DIURNAL FLUCTUATIONS IN WATER BALANCE OF *JUNIPERUS EXCELSA* M. Bieb. UNDER NATURAL CONDITIONS AT ZIARAT (BALUCHISTAN)

by

M. A. Quraishi, Abdul Khalique, Shahida Perveen

and

Perveen Akhtar*

Introduction. *Juniperus excelsa* M. Bieb (Syn. *J. macropoda* Boiss., *J. polycarpos* C. Koch) is one of the slowest growing trees of Pakistan and covers about 56,000 hectares in Baluchistan. The rainfall in this area is extremely low, erratic and climate conditions tend to be extreme during most parts of the year with high insolation, wind velocity and evaporation; and low soil moisture. Under such conditions the natural regeneration of this species is scanty and efforts are being made to plant it.

The aim of the present investigation was to gain information about the water balance factors of this species under natural conditions.

Review of Literature. Diurnal curves of various factors which determine plant water balance have been established in many plants. Transpiration curves are the most common ones and works of different investigators have been reviewed by STOCKER (1956). Many workers have also studied the changes in stomatal aperture. Similarily diurnal fluctuations in water content, water saturation deficit and osmotic values were established by KRAMER (1937), MAXIMOV (1929) and WEATHERLY (1951).

Material and Methods. The experiment was conducted on September 15, 1976 on a single tree situated near the Forest Rest-House at Ziarat; Longitude 67°.44′ E, Latitude 30°.23′ N. The candidate tree was 12 metre in height, 35 cm indiameter at breast height, was unpruned and free from any visible disease or physical damage. The soil is shaley mixed with limestone. The underwood consisted of *Caragana ambigua*, *Rosa* sp., and *Perovskia abrotenoides*. A heavy ra n continued for about a week just before the experiment and resulted in a net rainfall of 79 mm. During the experiment the moisture content of the soil in 10 to 60 cm depth varied from 21 to 30% by oven dry weight of soil.

The experiment started at 4 a.m. and continued till 6 p.m.—for 14 hours. The following factors were determined every three hours from 6 a.m. by three workers observing simultaneously. The initial reading was taken at 4 a.m. The soil moisture contents were determined only once at 9 a.m.

* The authors are respectively, Director, Biological Sciences Research Division; Plant Physiologist and Research Assistants in the Pakistan Forest Institute, Peshawar.

To measure transpiration a shoot of convenient size (200 to 700 mg) was cut from the sunny side of the tree and weighed immediately on a torsion balance (HUBER) determining the initial and final weight within 5 minutes. Preliminary investigations had revealed that rate of transpiration was about uniform for approximately ten minutes after plucking, declining thereafter. Transpiration rates were expressed as mg transpiration/g initial fresh weight/minute.

The method employed to establish the form of curves representing stomatal reaction in shoots without regular supply of water was as follows: The above shoot was later weighed successively after time intervals of 15, 30, 45 minutes, 1 hr., 2 hrs., 3 hrs., and 6 hours from the initial time of weighing. These specimens were then dried at 105°C and their water contents at the time of respective weighing were expressed as pecentage of the oven dried weight. The difference of water contents between two successive readings divided by the time elapsed gave the rate of water loss during that time interval.

Stomatal-opening measurements were carried out by examining a freshly pealed off strip of epidermis from the upper side of the leaf under the microscope without fixing. Mean aperture is based on at least ten stomata measurements.

Water contents were determined in the same specimens examined for transpiration and expressed as percent of the oven dry weight by the following formula:

$$\text{Water contents} = \frac{\text{Fresh weight—Oven dry weight}}{\text{Oven dry weight}} \times 100$$

Water deficit in shoots was determined by WEATHERLEY'S relative turgidity method as described by SLATYER and MCLLROY (1961).

Water potential was determined by CHARDOKOV change of density method as described by SLATYER and MCLLROY (1961).

Osmotic potential (OP) was measured by cryoscopic method following SLATYER and MCLLROY (1961).

Temperature and relative humidity were determined by a mechanically operated psychrometer, while evaporation was measured by the use of a Piche-disc evaporimeter suspended from the stem of the tree at breast height protecting it frm solar radiation.

