EFFECT OF SOIL SOLARIZATION ON THERMAL REGIME OF PLASTIC GREENHOUSE SOIL[1]

EFEITO DA SOLARIZAÇÃO SOBRE O COMPORTAMENTO TÉRMICO DO SOLO DE UMA ESTUFA PLÁSTICA

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SUMMARY

Temperature modification in soil of plastic greenhouse caused by solarization was measured during the summer in the Subtropical Central Region of the Rio Grande do Sul State, Brazil. The experiment was carried out in a 10m x 25m greenhouse covered with low density transparent polyethylene (PE). Four 6m x 4m plots were mulched with 100μm thickness PE sheets, from December 12, 1992 to March 7, 1993. Four other plots (same size) without the cover were used as control (bare soil). Results indicated that solarization incrased the maximum soil temperature. The average was 11.9, 10.8, 9.8, and 8.6°C over uncovered control soil at 2, 5, 10, and 20cm depth, respectively. The soil temperature reached values of up to 54.4°C at 2cm and 50.2°C at 5cm depth. Temperatures exceeding 45°C and 50°C in solarized soil have also occurred in several days. "Edge effect" in mulched plots was also detected.

Key words: soil solarization, soil temperature, mulching, plastic greenhouse.

RESUMO

Quantificou-se a modificação na temperatura do solo de uma estufa plástica causada pela solarização, durante o verão, em Santa Maria, RS. O experimento foi conduzido no interior de uma estufa de polietileno transparente de baixa densidade (PEDB) de 10m x 25m. A solarização foi feita em quatro parcelas de 6m x 4m utilizando PEDB 100μm de espessura, no período de 17 de dezembro de 1992 a 07 de março de 1993. Quatro parcelas de mesmas dimensões foram mantidas sem cobertura (solo desnudo). Os resultados demonstraram que a temperatura máxima do solo solarizado foi, em média, 11,9; 10,8; 9,8 e 8,6°C maior do que no solo não solarizado, nas profundidades de 2, 5, 10 e 20cm, respectivamente. Verificou-se

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também que ocorreram valores absolutos de 54,4°C na profundidade de 2cm e 50,2°C na profundidade de 5cm e em vários dias temperaturas que excederam a 45°C e 50°C no solo solarizado. Observou-se que na faixa de 20cm de bordadura ao redor da parcela solarizada ocorreu um declínio acentuado da temperatura do solo.

Palavras-chave: solarização do solo, temperatura do solo, cobertura do solo, estufa plástica.

INTRODUCTION

Solar heating of the soil by mulching with transparent PE (solarization) is a new approach for controlling soilborne pathogens. This technique was conceived and developed by KATAN et al. (1976) in Israel. PE mulching of moistened soil during the hot season can raise their temperature enough to kill many soilborne pathogens, arthropods, nematodes and weed seeds (KATAN et al., 1976; KATAN, 1981; KATAN, 1987).

Studies carried out in different countries have demonstrated the effectiveness of solarization. The primary effect of solarization is the increase in soil temperature. Results of several experiments demonstrated that the use of solarization has increased the soil temperature by 3°C to 18°C over nonsolarized soil (KATAN et al., 1987; SCHNEIDER et al., 1993). Advantages of this method are the low cost, simplicity, and nonhazardous. However, its effectiveness depends on the solar radiation available during solarization and the thermal properties of the soil. Thus, solarization method should be tested in the region where it will be used. The technique of soil solarization is not well known in Brazil, which is a country with several climatic conditions.

Water conservation is a primary benefit obtained from mulching of all types. The reduction of the number of irrigating in areas where water is scare may be of importance to growers. Soil mulching reduce movement and leaching of plant nutrients (CLARKSON, 1960). Soil solarization is a particular type of mulching, and the same effect of mulching on soil environment is expected by solarization. Field experiments indicate enhance plant growth in solarized soil, even in the absence of known pathogens (KATAN, 1981). Several studies have suggested changes in soil chemical properties and an increase in some nutrients in solarized soils (CHEN & KATAN, 1980; KATAN, 1981; KATAN, 1987). Other mechanisms, however, e.g., stimulation of beneficial organisms or elimination of toxic materials due to soil solarization are also described. All these factors contribute for increasing plant growth observed in solarized soils (CHEN & KATAN, 1980; KATAN et al., 1987).

