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http://hdl.handle.net/2324/8115

出版情報：BIOTRONICS. 14, pp.1-6, 1985-12. Biotron Institute, Kyushu University
バージョン：
権利関係：

BIOTRONICS **14**, 1–6, 1985

EFFECT OF SOIL WATER POTENTIAL ON TRANSPIRATION RATE IN CUCUMBER PLANTS

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(Received August 25, 1985)

CHO T., EGUCHI H., KURODA M., TANAKA A., KOUTAKI M., NG Ah Lek and MATSUI T. *Effect of soil water potential on transpiration rate in cucumber plants.* BIOTRONICS **14**, 1–6, 1985. In an attempt to examine the effect of soil water potential (pF) on transpiration rate, leaf temperature of cucumber plants was measured under various conditions of soil water potential, and transpiration rate was calculated from heat balance of the leaf. Transpiration rate decreased with reduction in soil water potential; transpiration rate dropped at soil water potentials lower than pF 3.0. This fact suggests that the reduction in soil water potential restricts water uptake in roots and causes a decrease in leaf water potential, which results in lower transpiration rate through stomatal response to the leaf water potential.

INTRODUCTION

It is known that transpiration in plants is affected by various environmental factors (*1–8*). In particular, soil water potential seems to be one of the important factors responsible for the transpiration. For optimalizing the irrigation system, it is necessary to examine the relation between transpiration rate and soil water potential. The present paper deals with analysis of effect of soil water potentials on transpiration rate in cucumber plants, on the basis of heat balance of leaf under controlled environment.

MATERIAL AND METHODS

Material plant

Cucumber plants (*Cucumis sativus* L. var. Hort. Chojitsu-Ochiai No. 2) were used in the experiments. The plants were potted in sandy loam soil moistened with nutrient solution as described below and grown at an air temperature of 23 ± 1°C and a relative humidity of 70 ± 5% in a phytotron glass room. When the plant

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was 22 days old (4 leaves stage), the intact 2nd leaf of healthy growth was used as a specimen.

Control of air

In a growth chamber, ambient air temperature and relative humidity were controlled at 25°C and 40%, respectively. The direction of air current was parallel to the leaf, and the air velocity was 0.3 m sec^{-1}.

Control of soil water potential and moisture content

Cylindrical plastic pots, 14.5 cm in diameter and 23.0 cm in height as shown in Fig. 1, were used to grow plants. A plant for measuring was planted in each pot. The upper part of the pots was filled with 7 cm of sandy loam soil with a dry bulk density of 1.25 g cm^{-3}. The remaining lower 15 cm was filled with glass beads (1.2 cm in diameter). A screen placed over the beads supported the soil layer. The soil moisture characteristic curve in drying process is shown in Fig. 2.

The variation of water potential, measured in the center of the 7 cm of soil, was kept small. Both the tensiometer and the psychorometer were used in the measurement of the potential (i.e. pF value). The aspirator controlled the potential and soil moisture at different initial values by applying suction at the bottom of soil layer. The soil surface was covered to prevent surface evaporation.

Instrumentation of transpiration rate

The leaf was fixed horizontally and radiated vertically with tungsten light after keeping the plant in darkness for 5 hr. The total flux density of the light was 171 mW cm^{-2} in 0.35–60 μm, which consisted of shortwave radiant flux density of 64 mW cm^{-2} in 0.35–3 μm (4 mW cm^{-2} in 0.4–0.7 μm) and longwave radiant flux

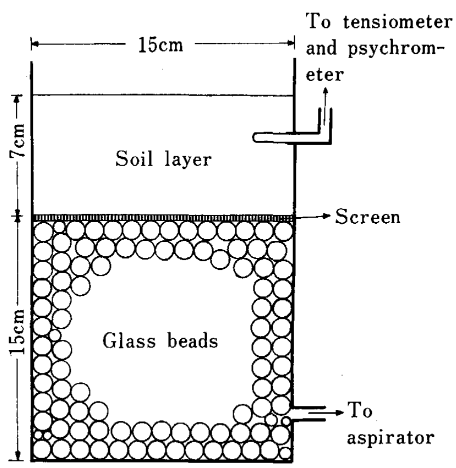

Fig. 1. Schematic diagram of soil water potential control.

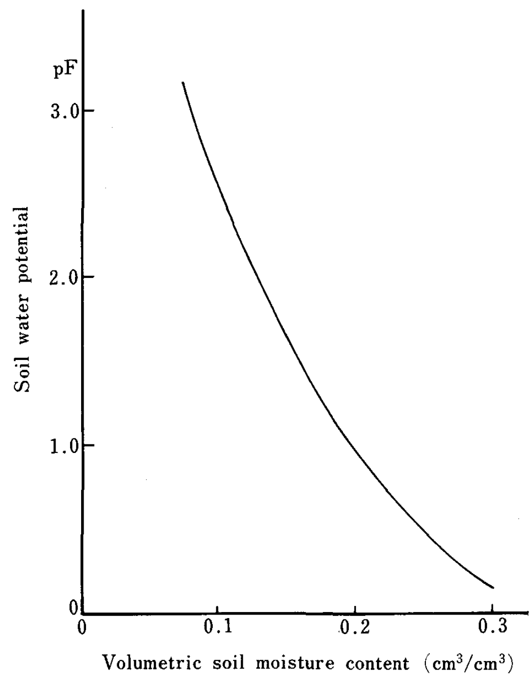

Fig. 2. Soil moisture characteristic curve.

density of 107 mW cm^{-2} in 3–60 μm. Leaf temperature was measured with thermocouple (copper-constantan) of 0.1 mm in diameter, which was inserted into a leaf. In this system, transpiration rate was calculated on the basis of heat balance analysis described below.

