
Solar Energy, Soil Management, and Frost Protection1

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Abstract. Management of the soil as a source of heat was investigated to evaluate possibilities for the conservation of oil presently used in frost protection. Two treatments involved the use of covers made from clear plastic and aluminum foil to trap solar energy. Maximum benefit was indicated for bare soil covered during the day and uncovered just before critical temperatures are reached at night. Bare soil and covered mowed grass gave an intermediate benefit while the mowed grass management scheme gave the least benefit to frost protection.

The soil is a major source of heat available to protect vegetation against frost injury. While it is generally recommended that the soil be kept bare, firm, and not covered to maximize the heat source, few studies have measured the benefit of following such a recommendation. Three studies which support the recommendation are Gradwell (4) who concluded that the difference between a dense and a loose soil could account for the reduced frost hazard on the dense soil; Fritton et al. (2) who showed that 50-80% of the nighttime net radiation loss from an orchard was derived from the soil; and Cochran et al. (1) who concluded that soil properties caused a pronounced difference in the orchard foliage temperature (7), and orchard frost protection (5).

Eight plots (5 x 5 m) arranged in 2 blocks of four plots each were location in an experimental apple (Malus domestica Borkh. cv. Golden Delicious) orchard located on the Pennsylvania State University Agricultural Research Center at Rock Springs. The soil in the area is a Hagerstown silt loam (Typic Hapludalf). The 4 treatments consisted of bare soil, grass covered soil, bare soil covered with clear plastic during the day and plastic and aluminum foil during the late afternoon and evening with both covers removed during the predawn hours when radiant frosts are most likely to occur, and grass covered soil with plastic covers managed the same as the previous bare soil treatment. All plots were originally managed as mowed grass. In order to prepare the bare soil plots, all vegetation was cut at the mineral soil surface and both the vegetation and a layer of organic residue were removed. The plastic covers were constructed from transparent (clear) plastic of 0.01-cm thickness. The aluminum foil covers were constructed from aluminum polyester laminate which had a 0.001-cm-thick layer of aluminum polyester laminated onto a 0.01-cm-thick black polyester plastic. All covers were weighted down at the edges with boards to reduce ventilation losses of energy and were constructed so that they could be quickly unrolled and rolled to cover and uncover plots.

At the center of each plot, a set of instruments was buried to measure the surface soil heat flux. The heat flux was measured at the 5.0-cm depth in each plot using a heat flux plate constructed following Fuchs and Hadas (3). The heat flux was then corrected for the heat stored in the top 5.0 cm of the soil using measurements of soil temperature at the 0.0, 2.5, 5.0, 9.0, and 27.0-cm depths, water content and bulk density of the 0 to 5.0-cm layer, and the specific heat capacity using techniques similar to Fritton et al. (2). Soil temperatures were measured with 4-junction thermopiles with the four reference junctions placed between 2 metal plates buried at about 30-cm and monitored with a thermocouple. All sensors were placed in an undisturbed wall of a pit dug in the center of each plot. The pits were then back filled and wet down to settle the soil. All areas were allowed 2 weeks to return to moisture equilibrium before data collection.

Data were collected at 5 min intervals at the end of the afternoon of May 22, 1978 before (1552-1602 hr) and just after (1607-1622 hr) the plots were covered with the plastic laminate cover. The evening and night were clear and had typical radiation cooling with a minimum air temperature of 6°C and winds less than 1 m/sec during the period of time (0153-0353 hr) when the plots were uncovered. Plots had been covered with the clear plastic at 1028 true solar time (TST) and with the plastic laminate at 1605 TST. Another set of data was collected before (0053-0148 hr) and just after (0153-0353 hr) the plots were uncovered (0150 TST) during the early morning hours of May 23, 1978. Data analysis followed procedures developed by Fritton et al. (2) and resulted in a surface heat flux value for each plot for each five minute interval.

