RADIATION INTENSITY AND TRANSPIRATION

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The energy necessary for plant transpiration must be supplied from the outside. It is quite sensible, therefore, to study the relationship between radiation energy and transpiration. In most textbooks on plant physiology this relationship is somewhat overlooked. It appears to be possible to calculate transpiration rates with the aid of rather simple formulae in which the factor energy is not accounted for. This suggests that this factor can never be the limiting factor. On the other hand, we find data in literature which show a distinct relationship between transpiration and radiation intensity. These data concern mostly a closed homogeneous vegetation.

Because of these deviating points of view, it seemed to be worth while doing some quantitative physiological work on this subject. The experiments described in this paper have been performed in the Botanical Laboratory at Groningen by one of the students mr. K. Posthuma.

The experimental set-up used is the following. The root system of a seedling of *Phaseolus vulgaris* was placed in a potometer. One of the first two leaves was removed. The other one was placed upside down in a perspex holder perpendicular to the entering beam of light. This whole leaf was greased with vasiline except for an area of 20 square cms. In this way the transpiration of a constant leaf surface could be determined. Air temperature, air humidity and wind velocity were kept constant. Leaf temperature could be measured and light intensity was varied.

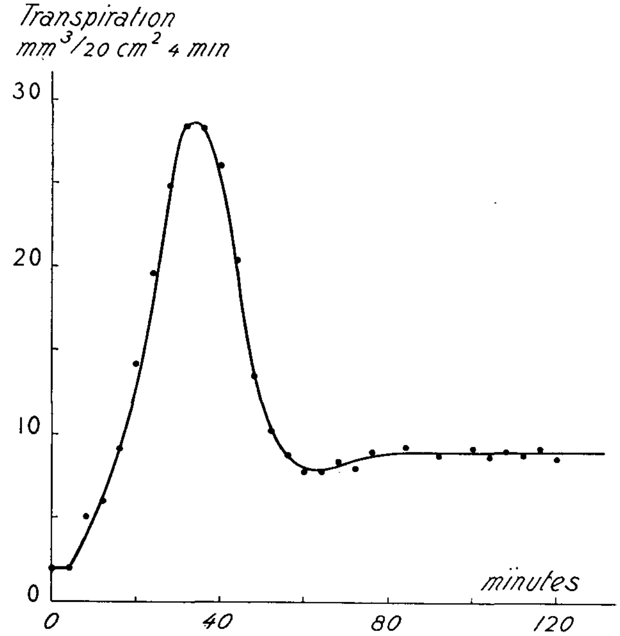

Fig. 1. The time versus the transpiration of bean leaves after transference from dark to light.

It appeared that the plants used showed a constant number of stomata per square cm leaf surface. It was possible, therefore, to compare transpiration rates of various plants.

After putting the plant in the experimental set-up a lamp was turned on. Figure 1 shows the time-course of the transpiration.

Immediately after turning on the light the transpiration increases rapidly, until a maximum rate is reached. There after, a gradual decrease takes place until a constant rate is attained and the steady state is reached. The maximum value as well as the value in the steady state is dependent on the light intensity used. Only the steady state values have been used in the graphs which will be shown in this paper. After a number of observations in the steady state the leaf was cut off and the mean stomatal aperture was measured microscopically.

If we plot the transpiration rates against the light intensities we get the picture which is shown in figure 2.

