Microclimate Conditions Found on Highway Slope Facings as Related to Adaptation of Species

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•OVER A period of years it has been observed that the direction which a highway slope faces affects the establishment and stand survival of sod along highways. Slope exposure also affects the adaptation of plant species used as sod. Bermuda grass, a warm season species, and Ky. 31 fescue, a cool season grass, may be found growing on opposite sides of the same highway. The cool season species will grow on the north-facing slope and the warm season species is adapted to the southern exposure.

According to Wang (4), the duration and intensity of light striking the soil is greatly modified by slope facing. Thus, the microclimate is altered by orientations of the soil surface with respect to the sun. This can be expressed mathematically as:

$$I_\theta = I_0 \cos \theta \quad (1)$$

where I_θ represents the intensity of radiation striking the soil surface, θ is the angle between the sun at normal emergence and that from which it is intercepted, and I_0 is the intensity of radiation for I_θ at normal emergence. A field situation is shown by the schematic diagram (Fig. 1) for a highway cut with north- and south-facing slopes. The south-facing or hot slope receives direct sunlight of high intensity, whereas the north-facing or cool slope intercepts light at a low angle. Much of the light received at such a low angle is reflected. If the sun is at a low angle or if the slope is steep, the cool slope may receive only indirect light.

The major factors governing heating and cooling of the soil surface are solar radiation, long-wave back radiation, and convection. Although the temperature has a direct effect on the physiology of a plant, an important indirect effect of temperature is its effect on water loss. With an increase in temperature, a corresponding increase is found in the rate of evaporation.

A study was initiated to characterize these slope conditions with the objective of acquiring a better understanding of microclimatic conditions in the establishment and maintenance of sod covers.

METHODS AND MATERIALS

The equipment used to measure these climatic conditions consists of a 24-point temperature recorder and a single pen potentiometric recorder used to record light intensities with silicon photocells. All sensors were duplicated for statistical purposes and thermocouple units were prepared with parallel leads to give an average temperature of three thermocouples for each point of the recorder. The thermocouples were inserted in the top ⅛ in. of soil to measure temperatures. The light sensors were installed just above the soil surface normal to the slope. Figure 2 shows the equipment in operation along a highway slope.

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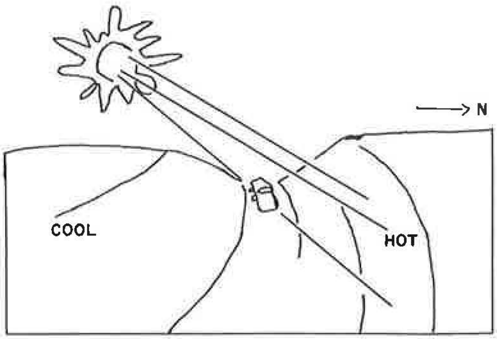

Figure 1. Relationship of slope facing to sun; south-facing or hot slope vs north-facing or cool slope.

Figure 2. Microclimate equipment in operation along highway slope showing recorders used in measuring soil temperature and light intensity.

Sites chosen for these experiments were 1:1 cut slopes with exposure facings as close to north and south as possible, unless otherwise indicated in the results. Sod cover consisted of Ky. 31 fescue in all experiments except one in which Lespedeza sericea was used. All data were taken in 1964 on clear days unless otherwise indicated.

RESULTS

An example of the difference in microclimate between north- and south-facing slopes is shown in Figure 3 with measurements made on February 7. All temperatures were approximately the same at 9:30 AM. The pronounced effect of slope facing is shown by a difference of over 40 F at midday between north and south exposures. This indicates