Soil moisture was determined from soil samples collected from a freshly dug pit under the candidate tree at 10 cm intervals from the soil surface to a depth of 60 cm. The soil samples were weighed immediately for initial weight, packed carefully and brought to the laboratory at Pakistan Forest Institute, Peshawar, where they were oven dried at 105°C. Soil moisture was expressed as a percentage of the weight of the oven dried soil.

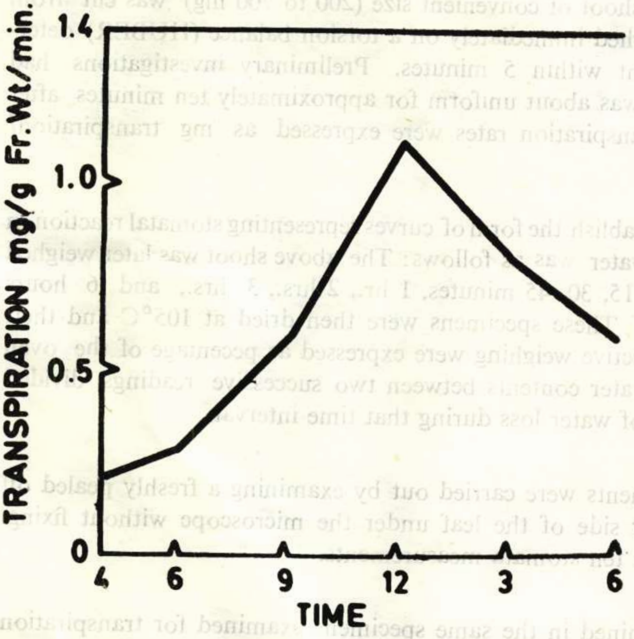

Figure 9 Daily march of osmotic potential

Results. 1. Transpiration rate: The transpiration rates of the tree at different times of the day are plotted in Figure 1. The curve shows that it rose gradually from sun rise mainly from 9 a.m. and attained its peak value at about noon, later a decline in the rate started and continued slowly up to sunset.

Time course of water loss from cut shoots is plotted for different times of the day in Figure 2. At 12 noon and 3 p.m. the curves represent three phases of transpiration: 1) stomatal phase, where a fairly uniform rate of transpiration prevails; then 2) closing phase with a decrease in the previous rate of transpiration accompanied by decrease in the stomatal aperture and lastly 3) the cuticular phase, where the rate of water loss is extremely low and is from the cuticle of the leafy shoot. However at 6 a.m. and 6 p.m. the curves are not well defined in terms of the above mentioned three phases. Particularly at 6 a.m. the transpiration is low at the start rising gradually during the day and falling afterwards.

The differences in the curves are partly due to the effect of different physical conditions at the time of observation and partly due to stomatal behaviour at that time. For instance the stomatal aperture probably decreased in size after about an hour from the time of plucking at 12 noon, while at early morning the moderately open stomata in the morning probably opened further.

Juniper leaves are minute, sessile with adnate leaf bases thus making the young shoots green and acting as transpiring organ (Fig. 3). A series of cross sections of the leaf revealed following anatomical features:

(*i*) The epidermis is heavily cutinized.

(*ii*) The stomata (Figure 4) are few in number and are concentrated at the basal part of the leaf.

(*iii*) A big resin canal occupies the main lumina of the leaf and reduces the mesophyll tissue considerably.

