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# EFFECT OF MULCH WIDTH IN HEATING SOIL FOR SOLARIZATION[1]

# EFEITO DA LARGURA DO "MULCH" NA SOLARIZAÇÃO DO SOLO

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## SUMMARY

Soil solarization is usually made with a single polyethylene sheet and thus, a "border effect" is verified in solarized plots. This study was carried out in order to analyse the effect of mulch width on soil temperature and to estimate the border effect in solarized plots of a loam soil at Santa Maria, RS, Brazil. The experiment was carried out in an open field using 40 cm-, 80 cm-, 120 cm-, 160 cm-, and 200 cm-wide mulches covered with transparent polyethylene. Soil temperature was measured at 2 cm, 5 cm, and 10 cm depths in the center of the mulched plots and in an unmulched control plot (bare soil). At 5cm depth, soil temperature was measured from center to the border of the mulched plots and 20cm outside the mulches. Narrow mulches (smaller than 50 cm-wide) do not solarized efficiently because the temperature in their center is lower. The border effect in solarized plots was estimated as being about 23 cm.

**Key words**: soil solarization, soil temperature, mulch width.

## RESUMO

O "efeito de borda" é comum nas áreas tratadas pela solarização do solo. Um estudo foi realizado para analisar o efeito da largura de mulching para solarização do solo e estimar o efeito de borda em parcelas solarizadas de um solo franco da região de Santa Maria, RS, Brasil. O experimento foi conduzido no campo utilizando coberturas de polietileno transparente com larguras de 40 cm, 80 cm, 120 cm, 160 cm e 200 cm e o solo desnudo sem cobertura. A temperatura do solo foi medida nas profundidades de 2 cm, 5 cm e 10 cm no centro das parcelas com cobertura e no solo desnudo. Na profundidade de 5cm a

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temperatura do solo foi medida a partir do centro até a borda das parcelas cobertas e no exterior a 20 cm da borda. Áreas com largura menor que 50 cm apresentam menor aquecimento no centro da parcela e devem ser evitadas. O efeito de borda no que se refere ao aquecimento do solo foi estimado como sendo uma faixa de aproximadamente 23 cm.

**Palavras-chave**: solarização do solo, temperatura do solo, largura de "mulch".

## INTRODUCTION

Various types of mulching materials are used to modify soil microclimatic conditions. Effects of mulching by straw, paper, aluminum, petroleum, and polyethylene films have been described in many papers (HOPEN, 1965; COURTER & DEBKER, 1966; ROSENBERG, 1974; STRECK et al, 1994b). Soil mulchings eliminate evaporation, promote changes in soil temperature, water balance, and nutrient availability. As a consequence an increase in growth and yield of vegetable crops is expected (TAKATORI et al, 1964; VANDENBERG & TIESSEN, 1972; HAYNES, 1987; STRECK et al, 1994b).

Transparent materials, with high transmissivity to solar radiation, are more effective in increasing soil temperature in comparison to opaque materials, which highly reflect or absorve solar radiation (ROSENBERG, 1974; MAHRER & KATAN, 1981; MAHRER, 1991; SCHNEIDER et al, 1993; STRECK et al, 1994b). Therefore transparent polyethylene films have been recommended for mulching moist soils during summer months, in an attempt to raise soil temperature high enough to kill soilborne pathogens (KATAN et al, 1976). This method is a new approach for controlling soilborne plant pests and is referred as Soil Solarization. Its effectiveness on soil temperature and soilborne pathogens was investigated in several countries (KATAN et al, 1987; KATAN & DEVAY, 1991; SCHNEIDER et al, 1993).

It is well known that solarization is significantly reduced near cover edges (MAHRER & KATAN, 1981; MAHRER, 1991; SCHNEIDER, 1993; STRECK, 1994; STRECK et al, 1994a). This border effect was observed and discussed earlier by JACOBSOHN et al (1980). In their experiment, solarization effectively controlled broomrape. However, broomrape infestation along the margin of the solarized plots was only partially reduced.

The optimal treatment width for covering a solarized plot would be full cover. However, the economic advantages resulting from a complete covering must be weighed against the additional work and cost envolved. In addition, commercial widths available are also a limiting factor. Thus, soil solarization is more commonly made with separate plastic films and the border effect appears due to heat loss to adjacent plots, resulting in a reduced solarization efficiency (MAHRER & KATAN, 1981; MAHRER, 1991; SCHNEIDER, 1993).

