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Field Measurements of Soil Water Loss Patterns in the Presence of Established Orchard Grass

II. The Water Balance of Root Zone

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ABSTRACT

Soil water depletion rates in the root zone of '*Dactylis glomerata* L' were determined for a growth period of 7 months, from March to September at Montpellier in France.

Soil moisture was measured by using a neutron moisture probe in 20 depths from the soil surface in 10 cm increments. Tensiometric measurements were made in the depths of 90 cm and 120 cm down from soil surface below the root zone.

From 10 cm to 60 cm depth interval the water loss increase while that of the lower depths remain constant. The actual evapotranspiration decrease gradually after a rainfall. The actual evapotranspiration reaches its minimum value of 3 mm a week in September after a long dry period.

INTRODUCTION

The water in the system of Soil–Plant atmosphere is in a continous motion. The knowledge of this movement permits to calculate the water requirements of vegetations.

Most of the water in the root zones is lost to the atmosphere in the form of water vapour. This loss is known as evapotranspiration, which correspond to evaporation of water from the soil and transpiration of the plants.

Many methods are proposed and used to measure the actual evapotranspiration. The water balance method is one of the most commonly used methods. The accuracy of data measurement is the only disadvantage of this method. Its application is facilitated by the use of a neutron moisture probe and tensiometers as have been used by Slatyer, (5); Van Bavel *et al.* (6), Daian *et al.* (2), and Daudet *et al.* (3).

MATERIALS AND METHODS

Field measurements of soil water loss patterns in the presence of established orchard grass (Dactylis glomerata L) were carried out on the experimental station of the ecological research Center of Louis Emberger in Montpellier in France. Hydraulic properties of the soil have been reported in a companion paper by Khalifa (4).

The water balance method consists of measuring the input (W_{in}) and the output (W_{out}) of the soil water. The difference between (W_{in}) and (W_{out}) of water during a certain period of time interval is equal to the change in the amount of water stored in the soil.

$$(W_{in}) - (W_{out}) = \Delta W \quad (1)$$

which can be written in the form of the following equation:

$$[P + I) - [R + d_z + C + (E + T)] = \Delta W \quad (2)$$

Where P, I are the precipitation and the irrigation respectively; R is the run off. It is generally small in the vegetated fields and may be taken as zero; d_z is the drainage of the root zone; C is the amount of water absorbed by the plant and fixed for the biological process of growth. It is very small, therefore it is always negligible; E is the evaporation of water from the soil; T is the transpiration of the plant and $\triangle W$ is the change in soil water content.

The most difficult data to be measured directly is the evapotranspiration (E + T). To be able to compute it from the water balance, accurately, measurements of all the other terms of the equation (2) are needed. According to Fig. 1 the water balance equation is written in the following form.

$$ETR = P + I \pm \Delta W - d_z \quad (3)$$

Where P, I are measured by a rain guage; W is measured by a neutron moisture probe and d_z is determined by the application of Darcy's equation.

