A Disk Camera System for Automatic Recording of Visual Data: Snow Depth in Field Plots

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ABSTRACT

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A disk camera triggered by a timed signal provided an inexpensive method of obtaining visual data at a remote site. We used the method successfully to record snow depth and duration in experimental plots during the winters of 1984–1985 and 1985–1986. The system can be adapted to accommodate any exposure interval greater than 1 sec, with the time between site visits limited by the number of exposures (15) available per film disk.

Additional key words: *Ascocalyx abietina*, data logger, *Gremmeniella abietina*, *Pinus resinosa*, Scleroderris.

Suitable sensors are available to equip remote weather stations for automatic recording of most aspects of the physical environment. For example, temperature, wind speed and direction, and relative humidity can all be sensed and recorded automatically at remote sites with relatively reliable, inexpensive equipment. In some cases, however, simple, inexpensive sensors are not available. Snow depth is an example of a kind of physical variable that is normally recorded visually. Adequate determination of snow depth either requires relatively sophisticated (and expensive) equipment, or a visual record (2,4). At times, however, a record of snow depth at a remote site is a necessary part of research in plant pathology. We were made aware of this by the following example:

Scleroderris canker and dieback, incited by the North American strain of the fungus *Gremmeniella abietina* (Lagerb.) Morelet, is a problem on red pine (*Pinus resinosa* Ait.) in northern Wisconsin. A relationship between disease occurrence and snow depth and cover has been suggested (3,5,6). Because the fungus is capable of growth at temperatures above −6 C (1), we proposed that the more temperate physical microenvironment created by snow favors colonization by the fungus.

To test this hypothesis, an automatic recording system was needed on two experimental plots established near Madison, WI, and two 420 km north of Madison. Three-year-old red pine seedlings were inoculated with a conidial suspension of *G. abietina* in June 1984. In southern Wisconsin, one of the plots was covered throughout the winter with artificial snow provided by a local ski club. In northern Wisconsin, a fine mesh aluminum-screened cage was placed over one plot. This cage prevented accumulation of snow on the trees but allowed penetration of light and air. The remaining two plots were exposed to natural snow conditions. Daily air temperatures within the canopy of the four plots were sensed with thermistors, recorded with a CR-21 (Campbell Scientific, Logan, UT) data logger, and stored in a solid state storage module (Campbell Scientific model SM64). Daily measurement of snow cover and depth, however, presented a problem.

Snow gauges commonly used at remote or unattended sites record only seasonal precipitation totals (2). To determine the depth of snow at a particular time and site, measurements must be made directly. Although devices are available that measure mass of snow by sensing pressure in a "snow pillow" or by attenuation of γ radiation (2), these were not appropriate for our needs.

Our objective was to develop an inexpensive, reliable technique to automatically record snow depth at regular intervals on the four experimental plots. We used the CR-21 data loggers already recording data at the sites, adding snow stakes and a switch relay, which automatically triggered two disk cameras at each location.

EQUIPMENT

Disk camera. Disk cameras are equipped with automatic advance, exposure control, and flash. These features are included in many cameras presently on the market; however, the disk camera combines these features and low cost. In addition, some disk cameras, for instance the Minolta Disc-7, also have two-zone focusing that allows for closeups (as close as 40 cm) and a shutter release that can be modified for external electronic triggering. This, in turn, allows control of the time of each exposure by a device external to the camera.

Triggering mechanism. Because of the automatic advance system of the disk camera, continued depression of the shutter release button will result in a continuous series of photographs taken at about 1-sec intervals. To avoid such multiple exposures when using remote triggering, a switching device should provide a pulse of less than 1 sec to actuate the shutter release. On the Minolta Disc-7, the cable release closes the internal shutter release circuit of the camera. A simple electronic relay connected to the cable release can be used to transmit a timed signal to trigger exposures. A suitable relay (Fig. 1) consists of a 2N2222 transistor and an RC circuit. The time constant of the RC circuit determines the length of time the camera release is actuated when a step signal is supplied. Diodes may be used to prevent crosstalk between cameras, if two or more cameras are to be triggered simultaneously

