

# EFFECT OF POLYETHYLENE MULCHES ON SOIL TEMPERATURE AND TOMATO YIELD IN PLASTIC GREENHOUSE<sup>1</sup>

N.A. STRECK<sup>2</sup>; F.M. SCHNEIDER<sup>2</sup>; G.A. BURIOL<sup>2</sup>; A.B. HELDWEIN<sup>2</sup>

<sup>2</sup> *Depto. de Fitotecnia -CCR/UFMS, CEP: 97119-900 - Santa Maria, RS.*

**ABSTRACT:** The effect of soil mulching with transparent, black, white, and co-extruded white-on-black polyethylene sheets on soil temperature and tomato yield was evaluated in the Subtropical Central Region of the Rio Grande do Sul State, Brazil. The experiment was carried out from August 21, 1994 to December 2, 1994 in a 10m x 25m nonheated plastic greenhouse located at the county of Santa Maria. Highest soil temperatures were obtained under transparent mulch. Maximum amplitude of soil temperature waves was smaller under opaque mulches. Tomato yield was not significantly affected by mulch treatments, however, a tendency of greater yield was observed for opaque mulches as compared to transparent mulch. Among opaque mulches, the highest yield was obtained from white mulches.

**Key Words:** mulching, soil temperature, tomato, plastic greenhouse

## EFEITO DA COBERTURA DE POLIETILENO SOBRE A TEMPERATURA DO SOLO E PRODUTIVIDADE DO TOMATEIRO EM ESTUFA PLÁSTICA

**RESUMO:** Este experimento foi conduzido para avaliar o efeito da cobertura do solo com polietileno transparente, preto, branco e co-extrudado branco-preto sobre a temperatura do solo e produtividade do tomateiro no interior de uma estufa plástica, em Santa Maria, Rio Grande do Sul, Brasil. O período experimental foi de 21 de agosto a 02 de dezembro de 1994. Observou-se que a temperatura máxima e média diária do solo foi maior sob polietileno transparente. A amplitude máxima da onda diária de temperatura do solo foi menor nos materiais opacos em relação ao transparente. Não houve diferença estatística na produtividade do tomateiro entre os tratamentos, mas a produtividade média foi maior com plásticos opacos do que com o plástico transparente. Entre os plásticos opacos, a maior produtividade foi obtida nos plásticos brancos, que refletem maior fração da radiação solar global incidente do que o plástico preto.

**Descritores:** cobertura, temperatura do solo, tomateiro, estufa plástica

### INTRODUCTION

Polyethylene (PE) mulches have induced large increases in growth and yields for a variety of crops, including tomato (EMMERT, 1957; TAKATORI *et al.*, 1964; VANDENBERG & TIESSEN, 1972; MULLINS *et al.*, 1992; LAMONT Jr., 1993). These growth and yield increases have been attributed to changes in soil and air temperature near the cover, soil water balance, and nutrient availability compared to unmulched soil (CLARKSON & FRAZIER, 1957; CLARKSON,

1960; BRUNINI *et al.*, 1976; HAYNES, 1987). Less soil compaction and hence improved aeration under mulched soil have also contributed to increased plant growth (EKERN, 1967; LAMONT Jr., 1993).

Soil temperature can be differentially affected by the type of PE mulch with temperatures generally following the order: transparent mulch > black mulch > white mulch (HAYNES, 1987). This is caused primarily through changes in the components of the radiation balance, due to the effect of mulches on albedo, sensible heat flux, latent heat flux, and soil heat flux (ROSENBERG, 1974;

<sup>1</sup> Research supported by FAPERGS (Fundação de Amparo à Pesquisa do Estado do Rio Grande do Sul) and PETROQUÍMICA TRIUNFO S.A.

LIAKATAS *et al.*, 1986). Transparent materials present high transmissivity to solar radiation and thus they are more effective in increasing soil temperature in comparison to the opaque materials, which highly reflect or absorb solar radiation (ROSENBERG, 1974).

