INFLUENCE OF SOIL SOLARIZATION ON SOIL MICROFLORA, PLANT GROWTH AND INCIDENCE OF DISEASES

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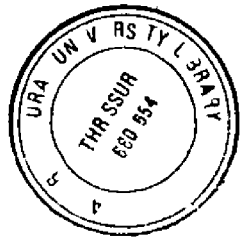

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I hereby declare that this thesis entitled "INFLUENCE OF SOIL SOLARIZATION ON SOIL MICROFLORA, PLANT GROWTH AND INCIDENCE OF DISEASES" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.

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INTRODUCTION

Crop plants are attacked by several soil borne pathogens, insects and weeds. Though they differ in their biology and life cycle, these pests share common behavioural features that are reflected in similar approaches being indicated for their control. They survive in soil and therefore are affected by organisms that surround them in the soil, as well as by the physical and chemical properties of the soil. Manipulation of these factors provides a powerful means of control. Controlling these pests by physical, chemical or biological means presents many difficult problems. It is difficult to reach the pests effectively at all sites in soil. Non target organisms, some of which are potential antagonists towards these pests, also may be affected. As the soil is an opaque, complex medium, it is difficult to detect pests in the soil *in situ*.

Soil borne pathogens gain importance when a certain crop is grown continuously. For the control of soil borne plant pathogens several methods are being practiced - crop rotation, fallowing, biological, physical and chemical control. Each method has its own advantages and disadvantages. Crop rotation and fallowing are not always possible where both crop options and

land are limited. Physical methods like steaming, flooding, etc. are highly expensive and not possible in all farming systems. Biological control though effective could not be recommended uniformily in different farming systems. Pesticide has become a common tool to fight the pathogens. While using pesticide the agricultural scientists and farmers fail to understand the negative side effects of these chemicals.

Agricultural Scientists throughout the world are working to find out cheap, effective, non hazardous and simple methods for the control of soil borne diseases. One such method is "Solarization".

Soil solarization is a method of hydrothermal disinfestation accomplished by covering moist soil with transparent polythene film during the hottest period of the year. This is known under different names - solar heating, plastic or polythene tarping, plastic mulching and solar pasteurization.

Solarization technique of plant disease control was first used by Jones et al., (1966) against Southern blight of tomatos. However, the credit for developing the finer details and popularising the method goes to Katan et al., (1976, 81). He and his colleagues, in Israel and U.S.A. demonstrated the usefulness of the

method for the control of diseases caused by Verticillium, Fusarium, Rhizoctonia, Sclerotium, Pyrenochaeta, and several other soil borne plant pathogens.

Apart from controlling fungal diseases, solarization has been found to be effective in controlling nematodes and weeds. Solarization has been found to increase the plant growth rate through better nutrient availability.

The exact mechanism of action of solarization has not been completely worked out. It was originally regarded as a means of physical control through thermal killing of the pathogen. A number of biological effects have also been attributed to solarization in controlling the pathogens. (Katan 1981, Horiuchi 1984).

Solarization technique is now being tried in several parts of the world - Israel, USA, Japan and England. In India this technique of plant disease control has not been tried so far. Hence a study has been undertaken to find out the efficacy of this technique in controlling collar rot disease of cowpea caused by Rhizoctonia solani. Since many crops are grown under partially shaded condition in Kerala, in the present investigation solarization technique was tried in open as well as in partially shaded condition in a coconut garden.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Soilborne plant pathogens cause severe damage to most agricultural crops. Continuous cultivation of a crop usually leads to a high inoculum build up of the soilborne pathogens resulting in a higher disease incidence. Control of soilborne diseases is rather difficult since surrounding soil microorganisms are also involved in the development of the diseases, besides the host and the pathogen. Fungicides are effective in the control of certain soilborne diseases, PCNB against Rhizoctonia solani and fumigants such as Chloropicrin, Vapam or Methylbromide against Pyrenochaeta terrestris. Application of these chemicals are usually associated with problems of phytotoxicity, residues, reinfestation of soil resulting from drastic reduction in antagonistic microorganisms, application techniques and high costs.

Search for new, effective, inexpensive and nonhazardous methods for the control of soilborne diseases are in progress throughout the world. One such method is solar heating of the soil. By mulching soil with transparent polyethene sheets in hot seasons prior to planting, a team of Israeli workers developed a solar heating approach for soil disinfestation. This was

further modified by Katan et al., (1976). They covered soil moistened by drip irrigation with transparent polythene sheets during the hot season. This increased the soil temperature and controlled pathogens (Verticillium dahliae and Fusarium oxysporum on tomato and eggplant) and weeds. Since then several studies are being carried out by scientists from different parts of the world Chen & Katan (1980), Elad et al., (1980). Grinstein et al., (1979), Rubin & Benjamin (1981, 1983 & 1984). Solarization was tried in Greece (Ursad, 1977), Jordan (Al-Raddad, 1979), Korea, (Kye & Kim, 1985) Italy (Tamietti & Garibaldi, 1980), England (White & Buczacki, 1979), USA (Pullman et al., (1981), Japan (Kodama & Fukui 1979) and in many other countries.

Principle of solarization

Mulching soil with polythene during winter to increase soil temperature for better crop growth in glasshouses and open field is a common practice in places where the winter is severe. Unlike mulching during winter, solarization involves the use of heat as lethal agent for pest control by the use of polythene sheets for capturing solar energy.

Katan (1980) observed that in order to get the best control of soilborne pathogens through solarization, polythene mulching should be done during the hottest season of the year. According to him for getting better results with solarization the following factors should be taken into account: (a) Soil mulching should be completed before planting. (b) Soil should be kept wet during mulching to increase thermal sensitivity of resting structures and to improve heat conduction. (c) The mulching period must be extended if the pathogens are noticed in deeper soil layers. (d) Thinnest polythene tarps are the best, as they are cheaper and increase soil temperature compared to thicker ones. (e) The soil should be in good tilth, allowing close contact between plastic sheets and the soil. (f) Prevent the formation of 'airpockets' which reduce heat conduction.