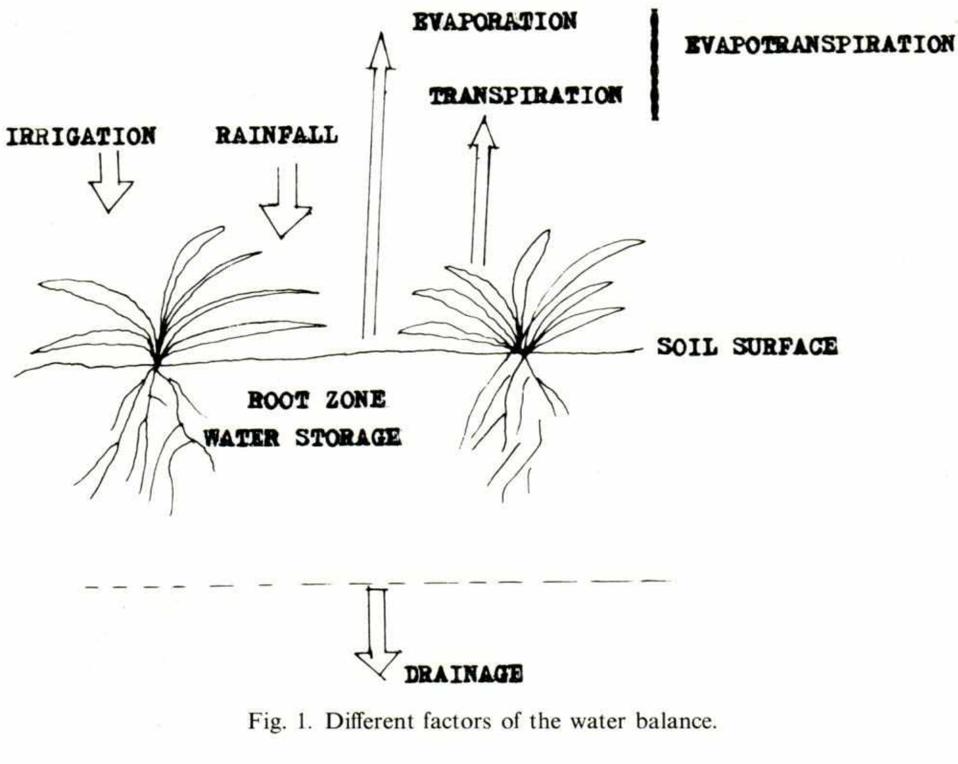

Fig. 1. Different factors of the water balance.

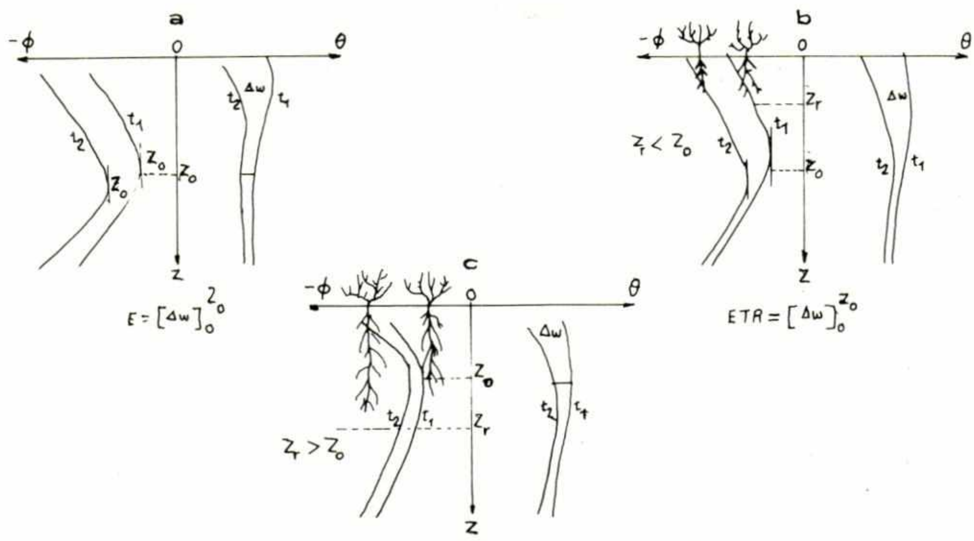

Fig. 2. Principle of water balance method.

The application of Darcy's equation needs simultaneous measurements of soil water content and hydraulic head. The principle of this method depends on the presence of vegetations and their root depths as shown in Fig. 2 (Daudet *et al.* 3). In the absence of vegetation (case 'a' of fig. 2) the zero flux plane can be used in which the hydraulic gradient $\partial\phi/\partial Z = 0$ at this depth no water movement will occur. There is a downward water movement 'drainage' when $\partial\phi/\partial Z < 0$ and an upward water movement 'evaporation' when $\partial\phi/\partial Z > 0$ as shown in Fig. 3. The zero flux plane can also be used in case 'b' of Fig. 2 where the roots happen to be above the level of the zero flux plant.

