EFFECT OF SOIL SOLARIZATION ON TOMATO INSIDE PLASTIC GREENHOUSE[1]

EFEITO DA SOLARIZAÇÃO DO SOLO SOBRE O TOMATEIRO EM ESTUFA PLÁSTICA

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SUMMARY

The effect of soil covering with transparent polyethylene sheets, known as soil solarization, on tomato crop inside a 10m x 25m plastic greenhouse was evaluated in the Subtropical Central Region of the Rio Grande do Sul State, Brazil. A 80-day solarization pre-planting treatment from December 17, 1992 to March 7, 1993 significantly enhanced marketable fruit weight of "Monte Carlo" tomato variety (91% increase). A large increase was observed in plant growth response resulted by solarization, even in the absence of known pathogens. Differences in chemical soil properties were not detected.

Key words: Solar heating, tomato, plastic greenhouse.

RESUMO

Este experimento foi conduzido para avaliar o efeito da solarização do solo sobre a cultura do tomateiro, cultivar "Monte Carlo", no interior de uma estufa plástica de 10m x 25m, em Santa Maria, RS. A solarização foi realizada de 17 de dezembro de 1992 a 07 de março de 1993, utilizando polietileno transparente de 100μm de espessura. Quatro parcelas de 6m x 4m foram solarizadas e outras quatro parcelas de mesmo tamanho foram mantidas sem plástico, constituindo a testemunha. Não foi verificada modificação nas propriedades químicas do solo com a solarização. O crescimento inicial das plantas foi maior nas parcelas solarizadas e como conseqüência, atingiram a altura de poda uma semana antes do que nas parcelas não solarizadas. A produção comercial de frutos foi 91% superior nas parcelas solarizadas. Evidenciou-se, portanto, o efeito positivo do método da solarização do solo sobre o tomateiro em estufa plástica.

Palavras-chave: solarização, tomateiro, estufa plástica.

INTRODUCTION

Since the middle 1980s the use of plastic materials to protect horticultural crops in tunnels and greenhouses is increasing in Southern Brazil. Polyethylene film is used by growers as covering material (BURIOL et al., 1995). Tomato crop represents up to 80% of the area under these conditions and is one of the most important crop out-of-season in the Rio Grande do Sul State.

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Repeated planting of the same crop is particularly common for valuable crops grown in plastic greenhouses, usually provides optimum conditions to increase inoculum potential and disease. As a result, soilborne diseases of protected crops are economically important in Southern Brazil. Tomato wilt caused by ***Fusarium*** sp. and ***Pseudomonas*** sp. are considered to be a limiting factor for tomato growing inside plastic greenhouses. In addition, monoculture intensifies the accumulation of deleterious factors which may cause growth retardation. In modern phytopathology, soil sickness is a term which describes the poor plant growth and yield decline of field crops under continuous cropping systems and monoculture (Sewell, 1984 apud CHEN et al., 1991). The term is also known as soil fatigue, replant disease, and tired soil. According to CHEN et al. (1991) plants growing in these soils show growth retardation, delayed flowering, and reduced yield.

Soil disinfestation is an effective practice for managing soilborne plant pathogens and controlling soil sickness (CHEN et al., 1991). In the last 50 years, soil disinfestation has been carried out with steam and the use of chemical fumigants (MUNNECKE & VAN GUNDY, 1979). However, chemical methods of soil disinfestation are highly toxic, expensive, and require special machinery and well trained personnel for application. In addition, pesticide-free agriculture has become very popular in recent years with increased demand for "health products". Thus, the search for new, effective, simple, inexpensive, and nonhazardous methods of soil disinfestation is an important research issue.

A pre-planting soil disinfestation method, known as soil solarization, for controling soilborne pathogens and weeds was suggested by KATAN et al. (1976). They showed that mulching a moistened soil during the hot season in Israel resulted in the control of several soilborne pathogens as well as weeds. This method is now praticed in many hot countries (KATAN, 1981; KATAN & DEVAY, 1991; SCHNEIDER et al., 1993). It has proved to be very effective in open ground against various pathogenic fungi of vegetable crops and has been tested with a variety of crops and diseases in several countries, frequently with successful results for both short and long term (KATAN et al., 1976; GRINSTEIN et al., 1979; RUBIN & BENJAMIN, 1983; KATAN & DEVAY, 1991).