The effectiveness of solarization is influenced by various factors like thickness of polythene sheets used, its colour and the method of laying, etc. Katan (1980) and Pullman et al., (1981) found that thinner transparent (25-30 μm) polythene sheets are more effective than thicker ones (100 μm) in the control of Verticillium diseases of tomato, eggplant, potato and cotton and R. solani on potato

and onion. This was contradicted by Fukui et al., (1981). According to them thicker sheets (100 µm) are more effective then thinner ones. Katan et al., (1976), Kodama & Fukui (1979) and Katan (1980) showed that black plastic film was less efficient in raising soil temperature than transparent ones. Black polythene, though it is greatly heated by itself, is less efficient in heating the soil (Horowitz 1980 and Waggoner et al., (1960).

In studies carried out by Katan et al., (1976), Grinstein et al., (1979) and Katan (1981) in various parts of Israel, they recorded soil temperatures of 45-55°C and 39-45°C at depths 5 & 20 cm respectively in soil mulched with transparent thin polythene sheets. Pullman et al., (1979) recorded 60°C at 5 cm depth compared to 46°C in nonmulched soil. Calculations by Mahrer (1979) indicate that in wet, mulched soils increased temperature is due primarily (80%) to the elimination of heat loss by evaporation and heat convection during the day time and partially to the "greenhouse effect", that is, preventing part of the long-wave radiation from leaving the ground.

For better control of soil diseases, polythene sheets should closely touch the soil (Katan 1976). This

prevents the formation of 'airpockets' which inturn reduce heat conduction. Analysis of spatial temperature regime in mulched soil shows that heating at the edges of mulches is lower than at the centre and that a narrow mulch strip is less efficient in heating than a wider one. At the edges of the polythene cover the temperature is usually 2 to 4°C lower than at the centre (Mahrer and Katan, 1981). A similar observation was also made by Fukui et al., (1981).

Disease control and yield increase in the field as a result of solarisation

Since 1974, field experiments are being carried out to evaluate the effectiveness of soil solarisation in plant disease control.

Rhisoctonia

Rhisoctonia solani was effectively controlled by solarisation in onion (Katan et al. 1980). This resulted an yield increase to the tune of 59 - 125 per cent. Elad et al., (1980) obtained significant control of diseases caused by the pathogen in potato while Pullman et al., (1981) was successful in reducing soil population of R. solani and in increasing yield of cotton through solarization.

Verticillium

Mulching with polythene sheets increased soil temperature and resulted in reduction of Verticillium wilt by 25 to 95 per cent and increased yield in the case of eggplants and tomato (Katan et al.,1976). Pullman et al.,(1981) reported that soil solarization greatly reduce propagules of V. dahliae in soil and increased cotton yield. Aloj and Noviello (1982) obtained effective control of Verticillium wilt of tomato, eggplant and potato. Ashworth and Gaona (1982) reported that mulching with clear polythene sheets for two months resulted in the elimination of V. dahliae in a 6 year old pistachio nutgrove. However, Horiuchi (1984) failed to get uniform results. In Australia, solarisation gave good control of Verticillium wilt of tomato (Anonymous 1985).

Plasmodiophora

In England, White and Buczacki (1979) noticed a reduction in the incidence of Plasmodiophora brassicae in cabbage seedlings grown in solarised soil. On the contrary, Horiuchi (1984) obtained variable results. Whereas Shimizu et al., (quoted by Horiuchi 1984) observed considerable reduction in the incidence of clubroot by

addition of cattle/hen dung prior to solarization. Solarisation of naturally infested soils reduced disease and increased yield in the case of Chinese cabbage (Porter and Merriman 1985).

Pyrenochaeta

Soil solarisation significantly reduced the incidence and severity of pinkroot disease of onion caused by Pyrenochaeta terrestris by 72 - 100 per cent (Katan et al., 1980). Similarly Malathrakis et al., (1983) in Greece and Goisque et al., (1984) in France obtained good control of P. lycopersici on tomato.

Fusarium

Solarization controlled Fusarium infection and increased yield in onion (59-125 per cent) and cotton (87 - 120 per cent) (Katan et al., 1980 & 1983). In Italy, effective control of Fusarium wilt of tomato, cotton and onion was obtained by Aloj and Novielio (1982). Kodama and Fukui (1982) found that disease incidence was significantly reduced in an experiment with Fusarium wilt of strawberry in Japan. Malathrakis et al., (1983) reported good control of brown rootnrot of tomato (F. oxysporum) in Greece. Soil solarization was also effective in delaying the onset of wilt symptoms as well as reducing

total disease incidence in watermelon (Martyn and Hartz 1985). Solarization of soil amended with cabbage residues practically eliminated F. oxysporum f.sp. conglutinans within 15 days and cabbage yellows was undetected on plants grown in pots containing this soil (Villipudua and Munnecke (1986). They reported that solarization or shade treatments (using black polythene tents) plus cruciferous amendments are more effective than solarization or shade treatments alone. However, in Brisbane, Australia, solarization was ineffective against race 3 of F. oxysporum f.sp. lycopersici (Anonymous 1985).

Pythium

Pullman et al. (1981) reported that solarization greatly controlled propagules of Pythium spp. Solarization also gave excellent control of poor rot syndrome in sugarcane associated with P. arrhenomanes and P. graminicola in Australia. (Anonymous 1985 a).

Sclerotium

Jones et al. (1966) obtained significant reduction and in one case excellent control of southern blight of tomato caused by Sclerotium rolfsii with solarization. Southern blight of peanuts (Grinstein et al. 1979) and

blight of sorghum, maize and beans caused by S. rolfsii were effectively controlled by solarization. However, it was not effective in the control of Macrophomina phaseolina in sorghum, maize and beans (Mihail and Alcorn 1984).

