When Tomatoes See Red

The horticultural tricks colored mulch can play

By JANET RALOFF

Plastic mulches have been part of the agricultural scene for some 40 years. They retain moisture in drip-irrigated rows, retard the emergence of weeds, and warm the roots of young crop plants. Early on, farmers or gardeners shopping for these sheets of impermeable plastic would find their range of hues limited to what Henry Ford offered 1914 Model T buyers: "Any color, so long as it's black."

Eventually, brown and greenish plastic joined the ranks. Only recently has real color begun to explode on the mulch scene. Half-mile-long sheets of red plastic have been available for a few years, and silver is expected to be marketed more widely this spring. Before long, yellow, blue, and a rainbow of other hues may also beckon from the pages of agricultural and gardening supply catalogs.

The shade of mulch a grower chooses is less likely to reflect personal style, however, than the wavelength of the light spectrum needed by the cultivar it will nurture. In fact, much of the growing interest in colored mulch stems from Michael J. Kasperbauer's more than 30-year scrutiny of light sensors in plants.

Kasperbauer, who is a plant physiologist with the Department of Agriculture's Coastal Plains Soil, Water, and Plant Research Laboratory in Florence, S.C., has spent his career probing how plants respond to light. Those investigations have demonstrated that wavelength—or color—plays as critical a role as intensity. In fact, the more experiments his team performs, the more traits they discover that can be altered by a mulch's color.

These studies are just beginning to suggest how the activation of color sensors in leaves orchestrates key operations in plants as diverse as tobacco, cotton, tomatoes, and carrots. Yet the preliminary data that he and others have already gleaned suggest that by outfitting a plant's soil in the appropriate hue, growers can improve not only the quantity and quality of their yields but also a plant's flavor and vulnerability to pests.

Kasperbauer

ARS

The wavelengths reflected by the red plastic shown here help tomatoes mature earlier and set bigger fruit. By spurring above-ground growth, they even help tomatoes resist the ravages of some pests, such as root-boring nematodes (inset).

Kasperbauer began studying phytochrome in 1961, just 2 years after it was discovered. In plants, this color-sensitive protein gauges the intensity of certain wavelengths of light, particularly those in the red (640 to 670 nanometers) and far-red (roughly 700 to 750 nm) range. Unlike the red wavelengths, those in the far red are not photosynthetically active—that is, they do not fuel plant growth and vigor. Rather, Kasperbauer has found, they serve as environmental cues.

"Green leaves reflect a lot of far-red light," he says. While these wavelengths fall just beyond what the human eye can see, phytochrome reacts to them like a beacon. Kasperbauer's studies have established that when plants sense a high ratio of far-red to red light, they realize that "lots of neighbors are nearby," threatening to siphon off a disproportionate share of the sun's growth-sustaining energy. Plants respond by redirecting more of their energy into above-ground growth, usually at the expense of roots. The resulting taller, thinner plants compete more successfully for sunlight.

In the mid-1980s, Kasperbauer teamed with Patrick G. Hunt, also at the Florence lab, to investigate whether other natural features might provide related spectral signals that influence growth. They started by looking down—to the stubble left on the ground and to the actual color of the soil. Again, materials that reflect a higher-than-usual proportion of far-red light onto the seedlings—such as brick-red soil or straw residues—spurred the plants' above-ground growth more than black soil, black mulch, or white plastic did.

The potential economic significance of these observations didn't emerge until Clemson (S.C.) University horticulturist Dennis R. Decoteau joined the team, turning its focus to tomatoes.

Decoteau recalls wondering whether it would be possible to fool a plant into thinking it was in crowded conditions by carpeting the soil with red mulch, thereby inducing a growth spurt in seedlings. In the field, plants surrounded by red plastic indeed grew faster than normal.

They also went on to produce earlier, larger fruit. In studies over the past decade, this far-red reflecting material has enhanced yields by 20 to 50 percent a season, depending on the weather.

Reasoning that the opposite tactic should benefit root crops, the scientists grew turnips in soil covered with an orange mulch. In fact, Kasperbauer notes, the plastic's orange appearance was only incidental. What mattered was that this mulch reflected up onto the plants' foliage a greater amount of red light and only a little far-red light.

Come harvest, turnips grown under the orange mulch indeed proved bigger than those mulched with black or red plastic.

The influence of a mulch's color doesn't end with yield. Three years ago, Kasperbauer and plant physiologist Robert E. Wilkinson of the Georgia Agricultural Experiment Station in Griffin turned their attention to plant waxes. A combination of fats, alcohols, and hydrocarbons, waxes are what make the surface of a leaf shiny. They not only keep a plant from losing water, they can serve as a barrier to pathogens and chemicals.

A self-professed "weed man," Wilkinson was especially interested in chemical deterrents. For years, he had puzzled over why some weeds succumb to a low dose of herbicides, while others of the same species thrive after being doused with the toxic chemicals. He suspected that the variability could be traced to differences in the film of wax that coats a leaf's surface—an idea that was heretical, he claims, because the prevailing wisdom held that a plant's wax content was fixed, immune to environmental modification.

As a test, he asked Kasperbauer for samples of plants grown under different wavelengths of light. The bell pepper leaves that he received came from plants grown within 100 yards of each other. Because those plants received identical sunlight from above, the primary difference between them was the amount and timing of far-red light reflected from the white, black, or red plastic mulch below.

