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Study of planting densities effects on olive tree by using sap flow method

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Abstract. In the semi-arid and arid Tunisian climate where the olive tree is the dominant cropping specie the cultural practices adopted aimed primarily optimisation of the rainwater use. As part of the restructuring of the traditional olive tree grove, the revision of planting densities is envisaged. Thus, we conduct in 1988 an experimentation to test the revision of traditional planting densities by increasing the number of tree by ha according to the traditional density used. The densities tested vary from 51 to 156 trees by ha. From the 17th year of planting, despite the level of yields by hectare as elevated as the planting density is high, we have noticed a trend towards decline in the yield per tree for the denser parcel. Thus, we tried to analyze the functioning of the global tree water in connection with the planting density using state thermoelectric measuring of sap flow in order to quantify the water consumption and to clarify the influence of planting density on the water state of the tree. In addition, we have tried to identify the relationship between the seasonal dynamics the sap flow and its major determinants as the plant water conditions and the environment.

These studies show the great capacities of the Chemlali olive-tree to be adapted to the hydrous conditions available. Indeed, we did not distinguish in a clear way of negative effects due to the highest densities, on the contrary for certain critical periods of the biological cycle of the tree these densities are distinguished by their best behavior, for example the spacing 10mx10m presents the highest values of clear photosynthesis by an average value of 17.46µmol.Co2.m-2.s-1 compared with 16.32µmol.CO2.m-2.s-1 for the spacing 14mx14m. This shows that this farming system exploited since 20 years can still be profitable. Other studies are necessary to better distinguish between the effect of the spacing and this while utilizing other biological and agronomic parameters.

Keywords: *Sap flow , f0 , fm, fv/fm, olive tree*

1. Introduction

In Tunisia, in particular in the Sahel region, one of the oldest and most important olive-growing areas, the olive is the kind of choices that enhanced environmental conditions ranked among the semi-arid and arid with a low water potential. Maintaining good water status and a low transpiration can be indicators of a good adaptation of plants to drought (Henchi et al. 1986). A number of characteristics are used to describe the water status of plants. Among its parameters we can rely on the flow of sap as a high positive correlation between transpiration and water status of the plant was reported by several authors (Shiya, 1991; Behboudian and Lawes (1995). Measuring the sap low provides an estimate of tree transpiration. It is an essential component of the hydrologic cycle. The daily and seasonal changing of transpiration gives an indication of water stress experienced by the tree.

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The thermal measurement of sap flow in trunks of trees is a fairly direct method of monitoring and estimating transpiration. The estimation of transpiration by the sap flow technique is a simple method of providing continuous measurements of plant water use. Soegaard and Boegh (1995). Using this approach dates to twenty years. It has been validated for measuring transpiration of trees in different agro-ecosystems (savanna, forest stands, tree orchards, etc...). The advantage of this approach is that it integrates the heterogeneity of the root system and canopy around the pseudostem or stem, single track for the water crossing (sap) between these two compartments of the tree. Ben Aïssa et al. (2009). The technique of Granier (1985, 1987) based on the sensor dissipation of heat that has been used; it proves to be the simplest and most appropriate for such an objective given the simplicity and convenience of the sensor for continuous measurements on long term.

Measurement of sap flow carried out directly on the plant can bean adequate method to estimate the amount of water transpired and there by deducing the water need of plants inside the oasis. Sellami and *al*. (2003).

2. Methodology

The work is performed in a plantation of pluvial driven olive. Different planting densities greater than those used in traditional plantations are tested on agricultural and biological plants and this has been the since set up of the parcel. These surveys showed a decline in production and vigor per tree with increasing planting density and this despite a production per hectare that increases with planting density (Boujnah et al. 2006). The objective of this work is to perceive the hydro physiological behavior in the tree for the different planting densities with a view to understand the behavior of the tree vis-à-vis the available water (through the different seasons and according to spacing) and to diagnose a possible effect of competition.