RESULTS AND DISCUSSION

Heat balance analysis

On the basis of heat balance of the leaf, transpiration rate (E) was calculated from following equation (*5*, *6*),

$$E=\frac{6\times10^{-2}}{\lambda}\left\{R_i-(1-A_b)R_s-2\cdot\varepsilon\cdot\sigma\cdot(273.16+T_l)^4 -10^3\cdot s\cdot m\cdot\frac{dT_l}{dt}-\frac{2\times10^3\cdot C_p\cdot\rho\cdot(T_l-T_a)}{r_{ah}}\right\} \quad (1)$$

where boundary layer resistance (r_{ah}) of leaf was given by resistance (r_f) to free convection and resistance (r'_{ah}) to forced convection as follows,

$$r_{ah}=\frac{r_f\cdot r'_{ah}}{r_f+r'_{ah}} \quad (2)$$

with

$$r_f=\frac{d}{0.405\cdot D_h\cdot(G_r\cdot P_r)^{1/4}} \quad (3)$$

In this experiment, coefficient (A_b) of shortwave absorption by leaf was 0.46 and resistance (r'_{ah}) to forced convection was 0.69 sec cm^{-1}, where measurements of A_b and r'_{ah} followed the manners reported by Kitano *et al.* (*5*).

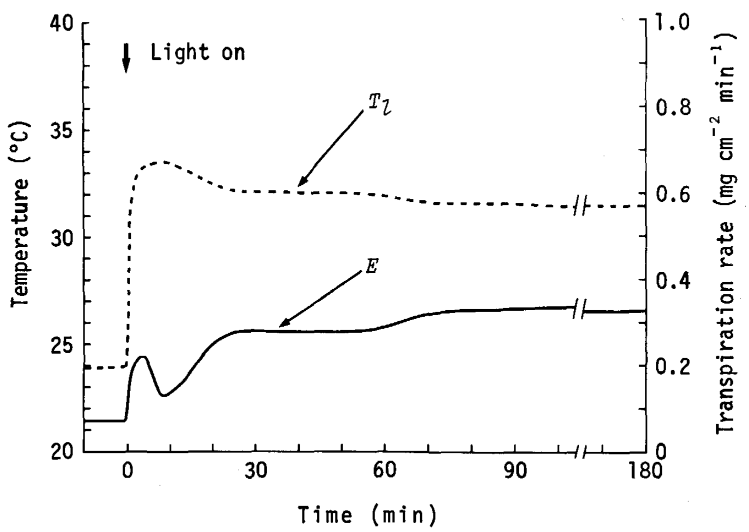

Fig. 3. Leaf temperature (T_l) and transpiration rate (E) in the 2nd leaf (at 4 leaves stage) radiated by tungsten light under a soil water potential of pF 1.8 and a constant air condition (25°C, 40% RH).

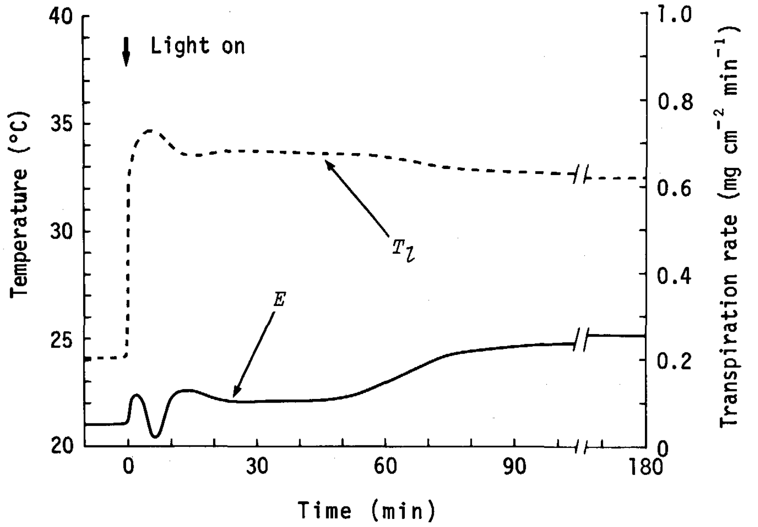

Fig. 4. Leaf temperature (T_l) and transpiration rate (E) in the 2nd leaf (at 4 leaves stage) radiated by tungsten light under a soil water potential of pF 2.6 and a constant air condition (25°C, 40% RH).