"To our joyous amazement," Wilkinson told SCIENCE NEWS, "that small difference in reflected light dramatically altered the quality of the waxes present on the leaf." He says it now appears that the ratio of far-red to red light picked up by the phytochrome determines which enzymes will be active and thus the composition and quantity of the resulting wax.

From the perspective of preserving its moisture, a plant might do better if it is mulched with white, which will give its leaves more wax, he says. Some fungi and other pests feed on those waxes, however, so from a crop protection standpoint, a farmer might prefer a black mulch, which would reduce the wax in favor of more pest-resistant alkanes (a type of pure hydrocarbon). Red mulch led to a wax equivalent to that obtained with a black plastic mulch but an alkane profile more like the one with white mulch.

As the South Carolina scientists grew tomatoes, strawberries, peppers, turnips, and other plants under different color regimes, they tasted subtle differences in the produce. "We figured that if we can taste the difference," Kasperbauer recalls, "chemists ought to be able to tell us why."

George F. Antonious of Kentucky State University in Frankfort and his colleagues decided to take a stab at it. They offered 25 adults samples of turnips. Unbeknownst to the volunteers, the vegetables came from batches grown on three different colors of mulch.

Twenty-four of the volunteers described turnips from blue-mulched plastic as "sharp," whereas those mulched in green tasted mild, "almost sweet." Turnips grown under white mulch possessed the least distinct flavor.

Consistent with the taste panel's observations, the roots grown under green mulch had the most soluble sugars, Antonious' group reported in the September 1996 PHOTOCHEMISTRY AND PHOTOBIOLOGY. Turnips mulched with blue contained the highest concentrations of glucosinolates, a family of chemicals responsible for imparting the bite to horseradish and mustard greens. Also found in broccoli, these compounds may reduce the risk of certain cancers (SN: 3/21/92, p. 183).

Since the blue and green mulches reflected roughly equivalent amounts of red, far-red, and photosynthetically active light, the scientists note, the chemical differences between turnips must trace to something else—perhaps the blue light (440 to 460 nm), which reflected most strongly off the blue mulch.


Kasperbauer/ARS

In field tests, colored mulches can affect a plant's stature, fruit yield—and even flavor.

Similar taste and chemical analyses of carrots and strawberries grown with different colored mulches are now under way.

Perhaps the least expected attribute of color has been its role in countering the ravages of nematodes, parasitic roundworms that burrow into the roots of plants, such as tomatoes. A root tumor that develops around each worm serves as a nest for the next generation of nematodes. While these worms usually do not kill their host, the energy they steal to fuel their growth and reproduction can severely diminish a plant's yield, as well as its resistance to other blights.

Earlier this year, Clemson University nematologist Bruce A. Fortnum sterilized the soil in a few small South Carolina plots to kill any resident root knot nematodes. Working with Hunt and Kasperbauer, he then planted tomatoes in red- or black-mulched rows in the sterilized plots and inoculated half of the plants in each mulch with up to 100,000 nematode eggs.

Despite high rates of infection, plants in the red-mulched rows yielded 85 percent as much fruit as nematodefree plants. The red-mulched plants suffered only half the yield losses of the plants in black-mulched plots.

What appears to have happened, Fortnum says, is that the red mulch enabled the plant "to mature a little quicker, so that it produced much of its fruit before the nematodes laid their eggs." It's during the egg-laying period that nematodes drain the most energy from the plant. Moreover, by telling the plant to concentrate most of its growth in the aboveground tissue, the red mulch may have caused malnutrition in the root-bound nematodes, he says, slowing their growth and reproduction.

Michael Orzolek, a vegetable crops scientist at Pennsylvania State University in College Park, has also observed pest-inhibiting advantages of mulches. Aphids appear to ignore plants mulched with silver, he says, and "we find the lowest populations of insects in plants mulched with blue."

Yellow, in contrast, attracts a host of bugs. Therefore, by judiciously mulching with yellow every seventh row or so—and using black, red, or some other mulch in all the others—"you limit the area you need to survey for pests," he's found. "If there are any pests, they'll be in that sentinel yellow row." The grower can then treat just the yellow row, as needed, or occasionally the whole field "if the pests are flying insects or move by leaping, as the leaf hopper does."

Before rushing out to place an order for vermilion mulch, consider a few words of caution.

Orzolek's preliminary work indicates that some of the effects may be cultivar-specific. For instance, in many of his trials, cucumbers have delivered more fruit and fewer misshapen fruits—a plus in the marketplace—when mulched with blue rather than black, red, or yellow. One year, on a whim, he tried the mulches on a hybrid cucumber and found that it appeared even more responsive to yield improvements with the blue mulch than the cultivar he tested earlier.

Brent Loy of the University of New Hampshire in Durham found that he couldn't reproduce Kasperbauer's tomato yield improvements with red mulch. The reason, he now suspects, is that he didn't stake his tomatoes, so they may have covered the mulch by midseason, erasing any reflective advantage it might have had. Alternatively, he notes, he may have oriented his rows so that by midseason each plant was shading its neighbor and much of the mulch.

Kasperbauer also points out that two red plastics that appear identical to the human eye may reflect quite different far-red light—rendering one beneficial and the other useless. The same may be true of blues or any other hue. Yet few other research labs have correlated a mulch's reflectance with yield or pest data, he says, making it hard to determine what underlies their reported benefits.

"That's why the patent that the U.S. Department of Agriculture and Clemson University have pending describes the specific reflection spectrum that a mulch must have," Kasperbauer says. While red mulches have been marketed by several companies for at least 10 years, the reflectance-specified type that would be covered by this patent is only now becoming widely available. □