In case 'C' of Fig. 2, the zero flux plane cannot be used because it occurs inside the root zone and a large amount of the actual evapotranspiration is ignored. Darcy's equation can be applied in a soil layer of a known conductivity located below the root zones, Darcy's equation is used to calculate the soil water flux q_z:

$$q_z = -K(\theta)\left(\frac{\partial\varphi}{\partial Z}\right)$$

Where $K(\theta)$ is the hydraulic conductivity in function of water content and $\partial\phi/\partial Z$ is the hydraulic gradient.

In sandy soils, Black *et al.* (1) found that the hydraulic gradient $\partial\phi/\partial Z$ is constant and equal to the unity, in this case.

$$q_z = K(\theta)$$

From the general balance equation (3) the actual evapotranspiration can be calculated.

Measurements of hydraulic head and moisture content were made in the presence of established orchard grass 'Dactylis glomerata L'. More than 90% of the roots are concentrated in the first 50 cm depth of the soil surface. The hydraulic head was measured by the use of two tensiometers of a mercury manometer, in the depths of

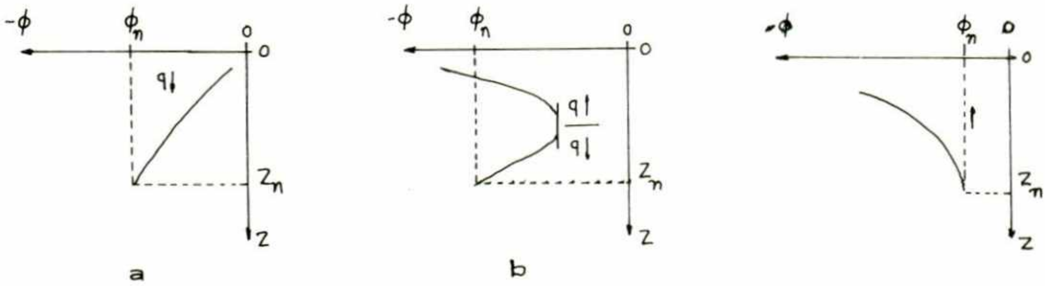

Fig. 3. Hydraulic head profiles to determine soil water movement direction.

