A SIMPLE GERMINATOR FOR CONIFEROUS AND SMALL HARDWOOD SEEDS

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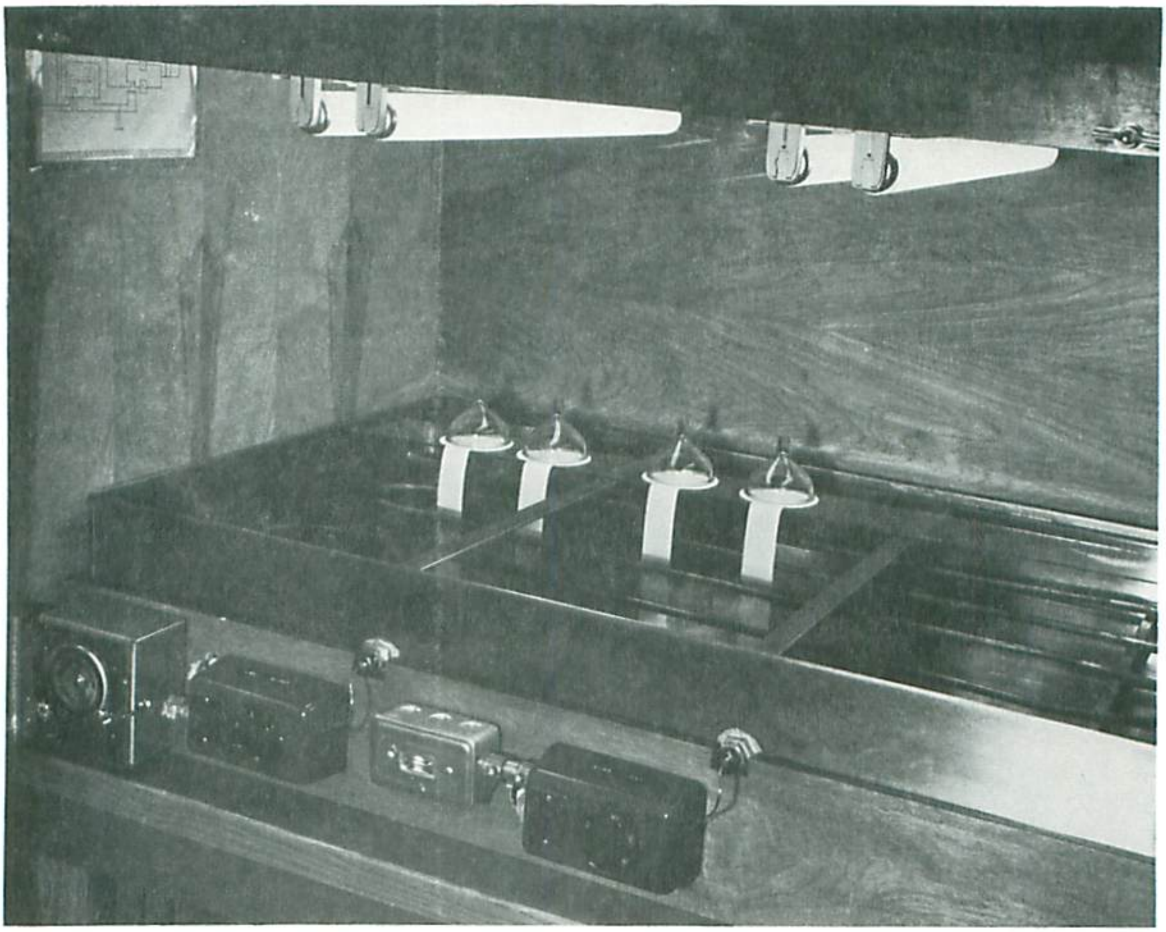

Frontispiece. *Germinator with water and five glass support plates removed (timeswitch and solenoid valve for cooling system not shown).*

ABSTRACT

A simple automated germinator is described, suitable for conducting germination tests on coniferous and small hardwood seeds under conditions recommended by standard seed-testing rules. The apparatus provides good control over germinating temperatures at the germinating surface when operating above ambient room temperature, and includes provision for a daily alternation of temperatures if required. An important advantage of this germinator is its ability to ensure a constant and uniform moisture supply to seed for the full duration of a test, thereby avoiding the fluctuations in moisture availability commonly associated with many other germination methods.