The use of plastic materials to protect horticultural crops in tunnels or greenhouses is a technology of increasing use in the southern part of Brazil. This technique leads to repeated cropping, mainly tomato, in the same land. Thus, problems related to soilborne pathogens are expected to occur. Chemical products usually utilized to control such pathogens are highly toxic and expensive (TOUSSON et al., 1970). Thus, attempts should be made to develop alternative methods.

Usually, greenhouses are not used for cropping in the summer (January and February) in Rio Grande do Sul State, which is the best time for solarization in the region. The purpose of this study was to measure temperature modification in soil of plastic greenhouse caused by solarization in the Subtropical Central Region of the Rio Grande do Sul State, Brazil. This research is part of a global program "Partially Modified Environments" of the Agrometeorology group of the Federal University of Santa Maria. The objective of program is to study the solarization method for controlling soilborne pathogens in the Central Region of Rio Grande do Sul State.

MATERIAL AND METHODS

The experiment was carried out in a 10m x 25m greenhouse covered with low density transparent polyethylene (PE), located in the Experimental Field of the Crop Production Department of the Federal University of Santa Maria, RS, Brazil (29°41'S latitude, 53°48'W longitude, and 95m altitude). Four 6m x 4m plots were mulched with 100μm thickness PE sheets, from December 12, 1992 to March 7, 1993. Four other plots (same size) without covering were used as control (bare soil). A loam soil, with 36% sand, 38% silt, and 26% clay was used. Soil was moistened to a depth of 50cm, two days before mulching, in order to increase thermal sensitivity of pathogens and improve heat conduction in soil according to KATAN et al. (1976) and KATAN et al. (1987). No additional water was applied in the covered plots during mulching. The nonmulched plots (control) were irrigated by sprinkling to keep the moisture near field capacity. Special care was taken to keep the soil in good tillage conditions before mulching. Herbicides were used to control weeds in uncovered plots. The greenhouse was kept opened during the experimental period.

Soil temperature was measured throughout the experimental period, by using a mercury column glass geothermometers. Daily measurements were taken at 9h, 15h30min, 16h, 18h, and 21h, local time, at 2, 5, 10, and 20cm depth. Afternoon measurements corresponded to the time of maximum temperature for 2, 5, 10, and 20cm, respectively, according to SCHNEIDER (1979). Additional geothermometers were buried at 2cm and 5cm depths in an attempt to determine horizontal profile of soil temperature in mulched plots, and thus to detect the "edge effect". Such geothermometers were located at 100cm, 150cm, 180cm, 200cm, and 220cm from the center of the mulch. Daily measurements were taken at same hours, from January 26, 1993 to March 03, 1993.

RESULTS AND DISCUSSION

Daily values of maximum temperature of both solarized and bare soil throughout the solarization period are presented in Figure 1. The maximum temperature was always higher in solarized soil than bare soil, regardless of the depth. Diurnal measures in solarized and bare soil demonstred that maximum temperature of soil was increased by solarization. The temperature differences among solarized and bare soil were greater on clear days, when the amount of solar radiation available was highest. Smaller differences were recorded on cloudy days. Incoming solar radiation thermal storage in the soil from past clear days contributes to temperature differences in cloudy days (LIAKATAS et al., 1986). Maximum temperature in both solarized and bare soil decreased when soil depth increased. This behavior follows the classical theory of soil heat flux, which states that there is a harmonic function of time and that the temperature wave is dampened when depth is increased. Thus, the efficiency of the polyethylene in soil heating decreases when soil depth increases (Figure 2).

