EFFECT OF SOLARIZATION ON DAMPING OFF DISEASES OF VEGETABLES

By

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THESIS

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Dedicated to
my loving parents

DECLARATION

I hereby declare that this thesis entitled "**Effect of solarization on damping off diseases of vegetables**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara,
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CERTIFICATE

Certified that this thesis entitled "**Effect of solarization on damping off diseases of vegetables**" is a record of research work done independently by **Kum. SAINA MOL KURIAN** under my guidance and supervision and that it has not previously formed the basis for the award of any Degree, Diploma, Fellowship or Associateship to her.

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Introduction

INTRODUCTION

To solarize is defined in Webster's new International Dictionary as "to expose to sunlight, to affect in some way by the action of the sunrays". This technique of heating the soil by solar energy was practiced for decades and centuries ago. As early as in 1939, Grooshevoy, a Russian pathologist succeded in establishing solar heating of soil as a means of pathogen control. Since plastic technology was not available then, his finding did not get wide acceptance among the farmers. "Plasticulture" - the use of plastics in agriculture, became popular with the development of plastic technology. Polyethylene sheets were used as a pre-planting soil treatment for control of several plant pests. Katan and co-workers (1976) popularised the concept of solarization - a technique of covering the wet soil during the hottest period of the year using polyethylene sheets.

Polyethylene mulching has the advantage in that it enables solarization of wet soil making a tremendous improvement because, 1. when wet, resting structures are usually much more sensitive to heat, 2. heating is much better in wet soil, 3. appropriate moisture promotes biological activity in soil that may lead to beneficial processes that enhance pest control.

Solarization technique of plant disease control was first used by Jones et al. (1966) against southern blight of tomatoes. Now, this technique is being practiced world wide to control several soil borne diseases caused by micro and macro organisms and also to control weed growth. Soil solarization is commercially used in Israel, USA, and Japan.

The exact mechanism of solarization has not been completely worked out. In addition to the physical effect of heat, microbial processes, induced by solarization may also contribute to disease control, since the impacts of any lethal agent in the soil extent beyond the target organisms (Katan et al., 1981).

Many experiments have been carried out to evaluate the potential of soil solarization in the pathogen population reduction, disease control and yield increase. Various explanations have been put forward to explain the increased yield by solarization. Apart from increasing the yield, solarization may also improve the quality of products (Grinstein et al., 1979). In certain cases, long term effect of solarization on disease control and/or yield increase, extending for a second or even the third crop was observed in various regions with a variety of pathogens and crops.

In India, solarization as a method of disease control is still in the experimental stage. Successful control of <u>Macrophomina phaseolina</u> on soyabean (Dwivedi and Dubey 1987) and <u>Rhizoctonia solani</u> on cowpea (Chandran, 1989) have been reported. The present study has been undertaken to find out the efficacy of this technique in the control of pre and post emergence damping off of chillies caused by <u>Pythium aphanidermatum</u> (Edson) Fitz.

Review of Literature

REVIEW OF LITERATURE

Principles of solarization

Soil solarization is a method for controlling soil borne plant pathogens, insect pests and weeds, by heating the soil using solar energy. It is a hydrothermal disinfestation process accomplished by covering moist soil with transparent polyethylene sheets during the hottest period of the year. According to Katan (1980), effective solar heating of soil can be brought about by the following principles. 1) Transparent, not black polyethylene should be used since it transmit most of the solar radiation that heats the soil. 2) Mulching should be carried out during the period of high temperature and intense solar radiation. 3) Soil should be kept wet during mulching to increase the thermal sensitivity of resting structures. 4) The thinnest polyethylene tarp possible should be used since it is cheaper and more effective.5) Mulching period should be sufficiently extended usually for four weeks or longer in order to achieve pathogen control at all desired depths. 6) The soil should be in good tilth allowing close contact between plastic sheets and the soil. 7) Prevent the formation of air pockets which reduce heat conduction.

According to Obgugi (1989), critical factors in the efficacy of soil solarization are 1) lethal soil temperature from sunlight 2) sufficient water in soil 3) soil texture. According to him, field soil to be solarized must be first ploughed and harrowed before it is irrigated.

Polyethylene reduces heat convection and water evaporation from the soil to the atmosphere. As a result of formation of water droplets on the inner surface of the polyehtylene film, its transmissivity to long-wave radiation is highly reduced, resulting in better heating due to an increase in its greenhouse effect (Malik and Tran, 1973).

Stapleton et al.(1987) reported that, transparent polyethylene raised soil temperature at 15-23 cm depth to 10-18°C while black polyethylene raised the temperature only upto 8-12°C. Black polyethylene, even though heated by itself, is less efficient in heating the soil (Waggoner et al. 1960, Kodama and Fukui,1979).

According to Garibaldi (1987), PVC was more effective than polyethylene in maintaining high soil temperature. Double layered polyethylene film gave 1-2° C higher soil temperature than those obtained with

PVC. Better efficiency of double layered polyethylene, over single layered one was also observed by Tamietti and Garibaldi (1989).

Katan (1980) and Pullman et al.(1981) found that thinner polyethylene (25 mm thick) sheets are more effective than thicker ones (100 um). This was contradicted by Fukui et al.(1981). According to them, thicker sheets are (100 um) are more efficient than thinner ones.

Increase in soil temperature as a result of solarization is more pronounced in the upper layers of soil. Katan (1981) reported 8-12^{o} C higher temperature in solarized soils. An increase of temperature upto 8-10^{o} C was observed at 15 cm depth at Trivandrum (Chandran, 1989). Increase in soil temperature as a result of solarization was also reported by Osman et al (1986), Tu et al. (1987), Wicks (1988), Tamietti and Garibaldi (1989), and Lodha et al. (1990).

Pullman et al.(1987) studied the relationship between time and temperature for four soil borne plant pathogens by using solarization treatment. They found that temperature of 37-50^{o}C for different periods were lethal to mycelia, spores and resting structures of

Verticillium dahliae, *Pythium ultimum*; *Theilaviopsis basicola* and *Rhizoctonia solani* on agar medium and in soil.

Villapudua and Munnecke (1986) reported that both solar heating alone and cabbage amendments plus cover under shade were effective in controlling cabbage yellows but not as effective as the combination of solar heating and cabbage amendments. According to Chandran (1989) increase in soil temperature as a result of solarization was more in open field than in partial shade.

Disease control

Effectiveness of solarization in controlling soil borne pests is being evaluated in different countries. Solarization was found to be effective against soil borne plant pathogens, like *Pythium*, *Phytophthora*, *Rhizoctonia*, *Fusarium*, *Verticillium*, *Plasmodiophora*, *Selerotium*, etc. by various workers. Apart from disease control, solarization also resulted in varying degrees of yield increase in crop plants.

Pythium

Control of rot syndrome of sugarcane associated with *Pythium arrhaenomanes* and *P. graminicola* in Australia (Chen and Katan, 1980) was the first report of successful control of a disease caused by Pythium spp. by solarization.P. aphanidermatum in an artificially infested cucumber field in Iraq was controlled effictively by solarization (Al-Sammaria et al. 1988). Hasan (1989) reported that P. aphanidermatum was moderately susceptible to solar heating. Gamliel et al. (1989) found that soil solarization improved plant growth and yield of gysophyla plants and its roots remained free of Pythium sp., throughout the 10 weeks testing period. Increase in yield by solarization were 15%, 46% and 48% respectively, at the first, second and third cycle of picking. Meron et al. (1989) found that, roots of snap bean plants, originating from non solarized soil were colonized with Pythium sp. where as roots of plants from solarized soil were free of this fungus.

Rhizoctonia

Effective control of Rhizoctonia solani in soil and an yield increase to the tune of 59-125% was reported by Katan et al.(1980). Solarization also reduced disease caused by Rhizoctonia sp. in potato, (Elad et al., 1980), cucumber (Al-samaria et al.,1988), cowpea (Chandran, 1989), gerbera (Kaewruang et al., 1989) and lettuce (Triollo et al.,1988).

Verticillium

Mulching with polyethylene sheets increased soil temperature and resulted in a reduction of verticillium wilt by 25-95% and increased yield of egg plants and tomato (Katan *et al.*, 1976). Solarization reduced propagules of *V. dahliae* in soil and enhanced cotton yield (Pullman *et al.*,1981). Solarization was also found to be effective in the control of verticillium diseases of tree crops. Ashworth and Gaona (1982) reported that mulching with polyethylene sheets eleminated *V. dahliae* in a six year old pistachio nut grove and Tjamos and Paplomatas (1987) also got similar results working with olive trees. However, Horiuchi (1984) failed to get effective control of verticillium diseases through solarization.

Fusarium

Control of *Fusarium oxysporum* f.sp. *lycopersici* has been reported by Katan, *et al.* (1980). Reduction in disease caused by *F. oxysporum* f.sp.*lupini* (Osman *et al.*,1986), *F. oxysporum* f. sp.*pini* (Mc Cain, 1986), *F. oxysporum* (Green berger *et al.*, 1987) *F.oxysporum* f. sp. *ciceri* (Arora and Pandey,1987) *F. oxysporum* f.sp. *neveum* (Joannou and Paullis. 1990) amd *F. solani* (Lodha and Vydya, 1990 and Sorhan, 1991) were also possible by solarization.

Rosellinia

Solarization was effective in the control of *Rosellinia necatrix* in apple-orchards (Sztejnberg *et al*.,1987) upto a depth of 30 cm (Freeman *et al*.,1990).

Sclerotium

Elad *et al*. (1980) reported that solar heating killed 76-100% of the *Sclerotium rolfsii* in soil. Grinstein *et al*. (1979) observed that, solarization resulted in a significant decrease in peanut rot by *S. rolfsii* and an increase of 52.8% in yield. Effective control of *S. rolfsii* by solarization was also reported by Greenberger *et al*.(1987). Matrod *et al*.(1991) reported that, in moist soils, viable number of sclerotia of *S. cepivorum* decreased by 75.2-83.2% in plots covered by clear plastic sheets compared to a decrease of 49.6-59.2% with black plastic mulch.

Macrophomina

A marked reduction in survivability of *Macrophomina phaseolina* was observed in solarized soil by Dwivedi and Dubey (1987). Solar heating by polyethylene mulching in June-August was used in Iraq as an effective and inexpensive method for controlling soil borne pathogens including *M. phaseolina* which reduced from 350/g to 7/g in soil in 15 days in dry and wet mulched plots compared with 335/g and 270/g in the corresponding non mulched controls.

Increased yield by solarization may depend on (1) damage caused by the disease (2) level of soil infestation (3) effectiveness of disease control and (4) increased growth response phenomenon, beyond the control of target pests.

Mechanisms involved in disease control

Soil solarization in its present form involves hydrothermal processes (Stapleton and De Vay, 1984), simultaneously causing many changes in the biotic and abiotic components of the soil, during and after solarization, which may finally lead to change in disease, plant growth and yield, or both.

The direct thermal effect was probably the major and essential factor in solarization, (Katan, 1980; Pullman et al.,1981; Cenis, 1989) since the treatment was most successful when soil temperature was raised to comparitively higher levels. Many workers noticed that the method was not only based on a physical (thermal killing) mechanism because sublethal temperature levels also gave some disease control (Pullman et al., 1981; Horiuchi, 1984).

Thermal inactivation of pathogens

Heat, at temperature exceeding the maximal for growth, has inhibitory or lethal effect on organisms. Baker (1962) suggested that exposing fungi to high temperature results in denaturation of proteins (including enzymes), lipid liberation, destruction of hormones and asphyxiation of fungal tissues. Eventhough enormous amount of literature are available with heat sensitivity of organisms, only very few deal with heating at mild temperature (35-60° C), which for long periods of time might be relevant to soil solarization. Thermal death rate of an organism depends on both temperature level and exposure time. Katan _et al_.(1976) suggested that sublethal temperatures also may cause death of pathogens by direct cumulative effect of temperature or by a combination of thermal and biological factors.

Katan (1980) opined that, fungal resting structures exposed to sub lethal temperatures are weakened and therefore are attacked even by micro organisms that ordinarily could not attack them. According to Pullman _et al_. (1981), sublethal temperatures impaired the ability of _Verticillium dahliae_ to penetrate the cotton plants and cause disease. Horiuchi _et al_. (1983) reported that, resting structures of Plasmodiophora brassicae lost infectivity when heated at 45° C for one day and that artificially infested soil in a slurry state failed to retain infectivity after 5 days at 45° C. They also found that periodical heating as well as continuous heating caused a disease suppressing effect.

The effect of damage inflicted on the propagule depends on its inherent heat sensitivity and on environmental conditions eg., moisture level, the protective effect of the soil, inoculum density, quality and age, nutritional conditions, and the presence of toxic substances (Katan, 1981).

Biological control

In addition to thermal killing of pathogen propagules, microbial processes induced by solarization may also contribute to disease control, since the impacts of any lethal agents in soil extent beyond the target organisms (Katan, 1981). Biological control is involved as a side effect in case of physical or chemical disinfection (Baker and Cook, 1974; Garret, 1970; Munnecke and Van-Gundy, 1979; Munnecke et al., 1976 and Papavizas and Lumsden, 1980). Biological control may operate at any stage of pathogen survival or disease development during or after solarization through antibiosis, lysis, parasitism or competition

(Papavizas and Lumsden, 1980).

Katan (1981) summarised the mechanism of biological control created or stimulated by solarization as follows:

I. The effect on inoculum existing in soil.

A. Reduction in inoculum density (in the dormant stage or during penetration to the host) through

1) microbial killing of the pathogens already weakened by sublethal heat.

2) partial or complete annulment of fungistasis and subsequent lysis of the germinating propagule.

3) parasitism or lysis by antagonists stimulated by solarization

B) Reduced inoculum potential due to antibiosis or competition enhanced by solarization

C) Diminished competitive saprophytic ability of the pathogen in the absence of host due to antibiosis or competition

II. Suppressing innoculum introduced to soil after solarization, from deeper soil layers or adjacent non treated plots, that is preventing reinfestation through activity of microorganisms possessing above mentioned mechanisms.

III. Effect on the host due to cross protection

Elad et al. (1980) found that solarization increased antagonist population (Trichoderma harzianum) and the incidence of disease caused by R. solani remained low throughout the season. Hassan (1989) reported that growth of saprophytic fungi such as Trichoderma sp. was activated by solarization. Microbial colonization and degradation of sclerotia weakened by sublethal temperature produced by solarization, reduced the populations of sclerotia of Sclerotinia sclerotiorum in soil and reduced the ability of surviving sclerotia to form apothecia (Philips, 1990).

According to Lifshitz et al. (1983) sublethal heating of S. rolfsii sclerotia increased exudation, and colonization of sclerotia by bacteria and streptomyces, thus reducing their pathogenic capacity. Scanning electron microscopic studies showed that heating increased the frequency of surface cracks on the sclerotia and concentrations of bacteria on or around the cracks were about ten times. Gamliel and Katan, (1991) reported that population of fluorescent pseudomonads increased upto 130 fold in the rhizosphere of plants in solarized plots though these bacteria are heat sensitive.

Munnecke *et al*. (1976) demonstrated the effect of sublethal heating on the survival of *Armillaria mellea*. Less time and lower temperatures were required for indirect killing of the pathogens than for killing at 41^{o}C . *Trichoderma* sp were the dominant colonizers of the heated roots. Tjamos and Paplomatas, (1987, 1988) reported that population of *Talaromyces flavus*, an antagonist of *Verticillium dahliae* increased in the rhizosphere of globe artichocke plants and olive trees with histories of wilt as compared with untreated control soils. The beneficial effect of a solarization lasted for three years and the activity of *Talaromyces flavus* inhibited germination of macrosclerotia or caused their death. *Aspergillus terreus*, another potential antagonist of *V.dhliae* was also found to survive and occasionally increase when the technique was used.

Triollo *et al* (1988) reported that solarization of a clay loam soil in green house increased the proportion of sclerotia of the lettuce collar rot pathogen (*Sclerotinia minor*) colonised by bacteria and fungi. There was prevellance of *Aspergillus*, *Furarium*, *Penicillium* and *Trichoderma* in the solarized soil.