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INTRODUCTION

The principal objective of all methods for testing seed viability is to provide a basis for estimating the percentage of seeds in a given lot that may be expected to produce healthy seedlings under favorable conditions. The simplest application of such test results is in the determination of sowing rates for nursery and field seeding, but they also provide an index by which the quality of one seed lot may be compared with that of another, enabling poor seed to be identified prior to storage or sowing, and such factors as the effects of seed treatments to be evaluated.

Although numerous indirect methods have been evolved for estimating seed viability without germination, the true germinative capacity of a seed lot can only be estimated satisfactorily by actually germinating a representative sample under controlled conditions. Where legal certification of seed quality is required, a laboratory test of germinative capacity, conducted in accordance with standard procedures incorporated in recognized seed-testing rules (Association of Official Seed Analysts 1965; International Seed Testing Association 1966), is normally mandatory. These standard procedures aim at maximizing germination under controlled, reproducible conditions of temperature, moisture and light, maintained as near optimum as possible for the species under test in order to promote rapid and complete germination of viable seed. Such conditions are obviously quite different from those to which seed will be exposed in outdoor sowings, but although one normally expects lower germination values in nursery sowings than in laboratory tests performed under optimum conditions, nevertheless the latter do provide, in terms of rate and amount of germination, the only satisfactory index of seed quality based upon the biological potential of a seed lot.

While there is a recognized need to define more clearly the predictive relationships between laboratory and field germination values (Stein 1967), this does not lessen the practical significance of dependable, up-to-date information on the germinative capacity and vigor of seed. In larger organizations this information may be supplied by centralized seed laboratories, but there are many other situations where the ability to conduct reliable on-the-spot germination tests under controlled conditions would be advantageous if reasonably cheap, effective facilities could be made available. Modern germination equipment, desirable as it may be for research purposes and for routine testing in centralized facilities, is expensive, and rarely can its use be justified for situations where the requirement is for only casual or small-scale testing operations. On the other hand, without some provision for moisture and temperature control, petri dishes and other simple arrangements commonly used in such cases provide a totally inadequate and unreliable means of testing seed viability. Moisture control is usually the most

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critical factor with these simple methods; and without frequent attention, particularly during the period of maximum moisture imbibition by seed, both germination rates and final germination values may be adversely affected by the fluctuating moisture conditions.

This report describes a simple automated germinator (Frontispiece) suitable both for routine germination tests and for the research worker with a relatively small amount of material, which gives good control over temperature and moisture and which can be built for about $300. Such a germinator has been used by the author for more than a year with entirely satisfactory results.

DESIGN

In basic design the germinator is essentially an elaboration of the Jacobsen germinator (sometimes "Copenhagen germinator"), which, in its various forms, is still one of the most widely used pieces of apparatus for testing tree seed in Europe. The underlying principle is simple--a pan of water over which the seeds are supported on a suitable germination medium, moisture being supplied at a constant rate by absorbent wicks dipping into the water. Because of its essential simplicity, the method has many attractions for small-scale application; and the modifications described here were principally designed to superimpose upon it, at reasonable cost, reliable and accurate control over temperature (level and diurnal alternation). While it is recognized that further improvements in design are possible, the aim in developing this apparatus was to retain the original simplicity as far as possible, avoiding elaborate control systems, and at the same time reaching a compromise between operational reliability and low cost. The main components are:

water tank, stainless steel, 22 gauge, 42 x 24 x 4 3/4 inches deep: local construction;