2.1. Experimental conditions

The experimental plot is located in Jemmel, eastern centre of Tunisia. It belongs to the field of the Vocational and agricultural Training Centre of Jemmel (CFPA of Jemmel). The area is part of the semi arid upper floor Mediterranean climate. The average annual rainfall is 350 mm. The dry season lasts eight months and the temperature variation is small. The soil is deep (50 to 60 cm), silty clay-limestone storage, the texture is medium, the rate of organic matter is low and the pH is around 8 (alkaline).

The experimental plot extends over 3.5 hectares. It is divided into four lots. Each lot is characterized by a different planting density. The tested densities were all less than that used in the surrounding which is 40 trees per ha (planted following the square spacing 16x16). These densities are as follows: 51, 70, 100 and 156 trees / ha which corresponds to the spacing 14x14 m, 12x12 m, 10x10m and 10x10m respectively .

The variety grown is the Chemlali. The trees are of 20 years old. This variety is vigorous, productive and resistant to drought.

2.2. Measurements made

2.2.1.Sapflow

The extent of xylem sap flow is measured by the thermal method of Granier (1985) with alternative heating (Do and Rauchteau, 2002). The flowmeter consists of two identical cylindrical probes of 20mm length and 1.8 mm diameter. One is heated in a discontinuous manner (20 minutes without heating and 10 minutes with heating). Each probe contains a copper-constantan thermocouple to measure the temperature difference between the two thermocouples. The electric heating voltage is provided by a 12V battery. The automatic data capture is programmed according to a periodic pace of 60s with an average saved in memory every 5mn at the rate of a heating / non-heating cycle of 10mn/20mn. The recorded data are collected every 15 days using a central data acquisition (Data Stay). Only the second heating phase value is considered for the quantification of sap flow, according to the following formula:

$$U = J.S$$

- J (m^3.s 1) is the flux density estimated by the amount of a coefficient K which depends on temperature differences between the two probes of the sensor, with K = [T (0) - T (u)] / T (u) where T (0) is the temperature difference at zero sap flow, T (u): the temperature difference of sap flow density u;
- S (cm^2) is the conductive surface of the wood, it is determined by staining sections of the generator after the experiment, it is estimated at 70% of the section of wood.

The identified samples were spread over the entire experimental period.

3. Results and discussion:

The curves in Figure 1(a, b, c, d) illustrate the changes during two consecutive days of sap flow as a function of planting density for the four seasons. This parameter quantifies the use of water by the plant. We note differences in water consumption depending on the seasons for the different planting densities. For the fall season the differences between the different densities are not cons significant. Instead a clear difference is observed during the summer season when water conditions are most severe.

The analysis of the chart (a, b, c and d) shows that the highest values are recorded by the spacing 8mx8m during the summer and winter by the respective values of 3689 and 1927 g / h compared with 2747 and 1381 g / h for the spacing 14mx14m. Instead, the highest values during the seasons of spring and autumn are recorded by the spacing 14mx14m by the respective values of 2039 and 1581 g / h. Compared to 2607 and 2281 g / h for 8mx8m spacing.

For a series of two days of continuous measurement during the summer season (from 20 to 21/08/2008), during this period the ambient temperature ranged from 12 to 18.8 ° C, which shows very clearly the conditions of highly evaporative demand. From the study of the changes in sap flow over time, we can see that the flow of sap during the summer season is synchronous during the measurement period. The peak values of sap flow recorded during the day are around 3689 g / h corresponding to the values of 2747 g / h during the winter season.

In summer, the olive tree seems up for the lack of water by increasing transpiration and therefore the extraction of water by roots.

From the general shape of the curves and the hourly scale, we can perceive a strong correlation between the changes in ambient temperature and the sap flow measured during the day.

During the spring the largest season transpiration is recorded for the high planting density, which shows that the winter water reserves are decisive for a proper physiological activity.

