

# DIURNAL AND SEASONAL FLUCTUATIONS in Osmotic Pressure of Plant Sap

BY

SHAFEY ALY, M., Ph.D.

Assistant Professor in Botany, University College for Girls, Ain-Shams University

Diurnal and seasonal fluctuations in osmotic pressure of plants have been recorded by various authors in different parts of the world. Such fluctuations usually associate fluctuations in the intensity of the atmospheric factors concerned in evaporation. They also sometimes associate fluctuations in the moisture content of the soil. In this country, records of such fluctuations of osmotic pressure are scanty. It was thought, therefore, of increasing these records by adding some new measurements at different times of the year and at different hours of the day.

There is difference in opinion as to whether the fluctuations in osmotic pressure are caused by such fluctuations in atmospheric or edaphic factors, i.e., whether the habitat factors and the osmotic pressure are related together as cause and effect.

## MATERIAL

In experiments on the diurnal march of osmotic pressure two mesophytes, namely, *Ricinus communis* and *Vicia Faba* were used. In experiments on the seasonal march xerophytes, collected from the desert near Cairo, were experimented with. The xerophytes used were, *Fagonia arabica*, *Zilla spinosa*, *Citrullus colocynthis*, *Haloxylon salicornicum* and *Zygophyllum simplex*. Xerophytes are of special interest since Egypt is a desert country, the natural vegetation of which is mainly represented by xerophytes.

## METHOD

The osmotic pressure of the plant sap was measured by the cryoscopic method. The latter has since long been widely used by various authors, such as Dixon & Atkins (1913), Walter (1931), Harris (1934) and several others. It has been usually preferred by various authors since it is more

adaptable to field conditions and because it yields average values of whole plants and plant organs. The method involves the determination of the freezing point of expressed sap, the osmotic pressure being directly proportional to the freezing point lowering. Reasons for the preference of this method over the plasmolytic and other methods are given by Crafts, Currier & Stocking (1949). According to these authors, the cryoscopic method is the most practical one for measuring the osmotic pressure of bulk tissue.

The apparatus used in the present work is similar to that described by Mathews (1921) and used by Stoddart (1935), Migahid (1948) and Migahid & Shafey (1953 & 1954). The formula used in calculating the osmotic pressure is :

$$P = 12.06 \Delta - 0.021 \Delta^2.$$

Where P is the osmotic pressure and  $\Delta$  is the freezing point depression.

## RESULTS

The mean osmotic pressures of leaf sap for *Vicia Faba* and *Ricinus communis* at different hours of the day are expressed in Fig. 1.

It is evident from Fig. 1. that the osmotic pressure of the sap of *Vicia* and *Ricinus* leaves was highest at 2 p.m. but decreased rapidly to a minimum that was attained during the night, increasing again in the following day. The daytime values were higher than the night values. Variations were most rapid at the beginning and end of the daytime period, but were slight during the night and in the middle of the day. Thus there was a rapid fall in the afternoon, between 2 and 6 p.m. and a somewhat rapid rise in the morning, between 6 and 10 a.m. But between 6 p.m. and 6 a.m. the variation was very small. From 10 a.m. to 2 p.m. there was some increase in the osmotic pressure, but which was also relatively small.

In Fig. 2 are expressed the values of atmospheric factors concerned in evaporation, namely, air temperature, relative humidity and evaporation rate at 3-hr. intervals, from 1 p.m. to 1 p.m. the next day. This was the same day as that on which osmotic pressures of the leaf sap of *Vicia* and *Ricinus* were recorded. Relative humidity was measured by means of a wet-and-dry bulb hygrometer while evaporation was measured in millimetres per hour by means of a piche evaporimeter.