timeswitch - two required. General Electric, Type TSA-47, Model 699XI, S.P.S.T., or equivalent (Canadian General Electric Co.);

heater - two required. Chromalox Strip Element Heater Type S, # S-2005, 500W (Canadian Chromalox Co., Rexdale, Ontario.);

thermostat - one each required of Chromalox Type AR-1014 (0-100°F), bulb style #4 with 12-inch stainless steel protective well, and Chromalox Type AR-2514 (60-250°F), bulb style #4 with 12-inch stainless steel protective well (Canadian Chromalox Co., Rexdale, Ontario.);

relay - Guardian Electric 1200-2C-115A or equivalent;

pilot light - 115V;

solenoid valve - Asco Midget # 8262C13, ¼/¼-inch, 115V (Ascolectric Brantford Ltd., Brantford, Ontario.);

light source - two double, 18-inch, fluorescent lamp fixtures, with 40W cool-white bulbs;

cooling coil - 24 feet of ½-inch copper tubing;

germination surface - six pieces of window glass, 41 x 3 inches.

The stainless steel water reservoir, which holds 15 gallons, is the basic component of the germinator, serving to supply both moisture and heat to the germination surface. During construction an internal rim, ½ inch wide, was formed ½ inch below the top edge of the tank walls, and this, together with 1¼-inch steel crosspieces (Frontispiece), serves to support the glass plates bearing the germination medium and seed under test. Glass plates are preferred to plexiglass or plastic mainly because they can be heat sterilized. The water reservoir is set into the top section of a wooden base containing the electrical wiring, with supplementary support being provided by two 42-inch lengths of 1-inch angle iron set 20 inches apart. The whole is enclosed in a wooden cabinet whose approximate dimensions are 48 x 32 x 40 inches high. This effectively insulates the internal atmosphere from that of the room, thereby eliminating temperature gradients across the germination surface and the cooling effects of excessive evaporation from the germination substrate.

Temperatures at the germination surface are indirectly controlled by the temperature of the water bath, so that for most effective control, particularly where alternating temperatures are used, it is usually desirable to maintain the water level within an inch or less of the glass support plates. A daily alternation of temperature over a fairly narrow range is normally recommended as being more favorable for germination than a constant temperature over each 24-hour period, and for most conifers and many hardwoods it is included in standard test procedures. In most cases a moderately rapid temperature changeover, lasting 2 hours or less, is desirable; and in order to achieve this two control systems are incorporated into the germinator design--one for heating and one for cooling (Fig. 1).

Two external 500-watt strip element heaters, set 14 inches apart with their ends resting on the iron tank supports, supply heat directly to the underside of the tank. With the tank filled the weight of water ensures intimate contact, and hence rapid heat transfer, between the heater surfaces and the bottom of the tank; and in practice this is found to give efficient, uniform water heating without the localized hot spots which might develop with immersion heaters. Alternating temperatures are controlled by two adjustable thermostats operating through a single timeswitch (Fig. 1), one thermostat (AR-1014; 0-100°F) controlling the night or low-temperature phase, the other (AR-2514; 60-250°F) controlling the daytime or high-temperature phase. Although it is usual to conduct routine germination tests over the 68 to 86°F range, the selection of a thermostat with a higher operating range for controlling the high-temperature phase permits a greater degree of versatility for experimental situations. Where this type of use is not contemplated, the 0 to 100°F range will be adequate for both thermostats. With the timeswitch contacts in the open position, current flows directly to the heaters via the low-temperature thermostat controlling the night phase, while in the closed position a relay is activated, isolating the low-temperature thermostat and switching current to the high-temperature thermostat. The thermostat bulbs, 5 inches long and each encased in a 12-inch protective well, are inserted through the front wall of the tank 2½ inches below the rim and at points 12 inches from each end. As shown in the Frontispiece, all controls are mounted on the front panel of the base for easy access.

