PHOTOELECTRIC DEVICE FOR RECORDING OF LEAF MOVEMENTS

(Research Note)

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Abstract. A photoelectric device is described that may have usefulness for sensing rhythmic leaf movements of plants in space experiments. The system provides an instantaneous record of the precise angular change in position of the leaf blade and avoids physical attachment or disturbance of the plant. This system has been utilized to record leaf movements for several weeks. The device is sufficiently sensitive to record small rapid oscillations by the leaf of only 2° angular movement.

1. Introduction

Several techniques have been developed for recording leaf movement rhythms in plants. The kymograph (Bunning and Moser, 1966; Shigemura and Yokoyama, 1967), time lapse photography (Hoshizaki and Hammer, 1964), strain gauges (Hoshizaki and Yokoyama, 1965) and electrical contact devices (Halaban, 1968; Pfeffer, 1907) have all been utilized effectively in certain experiments. The need for a method that would avoid physical attachment of the sensors to the plant and also provide an instantaneous and direct readout of the movement, led to the development of the following described photoelectric system.

2. Materials and Methods

The complete system consists of three units; a light source and detector, a servo amplifier and motor, and a recorder. The first two are shown in Figure 1. An incandescent light source (L) is mounted in a 3.0 cm by 5.0 cm lucite chamber. The bulb chosen was a GE 327 requiring about 0.9 W of power. The light output is directed by a 34″ length of fiber optics (American Optical LMG1) to the yoke (Y). The fiber optics were used to eliminate photothermic effects. The resulting 10 mm diameter collimated beam of light, passes across the yoke to the detector. The detector consists of two clairex CL 905L photo resistors forming two arms of an AC electrical bridge circuit. These photoresistors have a peak spectral response at 5500 Å. The resulting AC voltage is connected to an operational amplifier and its output is amplified by a transistorized power amplifier. This signal drives one winding of a two-phase servo motor. The other winding is driven by 110 V AC. The motor is coupled through gear trains to the yoke and to a potentiometer. The yoke revolves at the rate of 1.5° per sec. The DC signal from the potentiometer is displayed on a strip chart recorder. Figure 2 shows the essential features of the servo system.

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The plant is positioned beside the sensor and the instrument set so that the tip area of one leaf will be centered in the yoke and equal amounts of light fall on each photoresistor. The system is balanced when equal amounts of radiation illuminate each photoresistor. The yoke is positioned so that the axis of rotation of the yoke coincides with the junction of the blade and petiole, which is the axis of rotation of the leaf blade. As the leaf moves, the two photoresistors receive unequal quantities of radiation. This imbalance activates a servomotor to rotate the yoke and return the system to a balanced position. The yoke is constructed to rotate through a maximum of 150° at 0.5° per second. The output of the servo motor, which represents the movement of the leaf within the yoke, is recorded on a strip chart driven at 5″ per hour. The recording is a linear plot of the angular change in leaf position.

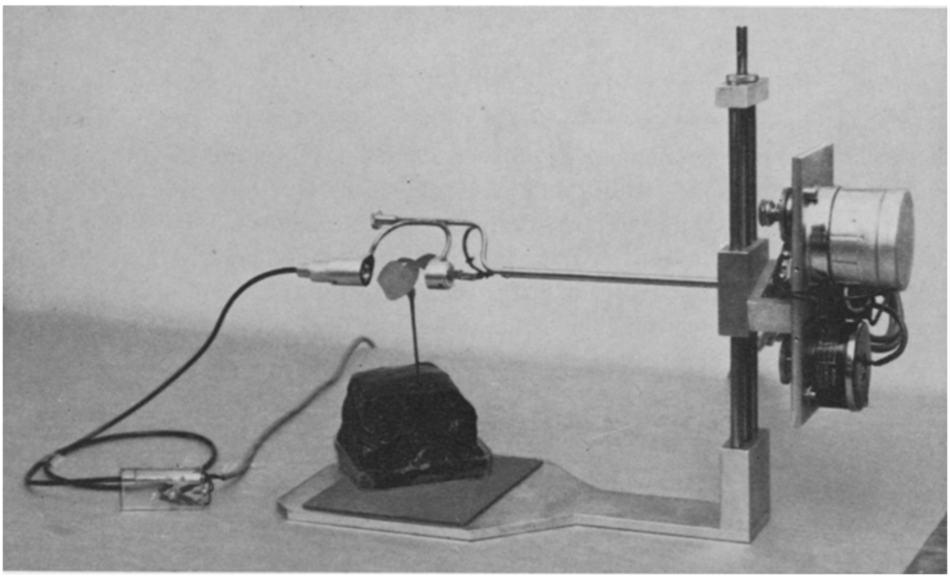

Fig. 1. Photoelectric system for recording of leaf movements in bean plants.

