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Research Brief

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The Hydrothermal Environment of Mulched Soil Beds

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Commercial production of vegetable/horticultural crops in Florida's sandy soils and humid subtropical climates typically requires a number of intensive management practices to maintain optimum soil water, aeration, nutrient, thermal, and pest-free soil environments for root systems of agricultural crops. A system of parallel, plastic-covered soil beds separated by bare furrows is commonly utilized for intensive production of high-value crops such as strawberry (Fig. A) and tomato.

Fig. A. Mulched soil beds with strawberry (courtesy of Gulf Coast Research and Education Center)

Elevated beds provide internal drainage of excess soil water during rain storms, as well as enhanced soil warming during cooler months. Furrows between the beds provide surface drainage. Thin polyethylene plastic sheets are commonly used mulch materials to cover agricultural soil beds. Black, white, and clear films provide selective barriers to the transfer of both heat and water vapor. The use of plastic film in agricultural production conserves soil water by minimizing evaporation, moderates soil temperatures during night-time with low air temperatures associated with colder winter months, suppresses weed growth, decreases soil compaction, minimizes leaching of agrichemicals (nutrients and pesticides) by preventing infiltration of excess water from intense rain storms, and decreases soil erosion. Plastic films increase soil temperature by minimizing latent heat loss through evaporation and decreasing long-wave radiative heat loss to the atmosphere at night. Fertilizer is typically applied in concentrated bands to the soil bed and pesticides are applied to minimize adverse effects of pests to plant root systems. Drip or subsurface irrigation and subsurface drainage practices are utilized to minimize periods of inadequate and excessive soil water environments, respectively.

Plastic films alter the soil thermal regime by intercepting incoming short-wave net radiation, modifying the surface albedo, limiting long-wave radiation to the atmosphere, and decreasing latent heat transfer by inhibited evaporation. Air gaps between plastic films and the soil surface create a complex thermal layering effect. Generally, air gaps act as thermal insulators due to the low thermal diffusivity of air. Thin air-gaps (0.65 mm) provide low contact resistance resulting in more effective soil warming during daytime relative to thick gaps, as well as less effective cooling at night.

Relative to bare soil, transparent plastic mulches tend to warm soil through a greenhouse effect whereby incoming short-wave solar radiation penetrates the plastic but long-wave radiation emitted by the soil undergoes absorption by vapor condensation on the underside due to temperature gradients. Condensation on the underside of opaque black mulch tends to be negligible since film temperature often exceeds soil temperature. In general, opaque mulches such as white and black films tend to simultaneously decrease temperature maxima and increase minima within soil beds although white and black films increase and decrease surface albedo, respectively, relative to bare soils.

A mechanistic model for coupled water-heat and chemical transport was used to investigate the diurnal dynamics of the hydro-thermal environment within raised soil beds covered with low-density polyethylene plastic films during February and June months. Two-dimensional cross sections of soil beds with black, clear, and white films, as well as, bare soil boundary conditions were simulated. Early season conditions (no transpiration) were assumed where plastic films contained no planting holes.

Optical properties of plastic films and the average width of the air gap between the film and the underlying soil were demonstrated as critical determinants of the hydro-thermal regime within mulched soil beds. An assumed air gap of 0.65-mm provided greater soil heating by black than clear films. For larger air gaps this order of heating is reversed. Simulations for February provide improved understanding of the dynamic nature for the multidimensional soil hydro-thermal regime that develops in mulched soil beds during early season production of strawberries and vegetables.

Diurnal contours of temperature (° C) and heat flux vectors (J h^{-1}) are shown in a black plastic mulched bed (0600 h and 1500 h) in February (Fig. B). Heat flux vectors reveal net warming of the soil at mid- afternoon as a consequence of short-wave solar radiation during the day and net cooling of the soil at early morning as a consequence of loss of long-wave radiation during the night. Differences in these two thermal environments reveal heat storage in the middle of the soil bed during the day, as well as loss at night.

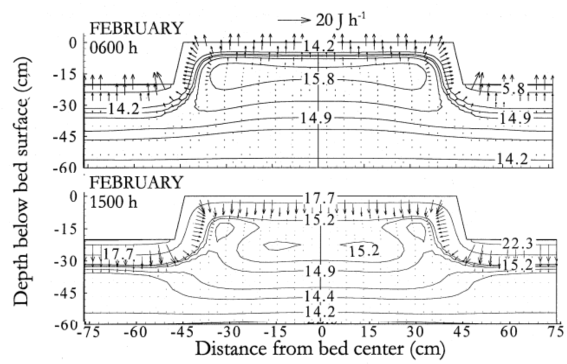

Fig. B. Soil temperature contours (Shinde et al 2001)

Simulations presented here provide insight into complexities of the dynamic hydrothermal regime of mulched soil beds used in agricultural production. A need exists to evaluate model simulations with field data and to modify the model to include water uptake by plant root systems.

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