The effects of various mulches on soil microclimate recently have been reviewed by STRECK *et al.* (1994). In this review the authors demonstrated that opaque mulches (black, white and colored plastics, paper, petroleum, bitumen, and straw) decrease the soil heat flux and the daily amplitude of the soil temperature. Transparent and translucent mulches promote a relatively large net radiation at the soil surface, increase soil heat flux and, as a consequence, the minimum and maximum soil temperature are increased.

LAMONT Jr. (1993) reviewed others aspects of plastic mulch as specifications, importance of color, and its advantages and disadvantages. The color of a mulch determines its energy-radiating behavior and its influence on the microclimate around the plant. Black, transparent, and white mulches predominate in the commercial vegetable production today over the world (LAMONT Jr, 1993). White mulch has been replaced largely by a co-extruded white-on-black.

Black mulch predominate in vegetable production systems in Southern Brazil. Transparent mulches are most used in collar regions to promote earlier yields (FARIAS-LARIOS *et al.*, 1994; LAMONT Jr., 1993; TABER, 1993; STRECK *et al.*, 1994). White, white-on-black, and aluminized materials constitute the family of reflective mulches. These mulches reflect back into the plant canopy most of the incoming solar radiation, and consequently, are more effective in increasing crop yields (PENDLETON *et al.*, 1966; LAMONT Jr., 1993; STRECK *et al.*, 1994; FARIAS-LARIOS *et al.*, 1994).

Since the middle 1980s the use of plastic materials to protect horticultural crops in tunnels and greenhouses is increasing in Southern Brazil. The atmosphere of plastic tunnels and greenhouses presents high values of relative humidity. Soil mulching reduce soil evaporation and an improve in the aerial environment around the plants is expected by its use. Tomato crop represents up to 80% of the protected area in Rio Grande do Sul State because its highest value.

The purpose of the current study was to determine the effects of different polyethylene

mulches on soil temperature and tomato yield inside a plastic greenhouse.

## MATERIAL AND METHODS

The experiment was carried out in a 10m x 25m nonheated greenhouse covered with low density transparent polyethylene with 100µm thickness, located at the Experimental Field of the Crop Production Department of the Federal University of Santa Maria, RS, Brazil (29° 43'S latitude, 53°48'W longitude, and 95m altitude). The texture of the greenhouse soil is loam, with 36% sand, 38% silt, and 26% clay.

Individual plots of 5.2m x 2m were arranged in a randomized complete block design with four replications. Soil mulching treatments were: opaque black PE (30µm thickness), transparent PE (50µm thickness), opaque white PE (50µm), and a co-extruded white-on-black PE (100µm thickness). The white side of the co-extruded white-on-black sheet was set up and consequently, it operated as a opaque white mulch. The mulches were applied on August 21, 1994. Organic fertilizer (6 kg of bovine compost/linear meter) was used in the plant row at 20cm depth. No chemical fertilizer was applied.

"Monte Carlo" tomato, an indeterminated growth variety, was sown on July 15, 1994. Seedlings of 4-leaf were planted on August 22, 1994, using 0.40m x 1.00m plant spacing. Each plot had two rows with tomato plants (13 plants/row and 26 plants/plot). Plants were irrigated by drip irrigation lines under the mulch. Water was applied through the irrigation lines as needed to keep tensiometer readings below 80kPa. Two tensiometers placed at 10cm depth within plant row monitored the soil moisture. The most common recommended agronomic practices for tomato in plastic greenhouse were followed throughout the investigation. Tomato plants were pruned at 1.80m height (6-7 clusters).

Soil temperature was measured throughout the plant growth period using mercury-in-glass geothermometers in one plot of each mulching treatment. Geothermometers were buried at 2cm, 5cm, 10cm, and 20cm depths in the mulched plots within the rows of tomato plants.