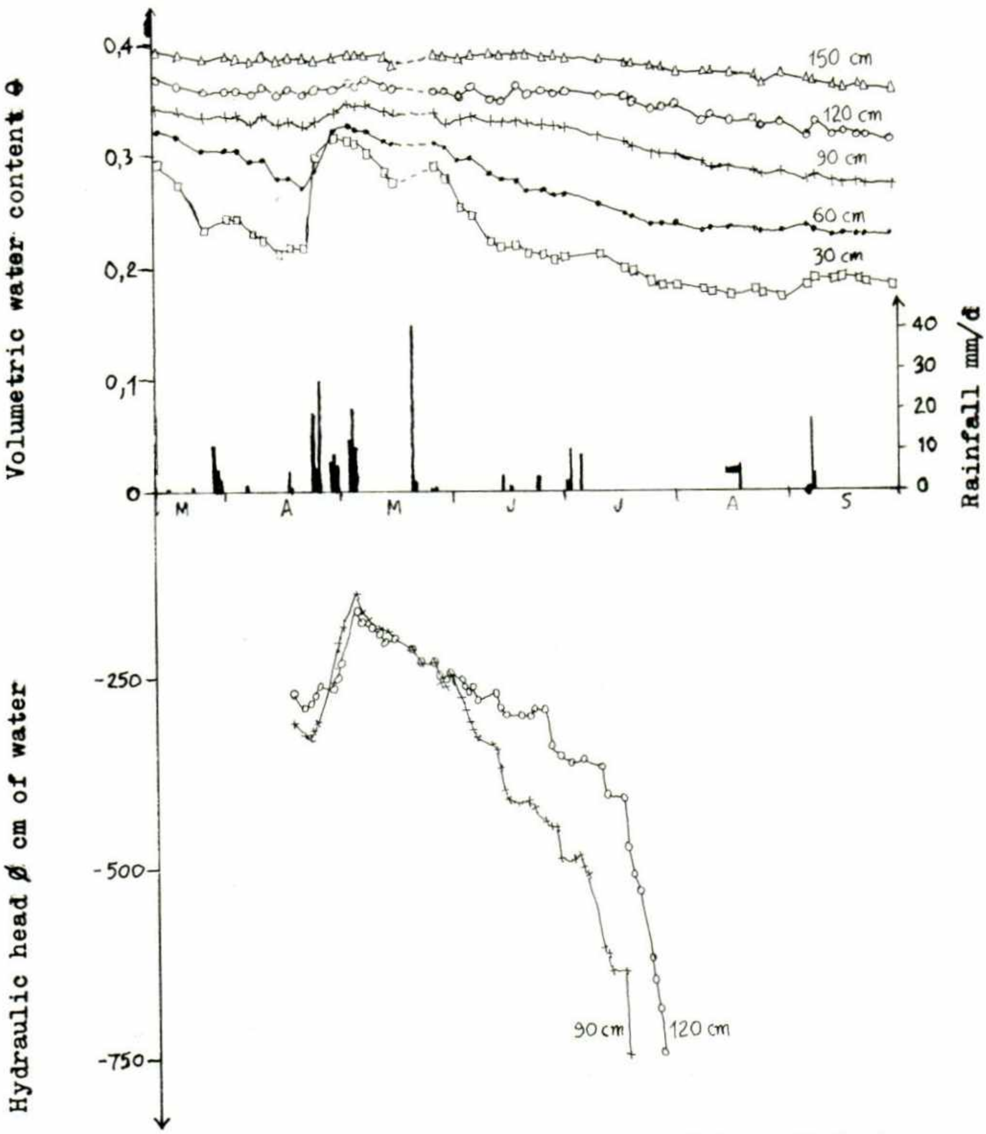

Fig. 4. Volumetric water content, daily rainfall and hydraulic head with the time.

90 cm and 120 cm. This layer is almost devoid of roots, in addition its hydraulic conductivity is known (Khalifa, 4). The soil moisture was measured by the use of a neutron moisture probe at 20 depths from 10 cm to 200 cm in 10 cm increments. Measurements of soil water content were made in 8 access tubes vertically inserted in the soil.

RESULTS AND DISCUSSION

The data obtained during the growing season in 1978 are shown in Fig. 4. These data show that the rainfall was concentrated in the months of April and May. During these two months it rains about 189 mm. The soil moisture of the depths of 30 cm and 60 cm increased and decreased rapidly for a few days following rainfall and then decreased at slow rate, while that of the depths of 90, 120 and 150 cm changed slowly