The optimal width of a single plastic sheet for solarization was studied in Israel and it was found to be influenced by the interaction of wind drag and lifting force on the laid plastic film, the cumulative destructive effect of tears, the ease of application, and the severity of soil compaction (KATAN & DEVAY, 1991). MAHRER & KATAN (1981) described a two-dimensional numerical model for calculating the soil temperature regime under polyethylene films and showed that narrow mulches provides less heating than wider mulches. These autors worked with mulch widths ranging from 10 cm to 200 cm. Their results allowed to conclude that when a 50% to 80% efficiency of wide mulch is allowed, then 10 cm- to 40 cm-wide mulches are sufficient, respectively. Narrow mulches with transparent polyethylene should be used to increase soil temperature during winter. In Brazil, transparent mulch for increasing soil temperature during cold seasons is a non common practice. Soil solarization is a new technique in Southern Brazil, presenting a good potential in the region, particularly inside plastic greenhouses (STRECK, 1994; STRECK et al, 1994a). Thus, the effectiveness of mulching to increase soil temperature should be maximized and the use of mulch widths smaller than 40cm should be avoided since the border effect in solarized plots is of the order of 25 cm (KATAN & DEVAY, 1991; STRECK, 1994; STRECK et al, 1994a). Southern farmers use most commonly 80 cm- to 150 cm-wide sheets in nurseries. Therefore this study was carried out in order to evaluate the effect of cover width and the border effect in solarized plots of a loam soil in the Central Region of the Rio Grande do Sul State.

## MATERIAL AND METHODS

The experiment was carried out at the Experimental Field of the Crop Production Department of The Federal University of Santa Maria, Rio Grande do Sul State, Brazil (29°41' S latitude, 53°48' W longitude, and 95 m altitude). The textural class of the soil is loam, with 30% sand, 46% silt, and 24% clay, in the 0-20 cm layer (SCHNEIDER, 1979).

Field plots 6m in length were varied in width. Treatments consisted of 40 cm, 80 cm, 120 cm, 160 cm, and 200 cm width of solarized mulch. A 6 m x 1 m plot was not mulched and used as a control (bare soil). The entire area was plowed and disced in order to keep the soil in good tillage conditions before mulching. Plots were covered with transparent polyethylene (PE) sheets (100 $m$m thick with UV absorbent) from October 27 to December 30, 1993. The soil was covered 1 day after a 41 mm rainfall and thus, soil moisture was high. No additional water was applied to the covered plots during the solarization period. The control plot was irrigated throughout the experimental period.

Soil temperature was recorded during 60 days using mercury collumn glass geothermometers placed in the center of the mulched and control plots at 2 cm, 5 cm, and 10 cm depths. Daily measurements were taken at 9 h, 15 h 30 mi n, 16 h, and 18 h, local time. According to SCHNEIDER

(1979), at Santa Maria, Rio Grande do Sul State, the daily maximum soil temperature at 2cm, 5cm, and 10 cm depths occur near the time of the afternoon measurements above cited.

In order to study the efficiency of the PE mulch to increase soil temperature, the relative efficiency ($EF_L$) of a cover of width **L** was examined according to MAHRER & KATAN (1981) by:

$$EF_L = \frac{T_L - T_0}{T_{200} - T_0} \qquad (1)$$

There $T_L$, $T_{200}$, and $T_0$ are the maximum soil temperatures obtained at the center of cover width of **L** cm, **200** cm, and 0 cm (no mulch), respectively. $EF_L$ was calculated with daily data of maximum soil temperatures at each soil depth.

The horizontal profile (from center to the border) of soil temperature in covered plots was determined at 5 cm depth. Temperatures were recorded between 8 h and 18 h through December 28 to 30, 1993 at 30 min intervals. Ten measurements per treatment were taken. Weather conditions during those days were clear. The purpose of these measurements was to detect the "border effect" in solarized plots.

Mahrer and Katan's efficiency model was used for calculating the efficiency in increasing soil temperature near the edges of the mulch $_B$):

$$EF_B = \frac{T_{FB} - T_{20}}{T_C - T_{20}} \qquad (2)$$

Where $T_{FB}$, $T_C$, and $T_{20}$ are the soil temperatures obtained at distance from border of mulch, at center of mulch, and 20cm outside the mulch, respectively. Measurements positions of $T_{FB}$ for each mulch width treatment is presented in Table 1.

Statistical analysis consisted of regression analysis. Independent variables were mulch width and distance from the border of the mulch. Dependent variables were $EF_L$ and $EF_B$.