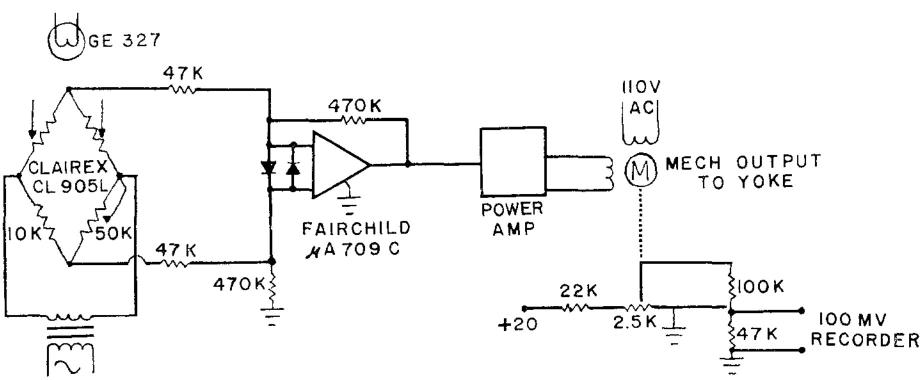

Fig. 2. Servo amplifier circuitry of the photoelectric device.

The movements of leaves of *Phaseolus angularis* maintained under 300 ft-c of fluorescent light have been followed with this system. The unifoliate leaf of a plant was aligned with the yoke and movement recorded. A reproduction of a few hours of recorded data obtained with this system is shown in Figure 3. The movement of the leaf is shown in degrees. The vertical position of the leaf is plotted as 0° and a horizontal

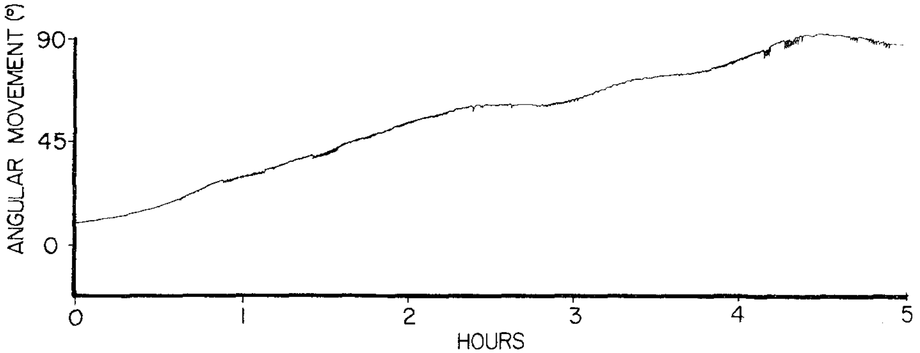

Fig. 3. Recorder plot of movement of leaf blade of a bean plant over a 5-hr period.

position of the leaf is plotted as 90°. The upward movement is not uniform, for the device recorded a number of irregular leaf movements during this interval as seen in the figure. The sensitivity of this device permitted the detection of leaf movements of less than 2° of angular change within short intervals of less than a minute. It was suspected that these short spike oscillations may have been due to instability in the electrical system; however, when an artificial leaf was placed between the sensor, these rapid oscillations were not observed on the recorder.

A plotting of several days of recorded data with a reduced time scale is shown in Figure 4. The distinct circadian movement of about 27 hours is evident in these data.

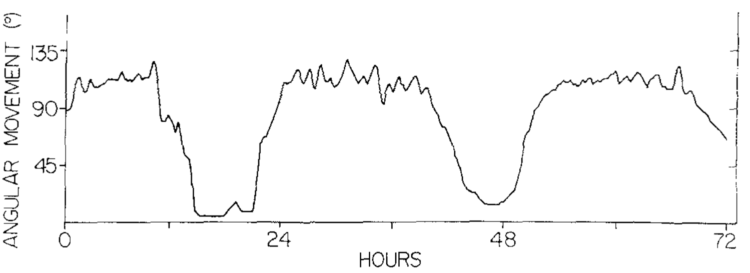

Fig. 4. Movement of leaf blade of a bean plant over a 72-hr period.

3. Discussion

This system has successfully tracked leaf movements for several weeks. It can effectively maintain tracking even though the leaf may exhibit sidewise movements which increases the amount of leaf surface intercepting the light beam. There is no apparent phototropic effect from the sensor light upon the experimental leaf, for it maintains a horizontal orientation in the center of the yoke while the sensor is operating. Nonetheless it would appear desirable to investigate the suitability of utilizing a radiation source and photoresistors for a wavelength range above 8000 Å to provide movement detection at wavelengths that would have no phototropic effects in plants.

It is anticipated that this system will have particular advantages for the sensing of leaf movement rhythms during space flight for it will permit remote sensing and require a minimum of data telemetry. In addition, studies have been initiated to determine the feasibility of utilizing this leaf movement system as a biological monitor of atmospheric pollution.

Acknowledgements

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