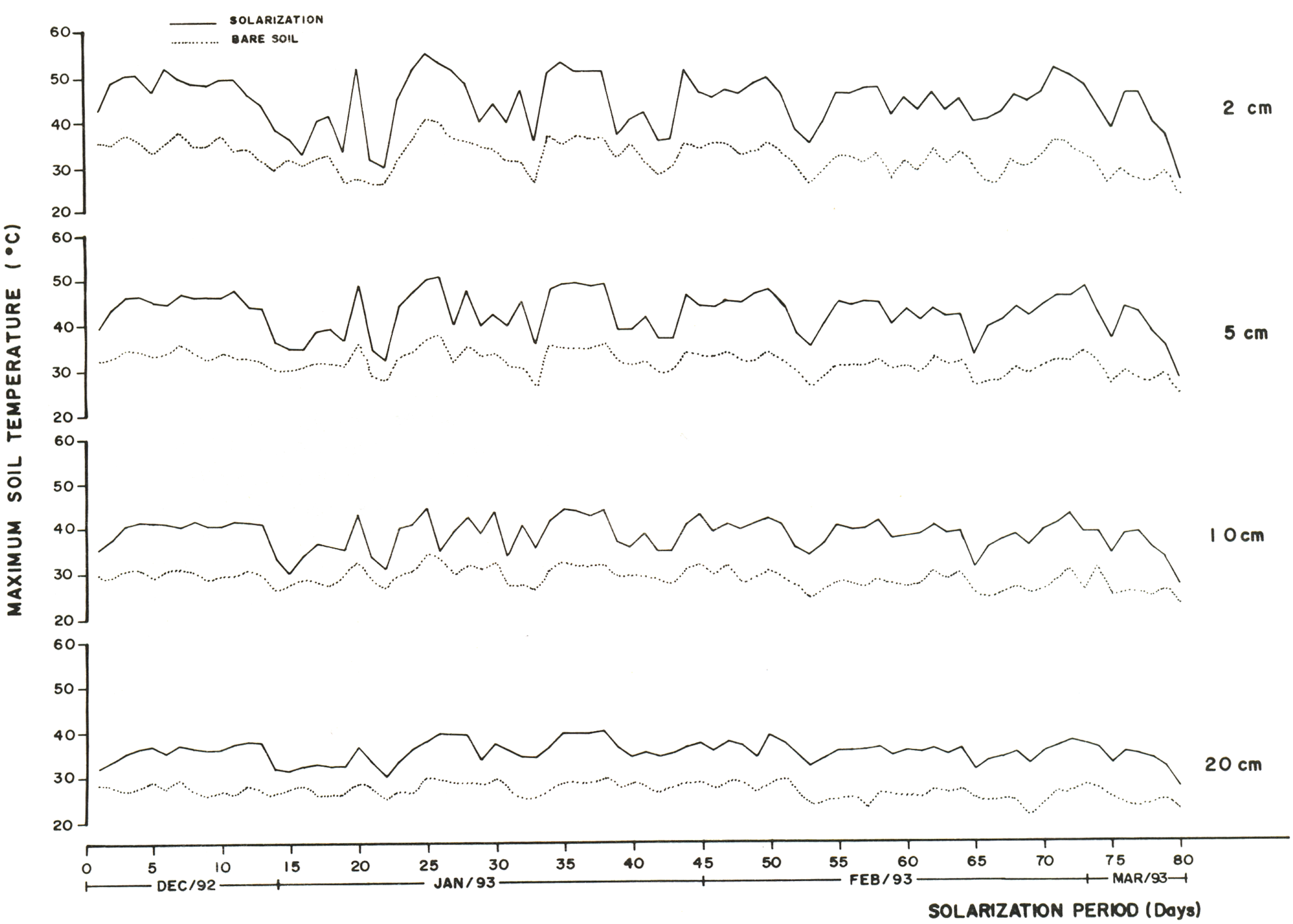

Figure 1. Maximum temperature of solarized and bare soil of the plastic greenhouse throughout solarization period. Santa Maria, RS, Brazil, 1992/93.