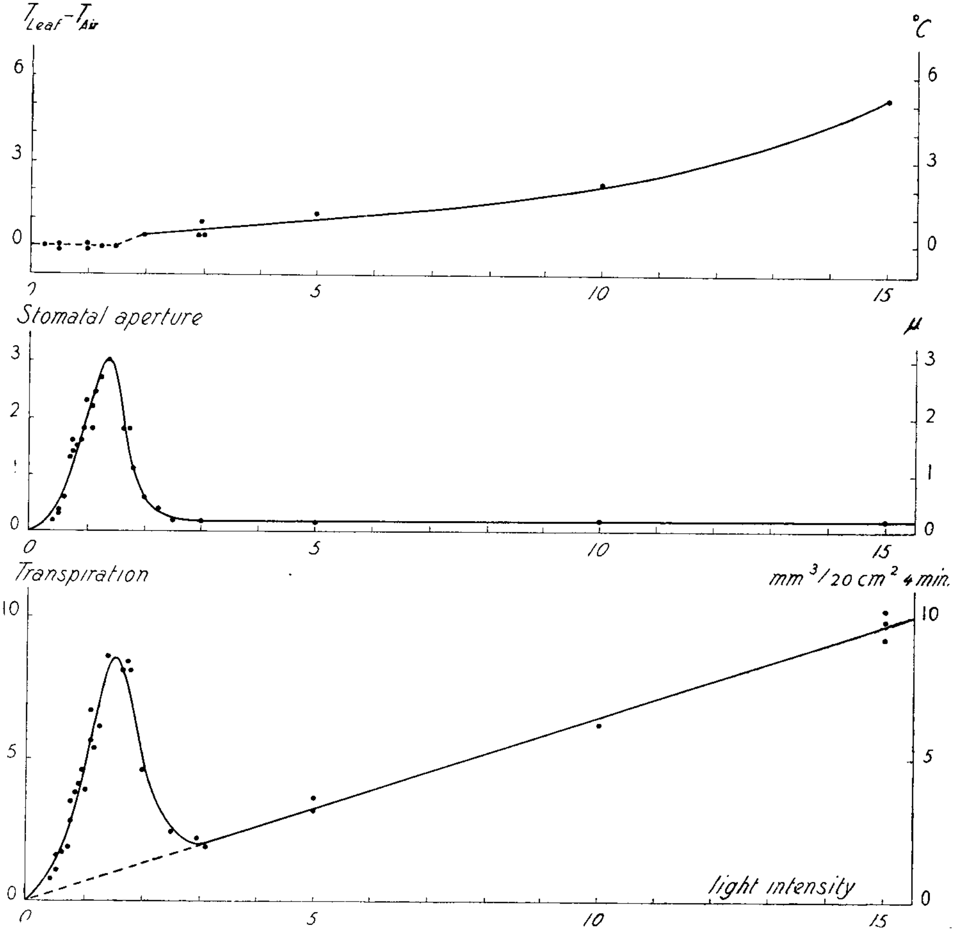

FIG. 2. THE RELATIONSHIP BETWEEN TRANSPIRATION AND LIGHT INTENSITY IN GALVANOMETER READINGS (1 unit = 12 × 10^3 erg cm^{-2} sec^{-1}).

All points represent data (observations) on different leaves in the steady state. At first sight this picture may seem to be a little surprising for there seems to be an optimum value at a rather weak light intensity. At the higher light intensities the transpiration rate increases rectilinearly with light intensity.

This picture, however, becomes more understandable if the corresponding values of the stomatal apertures are taken into account. For it appears that stomatal aperture increases with light intensity until a maximum value is reached and thereafter decreases until the stomata are completely closed.

It appears further that within this range of light intensity leaf temperature is not different from air temperature. A difference can be observed near the point of the minimum transpiration rate and on the right side of this point.

Beyond the minimum the transpiration rate increases rectilinearly with increasing radiant energy.

By extrapolating the line to the left, it passes through the origin. This means that there exists transpiration which is independent of stomatal aperture (the cuticular component of transpiration).

In the next figure a separation has been made between the two components of transpiration : stomatal and cuticular transpiration. The curved line (black dots) indicates the stomatal transpiration. These points were obtained by subtracting the cuticular transpiration from the total water loss. The straight line (open dots) is the cuticular transpiration from the preceding figure.