The march of temperature and evaporation curves shows a general parallelism to the march of osmotic pressure curve. There was a rapid

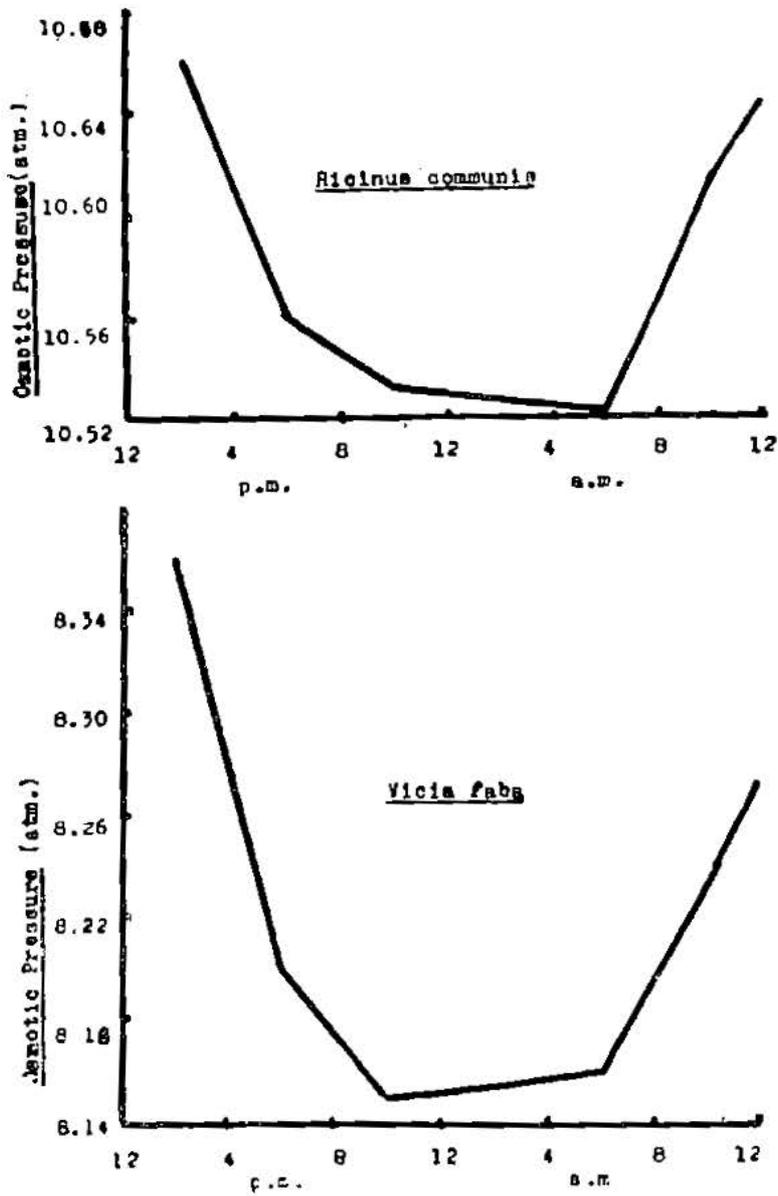


Fig. 1

Diurnal Fluctuations in Osmotic Pressures of *Vicia Faba* and *Ricinus communis*.