A partial or complete nullification of

fungistasis in the absence of the host is regarded as harmful to resistant resting structures. Ashworth and Gaona (1992) suggested a hypothesis of suicidal germination of *V. dahliae* microsclerotia by a substance that accumulates under mulch. Solarization may reduce fungistasis through suppression of competitors, release of mineral and organic compounds in the soil or nullification of possible inhibitory substances (Katan, 1981).

Preventing reinfestation is vital for proper disease control. Islands of reduced biological activity resulting from drastic soil disinfestation measures may enhance rapid recolonization (Harper, 1974). Solarization raises the soil temperatures of lower level compared to aerated steam and thus reduces the chances of biological vaccum (Katan, 1981). Freeman *et al*. (1990) reported that no reinfestation of solarized and solarized shaded soil was observed two years after the treatment, and that no death of replanted apple trees occurred in the solarized plots up to two years after solarization. Tjamos *et al*. (1991) found that rate of recovery of olive trees affected by verticillium wilt (*V. dahliae*) in solarized soil significantly exceeded natural recovery of untreated control trees and was attributed to the lack of root reinfection.

Volatiles and other mechanisms.

Apart from increased temperature and biological control, volatiles in the soil are also involved in pest control by solarization. The mulch cover seals the soil and causes an accumulation of volatiles such as CO_2, ethylene, and other substances (Rubin and Benjamin, 1984). Volatiles play a key role in fungistasis and biological control (Lewis and Papavizas, 1975; Smith, 1976; Pavilica et al., 1978; Papavizas and Lumsden, 1980 and Zakaria et al., 1980) Ammonia and volatile sulfur compounds formed in amended soil are found to suppress Fusarium and Aphanomyces sp (Lewis and Papavizas,1975 and Zakaria et al., 1980). Polyethylene is not permeable to many gases. Carbondioxide accumulates under plastic mulch upto 35 fold over non-mulched soil (Horowitz and Regev, 1980; Rubin and Benjamin, 1981; Horowitz et al., 1983). Rubin and Benjamin (1984) found that carbondioxide concentration in solarized soil increased rapidly during the first week and reached a maximum which was 20 fold higher than that formed in control.

Reductive soil condition may cause oxygen starvation which will effect survival of pathogen propagules. The weakened structures are easily attacked by antagonists (Horiuchi, 1984). Remirez and Munnecke (1987) found that solarization along with cabbage amendments was more effective and they suggested that a tarp is necessary, not only to increase the temperatures of the soil to critical levels but also to trap fungistatic gases emenating from the cabbage amendments.

Factors influencing solarization

Various factors like soil moisture, soil type, organic matter content of soil, duration of solar heating, season, sunlight/shade, type of materials used for covering, ridging, etc. are known to influence the effectiveness of solarization.

Soil moisture

High soil moisture under the tarp is necessary for heat conduction, for increasing the heat sensitivity of resting structures, and for providing better conditions for activity of the natural antagonists in the soil. It is generally known that hot water treatment is better than dry heat in inactivating pathogens. This may be due to high specific heat of water, reduction in thermal tolerance of the hydrated structures of the pathogen or to a state of partial anaerobiosis (Olsen and Baker, 1968). These effects may occur in solarized soil. Heat conduction may also be improved when the pore space is filled with water (Horiuchi, 1984).

By irrigating the soil with drip irrigation, Katan et al. (1976) obtained better control of Verticillium dahliae and Fusarium oxysporum on tomato and egg plant by solarization. Later they found that only a single irrigation just before (1-4 days) covering the soil with polyethylene is necessary for controlling soil borne pathogens. The importance of maintaining high soil moisture during solarization has been emphasised by many workers (Katan, et al., 1980; Martyn and Hartz, 1985 and Kaewruang et al., 1989).

Pullman et al. (1979) slightly modified the system by giving additional furrow irrigation under the polyethylene tarp for enhancing killing of V. dahliae in soil. Fahim et al., (1987) reported that, there were no significant differences due to extra irrigation under the mulch.

Arora and Panday (1987) reported that, there was no significant difference in mean maximum temperatures in solarized irrigated and non irrigated treatments at 5, 15 and 30 cm depths. However maximum soil temperatures at 5 to 15 cm depth were achieved after 5-7 days in solarized irrigated soil compared to 15-20 days in non irrigated soil. They suggested that role of moisture is minimal when solarization is conducted for longer periods but for 7-15 days solarization without irrigation is not effective.

Horiuchi et al., (1983) reported that, infected soil with a moisture content of less than 5% particularly in air dried state was less affected by heating than soil in a slurry state. Whereas Daelemans (1989) reported that, there was no influence of addition of water in control of primary infection by cercospora leaf spot of ground nut. Lodha and Vaidya (1990) found that, solarization increased soil temperature by 12 and 9°C at 5 cm depth in dry and wet plots respectively.

Soil Type

Soil type is having an important role in temperature fluctuation in a solarized soil. Soils vary in chemical properties, colour,texture and moisture content of soil influence absorption of light and heat energy. Stapleton and DeVay (1984) observed that, loamy sand and silty clay recorded the highest temperature (46°C) compared to sandy loam and sand (39-45°C) at 15 cm depth in solarized plots. In another study by them with capay silt clay, yolo loam, reiff fine sandy loam and loamy sand, it was found that, at 15 cm depth, soil temperature in solarized fine sandy loam was 9° C higher than in control and in loam soil it was 10°C higher. Maximum temperatures at 15 cm depth in the solarized and non covered plots were 47°C and 36°C respectively in the fine sandy loam soil and 44°C and 36°C respectively in the silty clay loam soil.

Season

The best season to get maximum effectiveness of solarization is during the hottest periods of the year. During the hottest months, temperature under the mulch will increase to lethal levels. (Katan _et_ _al_., 1976; Grinstein _et_ _al_., 1979; Katan, 1980, 1981; Chen and Katan, 1980; Pullamn _et_ _al_., 1981; Stapleton and DeVay, 1982; Horiuchi and Hori, 1983; Mihail and Alcorn, 1984; Martyn & Hartz, 1985).

A one dimensional numerical model which enabled the evaluation of the relative importance of the various factors involved in solarization namely type of mulching material, type of soil, moisture and climate was developed by Mahrer (1979). It enabled choice of suitable climatic region and time of the year most adequate for soil solarization taking into account the temperature that would develop under a set of conditions.

Horiuchi and Hori (1983) reported that, field trials of solarization using plastic film mulches were unsuccessful and suggested that it may be due to the exceptionally cool season. Malathrakis and Kabourakis (1989) observed that, when solarization was conducted during July, temperature under the mulch was 45°C while when the experiment was repeated on August the maximum temperature observed was only 40°C under the mulch.

Various attempts have been made to adapt solarization in climatically marginal regions or periods of the year. An interesting approach developed in Italy and Japan is mulching the soil inside glass houses (Kodama, *et al*., 1980; Tamietti and Garibaldi, 1989).

Duration of solar heating

The duration of solarization for effective control of the pathogen depends on various factors viz. pathogen type and propagule count, depth at which the pathogen is located, season, soil type, etc. Katan *et al*. (1976) observed that,at 5 cm depth, 5 days of solar heating was sufficient to eleminate 100% of *V*. *dahliae* sclerotia while at 25 cm depth, only a slight killing of the pathogen was observed . However, an additional exposure for 8 days enabled complete killing of sclerotia even at 25 cm depth. Hence, Katan (1981) recommended that, mulching period should be sufficiently extended to get pathogen control at all desired depths. At 5-20 cm depth mortality rates of scleriotia of Sclerotium rolfsii were 100 & 25 per cent after 19 days of solarization and 100 & 90% after 21 additional days respectively. Usmani and Gaffer (1982) reported that, 95-100% loss of viability of sclerotia in soil inoculated with S. oryzae occurred at 5 cm depth by mulching for one week and at 20 cm depth for 8 weeks. Fahim et al. (1987) reported that, solarization increased soil temperature by 7°C at 20 cm depth and reduced damping off and root rot of common bean were more pronounced by increasing the mulching period and yields were significantly greater due to mulching the soil for 6 weeks. Arora and Pandey (1987) reported that, preplant solarization for 45 days in 1985 significantly reduced, the wilt incidence in two subsequent chickpea crops, and that additional solarization of sub plots of the same soil during summer of 1986 further reduced the disease and the pathogen. Dwivedi and Dubey (1987) observed that, suvivability of Macrophomina phaseolina significantly declined in soil with increase in solarization period.

Shade

Shade reduced the effectiveness of solarization

(Stapleton and De Vay, 1984). Ashworth (1979) reported that, no reduction of inoculum occurred in the partially shaded area in a 4 year old pistachio nut grove by polythene mulching. Ashworth and Gaona (1982) obtained successful control of verticillium wilt in an established (6 year old) pistachio nut grove.

Stapleton and De Vay (1983) obtained decrease in nematode population in solarized shaded soil. Infections of peach roots by *Pythium* sp. were significantly reduced in three year old almond orchard, but not in six year old peach orchard (Stapletin and De Vay, 1984). Sztejnberg *et al*., (1987) reported that, soil temperatures in tarped shaded plots were only slightly higher than those in the non solarized plots. At 10 cm depth, maximum soil temperatures were 35°C, 37°C and 47°C in non solarized, solarized and solarized shaded plots respectively.

Villapudua and Munnecke (1986) found that, solar heating alone and cabbage amendments plus mulching under shade were effective, but not as the combination of both. Chandran (1989) could not effectively control *Rhizoctonia solani* causing web blight of cowpea by solarization under partially shaded conditions in a coconut garden while it was effective under open sun.

Organic matter content

Organic and inorganic matter content of soil have been found to influence the effect of soil solarization.Horiuchi et al.(1983) reported that presence of organic matter in soil intensified the effect of heating by solarization. Horuichi (1984) reported that, organic matter combined with water and calcium compounds improved the effect of solarization. Villapudua and Munnecke (1986) could eleminate *Fusarium oxysporum* f. sp. *conglutinans* propagules with in 15 days by solarizing soil amended with cabbage residues. Tu et al. (1987) reported that, addition of green manure gave increased control compared with plastic sheet covering alone in the case of southern blight of tomato.

Type of mulching material

Type of polyethylene used for solarization influences the effectiveness of solarization (Katan, 1981, Mc Lean et al., 1982). Katan (1981) opined that, transparent,not black polyethylene should be used for solarization. Since it transmit most of the solar radiation that heats the soil. Mc Lean et al. (1982) reported that, watermelon and rockmelon plants mulched with reflective (aluminium coated) polyethylene were less infected by (21-72%) than were those without mulch. Black polythene also produced the same effects .

but to a lesser degree. Stapleton et al. (1989) observed that, soil temperatures at 15-23 cm depth usually were raised by 10-18°C under transparent and 8-12°C under black film mulching. Matrod et al., (1991) reported that, viable number of sclerotia decreased by 75.2 - 83.2% in plots covered with clear plastic mulches, compared with a decrease of 49.6 - 59.2% with black plastic mulch.

Garibaldi (1987) used PVC and polyethylene covers for soil solarization in summer and found that PVC was more effective than polyethylene in maintaining high soil temperature. Double layered plastic have given soil temperature 1-2° higher than those obtained with PVC. Tamietti and Garibaldi (1989) observed that, temperature under single polyethylene film (0.05 mm thick) mulch was 36.9 to 44.5°C at 24 cm depth compared to 42.5°C or an average under double polyethylene film with bubbles (tristar) which was 2-2.5°C higher than with single film. They suggested that, double polyethylene film prevented heat dispersal more efficiently.

Garibaldi and Tamietti (1989) reported that, double layered polyethylene film reduced the percentage of infection by Phytophthora nicotianae var. parasitica on carnation plants but there was no significant difference between single and double layered polyethylene. Al-Asa (1990) reported that, two months tarping with either transparent or black film gave the best plant growth responses and yields.

Increased Growth Response

The phenomenon of plant growth enhancement in disinfected soils in the absence of known pests has been repeatedly reported with all disinfestation methods, including solarization. Increased yield of brinjal and tomato (Katan et al., 1976). Better development and uniform maturation in onion (Katan et al.,1980, Hasan, 1989 and Hartz et al., 1989) were observed in solarized plots. Improved plant growth and yield in the case of sorghum (Pullman et al., 1981) and cotton (Katan et al.,1983) were found to last for more than one crop season in solarized soil.

Significant increase in yield, nodulation and plant height at maturity of chickpea were observed by Arora and Pandey (1987). Triolo et al (1988) observed increased root length of lettuce plants grown in solarized soil. The mean weight of plants in solarized plots was 30% higher than in non-solarized plots. Jimenez et al (1991) reported that, soil solarization for two months in the absence of major pathogens increased the percentage of rooted cuttings and vigour of Indica rose rootstocks.

Gamliel et al (1989) found that, dry weight accumulation was more rapid in the plants from the solarized soil. Ten weeks after planting, dry weight of the plants in the solarized plots was 82% higher than that in the nonsolarized plots. Similar observations were also made by Osman et al (1986) and Meron et al. (1989) on lupin and beans respectively. Chandran (1989) recorded 21% more yield of cowpea in solarized plots while the yield increase was only 11% when solarization was done under partially shaded condition.

Beneficial effects of solarization were not observed in all plants when chilli cultivar, Resistant giant (Stapleton and DeVay, 1984) and parsely (Rubin and Benjamin, 1983) were grown in solarized soil. There was no increase in any of the growth parameters measured.

Soil solarization technology was first developed as a preplanting technique. However, in 1981, solarization successfully used in California to control verticillium wilt in pistachio nut groves (Ashworth and Gaona, 1982). Since then post-plant use of

Solarization experimentally controlled verticillium wilt of Olive (Tjamos *et al*, 1991) and white root rot (*Rosellinia necatrix*) of apple trees (Sztejnberg *et al*,. 1987) and reduced soil and root populations of *Pythium* sp., *Criconemella xenoplay*, *Paratrichodorus porosus*. *Paratylenchus vulnus* in California, in almond, peach and walnut orchards (Stapleton and DeVay 1984)

The pre requisites for achieving an effective control by solarization in an existing plantation are, 1) solarization does not cause root damage owing to elevated temperature 2) shaded area does not consist of a large proportion of the treated area, and does not reduce heating efficiency 3) the pathogen is killed at a desired soil depth (Katan, 1981).

Effect of solarization on microbes

Soil solarization has got pronounced effect on microbial activities in soil and may result in increased antagonistic activity and induced soil suppressiveness. (Greenberger *et al*., 1987). Hori *et al*.(1979) observed a drastic reduction in the population of total fungi and gram negative bacteria in soil during solarization. Stapleton and De Vay (1982) found that, population densities of *Agrobacterium* spp., fluorescent pseudomonads, gram positive bacteria and fungi were greatly reduced immediately after solarization. Actinomycetes and thermotolerant fungi were affected to a lesser extent. Fluorescent pseudomonads and fungi quickly recolonized the treated soil. Stapleton and De Vay (1984) showed that, solarized soils usually contained least micro organisms. They also found that, population of grampositive bacteria showing invitro antibiosis against Geotrichum condidum increased 20 fold in solarized soil .

According to Kaewruang et al (1989), solarization increased the total numbers of bacteria and acitno mycetes and the proportion of bacteria and fungi antagonistic to F. oxyspornum, F. Solani and R. Solani were increased by solarization. Solarization did not affect population of actinomycetes that are antagonistic to the pathogens at 0-10 cm but reduced the proportion at 10-30 cm. Triolo et al. (1988) reported that, number of different colonising spp. of bacteria and fungi on sclerotia of Sclerotinia minor was reduced, but the prevellance of Aspergillus, Fusarium, and Trichoderma increased.

Meron et al., (1989) by assessing the rhizosphere soil from cotton plants grown in solarized and non solarized soil, found that, the number of fluorescent pseudomonads was 50-100 fold higher in the rhizosphere of plants grown in the solarized soil than in the control, while the number of fungi was 20-100 fold lower.