Daily measurements of soil temperature were taken at 9h00min, 15h30min, 16h00min, 17h30min, and 21h00min, local standard time (LST). At Santa Maria, RS, the daily minimum soil temperature at 20cm depth occur near to 9h and the daily maximum soil temperature at 2cm, 5cm, 10cm, and

20cm depths, occur near the afternoon measurements above cited, respectively (SCHNEIDER, 1979). Thus, the daily mean soil temperature at 20cm depth ( $T_m$ ) was calculated by:

$$T_m = (T_{20cm0h} + T_{20cm24h})/2 \quad (1)$$

Where  $T_{20cm0h}$  and  $T_{20cm24h}$  are the minimum and maximum soil temperature at 20cm depth, respectively.

According to DECICO (1974) and SCHNEIDER (1979) if the mean soil temperature at a given depth is known, it can be assumed as being the mean temperature of the soil profile ( $T$ ). Assuming that the daily wave of soil temperature follow a sinusoidal model, regardless of the depth, the maximum amplitude of the soil temperature wave ( $T_0$ ) at each depth (i) can be estimated by:

$$T_0 = T_{max} - T_m \quad (2)$$

Equations (1) and (2) were used to estimate the mean temperature of soil and the maximum amplitude of each soil depth under the mulched plots.

Twelve tomato plants per treatment were tagged and the duration of planting-flowering and planting-ripening sub-periods were recorded in the lower cluster. Flowering date (anthesis) was considered when the first flower of the lower cluster was completely opened. Ripening date was assumed as the day when the first fruit of the plant was red dyed. Fruits were harvested once a week from October 27, 1994 to December 02, 1994. The yield parameters evaluated were number and weight of marketable and nonmarketable harvested fruits. Nonmarketable fruits were those with defects and/or disorders. Early yield was considered as the total weight of marketable fruits of the first three harvests. Crop yield was determined on basis of area per plot (10.5m<sup>2</sup>). Data were subjected to analysis of variance and differences among means were distinguished using the Duncan's test.

## RESULTS AND DISCUSSION

The highest soil temperature occurred under transparent PE followed by white, black, and co-extruded white-on-black PE, regardless the depth (TABLE 1). In general, this effect was more evident during the early crop season when tomato plants

TABLE 1. Average values of daily maximum temperature (°C) of mulched soil of the plastic greenhouse throughout the experimental period. Santa Maria, RS, Brazil, 1994.

Mulch	Depth (cm)			
	2	5	10	20
..... Average of the experimental period .....				
Co-extruded white-on-black	28.3	27.6	25.5	24.6
White	30.2	29.1	28.9	26.1
Black	29.0	28.2	26.7	24.9
Transparent	34.0	31.9	29.2	26.2
..... 10 first days of the experimental period .....				
Co-extruded white-on-black	23.0	22.0	20.7	19.6
White	27.8	26.0	25.2	22.5
Black	25.0	24.4	22.5	20.8
Transparent	28.8	27.3	26.0	23.0
..... 10 last days of the experimental period .....				
Co-extruded white-on-black	33.8	33.1	30.2	29.6
White	36.2	34.4	33.4	30.1
Black	34.2	33.8	31.8	29.5
Transparent	39.4	36.4	33.9	30.8

shaded less the soil surface. Average values of mean soil temperature followed the same trend (TABLE 2).

Transparent mulches are more effective in increasing soil temperature due a greater net radiation under the mulch compared to opaque mulches (ROSENBERG, 1974; LIAKATAS *et al.*, 1986; STRECK *et al.*, 1994). Consequently, the soil heat flux is substantially greater under transparent mulch. LIAKATAS *et al.* (1986) reported that the maximum soil heat flux was up to 67% higher under transparent mulch in comparison to the black mulch. White PE used in this study trended to increase maximum temperature compared to the other opaque mulches (black and co-extruded white-on-black PE). This increase probably occurred due to the white PE is not completely opaque. It is expected that white and co-extruded white-on-black PE have a similar effect on soil temperature.