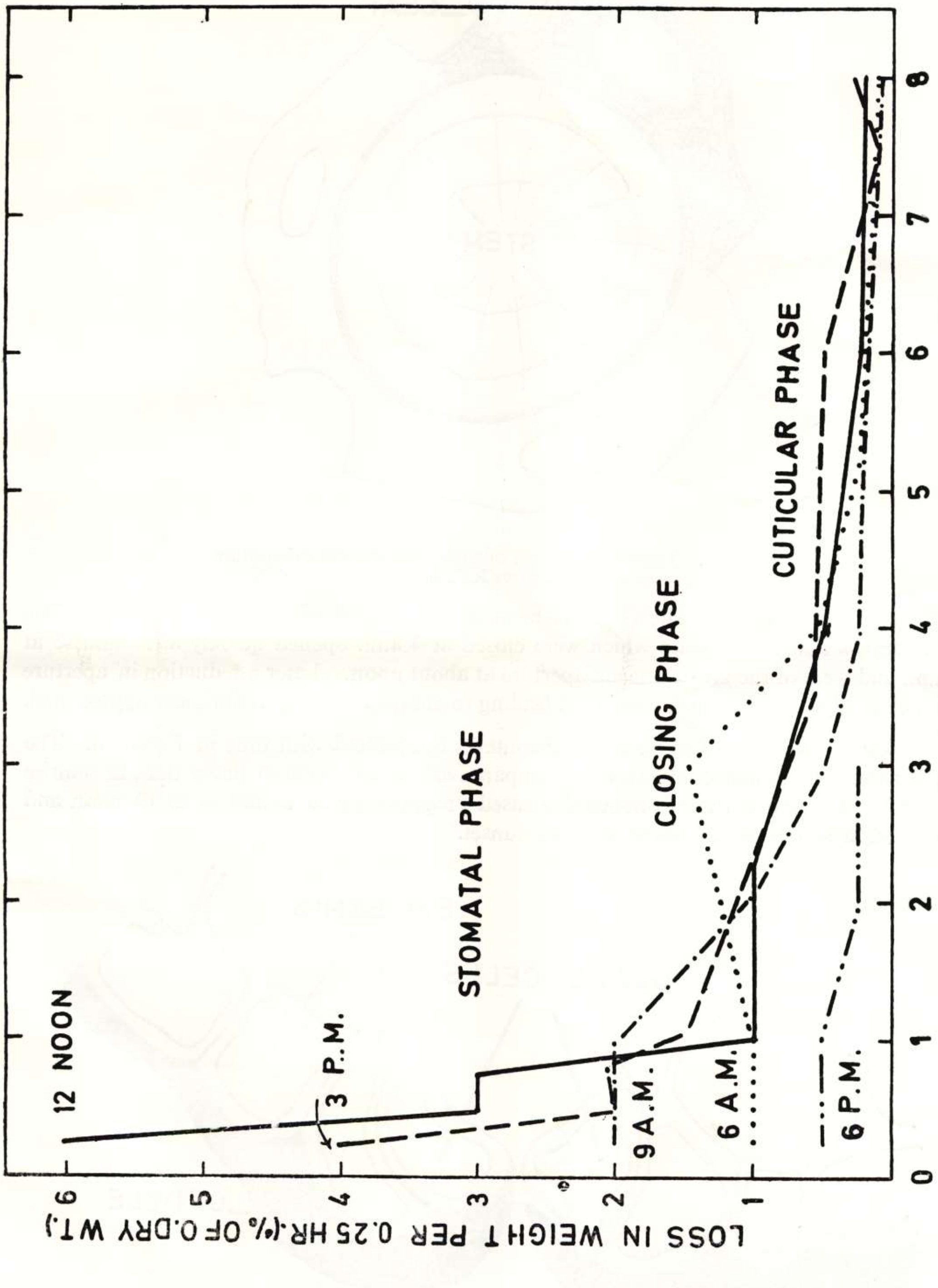

Figure 2. Time course of water loss per 0.25 hr. from excised leafy branches of juniper, expressed as percentage of oven dry weight.

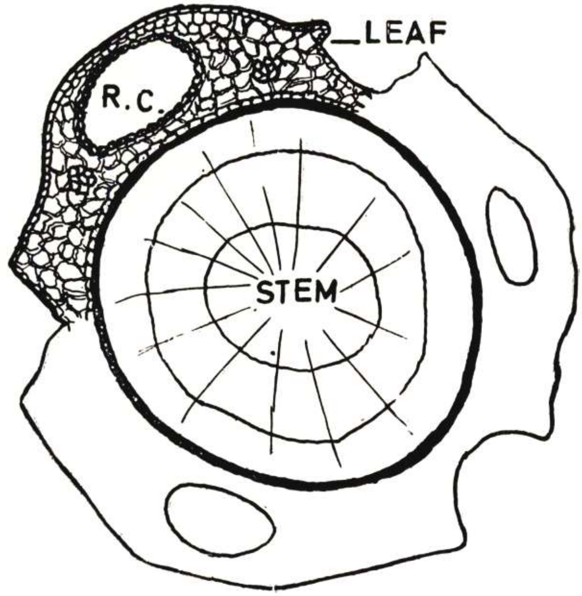

Figure 3. Transverse section of stem showing leaf orientation and its anatomical features R.C. is resin canal. X 30.

