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EFFECT OF COLORED PLASTIC MULCHES ON SOIL AND AIR TEMPERATURE INSIDE A PLASTIC GREENHOUSE[1]

EFEITO DA COR DO PLÁSTICO PARA COBERTURA DO SOLO SOBRE A TEMPERATURA DO SOLO E DO AR NO INTERIOR DE ESTUFA PLÁSTICA

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SUMMARY

Changes in soil and air temperature caused by colored plastic mulches were measured in the Central Region of Rio Grande do Sul State, Brazil. Two experiments were performed during 1996 inside a plastic greenhouse cropped with an indeterminated variety of tomato. Mulch treatments were: white, black, blue, green, yellow and red. White, yellow and green mulches reflected back more solar radiation than red, blue and black mulches. During the daytime, soil was warmer under black, red, and blue mulches, and the air 5cm over the mulches as well. Minimum air temperature however, was similar over the mulches.

Key words: mulching, reflectivity, temperature.

RESUMO

Foram medidas as modificações na temperatura do solo e do ar causadas por plásticos de diferentes cores utilizados como cobertura do solo (mulching). Dois experimentos foram conduzidos durante o ano de 1996 no interior de uma estufa plástica cultivada com tomateiro. Os tratamentos de cobertura do solo foram: plástico branco, preto, azul, verde, amarelo e vermelho. A refletividade à radiação

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solar foi maior no plástico branco, amarelo e verde. Durante o período diurno, as temperaturas do solo e do ar a 5cm da superfície foram maiores nos plásticos preto, azul e vermelho. A temperatura mínima do ar, no entanto, foi similar sobre os plásticos.

Palavras-chave: cobertura do solo, refletividade, temperatura.

INTRODUCTION

Since the middle 1980s the use of plastic materials in tunnels and greenhouses has been increased in South Brazil to protect horticultural crops during the coldest months. Soil mulching is a technique recommended to be used in protected systems, including wet climates as South Brazil, where the air inside plastic tunnels and greenhouses presents high relative humidity. This is because soil mulching reduces water evaporation from soil and so it can decrease air humidity. Consequently, an improve in the aerial environment around the plants can be expected by using it (ROSENBERG, 1974; SALMAN et al., 1990; STRECK et al., 1994; 1996).

Soil mulching with black polyethylene is a current technique used by South Brazilian growers in protected systems. Thus, the quantification of the changes in the microenvironment by using differents colored mulches is an important issue and should be encouraged. STRECK et al. (1994) reviewed various aspects about the effect of mulching on soil and air microclimate. In addition, LAMONT Jr. (1993) demonstrated how the color of the muches affects its enegy-radiating behavior and its influence on the microclimate around the plants. In general, when compared to the bare soil, opaque mulches (black and white plastics, paper, petroleum, bitumem and straw) decrease the soil heat flux and the daily amplitude of soil temperature. Transparent and transluced mulches promote a relatively larger net radiation at the soil surface, increasing soil heat flux and both minimum and maximum soil temperature.

Among opaque mulches, soil temperature under black plastic is almost greater than under white plastic. Consequently, black plastic is often recommended to be used in spring to warm root zone while in summer and fall plantings white-surfaces work better (FORTNUM et al., 1995; CSIZINSZKY et al., 1995). Among colored opaque mulches, black, red and blue usually promote higher soil temperature during the daytime than green, orange, yellow, aluminium and white ones (CHAKRABORTY & SADHRU, 1994; FARIA Jr. et al., 1994; CSIZINSZKY et al., 1995; FORTNUM et al., 1995). The air temperature near soil surface is also affected by mulching. FRITSCHEN & SHAW (1960) reported an increase of 0.6 up to 2.8°C in air temperature at 5cm over black polyethylene compared with bare soil while CLARKSON (1960) reported an increase of 2.8 up to 11.1°C.

These results were obtained in different countries and in open field crops. In protected conditions, particularly in South Brazil, there are a few studies with colored plastic mulches. STRECK et al. (1995) reported soil temperature changes by using clear, black, white and co-extruded white-on-black mulches inside a plastic greenhouse cropped with tomato in Santa Maria. More informations about the effect of the mulch color on micrometeorologycal changes in soil and air temperature in South Brazilian conditions are needed.

The purpose of this study was to measure changes in soil and air temperature near colored plastic mulches inside a plastic greenhouse.

MATERIAL AND METHODS

Two experiments were carried out inside a 10m x 25m nonheated greenhouse covered with low density transparent polyethylene film (100μm thickness) located at the Experimental Field Station of the Departamento de Fitotecnia of the Universidade Federal de Santa Maria, RS, Brazil (29°43'S latitude, 53°48'W longitude, and 95m altitude). Studies were performed during two crop-seasons, Fall and Spring 1996. Soil was mulched with 100μm tickness transparent polyethylene sheet. The opaque colored mulches treatments were obtained by painting individual plots of 4m x 2.5m in the following colors: white, black, blue, green, yellow and red. Commercial polivinil acetate paints were used. A bare soil plot was used as a standard control.