Solarization reduced diseases caused by Sclerotinia minor and S. sclerotiorum and increased yield in lettuce (Porter and Merriman 1985).

Thielaviopsis basicola in cotton (Pullman et al. 1981), Colletotrichum cocodes in tomato (Malathrakis et al. 1983) were also effectively controlled by solarization.

Mechanisms of disease control

Solarization was first regarded as a means of physical control by thermal killing of the pathogen. Even now the mostly emphasised factor in soil solarization is its thermal effect (Horiuchi 1984). However increased disease control obtained through solarization may not be exclusively based on a physical mechanism because sublethal temperatures also can give some degree of disease control (Katan, 1981 and Horiuchi, 1984). Apart from thermal effect, several other factors were also reported to be responsible in controlling pathogens in a solarized soil (Katan 1981).

Thermal inactivation of pathogen

The effect of temperature on microorganisms has been well documented. However, the lethal temperatures for organisms have been worked out mostly by exposing the organisms to controlled high temperatures (80-100°C) for quite short periods that is minutes or hours. The effect of exposure of organisms for long periods of time has not been studied in detail. Baker (1962) suggested that exposing fungi to heat, results in denaturation of proteins (including enzymes), lipid liberation, destruction of harmones and asphyxiation of fungal tissues.

According to Katan *et al.*, (1976) the effectiveness of sublethal temperature on pathogens might be due either to a direct cumulative effect of temperature or to a combination of thermal and biological factors. They worked out a linear relationship between logarithms of exposure duration required to kill 90 per cent of the pathogen (LD90) when plotted against the temperature level in the range of 37 to 50°C.

Katan (1980) opined that the fungal resting structures exposed to sublethal temperatures were weekened and therefore attacked even by the microorganisms that ordinarily could not attack them. According to Pullman *et al.*, (1981) sub lethal temperature caused enzyme

inactivation, phase change in fatty acids and membrane components and a slow turn over of heat-sensitive proteins. They suggested that this heat damage accumulated gradually. They also noticed delayed germination of pathogen propagules when exposed to sublethal temperatures.

Biological control

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 soil extend beyond the target organisms (Katan 1981). Biological control is also involved as "side effects" in case of physical or chemical disinfection (Baker and Cook, 1974, Garret, 1970, Munnecke and Van Gundy, 1979, Munnecke et al. 1976, 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 the 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 inoculum introduced to soil after solarisation, from deeper soil layers or adjacent non-treated plots, that is, preventing reinfestation through activity of microorganisms possessing mechanism A_2, A_3, B and C.

III Effect on the host due to cross-protection.

Katan et al. (1976) showed that soil fungistasis to Fusarium diminished as a result of soil heating and this in turn reduced population level of the fungus in soil. 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. According to Lifshitz et al. (1983) sublethal heating of S. rolfsii sclerotia increased

exudation and colonization of sclerotia by bacteria and streptomycetes, thus reducing their pathogenic capacity. Scanning electron microscopic studies by them showed that heating increased the frequency of surface cracks on the scleretia and the concentrations of bacteria on or around the cracks were about tan times. 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 direct killing at 41°C. Time exposures for direct and indirect killing were 4-7 hours and 0.5 - 1 hour, respectively. Trichoderma spp. were the dominant colonizers of the heated roots. Significant reduction of Fusarium wilt was exhibited by tomato seedlings planted in e previously solarized soil compared to nontreated soil indicating the development of a temporary suppressiveness in the solarized soil due to a favourable shift in microbial population towards antagonists. (Katan, 1981). Polythene mulching of the soil retains adequate soil moisture for such microbial activity for several weeks.

Preventing reinfestation is vital for proper disease control. Drastic soil disinfestation measures may result in islands of reduced biological activity which enhance recolonization (Harper 1974). Olsen and Baker (1968) showed that severe reinfestation occurred

with R. solani, when soils were disinfested by artificial heating at 80 - 100°C. Treating the soil at lower temperatures (50 - 60°C) reduced reinfestation. Temperature lowered by using aerated steam at 60 - 70°C was successfully tried for diminishing reinfestation and phytotoxic effects, encountered with steam at 100°C. (Baker 1962, 1970; Baker and Cook 1974). Solarisation is carried out at temperatures that are even lower than aerated steam and solarization thus reduces chances of biological vacuum (Katan 1981).

Volatiles and other mechanisms

Volatiles in the soil play a key role in fungistasis and biological control (Lewis and Papavizas, 1975, Smith, 1976, Pavlica et al. 1978, Papavizas and Lumsden, 1980 and Zakaria at al. 1980). Ammonia and volatile sulphur containing compounds formed in amended soil are found to suppress Fusarium and Aphanomyces spp. (Lewis and Papavizas, 1975 and Zakaria et al. 1980). Permeability of polythelene to many gases is not very high. Carbon dioxide 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 carbon dioxide concentration in solarized soil increased rapidly during the first week and reached a maximum which was twenty fold higher

than that formed in non-mulched soil. The oxygen starvation due to reductive soil condition is believed to affect the survival of pathogen propagules. The weakened structures may be attacked easily by soil antagonists which are activated by such soil conditions (Horiuchi, 1984).

Factors influencing solarization

The effectiveness of solarization has been found to be influenced by soil moisture, soil type, organic matter content of the soil, duration of the solar heating, season, sunlight/shade, types of materials used as covering, ridging, etc.

Soil moisture

Maintenance of high soil moisture is necessary for increasing soil conduction of heat and for increasing the sensitivity of organisms to high temperature. Katan et al. (1976) obtained better control of V. dahliae and F. oxysporum on tomato and eggplant by irrigating the soil with drip irrigation. Later studies by them showed that only a single irrigation just before (1-4 days) covering the soil with polythene is necessary to get good control of the soil borne plant pathogens. Grinstein et al. (1979) and Katan et al. (1980) reported successful control of S. rolfsii, V. dahliae and Fusarium by presolarization

irrigation. Martyn and Harts (1985) obtained significant reduction in disease incidence with Fusarium in watermelon through pretarping irrigation. Pullman et al. (1979) slightly modified the irrigation system. They used additional furrow irrigation under polythene tarps for enhancing the killing of V. dahliae.