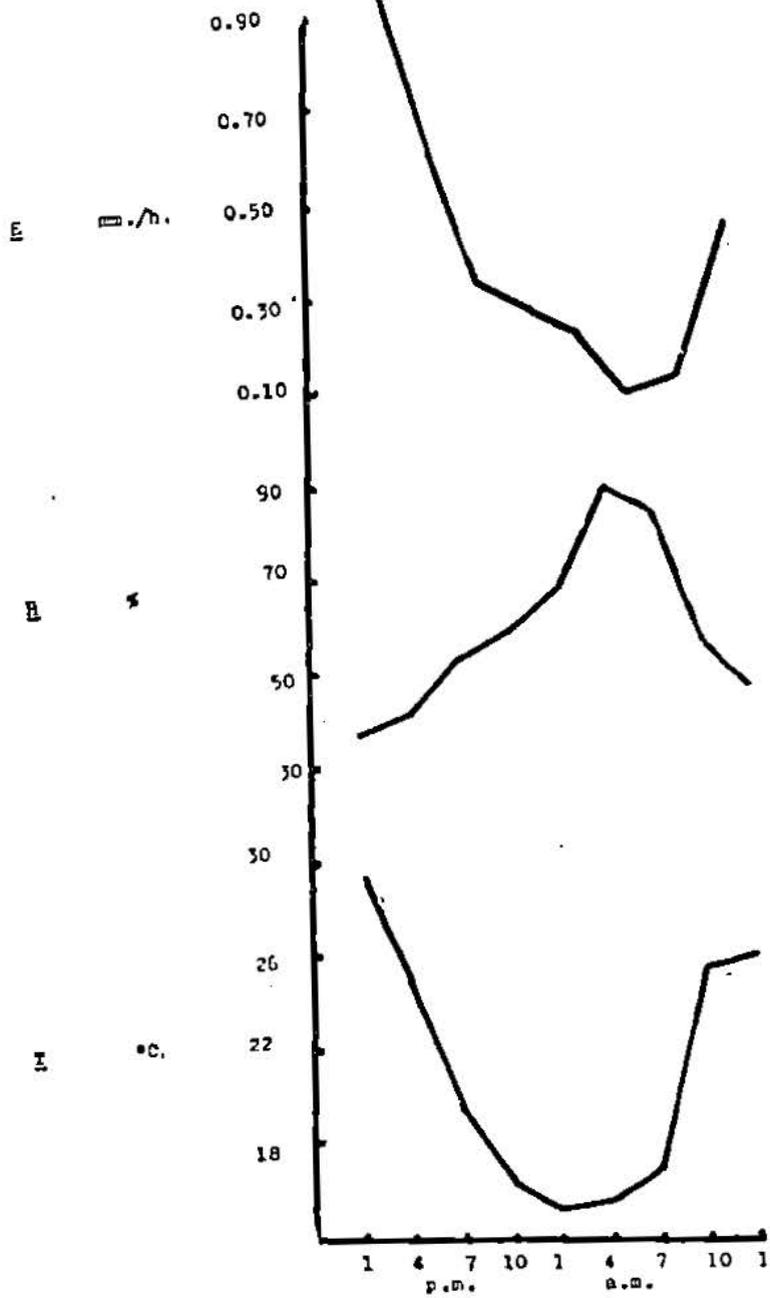


Fig. 2

*Diurnal Fluctuations in Atmospheric Conditions*  
T : Air temperature, H : Relative humidity & E : Evaporation.

fall in the afternoon of the first day, a rapid rise in the morning of the second day and smoothness during the night. Correlation was even more close with temperature than with evaporation. As might be expected the correlation with relative humidity is a negative one. The dawn hours correspond to the maximum relative humidity and to the minimum osmotic pressure as well as the minimum temperature and evaporation.

In Fig. 3 are given the osmotic pressures of some xerophytic plants growing wild in the desert near Cairo at different times of the year. Samples were taken from mature plants.

It is noticed that for *Fagonia arabica* and *Haloxylon salicornicum* the osmotic pressure was measured in February and August, and that the summer value was in both of them much higher than in winter. *Zilla spinosa*, one of the commonest perennials, had an osmotic pressure as low as 16.01 atmospheres in January. The osmotic pressure increased to 17.63 by March, and further to 18.56 in August. It then decreased to 15.35 by December. The osmotic pressure of *Citrullus colocynthis*, one of the evergreen perennials of the Egyptian desert, which flourishes particularly during the summer, was measured in winter, summer and autumn. The summer value of the osmotic pressure was considerably higher than either the winter or the autumn values. *Zygophyllum simplex* is one of the ephemerals of the desert, starting to appear in January, after the winter rains, and terminating its life cycle by the onset of the summer towards the end of May. The osmotic pressure of this species was measured in January and April, and the spring value was found to be considerably higher than the winter one.

In Fig. 4 are given the mean values of air temperature, relative humidity and evaporation rate for the successive months of the year in which the osmotic pressure data were recorded - as recorded at the Meteorological Station of the Cairo International Aerodrome.

Temperature and evaporation show the highest values in summer and the lowest values in winter. In spring they are rapidly rising and in autumn rapidly falling. The relative humidity curve is nearly a mirror image of the temperature and evaporation curves. The seasonal fluctuations in the osmotic pressure of the experimental plants would seem to be a response to the fluctuations in the evaporating factors of the atmosphere.