In addition to reducing the number of fungi, bacteria, nematodes, insects and weed seeds, soil solarization often results in increased plant growth response (IGR). This can be observed even when no major plant pathogens or pests can be isolated from soil or plant roots (CHEN & KATAN, 1980; KATAN, 1981; STAPLETON et al., 1985; KATAN & DEVAY, 1991). STAPLETON et al. (1985) found dry weight increases from 66 to 450% in radish plants when grown in solarized soils of three textures. ABDEL-RAHIM et al. (1988) reported yield increases from 25 to 432% in broad beans, onion, tomatoes, and clover in various soil types. IGR and related benefits of solarization such as faster seed germination, better stand establishment, and earlier maturity, are as valuable in some cases as disease and pest control (STAPLETON & DEVAY, 1986). In recents years, solarization was also studied in monoculture of annual crops. Gamliel et al. (1989) apud CHEN et al. (1991) showed significant improvement in plant growth and yield on gypsophila monoculture after solarization.

Among the mechanisms proposed for the observed IGR in solarized soils are the elimination of minor pathogens and parasits, induced biological control, release of toxic volatiles and soluble mineral nutrients (CHEN & KATAN, 1980; KATAN, 1981; STAPLETON et al., 1985; STAPLETON & DEVAY, 1986).

In cooler regions or under marginal climatic conditions the solarization method has little effect as a method to control soilborne plant pathogens (MAHRER et al., 1987; MAHRER, 1991; SCHNEIDER et al., 1993). In conditions where soil covered with plastic film does not reach high temperatures to control pathogens in open fields, solarization has been applied either in closed plastic houses or glasshouses to achieve high temperatures (MAHRER et al., 1987; Kodana & Fukui, 1979 apud KATAN & DEVAY, 1991).

Since field under plastic greenhouses are not cropped in January and February, this noncropping period can be used for soil solarization in the Rio Grande do Sul State. In a previous paper the potential of solarization to increase soil temperature inside plastic greenhouse in the Central Region of the Rio Grande do Sul State was demonstrated (STRECK et al., 1994). This study was initiated to evaluate the response of tomato crop to solarization inside a plastic greenhouse. It is part of the global program "Partially Modified Environments" of the Agrometeorology group of the Federal University of Santa Maria. Its aims are to study the soil solarization method in the Central Region of the 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) with 100µm thickness, 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). The area of the greenhouse was cropped with a sequence tomato-tomato-cucumber in the last two years before the soil solarization treatment.

Individual plots of 6m x 4m were arranged in a completely randomized design with four replications.

Solarized plots were covered with 100μm thickness PE sheets from December 17, 1992 to March 7, 1993. Noncovered plots of the same size were used as controls (bare soil). The texture of the greenhouse soil is loam, with 36% sand, 38% silt, and 26% clay. Soil solarization was applied according to KATAN (1981) recommendations. No fertilizer was applied. Soil samples for chemical analysis were taken at 0-10cm and 10-20cm depths, just before mulching and after removal of the PE sheets, from both solarized and nonsolarized plots. Six samples were taken per plots and composited by depth.

"Monte Carlo" tomato, an indeterminated variety, was sown on February 17, 1993 in paper bags (400cm^3). Seedlings of 4-leaf were planted on March 10, 1993, using 0.25m x 1.00m plant spacing. The most common recommended agronomic practices for tomato in greenhouse were followed throughout the investigation. Tomato plants were pruned at 1.80m height (6-7 clusters).

Twelve plants per treatment were tagged and the duration of planting-flowering and planting-ripening sub-periods was recorded for the lower cluster. Flowering date (anthesis) was considered the day 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. Plant height of tagged plants was measured weekly. Fruits were harvested once a week from June 21, 1993 to September 09, 1993. The yield parameters evaluated were number and weight of marketable and nonmarketable harvested fruits. Nonmarketable fruits were those with defects and/or disorders. Crop yield was determined on basis of area per plot (9.5m^2). Data were subjected to analysis of variance and differences between means were distinguished using the Tukey test.

RESULTS AND DISCUSSION

The chemical properties of soil analysed from samples colected at 0-20cm depth (Table 1) were similars. However, it can be noted that nutrient concentration increased for both solarized and nonsolarized soil after the mulching period. On the other hand, it was also observed that when nutrient concentration decreased in solarized soil it also decreased in nonsolarized soil, regardless the soil layer. Thus, it is difficult to make any inference about the effect of soil solarization on chemical properties in this experiment. Analysis and partition of N in NH_4^+ and NO_3^- were not made in this experiment. However, increasing in the concentrations of NH_4^+-N and NO_3^--N due to soil solarization have been reported by CHEN & KATAN (1980), STAPLETON & DEVAY (1982), KAEWRUANG et al. (1989), and KUMAR & YADURAJU (1992).

Table 1. Chemical properties of solarized and nonsolarized soil of the plastic greenhouse soil. Santa Maria, RS, Brazil, 1993.

