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Soil color and surface residue effects on seedling light environment

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Summary The quantity and spectral distribution (quality) of reflected light 10 cm above dry, wet and plant residue-covered soils were compared over black, brick-red, and gray-white soils. Photosynthetic photon flux density of reflected light ranged from about 4% of direct sunlight over bare, wet black soil to 21% over dry near-white soil. Plant residue on the soil surface increased the reflected light over the black soil and decreased it over the light-colored soils. The amount of reflected blue light was greatest over the whitest soil. When soil temperature differences were eliminated by insulation panels, stems of southern pea [*Vigna unguiculata* (L.) Walp.] seedlings elongated less over white surfaces than over black surfaces.

Introduction

Soil color and mulching effects on soil temperature have been studied extensively[3]. However, little attention has been given to soil color effects on the light environment of young seedlings. The objectives of the present study were (a) to assess the effect of soil color on reflected light 10 cm above the soil and (b) to determine whether seedling growth could be affected by soil surface color when soil temperature was held constant under the different surface colors.

Materials and methods

Soil surface reflections were measured under sunlight with a LiCor LI-1800 Spectroradiometer* with a remote cosine light collector on a 1.5 m fiber optic probe. The collector was clamped in a fixed position 10 cm above the soil, with the collector aimed downward. Black, brick-red, and gray-white soils were air-dried on a greenhouse bench and pulverized to pass a 1-mm mesh screen. Soil samples were spread about 2 cm deep on a 1-m^2 panel below the collector. The panel was centered on a 3 m × 4 m black cloth to minimize background reflection. In succession, each soil was spread on the panel and reflected light was measured over the dry, wet, and wheat (*Triticum aestivum* L.) straw residue-covered soil. The spectroradiometer was programmed to scan from 350 to 850 nm at 5-nm intervals. A reference spectrum was obtained by measuring direct radiation from the sun. All measurements were made during a 1-h period centered at solar noon on a cloudless day. Photosynthetic photon flux density (PPFD), blue light (400 to 500 nm), and the far-red to red light ratio were determined for each scan.

Field-grown southern pea [*Vigna unguiculata* (L.) Walp. cv. Colossus] seedlings were used to measure plant growth response to soil surface color. Seeds were sown about 5 cm apart in 9.5-m rows. After the seedlings emerged, 2-cm thick styrofoam insulation boards with black or white surfaces were placed on both sides of each row to provide different surface colors without altering

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soil temperatures in the plant root zone. Soil temperatures at 5, 10, and 15 cm below the surface were monitored using fixed thermocouples attached to a Campbell CR-7 unit to automatically record temperatures. Root zone temperatures did not differ with surface color.

Internodes were measured to determine effects of soil surface color on plant stem elongation. There were four replicate rows for each surface color.

Results and discussion

Light reflection

Differences were observed in the PPFD and in the blue light reflected upward from variously colored soils (Table 1). Also, differences were observed over dry, wet, and residue-covered surfaces within each soil color. Crop residue over dark soils more than doubled the PPFD; whereas, residues over gray-white soil decreased the quantity of reflected light. Spectral distributions of reflected light are shown in Figure 1. The far-red/red light ratios were slightly higher in reflected light than in direct sunlight, but differed very little over the various soil colors and residue covers (data not shown). However, reflected light was much greater over the light colored surfaces than over the dark colored ones (Table 1). Reflected light was measured at a point 10 cm above the soil because light variations at that height might influence early growth of rowcrop seedlings such as corn, southern pea, and soybean. The reflected light might influence amount of photosynthesis (if light was limiting), and even small differences in spectral distribution of reflected light can influence photosynthate partitioning within the seedlings[2,4,5,7]. Differences in reflected light over bare and residue-covered soils might help explain why differences in seedling establishment and growth between conventional and conservation tillage (plant residue-covered) plots are not always consistent among different geographic areas[1,6], with different soil color.

Plant responses

Internode elongation that occurred before canopy closure differed among southern pea plants grown over black vs white surfaces (Table 2) even though insulation panels kept soil temperature from differing under the black and white surfaces. The greater quantity of reflected light over the white surface did not result in more stem growth.

It appears that internode differences between southern pea seedlngs grown over black and white surfaces (Table 2) cannot be explained on the basis of far-red/red light ratio in the reflected light because these ratios were very similar over the two surface colors. However, blue light also plays a role in regulating physiological processes during plant growth and development[4,7,8]. Increased blue light during plant development often results in shorter and thicker plant structures[8]. In the present study, plants growing over the white surface received considerably more blue light (Table 1) and had shorter stems (Table 2) than did those over the black surface. Explanation of the mechanism controlling stem elongation differences over black and white surfaces is beyond the scope of the

Table 1. Light reflection upward to a point 10 cm above the soil

Light parameter	Soil color	Soil surface		
		Dry	Wet	Straw residue
*Photosynthetic photon flux density ($\mu mol\, m^{-2} s^{-1}$)**				
	Black	82	65	188
	Brick-red	164	114	219
	Gray-white	355	261	254
Blue (400 to 500 nm) as % of blue in direct sunlight				
	Black	5.2	4.4	8.4
	Brick-red	6.6	5.6	9.3
	Gray-white	20.8	15.0	12.2

* PPFD of direct sunlight was 1670 $\mu mol\, m^{-2} s^{-1}$.

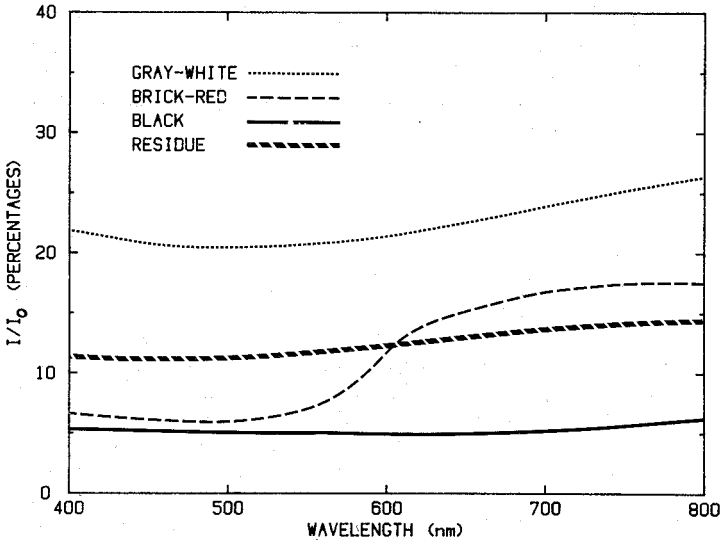

Fig. 1. Spectral distributions of reflected light 10 cm above a wheat residue-cover and dry gray-white, brick-red and black soils relative to direct sunlight (which was considered to be 100% for each measured wavelength).

Table 2. Internode lengths (mm) of southern pea seedlings grown in field plots over black or white panels that were insulated to maintain the same soil temperatures

Internodes*	Surface color	
	Black	White
7 + 8	68 ± 3.4**	42 ± 3.7
5 + 6	39 ± 1.9	29 ± 1.7
3 + 4	31 ± 1.1	23 ± 1.0

* Numbers are in ascending order above the cotyledons.
** Values are means ± standard error.

present study; however, the same pattern of results was obtained with soybean seedlings in which we are studying effects of reflected light on photosynthate partitioning among shoots and roots (unpublished results).

Conclusions

Light micro-environment differences over bare and residue-covered soils varied widely among soil colors, and seedling growth was highly influenced by soil surface color even when soil temperature did not differ below the different surface colors.

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