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Effects of grass cover and tillage on temperature of soil in sloping vineyard**

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A b s t r a c t. The effect of two management practices: grass cover (G) and traditional tillage (T) on the annual temperature variations of silt-loamy soil in inter-rows of sloping vineyard (Piedmont, Italy) was studied. Soil temperatures at depths of 6 cm and 11 cm and air temperature were recorded hourly during a whole year. In most of autumn and winter months the average daily soil temperatures were higher under G than T. The differences between minimum and maximum daily temperatures were pronounced the most strongly during the February - March period and in August. The mean standard deviations of monthly soil temperature at both depths were lower in G than in T in most months, mainly due to the damping effect of grass cover. In both treatments the deviations decreased with depth. Higher values of skewness and kurtosis of temperature in February and March under G than T indicate asymmetry and narrowness of daily temperature distribution in the former.

K e y w o r d s: soil temperature, sloping vineyard, tillage, grass cover

INTRODUCTION

Soil temperature is one of the most important environmental regulators of numerous physical and chemical processes in soil, plant roots and tops growth and nutrient availability (Abu-Hamdeh, 2000; Abu-Hamdeh and Reeder R.C., 2000). Heat flow and associated soil temperature are strongly periodic because of variations in daily and seasonal solar radiation (Alvenas, 1999; Buchan, 1982; Mihalakkou, 2002). These are greatly modified by grass cover or plant-residue and soil management practices. Grass cover and plant residue affect soil temperature mostly by altering the reflection coefficient, thereby changing the net radiation at the soil surface. They are considered in the literature as lowering soil temperature when compared to nonmulched soils (Griffith *et al*., 1973). In the study of Alvenas (1999), straw mulch caused a reduction of surface soil temperature by up to 8.5°C. The effect of the surface residues on root zone temperature is considered to be more important than any soil property in the tilled layer (Gupta *et al*., 1984).

Soil tillage practices may influence soil temperatures by changes in: aggregation, compaction and associated porosity and water content affecting soil thermal properties, such as thermal conductivity and heat capacity, or surface roughness influencing the reflection of solar energy (Abu-Hamdeh and Reeder, 2000; Skagg and Smith , 1968). In the study by Voorhees (1976), surface (at 5 cm depth) soil temperature in the compacted wheel track of a tilled clay loam soil was 3°C lower than in non-tracked soil. This decrease in temperature can be attributed to the effect of increased volumetric water content on heat capacity (linear relation), and to the higher thermal conductivity due to closer contact of soil particles in compacted soil (Usowicz *et al*., 1996). It was shown that sensitivity of thermal properties to soil compaction is greater in the low than in the high compactness range (Abu-Hamdeh and Reeder, 2000). It was shown that the relative effect of soil moisture compared to soil density on thermal properties is greater (Usowicz *et al*., 1995).

In many areas of the United States plant residues left on the soil surface reduced soil temperature under different tillage systems (Griffith *et al*., 1973). In the mild climate conditions in UK, plant residues on untilled soil insulated the soil from temperature fluctuations and resulted in less winter freezing than in ploughed soil (Hay *et al*., 1978).

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The effects of soil tillage and plant cover on soil temperature can be stronger on sloping ground of the Mediterranean region with irregular rainfalls. Traditional hillside viticulture uses deep and surface tillage that can lead to deterioration of soil physical properties and to soil water erosion. The controlled grass cover and reduced tillage technique were proposed to prevent soil structural degradation. On various hilly lands, in central Italy, the grass cover management of orchards has proved, by reducing runoff, to mitigate soil erosion (Bazzoffi and Chisci, 1999). To ascertain the efficiency of this practice to improve the physical properties of the soil and to increase the hydrological protection of hill-slope vineyards, a farm scale experiment was established in 1991.

The aim of this study was to determine the effects of controlled grass cover and traditional tillage managements in the inter-rows on annual course of soil temperature in a sloping vineyard.