Table 1 - Measurements positions of horizontal profile at 5cm depth in different mulch width of solarized plots.

| Mulch width (cm) | Distance from border to the center of mulch (cm) |
|---|---|
| 40 | 0, 5, 10, 15, 20 |
| 80 | 0, 10, 20, 30, 40 |
| 120 | 0, 10, 20, 30, 60 |
| 160 | 0, 10, 25, 40, 80 |
| 200 | 0, 10, 25, 50, 100 |

## RESULTS AND DISCUSSION

Maximum temperatures observed in the 200 cm-wide solarized plot were, on the average, 10.6°C, 10.2°C, and 9.1°C higher than for the bare soil, at 2 cm, 5 cm, and 10 cm depth, respectively. Soil temperature in solarized soil achieved maximum absolute temperature values of 52.0°C, 50.8°C, and 45.2°C at 2 cm, 5 cm, and 10 cm depth, respectively. Temperatures above 43°C were not observed in the bare soil at all the depths measured in this experiment. The results show that soil solarization in open field has a good potential in the Rio Grande do Sul State during the period studied. Maximum soil temperatures observed in solarized soil of this experiment are similar to those related inside greenhouse by STRECK (1994) and STRECK et al (1994a) during the months of January and February and by STRECK et al (1993) in nurseries covered with a low plastic tunnel during March and April, all for the same location.

The relative efficiency of the transparent polyethylene in increasing soil temperature at the center of the solarized plots of various widths and depths is presented in Figure 1. As indicated, soil temperature under narrow cover (40 cm width) was lower than those under the wider. MAHRER & KATAN (1981) suggest that a minimum of 80% efficiency should be expected when the solarization method is used. This means that for each increase of 10°C obtained at the center of the widest mulch, a minimum of 8°C should be obtained by mulch width under consideration. Israel is a warmer country and its solar energy availability is greater than in the Rio Grande do Sul State. Previous results show that soil temperature in solarized soil in the Subtropical Central Region of the Rio Grande do Sul State is similar to those obtained in Israel and other countries (STRECK et al, 1993; STRECK, 1994; STRECK et al, 1994a). Thus, the efficiency of a mulch width in increasing soil temperature should be taken greater than 80% and narrow sheets should not be used to solarize soil.

Estimated values for mulch width from regression equations (Figure 1) for 0.8 efficiency are

52.2 cm, 43.5 cm, and 59.8 cm, respectively, at 2 cm, 5 cm, and 10 cm depths. Thus, the average width for the three depths analysed is 51.8 cm. These results indicate the recommendation of never using solarization covers smaller than 50cm-wide. Wider covers raise soil temperature higher than did narrowers covers due to their larger solar radiation receiving area / heat dissipation area ratio (TAKATORI et al, 1964; MAHRER & KATAN, 1981; MAHRER, 1991; SCHNEIDER, 1993; STRECK et al, 1994a).

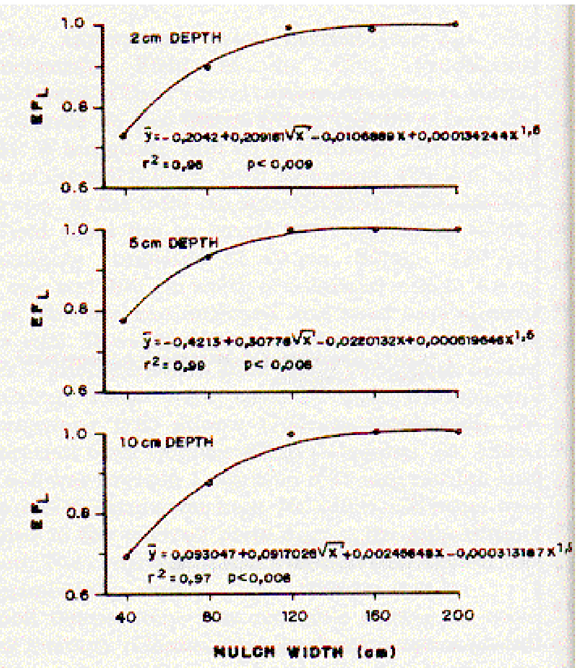


**Figure 1** - Relative efficiency ($EF_L$) of th transparent polyethylene in increasing soi temperature at mulch center as a function o its width. Santa Maria, RS, Brazil, 1993.

Observed and calculated values of relative efficiency in increasing soil temperature at the 5 cm depth, as a function of distance from the border are presented in Figure 2. A 80% efficiency was also used to define a soil margin where soil heating is lower. For example, if a soil temperature at the center of the cover is 50°C and outside the cover is 30°C, then the border effect begins when the soil temperature near the edge is lower than 46°C.