2. *Stomatal opening.* The stomatal behaviour is plotted with time in Figure 5. The curve shows that the stomata which were closed at 4 a.m. opened quickly after sunrise at 6 a.m. and were of the greatest mean aperture at about noon. Later a reduction in aperture size occurred at 3 p.m. which continued leading to complete closing as darkness approached.

3. *Water contents.* The plant water-contents are plotted with time in Figure 6. The curve shows that water contents were comparatively at low level at dawn than at sunrise (6 a.m.). Afterwards these contents decreased progressively to minimum at 12 noon and remained at somewhat the same level till sunset.

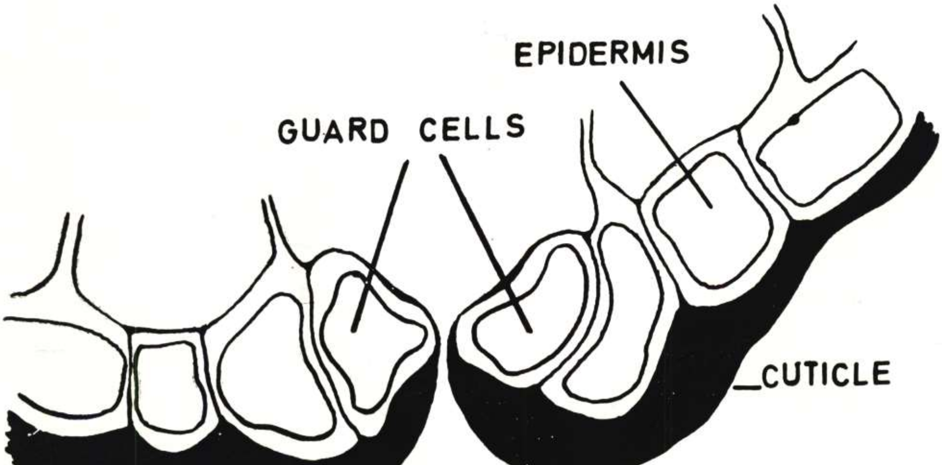

Figure 4. a. Cross section of leaf showing stomata.
b. Micro—photograph of stomata, X 600.

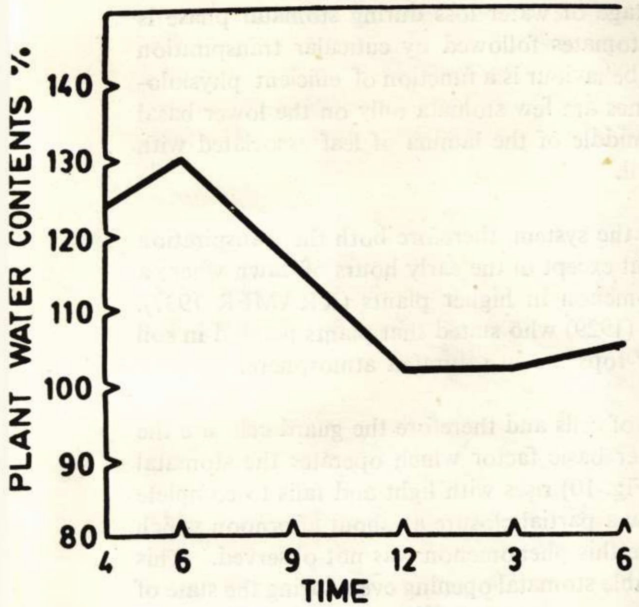

Figure 6. Daily march of plant water contents.

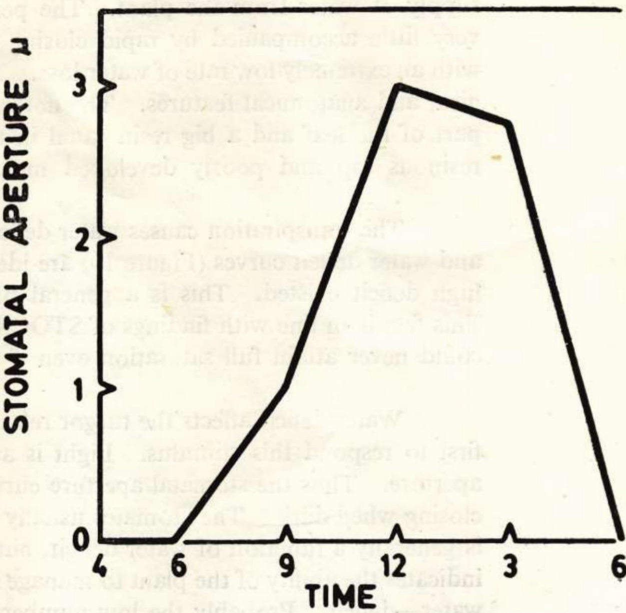

Figure 5. Daily march of stomatal opening.