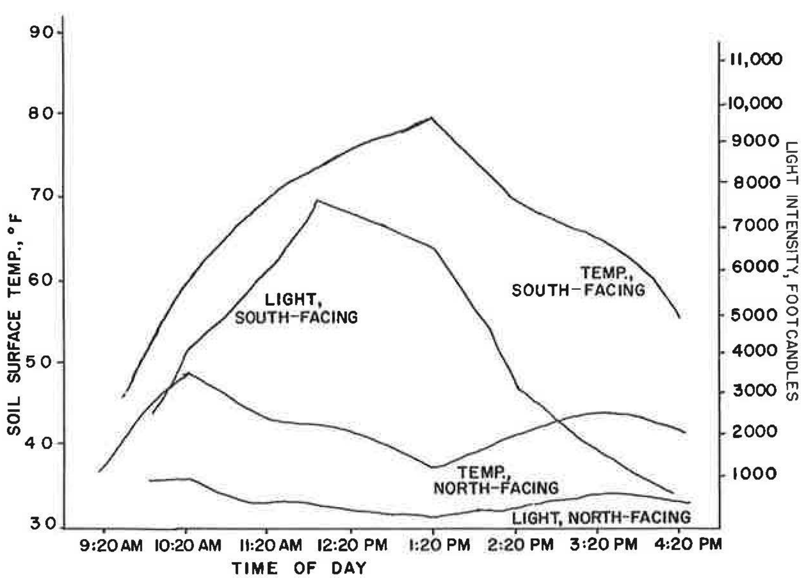

Figure 3. Relationship between light intensity and soil surface temperature for north- and south-facing slopes on Feb. 7, 1964.

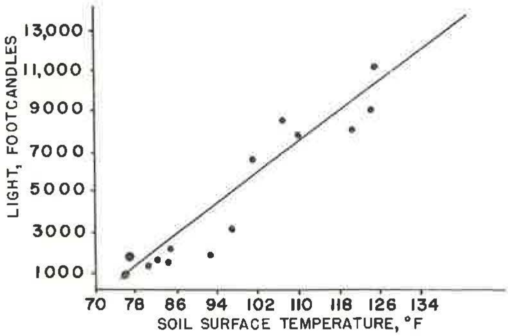

Figure 4. Effect of light intensity on soil surface temperature for south-facing 1:1 slope, July 2, 1964 (8 AM-12 Noon).

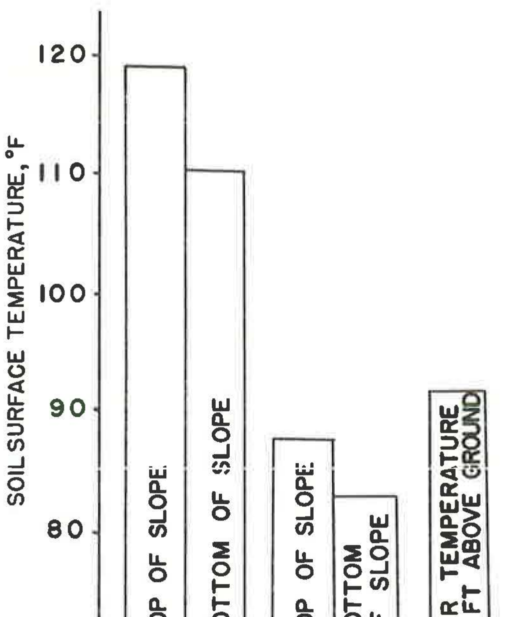

Figure 5. Soil surface temperatures at bottom and top of south-facing 1:1 slope with and without sod cover, May 5, 1964, 1:00 PM.

that microclimate is a major factor in species adaptation on highway slopes, where one species will survive on one side of a roadway and not on the other.

Figure 3 also shows a relationship between light intensity and soil surface temperatures. The higher light intensities correspond to the high temperatures. This relationship is shown in Figure 4 for a south-facing slope in summer. A very close relationship is found, indicating the importance of light interception in heating the soil. The closeness of this relationship would vary with different locations, depending on such factors as soil moisture and color, air movement, and degree of slope.

Cooper (2) found under field conditions that the microclimate of slopes varied from a cool moist extreme at the bottom of a north slope to a warm dry extreme at the top of south slopes. Conditions on north slopes resembled those of well-developed forests, whereas those on south slopes were more similar to the climatic conditions of exposed areas.

