Full Length Article

Temporal Variation of Soil Moisture Under Alley Cropping System in Pistachio in Semi-arid Region of Turkey

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ABSTRACT

Alley cropping is practiced to produce grain and forage crops, reduce soil and nutrient losses by surface runoff and improve nutrient availability. Growing barley and legumes for grain and forage in pistachio, olive and vineyards is a common alley cropping system applied in the southeastern Turkey. However, this practice is not being widely used by farmers because of their concern of that these forage crops severely compete the trees for water and nutrients. This study was therefore conducted to observe temporal variation in soil moisture content (SMC) under an alley cropping systems in pistachio to investigate the competition between main and secondary crops for SM in three alley cropping systems and to suggest the most proper alley crops to farmers in the region. The experiment was conducted in an orchard of 20 year-old pistachio trees. There were no differences in SM content among the four treatments from beginning until April 19, 2009. However, the means were significantly different after this date (April 19, 2009). The soil moisture deficit (SMD) calculated was 27.4 mm for control compared to 45.1 mm for alley cropped treatments. Even though there were no significant differences in SMC among the treatments during the whole experimental period, the effect of treatments on the yield or other physiological characteristics of pistachio trees needs investigating for a sound decision on the selection of the best alley cropping system. © 2010 Friends Science Publishers

Key Words: Soil moisture; Time Domain Reflectometry; Alley cropping; Pistachio; Soil moisture deficit

INTRODUCTION

Alley cropping is an additional source of income, possibly fitting workload patterns, it increases soil organic matter content, improves soil temperature regime, reduces erosion hazard, improves use of the three dimensional crop canopy, enhances nutrient turnover by nitrogen fixation, reduces nutrient leaching and improves biodiversity (Nair, 1993). In the southeastern Turkey, barley and legumes (Jordan *et al.,* 2002) are grown for grain and forage production in pistachios, olives and vineyards. However, this practice is not often used by farmers because of common concern of competition of these secondary crops with primary crops (pistachios) for water and nutrients (Hall *et al.*, 2006). Therefore, the negative interactions between trees and crops, particularly competition for water, should be minimized to improve the success of these systems in semiarid regions (Jose *et al*., 2000).

Alley cropping system has very complex ecological interactions (Anderson & Sinclair, 1993). In this system,

only little part (41%) of the annual rainfall is utilized by crops and the remaining rainfall is lost as runoff (26%) or as deep percolation (33%) (El-Swaify *et al*., 1987). Therefore, the inclusion of trees would increase the total productivity by enhancing the uptake of water below the rooting depth and utilizing rainfall fallen outside the annual cropping season (Rao *et al.*, 1991). Furthermore, soil moisture storage is promoted by cover crops with reducing runoff through stalks and litter and improving infiltration by root channel. Even though water competition is a crucial factor limiting the success of alley cropping systems (Singh *et al*., 1989; Ong *et al*., 1991), there are limited studies on such competition, especially in the semi-arid regions (Jose *et al.*, 2000; Everson *et al*., 2009). Therefore, the data on water competition especially in the semiarid regions are needed to understand the effect of alley crops on pistachios (*Pistachia vera* L.) to drive sound decisions on selecting proper alley crop species and their growing in the southeastern Anatolia.

Time Domain Reflectometry (TDR) has been used for a long time to measure soil moisture *in situ* (Mallants *et al*.,

1996; Vogeler *et al.*, 1997 & 2005; Persson & Berndtson, 1998; Topp *et al.*, 2000; Gauret *et al.*, 2003). The rationale behind use of TDR in soil moisture measurement in our study was simple. TDR is a nondestructive technique that it can be used multiple times to measure soil moisture in the same point, continuous automatic measurement of soil moisture can be taken by connecting the system to a data logger and the measurement of soil moisture at different depths with replications through multiplexing the probes can be done (Evett, 2000; Chandler *et al.*, 2004; Bittelli *et al.*,2008).