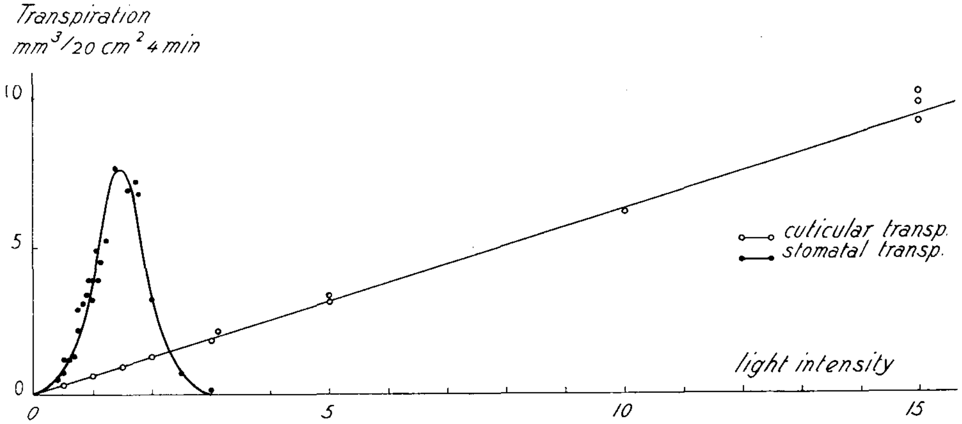

FIG. 3. THE RELATIONSHIP BETWEEN LIGHT INTENSITY AND TRANSPIRATION, STOMATAL APERTURE AND LEAF TEMPERATURE, AT CONSTANT AIR TEMPERATURE, RELATIVE HUMIDITY AND WIND VELOCITY.

Now we have to analyse the curved line representing the true stomatal transpiration. According to BANGE the relation between transpiration and stomatal aperture in wind can be expressed by the formula :

$$T = k\ (c - c_1) \times a.$$

In this formula T is the transpiration rate and a the stomatal aperture. The factor $(c - c_1)$ represents the vapour pressure difference between the air and the leaf. k is a constant dependent on structure, position of the stomata, etc.

In our experiments we measured T and the corresponding a value. Therefore we could compute the value of $k\ (c - c_1)$. From this it appeared that this value was not a constant. Because of the constancy of k we are forced to conclude that $(c - c_1)$ had a varying value in our experiments. c is the vapour pressure deficit of the air which was kept constant. So we arrive at the conclusion that the relative humidity in the leaf is not a constant factor as it is often assumed to be. It amounted to less than 100% at the ascending part of the curve, where the value of $k\ (c-c_1)$ was smallest.

From the foregoing we arrive at the conclusion that the formula given above does not hold in all cases for the stomatal transpiration as measured in our experiments.

How can a further analysis be made ?