It is generally known that hot water treatment is better than dry heat in inactivating pathogens. This effect may be due to high specific heat of water, reduction in thermal tolerance in the hydrated structures of the pathogens or to a state of partial anaerobiosis (Olsen and Baker, 1968). These effects may also occur in soil solarization. When the field to be solarized is watered, high soil temperature may last for a longer period, due to an increase in specific heat. Heat conduction of soil may also be improved when the pore space is filled with water (Horiuchi 1984). The importance of maintaining high soil moisture during solarization has been emphasised by many workers (Stover 1954, Katan et al. 1976, Grinstein et al. 1979, Elad et al. 1980). A satisfactory control could be obtained by moistening the field a single time just before tarping (Katan 1981, Horiuchi 1984).

Soil type

Influence of soil type on solarisation has not been studied in detail. However, there are indications that soil type plays an important role in temperature fluctuation in a solarised soil. The thermal properties of soil vary. Absorption of solar radiation varies according to the colour, moisture and texture of the soil. Stapleton and De Vay (1984) found 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 solarised plots. In another study with Capay silt clay, Yolo loam, Reiff fine sandy loam and loamy sand, Stapleton and De Vay (1984) observed that at 15 cm depth, soil temperature in fine sandy loam soil reached 45°C (9°C higher than in control) and that in solarised loam soil 44°C (10°C higher than in control).

Organic and inorganic matter content of soil

Organic and inorganic content of soil influence the effect of soil solarisation. Shimizu *et al.* (unpublished report, quoted Horiuchi, 1984) found that addition of dried cattle dung at the rate of 30 Mt/ha or dried hen droppings at the rate of 20 Mt/ha greatly reduced the incidence of clubroot disease where as solarisation without organic matter had less effect. Horiuchi (1984) reported that

organic matter combined with water and calcium compounds improved tha effect of solarization. Shimizu at al., (unpublished raport) also showed that solarization is more affective against clubroot disease if calcium cyanamide is incorporated into the soil before mulching.

Duration of solar heating

Increase in the soil temperature as a result of solarization is more pronounced in the upper layers of the soil than the deeper layers. Katan et al. (1976) obtained 52°C at 5 cm depth in mulched soil as against 38°C at 20 cm depth. They observed that at 5 cm depth five days of solar heating was sufficient to eliminate 100 per cent of V. dahliae sclerotia while at 25 cm depth only a slight killing of the pathogen was noticed. However, an additional exposure for eight days enabled complete killing of the sclerotia even at 25 cm depth. Hence, Katan (1981) recomended that mulching period should be sufficiently extended to achieve pathogen control at all desired depths. According to him, inorder to effectively control the pathogen, solarisation should be carried out for a minimum period of four weeks. Elad et al., (1980) reported that mortality rates of S. rolfsii sclorotia at 5 and 20 cm depth were 100 and 25 per cent after 19 days of solarization and 100 and 80 per cent after 21 additional

days respectively. Usmani and Gaffer (1982) observed 95-100 per cent loss of viability of sclerotia in soil inoculated with S. oryzae at 5 cm on mulching for one week and at 20 cm for 8 weeks.

Season

To get best results, solarization should be carried out during the hottest months of the year. This will enable to increase the maximal temperature in the hope of reaching lethal levels. (Katan et al. 1976, Grinstein et al. 1979 Katan, 1980, 1981a, Chen and Katan, 1980, Pullman et al. 1981, Stapleton and De Vay, 1982, Mihail and Alcorn, 1984, Martyn and Hartz, 1985).

Mahrer (1979) developed 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. The model enabled to choose 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.

Shade

Ashworth (1979) tried to control V. dahliae in 4 year old pistachionut grove by polythene tarping, where some shading of soil occurred daily. He reported

that no reduction of inoculum occurred in the partially shaded area after two weeks of solarization, where as inoculum density was reduced to trace in the open soil at 20 cm depth. But after 6 weeks of solarization the inoculum was reduced to trace to a depth of 60 cm in solarized soil in both open and partially shaded areas. Ashworth and Gaona (1982) obtained successful control of Verticillium wilt in established (6 year old) pistachionut groves.

Stapleton and De Vay (1983) reported decrease in nematode population densities in shaded solarized soil. In another study, infections of peach roots by Pythium spp. were significantly reduced in a three year old almond orchard, but not in a six year old peach orchard (Stapleton and De Vay, 1984). Villipudua and Munnecke (1986) in an experiment to control cabbage yellows (F. oxysporum f.sp. conglutinans) found that solar heating alone and cabbage amendments plus mulching under shade (provided with black polythene tents) were effective but was not effective as the combination of solar heating and cabbage amendments. However, cabbage amendments without cover were ineffective both under shade and in direct sunlight.

Ridging

Horiuchi (1984) reported that covering ridged field plots with polythene sheets easily raised soil temperature than in levelled ones. Higher ridges were more effective than lower ones because ridges have a greater surface area to receive solar radiation which is the primary source of energy for heating the soil.

Effect of solarization on microbes

In an experiment to control corky root in tomato in plastic green houses Hori et al., (1979) found a drastic reduction in the populations of total fungi and gram negative bacteria in soil during solarization period where as the total population of bacteria almost remained the same. At the transplanting time, 70 days after treatment terminated, the populations of both fungi and bacteria revealed a marked increase. They concluded that population of Pyrenochaeta lycopersici, the causal fungus, was reduced by solarization along with other fungi and its build up was limited by the dominant fungi or bacteria which promptly became established after solarisation.

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 thermophilic/thermotolerant fungi were affected to a lesser extent. Actinomycetes increased in the treated soil 3-6 months after completion of solarization. Agrobacterium spp and populations of gram positive bacteria remained significantly depressed in solarized soil after 6--12 months. Fluorescent pseudomonads and total fungi quickly recolonized the treated soil while actinomycetes and thermophilic/thermotolerant fungi attained higher population densities following solarization.