Pullman et al., (1981) observed that, mycorrhizal fungus Glomus fasciculatus survived tarping treatment as measured by colonization of cotton roots. However, no visible difference in the extent of root infections by V.A. Mycorrhizae (Glomus sp) was noticed by Stapleton and De Vay (1984) between the roots from solarized and control almond trees. Similar results were recorded by Triolo et al. (1988) working with lettuce plants.

Changes in soil physical and chemical properties of as a result of solarization

Most of the studies on changes in the chemical composition and other physico-chemical parameters have been carried out either with steam sterlized soils or with soil mulched with balck polyethylene, where the temperature increase was small. Only limited reports are available on the changes in physico-chemical properties of solarized soil where the heating course is entirely different.

Solarization was found to reduce EC (Hori et al., 1989), increase specific gravity (Davis, 1991) and to modify hydraulic conductivity of top soil (Al-Kayssi et al., 1989). Decline in nitrate nitrogen and an accumulation of ammoniacal nitrigen was reported by Hori et al. (1979) in solarized soil. However, the findings of Horiuchi (1984), Stapleton et al. (1985) and Kaewrauang et al. (1989) show that, solarization caused an increase in both nitrate and ammoniacal form of nitrogen in soil. An increase in P, (Stapleton et al.,1984) Ca, Mg (Chen & Katan, 1980; Horiuchi, 1984) K and Cl (Horiuchi, 1984) was reported in solarization. However, the work of Stapleton et al. (1985) shows that, solarization did not consistently affect available K, Fe, Mn, Zn, Cu and Cl concentrations in soil.

Al-Kayssi et al. (1989) reported that, soil solarization caused a considerable modification of the hydraulic condctivity of the top layer of soil 0-30 cm and this improved leaching of salts with irrigation water.

Kaewruang et al. (1989) reported that, solarization of soils with in plastic bags for 4 weeks increased availability of nutrients such as NH_4^+ and

PO_4^- and K in comparison to bagged soil kept on the shade for the samne period. They did not find any difference in K^+, Fe^{3+} organic C in pH both at 0-10 and 10-30 cm in the solarized soil in comparison to the fumigated and control soils. The phosphate concentration was significantly lower in the solarized soil than in fumigated or control soil at 10-30cm depth. Chandran (1989) could observe increase in available nitrogen both in open and shaded, solarized plots compared to nonsolarized. In the case of organic carbon, increase was more in open while level of available K increased in open and decreased in shaded solarized plots, and pH and EC were not markedly influenced by solarization (Chandran, 1989).

Nematode control by solarization

Control of nematodes by solarization has been reported by several workers. However, most of the information on nematode response to solarization has been restricted to endoparasitic phytonematodes. Solarization was found effective in reducing the population of pratylenchus thornei (Grinstein et al., 1979) Meloidogyne sp. (Katan, 1981; Al-Samaria, 1988; Cartia et al;1989) Dihylenchus dipsaci (Siti et al.,1982)

According to (Stapleton and De Vay, 1983), extent of control depended on 1) degree of solar heating, 2) crop and cropping history, 3) nematode spp. 4) it's distribution in soil and 5) depth. Lamondia and Brodie (1984) reported that the population of *Globodera rostochiensis* was reduced by 96.2 to 98.6% to a depth of 10cm totally eleminated encysted juvenilles upto 5cm depth and reduced survival to 10-15 cm depth.

Stapleton and De Vay, (1986) reported that, population of *M.incognita* and *Pratylechus neoamblycephalus* were unaffected by solarization.

Weed control by solarization

Effective weed control, one of the visible results of solarization can be considered as an indication of its success. possible mechanisms of weed control suggested by Katan (1981) are 1) thermal killing of seeds,2) thermal killing of seeds induced to germinate, 3) breaking of seed dormancy and consequent killing of the germinating seed and 4) biological control through weakening or other mechanisms.

Almost complete control of weeds by solarization has been reported by Katan, (1976), Bell, *et al*. (1985)

Del Busto *et al*.(1989) and Chandran, (1989). Control of annual weeds by solarization was reported by Grienstein *et al*.(1979), Katan (1980), Horowitz *et al*. (1983), Rubin and Benjamin (1983, 1984), Egley (1983), Brown *et al*.(1988), Tamietti and Garibaldi (1989), and Chandran (1989).

Many perennial weeds were also effectively controlled by solarization (Katan, 1980; Grinstein *et al*., 1979). Rubin and Benjamin (1983) found that, perennial weeds which propagate vegetatively were only partially controlled by solarization. According to Horowitz *et al*. (1983) established perennials escaped solarization.

Weeds controlled by solar heating include, *Anagallis*, *Avena*, *Capsella*, *Cynodon*, *Digitaria*, *Eleusine*, *Fumaria*, *Lactuca*, *Mercurialis*, *Notobasis*, *Phalaris*, *Poa*, *Sisymbrium*, *Solanum*, *Stellaria*, *Xanthium* (Katan, 1980; Horowitz *et al*., 1983), *Amaranthus*, *Chenopodium* (Katan, 1980; Horowitz *et al*., 1983; Tjamos and Paplomatas, 1988; Brown *et al*., 1988) *Ipomoea*, *Trianthema* (Egley, 1983), *Cynodon* and *Sorghum* (Rubin and Benjamin, 1984), *Malva sylvestris*, *Cyperus rotundus*, *Convolvulus arvensis* (Tjamos and Paplomatas, 1988), *Isachne miliacea*, *Brachiaria ramosa*, *Merremia tridentata*, *Hemidesmus indicus*, *Desmodium trifolium*, Alternanthera sessiles, Curcuilago orchioides, Sebastina chamaelea, Lindernia crustacea, Oldenlandia corymbosa, Ageratum conyzoides, Emilia sonetrifolia (Chandran, 1989), Chenopodium album and Polygonum persicaria (Brown et al, 1988).

Melilotus (Katan, 1980; Rubin and Benjamin, 1983), Conyza (Horowitz et al., 1983) were not controlled by soil solarization.

Egley (1983) found that, soil solarization did not eliminate dormant weed seeds from the germination zone, but nondormant seeds were killed. Stapleton et al.(1989) reported that, per cent ground cover by winter or summer weeds was reduced by more than 82% after solarization or black film mulching. Mulching with black polyethylene for seven weeks provided superior weed control indicating the involvement of darkness effect on seeds or soil volatile metabolites (Rubin and Benjamin, 1983).

Materials and Methods

MATERIALS AND METHODS

Location

The field studies on solarization were conducted at the experimental plot of the Olericulture department of the College of Horticulture, Vellanikkara, attached to Kerala Agricultural University, located at an altitude of 22.5m above M.S.L., between 10° 32' N latitude and 76° 16' E longitude. The area enjoys a warm humid tropical climate. Soil of the experimental field is of laterite type.

Field experiment

Field experiments were conducted to study the effectiveness of solarization on the pre and post emergence damping off of chillies caused by Pythium aphanidermatum (Edson) Fitz. The experimental area was solarized during April-May 1991. Chilli variety, Manjari, having resistance to bacterial wilt was used in the present study. The details of the experiment are,

Crop	: Chilli (Capsicum annuum L.)
Variety	: Manjari

Nursery

Design - R.B.D.

Treatments - T_1 45 days solarization

T_2 45 days control

T_3 30 days solarization

T_4 30 days control

T_5 15 days solarization

T_6 15 days control

Plot size - 1 x 1 m^2

Replication-5

Main field

Design - R.B.D

Treatments - T_1 control

T_2 solarization

T_3 neemcake + solarization

T_4 neemcake without solarization

Plot size - 2 x 1 m^2

Replication - 5

Spacing - 45 x 30 cm

Number of plants/plot - 12

All the agriultural operations connected with the study were conducted as per the Package of Practice Recommendations (Kerala Agricultural University, 1989).

Pathogen

The isolate of Pythium aphanidermatum used for the experiment was obtained from Department of Plant Pathology, T.N.A.U., Coimbatore. Pathogenicity of the isolate was proved on the Manjari variety of chilli. The identity of the pathogen was confirmed by comparing the characters of the isolate with typical characters of Pythium aphanidermatum.

Mass multiplication of the pathogen

The pathogen, P. aphanidermatum was mass multiplied on sand oats meal, sterilized bits of chilli plants and on potato dextrose agar medium.

Sand oats medium

Sand oats medium was prepared by mixing washed white sand with oats meal in the ratio 19:1. This mixture was taken in conical flasks (250 and 1000 ml) moistened with water and sterilized by autoclaving at 1.02 kg/cm^2 pressure for 20 minutes. Actively growing culture bits were aseptically introduced into the flasks containing sterilized sand oats medium and were incubated for two weeks at room temperature before incorporating in soil.

Chilli plant bits

The mature stem portions of chilli plants were cut into small bits of size 1.0 cm to 1.5 cm and autoclaved at 1.02 kg/cm^2 pressure for 15-20 minutes in 250 ml conical flasks. Actively growing culture was aseptically transferred into the flaks with sterilized chilli plant bits and were incubated at room temperature for two weeks. This was used for soil inoculation.

Potato dextrose agar

Fifteen day old culture of *Pythium aphanidermatum* on potato dextrose agar was mixed with soil @ 10 culture plates (9 cm diameter) per kg of soil. The soil after mixing with the culture was sieved twice in order to get a uniform distribution of the pathogen. Chilli seedlings were test planted in the soil and were found to be infected by the fungus.

Soil inoculation

For soil inoculation, the fungus (*P. aphanidermatum*) grown on sand oats medium, chilli plant bits and potato dextrose agar were used. Furrows with

5 cm depth, 10 cm apart were taken on nursery beds. All the three types of inocula were uniformly applied into the furrows and covered with soil.

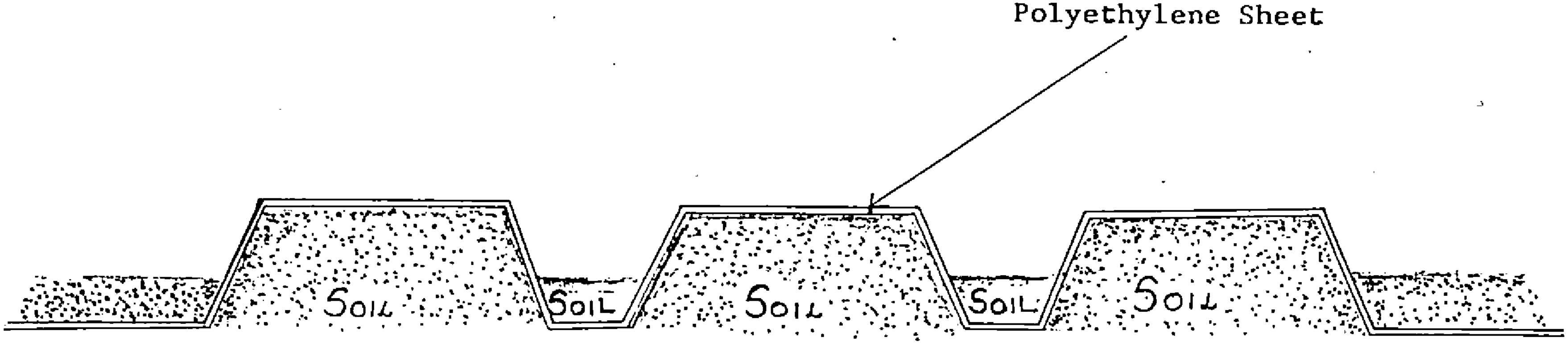
In the main field, all the three types of inocula were applied uniformly in the planting pits at a depth of 5 cm. The planting pits were taken at a spacing of 45 x 30 cm. After applying the inoculum, it was covered with soil. There were 12 pits in each bed of 2 x 1 m^2size.

Mulching with polyethylene and recording of soil temperature

For solarizing, 150 guage transparent polyethylene sheets were used. Plots were solarized during April-May 1991 both in nursery and mainfield. The beds for solarization were levelled and the pebbles presnt on the surface were removed. The beds were mulched with polyethylene sheets as shown in Fig. 1. Just before solarization, the plots were irrigated at the rate of 5 $1/m^2$. The sides of the sheets were covered with soil. This helped in keeping the sheets in position. Adequate care was taken to keep the sheets in close contact with the soil and to prevent formation of air pockets between soil and the sheets.

Fig. 1

Polyethylene mulched soil



Soil thermometers were installed in the centre of the bed at a depth of 10 cm. Soil temperatures were recorded at 8.30 am and at 2.30 pm.

Nursery

In the nursery, solarization for three different durations, viz., 15,30 and 45 days were tried. Nursery beds were inoculated with Pythium aphanidermanitum one day before solarization. The plots requiring 45, 30 and 15 days of solarization were mulched on 10/4, 25/4 and 10/5/91 respectively.

Experiment to assess the effect of solarization on the pre and post emergence damping off of chilli was conducted in the nursery. Four grams of the seeds (approximately 1050 seeds)/m^2 nursery beds were sown immediately after removing the polyethylene mulch. The seeds were sown along the inculated strips.

Before sowing, the rate of germination of the seeds were determined using top of paper technique and was found to be 85%.

Main field

The main field was solarized on 25.4.91. In treatments requiring application of neem cake, powdered neem cake at the rate of 250 g/m^2 was applied just before solarization. On 11th June, polyethylene sheets were removed from all the beds and one month old chilli seedlings were transplanted to previously marked pits.

Disease incidence

Nursery

The seeds started germinating after 3 days and the number of seedlings emerged out were counted 7 and 30 days after sowing. The seedlings showing damping off symptoms were removed and the identity of the pathogenic organism was established by isolating the causal organism of the disease.

Main field

In the main field, number of diseased plants in each treatment was determined at two days interval. The identity of the causal organism was established by isolating the pathogen from the roots of diseased plants.

Biometric observations

Biometric observations viz., height, number of branches, leaves, flowers, fruits, root lets, length of root system, fresh and dry weight of shoot and root of the plants in the main field were recorded, after 30,60 and 120 days of transplanting.

Laboratory studies

Collection of soil samples

From each plot, soil was collected randomly from 0-10 cm depth and mixed. Soil samples were collected, before solarization, just after solarization, and one month after solarization, from both nursery and mainfield. From the mainfield, samples were collected after two months of solarization and also after harvest.

Estimation of microbial population

Population of fungi, bacteria and actinomycetes in soil was estimated both in the nursery and main field, using serial dilution plate technique (Johnson and Curl, 1972). Martin's rosebengal streptomycin agar, Kenknight's agar and Thornton's standardisation medium were used for estimating fungus, actinomycetes and bacteria respectively.

Rhizosphere microflora of plants in the main field was estimated using dilution plate technique, at one month and two months after transplanting and at the time of harvest.

Estimation of V.A. Mycorrhizal infection

Root samples from the different treatment plots were stained for V.A. Mycorrhizal infection by the method of Phillips and Hayman (1970) and the percentage of infection was estimated.

Estimation of Nematode population

Nematode population was estimated using, modified Baerman's funnel method (Christie & Perry, 1951). For this, soil samples were collected before solarization and just after removing the mulch from nursery and main field. In the main field nematode population estimation was done two months after transplanting and at the time of harvest also.

Weed population

Weeds present in both nursery and main field were identified and counted before, just after the removal of the mulch and one month after solarization in the nursery. In the mainfield, weeds were counted before solarization, just after solarization and before each weeding till final harvest.

Meteorological observations

Soil temperature at 10 cm depth at 8.30 am and 2.30 pm were recorded during the entire period of solarization by installing soil thermometers in both solarized and control plots. Atmospheric temperature and rainfall during the period was collected from the Department of Meteorology, College of Horticulture.

Chemical analysis of soil samples

In order to find out the effect of solarization on the nutrient status of the soil, different plant nutrients were estimated, before and after solarization.

Nitrogen

Total nitrogen was estimated using Microkjeldahl digestion and distillation method (Piper, 1942).

Phosphorus

Available phosphorus was determined by chlorostannous reduced molybdophosphric blue colour method (Bray and Kurtz, 1945).

Potassium

Available potassium was determined by extraction with neutral ammonium acetate (1:5) and using flame photometer (Jackson, 1958).