This relationship also occurs on highway slopes where it has been observed that it is more difficult to establish plants near the top of south-facing slopes than near the bottom. Figure 5 shows the soil temperatures found at the top and bottom of a south-facing or hot slope during May. The top of the slope was from 5 to 10 F warmer than the base. As shown in Figures 5, 8, and 10, air temperatures 3 ft above the top of the slope showed little relationship to that of the soil surface.

Richards, Hagan, and McCalla (3) state that shade and insulation have an important influence on soil temperatures, largely to the extent to which they affect the exchange of heat at the soil surface by radiation. The interception of radiation by plant cover is probably the greatest single factor to be considered in the temperature relationships of the soil surface. Figure 6 shows the relationship existing in the spring between the number of Ky. 31 fescue seedlings per square foot and the soil surface temperature of a south-facing slope. These data indicate that in a very early stage of sod establishment, the plants produce a modifying effect on the microclimate of the slope. The data also indicate the importance of rapid establishment of adequate cover which tends to protect sensitive plant parts from extreme temperatures. Temperature measurements were made at the soil surface since this represents the region where a grass plant must germinate, as well as the site of physiological activity such as tiller and leaf development. Carroll (1) found that most nondormant plants are heat killed between 120 and 140 F; however, this temperature must be maintained for several

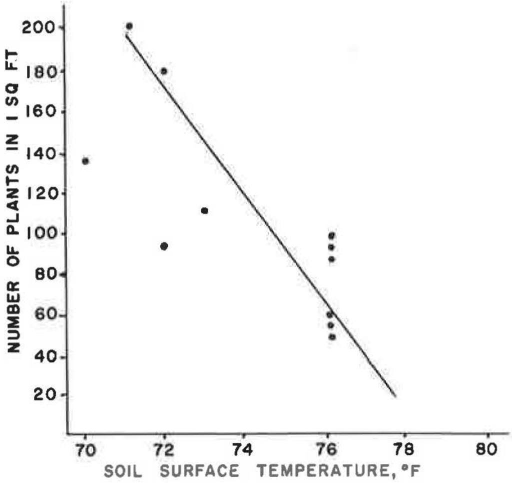

Figure 6. Effect of plant density on soil surface temperature for a 1:1 south-facing slope at 2:50 PM on May 15; Ky. 31 fescue seeded Mar. 20, 1964, seedlings 2 to 3 in. tall.

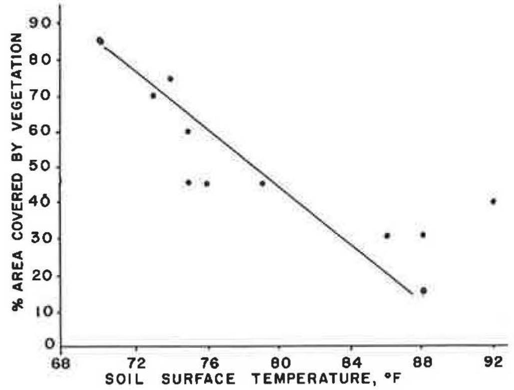

Figure 7. Effect of plant cover (estimated visually) on soil temperature for south-facing 1:1 slope at 2 PM on June 8, 1964.