In an experiment with selected microorganisms Stapleton and De Vay (1984) showed that solarized soils usually contained the least microorganisms, untreated control soils contained the most and shaded soils had intermediate population densities. They also found that the percentage of colonies of gram-positive bacteria exhibiting in vitro antibiosis against Geotrichum candidum increased 20 fold in solarized soil.

Pullman et al., (1981) observed that mycorrhizal fungus Glomus fasciculatus survived tarping treatment as measured by colonization of cotton roots. No visible difference in the extent of root infections by vesicular-arbuscular mycorrhizae (Glomus spp) were noticed by Stapleton and De Vay (1984) between roots from solarized and untreated almond trees.

Nematode control

Several workers have reported effective control of nematodes in soil covered with polyethelene mulches. Grinstein et al., (1979) obtained 80-100 per cent reduction of Pratylenchus thornei population by soil solarization in potato field. Solarization was effective in the control of Meloidogyne spp (Katan 1981a). However, the effectiveness of solarization varied with the species. Complete control of Ditylenchus dipsaci in garlic was obtained by Siti et al. (1982). The effectiveness of this lasted throughout the season.

Stapleton and De Vay (1983) found that population densities of free-living and phytoparasitic nematodes including Meloidogyne, Heterodera, Pratylenchus, Paratrichodorus, Criconemella, Helicotylenchus, Xiphinema and Paratylenchus spp were significantly reduced to 42-100 per cent by soil solarization and some residual effect lasted for several months. According to him the extent of reduction depended on (a) degree of solar heating (b) crop and cropping history (c) nematode involved (d) nematode distribution in soil and (e) soil depth.

The reduction in nematode population in shaded solarized plot was almost half of that noticed in open solarized plot. (Stapleton and De Vay 1983). Studies conducted by Lamondia and Brodie (1984) showed that the

population of Globodera rostochiensis could be reduced by 96.2 to 98.6 per cent to a depth of 10 cm, totally eliminate encysted juveniles burried 5 cm deep and significantly reduce survival of encysted juveniles burried 10 and 15 cm deep. Other nematodes controlled through solarization include clover cyst nematode (Heterodera trifoli) (Hadar et al.,1983) and Pratylenchus penetrans on celery (Porter and Merriman 1985).

Weed control

The presence of dormant weed seeds in agricultural soils provide a source for persistent weed problems that often require repeated control measures. A reduction in the number of dormant weed seeds in the soil should also correspondingly reduce weed persistence and weed control requirements. Almost complete weed control in the polythene mulched plots was noticed by Katan (1976). According to him weeds such as Alhagi maurorum Medik, Cyperus rotundus L., Notobasis syriaca (L) Cass., and Prosopis farcata Eig. could be effectively controlled by solarization. In many solarized fields weed control was evident even at the end of the growing season and nearly one year after mulching.

Control of annual weeds by soil solarization was reported by Katan (1980), Grinstein et al.,(1979)

Horowitz et al.,(1983), Rubin and Benjamin (1983, 1984) and Eglay (1983). Many perennial weeds were also effectively controlled by following this technique (Katan 1980, Grinstein et al. 1979). Rubin and Benjamin (1983) found that perennial weeds which propagate vegetatively were only partially controlled with short solar heating, but mulching for 8 to 10 weeks improved control. According to Horowitz et al.,(1983) established perennials escaped solarization treatment.

Weeds controlled by solar heating include -- Amaranthus, Anagallis, Avena, Capsella, Chenopodium, Cynodon, Digitaria, Eleusine, Fumaria, Lactuca, Mercurialis, Monita, Notobasis, Phalaris, Poa, Portulaca, Sisymbrium, Solanum, Stellaria, and Xanthium (Katan 1980, Horowitz et al.,1983), Ipomoea, Trianthema (Egley 1983), Cynodon and Sorghum (Rubin and Benjamin 1984). Egley (1983) reported increased emergence of purple nutsedge (Cyperus rotundus L) due to solarization in some instances, Melilotus (Katan 1980, Rubin and Benjamin 1983), Malva (Rubin and Benjamin 1983, Horowitz et al.,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 the treatment killed non dormant seeds and greatly reduced the number of weed seedlings that otherwise

would have emerged. Mulching with black polythene for seven weeks provided significantly superior weed control, indicating the possible involvement of a darkness effect on seeds/or soil volatile metabolites (Rubin and Benjamin 1983). The possible mechanisms of weed control by soil solarization could be: (a) direct thermal killing of germinating or even dormant seeds (Horowitz et al., 1983; Rubin and Benjamin 1983) (b) thermal breaking of seed dormancy followed by thermal killing (Rubin and Benjamin, 1983) (c) thermally induced changes in carbon dioxide/oxygen, ethylene and other volatiles which are involved in seed dormancy release (Katoh and Esashi 1975; Taylorson and Hendricks, 1981) (d) direct effect of high temperature interacting with toxic volatiles released from decomposing organic matter (Pavlica et al., 1978) or seed metabolism (Vancura and Stotzky, 1976) and (e) indirect effects via microbial attack of seeds weakened by sublethal temperature (Hendricks and Taylorsan 1976).

Increased growth response

Solarisation has been found to increase plant growth and yield. Increased yield of brinjal and tomato (Katan et al. 1976), wheat and turnip (Rubin and Benjamin, 1983) sugarbeet and radish (Stapleton and De Vay, 1984), better bulb development and uniform maturation in onion

(Katan et al., 1980) were observed in solarized plots. In some cases the effect of solarisation lasted for more than one season. Improved plant growth and yield in the case of sorghum (Pullman et al., 1981) and cotton (Pullman 1981 and Katan et al., 1983) were found to last for more than one crop season in solarized soil compared with nonsolarized soil.