4. *Water deficit.* The water deficit curve (Figure 7) shows a considerable deficit at 4 a.m. which decreased rapidly at 6 a.m. and again rose quickly attaining its maximum value at 12 noon. Later a slight decrease occurred at 3 p.m. but even at the time of sunset it was considerably high.

5. *Water potential.* The water potential curve (Fig. 8) represents a high (28 atm) potential during 4-6 a.m. interval, later a decrease started reaching to minimum at 12 noon and followed by a slight rise in the afternoon and again falling to the level at 12 noon.

6. *Osmotic potential.* The curve (Figure 9) shows a high value at dawn which decreased during morning (6-9 a.m.) and rose rapidly again to attain peak value (25 atm) at noon. Later this value decreased rapidly to a value of 22 atm which persisted till sunset.

Discussion. A comparison between the various physiological factors and the climatic factors (Figure 10) clearly points out that juniper has an active control on its water relations and is adapted to habitat with permanent water deficiency. The rate of transpiration is low and is also limited, i.e., even under better soil moisture conditions, it is not able to exceed certain low limits. The transpiration curve runs almost parallel to evaporation curve and as evaporation is basically a function of vapour-pressure which is directly related to temperature, therefore the peak value of transpiration coincides with the peak value of temperature. At morning and evening the rate of transpiration is low and goes in agreement with the physical conditions of the atmosphere; especially the curve of relative humidity.

The control on water loss is reflected in the water-loss decline curves (Figure 2), where severe stress of water supply was imposed on the tissues by cutting of the normal supply of water from the plant. The percentage of water loss during stomatal phase is very little accompanied by rapid closing of stomates followed by cuticular transpiration with an extremely low rate of water loss. This behaviour is a function of efficient physiological and anatomical features. The notable ones are few stomata only on the lower basal part of the leaf and a big resin canal in the middle of the lamina of leaf associated with resinous sap and poorly developed mesophyll.

The transpiration causes water deficit in the system, therefore both the transpiration and water deficit curves (Figure 10) are identical except in the early hours of dawn where a high deficit existed. This is a general phenomenon in higher plants (KRAMER 1937). This fact is in line with findings of STOCKER (1929) who stated that plants planted in soil could never attain full saturation even if their tops are in saturated atmosphere.

Water deficit affects the turgor relations of cells and therefore the guard cells are the first to respond this stimulus. Light is another basic factor which operates the stomatal aperture. Thus the stomatal aperture curve (Fig. 10) rises with light and falls to complete closing when dark. The stomates usually show a partial closure at about afternoon which is generally a function of water deficit, but here this phenomenon was not observed. This indicates the ability of the plant to manage suitable stomatal opening even during the state of water—deficit. Probably the low number of stomata cover the risk of overloss.

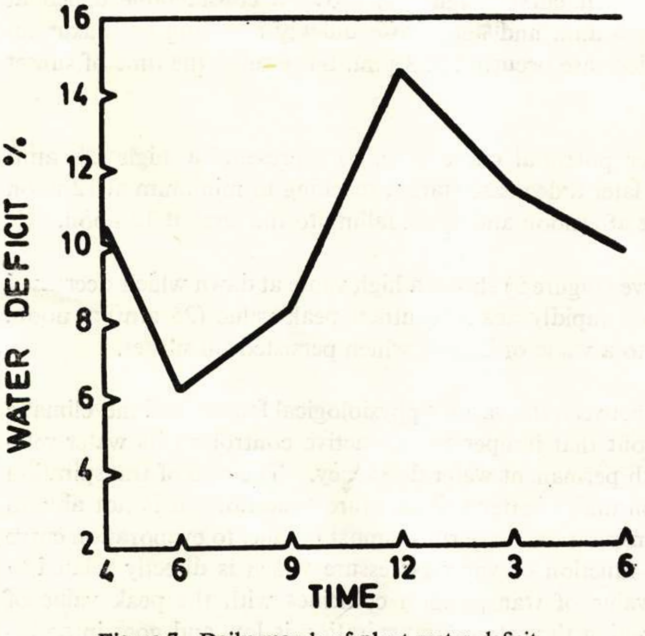

Figure 7. Daily march of plant water deficit.