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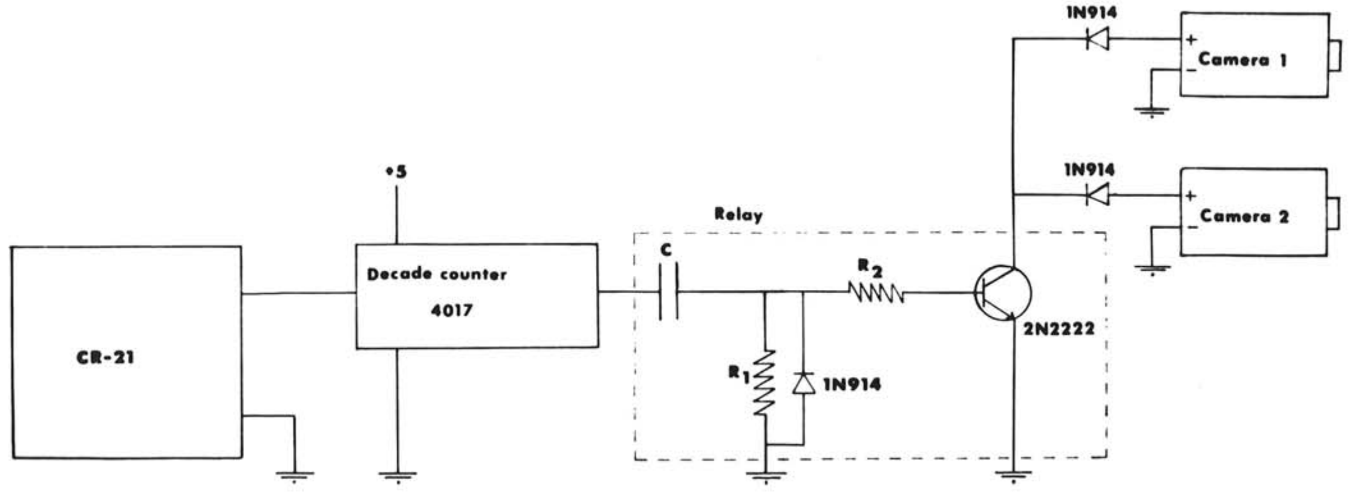

Fig. 1. Schematic of disk camera connected to CR-21 via decade counter and relay circuit. Suggested values might be $R_1 = 2.2$ mega ohm, $R_2 = 6.8$ kilo ohm, and C = 0.33 μF.

(Fig. 1). The signal can be provided by any suitable timing device. Some data loggers (e.g., the CR-21) have output ports that can be programmed to deliver a signal at predetermined times, or at the time of a given event. Data loggers with this capability are frequently used to gather environmental data and can conveniently be used concomitantly to provide the triggering signal(s) for the camera. The CR-21 data loggers that we were already using at the sites to gather other data were suitable for this purpose.

The time interval between exposures can be varied in two ways. First, the interval between triggering signals from the timer can be varied. By varying the programmed control port interval of the Campbell Scientific CR-21, for example, exposure intervals between 2 min and 24 hr can be obtained. Second, an integrated circuit counter/divider (Fig. 1) can be used to trigger the camera only every *n*th time the initial signal goes positive. Coupled with a CR-21, this allows for exposure intervals greater than 24 hr.

SNOW DEPTH MEASUREMENTS

We used the system throughout the winter of 1984–1985 and again in 1985–1986 at the *G. abietina* experimental plots. The equipment included Minolta Disc-7 cameras, the relay described above, and a CR-21 data logger. The CR-21 was programmed to output a 5-V signal of 1-min duration to the relay at 24-hr intervals; a 4017 decade counter/divider was set to divide this time by two and thus trigger the camera once every 48 hr (Fig. 1). The clock of the CR-21 was offset by 12 hr to trigger the camera at noon rather than at midnight. The sites were visited every 30 days to check the equipment and change film (15 exposures).

The cameras were secured within plywood boxes with acrylic plastic windows in front and back. The boxes were mounted on pipes driven into the ground, at a height and angle suitable to view the experimental plots. Graduated stakes were driven into the ground in view of the cameras (Fig. 2). Our method would have been improved had we used thinner stakes to avoid a depression in snow cover at the base of the stakes. A 115-V AC, 18-W heating tape in series with a thermostat was wrapped around the inside of each box. The heaters, powered from an outlet in a nearby building, heated the cameras when temperatures dropped below 0 C. Housed in this manner, the cameras functioned throughout the winter, at ambient air temperatures as low as −36 C. The automatic flash was found to be unnecessary even on overcast days, and was covered to eliminate reflection in the windows. A temporary covering was placed behind the cameras to reduce reflections from external light and prevent heating of the camera backs in bright sunlight. With these modifications, photographs with sharp focus, adequate light, and acceptable color and contrast were obtained (Fig. 3). The photographs provided evidence that the seedlings in the "snow" plot (Fig. 3A) were, indeed, completely covered by snow, while those in the "no-snow" plot (Fig. 3B) were free from snow cover. Snow depth between the stakes was interpolated from the photographs (Fig. 4). This illustrates the potential for the camera system to provide valuable qualitative, as well as quantitative, information.