The objectives of this study were to: (a) compare different alley cropping systems for temporal variation in soil moisture content (SMC) in alley of pistachios, (b) evaluate water consumption of secondary crops in three alley cropping systems and analyze interaction between primary and secondary crops competing for water, (c) suggest the best alley crop for pistachios in the region.

MATERIALS AND METHODS

The field experiment site was situated 2 km from Oguzeli town, Gaziantep Province (368530 N, 4091736 E, UTM Zone 37S) in a site representing typical pistachio growing areas with a slope of aproximately 15%. The location of field experiment is given in Fig. 1. Note the gullied slopes and lighter brown areas due to high calcium carbonate in subsoil exposed by soil erosion. A white chalky material in road cut seen background reveals shallow Rendzina soils common in this region. Fig. 1 also shows long term effect of severe erosion. Erosion by water, wind and tillage creates areas of lighter colored soils (Hall, 1985 & 1990). Soils in the region are mainly classified as rendzinas (Anonymous, 2003). Despite caliche predominatly occurs in the region, topsoil has a well developed structure; however, crusting and compaction do pose problem in some localities. In general, soil depth is between 20 and 40 cm. The region has a semiarid continental climate with an average annual temperature of 15.8°C. Monthly mean temperature ranges from 3.7°C in January to 29.1°C in July. The average annual precipitation is 393.2 mm. Of the total precipitation, 81% falls between December and April (Anonymous, 2010).

The experimental treatments were control, barley, vetch and a mixture of barley and vetch. Each treatment was repeated in four 12 by 16 m plots (Fig. 2) having six 20-year old pistachio trees. No fertilizers were applied to any of the treatments. Soil moisture measurements were performed biweekly from sowing in November until April and weekly from April until harvest of forage crops for livestock in May. The soil water content was measured at two depths (0-10 & 10-20 cm) at three randomly determined points at each plot with a TDR system (Qiu *et al.*, 2001). That soil depth varied and due to presence of caliche just below the topsoil restricted monitoring the soil moisture change to the top 20 cm. However, the pistachio trees and alley forages can use soil water stored in deeper depths. The TDR system consisted a TDR, CS640 probes, PCTDR software (Campbell Scientific, 2006) and a laptop computer to control the system. The TDR probe rod was a 3-rod steel with 7.5 cm in length and 0.159 cm in diameter and the probe was connected to a 12 m cable. The basic principle of TDR reading is to relate dielectric constant (K_a) to volumetric SMC described by Topp *et al.* (1980) as follows:

$$\theta_v = -5.3*10^{-2} + 2.92*10^{-2} K_a - 5.5*10^{-4} K_a^2 + 4.3*10^{-6} K_a^3 \quad\quad (1)$$