Soil Treatment	Sampling Time	Depth (cm)	P ---ppm---	K	Ca+Mg (meq/100ml)	O.M.* (%)	pH
CONTROL	Before mulching	0-10	63.8	77	8.8	4.1	5.6
		10-20	23.5	35	6.6	2.7	5.7
	After mulching	0-10	41.7	83	8.8	3.5	5.5
		10-20	25.3	46	8.0	2.8	5.5
SOLARIZED	Before mulching	0-10	72.5	82	8.9	3.8	5.7
		10-20	22.2	42	7.5	2.7	5.8
	After mulching	0-10	57.5	91	7.5	2.7	5.8
		10-20	34.6	55	9.1	3.7	5.6

*Organic Matter content

Values of plant height observed before pruning are presented in Figure 1. Crop establishment was affected by soil treatment and consequently plants were initially higher in solarized plots. However, the growth rate during the crop development was similar for both solarized and nonsolarized plots. Plants of solarized plots were pruned one week earlier. Damping-off simptoms were not observed in either treatments. Increased tomato vigor due to solarization was evident throughout the growing season.

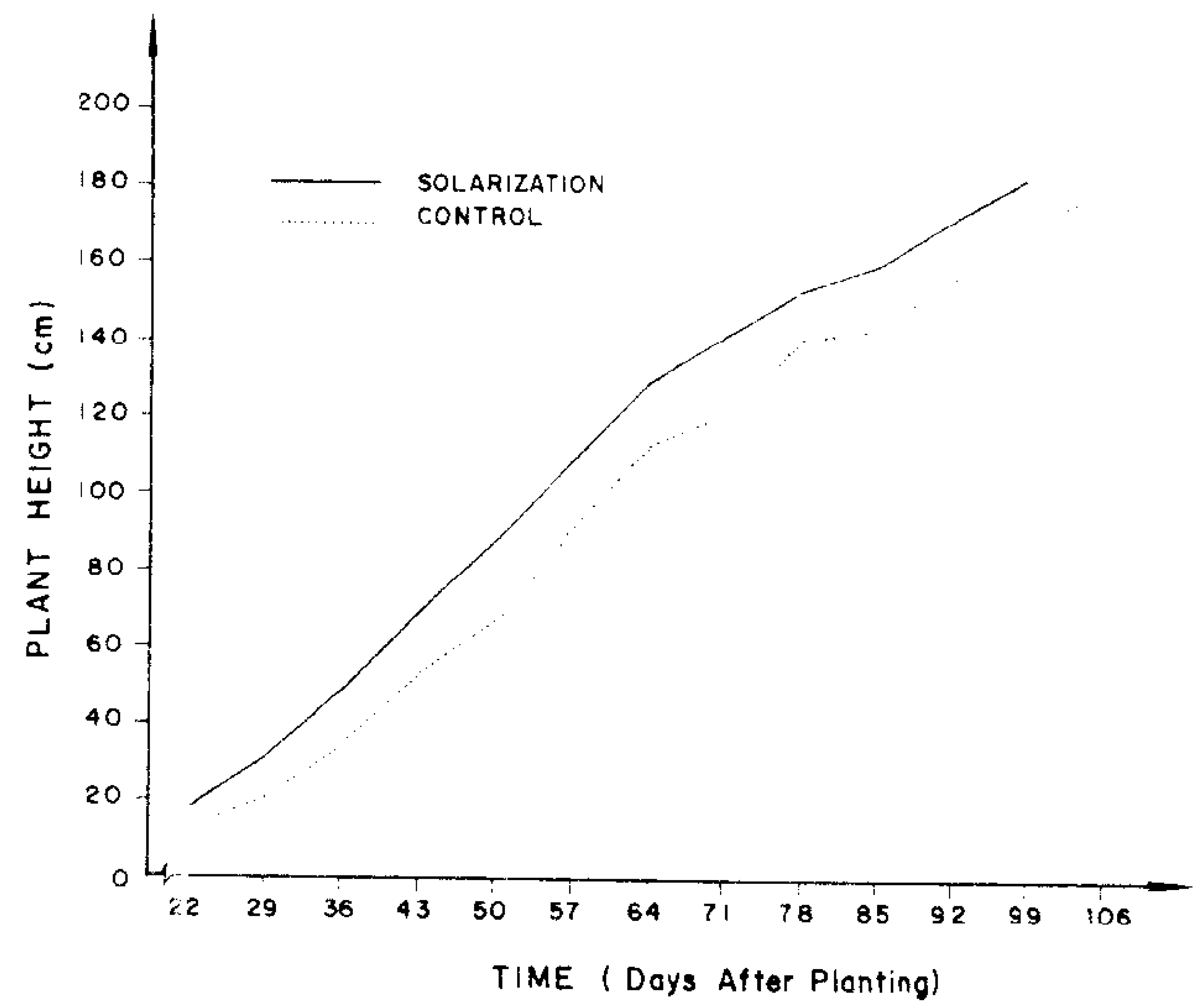

Figure 1. Effect of soil solarization in plastic greenhouse on plant growth expressed as height of tomato plants as a function of time. Santa Maria, RS, Brazil. 1973.