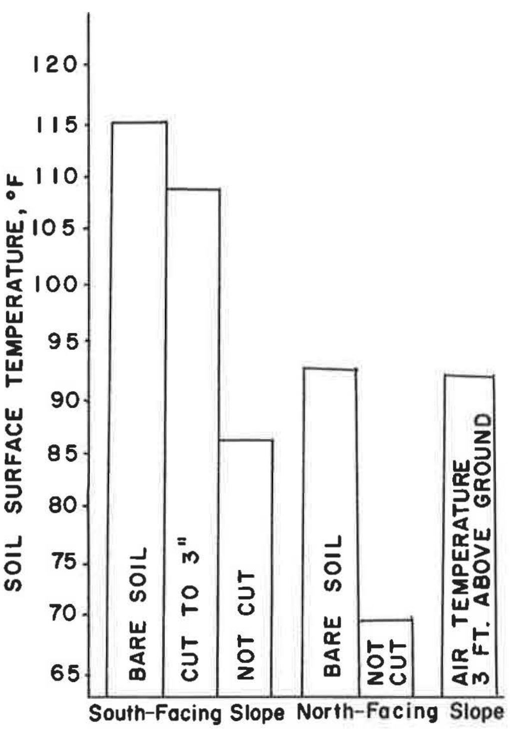

Figure 8. Effect of clipping management on soil surface temperature in May for north- and south-facing slopes at 1 PM as compared to air temperature; plant cover consisted of 80 percent stand of Ky. 31 fescue 18 in. tall.

hours to be lethal. High soil temperatures appeared to be more harmful than high air temperatures.

Since density of stand is often estimated visually and expressed as percent cover, the relationship between percent cover and soil surface temperature is shown in Figure 7. A close relationship is found between temperature and ground cover in stands of greater than 30 percent cover. It has been observed that grass stands deteriorate at a faster rate when the stand is reduced to less than 30 to 40 percent cover, indicating the dependence of plant persistence on temperature.

If plant cover has a moderating effect on soil temperature, removal of plant cover by mowing should alter soil surface temperatures. Figure 8 shows the effect of clipping Ky. 31 fescue on soil temperature for both hot and cool slopes. These slopes had approximately 80 percent cover and the plants were 18 in. tall when measurements were made on May 5. Cutting the fescue to 3 in. increased temperature almost to the same extent as complete removal of the sod. The effect of aspect is very pronounced with higher temperatures occurring on the south-facing slope. The effect of clipping height is shown for a cloudy day in Figure 9. The results were taken from the same location as those in Figure 8 but 1 month later. These graphs show the same effect of clipping on cloudy and clear days; however, the effect of slope facing is less pronounced under cloud cover.

The relationships found under grass stands is also shown in Figure 10 for

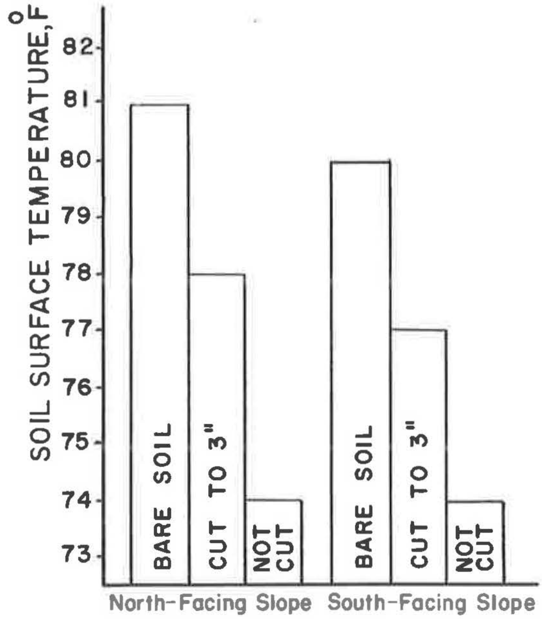

Figure 9. Effect of clipping management on soil surface temperature for north- and south-facing slopes in June under cloud cover (average 9 AM to 4 PM).

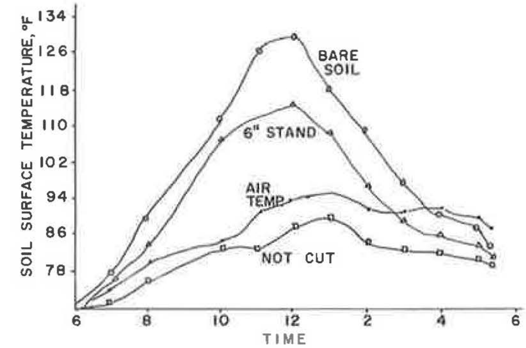

Figure 10. Effect of cutting height on soil surface temperature in stand of Lespedeza sericea on a southeast-facing slope, July 2, 1964.