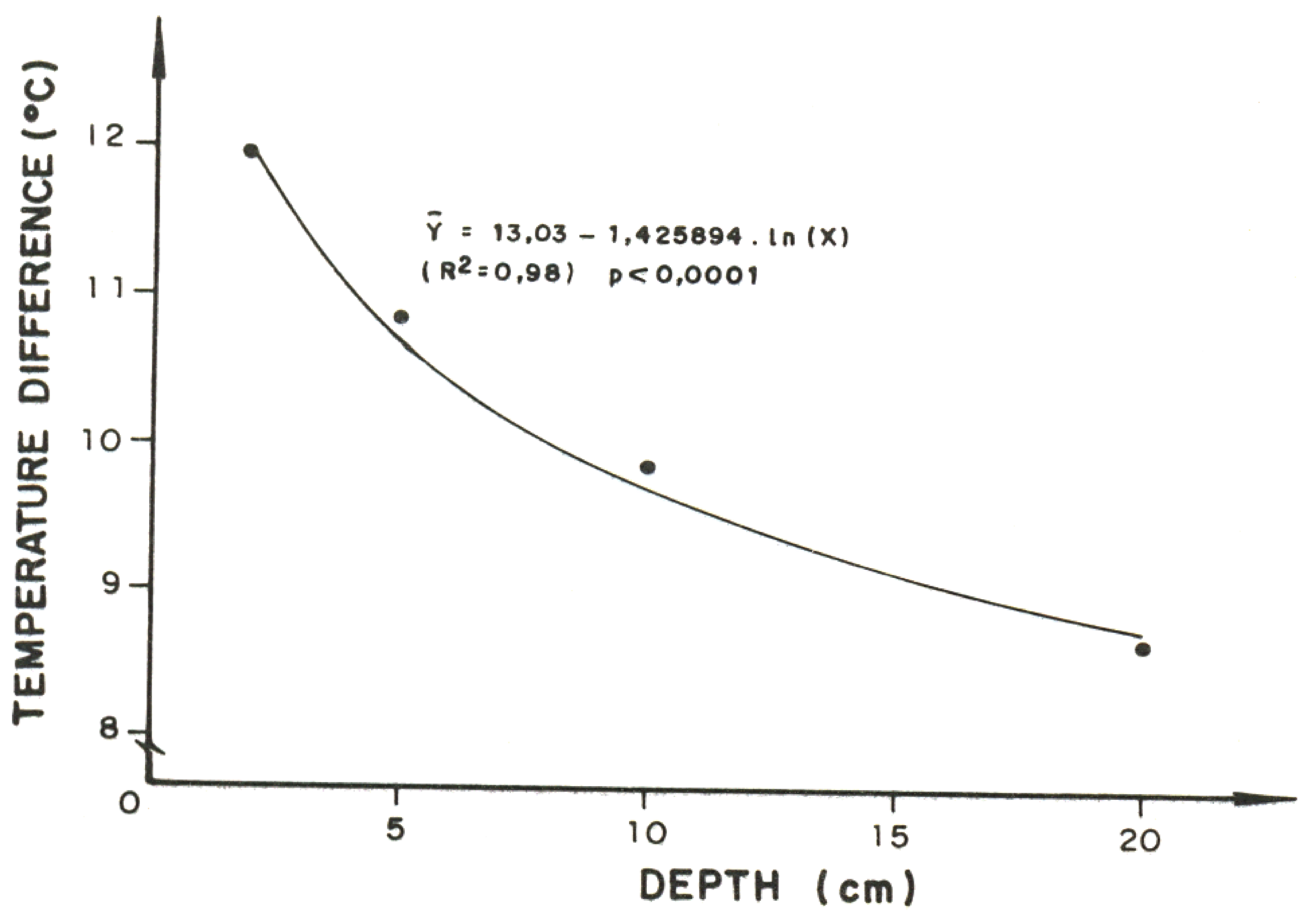

Figure 2. Relationship between depths and difference of maximum temperature among solarized and bare soil. Santa Maria, RS, Brazil, 1992/93.