The photographic data, coupled with the temperature data collected on the CR-21, provided good information on the microclimate to which the seedlings were exposed throughout the winter. The difference in canopy level air temperature between the snow and the no-snow plots for a single day is illustrated in Figure 5. Thus, photographic logging was used to supplement the physical measurements, and accurate data about specific sites were obtained, while the number of necessary visits to the sites was minimized.

DISCUSSION

This photographic technique successfully documented snow depth and duration of cover, which we related to changes in the thermal microenvironment of four experimental plots. Differences between snow depths as estimated photographically in our plots and visually in a nearby woods are probably due to the different

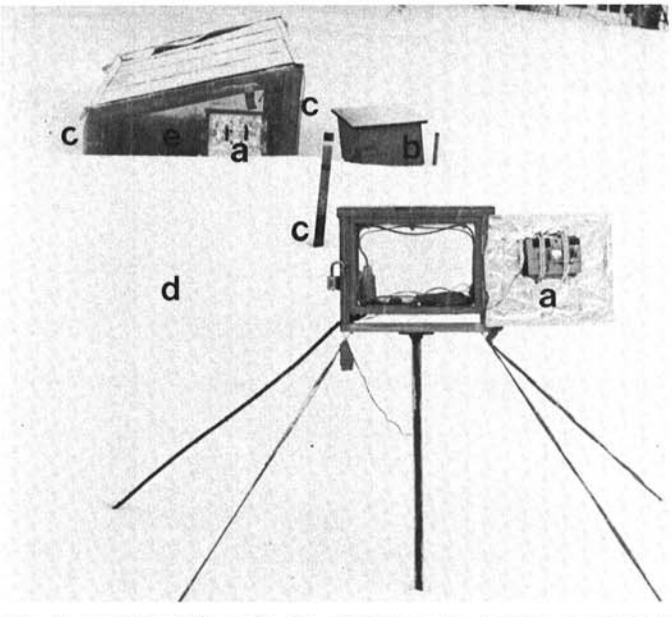

Fig. 2. Northern Wisconsin site showing boxes housing cameras as described in text (a), box housing CR-21 (b), graduated stakes (c), "snow" plot (d), and "no-snow" plot under cage (e).

exposures of the two sites to sun and wind. In addition to assessing snow cover or measuring snow depth, this technique may be applicable to many other data gathering situations. The system was originally developed to detect differences in the configuration of water from rain or dew on leaf surfaces. Although droplets on leaves could be observed, thin films, which are present on some crops (e.g., *Phaseolis vulgaris* L.), could not be distinguished from the dry-leaf surface. Other applications in plant pathology might include the documentation of symptom development on a given plant or plot over time or the change in percent canopy cover. In other fields the system might be used to record plant growth, insect defoliation, the presence of birds in a rookery, or movement of a glacier. The system is also suitable for the visual recording of rare events that could be triggered by an external source, such as a flood stage recorder. The necessary equipment is a relatively inexpensive addition to a common data-recording system, and the technique can be easily adapted to numerous experimental situations. Major drawbacks are the limited number of exposures available on one film disk and the lack of high resolution.

