On a New Automatic Leaf-Area Meter

Y. MURATA

Chief, 1st Division of Physiology, Department of Physiology and Genetics,
National Institute of Agricultural Sciences

Introduction

In the physiological or ecological studies of crop plants, leaf area measurement is very frequently needed. However, the practice is quite tedious and time-consuming, be it done by the linear measurement method, the planimeter method or the blue print-weighing method. Various apparatuses, such as an air-flow planimeter, photoelectric planimeter, and others have already been devised and reported, but they are not very satisfactory either in efficiency or in accuracy.

Very recently, however, a new, automatic, photoelectric leaf-area meter has been developed in Japan[1] after several years of trials and improvements. It is very accurate and at the same time highly efficient with a semi-automatic feeding mechanism which was never realized in any previous apparatus.

Principle

The outer look is shown in figures 1 and 2. Two types, a combined one and a separate one, are available. The principle of the apparatus is shown schematically in figure 3.

Material leaf, A, is conveyed horizontally at a definite speed as it is gently pressed between two layers of transparent plastic belt, B_1 and B_2. As the leaf proceeds, it passes across a screen of light which has been emitted from a small lamp, L_1, and reflected by a specially-designed concave mirror, R_1, so as to fall at right angle on the leaf surface. After interception by the leaf, the remaining part of the light screen falls into a narrow, curved slit, D, bored on a light-shielding plate, C, which is placed horizontally beneath the belt B_1. After passing the slit, the light screen is cut into