Smooth curves drawn through the soil surface temperature data show that at the end (1605 TST) of solar energy trapping, the covered bare soil treatment was significantly (5% level) warmer than the uncovered grass treatment (Fig. 1). The bare soil and covered grass treatments were within 3 or 4°C of being significantly different from the uncovered grass plots. The grass plots had the highest temperature (19-25°C) at this late afternoon time. The bare soil surface without covers was considerably warmer with temperatures

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between 30 and 35°. The grass plots with clear plastic covers were somewhat warmer than the uncovered plots ranging from 32 to 38° and the bare covered plots were the warmest at 37 to 41°.

The surface soil temperature in all plots was decreasing by 1600 TST and continued to decrease throughout the night. Vegetation in the covered grass plots was severely injured by the near 40°C temperatures during the day. In one of the plots, this injury was more severe than in the other. In this plot, the upwind side of the plot had less injury, probably indicating that some ventilation under the plastic was taking place during the day. Differences in vegetation also caused greater differences between replicates in the soil surface temperatures of the grass plots whether covered or uncovered when compared to the bare soil plots.

Soil surface temperatures which were monitored for an hour starting at 0053 TST before the surface plastic covers were removed showed that all plots were still cooling and temperature differences between treatments had narrowed. The covered bare soil was significantly (5% level) warmer than all other treatments and the covered grass plot was warmer than the grass treatment at the 10% level of significance. The grass plots were at about 10°C, the bare soil between 10 and 12°, the covered grass at about 13°, and the bare covered plots at about 17°. Upon removal of the covers, the bare soil which had been covered showed an immediate response and cooled quickly to below 12°C. The grass plot which had been covered showed some acceleration in cooling, but at a much reduced level. The bare and grass plots which had never been covered continued the cooling trend observed earlier in the evening.

The average heat flux at the soil surface for each of the 4 treatments is shown in Fig. 2. Considerable scatter was shown in the individual data points and thus, for clarity, only the trend lines are drawn in Fig. 2. The covered bare soil released heat significantly (5% level) faster than all other treatments. The bare soil which had not been covered released heat at a rate twice as significant at the 10% level that of the grass plot (—6.4 vs. —3.1 mW/cm²). The grass plot which had been covered released heat at the same or at a greater rate than the bare soil for a short period of time and then dropped below the bare soil rate after about one hour. The bare soil which had been covered, on the other hand, released a large quantity of heat reaching the equivalent of one-half (—33 mW/cm²) of full sunlight for a very short period of time and staying above —10 mW/cm² for the whole 2-hr cooling period. This represents a greater than doubling of heat output when compared to the bare soil which had not been covered.

The bare soil gave off more heat as expected than a grass covered soil at least when a radiant cooling night followed a bright sunny day. It is also evident that covering a bare soil results in a large increase in heat available for frost protection while covering a grass surface results in an amount of heat available for frost protection approximately equivalent to maintaining a bare soil plot uncovered. Welles et al. (7) have calculated that an increase in soil surface temperature of 10°C would reduce the required burn rate of orchard heaters by about 25%. Or, alternatively, for temperature conditions such that the air temperature had fallen to the critical temperature for blossoms, Welles et al. (7) found that a 10°C increase in soil surface temperature would save an additional 35% of the blossoms (50% vs. 15% for their specific example). The data reported in this paper indicate that a 10°C difference between covered bare soil and uncovered plots is feasible if practical ways of trapping solar energy can be discovered.

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**A Method for Harvesting, Cleaning, and Treating Achenes of Guayule (Parthenium argentatum Gray)**

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**Abstract.** Procedures are described to mechanize partially harvesting, cleaning, and pretreatment of guayule achenes. Achenes are harvested with a vacuum insect net and cleaned by a series of screening, threshing, and forced air separations, then treated to overcome seed coat immeasurability in a semiautomatic system that presoaks, treats with 0.5% sodium hypochlorite, and rinses. Achenes may be sown immediately or dried for storage. Procedures outlined involve commercial equipment and are adaptable to small or large operations.

**Guayule is a rubber-synthesizing shrub native to portions of the Chihuahuan Desert in Texas and Mexico. Commercial interests and the United States government through the Emergency Rubber Project (ERP) investigated guayule rubber production from 1922 to 1959. A complex interaction of various political and economic forces has resulted in renewed interest in commercial guayule rubber production (6, 7). A major concern is the rubber content, which varies greatly among genotypes.**

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**Literature Cited**