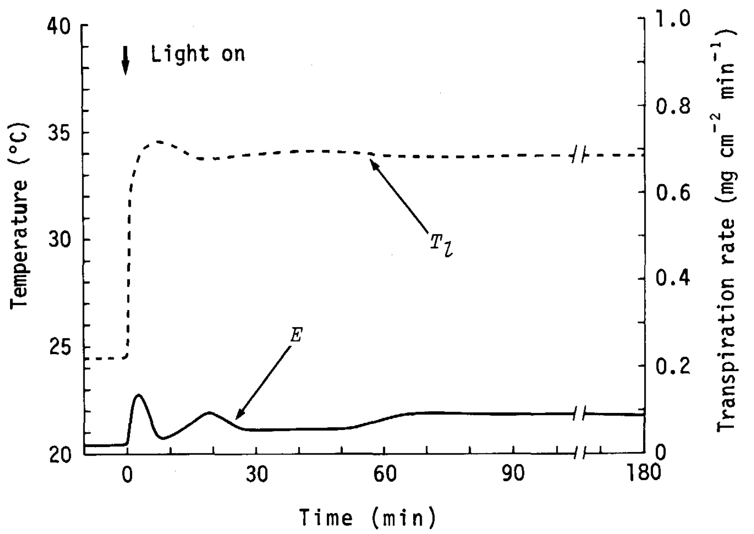

Fig. 5. Leaf temperature (T_l) and transpiration rate (E) in the 2nd leaf (at 4 leaves stage) radiated by tungsten light under a soil water potential of pF 3.8 and a constant air condition (25°C, 40% RH).

Transpiration rate

Figure 3 shows time course pattern of leaf temperature and transpiration rate under a soil water potential of pF 1.8. When the leaf was radiated, the leaf temperature rose rapidly, and settled in course of time within 180 min after radiation. The transpiration rate became almost constant 60 min after radiation and was about 0.32 mg cm^{-2} min^{-1}. Figure 4 shows time course pattern of leaf temperature and transpiration rate under a soil water potential of pF 2.6. The transpiration rate

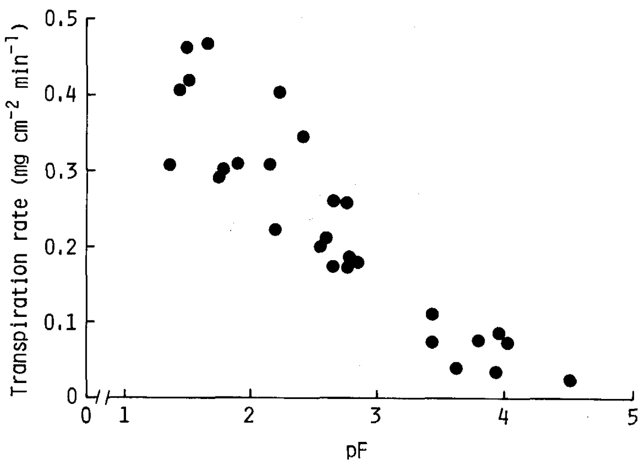

Fig. 6. Relation between soil water potential (pF) and means of transpiration rate for 180 min after radiation of tungsten light under a constant air condition (25°C, 40% RH).

appeared similar to the pattern of Fig. 3, but its elevation was lower as compared with that at pF 1.8 (Fig. 3). Furthermore, the experiment was carried out in a treatment where soil water potential was much reduced. Figure 5 shows time course pattern of leaf temperature and transpiration rate under a soil water potential of pF 3.8. The transpiration rate settled 60 min after radiation and became remarkably low.

To estimate the effect of soil water potential on transpiration rate, the transpiration rate was averaged for 180 min after radiation and plotted on pF as shown in Fig. 6. Distinct relation was found between transpiration rate and soil water potential. The transpiration rate decreased gradually with reduction in soil water potential and became remarkably low at soil water potential lower than pF 3.0. This fact suggests that a change in soil water potential can affect the water balance of leaf, and the reduction in soil water potential results in a decrease in transpiration rate by decreasing the water potential of leaf.

APPENDIX: LIST OF SYMBOLS

A_b	coefficient of shortwave absorption by leaf.
C_p (J g^{-1} °C^{-1})	specific heat of air.
d (cm)	characteristic length of leaf.
D_h (cm^2 sec^{-1})	thermal diffusivity of air.
E (g cm^{-2} min^{-1})	transpiration rate.
G_r	Grashof number.
m (g cm^{-2})	leaf weight per unit area.
P_r	Prandtl number.
r_{ah} (sec cm^{-1})	boundary layer resistance of leaf to heat transfer.
r'_{ah} (sec cm^{-1})	resistance to forced convection.
r_f (sec cm^{-1})	resistance to free convection.
R_t (mW cm^{-2})	total radiant flux density.

R_s (mW cm^{-2})	shortwave radiant flux density.
s (J g^{-1} °C^{-1})	specific heat of leaf.
t (sec)	time.
T_a (°C)	air temperature.
T_l (°C)	leaf temperature.
ε	emissivity of leaf.
λ (J g^{-1})	latent heat for vaporization of water.
ρ (g cm^{-3})	density of air.
σ (mW cm^{-2} K^{-4})	Stefan-Boltzmann constant.

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