Results in Table 1 indicated that maximum temperature of solarized soil was, on the average, 11.9, 10.8, 9.8, and 8.6°C higher than bare soil at 2, 5, 10, and 20cm depth, respectively. The differences in temperature among transparent PE and bare soil are similar to those observed by other researchers (KATAN et al., 1987; SCHNEIDER et al., 1993). The raise in temperature of solarized soil during the daytime is due to a decrease in sensible and latent heat fluxes, and thereby it increases the amount of heat available for soil heating. This hypothesis have been proved by many reports (MAHRER, 1979; AVISSAR et al., 1986; LIAKATAS et al., 1986). Furthermore, field observations show that immediately after the laying of a PE sheet on wet soil, water condenses on its inner surface. As a result of the formation of water droplets, the transmissivity of polyethylene to long wave radiation is reduced, while its transmissivity to short wave radiation is almost unaffected. Consequently, soil heating is also increased due to an increase in greenhouse effect (MAHRER, 1979; AVISSAR et al., 1986; LIAKATAS et al., 1986; SCHNEIDER et al., 1993).

Soil temperature reached absolute values of up to 54.4°C at 2cm depth and 50.2°C at 5cm depth (Table 1). Temperatures exceeding 45°C and 50°C in solarized soil have also observed in several days. Temperatures above 41°C were not observed in bare soil at the measured depths.

The results obtained in this experiment are similar to those reported in other regions. In Israel, where the method was conceived and developed, soil temperatures of mulched soil at depths of 5cm and 20cm were 45-55°C and 39-45°C (KATAN et al., 1976; KATAN, 1981). In California, temperatures of tarped soils were either similar or higher, reaching 60°C at the 5cm depth (PULLMAN et al., 1981). The LD_{90} for ***Verticillium dahliae*** collected from soil at field capacity moisture was achieved in a 120 minutes exposure at a temperature of 45°C, while the LD_{90} for ***Rhizoctonia solani*** in PDA medium was 190 minutes. At 50°C, the exposition time was 10 minutes for both soilborne pathogens (PULLMAN et al., 1981).

Table 1 - Absolute (Mx) and mean (M) values of maximum temperature and number of days (N) in which the temperature exceeded 45°C and 50°C in solarized and bare soil of plastic greenhouse. Santa Maria, RS, Brazil, 1992/93.

Treatment	Soil Depth (cm)	Maximum temperature (°C)		N	
		Mx	M	45°C	50°C
Solarization	2	54.4	43.8	41	15
	5	50.2	42.0	22	1
	10	46.0	38.3	1	0
	20	41.2	35.3	0	0
Bare soil	2	40.4	31.9	0	0
	5	37.6	31.2	0	0
	10	33.6	28.5	0	0
	20	29.8	26.7	0	0

Observed average maximum soil temperature at 2cm and 5cm depths as a function of distance from the center of the mulch are presented in Figure 3. The highest temperatures were obtained at the center of the cover. Near the edges the temperature has dropped along a steep gradient. The lower temperatures at the edges of the mulch may reflect in a slower killing of the pathogens existing in the soil under the mulch. Thus, longer periods of heating are required in order to kill the pathogens at the edges of the mulch (MAHRER & KATAN, 1981).

The results suggested that an edge of 20cm-wide should be taken into account in covered plots, due to the abrupt horizontal gradient of soil temperature. The "edge effect" is particularly important when nurseries and narrows are solarized.

The thermal death rate of a population of an organism depends on the temperature level and exposure time, which are inversely related (PULLMAN et al., 1981). Therefore, it is necessary to know the period of time that the temperature remains above ethal levels. Numerical models demonstrated by MAHRER (1979) and MAHRER & KATAN (1981) can be used to predict temperature of mulched soil. In subsequent studies these models will be tested in the region.