The plant-water-contents (Figure 6) remain at low level during the day time which is obviously due to excessive transpiration under the impact of various physical factors of the atmosphere, while at dawn a depression is a wide spread phenomenon in higher plants and MEYER and ANDERSON (1952) has explained it by suggesting that "during the early morning hours the leaves lose water by translocation to other organs of the plant."

The water potential and osmotic potential (Figure 8 and 9) are the major water driving forces in the plants. The high water potential in the morning accounts for the high water deficit in the morning, while during the day time when the water absorption is under the influence of matric potential, the values fluctuate in between 22.4 to 25 atm. An increase in OP at noon is probably due to an increase in the quantity of osmotically active substances as proposed by MEYER and ANDERSON (1952).

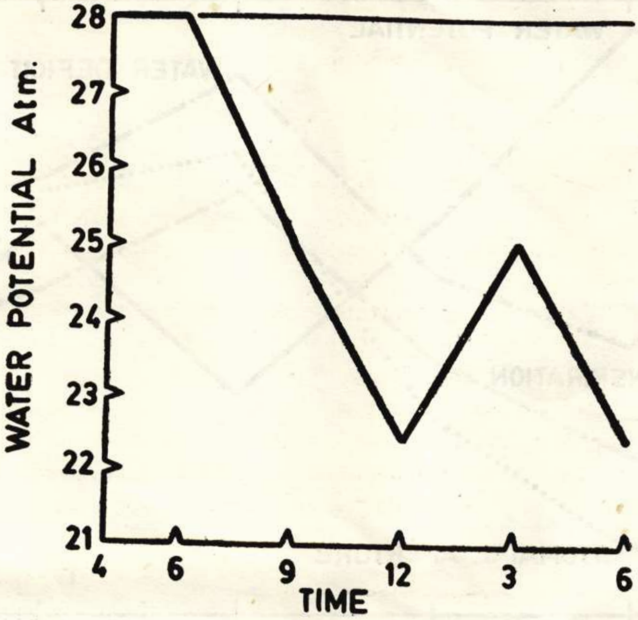

Figure 8. Daily march of water potential.

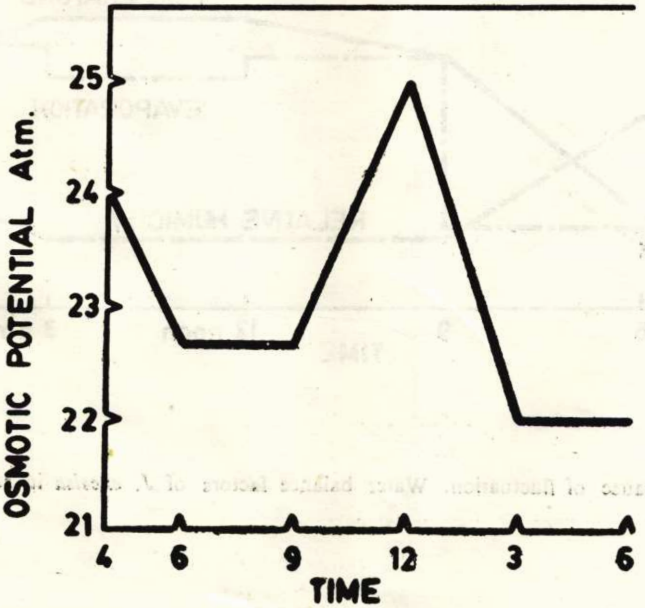

Figure 1. Daily march of transpiration.