Exchangeable cations (Ca, Mg, Na, K)

Exchangeable cations were determined by extraction with 1N neutral ammonium acetate solution (1:5) (Jackson 1958). From thus extract, Ca and Mg were estimated by titration. Exchangeable Na and K were estimated in a flame photometer.

Organic carbon

Organic carbon was determined by the Walkley and Black's rapid titration method as described by Hesse (1971).

Electrical conductivity

Electrical conductivity was determined by extraction in water (1:2.5) using a Elico conductivity bridge.

Results

RESULTS

Temperature and Rainfall

Details regarding soil temperature (at 10 cm depth), atmospheric temperature, and rainfall during the period of solarization (10.4.91 to 25.5.91) are presented in Table 1. The atmospheric temperature during the period ranged from 20°C to 38°C. There was considerable difference between soil temperature in the solarized and non solarized plots. The soil temperature in solarized plots was always higher than in the non solarized plots.

The average weekly atmospheric temperature during the period ranged from 25.3 -35.5°C (Table 2, Fig. 2). The weekly average maximum temperature fluctuations in atmospheric temperature was only 1.7°C (34.7°C - 36.4°C) while the fluctuations in average weekly minimum temperature was 2.9°C (23.3°C - 26.2°C). The weekly average maximum soil temperature at 10 cm depth in non solarized soil was 4.4°C more than the atmospheric temperature.

After mulching with polyethylene sheet, heat build up occurred within 24 to 48 hours (Table 1). But a fall in temperature both in solarized and non

Table 1

Maximum and Minimum atmospheric and soil temperatures and rainfall during the solarization period (10.4.91 - 25.5.91)

Date	Atmospheric temperature°C		Rainfall	Soil temperature at 10cm depth°C			
	Max.	Min.	(mm)	Solarized soil		Non solarized soil	
				8.30 am	2.30 pm	8.30 am	2.30 pm
10.4.91	36.0	23.0			43.5		37.0
11.4.91	35.5	25.5		33.5	43.8	31.0	37.0
12.4.91	36.0	26.5		34.5	49.5	32.0	39.5
13.4.91	35.8	25.2		33.5	48.0	31.5	38.5
14.4.91	36.0	25.6	24.4	33.0	47.5	31.5	40.5
15.4.91	38.0	23.0		32.5	45.5	30.0	35.5
16.4.91	34.4	24.5		33.5	47.0	31.0	38.0
17.4.91	35.2	26.2		34.5	47.0	41.0	40.0
18.4.91	36.0	27.0		34.0	49.0	31.0	41.5
19.4.91	36.5	27.5		35.0	48.5	32.5	42.0
20.4.91	36.6	24.4		34.0	47.5	31.7	39.5
21.4.91	34.0	26.0	1.4	34.5	47.5	32.0	41.0
22.4.91	35.6	24.8		34.0	48.5	31.5	41.0
23.4.91	34.9	25.4	25.8	32.0	48.5	29.5	37.0
24.4.91	35.5	20.0		34.0	48.5	30.0	37.0
25.4.91	34.5	25.5		34.0	48.5	30.0	37.0
26.4.91	34.2	25.4	9.2	34.5	48.5	30.0	37.5
27.4.91	35.6	22.0		33.0	47.5	29.5	37.5
28.4.91	34.5	22.0		34.0	47.5	29.5	38.0
29.4.91	34.0	23.0		34.0	47.0	30.5	39.0
30.4.91	34.7	25.0		34.0	48.5	31.0	40.5
01.5.91	35.0	25.2		34.5	50.0	31.5	41.5
02.5.91	35.2	25.5		35.0	50.0	32.0	42.0

Date	Atmospheric temperature°C		Rainfall	Soil temperature at 10cm depth°C			
	Max.	Min.	(mm)	Solarized soil		Non solarized soil	
				8.30 am	2.30 pm	8.30 am	2.30 pm
03.5.91	34.0	27.0		34.0	50.0	31.0	41.5
04.5.91	34.0	26.5		34.5	49.5	31.5	41.5
05.5.91	34.5	25.0		34.5	49.5	31.5	41.5
06.5.91	34.5	25.5		34.5	49.0	31.5	41.0
07.5.91	35.5	26.0		34.5	50.0	31.5	42.0
08.5.91	35.5	26.2		33.0	48.5	36.0	49.0
09.5.91	35.5	26.6		34.5	42.5	33.5	38.0
10.5.91	34.8	25.8		33.5	48.0	32.0	42.5
11.5.91	36.0	27.0	1.4	35.5	48.0	33.5	41.5
12.5.91	35.5	25.5		34.0	50.0	31.5	41.5
13.5.91	36.6	25.5		35.0	47.5	32.5	41.0
14.5.91	35.8	26.5	1.2	35.0	48.5	32.0	41.5
15.5.91	36.2	26.5		35.0	48.0	33.0	41.0
16.5.91	37.0	25.8		35.5	47.0	33.0	41.0
17.5.91	36.0	26.0		35.0	47.0	33.5	40.5
18.5.91	35.5	25.2		35.0	51.0	33.0	42.0
19.5.91	38.4	28.0		35.5	49.5	33.5	40.5
20.5.91	35.6	26.0	4.6	35.0	47.5	33.5	41.0
21.5.91	36.0	22.2		34.0	47.0	31.0	39.0
22.5.91	36.0	25.2	0.6	35.0	49.0	32.5	41.0
23.5.91	34.8	25.5	22.7	35.0	49.0	33.0	42.0
24.5.91	36.4	27.0	8.4	34.0	50.0	31.5	39.0
25.5.91	34.5	25.0		34.0	48.0	30.5	37.0

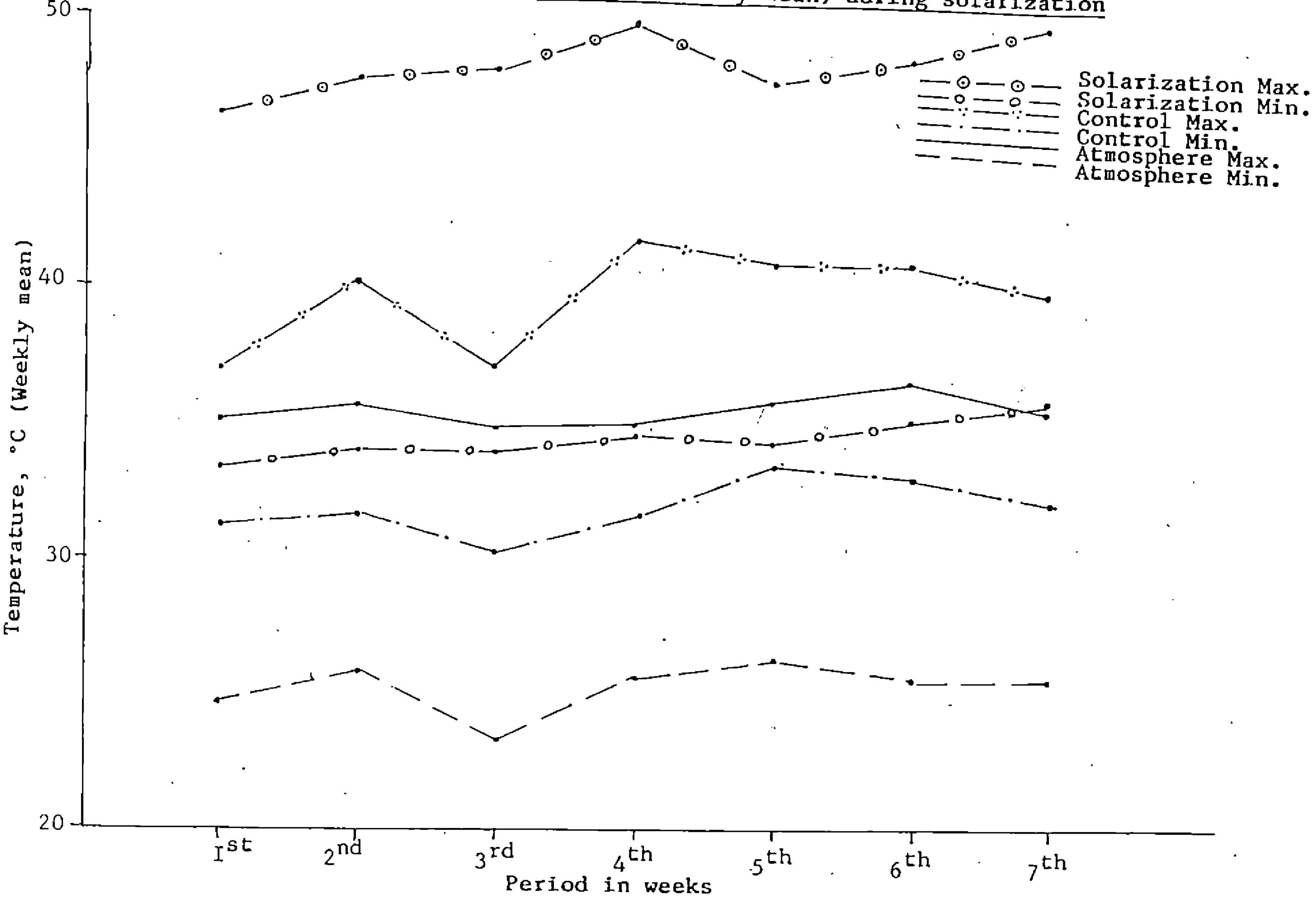
Table 2

Soil and atmospheric temperature during the solarization period

(10.04.91 - 25.05.91 Weekly mean)

Week	Atmospheric temperature°C		Soil temperature at 10 cm depth°C			
	Max.	Min.	Solarized soil		Non solarized soil	
			8.30 am	2.30 pm	8.30 am	2.30 pm
1	35.0	24.8	33.3	46.4	31.2	38.0
2	35.5	25.9	34.0	47.8	31.5	40.3
3	34.7	23.3	33.9	48.0	30.1	38.0
4	34.8	25.8	34.5	49.7	31.5	41.6
5	35.6	26.2	34.1	47.5	33.1	40.9
6	36.4	25.7	35.0	48.1	32.9	40.7
7	35.4	25.7	34.5	49.0	31.9	39.7
Average	35.5	25.3	34.2	48.1	32.3	39.9

Fig. 2. Atmospheric and soil temperature (weekly mean) during solarization



solarized plots was noticed on rainy days. However, heat build up occurred again and normal temperature was regained within a period of 24 to 48 hours after rain. Measurable rainfall was recorded for 10 days during the period when the soil was mulched with polyethylene sheets.

Maximum temperature of 51°C in the solarized plot was recorded on 18.5.91, which was 9°C higher than the non solarized soil and 15.5°C more than the atmospheric temperature. Lowest temperature recorded in solarized soil was 32°C while in non solarized soil, it was 29.5°C. Thus, during the course of the study, the maximum temperature difference at 2.30 pm between solarized and non solarized soils was 11.5°C on 23.4.91, and the minimum difference was 3.9°C on 9.5.91. However, at 8.30 am, the corresponding temperature differences were 4.5°C and 1.5°C respectively. The average daily fluctuation in temperature was 13.9°C (34.2°C - 48.1°C) 7.6°C (32.3°C-39.9°C) and 10.2°C (25.3°C- 35.5°C) in solarized soil, non solarized soil and atmosphere respectively. The difference in the maximum temperature between solarized and non solarized soils was > 10°C for 9 days and > 8°C for 26 days.

Based on the soil and air temperatures, simple and multiple regressions were calculated with a view to predict, the soil temperature under the mulch.

The regression of maximum soil temperature under polyethylene cover (Y) against maximum soil temperature (X) in non solarized soil at 10 cm depth was

$$Y = 30.33631 + 0.4453 \times X$$

The coefficient of determination was 24.85 per cent for this regression equation.

Another simple regression equation calculated based on the maximum air temperature (X) was

$$Y = 57.1225 - 0.2534 \times X$$

However, the coefficient of determination for this regression equation was only 2.43 per cent.

A multiple regression equation using soil temperature at 10 cm depth (X_1) under non solarized soil and maximum atmospheric temperature (X_2) was also calculated, to find out the maximum temperature at 10 cm depth under solarized soil.

$$Y = 38.815 - 0.2359 \times X_1 + 0.4425 \times X_2$$

The coefficient of determination for this multiple regression equation was 26.96 per cent.

Effect of solarization on disease incidence

Nursery

There was considerable variation in the rate of germination of chilli seeds in solarized and non solarized (Table 3, Fig. 3) plots. The effect of solarization on the pre emergence damping off of chillies was scored by counting the number of seeds germinated at the end of seven days of sowing. Maximum percentage of germination of seeds was noticed in plots solarized for 45 days (44.03%). However, germination rates in plots solarized for 30 and 15 days (40.63% and 39.23%) were on par with that observed in plot solarized for 45 days. Among the non solarized control plots, maximum germination (18.76%) was observed in plots which were inoculated with Pythium aphanidermatum 15 days before seeding, while it was least (1.2%) in plots where the inoculum was applied 45 days before seeding.

Table 3

Effect of soil solarization on germination of chilli seeds

Treatment		Germination % (Mean values)
T_1	45 days solarized	45.56 (44.03)*
T_2	45 days control	6.28 (1.20)
T_3	30 days solarized	39.58 (40.63)
T_4	30 days control	15.33 (6.99)
T_5	15 days solarized	38.76 (39.23)
T_6	15 days control	25.66 (18.76)

CD (5%) = 6.198

Ranking $\overline{T_1, T_3, T_5}$, T_6, T_4, T_2

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* Data after angular transformation. Values in parentheses are retransformed values.

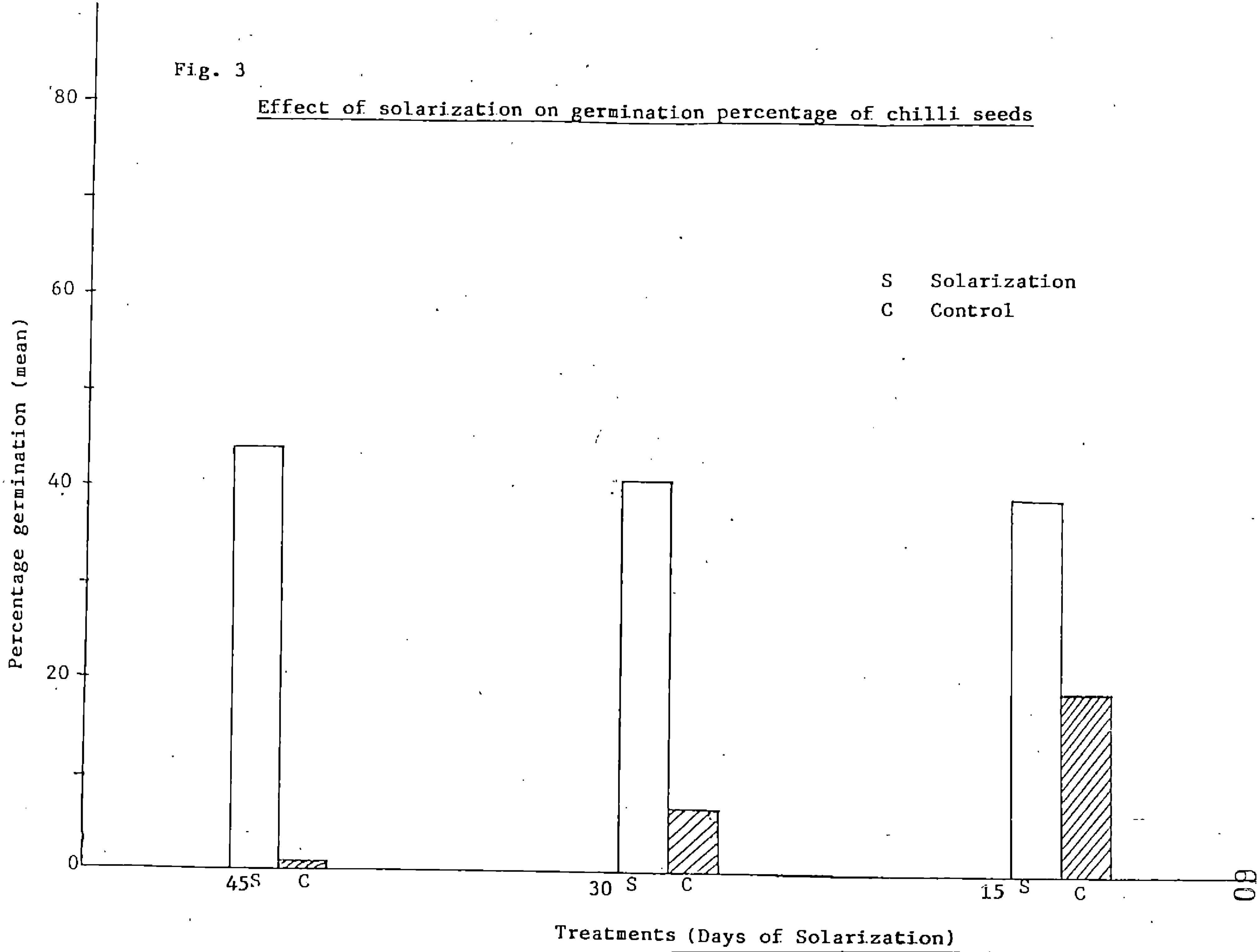

Fig. 3

Effect of solarization on germination percentage of chilli seeds

Post emergence damping off was also observed in the nursery. The reduction in population of seedlings from seven days to the time of transplanting (30 days) was considered to be due to post emergence damping off. All three solarization treatments were found to retain more number of seedlings than respective control plots (Table 4, Fig. 4). At the time of transplanting, there were 17.51 per cent seedlings in plots solarized for 45 days while in the corresponding control plot it was only 0.42 per cent. There was significant difference between control and solarized plots in the case of 45 and 30 days solarization treatments. However, in plots solarized for 15 days the seedling stand was not significantly better than the corresponding control.