The cooling system consists of a 24-foot coil of ½-inch copper tubing, supported 2 inches above the bottom of the tank, through which mains water[1] is allowed to flow under the control of a solenoid valve and second timeswitch. The cooling coil and supports are shown in the Frontispiece. After passing through the coil, the water is piped directly to the waste system. To avoid undue wastage, the flow rate can be controlled by installing a pressure-reducing valve on the intake side of the solenoid valve. The two timeswitches are synchronized so that water starts to flow at the same time as the changeover from the high- to low-temperature thermostat, and continues for a period predetermined (by trial and error) to reduce the temperature at the germination surface to or slightly below the set point of the low-temperature thermostat. Once the water supply is shut off, the low-temperature thermostat takes over control for the balance of the night phase. In practice, with the low-temperature thermostat set close to ambient room temperature, no problem has been encountered with rising temperatures after shutting off the water flow because of the insulating effect of the enclosing cabinet; but in more extreme situations it would be advisable to operate the germinator in a room slightly cooler than the thermostat setting to avoid temperatures creeping up overnight. Without this supplementary cooling, up to 6 hours was required for a drop of 16°F to ambient room temperature at the germination surface, mainly because of the large volume of water involved and the effect of the enclosing cabinet in retarding heat loss.

Light, although rarely an essential requirement for the satisfactory germination of tree seed, is often beneficial in stimulating more rapid germination than can be obtained in complete darkness. Consequently, artificial illumination is recommended for the laboratory testing of most important tree seeds, especially conifers (International

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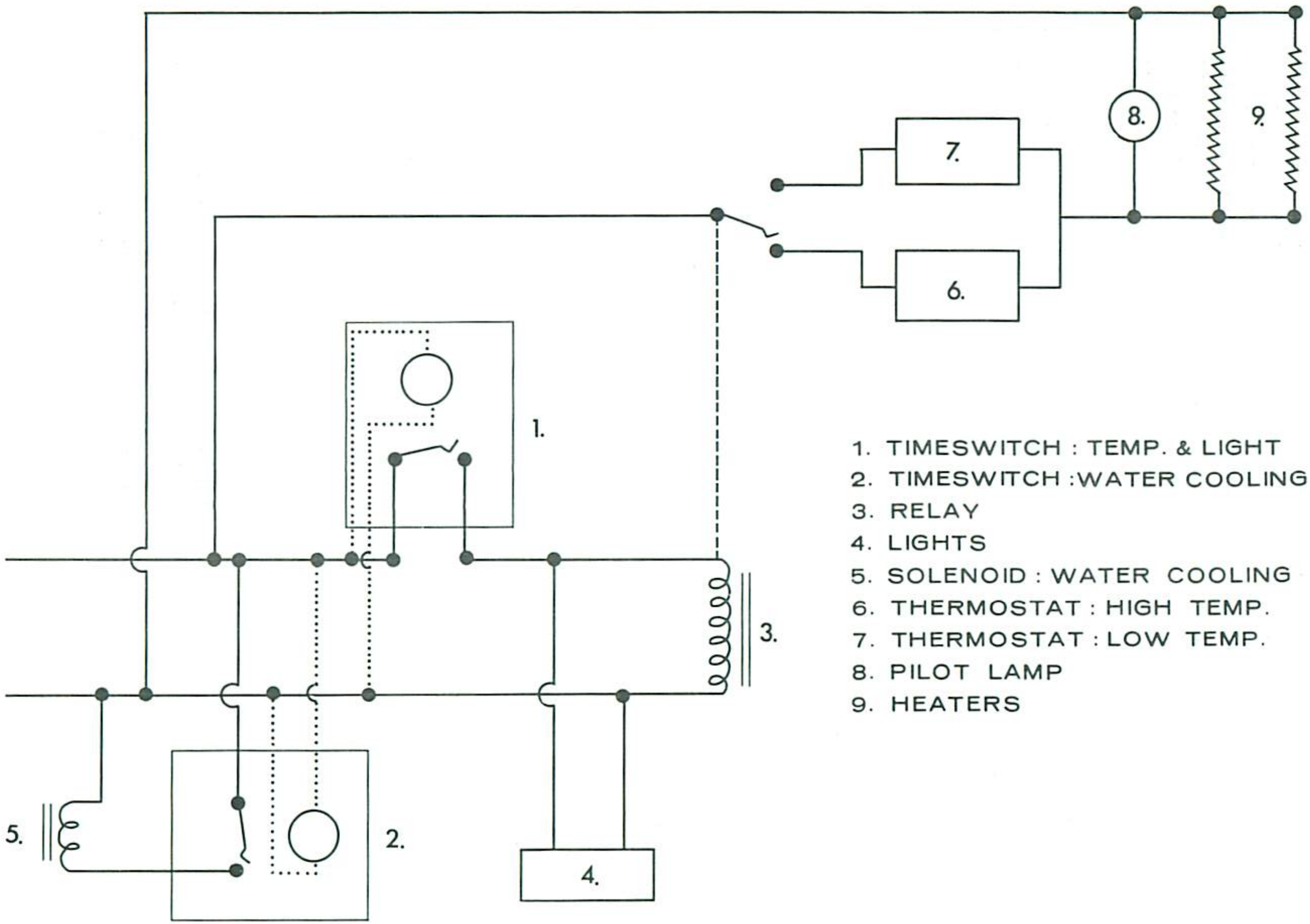
[1] "Mains water" signifies city water supply or equivalent.



