall time was found sufficient (6 min) for providing a good statistical run-off curve. Runoff and sediment samples were collected immediately after every 60 sec of each simulated rainfall. Runoff samples were collected in plastic bottles and then dried at 105°C for determining the sediment mass (Greene et al.1994; Erpul and Canga, 1999; Yonter and Geren, 2006; Luo et al. 2013; Wenming et al. 2014). Time to runoff, runoff, maximum runoff rate, runoff coefficient (% runoff/rainfall), sediment concentration, maximum sediment concentration, and total soil loss like factors were determined for each plot. The experiments were carried out in 4-5 May, 2012 when the average soil moisture was 1.69%.

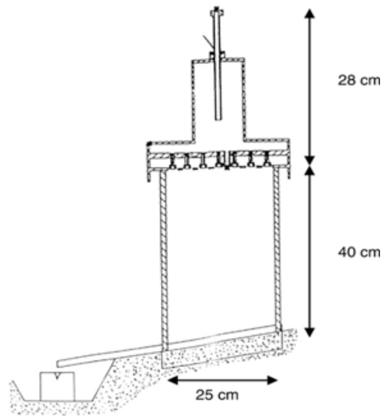

Figure 2. Schematic plan for mini rainfall simulator.

The percentage values of plant cover of the rainfall simulation plots were estimated visually. Crops were harvested at the end of the first year and soil samples were taken from a depth of 0-5 cm. These samples were used to determine the aggregate stability of micro aggregates (<0.25 mm) with a Yoder-type wet sieving apparatus (Kemper and Rosenau, 1986).

Statistical analysis: The data obtained from rainfall simulations (time to runoff, runoff, maximum runoff, runoff coefficient, sediment concentration, peak of sediment and total soil loss) were arranged in group regarding to simulation plots. Moreover, aggregate stabilities and the percentage values of plant cover of each cover crop were also arranged in group.

Statistical data have been analyzed by analysis of variance (ANOVA), and the means were subjected to the Duncan's test ($p<0.05$) for obtaining the main differences between different plots. Data were statistically analyzed using Minitab 16 for Windows program.

RESULTS and DISCUSSION

According to the results of cover crops, the highest (63.75%) plant cover was observed in field pea + wheat plot while the lowest (23.75%) plant cover has been found in horse bean plot. Cover ratios were noted to be as 31.25% in field pea plot, 37.50% in vetch plot and 46.25% in vetch + wheat plot (Table 1). Increasing vegetative cover also increases root development. Zhou and Shangguan (2007), reported close relationships between plant roots and soil erodibility and indicated improved soil strength, shear strength, structural stability and aggregate stability with improved soil properties. However, any root-related parameters were not determined in this study. Significant differences were not observed in aggregate stabilities of soil samples taken from experimental plots. The lowest aggregate stability (31.19%) was observed in control plot while the highest (66.29%) one in vetch plot (Table 1). According to the studies of Gomez et al. (2011), a period of two years is not sufficient to increase significantly organic matter and aggregate stability in olive planted sites by establishing cover crops.

Table 1. Plant cover percentages of plots (%) along with aggregate stability values of soil samples (%)

Plot	Average ± standard deviation	
	Plant cover percentages (%)	Aggregate stability (%)
Horse bean	23.75±7.50 **d**	56.22±33.99
Field pea	31.25±6.29 **cd**	51.06±38.95
Vetch	37.50±11.90 **bc**	66.29±28.48
Vetch + wheat	46.25±9.46 **b**	59.53±30.63
Field pea + wheat	63.75±7.50 **a**	48.15±9.57
Control	0.00±0.00 **e**	31.19±13.48
p	0.000*	0.731

* Significant at 5% level.