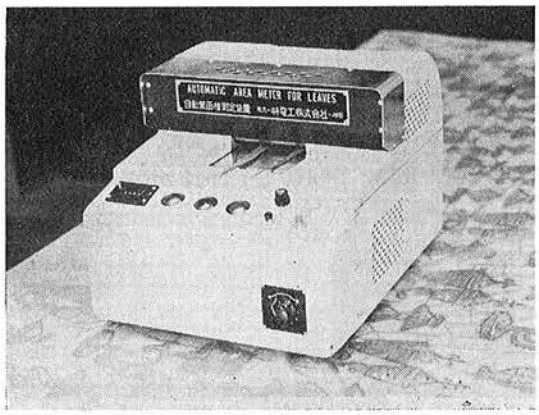

Fig. 1 Automatic leaf-area meter, combined type

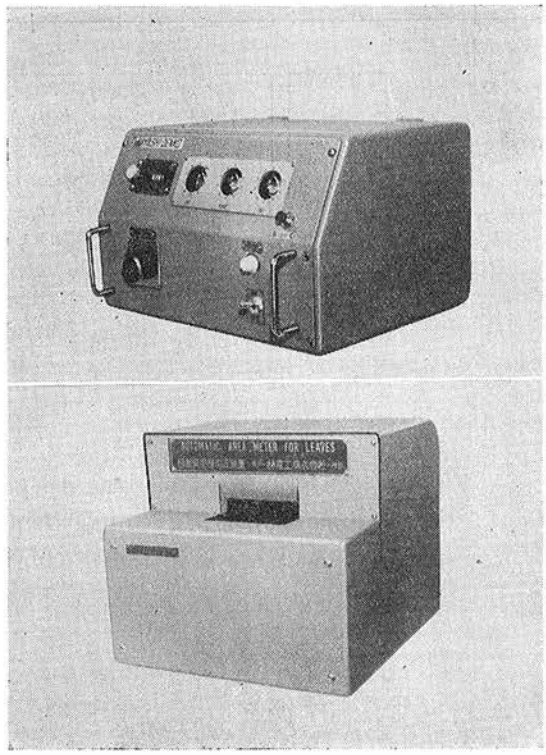

Fig. 2 Automatic leaf-area meter, separate type

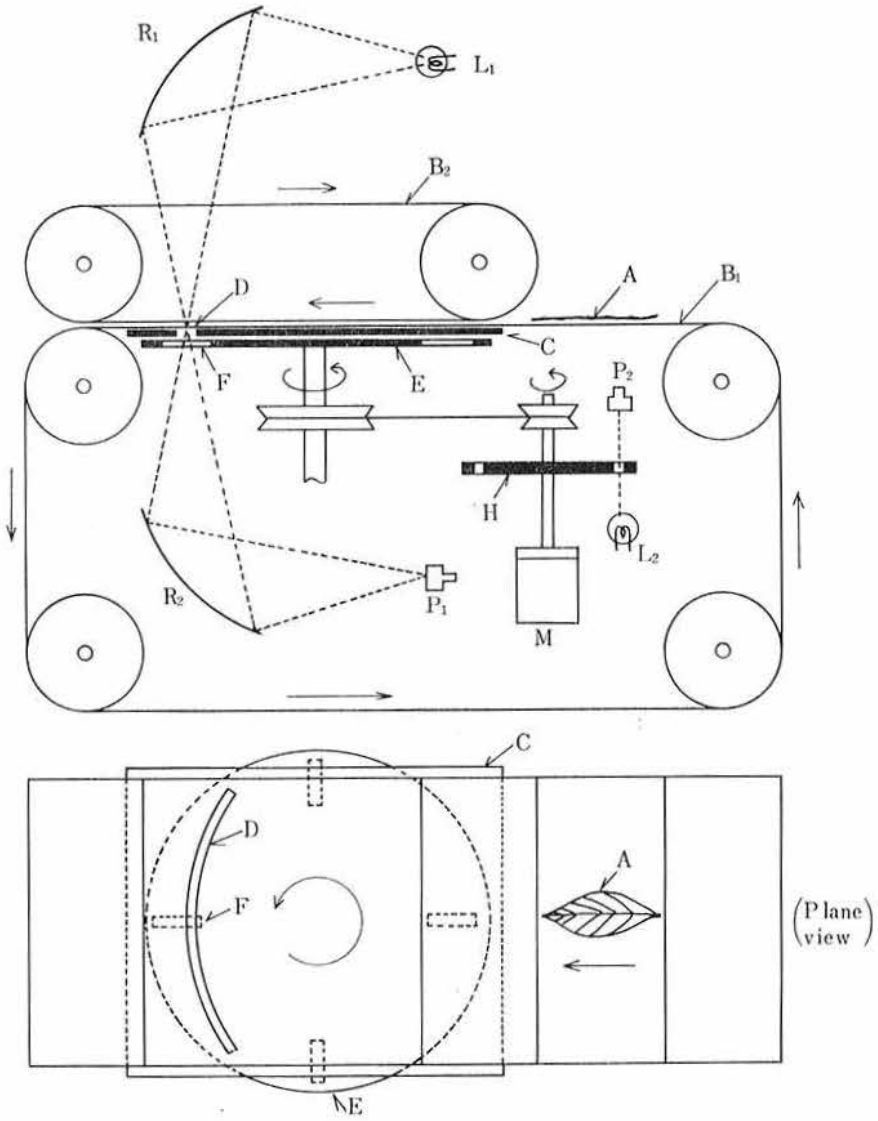

Fig. 3. The principle and basic design of the automatic leaf-area meter.
A: sample leaf, B_1, B_2: transparent belt, C: shielding plate, D: curved slit.
E: rotating plate with radial slits (F), L_1, L_2: lamp, R_1, R_2: concave mirror.
P_1, P_2: photo-transistor, H: perforated disk, M: motor.

a moving light beam with a unit cross area by a series of revolving slits, F, arranged radially on a horizontal disk, E, which is revolving beneath the curved slit.

In this way, the transparent belt, with the sample leaf on it, is continuously scanned by the moving light beam from one side of the belt to the other side. The moving light beam which is made intermittent as a result of interception by the leaf is reflected and concentrated by a second concave mirror, R_2, and finally received by a photo-transistor, P_1. Here, the light beam is changed into corresponding, intermittent electric signals, *controlling pulses*, which in turn are sent to an electric scaling circuit ——not shown in the figure——so as to control the function of the latter to count the *basic pulses* which are continuously generated and fed by a separate device composed of a second lamp, L_2, a perforated revolving disk, H, and a second photo-transistor, P_2.

The controlling pulse-generating circuit is connected to the scaling circuit via an appropriate gate circuit——also not shown in the figure——and the whole circuits are so arranged that the number of basic pulses are counted only when the difference in the magnitude of signals between the basic pulses and the controlling pulses exceeds a certain level, in other words, only when the sample leaf is intercepting the light beam. The scaling circuit is connected to a magnetic counter to show the area of the sample leaf directly in numerals.

Performance

Special designs and devices are adopted to eliminate the causes of error as far as possible so as to attain the highest accuracy.

To minimize the influence of changing speed of various moving parts, namely, the transparent belts (B_1, B_2), revolving plate (E), and the perforated disk (H), all the movement of these parts are synchronized, being driven by a single motor (M).

The surface of the concave mirrors, R_1 and R_2, has a specially-designed curve to change the radial light from the lamp, L_1 into parallel one which focuses near the fixed, curved slit, D, with the aim to prevent the reflecting light from weakening and at the same time to make free from the influence of outside light migrating into inside. Special design is also adopted in the shape of the curved slit in order to make the component of the lateral velocity of the scanning light equal throughout the whole width of the slit.

It was one of the most difficult problems in all the hitherto-devised photoelectric apparatuses, except for the single case of Orchard's apparatus[2], how to eliminate the error arising from the difference in leaf thickness. In the present apparatus, the area-measurement does not depend on what extent the reduction of light intensity occurred, but on whether there occurred differences beyond a certain level between the light intensity before and after the interception by the leaf sample, making the area-measurement completely free from the differences in leaf thickness. This is one of the most important advantages of a digital type apparatus in contrast to an analogue type one.

As a result of all these improvements, the error of one measurement by the present apparatus falls within ± 1.5 per cent of the measured value, regardless of the difference in shape, size or color of the sample. The sensitivity, that is, the smallest measurable area is 0.04 square centimeter.

As for the speed of measurement by this apparatus, it took, for instance, 5 minutes 22 seconds to measure the total area of a sample which consisted of 140 pieces of section paper, each of which having from 5 to 50 square centimeters and 1,000 square centimeters in total area.

References

1) Murata, Y., and Hayashi, K.: On a new, automatic device for leaf area measurement. Proc. Crop Sci. Soc. Japan, 36, in press
2) Orchard, B.: An automatic device for measuring leaf area. Jour. Exptl. Botany, 12 (36) 458-464, 1961