1. TIMESWITCH : TEMP. & LIGHT
2. TIMESWITCH :WATER COOLING
3. RELAY
4. LIGHTS
5. SOLENOID : WATER COOLING
6. THERMOSTAT : HIGH TEMP.
7. THERMOSTAT : LOW TEMP.
8. PILOT LAMP
9. HEATERS

Figure 1. Germinator circuit diagram.

Seed Testing Association 1966; Heit 1968). With seeds for which light and alternating temperatures are prescribed, illumination is provided during the high-temperature phase only, this being achieved quite simply by connecting the light fixtures to the circuit supplying the high-temperature thermostat (Fig. 1). In situations where a constant germinating temperature is used, light is normally provided for at least 8 hours in every 24. A cool-white fluorescent light source is recommended in preference to an incandescent source since the latter has a high spectral emission in the far-red region that inhibits germination. By contrast cool-white lamps have a relatively low emission in the far-red but a high spectral emission in the red region that promotes germination. With four 18-inch fluorescent lamps at the height shown, a light intensity of approximately 125 foot candles is maintained at the germination surface.

OPERATION

In normal use the germinator provides seeds with optimum conditions for germination. Temperature is fully controllable above ambient room temperature, and provided that a constant water level is maintained in the reservoir a uniform moisture supply to the seed can be assured with the use of an artificial germination medium and absorbent wick. Although artificial media are generally preferable for routine tests of small seeds, natural substrates such as peat, sand or soil may be used with minor modification of the support plates. Natural media, however, have the disadvantage that it is often difficult to ensure a uniform moisture supply to seed, or, with the depths of soil needed to germinate larger seeded species, to achieve sufficiently rapid temperature changes under alternating temperature conditions. In general the use of natural substrates is not recommended for routine testing in this germinator, one of the several artificial media being preferred (filter paper, blotters, flannel pads or porous clay plates). In the arrangement described here, 3½-inch-diameter circles of germination-grade filter paper (Barcham Green #L.R. 52) were used with entirely satisfactory results, utilizing 1¼- x 8-inch strips of the same material, placed under the circles for the full width of the support plates, as the absorbent wicks. The maintenance of a high atmospheric humidity around seeds is equally as important for maximizing germination as a moist substrate and in order to achieve this each germinating surface should be covered with a ventilated bell jar as shown in the Frontispiece. The 3-inch-diameter moulded glass powder funnels shown in the illustration are perfectly suited to this purpose and are readily available from scientific equipment stocklists. For the dimensions quoted, each support plate will accommodate up to 12 individual germinating environments of this type.