We used this equation as it is appropriate for applications in mineral soils. Soil properties were determined by conventional methods (Day, 1965; Grossman & Reinsch, 2002). Rainfall was recorded by an automatic datalogged raingauge located in the study area during the study period.
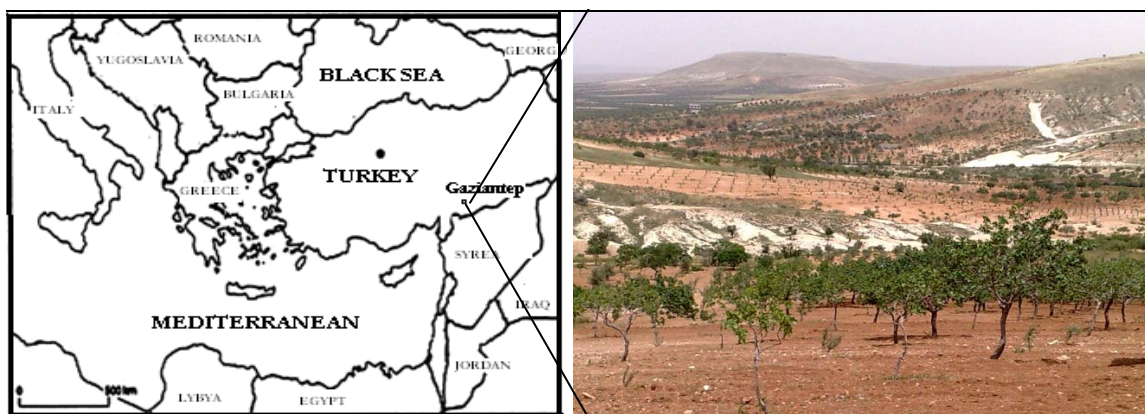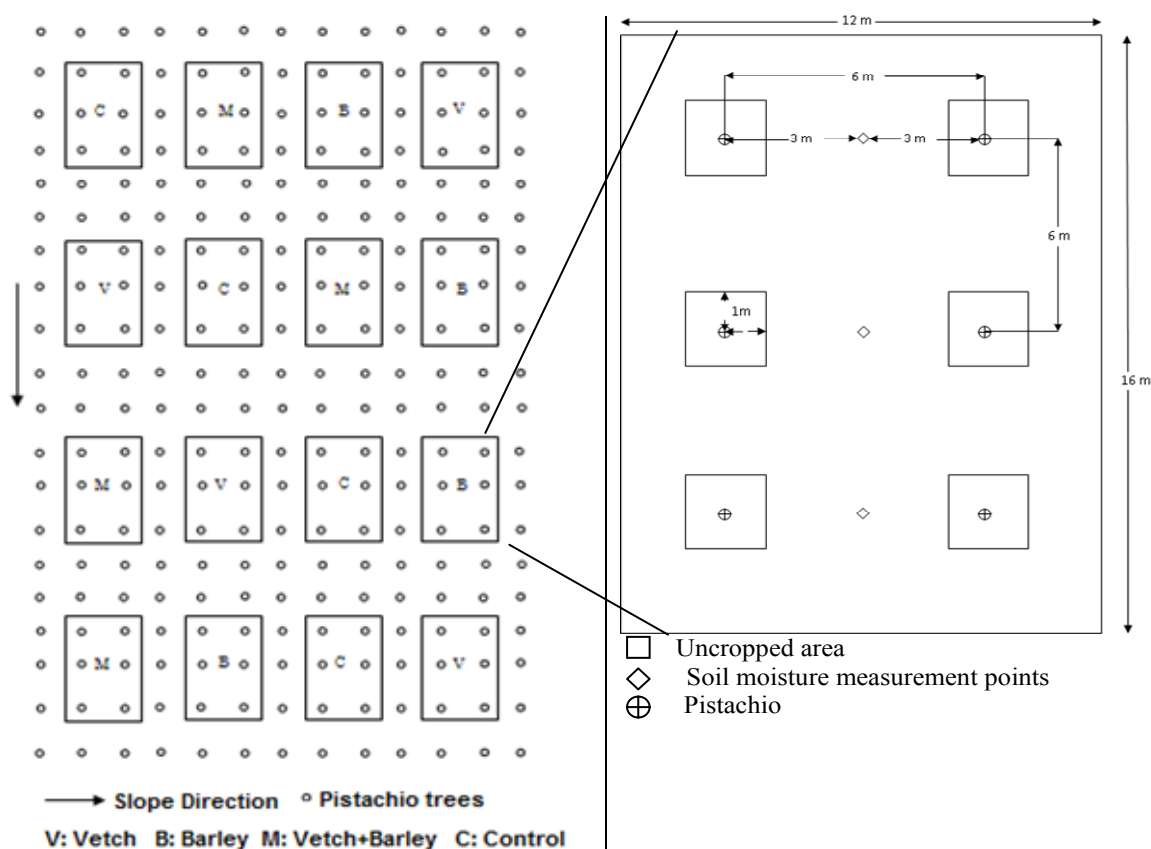
Difference among the treatments was tested by one-way ANOVA technique and means were grouped with Tukey's procedure (SPSS, 1993). Significance level of 0.05 was applied to all tests.