The differences in time to runoff values of the plots were found to be significant (p=0.012). The highest value (72.50 s) was simultaneously observed in both of horse bean as well as vetch+wheat plots. While the lowest value (27.75 s) has been seen in control plot (Table 2). In case of time to runoff values, a higher yield was obtained from cover crops because plant cover can easily reduce the runoff rates. Runoff and maximum runoff values were observed in control plot of this study work noted as 2.29 ml s^{-1} and 3.14 ml s^{-1}, respectively. The lowest and minimum values were seen in vetch + wheat plot i.e.; 1.34 ml s^{-1} and 1.98 ml s^{-1}, respectively. Significant differences were not found in runoff coefficients of any plot but the highest runoff coefficient (14.60%) was only observed in control plot and the lowest (8.57%) in vetch + wheat plot (Table 2). The plots with plant cover had lower runoff coefficients than control plot. Gomez et al. (2011) reported that the average annual runoff coefficients of olive planted sites with plant cover ranging between 1.9 – 25%. Runoff and maximum runoff were not affected by plant cover during this study. Any negative linear or exponential relationship between plant cover and runoff did not find in this study as compared to the studies of Bochet et al. 2006; Duran Zuazo and Pleguezuelo 2008. Because of fact that the abiotic soil parameters having better explanatory variables for runoff than that of actual level of vegetation cover (Bautista et al. 2007; Martin et al. 2010).

Table 2. Values of time to runoff , amount of runoff, maximum runoff and runoff coefficient on different cover crops grown in plots

Plot	Average ± standard deviation			
	Time to runoff (sn)	Runoff (ml sn^{-1})	Maximum runoff (ml sn^{-1})	Runoff coefficient (%)
Horse bean	72.50±17.08 **a**	2.28±0.61	2.94±1.10	14.19±4.31
Field pea	41.75±14.34 **bc**	2.22±0.51	2.92±0.66	14.18±3.25
Vetch	39.50±13.82 **bc**	2.03±0.76	2.83±0.95	13.00±4.89
Vetch + wheat	72.50±18.93 **a**	1.34±0.49	1.98±0.88	8.57±3.10
Field pea + wheat	59.00±30.56 **ab**	1.74±0.81	2.29±0.87	11.12±5.17
Control	27.75±9.32 **c**	2.29±1.04	3.14±0.58	14.60±6.69
p	0.012*	0.412	0.402	0.454

* Significant at 5% level.

The highest erosion sediment concentration (55.15 g l^{-1}), highest sediment peak (81.37 g l^{-1}) and the highest total soil loss (583.10 g m^{-2}) were observed in control plot shown in Table 3. On the other hand, the lowest values of above mentioned three parameters were observed in field pea + wheat plot as 5.86 g l^{-1}, 17.46 g l^{-1} and 47.20 g m^{-2}, respectively. Such differences have been occurred mainly due to significant reduction in soil erosion by cover crops, and this reduction came out because of the combination of cover crop attributes like protection of the soil surface against raindrop impact, anchorage of the soil by plant roots, and filtering of dislodged soil particles by surface vegetation (Gomez et al. 2011). Soil losses in covered areas are significantly lower than that of bare soils. Such case does not happen only because of lower runoff yields but also because of lower sediment concentrations. It is well - known that plants reduce soil erosion by intercepting raindrops, enhancing infiltration, transpiring soil water and providing additional surface roughness by adding organic substances to soil (Styczen and Morgan, 1995).

Table 3. Sediment characteristics values and total soil loss on different cover crops grown in plots

	Average ± standard deviation		
Plot	Sediment concentration (g lt-1)	Peak of sediment (g lt-1)	Total soil loss (g m-2)
Horse bean	21.43±12.20 **b**	39.56±22.37 **b**	302.80±250.50 **ab**
Field pea	19.34±6.55 **b**	37.97±10.04 **b**	259.20±117.00 **ab**
Vetch	35.28±19.39 **ab**	49.78±25.03 **ab**	370.20±230.80 **ab**
Vetch + wheat	22.81±12.36 **b**	37.83±14.16 **b**	147.10±70.80 **b**
Field pea + wheat	5.86±3.22 **b**	17.46±16.25 **b**	47.20±26.20 **b**
Control	55.15±40.31 **a**	81.37±44.08 **a**	583.10±299.00 **a**
p	0.044*	0.041*	0.048*