Variability in moisture conditions of the substrate can often lead to serious lack of uniformity in germination results, and the desirability for maintaining a uniform moisture supply to seed for the full duration of a test cannot be overemphasized. Reproducibility is essential not only between tests but also between samples in the same test if germination results are to have any meaning. Isely (1958) emphasized the difficulties involved in attempting to maintain uniform moisture conditions where replacement of losses is dependent upon rewatering, and showed that even in some of the most sophisticated of modern germinators, incorporating meticulous temperature control, this may lead to seeds being exposed to wide fluctuations in moisture availability during a test. The problems of rewatering are avoided in the germinator described here, and, provided that certain precautions are taken, it is possible to ensure a constant and uniform moisture supply to all germination surfaces for the full duration of a test. Maintenance of a constant water level in the reservoir is the most important requirement, since moisture availability at the germination surface is largely determined by the distance between water and substrate (Kamra 1968). Experience will show the best level for a given situation, but in general it should not exceed 1 inch below the support plates, otherwise there will be loss of control over germination temperatures at the substrate surface. As a further precaution, it is usually advisable to use only deionized or distilled water in the germinator. Where ordinary tap water is used, mineral deposits often clog the absorbent wicks, leading to reduced capillary movement of water and causing a gradual decrease in moisture availability at the germination surface as a test proceeds. If only tap water is available, the wicks should be changed at least once a week.

At an ambient room temperature of 65 to 70°F, little difficulty should be experienced in creating those temperature conditions most commonly recommended for routine germination testing. However, as noted earlier, for situations or species requiring germination temperatures lower than 68°F, the germinator should be operated in a room slightly cooler than the required temperature to avoid control problems. The accuracy of temperature control was tested under conditions most frequently employed for the testing of coniferous seed--diurnal temperature alternation with the lower temperature maintained for 16 hours, lights off, at 65°F, and the higher temperature for 8 hours at 86°F with lights on. (Although the range 68 to 86°F is normally used for routine tests, 65°F was adopted as the lower set point in order to check operational uniformity below an ambient room temperature of 70 to 72°F). By using miniature thermistors, temperatures were measured at the centre of moist blotters covered with bell jars for six equally spaced positions on each of five support plates. Six separate readings were taken for each of the 30 positions at half-hourly intervals. The results, given in Table 1, indicate close agreement in temperatures at the germination surface both with respect to position on the germinator and in course of time.

Table 1 Mean temperatures (°F) at the germination surface and standard errors of means (based on six readings at 30 positions)

Temperature set point	Mean temperature	Standard error of means
65.0	65.2[a]	0.34
86.0	85.5	1.43
65.0	65.2[b]	0.06
86.0	85.5	0.10

[a] Variation between positions.

[b] Variation between overall means with time.

Rates of heating and cooling at the germination surface for alternating temperatures of 68°F and 86°F may be seen from Figure 2, which shows the characteristic temperature pattern, taken during a routine germination test, for a single 24-hour period. At the onset of the high-temperature phase, the rise from 68°F to 86°F is completed in less than 2 hours from the time of switching to the high-temperature thermostat. Cooling takes somewhat longer, but in all instances a 2½-hour flow of water through the cooling coil has been found sufficient to reduce the temperature at the germination surface to the lower set point in less than 3 hours. This is considered quite satisfactory for the type of equipment. Once the correct duration of water flow for achieving the required degree of cooling has been established, little prolem should be encountered with short-term fluctuations in response where mains water is used. However, occasional adjustments will be necessary to compensate for seasonal changes in the temperature of the cooling water, a somewhat longer duration being required in summer than in winter to achieve the same degree of cooling.