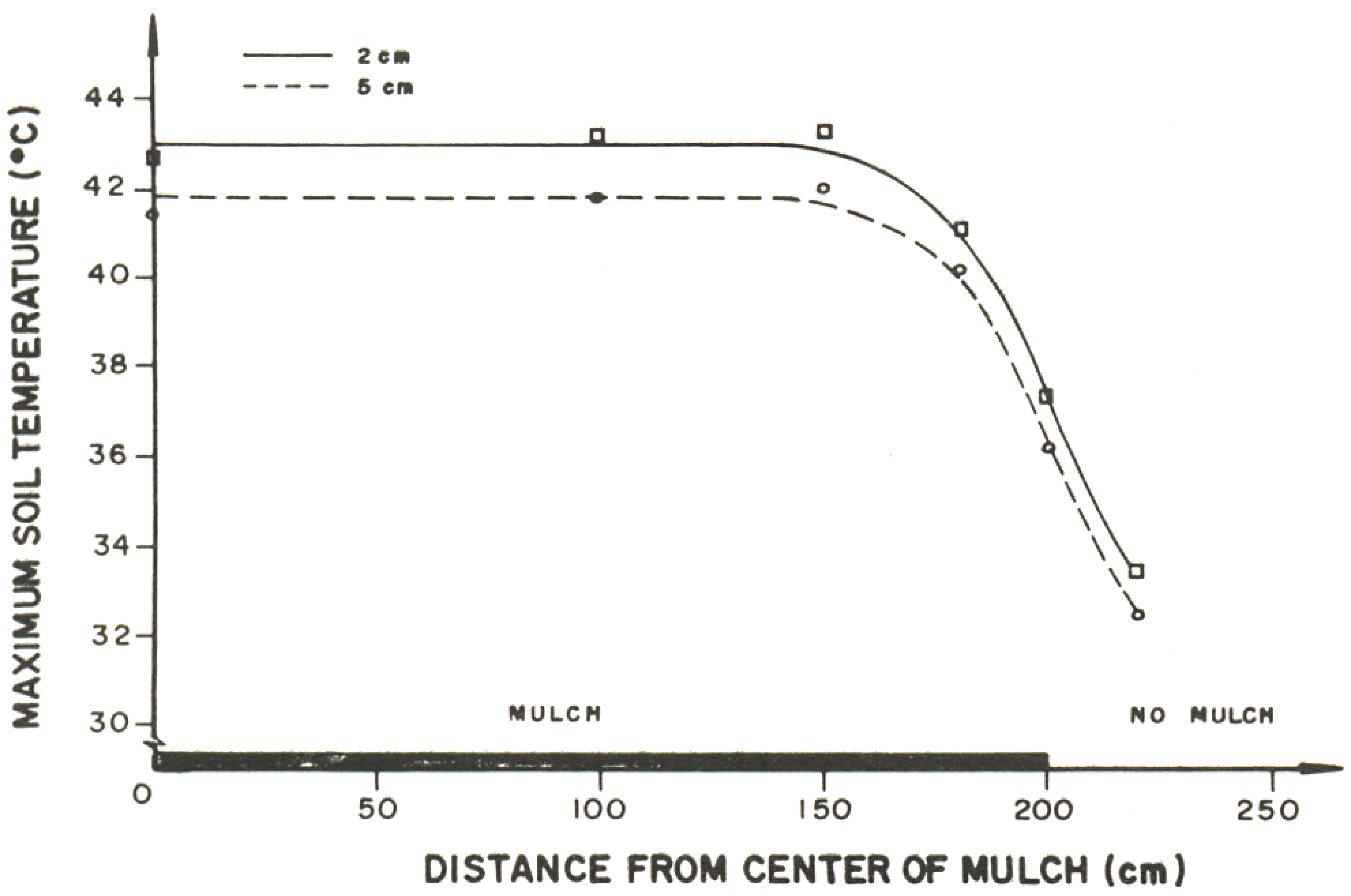

Figure 3. Daily average maximum soil temperature at 2cm and 5cm depths in different distance from the center of a 400cm-wide mulch. Santa Maria, RS, Brazil, 1993.

Solarization is a promising method of nonchemical disease and pest control. Results presented in this paper, suggest that solarization is a potentially useful practice for commercial vegetable production in the central region of Rio Grande do Sul Sstate, particularly in plastic greenhouses. The incoming global solar radiation in the region during the summer months is high (about $500 cal.cm^2.day^1$) and probably is possible to increase the efficiency of solarization by keeping the greenhouse closed. However, clarification of the benefits and limitations of solarization method under subtropical conditions are still needed.

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