***** Significant at 5% level.

Snelder and Bryan, (1995) carried out a study on 30 and 60 minute rainfall simulations and then reported that the low runoff discharges (9 ml s^{-1} and 21.5 ml s^{-1}) and minimum soil losses (0.5 and 31.5 g m^{-2}) along with a vegetative cover over 55% as a result. They also reported the discharges of 24.8 ml s^{-1} and 40.2 ml s^{-1}, and soil losses of 4.6 g m^{-2} and 12.5 g m^{-2} for cover ratios between 25 – 55%. Such, the results indicated 25-55% efficiency of plant covers in erosion control. Zuzel and Pikul, (1993) evaluated the effect of several rates of straw mulch (0, 25, 50, 75, and 100 percent cover) on erosion and obtained a negative correlation between percent straw cover and soil loss. Wilson et al. (2008) reported that the annual soil losses were reduced by 47% and 54% for 50% and 100% plant populations, respectively as compared to control. Martin et al. (2010) carried out a research in disturbed alpine site using mini rainfall simulator and then reported that the sediment yield has been reduced to 83% in a 60% vegetation covered area as compared to un-vegetated plots.

Fleskens and Stroosnijder (2007) conducted a research in Italian and Portuguese olive orchards using mobile rainfall simulator as well as Kamphorst, and indicated that the plant cover was found highly effective in soil loss control ($p<0.05$). The researchers investigated runoff coefficient and soil loss under three different hillslope positions and reported runoff coefficients in between 47.2 - 52.1% and soil losses between 98 - 336 g m^{-2}. Such kind of variable results have been obtained from this study basically due to different hillslope positions, plant covers and slopes.

Espejo-Perez et al. (2013) implemented 2-year study on olive groves with 24 plots and reported that an average of 76% decrease of soil losses observed in all plots and 22% decrease of water losses in 18 plots covered with plant. Decreasing soil loss and runoff sediment concentrations were observed with increasing cover percentages. Researchers reported the runoff coefficient of covered plots as 0.062% and found soil loss reduction with plant cover as more effective than runoff reduction.

CONCLUSIONS

According to the overall obtained results, significant differences were not observed among plots regarding to the aggregate stability values of soil samples taken from the experimental plots at the end of first year of research. Rainfall simulator method provides limited data due to small plot sizes and simulator design. That is why, it is hard to estimate the sediment production at larger scales. Nevertheless, simulation results can be used for comparative purposes. Significant differences were not also observed in runoff, maximum runoff and runoff coefficient values of the plots. Compared to field pea+wheat plot, 9.4 and 4.6 times higher values were observed respectively in sediment concentration and sediment peak of the control plot. A total soil loss in control plot was noted as 583.10 g m-2 while in field pea + wheat plot it observed as 47.20 g m-2. Combined sowing of legume along with other grass species was seemed to be more effective in soil loss control than sole sowing of legume. Field studies including sediment budget monitoring of basins have been recommended for future studies to determine the erosion rates of olive planted sites.

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REFERENCES

Anonymous, 2012. Republic of Turkey Ministry of Food, Agriculture and Livestock. Statistics of Provincial Food of Canakkale Directorate of Agriculture and Livestock. (in Turkish).

Atalay, I. 1994. Vegetation Geography of Turkey. Ege University Press. Izmir.

Atay, G. and C. Tunoglu. 2002. Ostracoda fauna and their bioprovince of the Kilitbahir drilling samples (Eceabat/Canakkale). Bulletin of Earth Sciences Application and Research Centre of Hacettepe University, 26: 119-144.

Bautista, S., A. G. Mayor, J. Bourakhouadar and J. Bellot. 2007. Plant spatial pattern predicts hillslope semiarid runoff and erosion in a Mediterranean landscape. Ecosystems, 10: 987–998.