After painting the mulches, plots were cropped with "Monte Carlo" tomato. Three rows of plants were used with a 1m x 0.33m plant spacing, two rows in each plot border (guard plants) and the third one in the center of the plots. Each treatment was replicated three times. Irrigation was performed by drip lines under the mulch. Water was applied through the irrigation lines to keep tension lower than 80 Kpa. The control plot was irrigated in order to keep the soil moisture similar to the mulched ones.

The Experiment-I was conducted from February 27th to July 11th. Soil temperature at 2cm and 5cm depth was measured by mercury-in-glass geothermometers on four clear days during the cropping period. The measurements were done from 7:00 a.m. up to 7:00 p.m., local standard time (LST), every hour.

The Experiment-II was performed from July 23rd to December 26th. Before tomato planting, reflectivity to solar radiation of the mulches was measured at 70cm height over the center of one plot in each treatment by using a LI-COR radiometer with piranometer sensors (Lambda Instrument Co.). Measurements were taken on five clear days during July 24th to July 31st from 10 a.m. up to 2 p.m. The reflectivity (R) was calculated by:

$$R\ (\%) = \frac{Rs_{out}}{Rs_{in}} \times 100 \qquad (1)$$

Where Rs_{out} and Rs_{in} are the reflected and incident solar radiation measured over the mulch, respectively. Soil temperature at 2cm and 5cm depth and air temperature at 5cm over the mulches were also measured during July 30^{th}, july 31^{st} and August 1^{st}, clear days, from 7:00 a.m. to 7:00 p.m., LST, every hour. The soil heat flux (S) was also estimated on this three clear days according to Fick's law:

$$S = -K\left(\frac{\Delta T}{\Delta X}\right) \qquad (2)$$

Where K = thermal conductivity and $\Delta T / \Delta X$ = temperature gradient. Thermal conductivity of mulched and bare soils was estimated according De VRIES (1963) and DECICO (1974).

Throughout cropping period, the soil temperature was measured daily using mercury-in-glass geothermometers at 2cm and 5cm depth buried within the central plant row of the plots. Measurements of soil temperature were taken at 3:00 p.m. and 4:00 p.m., LST, when the maximum soil temperature occurs at 2cm and 5cm depths, respectively, in Santa Maria (SCHNEIDER, 1979). Minimum air temperature was measured daily by alcohol-in-glass thermometers located at 5cm over mulch surfaces within the central plant row.

Outside data as minimum air temperature at 5cm over bare soil, grass-cropped soil and straw-mulched soil were obtained from a Meteorological Station located 100m far from the Experimental area.

RESULTS AND DISCUSSION

The average reflectivity to solar radiation, minimum air temperature over the treatments and maximum soil temperature under them and in bare soil are presented in Table 1. White, yellow and green mulches reflected back more solar radiation than red, blue and black mulches as well as the bare soil. Minimum air temperature inside the greenhouse was similar over all plastic mulches and lower than on bare soil. Maximum soil temperature followed the sequence black > red > blue > bare soil > green > yellow > white.

Having similar transmissivity, surfaces with high reflectivity have low absortivity and vice-versa. Thus, during the daytime, surfaces with high reflectivity are cooler than surfaces with low reflectivity. Since the air surrounding the surface cools and warms in contact with it, the air layer near the warmest mulches (black, red and blue) had a higher temperature than near the coolest ones (Figure 1). Soil temperature under the mulches followed the same trend, but greater differences among treatments were observed certainly because sensible air heat over the mulches is lost faster by mass flux (convection) than in soil, where heat is transfered by conduction, i.e., do not so fast. Mulches were opaques to solar radiation, so heat was transferred towards the soil by conduction from the mulch surface. Consequently, the greater the temperature of the mulch the greater the soil heat flux. When plants grew, differences of maximum soil temperature among treatments, in general, decreased due to interception of solar radiation by the canopy (Experiment II, Table 2). Similar results were observed during Experiment- I.

Soil and air temperature during daytime were always higher on mulched plots than on bare soil before and during the cropping season (Figure 1 and Table 2). In the bare soil, a greater quantity of net radiation is used as latent and sensible heat fluxes, resulting little fraction of energy for soil heat flux. Under the mulches however, the latent flux is near zero because water evaporation is strongly reduced (STRECK et al., 1994; STRECK et al., 1996). Thus, soil heat flux was greater under the mulches, mainly under black, blue and red. On the bare soil, certainly latent flux was greater than sensible heat because soil was irrigated in order to keep soil moisture similar among treatments. Differences between bare soil and mulched soil increased towards the end of cropping season, maybe because the tomato plants did not cover the whole area between the plant lines.