The maximum amplitude of soil temperature was different in the mulch treatments (TABLE 2). Small amplitude was achieved in opaque mulches. This effect was greater on clear days, but it remained on cloudy days. Similar results were reported by

LIAKATAS *et al.* (1986). The amplitude of the soil temperature wave decreased with depth, regardless the mulch. This behavior follows the classical theory of soil heat flux, where temperature wave is dampened when the depth increases.

The effect of mulching materials on soil temperature obtained in this study are in agreement with those reported by others researchers (ROSENBERG, 1974; LIAKATAS *et al.*, 1986; HAYNES, 1987; STRECK *et al.*, 1994).

Tomato plants began flowering and ripening at the same time in the mulch treatments (TABLE 3). Small differences were observed in ripening between white and black mulch (5 days). Parameters of tomato yield were not significantly affected by mulch treatments. However, it can be observed that highest tomato yields were obtained in opaque mulches. Similar results were reported by SALMAN *et al.* (1990) with cucumber and cantaloupe inside a plastic greenhouse.

As indicated previously, transparent PE raised soil temperature compared to the opaque PE. According to REY & COSTES (1965) the optimal range of soil temperature for tomato root growing is

TABLE 2. Values of mean temperature (T) and maximum amplitude (T<sub>0</sub>) of temperature (°C) of mulched soil of the plastic greenhouse. Santa Maria, RS, Brazil, 1994. °

Depth (cm)	Co-extruded White-on-black		White		Black		Transparent	
	T	T <sub>0</sub>	T	T <sub>0</sub>	T	T <sub>0</sub>	T	T <sub>0</sub>
..... Average of the experimental period .....								
2	23.9	4.4	25.1	5.2	24.2	4.6	24.9	9.1
5		3.7		4.0		4.1		7.0
10		1.6		3.8		2.6		4.4
20		0.7		1.0		0.9		1.4
..... 5 clear days (n/N > 0.9) .....								
2	24.1	5.7	25.4	6.3	24.4	5.5	25.7	11.6
5		4.9		5.4		5.1		9.2
10		2.1		4.2		3.1		5.5
20		1.1		1.3		1.1		1.9
..... 5 cloudy days (n/N < 0.1) .....								
2	22.6	1.7	23.8	2.2	23.0	2.0	23.3	3.9
5		1.5		1.5		1.7		3.5
10		0.8		1.0		0.7		1.7
20		0.3		0.3		0.2		0.3

n = sunshine duration (hours/day)

N = day length (hours/day)

20-30°C, while temperatures of 38°C or more decrease water absorption and reduce plant growth. Soil temperature at 2cm depth achieved absolute values of up to 42.2, 40.8, 38.0, and 37.0°C under transparent, white, black, and co-extruded white-on-black PE, respectively, during the tomato growing period. Observed maximum temperature at 2cm depth exceeded 38°C in 23, 2, and 1 days under transparent, white, and black PE, respectively. Thus, soil temperature was probably harmful to the tomato plants in the transparent mulch. High soil temperature enhances vegetative growing and decreases tomato yield (REY & COSTES, 1965).

Several papers have demonstrated that transparent mulches increase yield and improve crop growth of many field-grown vegetable crops

compared to the opaque mulches (TABER, 1993; FARIAS-LARIOS *et al.*, 1994). This increase have been reported especially in cold regions, where soil temperature is low and limitant for plant growth. Soil temperature of plastic greenhouses in Central Region of the Rio Grande do Sul State is not a limitant factor to the greater number of horticultural vegetable crops (SCHNEIDER *et al.*, 1993). This can explain the lowest yield obtained with transparent PE mulch in this experiment. As a consequence of high temperature, the use of transparent PE mulch probably also reduced plant survival compared to the opaque mulches (TABLE 4).

Other problem presented by transparent mulch is the weed growth. A new

TABLE 3. Effect of polyethylene mulches on duration of planting-flowering (P-F) and planting-ripening (P-R), early yield (EY), and marketable (MK) and nonmarketable (NMK) yield of tomato inside a plastic greenhouse. Santa Maria, RS, Brazil, 1994.