Bochet, E., J. Poesen, and J. L. Rubio. 2006. Runoff and soil loss under individual plants of a semi-arid Mediterranean shrubland: Influence of plant morphology and rainfall intensity. Earth Surface Processes and Landforms, 31: 536–549.

Duran Zuazo,V. H. D. and C. R. R. Pleguezuelo. 2008. Soil-erosion and runoff prevention by plant covers: A review. Agronomy for Sustainable Development, 28: 65–86.

Erpul, G. and M.R. Canga. 1999. Effect of subsequent simulated rainfalls on runoff and erosion. Turkish Journal of Agriculture and Foresty, 23: 659-665.

Espejo-Perez, A.J., A. Rodriguez-Lizana, R. Ordonez and J.V. Giraldez. 2013. Soil loss and runoff reduction in olive-tree dry-farming with cover crops. Soil Science Society of America Journal, 77: 2140–2148.

Fleskens, L. and L. Stroosnijder. 2007. Is soil erosion in olive groves as bad as often claimed? Geoderma, 141 (3–4): 260–271.

Gee, G. W. and J.W. Bauder. 1986. Particle size analysis. In: Methods of Soil Analysis, Part 1, Physical and Mineralogical Methods (Ed. Klute A.), American Society of Agronomy, Soil Science Society of America, Madison,Wisconsin. pp. 383-411.

Geren, H. and G.Yonter. 2007. Investigations on the effect of soil erosion by water of some cool season turf grasses under laboratory conditions. Journal of Agriculture Faculty Ege University, 44 (2): 1-15. (in Turkish).

Gomez, J.A., P. Romero, J.V. Giraldez and E. Fereres. 2004. Experimental assessment of runoff and soil erosion in an olive grove on a Vertic soil in southern Spain as affected by soil management. Soil Use and Management, 20: 426–431.

Gomez, J.A., C. Llewellyn, G. Basch, P.B. Sutton, J.S. Dyson and C.A. Jones. 2011. The effects of cover crops and conventional tillage on soil and runoff loss in vineyards and olive groves in several Mediterranean countries. Soil Use and Management, 27: 502–514.

Greene, R.S.B., P. Kinnell, J.T. Wood. 1994. Role of plant cover and stock trampling on runoff and soil erosion from semiarid wooded rangelands. Australian Journal of Soil Research, 32(5): 953-973.

Kamphorst, A. 1987. A small rainfall simulator for the determination of soil erodibility. Netherlands Journal of Agricultural Science, 35: 407-415.

Kemper, W.D. and R.C. Rosenau. 1986. Aggregate stability and size distribution. In: Methods of Soil Analysis, Part 1, Physical and Mineralogical Methods (Ed. Klute A.), American Society of Agronomy, Soil Science Society of America, Madison,Wisconsin. pp. 425-442.

Luo, H., Z.Tingning, D. Mei, G. Jun, P. Xianfeng, G.Yu, W. Zhiming and L. Chao. 2013. Field studies on the effects of three geotextiles on runoff and erosion of road slope in Beijing, China. Catena, 109: 150-156.

Martin, C., M. Pohl, C. Alewell, C. Körner and C. Rixen. 2010. Interrill erosion at disturbed alpine sites: Effects of plant functional diversity and vegetation cover. Basic and Applied Ecology, 11: 619–626.

Martinez, F., M.A. Casermeiro, D. Morales, G. Cuevas and I. Walter. 2003. Effects on run-off water quantity and quality of urban organic wastes applied in a degraded semi-arid ecosystem. The Science of the Total Environment, 305: 13-21.

McLean, E. O. 1982. Soil pH and lime requirement. In: Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties, (Eds. Page, A.L., Miller, R.H., Keeney, D.R.), Agronomy No: 9, ASA, SSSA, Madison, Wisconsin, pp. 199-223.

Nelson, R.E. 1982. Carbonate and gypsum, In: Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties, (Eds. Page, A.L., Miller, R.H., Keeney, D.R.), Agronomy No: 9, ASA, SSSA, Madison, Wisconsin, pp. 181–197.