Mainfield

Thirty day old chilli seedlings raised in a disease free nursery were transplanted to the mainfield and the incidence of disease intensity was recorded at regular intervals. The mainfield was solarized for 35 days. Solarization had profound influence on the control of post emergence damping off of chilli seedlings in the mainfield (Table 5). None of the

Table 4

Effect of soil solarization on the stand of chilli seedlings in the nursery at transplanting stage

	Treatment	Percentage of surviving seedlings (Mean values)	
T_1	45 days solarized	24.73	(17.51)*
T_2	45 days control	3.71	(0.42)
T_3	30 days solarized	10.73	(3.47)
T_4	30 days control	6.23	(1.18)
T_5	15 days solarized	21.10	(12.97)
T_6	15 days control	19.00	(10.61)

CD (5%) 5.598

Ranking $\overline{T_1, T_5, T_6}, \overline{T_3, T_4, T_2}$

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* Data after angular transformation. Values in parentheses are retransformed values.

Fig. 4 Effect of solarization on survival percentage of chilli seedlings in the nursery

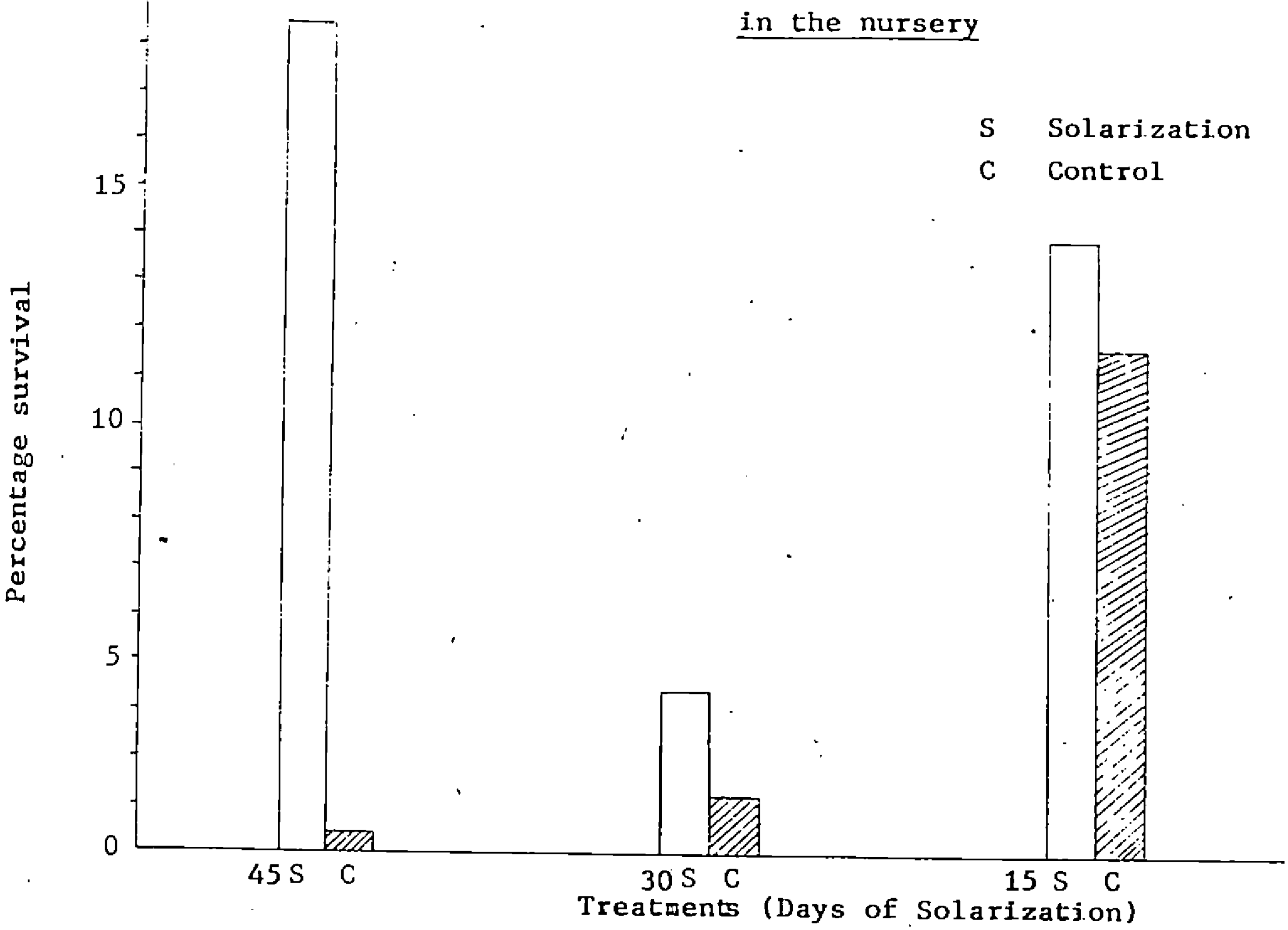


Table 5

Effect of solarization on damping off of chillies in the mainfield

Treatment	Days after transplanting									Percentage
	5	8	10	12	14	17	19	21	25	
	Number of diseased plants									
T_1 Control	2	4	4	8	8	9	9	9	10	16.66
T_2 Solarization	-	-	-	-	-	-	-	-	-	0.0
T_3 Neemcake + Solarization	-	-	-	-	-	-	-	-	-	0.0
T_4 Neemcake alone	7	12	12	13	13	15	15	15	15	25.0

seedlings transplanted in solarized plots with or without neemcake amendment showed any damping off symptoms till the final harvest.

In the non solarized plots, disease incidence was first observed on the 5th day after transplanting, and 3.3% of the plants exhibited damping off symptoms in the non amended control plot. The corresponding figure for neemcake applied non solarized plot was 11.7 per cent. During the second week, number of diseased plants in control and neemcake applied non solarized plots were 8 and 13 respectively.

Incidence of damping off was not noticed in non solarized control plots after 25 days and neemcake applied control plots after 17 days.

Effect of solarization on soil microflora

The effect of solarization on population of fungi, bacteria and actinomycetes in soil was studied in the nursery as well as in the mainfield. The population counts of the micro organisms in nursery were taken immediately after removing the mulch and one month after solarization. In the mainfield, apart from the observations taken in the nursery, population of the micro organisms was also estimated two months after solarization and after harvest.

Effect of solarization on population of fungi

Nursery

The population of fungi in solarized soil was less than in non solarized soil when the population was estimated immediately after removing the polythene mulch (Table 6). This reduction was maximum in soil solarized for 45 days and minimum in soil solarized for 15 days. Compared to 34.8 propagules in non solarized soil, in soil solarized for 45 days the corresponding figure was only 5.3. Almost a similar trend was noticed when the fungal population was estimated one month after removal of the mulch (Table 6). However, fungal population in 15 days solarized plot (39.8) was higher than in the corresponding control (22.2).

Mainfield

As was observed in the nursery, in the mainfield also there was a reduction in the fungal population in non amended solarized soil (6.3) compared to the

Table 6

Effect of soil solarization on fungal population in soil

(Number of colony forming units/ Plate).

Treatment Nursery	Just after solarization	One month after solarization
T_1 45 days solarized	2.31 (5.34) *	3.95 (15.57)
T_2 45 days control	5.90 (34.81)	6.00 (36.03)
T_3 30 days solarized	2.96 (8.75)	5.20 (27.03)
T_4 30 days control	6.15 (37.85)	6.05 (36.10)
T_5 15 days solarized	3.12 (9.74)	6.32 (39.89)
T_6 15 days control	4.53 (20.54)	4.72 (22.28)
CD (5%)	1.569	N.S.
Ranking	T_4, T_2, T_6, T_5, T_3, T_1	

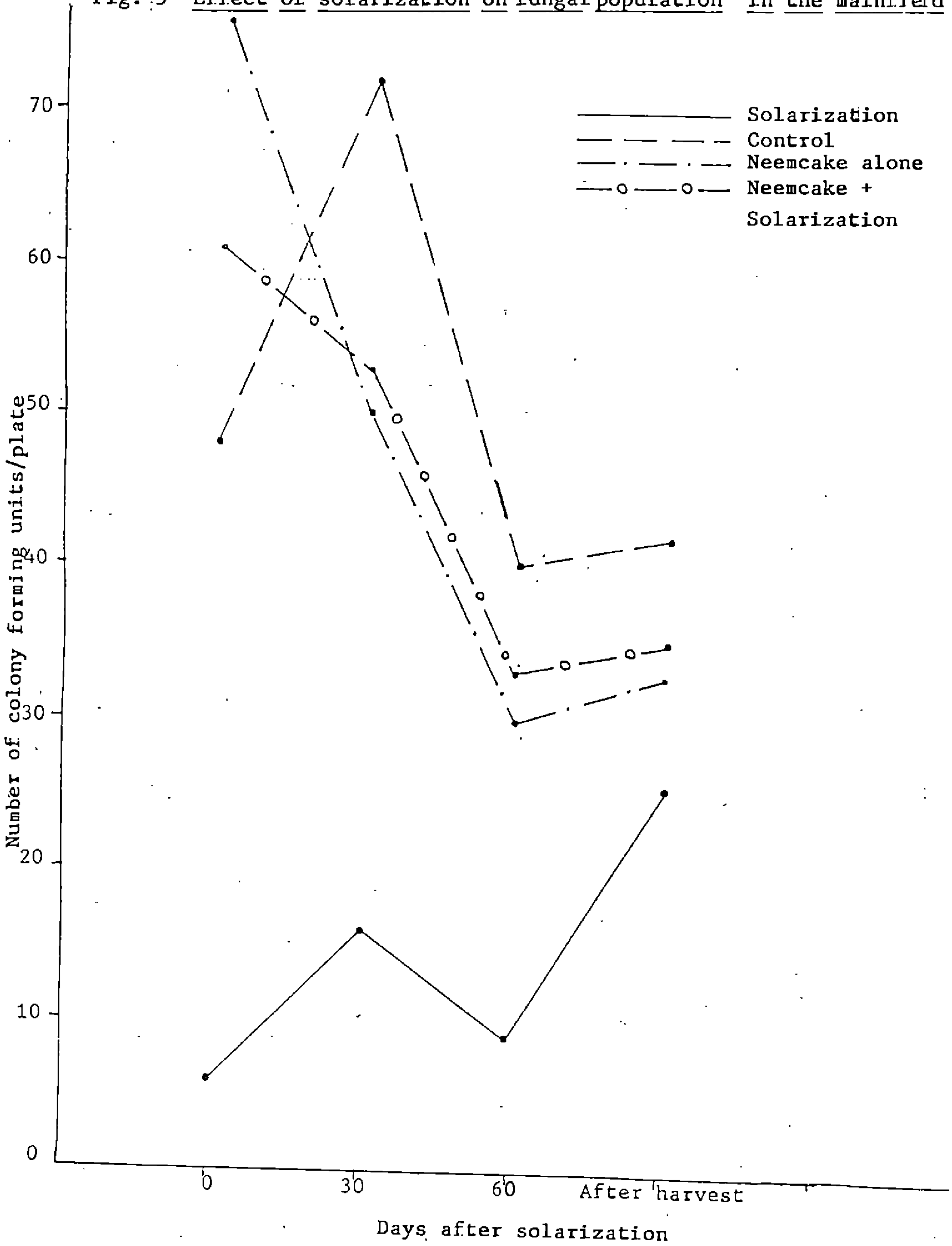
Mainfield	Just after solarization	One month after solarization	Two months after solarization	After harvest
T_1 Control	48.42	72.0	39.58	42.48
T_2 Solarization	6.32	16.3	9.22	28.64
T_3 Neemcake + Solarization	61.1	53.9	33.02	34.8
T_4 Neemcake alone	74.16	50.0	30.42	33.3
CD (5%)	40.16	21.13	19.5	N.S.
Ranking	T_4,T_3,T_1,T_2	T_1,T_3,T_4,T_2	T_1,T_3,$T_4$$T_2$	

* Data after $\sqrt{x}$ transformation. Figures in parentheses are retransformed values.
N.S. Not significant.

control (48.4), when the observation was recorded immediately after removing the mulch. During this period, the population of fungi in amended soil, in both solarized and non solarized fields, were higher than in control. Maximum fungal population at the end of one month and two months after removal of the mulch and at the time of harvest were observed in non amended non solarized plot followed by neemcake amended solarized plot.

A change in the pattern of population build up of fungi in the various treatments was observed in soil one month after removal of the mulch. Eventhough the least number of fungi (16.3) was recorded in the non amended solarized soil, the maximum population was noticed in non amended control (72). The population of fungi at the end of two months after removal of the mulch was least in non amended solarized soil and there was no significant difference among the other treatments. Similarly, no significant difference was noticed in the fungal population among the treatments at the time of final harvest(Fig. 5).

Fig. 5 Effect of solarization on fungal population in the mainfield



Effect of solarization on population of bacteria

Nursery

Solarization of nursery soil for varying periods of time (15, 30 and 45 days) did not influence the bacterial population immediately after and one month after removing the mulch (Table 7).

Mainfield

In the mainfield, maximum bacterial population (72.5) was observed in non solarized neemcake amended plot when it was estimated immediately after removing the mulch (Table 7). However, there was no significant difference among the other treatments. Similarly the bacterial count among the different treatments did not differ significantly, when it was observed, one month after solarization and at the time of harvest. But at the end of two months, non solarized plot had the maximum bacteria (40.9) while all the other treatments did not differ from one another.(Fig. 6).