Mulch	P-F days	P-R days	EY (kg/m <sup>2</sup> )	Total Yield			
				Fruit weight (kg/m <sup>2</sup> )		Fruit number/m <sup>2</sup>	
				MK	NMK	MK	NMK
Co-extruded white-on-Black	27	75	0.55a*	4.27a	0.55a	25a	7a
White	27	73	0.64a	4.01a	0.42a	25a	5a
Black	28	77	0.40a	3.81a	0.42a	23a	5a
Transparent	28	75	0.44a	3.60a	0.45a	21a	6a
C.V. (%)			65.38	14.55	26.02	16.77	20.37

\*Means in each column followed by the same letter are not significantly different by Duncan's Multiple Range test (P < 0.05).

TABLE 4. Tomato plant survival sampled during the fruit harvest period in the soil mulch treatments of the plastic greenhouse. Santa Maria, RS, Brazil, 1994.

Mulch	plant/plot			
	1st harvest		6th harvest	
	number	%*	number	%
Co-extruded white-on-Black	24	92	24	92
White	25	96	24	92
Black	25	96	25	96
Transparent	20	77	20	77

\*% over the initial plant number/plot (26pl/plot).

wavelength-selective plastic mulch has been developed that combine the properties of the black and the transparent mulch (TABER, 1993; LAMONT Jr, 1993). This new films transmit solar infrared radiation that warms the soil but blocks a portion of the photosynthetic radiation, thus limiting weed growth. The color of this mulch can be blue-green or brown (LAMONT Jr, 1993). TABER (1993) reported that the muskmelon yield from a wavelength-selective mulch in IOWA, USA, was comparable to transparent plastic, but its extra cost is not justified.

Among opaque mulches, highest tomato yield was obtained in white mulches (TABLE 3). PENDLETON *et al.* (1966) reported yield increases from 7 to 12% in corn plants grown in white plastic compared to unmulched soil, while black plastic resulted in small yield increase (3 to 5%). ROBERTS & ANDERSON (1994) reported that two out of 3 years, plots with a black plastic mulch had marketable yield lower than those from others treatments including opaque white plastic. The yield increases of crops due to white mulch have been attributed to an increasing of reflected solar radiation.

Economic questions also need to be addressed to determine if using black or white mulch in protected tomato crop in Southern Brazil. In this experiment did not have estatistical differences among mulch treatments. But the yield increase from the co-extruded white-on-black compared to black mulch was 12%. This increase represented 115 kg of tomato fruits in a 250 m<sup>2</sup> greenhouse. It is possible that the yield increase by white PE recompense it additional cost compared to the black PE.

The use of mulching with transparent plastic during crop growth is not expected in Southern Brazil. But, its use during the summer months for soil disinfestation (soil solarization) have a good potential (STRECK, 1994). It is recommended to paint the mulch after the solarization period. White is the color most recommended when transparent mulch will be transformed in opaque mulch.