Better growth and yield in perennial trees using solarisation was also reported by Stapleton and De Vay (1982). They found an increased plant height to an extent of 24.7 and 26.7 per cent and increased yield of 42.4 and 58.1 per cent in peach and walnut respectively when soil was solarized for 4 - 4.5 weeks.

The beneficial effect of solarisation was not observed in all plants. When chilli cultivar resistant plant (Stapleton and De Vay 1984) and parsely (Rubin and Benjamin 1983) were grown in solarized soil there was no increase in any of the growth parameters measured.

Apart from many other factors, increased plant growth response following solarisation might be due to changes in populations of soil microorganisms (Stapleton and De Vay 1982) nematodes, weeds and soilborne insects (Stapleton et al., 1985).

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

Physical and chemical changes that take place in soil are also altered slightly by solarization. A rapid decline in soil electrical conductivity and a corresponding decline in nitrate nitrogen was noticed by Hori et al., (1979) immediately after solarization. This suggests the accumulation of ammoniacal nitrogen under reductive and high temperature conditions in the soil. On the contrary Horiuchi (1984) pointed out an increase of both NO_3-N and NH_4-N when bulk organic materials were used./ Kodama et al., (1980) reported a drastic reduction of nitrite and nitrate bacteria in solarized soil. This in turn indicated a delay in ammonia nitrification after the treatment terminated. These results suggested the advantage of solarization in nitrogen fertilization.

Analysis of solarized soils of various types showed a significant increase in calcium and magnesium concentrations as compared to non treated soil. (Chen and Katan, 1980). Calcium ions play an important role in plant resistance. Horiuchi (1984) also found an increase of free $\bar{NO_3}$, $\bar{NH_4}$, K^{+}, Ca^{++}, Mg^{++} and $\bar{Cl}$ in the solarized soils. According to him these elements enhance plant growth.

Stapleton and De Vay (1982) reported that though increases in nitrate nitrogen were noted in solarized soil major difference in the other nutrient levels were not apparent.

Stapleton et al., (1985) reported that soil solarisetion increased concentrations of $N\bar{O}_3$ and $N\bar{H}_4$ nitrogen upto six times compared to non treated soils. Concentrations of P, Ca^{++} and Mg^{++} and electrical conductivity increased in some of the solarized soils. They observed that solarization did not consistently affect available K^{+}, Fe^{3+}, Mn^{2+}, Zn^{2+}, Cu^{2+}, $C\bar{l}$ concentrations, soil p^{H} and total organic matter. Increases in $N\bar{O}_3$ plus NH^{+}_{4} nitrogen were no longer detected in fallowed soils 9 months after solarization.

MATERIALS AND METHODS

MATERIALS AND METHODS

Location of field experiment

The field experiment on solarization was conducted at Madavoor, 45 Km from Trivandrum.

Field experiment

Before commencement of the field experiment a bulk crop of cowpea was raised in the plot set apart for the experiment during March-April 1986. This crop was incorporated into the soil 40 days after planting to get a uniform distribution of the cowpea residues in the field.

The land was then dug to a fine tilth. Clods and root bits were crushed or removed and the land was levelled properly. Raised beds of height 15 cm and size 2 x 2 m were formed. The experimental plot was fenced all around to avoid trampling of mulch by stray animals. The field experiment was laid out during May 1986. The details of the experiment were as follows.

Crop	-	Cowpea (*Vigna unguiculata*) (local variety)
Design	-	2^3 factorial in Randomised Block Design for the factors A, B and C for the main experiment.
Factor	-	A = Shade
Factor	-	B = Irrigation
Factor	-	C = Solarization

For the other factors viz. incidence of disease, total microflora, plant growth, weed growth and availability of nutrients simple RBD was used.

Spacing - 25 cm in between rows and 25 cm in between plants.

Plot size - 2 x 2 m

No. of plants per plot: 64

Replications - 4

The treatments were:

T_1 - Open irrigated control (OIC)

In this the bed was pot irrigated once and was not covered with polythene sheet.

T_2 - Open irrigated solarised (OIS)

Just before covering with polythene sheets the bed was pot irrigated once.

T_3 - Open nonirrigated solarized (ONIS)

Same as T_2 but before mulching the bed was not irrigated.

T_4 - Open nonirrigated control (ONIC)

The bed was neither irrigated nor covered with polythene sheet.

T_5 - Shade irrigated control (SIC)

Same as T_1 but the bed was laid out under coconut trees.

T_6 - Shade nonirrigated control (SNIC)

Same as T_4 but bed was laid out under coconut trees.

T_7 - Shade irrigated solarized (SIS)

Same as T_2 but the bed was laid out under coconut trees.

T_8 - Shade nonirrigated solarized (SNIS)

Same as T_3 but bed was laid out under coconut plants.

Isolation of the pathogen

Rhizoctonia solani Kuhn causal organism of collar rot disease of cowpea, used for the study was isolated from naturally infected cowpea plants from the Instructional Farm, College of Agriculture, Vellayani, Trivandrum. The infected stem showing typical collar rot symptoms was cut into small bits, surface sterilized with 0.1 per cent mercuric chloride solution for one minute and then washed in three changes of sterile distilled water. These bits were then placed on potato dextrose agar (PDA) in sterile petridishes and incubated at room temperature. On the second day, the growth of the fungus mycelium was visible and it was asceptically transferred to PDA slants. The isolate was purified by hyphal tip method and maintained on PDA by periodic subculturing. The identity of the pathogen was confirmed by comparing the characters of the isolate with the type fungus available at the department of Plant Pathology, College of Agriculture, Vellayani.

Mass culturing of Rhizoctonia solani

Sand maize medium

For mass multiplication, the pathogen was grown on sand maize medium. Sand maize medium was prepared by mixing washed white sand with maize meal in the ratio 19:1. This mixture was taken in 1000 ml conical flasks, moistened with water and sterilized by autoclaving at 1.02 kg/cm^2 pressure for 15 - 20 minutes. Actively growing three day old culture bits were asceptically introduced into the flasks containing sterilized sand maize medium and were incubated for twenty days at room temperature before incorporating in soil.