Table 7

Effect of solarization on bacterial population in soil

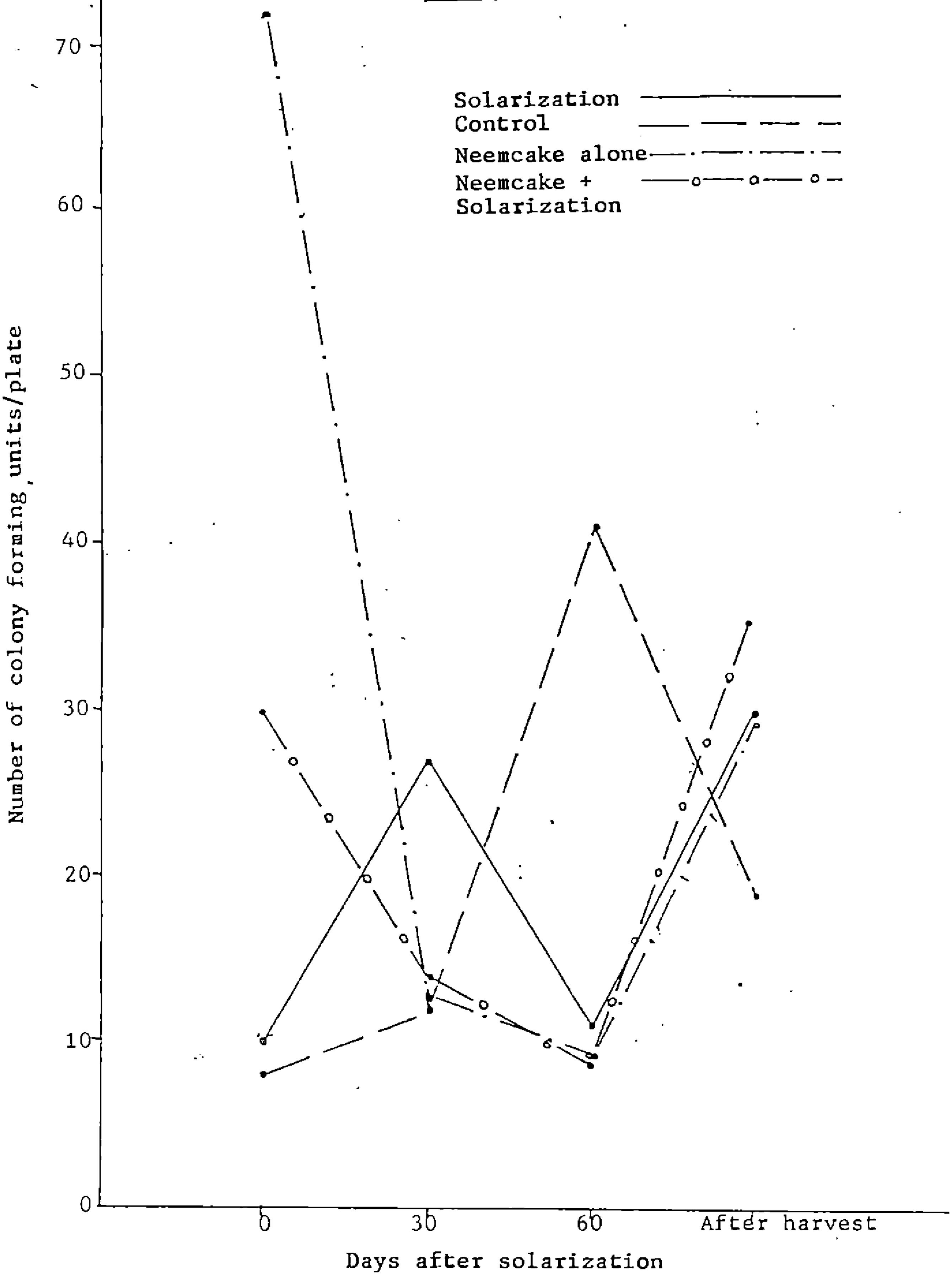
(Number of colony forming units/Plate)

Treatment Nursery	Just after solarization	One month after solarization
T_1 45 days solarized	1.89 (3.57)*	2.47 (7.10)
T_2 45 days control	2.4 (5.75)	3.32 (10.95)
T_3 30 days solarized	2.03 (4.12)	4.16 (17.26)
T_4 30 days control	2.28 (5.19)	3.50 (12.27)
T_5 15 days solarized	2.36 (5.58)	4.12 (16.86)
T_6 15 days control	2.73 (7.41)	3.31 (10.93)
	N.S.	N.S.

Mainfield	Just after solarization	One month after solarization	Two months after solarization	After harvest
T_1 Control	8.04	11.63	40.92	18.82
T_2 Solarization	9.58	26.77	11.38	30.32
T_3 Neemcake + Solarization	30.32	13.57	8.54	34.82
T_4 Neemcake alone	72.54	13.43	8.64	29.82
CD (5%) Ranking	40.25 T_4, T_3, T_2, T_1	N.S.	18.25 T_1, T_2, T_4, T_3	N.S.

* Data after $\sqrt{x}$ transformation. Figures in parentheses are retransformed values.
N.S. Not significant.

Fig. 6 Effect of solarization on bacterial population in the mainfield



Effect of solarization on population of actinomycetes

Nursery

There was no significant difference in the population of actinomycetes just after removal of the mulch in soil solarized for 15, 30 and 45 days (Table 8). Maximum number of actinomycetes in soil immediately after solarization was noticed in 30 days control (9.2), followed by 45 days control. Maximum population count of actinomycetes, after one month of removal of the mulch was noticed in 45 days control (8.39) and the least in soil solarized for 45 days (2.98). However, the population of the actinomycetes in soil solarized for 30 (3.01) and 45 days (2.98) did not differ significantly from each other. Similarly, significant difference was also not noticed between soils solarized for 15 days and the corresponding control.

Mainfield

The changes in the actinomycete population in the mainfield are given in (Table 8, Fig. 7). As was

Table 8

Effect of solarization on actinomycete population in soil

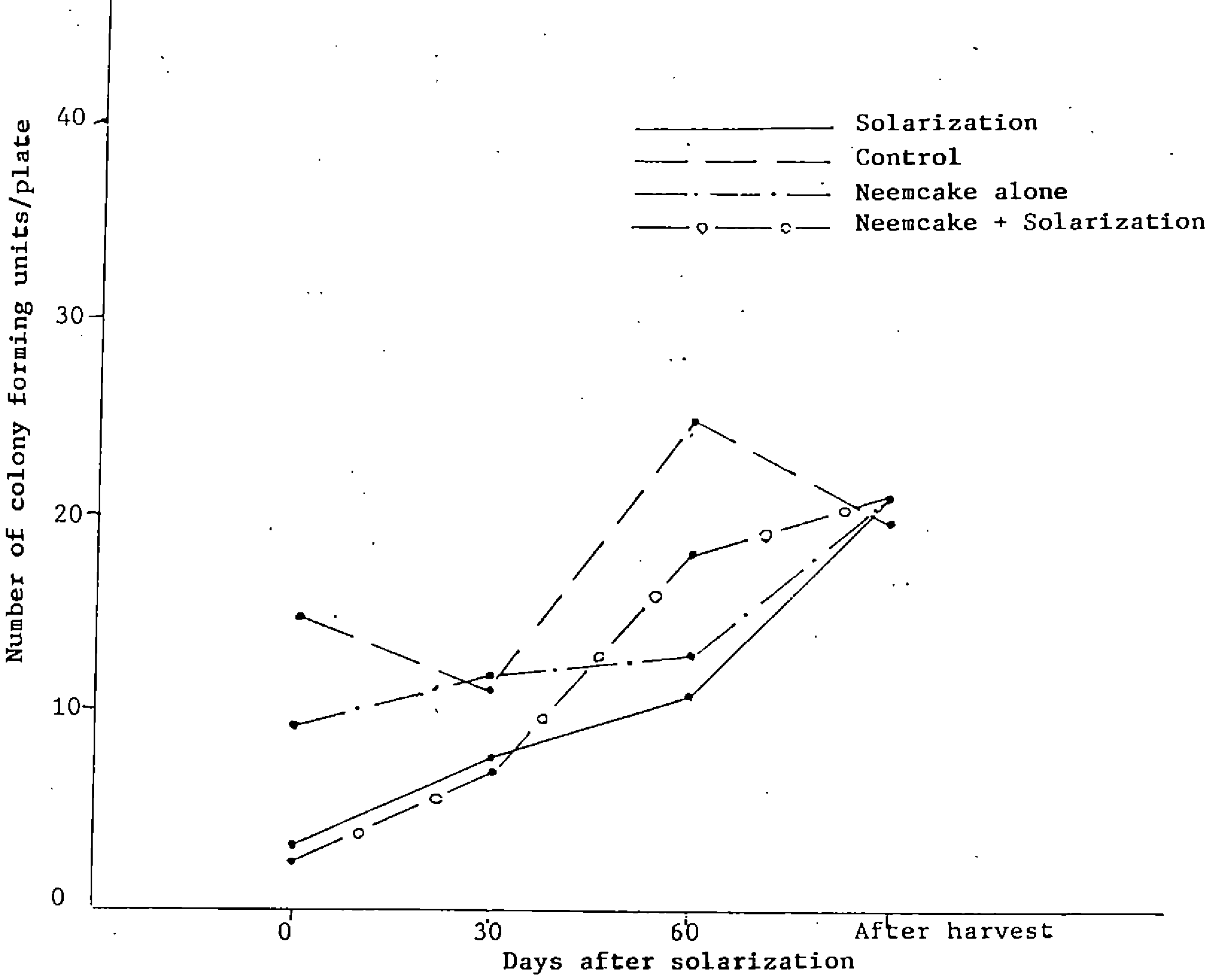
(Number of colony forming units/Plate)

Treatment Nursery	Just after solarization	One month after solarization
T_1 45 days solarized	1.83 (3.33)*	1.73 (2.98)
T_2 45 days control	2.41 (5.80)	2.90 (8.39)
T_3 30 days solarized	1.80 (3.24)	1.73 (3.01)
T_4 30 days control	3.03 (9.2)	2.06 (4.23)
T_5 15 days solarized	1.77 (3.12)	2.37 (5.61)
T_6 15 days control	1.98 (3.93)	2.39 (5.69)
CD (5%)	0.399	0.372
Ranking	$T_4, T_2, T_6 . T_1, T_3, T_5$	$T_2, T_6, T_5, T_4, T_3, T_1$

Mainfield	Just after solarization	One month after solarization	Two months after solarization	After harvest
T_1 Control	14.67	11.27	24.48	19.68
T_2 Solarization	3.4	7.77	10.88	21.04
T_3 Neemcake + Solarization	2.94	6.87	18.2	21.06
T_4 Neemcake alone	9.8	11.97	12.7	21.26
CD (5%)	3.75	N.S.	7.72	N.S.
Ranking	T_1, T_4, T_2, T_3		T_1, T_3, T_4, T_2	

* Data after $\sqrt{x}$ transformation. Figures in parentheses are retransformed values.
N.S. Not significant

Fig. 7 Effect of solarization on actinomycete population in the mainfield



observed in the nursery plots, in the mainfield also actinomycete population was inhibited as a result of solarization. Maximum actinomycete count in the mainfield, immediately after removing the mulch was noticed in the non amended non solarized plot (14.67) followed by neemcake amended non solarized treatment (9.8). Eventhough there was no significant difference between neemcake amended solarized plot and solarized non amended plot, they were in turn significantly lower than the non solarized plot.

When the actinomycete population was recorded one month after removal of the mulch, and at the time of harvest, significant difference among the solarized and non solarized treatments was not observed. However, two months after solarization, actinomycete population was maximum in the control plot (24.48) and it was on par with the neemcake amended, solarized plot (18.2). There was no significant difference among the other three treatments.

Effect of solarization on rhizosphere microflora

The rhizosphere microflora of chilli plants in the main field were estimated one and two months after transplanting and at the time of harvest.

Fungi

There was no significant difference in the rhizosphere population of fungi among the treatments when it was estimated one month, two months after transplanting and at the time of harvest (Table 9). But the fluctuation in the population of fungi showed a definite trend. The fungal population in rhizosphere in control and neemcake amended soil gradually increased from one month after solarization till the harvest. While in solarized plots, there was a reduction in the population at the end of two months compared to one month. However, the population increased in these two treatments from two months till the harvest.

Bacteria

The bacterial population in the rhizosphere was not significantly different among the treatments at the end of one month and two months after transplanting (Table 9). However, at the time of harvest, chillies grown in non amended solarized plot, supported maximum rhizosphere bacteria. When the pattern of development

Table 9

Effect of solarization on rhizosphere microflora

(Number of colony forming units/Plate)

Treatment	Fungi			Bacteria			Actinomycetes		
	1 MA	2 MA	AH	1 MA	2 MA	AH	1 MA	2 MA	AH
T_1 Control	4.4	9.0	38.8	15.4	74.7	43.1	8.2	4.8	15.8
T_2 Solarization	8.7	4.0	69.5	17.2	75.9	77.6	5.0	3.7	31.3
T_3 Neemcake + Solarization	24.6	7.7	19.8	23.0	23.5	24.7	2.0	8.8	9.3
T_4 Neemcake alone	12.0	19.6	45.4	23.2	30.8	32.9	5.8	7.3	6.6
CD (5%)	N.S.	N.S	N.S	N.S	N.S	23.7	N.S	N.S.	N.S.
Ranking						$T_2, \overline{T_1, T_4, T_3}$			

MA Months after solarization.

AH After harvest.

of bacteria was studied, it was found that there was an increase in population of bacteria from one month after transplanting till harvest in all treatments except in control where a reduction in population at the time of harvest was noticed.

Actinomycetes

Differences in the actinomycete population among the treatments were not significant at the three different stages of observation (Table 9). However, there was a variation in the pattern of multiplication of actinomycetes during the different stages of growth of chilli plants. In the control as well as in non amended solarized plot, there was reduction in the population of actinomycetes at the end of two months of transplanting over the population observed at the end of one month after transplanting. While, in the neemcake amended plots, the population showed an increasing trend during this period. In all the treatments except in non solarized neemcake amended plots, the population of actinimycetes increased from the second month till harvest.

Effect of solarization on VAM

VAM colonization in plants grown in solarized plots was greater than in non solarized plots (Table 10). VAM colonization was maximum in non amended solarized plot followed (22.8%) by neemcake amended solarized plot (18.8%). Eventhough among the non solarized plots, significantly higher colonization of VAM was recorded in neemcake amended plots compared to control (10.5%) This stimulatory effect of neemcake was not observed when neemcake amended soil was solarized. The difference in per cent colonization between solarized and non solarized plots was 15.6%, while the difference between amended and non amended soil was only 3.3%. It was observed that, 22.8% of roots in solarized plots were infected compared to 7.2% in control.

Effect of solarization on nematode population

Solarization influenced the population of nematodes in soil (Table 11). Compared to the pre treatment count, a reduction in the population of nematodes was observed in solarized plots, while in non

Table 10

Effect of solarization on VAM colonization

Treatment	Number of root bits examined	Number of VAM positive root bits (Mean values)	Percentage of VAM infection (Mean values)
T_1 Control	180	13	7.2
T_2 Solarization	180	41	22.8
T_3 Neemcake + Solarization	180	34	18.8
T_4 Neemcake alone	180	19	10.5
CD (5%)			2.977
Ranking			T_2, T_3, T_4, T_1

Table 11

Effect of solarization on total nematode population
(Number of nematodes/100 ml of soil, Mean values)

Treatment	Just after solarization	Two months after solarization	After harvest
T_1 Control	11.0 *	17.8	40.6
T_2 Solarization	3.2	7.0	24.2
T_3 Neemcake + Solarization	3.8	4.2	15.8
T_4 Neemcake alone	17.2	14.2	24.6
CD (5%)	11.05	N.S	N.S.
Ranking	$\overline{T_4, T_1}, \underline{T_1, T_3, T_2}$		

* Population of nematodes before solarization = 4.5/100 ml of soil.
N.S. Not significant.

solarized plots, there was an increase. This increase was more pronounced in neemcake amended soil. Just after removing the mulch, population of nematodes was higher in the neemcake applied non solarized plot (17.2) followed by control (11.0). In non amended solarized and neemcake amended solarized treatments, nematode population was 3.2 and 3.8 respectively.

The population of nematodes in neemcake amended solarized plot (4.2) was the least when the count was taken two months after solarization. This was followed by non amended solarized plot (7.0). At the time of harvest also, the least nematode count was recorded in neemcake amended solarized plot (15.8). At this stage there was no marked difference in the nematode population between non amended solarized (24.2) and neemcake amended non solarized (24.6) treatments.