RESULTS AND DISCUSSION

The temporal changes in the mean soil moisture content (SMC) were apparent (Fig. 3 a & b). SMC varied from 11.3% to 25.6% and SMC increased with rainfalls in February and decreased with drought and high evapotranspiration (ET) after April (Table I). In general, the peak in SMC corresponded to greater precipitation in early March. However, after late March, the SMC was significantly influenced by treatments as shown by increased gap between control and treatment. The main reason for differences may be the influence transpiration of alley crops (Fu *et al.*, 2003). The greater mean SMC in the control (bare soil) was attributed to relatively lower ET in these plots. The results showed a greater variation in SMC for 0-10 cm compared to 10-20 cm. Similar effects were reported by others (Anderson & Burt, 1978, Barling *et al.*, 1994; Fu *et al.*, 2003).

Statistical parameters of SMC for forage crops with time during the growth period in the top soils (0-10 cm) and sub-soils (10-20 cm) were calculated (Table II & III). Differences among the treatments turned to be significant after the April 19, 2009. Volumetric soil water content in vegetated plots was 3.0 to 4.8% lower than that in the control. The maximum difference occurred on the April, 28 and the difference among the treatments declined to 3.3% by May, 7. Multiple comparisons indicated that means for forage crops were not significant for both top and sub soils.

Soil moisture deficit (SMD) is the amount of precipitation required to bring the current water content in the root zone to field capacity water content and it is expressed in mm. In our study SMD was 27.4 mm for the control and 45.1 mm for alley cropped treatments. However, no significant differences occurred in SMD for forage types. At the harvest of forages, SMD was 23 greater for topsoil

Fig. 1: Location of study site and orchard where the field trial was conducted (seen in front)

Fig. 2: Experimental design with a sample plot showing soil moisture monitored points and pistachio trees

☐ Uncropped area
◇ Soil moisture measurement points
⊕ Pistachio

→ Slope Direction ∘ Pistachio trees
V: Vetch B: Barley M: Vetch+Barley C: Control

and 23 greater for subsoil for alley cropped treatments compared to the control. The differences in the SMDs among the treatments may be due to soil textural changes from sandy clay loam to clay loam, where clay content is approximately 5% lower in block 4 at the top of the slope probably due to erosion (Table IV). The effect of these differences in SMD on the yield of pistachios is the main concern. Similar to those reported by Arif and Malik (2009), the rainwater use efficiency was nearly maximum because all

of the rain water was stored in the soil as indicated by the SMD.

Kallsen (2003) investigated water consumption of pistachios. Since this crop is drought resistant and water logging and dampness depress their yield, he concluded limited water application to reducing irrigation water use and achieve a good quality for the nut fruits. Poor nut splitting is due to either excessive or inadequate irrigation inputs. A SMD may not necessarily reduce yield if the SMD occurs before and in the early stages of shell hardening.

Table I: Mean for long-term precipitation and precipitation and ET measured for experimental year

Months		November 2008	December 2008	January 2009	February 2009	March 2009	April 2009	Total
Precipitation (mm)	Measured in exp. year	37.9	36.4	29.0	81.3	47.3	25.7	257.6
	Long–term mean	57.3	59.9	51.6	74.7	49.3	29.6	322.4
ET (mm)	Measured in exp. year	0	0	0	0	0	104.3	104.3

Table II: Statistical analysis of soil water content (SWC) measured for treatments in 0-10 cm soil depths