On cowpea plant bits

The mature stem portions of cowpea plants were cut into small bits of size 1 to 1.5 cm and autoclaved at 1.02 kg/cm^2 pressure for 15 - 20 minutes in 500 ml conical flasks. Actively growing three day old culture was asceptically transferred into the flasks with sterilized cowpea bits and were incubated at room temperature for twenty days. This was used for soil inoculation.

Soil inoculation

For soil inoculation, the fungus (R.solani) grown on sand maize medium and cowpea plant bits was used. Twenty day old culture of the fungus in the sand maize

medium was thoroughly mixed in the conical flask before incorporating into the soil. Furrows with 2-5 cm depth, 25 cm apart were taken and mycelial mat with sclerotia in sand maize medium and cowpea plant bits were uniformly applied into the furrows and covered with soil. There were 8 furrows in a plot of 2 x 2 m. Five hundred gram of mycelial mat with sclerotium in sand maize medium and cowpea plant bits were used for inoculation in one plot. Irrespective of the treatment, all plots received equal quantity of fungal inoculum.

Mulching with polythene sheets and recording of soil temperature

Transparent polythene sheets of 200 guage (0.05mm thick) were used for, mulching the soil. Each sheet was of size 2.5 x 2.25 metre. The levelled beds were mulched manually as shown in figure 1. The edges of the sheet were covered by soil. Thus the polythene sheet was in close contact with the soil. Special care was taken to prevent the formation airpockets.

A soil thermometer was buried at the centre of the bed at 15 cm depth. Soil temperature was recorded at 2.30 PM everyday during the entire period of solarization. Soil temperature was also recorded from the plots not covered with polythene sheets. Polythene mulching was done on 7-5-1986 and was removed after 47 days (on 22-6-86).

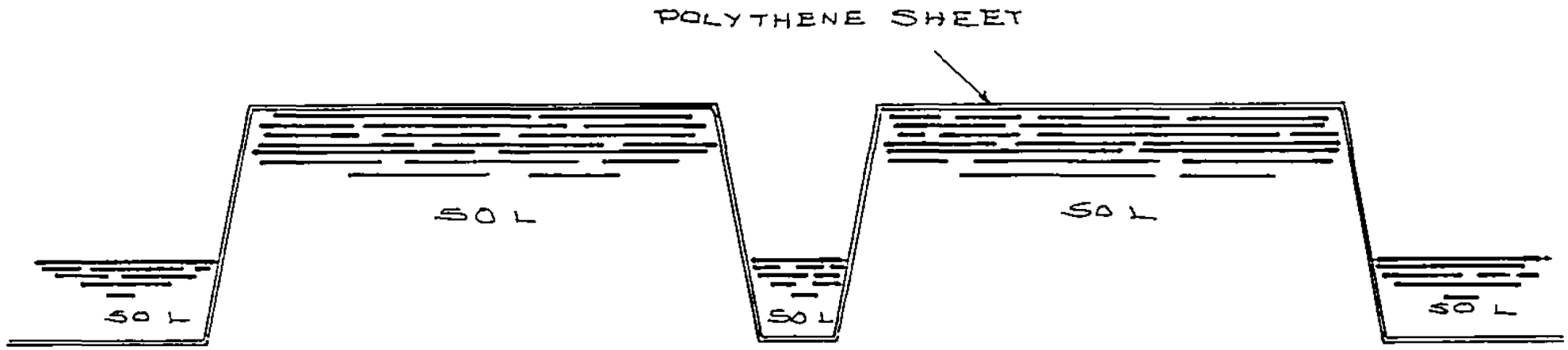


FIG 1 POLYTHENE MULCHED SOIL

In treatments requiring irrigation, a single irrigation by pot watering was given just before covering the beds with polythene sheets. Hundred litres of water was used for irrigating each plot of size 2 x 2 m.

Planting

The cowpea seeds (local variety) used for the experiment were treated with rhizobium culture. The rhizobium culture used for treating the seeds was obtained from department of Plant Pathology, College of Agriculture, Vellayani. Two seeds were dibbled into the furrows at a spacing of 25 x 25 cm. Seeds were sown on 22-6-1986 immediately after removing the mulches. The planting was so adjusted that the seeds were dibbled at the same place where Rhizoctonia inoculum was placed at the time of soil inoculation. Seedling emergence was completed within 4-5 days. The number of seeds germinated in each plot after 5 days were counted. The plants were thinned after seven days and the number of plants per plot was kept at 64.

Disease incidence

Weekly observations were taken for the possible incidence of collar rot and web blight of cowpea. The number of plants showing collar rot symptoms were counted at weekly intervals. The diseased plants were removed

once the plant was killed. The identity of the pathogen was established by isolating the causal organism of the disease. An exponential model ($Y = AB^t$) was developed to predict the disease incidence at weekly intervals. (Table 6).

Biometric observations

The height and number of leaves per plant were recorded at 20th, 40th and 60th days after sowing. The height was measured from the soil level to the terminal bud. The observations were taken from four plants selected at random in each plot.

Harvest and yield

Ripe pods were harvested separately from each treatment and dry weight of cowpea seeds were recorded. The first picking was done 64 days after planting. Four picking were done and the last harvest was on 5-9-86. After the final harvest the plants were ploughed into the soil.

Laboratory studies

Collection of soil samples

Soil samples used for the laboratory studies were collected from the different experimental plots. From each plot soil sample was collected from four different locations at random. From these locations soil from 0 - 15 cm region were collected using a spade. Soil

samples collected from plots receiving similar treatments were pooled together and this was used for all the laboratory studies viz. for estimating the population of fungi, bacteria, actinomycetes, nematodes and also for chemical analysis. Soil samples were collected one day before mulching (6-5-86), immediately after removing the polythene sheets (22-6-86), ten days after solarization (2-7-86), one month after solarisation (28-7-86), two months after solarisation (20-8-86) and on the date of final harvest (5-9-86) viz. 75 days after solarization.