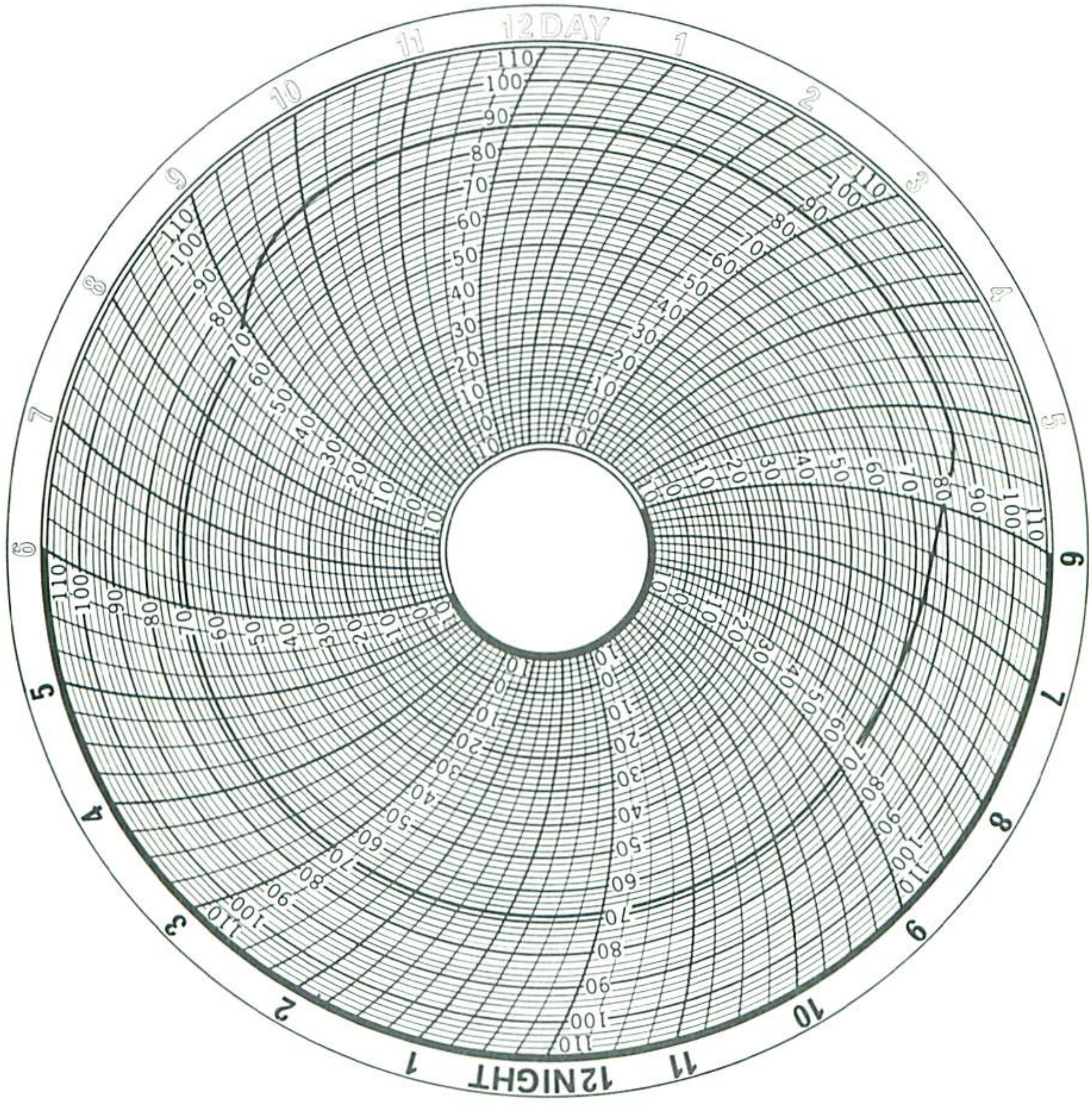


Figure 2. Daily temperature pattern at germination surface.

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