MATERIAL AND METHODS

The experiment was conducted over the period of February 1999 – April 2000, in a vineyard at a site with 450 m elevation, representative of the Piedmontese hillside viticulture (NW Italy). The vineyard, with slopes from 15% to 32% (facing SW), grows on silt-loam soil resting on marls (middle Miocene): on average the soil consists of: 33% sand, 58% loam, 9% clay in the plough layer. Some characteristics of the soil are reported in Table 1. The climate of the area has cold winter with snow and dry summers with rainstorms; annual rainfall averages 836 mm and temperature 11°C.

The traditional tillage (T) included autumn ploughing to a depth of 18 cm (late October), rotary hoeing on 29 March, beginning of June and in August to control and incorporate the herbs with the soil to a depth of 10 cm. Following about 10 days after each pass of rotary hoe, the soil surface was free of plant cover through about 10 days and then it was increasingly covered by developing plants. During the winter approximately 80% of the soil surface was bare. The controlled grass cover (G) consisted of mowing and chopping of the plant cover, performed in April, beginning of June and late August, leaving plant residues on the soil surface. During winter and spring, the soil was under plant cover. Plot size in each treatment was 2.75 m wide (distance between two successive rows of vine trees) along the slope and 40 m long, divided into three subplots.

Interrows of the G treatment were sown in 1989 with a mixture of *Lolium italicum* and *Trifolium repens*. With time, the herbs sown were replaced by the local flora, mainly broad-leaved plants; up to 57 species were detected (Ferrero *et al*., 2001; Ferrero and Nigrelli, 1998). The mean height of the mown herbs varied from 50-56 cm in May to 19-26 cm in July. In the T plot, the prevailing species were tall plants, i.e., *Amaranthus retroflexus, Chenopodium album*. After 5-year survey, the mean ground covering of herbs was found to be for the G plot: 86 in April, 78 in July, 71% in October while for the T inter-row: 18, 25, and 15%, respectively (Usowicz *et a*l., 1996). The ground cover of standing plants and herbage debris varied along the plots. In April 2000, for instance, on the upper inter-rows, some 70% of the ground was covered, in the middle area – 96%, in the lower part – 76%. On the middle surface of the inter-row the debris of chopped herbs has formed a 1.5-2 cm thick layer, almost continuous. In the T plot the herb cover was mainly located on the central area of the inter-row.

Temperature data were collected at 6 and 11 cm depth in three subplots of each treatment. Air temperature was recorded in a meteorological station that was situated within the vineyard area. Temperature readings were taken hourly (one reading was an average of 6 measurements taken every 10 min) by means of T-type thermocouples and a computer datalogger. The sensors were located in plots transverse to the inter-rows in the upper tractor rut, inter-rut and lower rut areas.

Both direct and indirect radiation measurements were performed using a cosine corrected quantum-photo-radiometer indicator – Delta OHM, and a photosensitive probe - LP9021. The photosensitive probe was placed on a stand, 20 cm above the ground, facing vertically up or down depending on the radiation measured - reflected or direct. Measurements were made twice a day, at 12 and 16 h, and averaged monthly.

Statistical analyses for significance of differences in the minimum and maximum daily soil temperatures between

T a b l e 1. Selected soil characteristics, at two depths (0-9 and 10-19 cm), in sloping vineyard after 10 years of traditional tillage or grass cover management

Parameters measured	Tilled soil (T)		Grass cover (G)	
Depth (cm)	0-9	10-19	0-9	10-19
Organic matter (g kg^{-1})	29**	26*	55**	38*
Bulk density (Mg m^{-3})	1.19*	1.23*	1.22*	1.27*
Saturation capacity (%, v/v)	54.2	48.5*	53.8	51.0*
Field capacity (%, v/v)	35.0*	33.3*	38.4*	37.0**
Saturated conductivity, °Kfs (m d^{-1})	1.51*		0.67*	

°Kfs measurement depth: 10-20 cm. Means with * and ** at the same depth are significantly different at the 0.05 level and at 0.01 by the LSD test.

the tilled (T) and grass covered (G) treatments were made using Test T.