3.2. Evolution of sap flow over time:

The analysis of the graph of Figure 2 shows that the evolution of sap flow over time varies depending on temperature. Among the different planting densities, the daily kinetic flow follows the same type of evolutionary pace. Indeed, the values of sap flow are almost constant throughout the measurement period for the14mx14m spacing while for 8mx8m spacing, the highest values were recorded during the period of 07, 08 and 09/09 / 07 which corresponds to the more temperate days of the entire measurement period.

For both spacing, the values of sap flow recorded a remarkable fall in the day of 14/09/2007 which coincides with a remarkable fall in temperature (Figure 3).

Since the days of measurement differ only by the values of the temperature, the obtained results show the importance of light interception in the heterogeneity of transpiration and hydraulic conductance in the soil-xylem-leaf system. Alarcon and *al*. (2003).
Many authors have shown that the implementation of different thermal methods allow to quantify, in the trunks of trees, the overall flow of sap through the plant according to the climatic demand (Cohen et al.1981; Granier, 1985; Valancogne and Nasr, 1989) cited by Cabibel (1991).

The use of the thermal method of Granier and Rocheteau for estimating sap flow in olives has highlighted the importance attached to the light interception and consequently, the way of size and the advocated density planting. Chehab and *al*. (2007).

Cabibel and Do (1991a, b) prove that it is possible by thermal way to quantify the instant balance between the climatic need undergone by the orchard and the local availability of water in the soil root interface

3.3. Daily evolution of sap flow:

The analysis of the graph in Figure 4 that shows the evolution of the daily sap flow varies depending on the density of planting. Among the different planting densities, the hourly kinetics of sap flow follows the same type of evolutionary pace. Indeed, early in the day (07H) the flow of perspiration increases gradually to reach maximum values (10h: 30min) and decreased at the end of the day around the minimum values (18H). The highest values of 10000 and 7449 g / l are recorded at 10H: 30 minutes respectively by the densities 14mx14m and 8mx8m. The flow of sap is circadian in the order of 228 and 69 g / l respectively for the densities 14mx14m and 8mx8m. Renewed elevation of sap flow is initiated at 6 in the morning for the density 8mx8m when it is triggered at 07: 30 min for the density 14mx14m.
This shows that the greater the evaporative demand of the atmosphere is the greater the flow of sap and the more intense the root uptake is intense.

Hence the interest of measuring the flow of sap to understand the mechanisms of water flow through the tree and quantify transpiration.

4. General conclusion:

The use of biological sensors is very important especially in the open field where the control of environmental factors is impossible.

The daily tracking of transpiration losses thanks to the measures of sap flow gives an accurate idea of the water consumption of the tree and allows the timely diagnosis of stress. The measurements of sap flow can be used to prevent a water shortage that could affect the functioning of the tree and provides information on the intensity and the period of susceptibility to stress.

Measuring the flow of sap is very important to understand the mechanisms of water flow through the tree and quantify transpiration. In fact, during periods of intense evaporative demands, the highest transpiration is noticed among the olive trees planted at greater planting densities which may indicate an increased uptake of soil water showing the broad capabilities of olive Chemlali to adapt to available water conditions.

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6. Figures captions:

Figure.1.a. Daily evolution of sap flow during the summer season

Figure1.b. Daily evolution of sap flow during the winter season

Figure1.c.daily evolution of sap flow during the autumn season

Figure.1d. daily evolution of sap flow during the spring season

Figure.2. Evolution of sap flow over time

Figure.4. daily evolution of sap flow

Figure.3. Evolution of temperature over time

Figure.1.a. Daily evolution of sap flow during the summer season

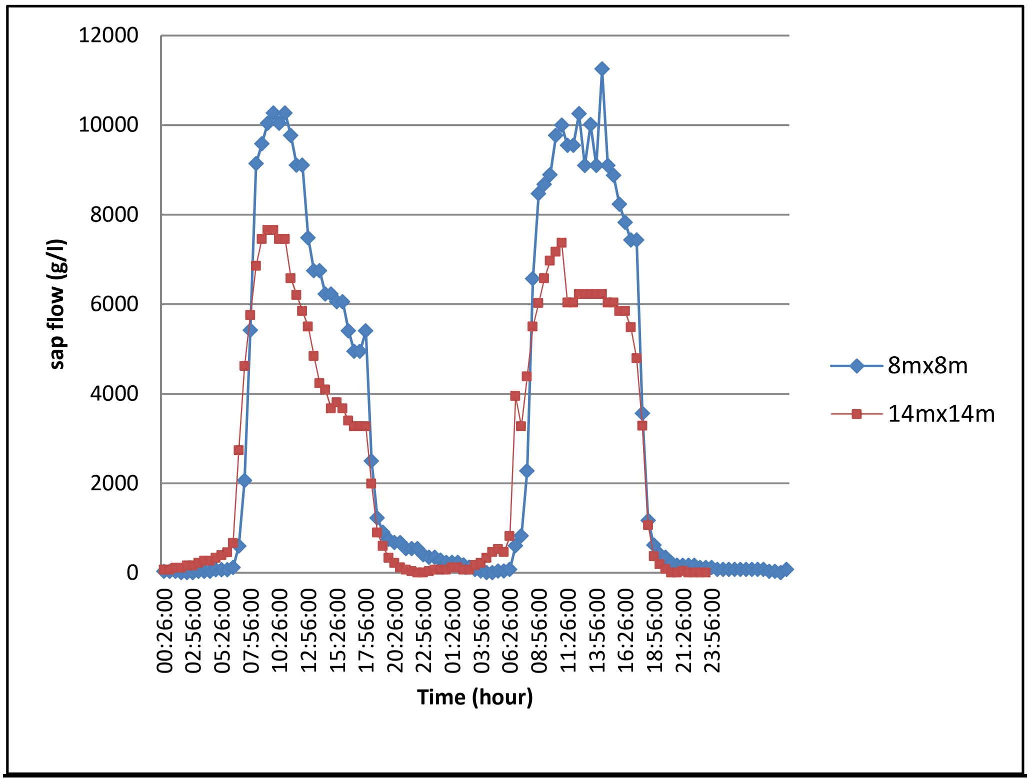