As expected, the highest temperatures were obtained at the center of covers. Near the edges, the temperatures dropped along a steep gradient (Figure 2). Narrow covers (mulch width less than 50cm) promote lower soil heating than wider covers and the horizontal gradient from border to center is linear. As a consequence of the lower temperatures at the edges milder patogenic effect is expected along the margin of solarized plots. Thus, longer periods of heating are required in order to control the pathogens at the edges of the mulch (MAHRER & KATAN, 1981). Estimated values of the distance from the border of the mulch that promote 0.8 efficiency, using the regression equations shown in Figure 2, are 21.7 cm, 22.5 cm, 20.2 cm, and 29.6 cm, respectively, for 80 cm-, 120 cm-, 160 cm-, and 200 cm-wide mulches. The average of these values is 23.5 cm. Border effects reported in the literature are of the order of 25 cm, ranging from 20 cm to 30 cm (MAHRER & KATAN, 1981; MAHRER, 1991; KATAN & DEVAY, 1991; SCHNEIDER et al, 1993; STRECK et al, 1994a). Thus, the results obtained in this experiment are in agreement with previous studies.

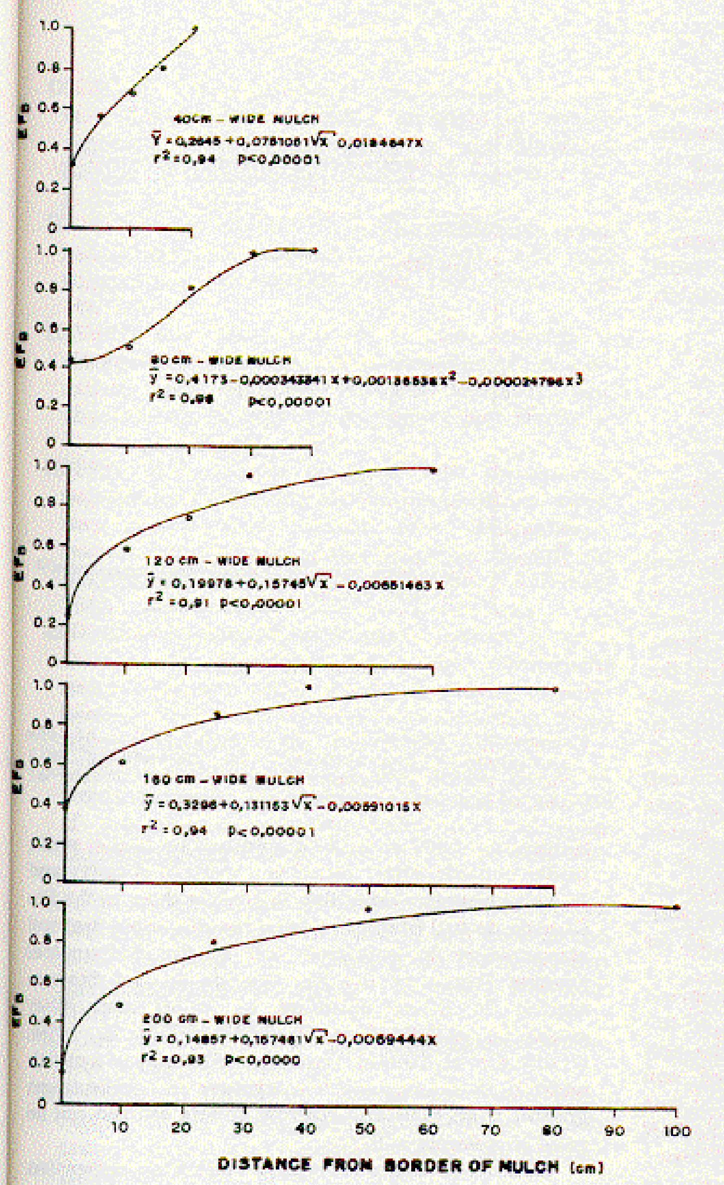


Figure 2 - Relative efficiency ($EF_B$) in increasing soil temperature at 5cm depth as a function of the distance from border to the center of various cover widths. Santa Maria, RS, Brazil, 1993.

From the results of mulch width and border effect, an inference can be made about the minimum width recommended for solarization. The greater the width of the mulched plots, the less significant is the border effect. Thus, a continuous mulch is desirable. The border effect in solarized plots can be easily identified by the presence of a strip of diseased plants along the edges of the mulched plots, showing partial or no control. If pathogen inoculum is concentrated in the upper soil layer, the border effect is less significant (GRINSTEIN & HETZRONI, 1991). MAHRER & KATAN (1981) reported that the rate of killing of the pathogen *Verticillium dahliae* was maximum in a soil mulched with transparent polyethylene of 140 cm width. A similar "border effect" was also recorded after soil fumigation. This phenomenon is related to gas leakage from the edges of the mulched plots (Greenberg et al, 1986 apud GRINSTEIN & HETZRONI, 1991). According to KATAN & DEVAY (1991) if a 160 to 200 cm-wide mulch and a 40 to 50 cm ways between plots is used, then 25 to 30% of the area is not covered. The uncovered/covered ratio (i.e., untreated/treated area) decreases when a wider plastic is used.