## DISCUSSION

In a previous paper ( Migahid & Shafey 1955 ) it was clearly shown that variations of soil moisture content and soil salinity produce considerable variations in the osmotic pressure of plant sap. The higher the soil water

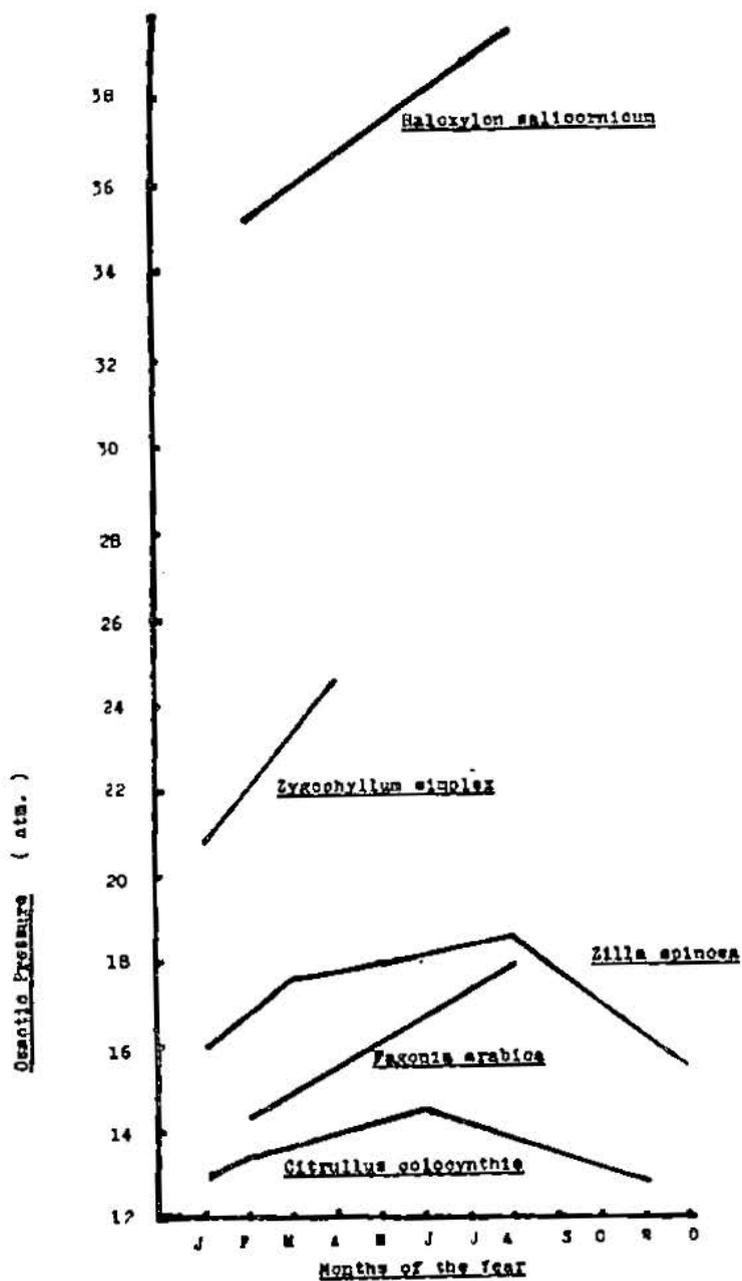


Fig. 3.

Osmotic Pressure of Some Xerophytes at Different Months of the Year.