Figure1.b. Daily evolution of sap flow during the winter season

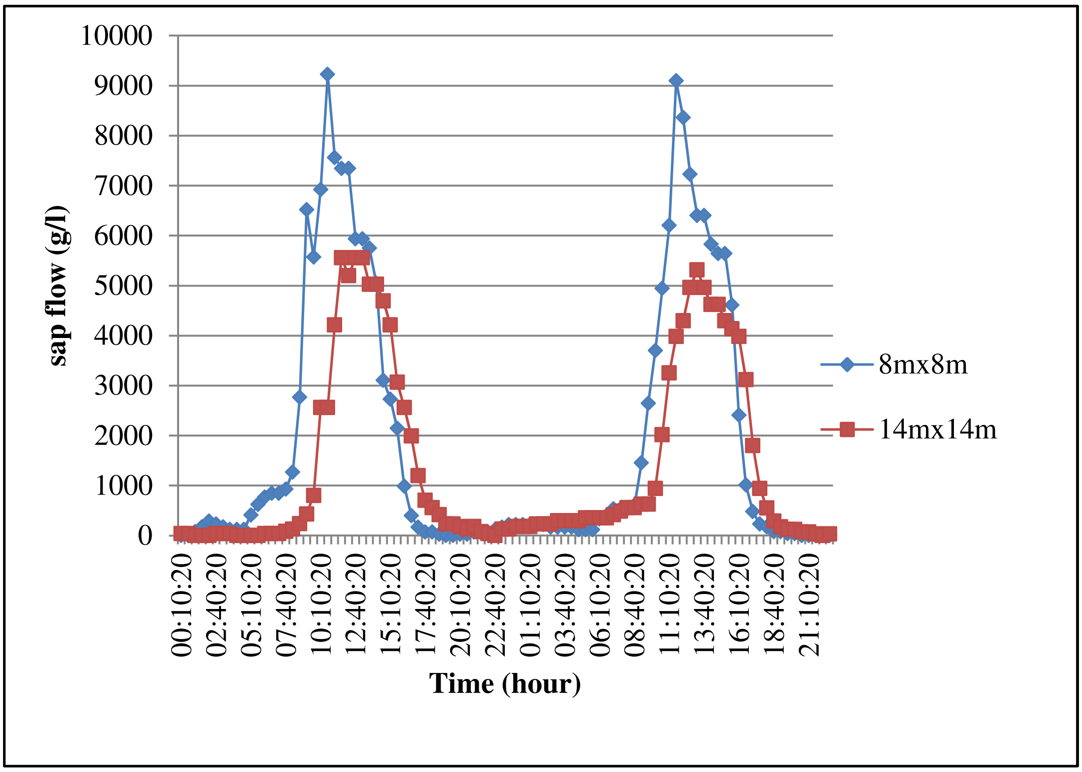


Figure1.c.daily evolution of sap flow during the autumn season

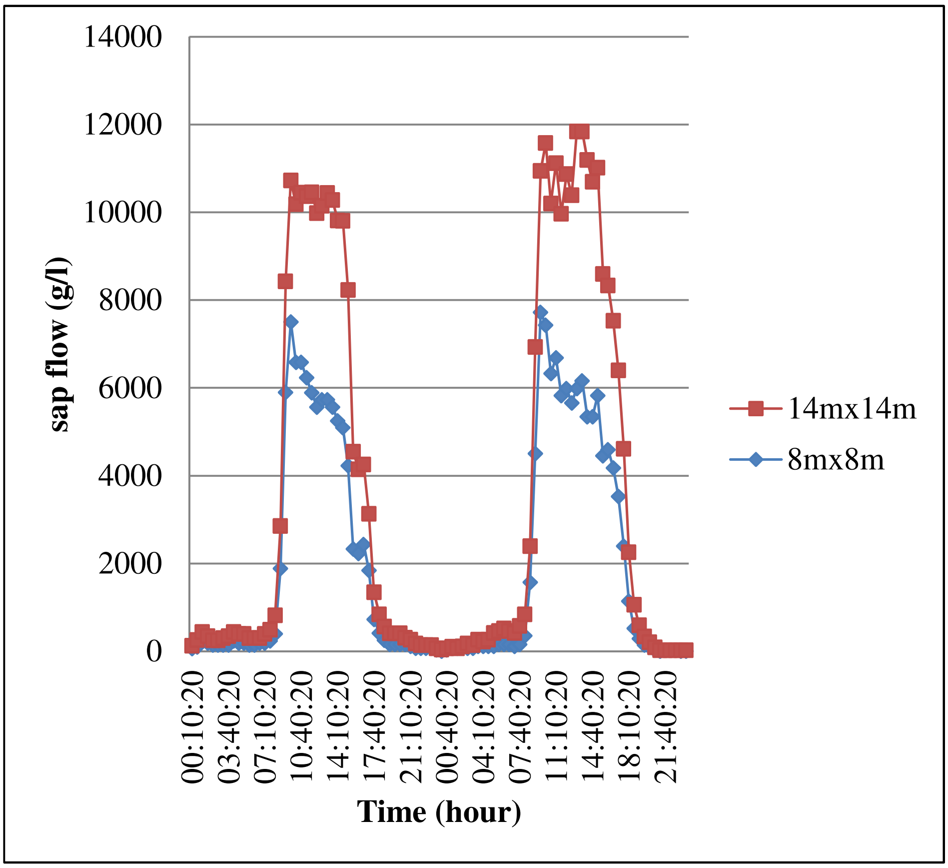


Figure.1d. daily evolution of sap flow during the spring season