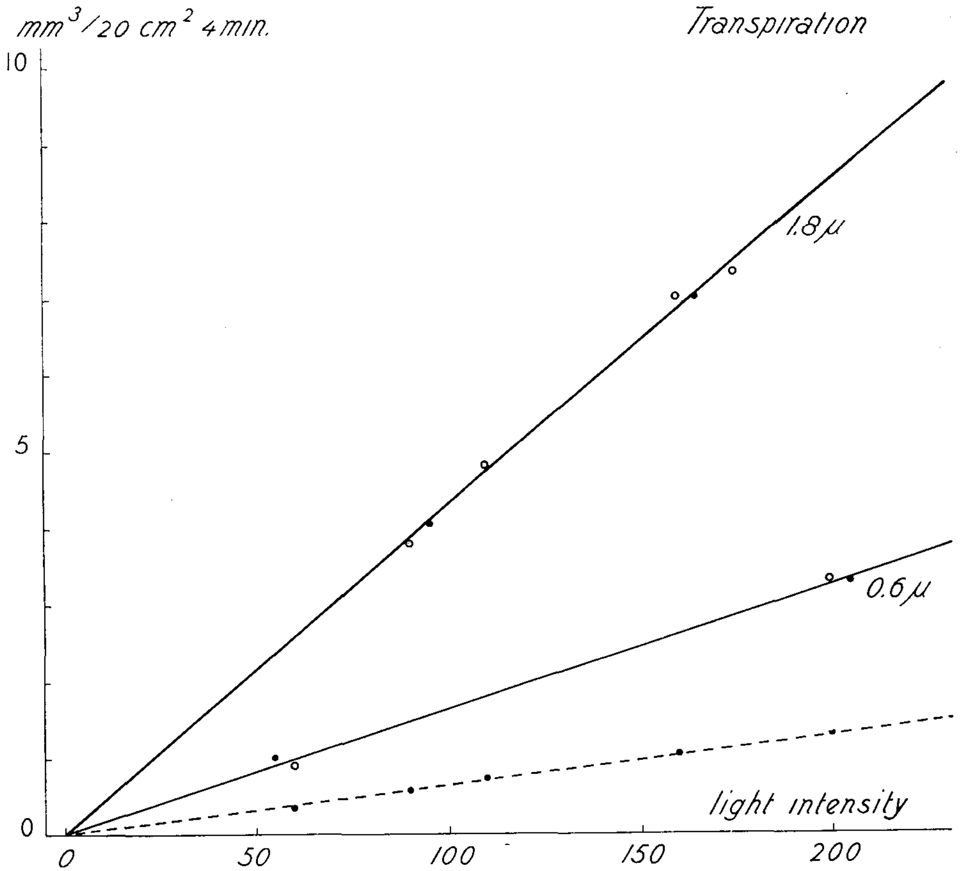

FIG. 4. STOMATAL TRANSPIRATION AND CUTICULAR TRANSPIRATION AS A FUNCTION OF LIGHT INTENSITY.

We tried to do so by comparing the transpiration rates obtained with the same stomatal apertures at different light intensities. These results are plotted in figure 4 for stomatal apertures 0.6 and 1.8 micron. For stomatal aperture 0.6 μ we had four observations, two at a light intensity of about 60 galvanometer scale units and two at 200 scale units. These points give a straight line passing through the origin. The same holds good for the six points with stomatal aperture 1.8 μ. This means that for a given stomatal aperture, the transpiration rate is proportional to the radiant energy.

In this way it is possible to compare the transpiration rates for various stomatal apertures and corresponding energy supply. The outcome of this operation is given in figure 5. It appears that, whatever the stomatal apertures, the tran-

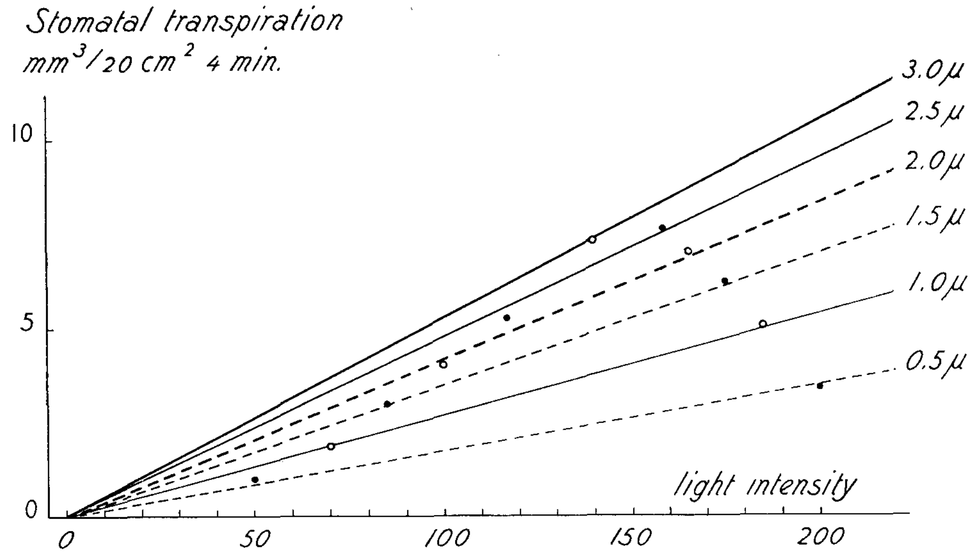

FIG. 5. THE RELATIONSHIP BETWEEN LIGHT INTENSITY AND TRANSPIRATION AT VARIOUS STOMATAL APERTURES.

spiration rate was proportional to the light intensity. It is clear, however, that the slope of the various lines does not increase proportionately to the stomatal aperture. The greater the stomatal aperture the lesser the difference in slope.