Effect of solarization on weeds

In the experimental field, thirty different types of weeds were observed; out of which, six were monocots and the remaining, dicots. Initially, total weed population was almost the same in the different treatment plots. At the time of removal of the mulch, there were no weeds in the solarized beds, while the control and amended non solarized beds were covered with different weed species (Table 12). At this time there were 125 dicot weeds in control plots while 57 weeds were seen in neemcake amended non solarized plot. The common weeds in the control plots were Corchorus (21), Hyptis suaveolens (15), and Phyllanthus niruri (15). While the most common weed in non solarized, amended plot was Euphorbia hirta (32). In both amended and control plots, monocot weeds were not observed at this stage.

One month after removing the mulch also, the least number (40) of weeds was observed in non amended solarized plot followed by neemcake amended solarized plot (52). In solarized plots, monocot weeds especially Cyperus rotundus was common. Neemcake amended non solarized plots had the maximum number of weeds. Scoparia dulcis was the most common weed in this treatment (159). The weed population at the end of two months after removing the mulch was similar to that observed at the end of one month with non amended solarized plot having the minimum (23) and neemcake amended non solarized plot, the maximum (288). At the

Table 12

Effect of solarization on weeds

	Treatment																			
Monocots	Control					Solarization					Neemcake + Solarization					Neemkake alone				
	BS	AS	1MA	2MA	AH	BS	AS	1MA	2 MA	AH	BS	AS	1 MA	2MA	AH	BS	AS	1MA	2MA	AH
1. Brachiaria sp	–	–	4	–	–	–	–	3	–	–	–	–	–	–	–	–	–	4	–	–
2. Bulbostylus sp	–	–	–	6	4	–	–	1	–	3	–	–	–	15	20	–	–	–	28	26
3. Curcuilago orchioides	–	–	11	2	6	–	–	–	5	7	–	–	1	–	13	–	–	3	2	10
4. Commelina benghalensis	–	–	8	1	4	–	–	7	4	2	–	–	5	2	–	8	–	25	2	–
5. Cyperus rotundus	–	–	9	4	–	–	–	11.	4	–	–	–	25	1	–	–	–	25	11	–
6. Digitaria sp	–	–	1	27	–	–	–	–	3	–	–	–	–	3	–	–	–	1	–	–
Total	–	–	**33**	**40**	**14**	–	–	**22**	**16**	**12**	–	–	**31**	**21**	**33**	**8**	–	**58**	**43**	**36**
Dicots																				
7. Amaranthus viridis	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
8. Alesicarpus sp	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
9. Crotolaria juncea	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–
10. Cassia sp	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–
11. Centrosema sp	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
12. Corchorus sp	–	21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6	–	–	–
13. Desmodium trifolium	–	–	3	1	1	–	–	3	–	1	–	–	1	–	–	–	–	–	–	1
14. Euphorbia hirta	–	13	–	–	–	1	–	–	–	–	3	–	–	–	–	2	32	–	–	–
15. Emilia sonchifolia	–	4	–	–	4	–	–	–	–	–	1	–	–	–	1	–	4	–	–	3
16. Elephantopus scaber	–	–	2	3	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–
17. Hyptis suaveolens	–	15	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
18. Knoxia sp	–	9	–	1	–	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–
19. Ludwigia parviflora	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	

	Control					Solarization					Neemcake + Solarization					Neemcake alone				
	BS	AS	1MA	2MA	AH	BS	AS	1MA	2MA	AH	BS	AS	1MA	2MA	AH	BS	AS	1MA	2MA	AH
20. *Mimosa pudica*	1	7	–	–	–	1	–	–	–	–	4	–	–	–	–	22	–	–	–	–
21. *Mullugo* sp	–	–	9	–	–	–	–	3	–	–	–	–	1	–	–	–	–	12	–	–
22. *Phyllanthus niruri*	2	15	4	–	–	1	–	–	–	–	4	–	1	–	–	5	11	2	8	–
23. *Physalis minima*	–	–	2	–	1	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
24. *Portulaca oleraceae*	–	2	–	4	1	–	–	–	–	–	–	–	1	3	–	–	–	–	5	–
25. *Passiflora edulis* var. *foetida*	3	–	–	–	–	4	–	–	–	–	1	–	–	–	–	5	–	–	–	–
26. *Phyllanthus* sp	–	10	–	–	1	–	–	–	–	–	–	–	–	–	–	1	–	–	–	1
27. *Scoparia dulcis*	3	2	9	167	64	4	–	15	7	13	2	–	18	35	15	6	–	159	232	122
28. *Stachytarpheita indica*	1	1	–	–	–	3	–	–	–	–	8	–	–	–	–	3	–	–	–	–
29. *Sida rhombifolia*	–	14	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1	–	–	–
30. *Tridax procumbens*	–	1	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1	–	–	–
31. *Vernonia cineria*	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–		–	–	–	–
Total	9	125	27	175	72	19	–	18	7	14	23	–	21	38	17	46	57	174	245	128
Grand Total	9	125	60	215	86	19	0	40	23	26	23	0	52	59	50	46	57	232	288	164

BS	Before solarization
AS	After solarization
MA	Months after solarization
AH	After harvest

time of final harvest also the non amended solarized plot had the minimum (26) and neemcake amended non solarized plot the maximum (169) weeds. In general, solarization was found to be effective against dicot weeds rather than monocots.

Effect of solarization on nutrient status, and EC of the soil

Solarization was found to influence the availability of some nutrients (Table 13). Mulching with polyethylene sheet for 35 days had no significant influence on the total nitrogen content of the soil. Similarly, there was no marked difference in the available P content when non amended soil was solarized. However, there was a significant increase in the available P content when neemcake amended soil was solarized (119.2 to 148.9 kg/ha). But this increase in P content was not observed in neemcake amended non solarized plot.

Solarization was found to increase the available K in soil. This increase was noted in both non amended (16.9%) and neemcake amended solarized soils

Table 13

Effect of solarization on nutrient status and EC of soil

	Control		Solarization		Neemcake + solarization		Neemcake alone	
	BS	AS	BS	AS	BS	AS	BS	AS
Total nitrogen, %	0.127	0.088	0.141	0.096	0.169	0.107	0.113	0.088
Available P, kg/ha	72.4	52.8	80.9	80.9	119.2	148.9	83.0	81.7
Available K, kg/ha	85.4	52.1	82.6	96.6	78.4	100.8	91.0	64.7
Exchangeable Ca, me/100g	0.336	0.321	0.336	0.384	0.408	0.365	0.312	0.295
Exchangeable Mg, me/100g	0.24	0.079	0.048	0.106	0.024	0.086	0.24	0.122
Exchangeable Na, me/100g	0.146	0.157	0.138	0.201	0.125	0.151	0.142	0.134
Exchangeable K, me/100g	0.702	0.413	0.65	0.853	0.590	0.814	0.624	0.549
Organic carbon, %	0.75	0.84	1.02	0.84	0.75	0.94	0.59	0.89
EC, μmho/cm	233.1	105.8	126.2	251.4	226.0	138.2	236.0	119.4

BS	Before solarization
AS	After solarization

(28.5%). Solarization exerted marked influence on the exchangeable cations. Per cent increase in exchangeable K, Ca, Mg and Na in non amended solarized plots over non solarized plot immediately after removal of the mulch was 31.2, 14.2, 120.0 and 45.6 per cent respectively. A similar trend was noticed when neemcake amended soil was solarized. But, a reduction in the Ca content as a result of solarization in the amended soil was noticed.

The pattern of organic carbon fluctuations in the different periods of observation in solarized and non solaized plots differed. In control, the organic carbon increased from the initial level of 0.75 to 0.84% In neemcake amended soil also, the organic carbon content showed an incrase, 35 days after application. In non amended solarized plot, organic carbon decreased from the original value of 1.02 to 0.836 immediately after solarization while in neemcake amended solarized plots, there was an increase in the corresponding values (0.75 to 0.942).

EC, which is a function of total soluble salt concentration, increased (99.2%) in non amended solarized soil when it was estimated immediately after removing the mulch. However, when neemcake amended soil was solarized, there was a reduction in the EC rate (38.8%). In all the plots i.e., solarized or non solarized, there was a decrease in EC over the initial value at the time of harvest.

Effect of solarization on plant growth

Plant height

Plants in solarized plots were in general, taller compared to those in control (Table 14). However, the difference was significant only two months after transplanting. Plants in solarized plot without amendment recorded the maximum height of 43.83 cm and was significantly higher than in all the other treatments except the treatment in which neemcake amended soil was solarized. The difference in the height of plants in control and neemcake amended soil did not differ significantly. Almost a similar trend was noticed at the time of harvest also.

Number of leaves

Leaf production by the plants was found to be influenced by solarization (Table 14). The number of

Table 14

Effect of solarization on the growth parameters of chilli plants

Treatment	Height of plants(cm) (mean values)			Number of leaves/plant (mean values)		
	1 MA	2 MA	AH	1 MA	2 MA	AH
T_1 Control	15.0	30.2	36.8	30.7	77.7	176.3
T_2 Solarization	19.0	43.8	43.8	41.3	203.7	274.0
T_3 Neemcake + Solarization	18.3	36.8	49.3	33.0	131.7	274.0
T_4 Neemcake alone	13.0	31.0	34.8	27.7	90.0	166.0
CD (5%)	N.S	9.7	10.54	N.S.	52.1	N.S.
Ranking		$\overline{T_2,T_3},\overline{T_4,T_1}$	$\overline{T_3,T_2},\overline{T_1,T_4}$		$T_2,\overline{T_3,\underline{T_4}}\underline{,T_1}$	

Treatment	Fresh weight of shoot (g)			Dry weight of root (g)	
	1 MA	2 MA	AH	2 MA	AH
T_1 Control	5.8	28.7	37.0	0.6	1.0
T_2 Solarization	11.2	131.3	92.8	2.2	1.8
T_3 Neemcake + Solrization	8.8	122.7	85.2	1.6	2.9
T_4 Neemcake alone	3.0	47.3	48.2	2.3	1.6
CD (5%)	5.41	74.8	22.13	N.S.	0.69
Ranking	$\overline{T_2,T_3,T_1},T_4$	$\overline{T_2,T_3}.\overline{T_4,T_1}$	$\overline{T_2,T_3},\overline{T_4,T_1}$		$T_3, \overline{T_2,\underline{T_4}}\underline{,T_1}$

MA	Months after solarization
AH	After Harvest
N.S.	Not significant.

leaves per plant after two months of solarization was maximum in non amended solarized treatment (203) followed by plants in neemcake amended solarized plot (131.7). At the time of harvest, number of leaves per plant in both the solarized treatments were the same (274). While least number of leaves was observed in neemcake amended non solarized plot (166).

Shoot

Solarization enhanced the shoot development of chilli plants (Table 14). Maximum fresh weight of shoot was observed in plants grown in solarized plots (11.2g) followed by neemcake amended solarized treatment (8.8g)after one month of removing the mulch. There was no significant difference between control and non solarized amended treatments. The same trend was observed at the end of two months of growth and also at the time of harvest.

Roots

The dry weight of roots of the plants was recorded only at the end of two months and at the time of harvest. Significant difference in the dry weight of roots was not noticed among the various treatments at the end of two months (Table 14). However, at the time of harvest, plants of the neemcake amended solarized plots had the maximum dry weight (2.9g). This was followed by plants grown in non amended solarized plots (1.8g). There was no significant difference in the weight of roots between the control and neemcake amended treatments.

Yield

Solarization increased the yield of chillies (Table 15). The increase in mean yield in non amended solarized plot (694.58g) was 226.8% over the control. The yield of chillies grown in neemcake amended non solarized plot (115.5g) did not differ significantly from the control.

Yield per plant was found out by calculating the average yield of three tagged plants in each plot, and this differed significantly. Yield per plant in the solarized plot (98.9g) was 202.9% over the control (32.65g). Neemcake applied solarized plot gave only 120.8% increase over control (72.1g). Eventhough neemcake applied non solarized plot gave better yield (35.58g) than the control , this difference was not significant.

Table 15

Effect of solarization on yield of chilli fruits

Treatment	Mean yield g/plot	Mean yield g/plant*	Number of chilli fruits/plant
T_1 Control	212.50	32.57	30.20
T_2 Solarization	694.58	98.95	91.80
T_3 Neemcake + Solarization	528.90	72.11	63.50
T_4 Neemcake alone	115.58	34.58	29.87
CD (5%)	269.7	43.98	37.95
Ranking	$\overline{T_2}, \underline{T_3, T_1}, T_4$	$\overline{T_2}, \underline{T_3, T_4, T_1}$	$\overline{T_2}, \underline{T_3, T_1, T_4}$

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* Mean yield of three plants/plot.

Number of fruits per plant in solarized plots was higher compared to the control plots. Maximum number of fruits was produced by plants in solarized plot without neemcake (91.8) which was 204% more over the control. In the neemcake amended solarized plot, average number of chillies per plant was 63.5, which was 110.3% more compared to control (30.2).

Discussion

DISCUSSION

Plant growth, yield and quality, may be limited by several soil borne micro as well as macro organisms. Several soil borne fungal pathogens and other soil micro organisms have been reduced in population densities following soil solarization. The results presented here further indicates that soil solarization apart from controlling several soil borne pathogens, also increases the plant growth response by reducing the competition by weed flora and by improving the nutrient status of the soil and also by improving the uptake of nutrients by the plant by enhancing VAM colonization.

One of the major mechanisms by which solarization reduces the disease and increases the plant growth is by increasing the soil temperature under the mulch (Katan, 1976). Mulching of wet soil with transparent polyethylene during the warm season of the year led to an increase in soil temperature. The increase in soil temperature in solarized plots over the control ranged from 6°C- 11.5°C. The maximum temperature attained at 10 cm depth under mulch was 51°C while in non solarized soil it was 42 °C. These data are in agreement with other published reports. (Akashi and Maeda 1989, Chandran, 1989). The increase in soil temperature recorded in the present investigation was lower than those reported by other workers (Delbusto _et al._, 1989). The increase in temperature in mulched soil is due to the green house effect caused by polyethylene and varies with air temperature, humidity, radiation, wind velocity and soil characteristics (Katan, 1981, Mahrer, 1979). In most of the places where solarization was tried, the atmoshperic temperature was higher than what observed in the present study. Further, in most of the studies thinner polyethylene sheets (25 - 30 µm) were used as the mulch. In the present investigation thicker polyethylene sheets (150 µm) were used. Thinner ones are more efficient in increasing soil temperature than thicker ones (Pullman _et al._, 1981). During the period of solarization measurable rain fall was received for 10 days which also was responsible for reducing the soil temperature under the mulch. Soil temperature under mulch is also related to plot size. Greater rise in temperature under mulch could be obtained if larger plots are mulched (Mahrer & Katan, 1981). The small plot size in the present study thus, also was responsible for not getting higher temperature under the mulch.

Solarization was highly effective in reducing both pre and post emergence damping off of chillies caused by Pythium aphanidermatum (Edson) Fitz. In the nursery beds better germination of chilli seeds was observed in solarized field compared to control. However, there was no significant difference in the germination rate of chillies grown in fields solarized for 15,30 and 45 days. In the present study, germination of chillies in solarized nursery plots ranged from 39.22% to 44.03% compared to 1.2% - 18.7% in control plots. In the main field none of the seedlings transplanted in solarized plots with or without neemcake amendment showed any damping off symptoms till harvest while 16.6 and 25% plants succumbed to the disease in non solarized and non solarized amended plots.

Pullman et al. (1981) presented a detailed study on the thermal death of some soil borne plant pathogens. They showed that 90% of Pythium ultimum propagules could be destroyed on exposing the fungus grown on potato dextrose agar at 47°C for 180 min. or 37°C for 20 days. The time required to get an equivalent control in soil may be more because of the complex nature of the soil environment. In the present study the average maximum temperature in solarized soil was 48.1°C. While it was 39.9°C in non solarized soil. This high temperature in solariszed soil could have killed or inactivated large number of Pythium propagules which resulted in a reduced incidence of disease in solarized soil. Predisposition of pathogen propagules to damage from anaerobes by exposing the propagules to low redox potentials also may be one of the reasons for their accelerated death rate in soil tarped with polyethylene sheets (Cook & Baker, 1983). The tarps elevated the soil temperature, increased soil respiration and served as a barrier to O_2 diffusion into the soil and CO_2 diffusion out of it. The presence of fresh organic materials like neemcake and adequate soil moisture under the mulch would enhance this effect.