Tomato plants began flowering and ripenig, on average, 6 and 10 days earlier in solarized plots (Table 2). Early tomato yield, expressed as the total fruit weight of the first three harvests, was substantially higher in the solarized plots (400% increase over nonsolarized plots). Marketable yield was significantly greater in solarized plots. Fruit weight and number increased 91% and 106%, respectively. Tomato production was generally low in this experiment because the autumn-winter growing season does not have optimum conditions for greenhouse tomato in the South of Brazil (the relative humidity of the air was high during the growing season and the air temperature was low during flowering period). Nonmarketable yield was similar in solarized and nonsolarized plots.

Table 2. Effect of soil solarization on duration of planting-flowering (P-F) and planting-ripening (P-R) sub-periods, early yield (EY), and marketable (MK) and nonmarketable (NMK) yield of tomato in plastic greenhouse. Santa Maria, RS, Brazil, 1993.

Soil treatment	P-F	P-R	EY	Total Yield			
	days		(kg/m^2)	Fruit weight (kg/m^2)		Fruit number/m^2	
				MK	NMK	MK	NMK
SOLARIZED	40	104	0.91a*	4.07a	0.24a	33a	6a
CONTROL	46	114	0.22 b	2.13 b	0.21a	16 b	5a

* Means within each column not followed by the same letter are significantly different at the 5% level according to Tukey test.

The results obtained in this experiment are similar to results obtained with other mulching materials. Yield and growth increase of many vegetable, fruit, field and landscape crops have been reported in conjunction with plastic mulching (JONES et al., 1977). STAPLETON & DEVAY (1982) observed increases in peach and walnut seedling height by 25 and 12%, respectively, and in weight by 43 and 59%, respectively, 11 months after planting in solarized soils. Despite these positive effects no detectable major plant pathogens were found in the soils from their experiments. Plastic-mulched and steamed soils usually contain higher levels of soluble nutrients than untreated soils (JONES et al., 1977; STAPLETON & DEVAY, 1986; CHEN et al., 1991). This phenomenon was also found in soils treated by solarization in Israel (CHEN & KATAN, 1980) and in California (STAPLETON et al., 1985). However, for the soil used in the present study (0-20cm depth) differences in nutrient levels were not noticeable. This discrepancy could be mainly attributed to differences in assay procedures, soil type, and sampling depth. For the purpose of detecting changes in quantities of mineral nutrients by solarization, the soil solution should be analysed (CHEN & KATAN, 1980; STAPLETON et al., 1985).

Soil temperature in the solarized plot of this experiment achieved absolute values of up to 54.4°C at 2cm depht. In the same experiment STRECK et al. (1994) observed temperature exceeding 45°C and 50°C in solarized soil occured in 41 and 15 days, respectively, at 2cm depht. The major goal of all disinfestation methods is to eliminate harmful organisms from the soil. It is well established, however, that the consequences of such soil treatment extend beyond the control of harmfull organisms. Thus, chemical, physical, and biological changes may occur in the soil, creating benefical or harmful side effects (CHEN & KATAN, 1980). The limited changes in nutrient levels as determined by soil chemical analyses in this experiment, suggest that the increased plant growth response (IGR) following solarization may be due to changes on population of soil microorganisms. This possibility has been raised in previous reports on the effectiveness of soil solarization (KATAN et al., 1976; GRINSTEIN et al., 1979; ELAD et al., 1980; KATAN, 1980). In addition, soil sickness may have been associated with the response of tomato crop to solarization. Further investigations are necessary to verify the effects of solarization on tomato monoculture in plastic greenhouse.

Increased plant growth and yield by solarization is a common phenomenon, evident even in the absence of known pathogens. The results obtained in this study support the above affirmation and are in agreement with others papers (KATAN, 1980; STAPLETON & DEVAY, 1982; STAPLETON et al., 1985; STAPLETON & DEVAY, 1986; ABDEL-RAHIM et al., 1988; SCHNEIDER et al., 1993). The present study demonstrated that growth and yield of tomato plants in previously solar heated soil was improved independent of apparent effects on pathogens and mineral nutrients in the soil.

The results obtained in this experiment suggest that soil solarization is a potentially usefull pratice for commercial vegetable production in the South of Brazil. The next step of solarization studies in this region is to verify its effectiveness on soilborne plant pathogens.

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