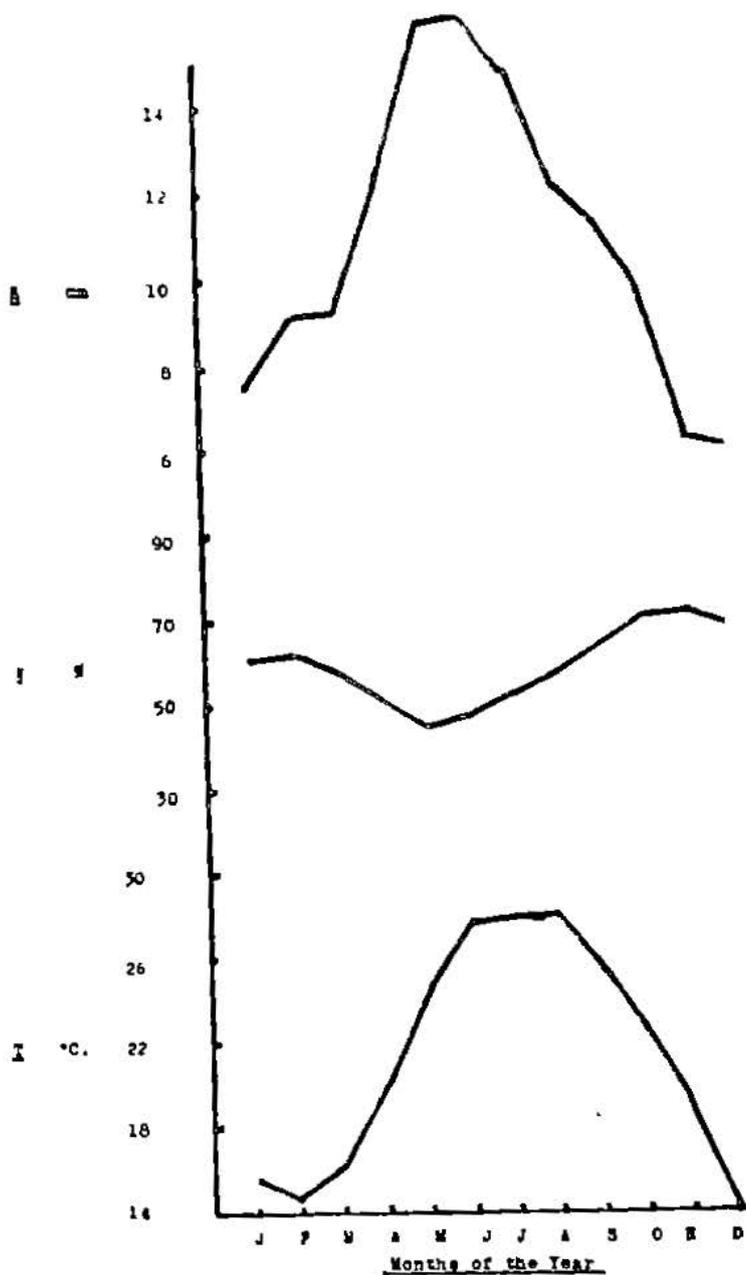


Fig. 4.

*Monthly Fluctuations in Climatic Factors*

*E* : Evaporation, *H* : Relative humidity & *T* : Air temperature.

content and the lower its salt content, the lower the osmotic pressure of the leaf sap and vice versa. It was also observed (Migahid & Shafey 1954) that the osmotic pressure of the plant sap varies greatly in plants of different ecological groups, being higher in xerophytes than in mesophytes and in halophytes than in either xerophytes or mesophytes. Xerophytes are plants of dry habitats subjected to both atmospheric and edaphic drought. Halophytes are plants of saline habitats, subjected either to physiological drought alone or to both physiological and atmospheric droughts, Mesophytes are plants of optimum moisture content of soil and air.

As a matter of fact it is not only the soil environment that affects the osmotic pressure of the plant sap, but the atmospheric environment as well must have a great effect. The plant acts as a balancing factor between the soil moisture surrounding the roots and the air surrounding the tops. If the soil supplies moisture as fast as the air removes it then the osmotic pressure must be low. If the air removes more water, as it is the case under conditions of atmospheric drought (e.g. in xerophytes as compared with mesophytes, in summer as compared with winter, and in mid-day hours as compared with night hours) and the osmotically active substances remain constant, the osmotic pressure rises proportionately. The plant may be considered as a product of its environment and the osmotic pressure as an expression of the effect of that environment. The results of the present investigation confirm this conclusion.