P. aphanidermatum could survive in soil for a long period of time through sporangium or oospore. The temperature required to kill the vegetative structures of Pythium is usually less than that required to kill the sexual spores. The temperature which was recorded in the present study though not lethal, could injure the surviving propagules. The propagules of fungi become more vulnerable to other soil micro organisms when exposed to sub lethal levels of temperature. This has already been suggested as a tool for achieving integrated control and has been demonstrated with Armillaria mellea (Munnecke et al., 1976) and Sclerotium rolfsii (Elad et al., 1980). Increased leakage of nutrients from sclerotia of S. rolfsii has been shown to be detrimental to survival of these structures. Dried and remoistened sclerotia leaked large quantities of sugars and amino acids resulting in their death (Smith, 1976). This weakening effect of heat on pathogen resting structures may explain the effective control achieved by solar heating at deeper layer where temperature is relatively low.

Eventhough all the seedlings transplanted in the solarized mainfield survived, only less than 50 per cent of the seeds germinated in the solarized nursery beds. High inoculum level and susceptibility of germinating seeds to Pythium are responsible for higher rate of incidence in the nursery seed beds. Seedlings develop resistance to damping off with age. This is clear from the observation that, in non solarized control plots, damping off disease was not noticed 25 days after transplanting.

There was no significant variation in the incidence of disease in nursery beds solarized for varying periods of time. But there is a definite trend showing superiority of longer days of solarization in the disease control. Fahim et al. (1987) have obtained similar results. They have reported that, increase in mulching period led to both better stand and healthier plants.

Solarization inhibited the population of fungi, bacteria and actinomycetes in soil. As the period of solarization increased from 15 to 45 days, there was a corresponding reduction in the fungal population. Fungi were the group most affected by solarization. Gamliel and Katan (1991) observed a significant reduction in the population of fungi in most of the solarized soils. Maximum soil temperature at 10 cm depth under polyethelene mulch reached above 47°C for most of the days and 50°C for few days. This is greater than or close to the thermal death point for most of the fungi (Pullman et al., 1981). Temperature below 45°C can also be lethal if maintained for longer periods (Grooshevoy [illegible], 1939). The sublethal heating decreases the ability of propagules to withstand stresses (Pullman et al., 1981). Presence of moisture increases heat sensitivity of fungal resistant structures (Katan 1981). Soil under mulch retained moisture during the entire period of solarization and this enhanced killing of fungal propagules in the present study. The reduction in the population of bacteria under plastic mulch was reported by Stapleton and De Vay (1982) and Gamliel and Katan (1991).

The major factors involved in soil heating in a solarized soil are climatic (solar radiation intensity, air temperature, air humidity and wind velocity) and soil properties. Mahrer (1979) developed a one dimensional model with a high degree of accuracy for predicting soil temperature in mulched and bare soils at different depths at each hour of the day. For this he used parameters like polyethylene cover reflectivity, cover transmissibility, temperature under polyethylene, atmospheric temperature etc. Chandran (1989) developed a simple regression equation for predicting temperature under the mulch using air temperature. In the present investigation, two simple regression equations, one based on air temperature and the other based on soil temperature were developed. A multiple regression equation based on soil and air temperature was also derived. The coefficient of determination for the multiple regression equation was the highest (26.96). The coefficient of determination for equation based on bare soil temperature was 24.85, while that of the equation based on air temperature was only 2.43. Thermal death points of different pathogenic micro organisms have been worked out (Pullman, 1981). Thus, using this model, it is possible to find out the period of solarization required for obtaining satisfactory control of the disease by knowing the air temperature. Since the coefficients of determination of these models are very low, further studies are required to increase the accuracy of prediction using this model. Once accurate models are developed, it can replace tedious work of temperature measurement under the mulch and enable us to choose the most appropriate time of the year for solarization. Thus an accurate prediction model provide an extremely valuable tool for improving solarization.

Solarization had a profound effect on weed population. At the time of removal of the mulch there were no weeds in the solarized plots and weed population remained lower in the solarized plots till harvest of the crop. Detrimental effect of solarization on weeds have been reported by several workers (Egly, 1983, Rubin & Benjamin, 1984, Abdel - Rahim _et al_., 1987, Stepleton, _et al_. 1989, Chandran, 1989). Heating seeds above the optimum for germination results in a reduction of germination probably due to denaturation of functional protein (Levitt, 1980). High temperature also modify the permeability of seed coat which causes leakage of endogenous aminoacids resulting in a reduction in germination rate.

Dry seeds of many weed plants are resistant to temperature as high as 120°C while hydrated seeds of the same plants are killed at 50°C (Levitt, 1980). It is suggested that in presence of water, less energy is required to damage the peptide chain configuration of proteins resulting in decreased heat resistance (Katan, 1981). Soil temperature under the mulch during the present study reached 50°C for many days and soil under the mulch was wet throughout the period of solrization, which reduced heat resistance of hydrated seeds. This may be a possible reason for the reduction in weed count under the mulch.

Soil O_2 concentration under plastic mulch do not differ appreciably from unmulched control while the concentration of CO_2 arise upto 30 times or more (Rubin & Benjamin, 1981), which can induce seed germination (Koller, 1972). The changes in CO_2/O_2 levels in mulched soil may cause partial or complete breaking of seed dormancy thus enchancing germination. Such germinated seeds got killed under the mulch since the temperature is high.

The reduction in weed population noticed in solarized plot may not be due to a single factor. A combination of factors like thermal killing of seeds, inducing secondary dormancy, breaking of seed dormancy through production of CO_2 and other gases in soil, altering seed metabolism or action of soil microflora on the weakened seeds may all be responsible for destruction of weeds under the mulch. (Hendricks and Taylorson 1976, Pavlica *et al*., 1978 and Rubin & Benjamin, 1984).

Weeds such as *Cynodon dactylon* which propagate mainly by vegetative parts and rhizomes were not effectively controlled by solarization. Relatively high tolerence of these species may be due to the fact that at least a part of their subterranean vegetation is located in a relatively deep layer which is not affected by solarization. It is assumed that, the seeds of those weeds which were present in the upper layer of the soil were killed by the high temperature, but those seeds which were in deeper layers were not killed by the relatively low temperature and thus were able to grow after removal of the polyethylene mulch.

As a result of solarization, there was a reduction in total nematode population. No attempt was made to differentiate the parasitic nematodes from non parasitic ones. The extent of reduction of nematode population under the mulch depend on several factors like the extent of solar heating, temperature under the mulch, the cropping history, nematode taxa involved, nematode distribution in soil and soil depth (Stapleton and De Vay, 1983). The role of neemcake as a nematicide is a well established fact (Peethambaran, 1975). The neemcake under partial anaerobic conditions which is presnt below the mulch caused a high degree of population reduction. As the population of plant parasitic nematodes were not estimated, it is not possible to arrive at any conclusion regarding the role of mulch in reducing the plant parasitic nematodes there by increasing the yield chillies.

Most of the experiments that have been successful in increasing per cent root colonization by mycorrhyzae and subsequent weight and yield of crop plants have been performed in fumigated or sterilized soil. In the present study, VAM colonization was found to be more in roots of plants grown in solarized soil. Recent studies conducted by Nair _et_ _al_. (1990) and Afek _et_ _al_. (1991) have shown that VAM colonization of roots could be improved by solarization. Several researchers, have reported that failure of plants to become colonized by VAM fungi in natural soil is due to micro organisms that compete with mycorrhyzal fungi on roots and interfere with its development (Alexander, 1965, Schenek and Kinlock, 1974). Increased VAM colonization in plant roots in solarized soil may be due to the fact that, solarization might have inhibited deliterious micro organisms. Afek _et_ _al_. (1991) has shown that, solarization reduced microbes that compete or interfere with mycorrhyizal development. Thus the present study leads to the conclusion that VAM combined with soil solarization could be one of the approaches to increase the root growth and subsequent development of the plants through non chemical means.

The present study showed that, fertility of the soil was improved by solarization. Amounts of soluble minerals and organic materials in the soil generally increasd with solarization. Significant increase in available P and K found in the solarized soil was almost similar to that reported by chen and Katan (1980). There was an increase in the organic carbon content also. It may be possible that, the increases of P and minerals might have resulted from decomposition of organic matter. Although the raised levels of K can not be explained.

The response of chilli plants to solarization in the present investigation is evident mainly as taller plants, more leaves per plant, more fruits per plant and also better root system. These are typical of the responses of plants to improved fertility of the soil. Yield of chillies in solarized plots was found to increase by 230 per cent over control. This yield increase was due to an increase in number of surviving plants in the plots and also due to an increase in the yield on per plant basis. Yield increase by solarization has been reported by many workers in a variety of crops like broad bean and tomatoes (Abdel - Rahim, et al., 1987) cowpea (Chandran, 1989; Nair et al., 1990), and gerbera (Kaewruang et al., 1991).

A marginal reduction in the growth charcters of chillies in neemcake amended solarized and non solarized soils was observed. Incorporation of organic materials into moist warm soil and the resultant development of large volume of anaerobic sites can lead to problems of plant growth reduction because of production of acids like acetic, butyric, reduced sulfur compunds and other compounds injurious to plant roots (Russel, 1977).

Summary

SUMMARY

The study, 'Effect of Solarization on damping off diseases of vegetables' was conducted at the experimental plot of the Olericulture department of College of Horticulture, Vellanikkara. Both nursery and mainfield were solarized during April - May 1991. Before mulching with polyethylene sheets, plots were inoculated with Pythium aphanidermatum (Edson) Fitz. In the nursery, three different durations of solarization viz., 15, 30 and 45 days were tried. Daily soil temperature at 10 cm depth was recorded during the entire period solarization.

The difference in maximum soil temperature in solarized soil over non solarized soil ranged from 6 °C to 11.5°C. Soil temperature under the mulch reached a maximum of 51°C while in the non solarized soil, it was 42°C. In the solarized soil, temperature was 15.5°C above the atmospheric temperature.

Solarization was highly effective in reducing both pre and post emergence damping off of chillies. In the nursery, better germination of chilli seeds was observed in solarized beds over the control. However, there was no significant difference in

the germination rate of chillies grown in fields solarized for 15, 30 and 45 days. In the solarized beds, percentage germination of chillies ranged from 39.22 to 44.03 compared to 1.2 to 18.7 in non solarized beds. In the mainfield, none of the seedlings transplanted in solarized plots with or without neemcake amendment got infected while, 16.6% and 25% of the plants succumbed to infection in neemcake amended and non solarized plots respectively.

Solarization resulted in reduction of fungal, bacterial and actinomycete population in soil. However, fungi was most affected by solarization. As the period of solarization increased, there was a corresponding reduction in fungal population.

Solarization had a profound effect on the weed population. At the time of removal of the mulch, there were no weeds in the solarized beds. Weed population remained lower in the solarized plots till harvest. Dicot weeds were more effectively controlled compared to monocots.

Total nematode population in solarized soil was less compared to non solarized soil. In neemcake amended plots also a reduction in population of nematodes was observed.

Colonization by V.A. Myoorrhirae was more in roots of plants grown in solarized soil . When only 7.2% of the root bits taken from control plot were VAM positive, the corresponding figures were 25.6% in non amended solarized plot and 18.8% in neemcake amended solarized plot.

Availability of nutrients like avilable P, K, exchangeable Ca, Mg, Na and K was observed in solarized soil. Electrical conductivity of the soil was also increased as a result of solarization.

Increased growth response of plants was observed in solarized plots. Plants grown in solarized plots were taller, compared to those in control plots. All other growth parameters measured viz., number of leaves, fruits, flowers and number of roots were better in plants grown in solarized plot There was a pronounced increase in the yield of chillies as a result of solarization.

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Appendices

Appendix I

Abstract of anova, Nursery (M.S.S Values)

Source	DF	Table 3	Table 4	Table 6	Table 8	
				J.A.S	JAS	1 MA
Replication	2	72.43	48.15	0.52	2.72	0.18
Treatment	5	1071.12	367.19	7.84	0.75	0.61
A	2	173.07	334,89	0.81	0.44	0.41
Bet. B_1	1	3110.34	1104.46	19.31	0.51.	2.06
Bet. B_2	1	1469.88	50.75	15.30	2.28	0.16
Bet. B_3	1	429.43	10.99	2.98	6.94	4.43
Error	10	22.07	18.00	0.74	4.82	4.18

JAS	Just After Solarization
MA	Moths After solarization
Bet.	Between.

Appendix II

Abstrat of anova, mainfield (M.S.S. values)

Source	Table 6						Table 7					
	DF	JAS	2 M A	AH	DF	1MA	DF	JAS	2 MA	AH	DF	1 MA
Replication	4	793.5	77.9	619.5	2	272.3	4	133.0	117.3	6.7	2	67.8
Treatment	3	4320.6	863.0	165.3	3	1619.7	3	4514.9	1241.1	231.6	3	147.0
Error	12	866.2	200.4	227.8	6	111.8	12	329.3	175.3	115.3	6	34.8

Source	Table 8						Table 9		Table 11	
	DF	JAS	2 MA	AH	DF	1 MA	DF	Bact. AH	DF	JAS
Replication	4	5.2	13.4	65.8	2	8.4	2	727.2	4	62.5
Treatment	3	156.5	187.6	2.6	3	19.1	3	1621.9	3	251.5
Error	12	7.4	31.4	35.3	6	9.9	6	140.5	12	64.3

JAS	Just After Solarization
MA	Months After Solarization
AH	After Harvest
Bact.	Bacteria.

Source			Table 14				Table 15	
		Leaves	Height			MY/Plot	MY/Plant	Number of Chilli Fruits
	DF	2 MA	2 MA	AH	DF			
Replication	2	1195.8	20.0	8.6	4	57671.9	11042.7	6114.2
Treatment	3	9696.1	119.9	132.7	3	364761.6	45844.7	40027.4
Error	6	679.8	23.4	28.8	12	38298.1	9140.2	6826.5

MY **Mean Yield.**

EFFECT OF SOLARIZATION ON DAMPING OFF DISEASES OF VEGETABLES

By

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ABSTRACT OF A THESIS

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requirement for the degree

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ABSTRACT

The effect of solarization on damping off of chilles caused by Pythium aphanidermatum was studied at the college of Horticulture, Vellanikkara, Trichur during 1991-92. For solarizing, 150 guage transparent polyethylene sheets were used. Both nursery and mainfields were inoculated with the fungus prior to solarization.

Atmospheric temperature during the period of solarization ranged from 20°C to 38°C. The soil temperature in solarized plots was always higher (6°C-11.5°C) than the non solarized plots. Maximum soil temperature recorded at 10 cm depth in the solarized soil was 51°C while that in the non solarized soil was 42°C. Nursery beds were solarized for 15, 30 and 45 days while the main field was solarized for 35 days.

Solarization effectively reduced pre and post emergence damping off in the nursery. In the main field, solarization completely checked the disease. As the period of solarization increased, better control of the disease was observed. Neemcake amendment did not improve the disease control even with solarization.

The population of fungi, bacteria and actinomycetes were reduced as a result of solarization. The nematode population also was significantly reduced by solarization. Eventhough solarization substantially reduced weed population, its effect was more pronounced on dicots rather than monocots. Root colonization by VA Mycrrhizae was significantly better in solarized plots, compared to control.

Growth parameters like, plant height, number of leaves, shoot and root weight were increased through solarization. Plants grown in solarized plots gave 230% more yield over those in the control plots. However, neemcake amendment didnot favour either plant growth or yield. Availability of plant nutrients like P,K, Ca, and Mg was found to be better in solarized plots. Increase in organic carbon content and EC was also noticed in solarized plots. However, total N content of the soil was not altered by solarization.