Nelson, R.E., L.E. Sommers. 1982. Total carbon, organic carbon and organic matter, In: Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties, (Eds. Page, A.L., Miller, R.H., Keeney, D.R.), Agronomy No: 9, ASA, SSSA, Madison, Wisconsin, pp. 539–580.

Ordonez-Fernandez, R., A. Rodriguez-Lizana, A.J. Espejo-Perez, P. Gonzalez-Fernandez and M. Milagros Saavedra. 2007. Soil and available phosphorus losses in ecological olive groves. European Journal of Agronomy, 27: 144–153.

Parlak, M. 2012. Determination of soil erosion over different land uses by mini rainfall simulator. Journal of Food, Agriculture and Environment, 10(3-4): 929-933.

Rhoades, J. D. 1982. Soluble salts. In: Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties, (Eds. Page, A.L., Miller, R.H., Keeney, D.R.), Agronomy No: 9, ASA, SSSA, Madison, Wisconsin, pp. 167-179.

Romero C.C., L. Stroosnijder and G.A. Baigorria. 2007. Interrill and rill erodibility in the northern Andean Highlands. Catena, 70: 105-113.

Sakar, E. and H. Unver. 2011. Olive cultivation and some conducted selection and adaptation studies in Turkey. Journal of Agriculture Faculty Harran University, 15(2): 19-25. (in Turkish).

Snelder, D.J. and R.B. Bryan. 1995. The use of rainfall simulation tests to assess the influence of vegetation density on soil loss on degraded rangelands in the Baringo District, Kenya. Catena, 25: 105-116.

Styczen, M.E. and R.P.C. Morgan. 1995. Engineering properties of vegetation, In: Slope Stabilization and Erosion Control: A Bioengineering Approach, (Eds. Morgan, R.P.C. and R.J. Rickson), Taylor & Francis, London, UK, pp 4–60.

Tepecik, M., B. Esetlili, N.T. Barlas, D. Anac. 2011. Nutrient status of different olive cultivars. In: The National Olive Congress. Akhisar-Turkey. 22-25 February 2011. p. 368-373. (in Turkish).

Turkes, M., T. Savas, H. Baytekin, K. Ugur. 2011. Possible climate changes in Canakkale and effects on agricultural production. Canakkale Agricultural Semposium (Past, Present and Future). Canakkale. 10-11 January 2011. p. 257-258. (in Turkish).

Unal, H. B., U. Kaya and E. Gulsoylu. 2007. Soil and water conservation measures in rainfed olive growing: Alternative soil tillage practices. Journal of Agriculture Faculty Harran University,11 (3/4): 73-79. (in Turkish).

Wenming, M., Z. Li, K. Ding, J. Huang, X. Nie, G. Zeng, S. Wang and G. Liu. 2014. Effects of soil erosion on dissolved organic carbon redistribution in subtropical red soil under rainfall simulation. Geomorphology, 226: 217-225.

Wilson, G.V., K.C. McGregor and D. Boykin. 2008. Residue impacts on runoff and soil erosion for different corn plant populations. Soil and Tillage Research, 99(2): 300-307.

Wortman, S.E., C.A. Francis and J.L. Lindquist. 2012. Cover crop mixtures for the Western Corn Belt: Opportunities for increased productivity and stability. Agronomy Journal, 104 (3): 699-705.

Yonter, G. and H, Geren. 2006. Pre-investigations on the effect of soil erosion by water of different pasture mixtures under laboratory conditions. Journal of Agriculture Faculty Ege University, 43 (1): 121-131. (in Turkish).

Zhou, Z.C. and Z.P. Shangguan. 2007. The effects of ryegrass roots and shoots on loess erosion under simulated rainfall. Catena, 70: 350–355.

Zuzel, J.F. and J.L. Pikul. 1993. Effects of straw mulch on runoff and erosion from small agricultural plots in northeastern Oregon. Soil Science, 156 (2): 111–117.