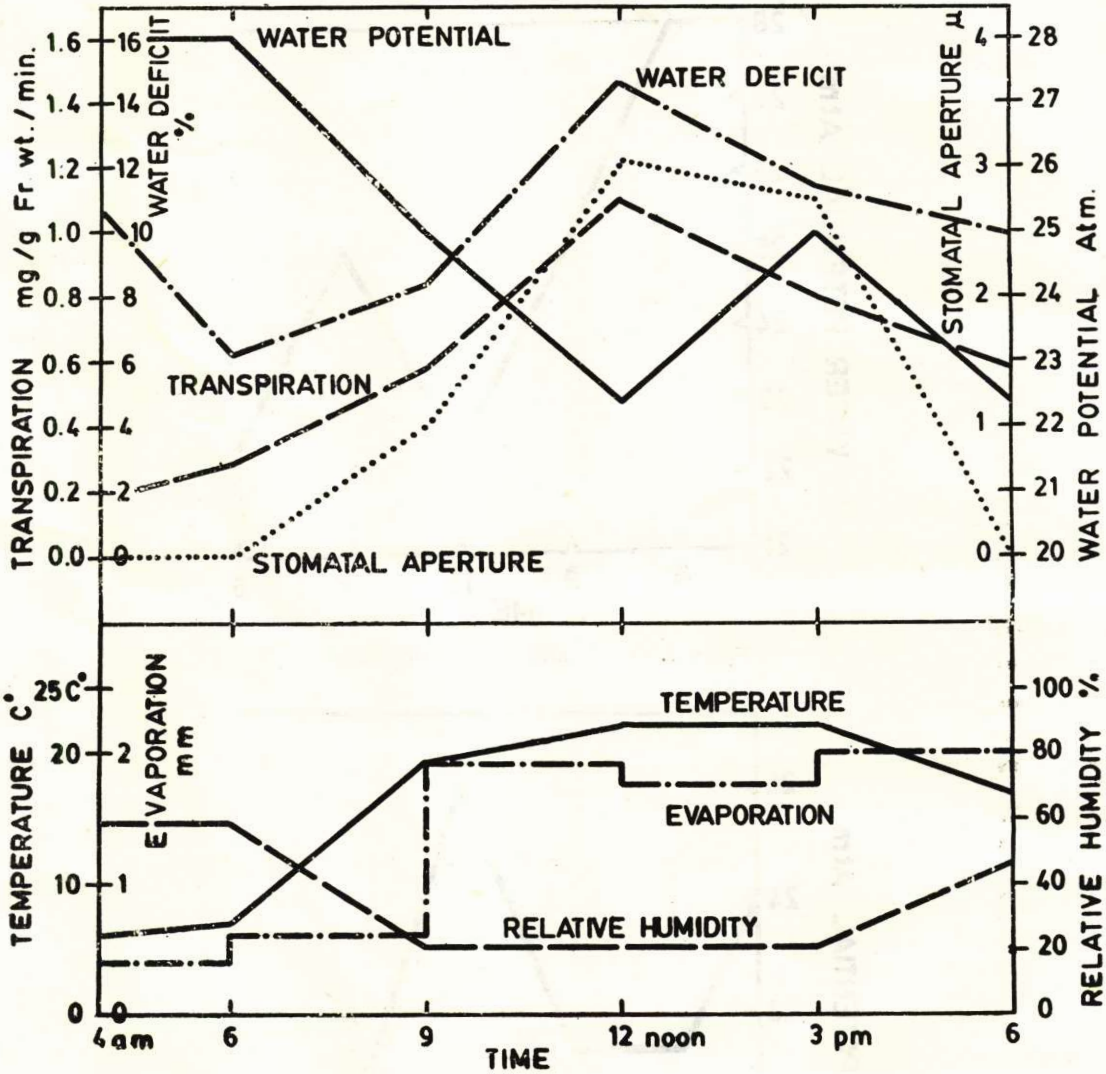

Figure 10. Diurnal cause of fluctuation. Water balance factors of *J. excelsa* in relation to meteorological data.

References

1. Kramer, P.J. (1937). The relation between rate of transpiration and rate of absorption of water in plants. Amer. J. Bot., 24, 10-15.

2. Maximov, N.A. (1929). The plant in relation to water. London, pp. 451.

3. Meyer, B.S. and D.B. Anderson. (1952). Plant Physiology (2nd. Ed.) Van Nostrand Co. Princeton. pp. 784.

4. Slatyer, R.O. and I.C. McIlroy. (1961). Practical microclimatology. UNESCO publication.

5. Stocker, O. (1929). Das wasserdefizit von Gefasspflanzen in verschiedenen klimazonen. Planta 7: 182-87.

6. Weatherley, P.E. (1950). Studies in the water relations of cotton plant. I. The field measurements of water deficit in leaves. New Phytol. 49. pp. 81-97.