Many authors have arrived at similar conclusions. Of these may be mentioned Eaton (1929), Enomoto (1930) who found that sap concentration varies directly with the temperature and inversely with the atmospheric humidity. Korstian (1924) also noted the lowest concentration in *Pinus ponderosa* in the winter season, but this he referred to the formation of emulsions of fats and oils with a low concentration in winter. In spring there is more sugar present to be used in growth and thus there is an increase in pressure.

In contradiction to the above findings Gilbert & Adams (1929) concluded that environmental conditions have little effect upon the concentration of expressed plant solution, and that moisture in the soil has no direct relationship to pressure in leaves. Gail & Cone (1929) found in the leaves of *Pinus ponderosa* a minimum pressure in July and a maximum in December. They think that rapid growth in April, May and June causes lower osmotic pressure. The use of carbohydrates and other substances for growth of the new leaves and stems results in a decrease in the osmotic pressure.

The present writer is of the opinion that increase in osmotic pressure during the warmer and drier hours of the day as well as during the drier

and warmer months of the year, and its decrease in the cooler and more humid hours and months must be regarded as the general rule among plants. Deviations from this rule must be regarded as exceptions and are often referable to special metabolic characters. During the warmer part of the day transpiration exceeds absorption and the water balance of the plant is disturbed. Such disturbance results in decrease of the tissue water content and increased concentration of the plant sap. By night, transpiration decreases and the water balance and turgidity of the plant are restored. Consequently the sap is diluted and the osmotic pressure diminishes. In the drier and warmer months of the year, apart from the atmospheric drought, edaphic drought also prevails. Thus in addition to increased transpiration, absorption is somewhat retarded. This enhances the disturbance of the water balance and the decrease of tissue water, leading to increased concentration and higher osmotic pressure of the sap.

Finally the writer wishes to thank prof. A. M. Migahid for kind help and for reading the manuscript.

#### SUMMARY

1. The osmotic pressure of the leaf sap was measured and compared at different hours of the day for the two mesophytes *Vicia Faba* and *Ricinus communis* and was found to be higher by day than during the night. The daily march of atmospheric factors concerned in evaporation, such as temperature, relative humidity and evaporation rate were recorded. Considerable parallelism was observed between the march of osmotic pressure and that of either evaporation or temperature. The march of the relative humidity curve was a mirror image of that of other evaporation factors.

2. The seasonal fluctuations in osmotic pressure of a number of typical desert plants was also investigated. It was observed that the osmotic pressure is not constant throughout the year, but tends to be higher in summer than in winter and in the warmer and drier months than in the cooler and more humid ones.

3. The writer is of the opinion that the fluctuations observed are due to changes in the balance between absorption and transpiration, leading to fluctuations in the tissue water content and in the concentration of the sap. Such fluctuations are likely to be of general occurrence in plants, and any deviation must be referred to special metabolic characters. Further data are, however, needed before such generalisation can be made.

BIBLIOGRAPHY

- Crafts, Currier & Stocking, 1949; Water in the physiology of plants. *Chronica Botanica*, U. S. A.
- Gail, F.W. & Cone, W.H., 1929; Osmotic pressure and pH measurements on cell sap of *Pinus ponderosa*. *Bot. Gaz.* 88.
- Migahid, A. M., 1938; Binding of water in relation to drought resistance. *Bull. Fac. Sci. Fouad I Univ.* 18.
- Migahid, A. M. 1945; Binding of water in xerophytes and its relation to osmotic pressure. *Bull. Fac. Sci. Fouad I Univ.* 25.
- Migahid, A. M. & Shafey Aly, M., 1953; Osmotic pressure of plants of different ecological groups. *Bull. de L'Inst. du Desert, D'Egypte Cairo*, Tome III, No. 2.
- Migahid, A. M. & Shafey Aly, M., 1955; Osmotic pressure of plant sap as related to salinity and water content of the soil. *Bull. de L'Inst. du Desert D'Egypte*, Tome V, No. 1.
- Stoddart, L. A., 1935; Osmotic pressure and water content of Prairie plants. *Plant Physiol.*, 10.