Lespedeza sericea on a southeast-facing slope. In this case the sericea was clipped at 6 in. instead of 3 in., since the legume has a more erect growth habit. However, the effect of clipping appears to be similar to that found with grass. As in the case of the grass, the air temperature is higher than that under an undisturbed sod.

The diurnal effect of slope facing is shown with and without sod in Figure 11

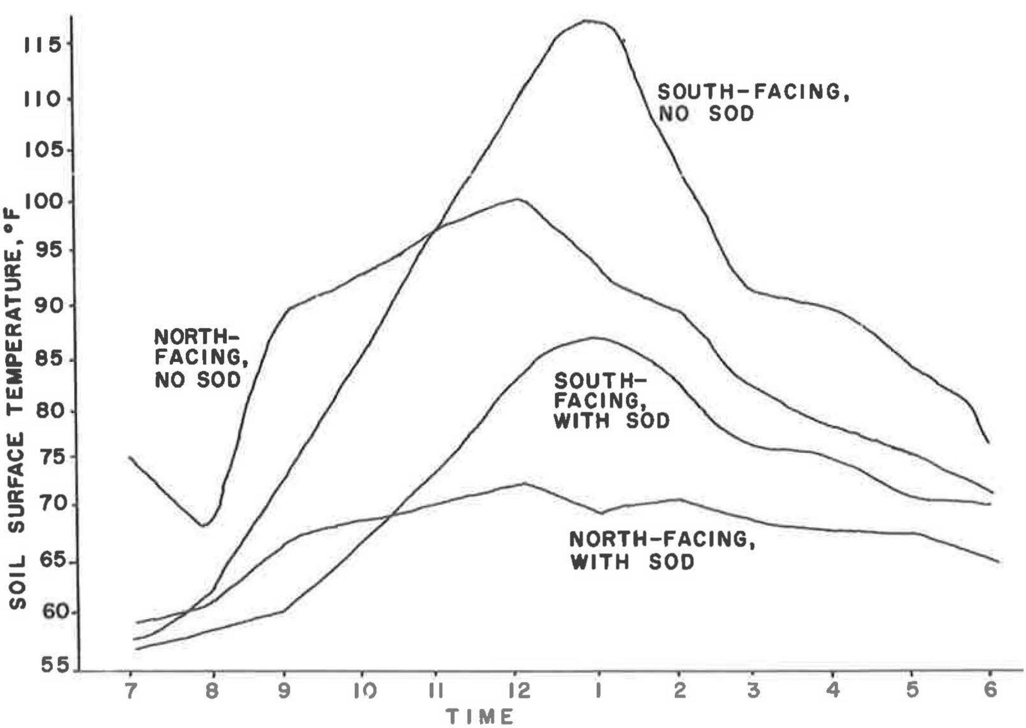

Figure 11. Effect of sod and slope facing on soil surface temperature on May 5, 1964.

with measurements being made between 7 AM and 6 PM. These results are from the same experiment as represented in Figures 6 and 7. Sod had little effect in early morning and late afternoon but reduced soil surface temperatures 30 to 40 F at midday. The high temperature (120 F) of the bare soil on south-facing slopes, if maintained for several hours, would probably inhibit germination of many grass species. The north-facing slope was cooler than the south-facing slope except in early morning.

In comparing the extreme difference in maximum temperatures between slope facings with those from weather station data, a difference is seen similar to differences in air temperatures found between New England and the southeast for a given season. Plant height had a pronounced effect on soil temperature. The bare soil surface reached a temperature of 134 F at midday.

SUMMARY

Measurements of microclimate conditions were made on slope facings at various times during the season and under several conditions of plant cover. Close relationships were found between soil surface temperature and light intensity, density of sod, clipping height, and slope facing. There was little relationship between the temperature 3 ft above the soil and at the soil surface.

On the basis of these observations, slope facings should be considered in selecting species, mulches, and fertilizers for turf establishment. To take advantage of favorable temperature conditions, south-facing slopes might be seeded earlier in the spring and later in the fall than north-facing slopes.

ACKNOWLEDGMENTS

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