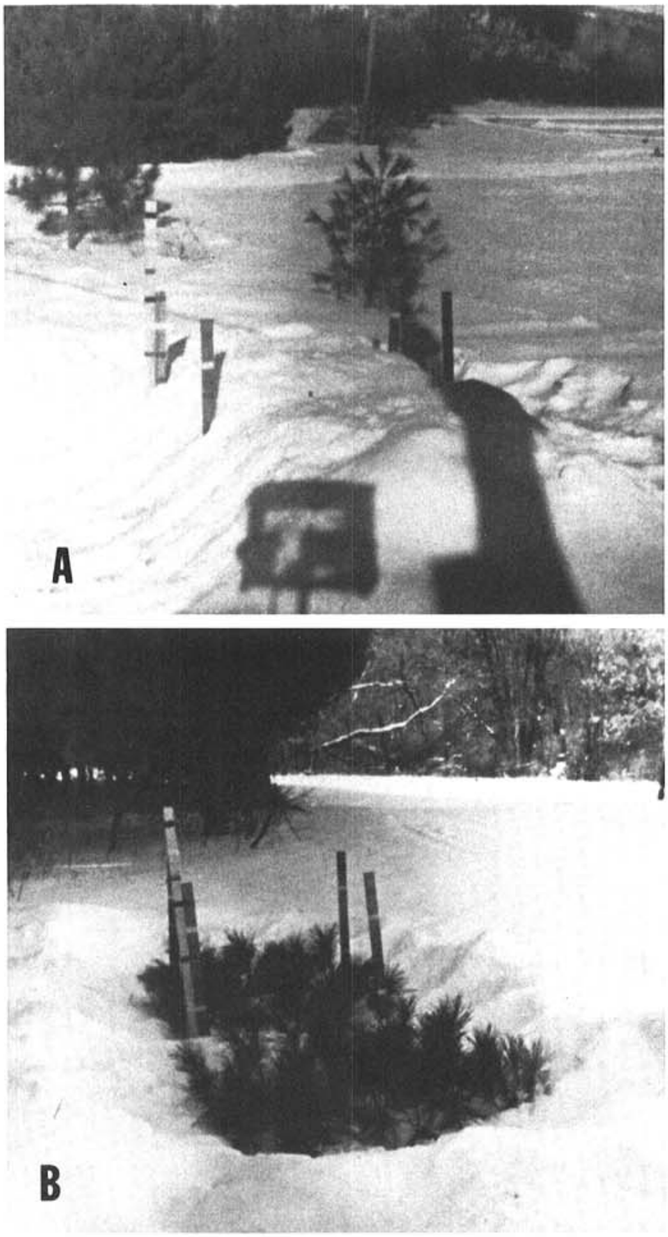

Fig. 3. Photographic record of the southern Wisconsin "snow" **(A)** and "no-snow" **(B)** plots made automatically with the disk cameras on 22 January 1985, verifying the presence and absence, respectively, of snow cover. The locations of the trees relative to the stakes are the same in the snow as in the no-snow plot.

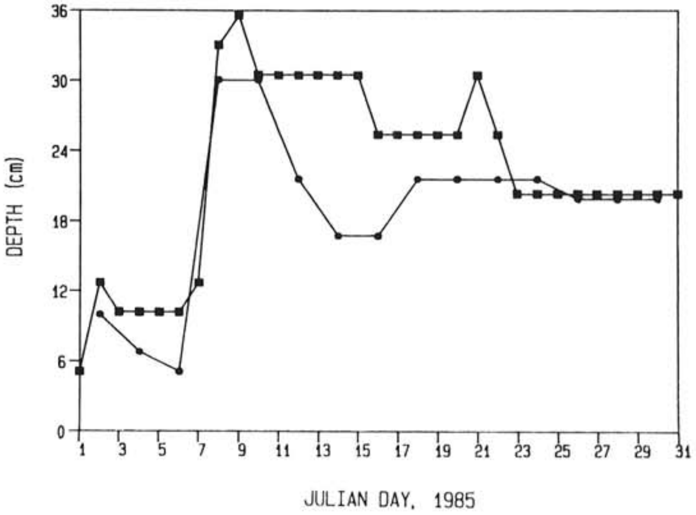

Fig. 4. Snow depth as recorded by the camera system (●) or by a local weather observer (■). Depth estimates from the camera system were made from photographs by interpolation between color-coded gradations on the stakes (see Fig. 2). Depth estimates recorded by the local observer were made by viewing snow stakes with binoculars. Stakes for these observations were 30–50 m from our plots and within the forest understory.

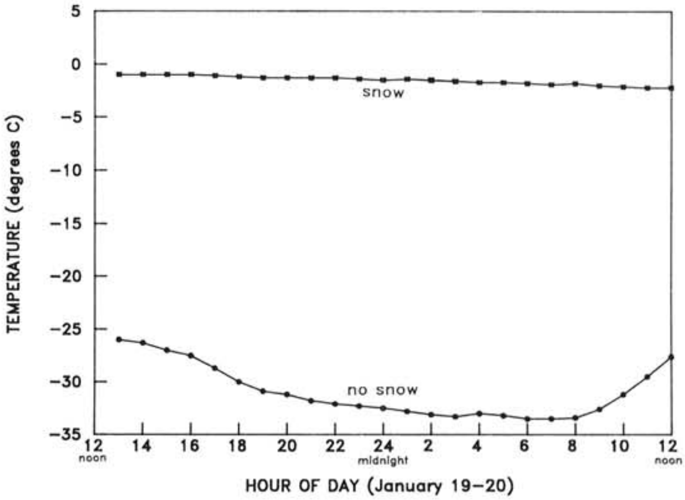

Fig. 5. Twenty-four hour temperature record (19–20 January 1985) for the plots shown in Figure 2.

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