RESULTS AND DISCUSSION

Figure 1 shows the trend of month-to-month variations of both mean air and soil temperature under T treatment in response to the time-course during the year. The differences between mean monthly T and G temperatures (Fig. 2) indicate that in most months the mean temperature was higher in G. They were pronounced mostly in the January-March period, November and December, when temperatures were higher in the G field, by up to 1.3 and 1.6°C at 6 and 11cm, respectively. However, during the hottest month (August), mean soil temperatures were higher in T than G by up to 1.5 and 2.0°C at 6 and 11cm depth, respectively. The effect of the treatment on the differences in mean and extreme temperatures between T and G temperatures was largely dependent on time during the year. Figure 2 indicates that minimum and maximum daily temperatures were lower in the T than the G treatment in: January, October, November and December at the two depths, and in September at the 6cm depth, whereas in the February – March period the average maximum temperature was higher and the minimum - lower in T.

The differences in average daily soil temperatures between the treatments can be partly explained by the lack of insulating layer of vegetation, under T, and exposure to the direct solar radiation. This can be supported by the occurrence of a similar increase of average air and soil temperature under T in August as compared to July (Fig. 1); a much smaller increase of soil temperature was recorded in G plots (Fig. 2). It is important to note that the higher average August temperature in T than in G occurred despite the higher reflected radiation in the former (Fig. 3). Plant cover or mulch may impede ventilation in a similar way as plastic mulch (Ghuman and Lal, 1982), and result in a higher average soil temperature under the cover.

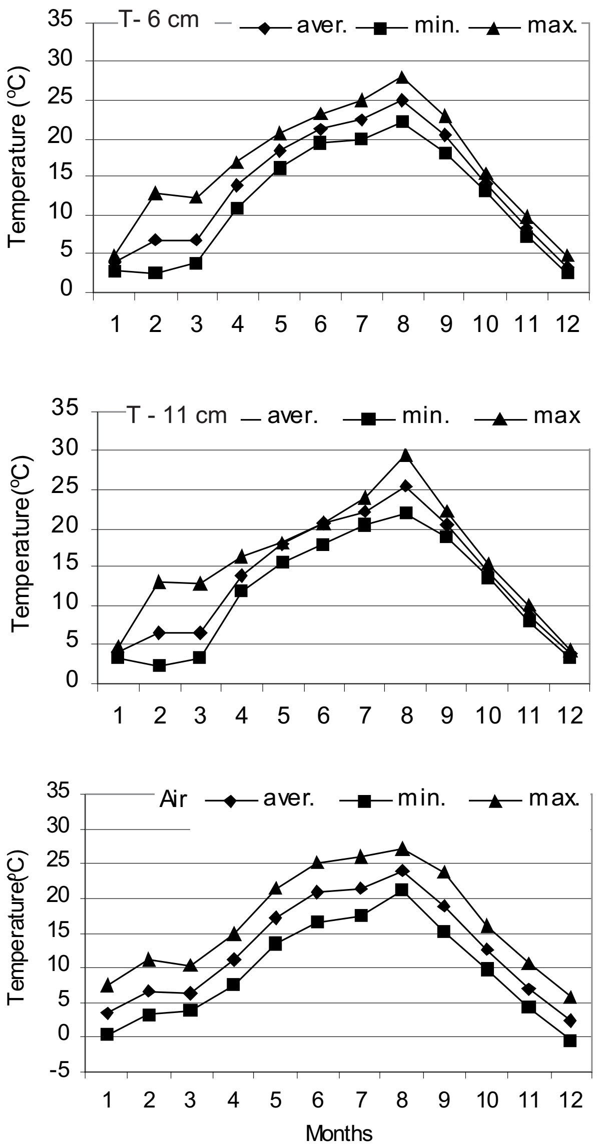

Fig. 1. The average and the maximum and minimum daily soil temperatures in the tilled soil (T) at 6 and 11 cm depths, and air temperature for each month.