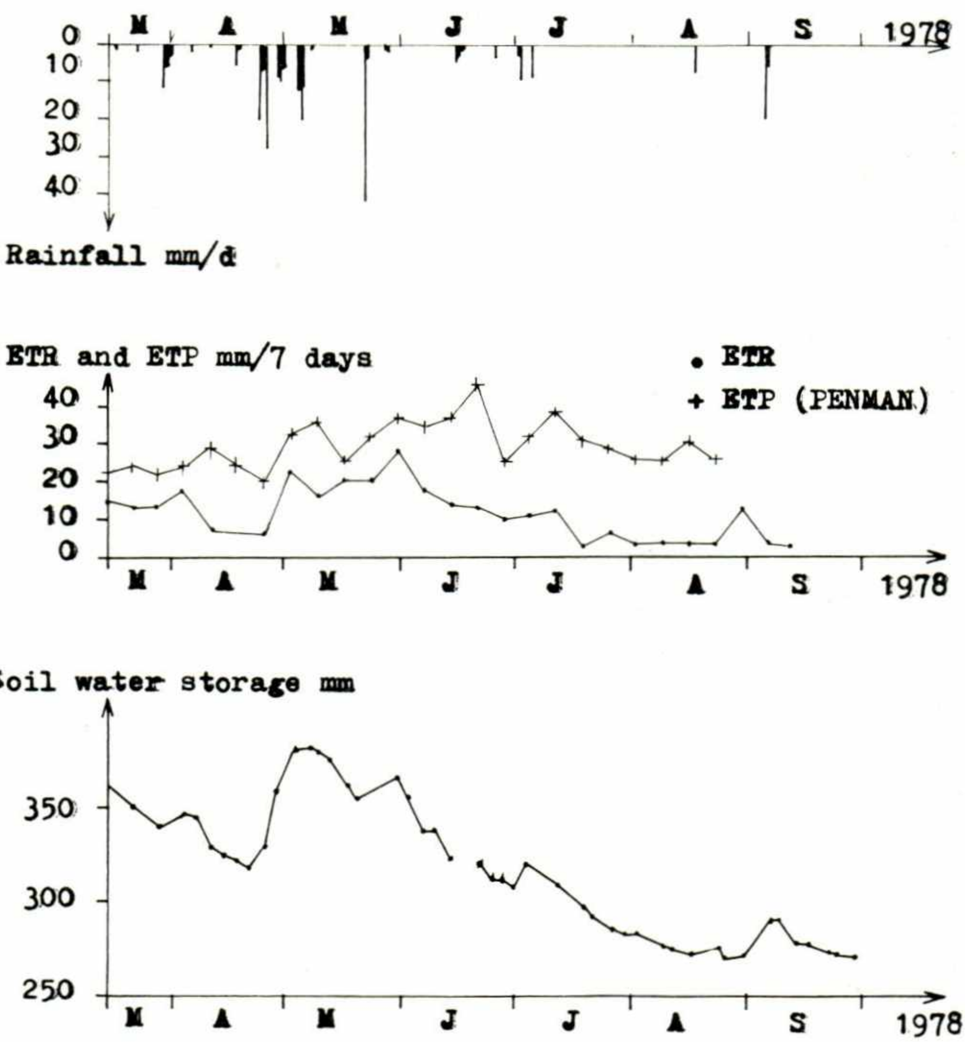

Fig. 5. ETR, ETP, Soil Water Storage and Rainfall with the time.

or remained constant. This appear to result from the root concentration where more than 90% of the roots are concentrated within the layers from the soil surface down to 60 cm depth and from the texture of the soil where the clay percentage increased with the depth. The hydraulic head of the depths of 90 and 120 cm indicates that there is a drainage during a period of 23 days starting from 25 April to 15 May and from 25 to 28 May, a zero flux plane during the period of 16 to 24 May and an evapotranspiration during the rest of the period.

The data obtained were used in the calculation of the actual evapotranspiration (ETR) using equation (3). Some results are shown in Fig. 5. The potential evapotranspiration ETP is calculated by the application of Penman formula. The climatological data are obtained from a meteorological station installed in the same experimental station.

Fig. 5 shows that the values of ETP are more than those of ETR and the ratio of ETR/ETP varies from 0.1 to 0.7. There is a good agreement between ETR and ETP during the period of March–May and during the period of June–September. The actual evapotranspiration reaches its maximum value of 32 mm a week during the growing season in May and a minimum value of 3 mm a week in September. During the dry period July–September the plants cease to grow; in this case the atmospheric loss of soil water is only due to the evaporation from the soil surface.

To study the water requirements of certain crops under certain climatological conditions, the water balance method is the only method that could be applied in the field in a large scale. As has been discussed above it needs only a neutron moisture probe, sets of tensiometers and rain gauges.

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