Air temperature on the bare soil was lower than on the mulches (dry surfaces) where latent flux is near zero. This hipothesis may explain the highest air temperature observed over the white mulch than over bare soil between 12:00 and 14:00 (Figure 1b) even the reflectivity of white mulch had been much higher than bare soil (almost four times greater). So, this certainly may be explained by partition of the components of energy balance over both surfaces.

On the other hand, minimum air temperature was lower over the mulched plots than on the bare soil (Table 1). A mulched surface emits radiation and its temperature decreases. The thin air layer between the mulch and the soil and also the mulch cover itself, which is a dry surface, may work as an insulator, decreasing the transference of heat from the soil to the mulch. In bare soil however, heat is transfered up from lower layers and may supply part of the energy lost by soil surface.

From a pratic point of view, it may be expected that a greenhouse which has the soil surface covered with a mulch would have lower night temperatures, mainly in the early morning, than a greenhouse that would have a nonmulched soil. However, minimum air temperature even over the mulches inside de greenhouse was greater than outside (Table 1). In the coldest days, when the risck of freezing damage to crops is higher, differences between minimum air temperature over mulches inside the greenhouse and the grass-cropped soil outside reached up 5.1°C. These differences were high enough to protect a tomato crop against frost and similar to those reported by BURIOL et al. (1993) who demonstrated the effectiveness of nonheated plastic greenhouses as a technology to protect horticultural crops from freezing in Central Region of Rio Grande do Sul State.

Results presented in this paper about the effect of colored mulches on soil and air temperature inside greenhouse are in agreement with others works performed in open field studies (PENDLETON et al., 1966; SILVA, 1980; BERTON, 1981; CHAKRABORTY & SADHRU, 1994; FARIA Jr. et al., 1994; CSIZINSZKY et al., 1995; FORTNUM et al., 1995). In general, black, blue and red mulches absorb more solar radiation and transfere more energy as sensible heat to the air over and also to the soil under the mulch surface as compared to green, yellow and white ones. As the temperature differences between black and white mulches in the afternoon reached up 2.6°C in air and 6°C in soil (Figure 1 and Table 2), the warm mulches should be carefully used during the hotest months of the year in order to prevent heat damage, particularly to young plants.

Another information presented in this paper is concerning the reflectivity of colored mulches. According to ESTEFANEL et al. (1998), the lower availability of solar radiation during the winter months in Santa Maria is a limitant factor for tomato production inside plastic greenhouse. The colored mulches, specially white and yellow ones, are a very useful tool for increasing solar radiation availability to promote plant growth during the winter inside plastic greenhouses.

Table 1. Average values of reflectivity to solar radiation (R), minimum air temperature and maximum soil temperature inside and outside the greenhouse. Santa Maria, RS, Brazil, 1996.

Mulch	R (%)	Minimum air temperature at 5cm height (°C)			Maximum soil temperature (°C)	
		A	B	C	2cm depth	5cm depth
Inside greenhouse						
Black	12.02	14.0	4.2	22.8	29.7	28.6
Blue	28.93	13.9	3.9	23.6	27.4	26.1
Red	34.54	14.0	4.2	23.2	27.9	26.8
Green	48.93	13.8	3.9	22.6	26.2	25.3
Yellow	59.56	13.8	3.7	22.9	26.2	25.5
White	55.95	13.7	4.2	22.7	24.7	24.3
Bare Soil	13.50	14.3	4.7	22.7	26.5	25.9
Meteorological Station						
Bare soil	-	0.2	0.5	19.4	26.1	24.9
Grass-cropped soil	-	11.1	-0.9	18.8	23.2	21.6
Straw-mulched soil	-	-	-	-	21.5	20.9
n	25	151	10	10	166	166

A= average of the experimental period B = ten coolest days
C = ten warmest days n = number of observations

Table 2. Differences of maximum soil temperature (°C) among mulch treatments inside plastic greenhouse, Santa Maria, RS, Brazil, 1996. Read vertical - horizontal.