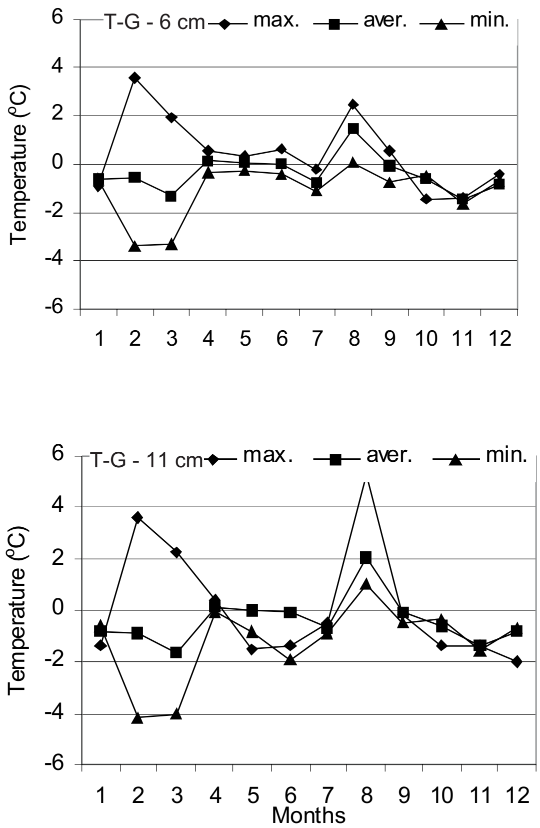

Fig. 2. Differences in the average and the maximum and minimum daily soil temperatures for each month between the tilled (T) and the grass covered (G) soil at 6cm and 11 cm depths.

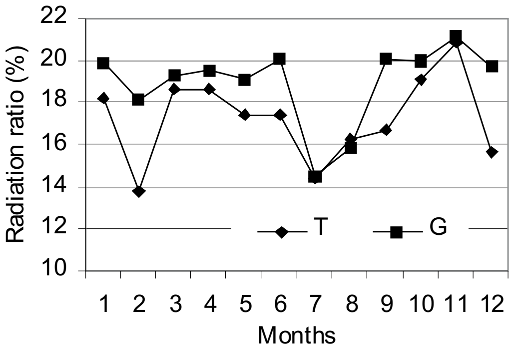

Fig. 3. The ratio of direct (D_r) and reflected (R_r) radiation in the tilled (T) and the grass covered (G) soil (R_r D_r^{-1} 100%).

The differences in maximum and minimum daily temperatures between T and G (Fig. 2) observed during the February-March period can be due to the dumping effect of the surface residues in G, reflecting high daily solar radiation and reducing soil cooling during low night temperatures (Ghuman and Lal, 1982). Residues reflect a portion of the solar energy that would otherwise reach the soil surface. In addition, residues delay soil drying. High soil moisture results in cooler spring soil temperatures because wetter soils require more energy to warm up than drier soils do (Herrero *et al*., 2001). The effect of the management practices on the minimum and maximum temperatures is related to the period during the year, due to the different effects of crop canopy, standing and chopped herbs ground-covering in G plots, and surface roughness and porosity in T plots. The effect of crop canopy cover and plant residues on reducing soil cooling during the period with low night temperatures (October -January) could be responsible for higher soil temperatures under the G than the T treatment. In most cases the differences in extreme daily soil temperatures between G and T were significant at the level of 0.05 (Table 2).

T a b l e 2. Results of test t for significance (level 0.05) of differences in the minimum and maximum daily soil temperatures (6 and 11cm depths) for each month between the tilled (T) and the grass covered (G) treatments. S – significant, NS – not significant

Month	Min	Max	Min	Max
	6 cm		11 cm	
1	S	S	S	S
2	S	S	S	S
3	S	NS	NS	NS
4	S	S	NS	S
5	S	NS	S	S
6	S	S	S	NS
7	S	S	S	S
8	S	S	S	NS
9	S	S	NS	S
10	S	S	S	S
11	S	S	S	S
12	S	S	S	S

Figure 4 presents the impact of management practices on month-to-month mean temperature variations as characterised by standard temperature deviations. During most months of the year, standard deviations of soil temperature were lower in the G than the T treatment, or similar (in January, May, June and October) at both depths. The highest standard deviation of daily temperature occurred in the T plots at 6cm depth in March. Lower temporal variation under grass cover compared to tilled soil can be primarily associated with the damping effect of grass cover on soil temperature through the year. This is supported