Date	SMC %			
	Vetch	Barley	Vetch+Barley	Control
06.12.2008	16,0[a]	15,1[a]	15,3[a]	15,4[a]
20.12.2008	16,5[a]	14,4[a]	15,8[a]	16,8[a]
11.01.2009	16,1[a]	14,4[a]	16,1[a]	16,3[a]
08.03.2009	23,7[a]	19,4[a]	22,8[a]	20,5[a]
22.03.2009	19,1[a]	17,3[a]	18,2[a]	19,3[a]
03.04.2009	17,6[a]	16,7[a]	17,0[a]	19,0[a]
12.04.2009	19,7[a]	18,7[a]	19,8[a]	21,4[a]
19.04.2009	18,3[a]	19,0[a]	18,6[a]	22,1[a]
28.04.2009	12,9[a]	13,4[a]	13,3[a]	18,4[b**]
07.05.2009	11,5[a]	11,3[a]	11,9[a]	17,3[b**]

**: Significant at P < 0.01 level

Our results showed that the forage crops compete with pistachios for water in the 0-10 cm soil depth. The effective rooting depth of the pistachios is deeper than 20 cm and this suggest that the water in first 10 cm of the soil is benefited by forages, otherwise this water would be lost by evaporation. Moreover, growers in the Gaziantep region irrigate the pistachios and after irrigation water stored in the 0-10 cm upper part of the soil may be lost by evaporation rapidly. Therefore, it is wise to suggest growers grow forages as alley crops. In the following year of this project, we monitor soil moisture change from May to harvest of pistachios.

In contrast to no runoff occurred at the alley cropped plots, some surface runoff occurred at control plots, especially at highly sloping localities. This is important to protect the topsoil against erosion and/or increase its thickness for a sustainable agricultural production.

CONCLUSION

In southeastern Turkey, growers avoid alley crapping due to the common belief that allayed crops deplete soil water, leading to decrease in pistachios' yield. This study proved that some alley crops can be grown safely in pistachio growing areas of the studied region since growing alley crops resulted in no significant differences in water stored in the soil profiles, until April 19, which is the satisfactory time for the growth of the frorage crops Barley consumed less water than sole vetch and a mixture of vetch and barley. Therefore, we concluded that barley or composed of Vetch and Barley should be preferred over vetch.

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Table III: Statistical analysis of soil water content (SWC) measured for treatments in 10-20 cm soil depths

Date	SMC %			
	Vetch	Barley	Vetch+Barley	Control
06.12.2008	15,2[a]	12,6[a]	13,7[a]	14,3[a]
20.12.2008	17,2[a]	14,9[a]	15,5[a]	17,0[a]
11.01.2009	17,7[a]	16,0[a]	17,7[a]	18,3[a]
08.03.2009	24,8[a]	23,0[a]	24,0[a]	25,6[a]
22.03.2009	19,7[a]	17,3[a]	19,3[a]	20,5[a]
03.04.2009	18,8[a]	17,3[a]	19,0[a]	21,1[a]
12.04.2009	20,1[a]	19,4[a]	20,6[a]	21,9[a]
19.04.2009	18,9[a]	18,2[a]	19,2[a]	21,6[a]
28.04.2009	15,3[a,b]	14,1[a]	14,6[a]	19,4[b]
07.05.2009	13,7[a]	12,0[a]	13,1[a]	18,1[b]

Table IV: Some selected properties of experimental soils

Block	Plot	Particle size (%)			Bulk density (g/cm³)
		Sand	Silt	Clay	
I	1	46.7	26.1	27.2	1.46
	2	46.6	27.1	26.3	1.46
	3	47.0	28.4	24.6	1.46
	4	46.3	29.7	24.0	1.48
	5	47.0	27.7	25.3	1.44
II	6	42.7	29.8	27.4	1.48
	7	45.3	30.2	24.5	1.50
	8	42.4	32.5	25.1	1.55
	9	42.0	30.1	27.9	1.51
III	10	43.2	29.1	27.7	1.41
	11	47.6	29.2	23.3	1.45
	12	44.2	30.1	25.7	1.46
	13	52.7	28.0	19.3	1.39
IV	14	48.5	30.1	21.3	1.46
	15	49.4	30.0	20.6	1.47
	16	48.6	30.2	21.2	1.31

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