## REFERENCES


COURTER, J.W., DEBKER, N.F. Comparison of paper and polyethylene mulching on yield of certain vegetable crops. Proceedings of the American Society for Horticultural Science, St Joseph, v. 88, p. 526-531, 1966.

GRINSTEIN, A., HETZRONI, A. The technology of soil solarization. In: KATAN, J., DEVAY, J.E. Soil solarization. Florida: CRC Press, 1991. Cap. 11, p. 160-169.

HAYNES, R.J. The use of polyethylene mulches to change soil microclimate as revealed by enzime activity and biomass nitrogen, sulphur, and phosphorus. Biology and Fertility of Soil, Berlin, v. 5, n. 3, p. 235-240, 1987.

HOPEN, H.J. Effects of black and transparent polyethylene mulching on soil temperature, sweet corn growth, and maturity in a cold growing season. Proceedings of the American Society for Horticultural Science, St Joseph, v. 86, p. 415-420, 1965.

JACOBSOHN, R., GREENBERG, A., KATAN, J., et al. Control of Egyptian broomrape (*Orobanche aegyptiaea*) and other weeds by means of solar heating of the soil by polyethylene mulching. Weed Science, Urbana, v. 28, p. 312-319, 1980.

KATAN, J., GREENBERGER, A., ALON, H., et al. Solar heating by polyethylene mulching for control of diseases caused by soilborne pathogens. Phytopathology, Saint Paul, v. 66, p. 683-688, 1976.

KATAN, J., GRINSTEIN, A., GREENBERGER, A., et al. The first decade (1976-1986) of soil solarization (solar heating): A cronological bibliography. Phytoparasitica, Bet Degan, v. 15, n. 3, p. 229-255, 1987.

KATAN ,J., DEVAY, J.E. Soil solarization. Florida: CRC Press, 1991. 267 p.

MAHRER, Y., KATAN, J. Spatial soil temperature regime under transparent polyethylene mulch:

numerical and experimental studies. Soil Science, Baltimore, v. 131, p. 82-87, 1981.

MAHRER, Y. Physical principles of solar heating of soils by plastic mulching in field and in glasshouses and simulation models. In: KATAN, J., DEVAY, J.E. Soil solarization. Florida: CRC Press, 1991. Cap. 6, p. 75-86.

ROSENBERG, N.J. Microclimate: The Biological Environment. New York: John Wiley & Sons, 1974. 315 p.

SCHNEIDER, F.M. Comportamento e propriedades térmicas do solo Santa Maria. Piracicaba, SP, 1979. 77 p. Dissertação (Mestrado em Agrometeorologia), Escola Superior de Agricultura "Luiz de Queiróz", 1979.

SCHNEIDER, F.M., STRECK, N.A., BURIOL, G.A. Modificações físicas causadas pela solarização do solo. Revista Brasileira de Agrometeorologia, Santa Maria, v. 1, n. 1, p. 149-157, 1993.

STRECK, N.A., SCHNEIDER, F.M., BURIOL, G.A. Soil temperature modifications caused by solarization in nurseries. Ciência Rural, Santa Maria, v. 23, n. 3, p. 385-386, 1993.

STRECK, N.A. Modificação na temperatura do solo causada pela solarização do solo em estufa plástica. Santa Maria, RS, 1994. 82p. Dissertação (Mestrado em Agronomia), Universidade Federal de Santa Maria, 1994.

STRECK, N.A., SCHNEIDER, F.M., BURIOL, G.A. Effect of soil solarization on thermal regime of plastic greenhouse soil. Ciência Rural, Santa Maria, v. 24, n. 2, p. 229-233, 1994a.

STRECK, N.A., SCHNEIDER, F.M., BURIOL, G.A. Modificações físicas causadas pelo mulching. Revista Brasileira de Agrometeorologia, Santa Maria, v. 2, p. 131-142, 1994b.

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 the American Society for Horticultural Science, St Joseph, v. 85, p. 532-540, 1964.

VANDENBERG, J., TIESSEN, H. Influence of wax-coated paper and polyethylene coated paper mulches on growth and flowering tomato. HortScience, East Lansing, v. 7, p. 464-465, 1972.