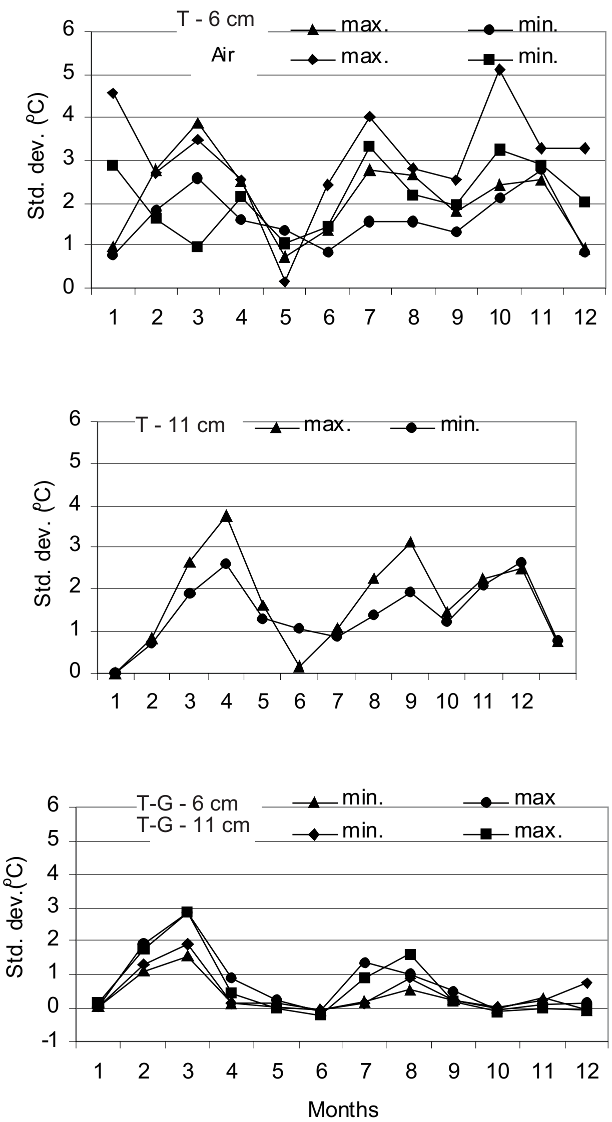

Fig. 4. Standard deviation for air and soil temperatures at two depths, 6 and 11 cm, under traditional tillage and for the differences between T and G.

by the results of Alvenas (1999) indicating that only a very small portion of the net radiation above the grass reached the soil surface, which leads to reduced temperature fluctuations. The lowest differences between the treatments, occurring in the September – November period, can be an effect of reduced soil bulk density in the T plot, influencing soil moisture and other physical characteristics that affect soil thermal properties (Abu-Hamdeh and Reeder, 2000; Voorhees, 1976). Relatively low standard deviations of average daily temperature in the G and T plots in January and December despite high variations in air temperature are probably the result of the dumping effect of snow cover. This contrasts with other months, when differences in standard deviations of daily temperature between cultivated vineyard and air were not so high. As expected, in general, standard deviation of temperature decreases with depth in both treatments.

Distribution of the temperature data is characterised by skewness, being a measure of asymmetry, and kurtosis revealing how flat or steep the distribution is. The differences in skewness between the treatments occurred mostly in February and March with higher skewness under G than T (Fig. 5), indicating the occurrence of longer tail distribution of higher temperatures in the former. The course of changes of skewness through the year was similar at both depths. Skewness of air temperature distribution was lower than soil temperature under both treatments during most of the months, except February, when the reverse occurred in the plot T.

The values of kurtosis ranged from –2 to +2 in the course of the year, except for January and December in both treatments, and February and March in G, when the values of kurtosis reached higher values, indicating wider distribution during those months (Fig. 6). The differences in kurtosis between the G and T treatments appeared at both the depths in February and March, when kurtosis were higher in G, while in July and August it was higher in the T treatment.

The values of the skewness and kurtosis of air temperature distribution were closer to the respective values calculated for temperatures of the T rather than the G plots. This implies that soil temperatures were less sensitive to soil roughness due to tillage than to mulches. Similar observations were reported from fields with higher variety of soil residues and roughness (Griffith *et al*., 1973).