## REFERENCES

- BRUNINI, O., SANTOS, J.M., ALFONSI, R.R., *et al.* Estudo micrometeorológico com cenouras (Variedade Nantes): I. Influência da temperatura do solo. *Bragantia*, v.35, n.4, p.49-54, 1976.
- CLARKSON, V.A. Effect of black polyethylene mulch on soil and microclimate temperature and nitrate level. *Agronomy Journal*, v.52, n.6, p.307-9, 1960.
- CLARKSON, V.A.; FRAZIER, W.A. Effect of paper and polyethylene mulches and plastic caps on cantaloupe yields and earliness. *Proceedings of American Society for Horticultural Science*, v.69, p.401-4, 1957.
- DECICO, A. A determinação das propriedades térmicas do solo em condições de campo. Piracicaba, 1974. 78p. Tese (Livre-Docência)-Escola Superior de Agricultura "Luiz de Queiróz"/Universidade de São Paulo.
- EKERN, P.C. Soil moisture and soil temperature changes with the use of black vapour-barrier mulch and their influence on pineapple (*Ananas comosus* (L.) Merr.) growth in Hawaii. *Soil Science Society of America Proceedings*, v.31, n.2, p.270-5, 1967.
- EMMERT, E.M. Black polyethylene for mulching vegetables. *Proceedings of American Society for Horticultural Science*, v.69, p.464-8, 1957.
- FARIAS-LARIOS, J.; GUZMAN, S.; MICHEL, A.C. Effect of plastic mulches on the growth and yield of cucumber in a tropical region. *Biological Agriculture and Horticulture*, v. 10, p. 303-6, 1994.
- HAYNES, R.J. The use of polyethylene mulches to change soil microclimate as revealed by enzyme activity and biomass nitrogen, sulphur and phosphorus. *Biology and Fertility of Soil*, v.5, n.3, p.235-40, 1987.
- LAMONT Jr., W.J. Plastic mulches for the production of vegetable crops. *Hort Technology*, v.3, n.1, p.35-9, 1993.
- LIAKATAS, A.; CLARK, J.A.; MONTEITH, J.L. Measurements of the heat balance under plastic mulches. *Agricultural and Forest Meteorology*, v.36, p.227-39, 1986.
- MULLINS, C.A.; STRAW, R.A.; RUTLEDGE, A.D. Tomato production with fertigation and black plastic mulch. *Tennessee Farm and Home Science*, p.23-8, 1992.
- PENDLETON, J.W.; PETERS, D.B.; PEEK, J.W. Role of reflected light in the corn ecosystems. *Agronomy Journal*, v.58, p.73-4, 1966.
- REY, Y.; COSTES, C. *La physiologie de la tomate: Étude bibliographique*. Versailles: Institut National de la Recherche Agronomique/ Station Centrale de Physiologie Végétale, 1965. 111p.
- ROBERTS, B.W.; ANDERSON, J.A. Canopy shade and soil mulch affect yield and solar injury of bell pepper. *HortScience*, v.29, n.4, p.258-60, 1994.

- ROSENBERG, N.J. *Microclimate: the biological environment*. New York: John Wiley, 1974. 315p.
- SALMAN, S.R.; BAKRY, M.O.; ABOU, A.F., *et al.* The effect of plastic mulch on the microclimate of plastic greenhouse. *Acta Horticulturae*, n.287, p.471-425, 1990.
- SCHNEIDER, F.M. *Comportamento e propriedades térmicas do solo Santa Maria*. Piracicaba, 1979. 77p. Dissertação (Mestrado) Escola Superior de Agricultura "Luiz de Queiróz"/Universidade de São Paulo.
- SCHNEIDER, F.M.; BURIOL, G.A.; ANDRIOLO, J.L., *et al.* Modificação na temperatura do solo causada por estufas de polietileno de transparente de baixa densidade em Santa Maria, RS. *Revista Brasileira de Agrometeorologia*, v.1, p.37-42, 1993.
- STRECK, N.A. *Modificação na temperatura do solo causada pela solarização em estufa plástica*. Santa Maria, 1994. 82p. Dissertação (Mestrado)-Universidade Federal de Santa Maria.
- STRECK, N.A.; SCHNEIDER, F.M.; BURIOL, G.A. Modificações físicas causadas pelo mulching. *Revista Brasileira de Agrometeorologia*, v.2, p.131-42, 1994.
- TABER, H.G. Early muskmelon production with wavelength-selective and clear plastic mulches. *Hort Technology*, v. 3, n. 1, p. 78-80, 1993.
- TAKATORI, F.H., LIPPERT, L.F., WHITING, F.L. The effect of petroleum mulch and polyethylene films on soil temperature and plant growth. *Proceedings of American Society for Horticultural Science*, v.85, p.532-40, 1964.
- VANDENBERG, J.; TIESSEN, H. Influence of wax-coated and polyethylene-coated paper mulch on growth and flowering of tomato. *HortScience*, v.7, n.5, p. 464-65, 1972.

---

Recebido para publicação em 26.06.95

Aceito para publicação em 25.08.95