Mulch	Depth (cm)	Mulch: Black	Blue	Red	Green	Yellow	White
		......Average of 30 first days......					
Bare soil	2	-2.7	-1.2	-1.5	1.0	2.5	3.3
	5	-2.3	-0.5	-0.5	1.4	2.7	3.6
Black	2		1.6	1.2	3.7	5.2	6.0
	5		1.9	1.8	3.7	5.0	5.9
Blue	2			0.4	2.2	3.6	4.4
	5			0.1	1.8	3.2	4.0
Red	2				2.5	4.0	4.8
	5				1.9	3.2	4.1
Green	2					1.4	2.3
	5					1.3	2.2
Yellow	2						0.8
	5						0.8
		......Average of 30 last days......					
Bare soil	2	-5.5	-2.6	-3.1	-1.3	-1.2	-0.2
	5	-4.9	-2.2	-3.0	-1.4	-1.9	-0.9
Black	2		2.9	2.4	4.2	4.3	5.3
	5		2.7	1.8	3.5	3.0	3.9
Blue	2			-0.5	1.3	1.4	2.4
	5			0.9	0.8	0.3	2.7
Red	2				1.8	1.9	2.9
	5				1.7	1.2	2.1
Green	2					0.1	1.1
	5					-0.5	0.5
Yellow	2						1.0
	5						0.9

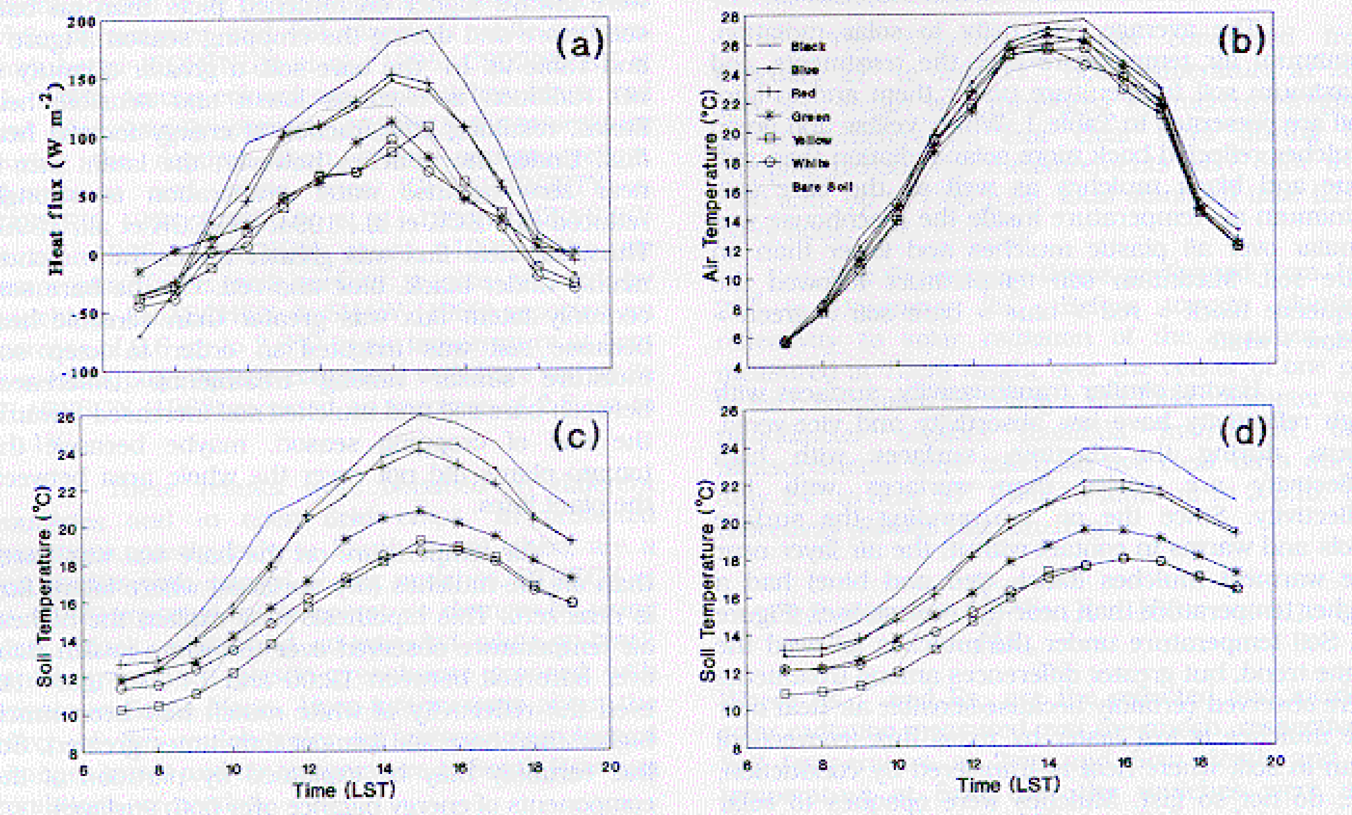

Figure 1. Daytime variation of soil heat flux (a), air temperature 5cm over mulches (b) and soil temperature at 2cm depth (c) and 5cm depth (d) under colored plastic mulches inside a plastic greenhouse. Santa Maria, RS, Brazil. Hourly average values of 3 clear days (July 30th, July 31st and August 1st, 1996).

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