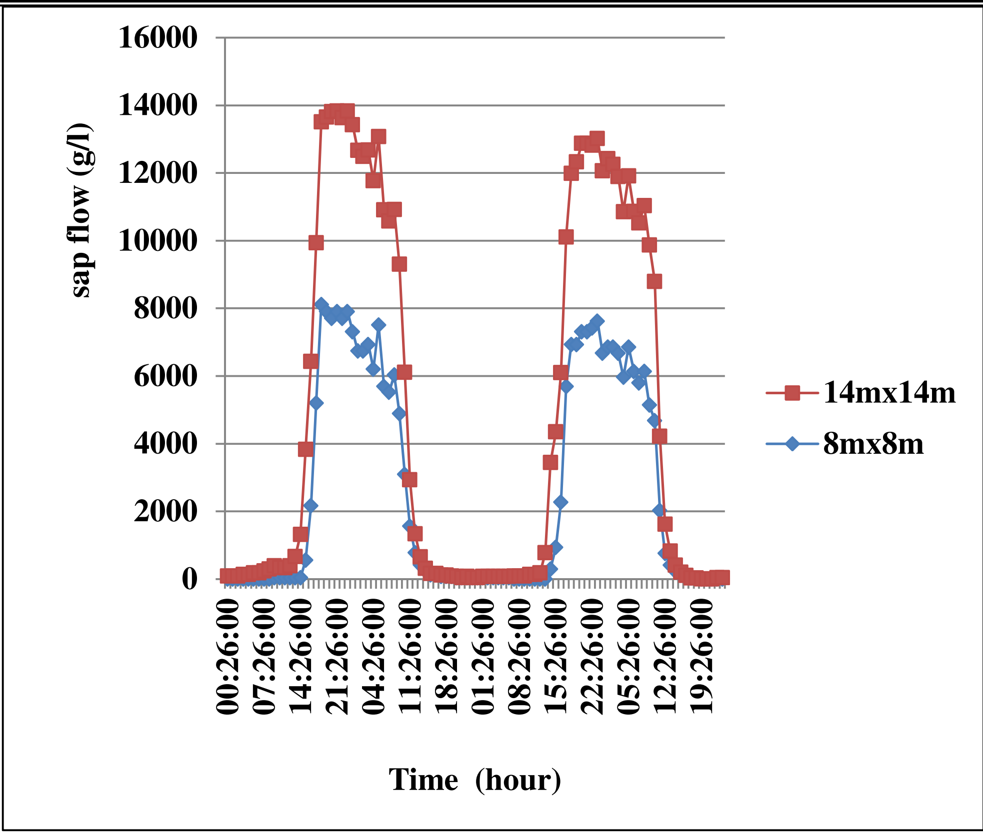


Figure.2. Evolution of sap flow over time

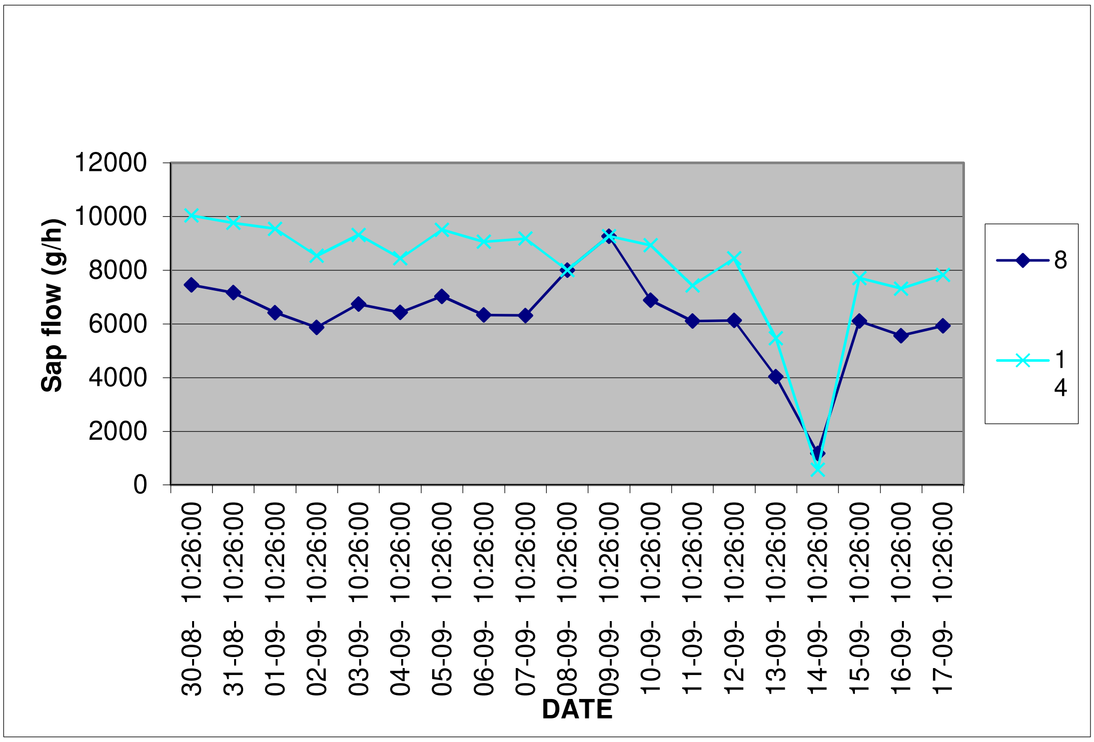


Figure.4. daily evolution of sap flow

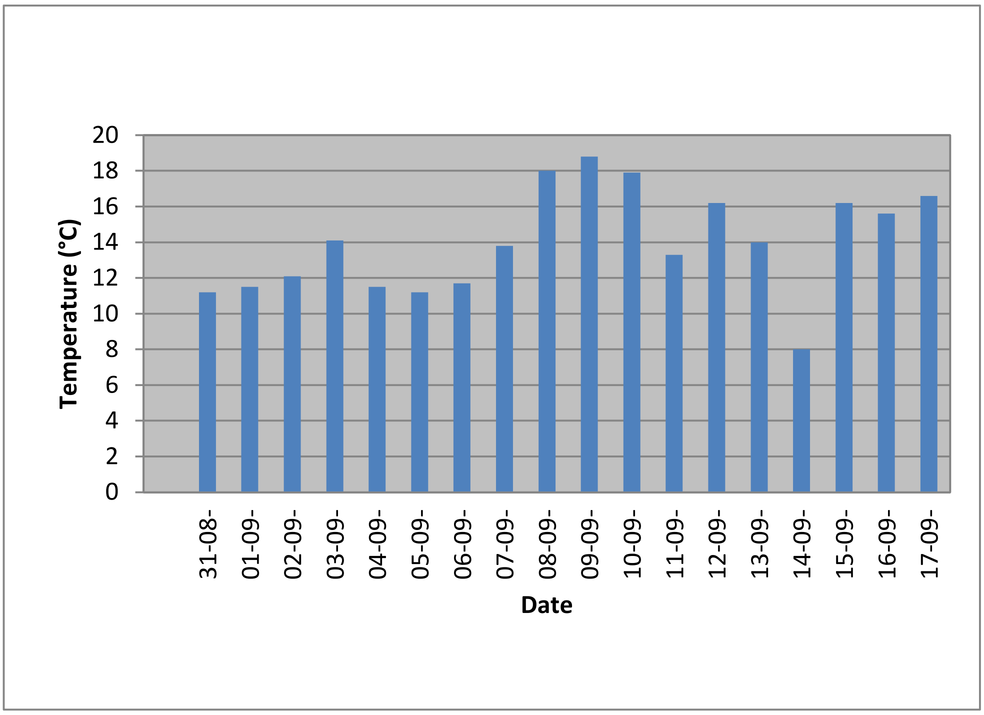
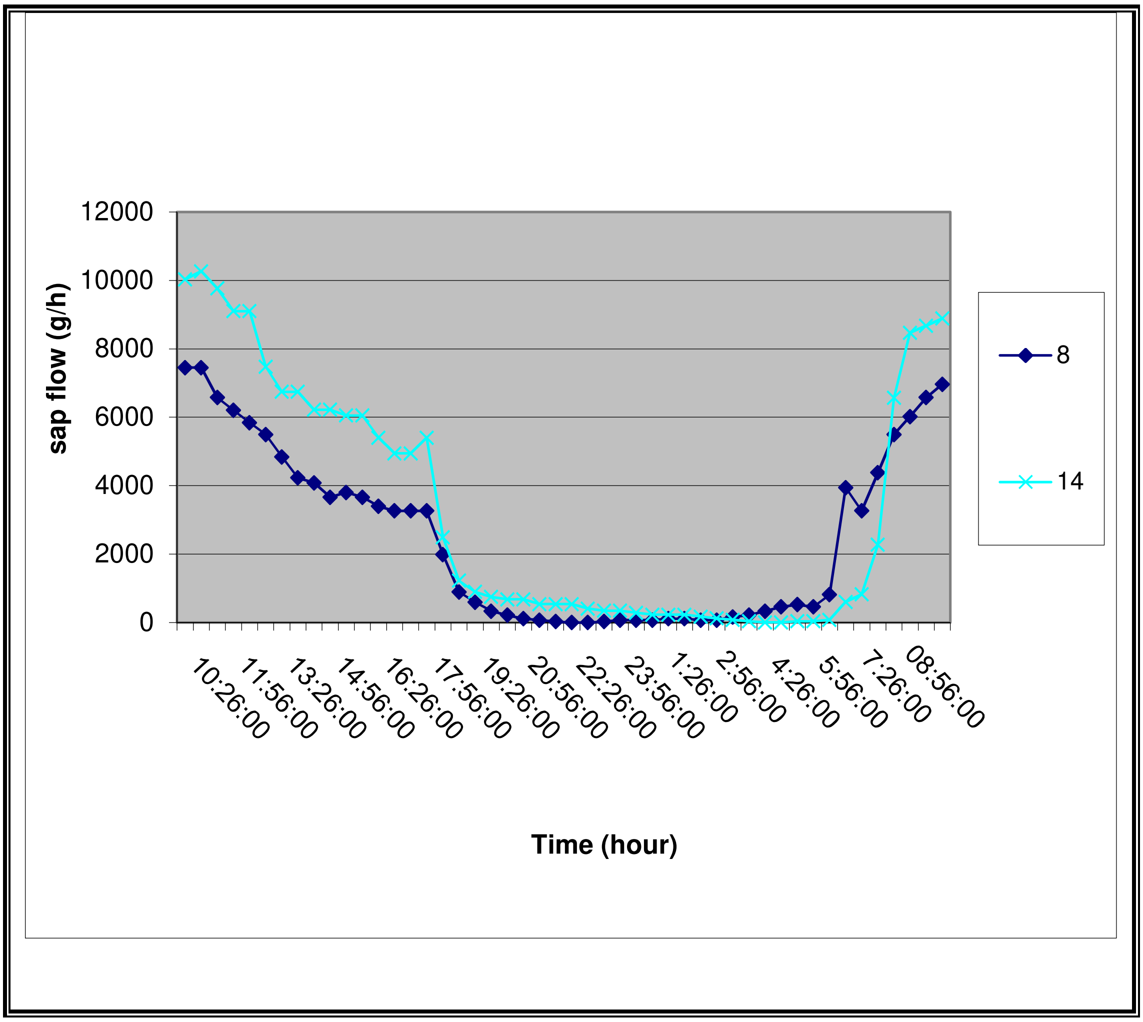


Figure.3. Evolution of temperature over time



12000
10000
8000
6000
4000
2000
0
sap flow (g/h)
10:26:00
11:56:00
13:26:00
14:56:00
16:26:00
17:56:00
19:26:00
20:56:00
22:26:00
23:56:00
1:26:00
2:56:00
4:26:00
5:56:00
7:26:00
08:56:00
Time (hour)
8
14