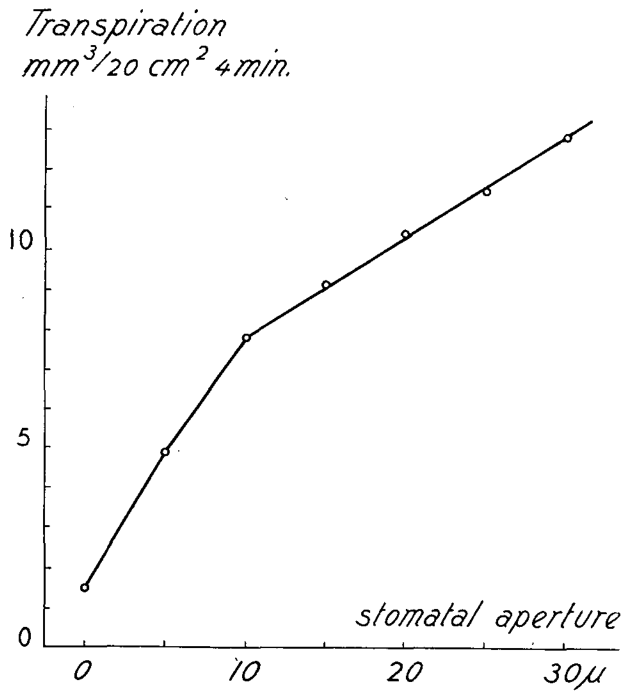

FIG. 6. THE RELATIONSHIP BETWEEN STOMATAL APERTURE AND TRANSPIRATION AT CONSTANT LIGHT INTENSITY.

Because of the fact that we have straight lines here, this holds good for all light intensities.

In figure 6 we have plotted transpiration rate against stomatal aperture at constant energy supply. This gives the familiar picture which can also be found in most textbooks. According as the stomatal aperture increases, the increase in transpiration rate becomes flattened.

Summarizing we arrive at the conclusion that it is not possible to find a simple proportionality between transpiration rate and energy supply. This makes it clear that there is much more in the process than mere physical evaporation. Although the rate of water loss is partially governed by physical factors in the environment, in much the same way as this is the case with evaporation from a water surface, frequently there exist notable differences from the former phenomenon.

The stomatal aperture as well as the energy supply is important in determining transpiration rate, but the relationship between these two factors and the transpiration is a rather complex one, because of the interaction of light intensity and stomatal aperture, as the one factor, light intensity, has a distinct influence on the other factor, stomatal aperture.

If in agricultural practice the transpiration is found to be proportional to radiant energy we have to assume that in the different observational periods equal mean stomatal apertures have occurred.

TRANSPIRATION OF GLASSHOUSE TOMATOES, LETTUCE AND CARNATIONS

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Summary

The relationship between the transpiration from glasshouse crops and the total incoming radiation is shown graphically for tomatoes, lettuce and carnations. Daily values of transpiration and radiation are plotted for all three crops, the results including readings taken in winter as well as summer months and also illustrating the effect of incomplete vegetative cover of the glasshouse area. In addition hourly values of radiation and transpiration of tomatoes and carnations measured over two-day periods during the summer, are presented.

Introduction

The purpose of this contribution is to provide some experimental results on the transpiration of glasshouse crops, and to emphasize the high correlation of daily and hourly values of transpiration with tolat radiation from the sun and sky. It is hoped that the data will usefully supplement results already obtained for outdoor crops by Penman and others. No attempt is made here to discuss the results in the light of the theoretical work of Penman (1948), Thornthwaite (1948), and de Vries et al. (1953, 1954). Attention is directed rather to the