Higher values of skewness and kurtosis of soil temperature in January and December in T, and in the January – March and December in G, indicate a higher asymmetry and narrowness of the soil temperature distribution compared to other months.

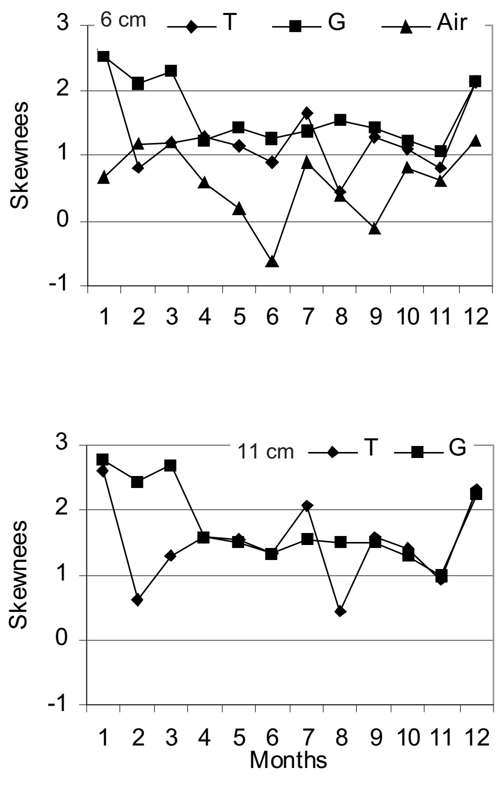

Fig. 5. Skewness of monthly soil temperatures at two depths, 6 and 11cm, under controlled grass cover (G) and traditional tillage (T) managements, and of air temperature.

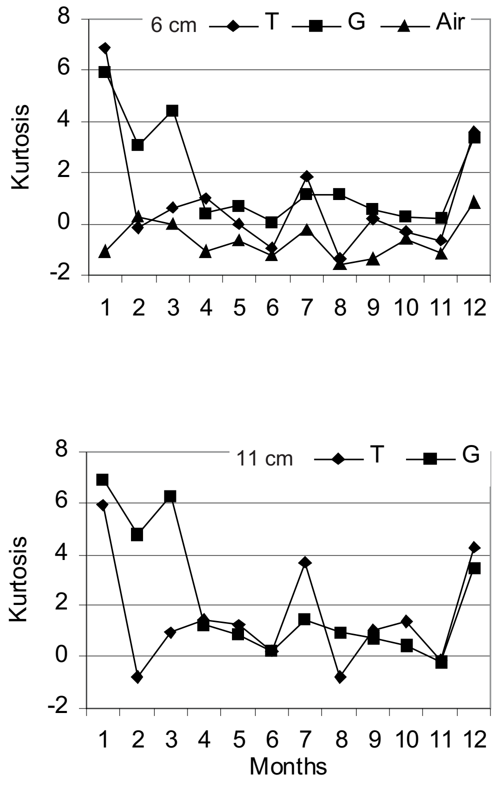

Fig. 6. Kurtosis of average daily soil temperatures for each month at two depths, 6 and 11cm, under controlled grass cover (G) and traditional tillage (T) managements, and of air temperature.

CONCLUSIONS

1. The effect of the soil management practices on soil temperature in vineyards is related to the period during the year. The differences were pronounced mostly in February and March, when mean temperatures under the grass cover compared to the traditional tillage treatment were higher by up to 1.3 and 1.6°C, at 6 and 11 cm, respectively. In August, however, the soil temperature was higher under traditional tillage than grass cover. The differences in the maximum compared to the mean temperatures during these months were more pronounced and consistent.

2. In most of the months soil temperature deviations were lower in grass cover than in traditional tillage, which can be associated with the damping effect of grass cover on soil temperature. Irrespective of the treatment, average temperature deviation decreased with depth.

3. The differences in skewness between the treatments occurred mostly in February, March and August, and those in kurtosis - mostly in the February-March period, with higher values of both characteristics under grass cover than under traditional tillage.

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