Estimation of microbial population

Total fungi, bacteria and actinomycetes from the soil samples collected were estimated by Serial Dilution Plate Technique (Johnson and Curl 1972). For fungi 10^{-3}, for actinomycetes 10^{-5} and for bacteria 10^{-7} dilutions were made. Martins Rose Bangal Streptomycin Agar, Soil Extract Agar and Kenknight Agar were used for estimating fungi, bacteria and actinomycetes respectively. Colonies of fungi, bacteria and actinomycetes were counted on 3rd, 5th and 10th day of plating respectively.

Nematode population

Nematode population was estimated by modified Baerman Funnel Technique of Christie and Perry (1951). For the purpose, soil samples were collected one day before polythene mulching, immediately after the removal

of polythene sheets and on the day of final harvest. Saprophytic and parasitic nematodes were estimated separately and parasites were identified.

Nodule count

The number of nodules present on cowpea roots were counted on the day of final harvest. Three plants per plot were selected at random for this purpose. Nodules could not be counted before, as it was not possible to uproot the plants from the experimental plots before harvest.

Weed population

With a view to study the effect of solarization on weedflora, weed populations were counted and identified before preparation of the land in each of the demarcated plot. The weed count was also taken on the day of removal of polythene sheets, one month after sowing and on the day of final harvest. In all these cases once the count was made, all the weeds present in the field were removed.

Chemical analysis of soil samples

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

Nitrogen

Available nitrogen was determined by the alkaline permanganate method (Subbiah and Asija 1956).

Phosphorus

Available phosphate was determined by Dickson and Bray§ (1940) molybdennum blue method in a Klett-Summerson photoelectric colorimeter.

Potassium

Exchangeable cations were determined in neutral normal ammonium acetate extract by flame photometer (Model - EEL flame photometer) Jackson (1973).

Calcium and Magnesium

Exchangeable cations were determined in neutral normal ammonium acetate extract using Perkin Elmer 3030 Model Atomic Absorption Spectrophotometer (Black 1965).

Organic carbon

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

Soil Reaction

The p^H was read in a 1:2.5 soil water suspension using a Perkin - Elmer p^H meter.

Electrical conductivity

E.C. was measured in the filtered extract of 1:2.5 soil water suspension using Elico conductivity bridge.

RESULTS

RESULTS

Isolation and purification of pathogen

The pathogen causing collar rot of cowpea was isolated from naturally infected cowpea plants. The isolate was purified by hyphal tip method and maintained on PDA slants by periodic subculturing. The pathogenicity of the fungus was established by artificially inoculating fresh cowpea seedlings with the culture. The fungus was then reisolated from the inoculated plants and characters studied. The fungus causing collar rot was identified as *Rhizoctonia solani* Kuhn. The characters of the original isolate and the one isolated from artificially inoculated plants were similar.

Soil temperature

Soil and atmospheric temperature for the period of solarization (7-5-86 to 21-6-86) is presented in the table 1. During this period, maximum atmospheric temperature of 34.2^{o}C was recorded on 12-5-86. The atmospheric temperature ranged from 28.5 to 34.2^{o}C where as the soil temperature at 15 cm depth ranged from 29.5^{o}C to 39.5^{o}C. Eventhough there was considerable variation in the soil temperature between solarized

Table 1

Maximum and minimum atmospheric and soil temperature during soil solarization periods (7.5.86 to 21.6.86)

Date	Atmospheric temperature		Soil temperature at 15 cm depth					
			Treatments					
			Solarized				Non-solarized	
			Wet		Dry		Wet	Dry
	Maximum °C	Minimum °C	Open °C	Shade °C	Open °C	Shade °C	Open °C	Shade °C
May 1986								
7	32.7	25.0	33.0	30.0	33.0	30.0	33.0	30.0
8	32.3	25.7	39.5	31.5	39.5	31.5	34.5	30.0
9	33.0	25.8	41.0	33.0	41.0	33.0	36.5	30.5
10	33.5	26.2	41.0	34.0	41.0	34.0	37.5	30.5
11	33.3	25.6	41.5	34.0	41.5	34.0	38.5	30.5
12	34.2*	25.0	41.0	35.0	41.0	35.0*	39.0	31.5
13	33.2	25.6	42.0	34.5	42.0	34.5	39.5*	31.5
14	32.6	26.1	39.5	33.0	39.5	33.0	37.0	30.5
15	31.8	25.9	38.0	33.0	37.5	33.0	34.5	30.5
16	31.8	25.4	41.5	34.5	41.5	34.5	38.0	30.5
17	33.0	24.9	40.0	32.5	40.0	32.5	38.0	30.0
18	32.4	26.0	41.0	33.0	41.0	33.0	38.5	30.5
19	33.8	25.0	40.0	32.0	40.0	32.0	37.0	30.0
20	33.0	25.4	42.5*	34.0	42.5*	34.0	39.0	30.5
21	33.9	25.5	42.5*	34.5	42.5*	34.5	39.0	31.5

(Contd...2)

Date	Atmospheric temperature		Soil temperature at 15 cm depth					
			Treatments					
			Solarized				Non-solarized	
			Wet		Dry		Wet	Dry
	Maximum °C	Minimum °C	Open °C	Shade °C	Open °C	Shade °C	Open °C	Shade °C
May 1986								
22	33.5	25.7	40.5	34.5	41.0	34.5	38.0	31.0
23	33.1	26.4	42.0	34.5	42.0	34.5	39.0	32.0
24	32.7	25.0	38.5	32.0	38.5	32.0	35.5	30.0
25	32.1	25.8	39.0	33.0	39.0	33.0	35.0	30.0
26	32.1	25.6	40.5	33.0	39.5	33.0	36.5	30.0
27	32.7	26.0	39.0	33.0	39.0	33.0	35.0	30.0
28	33.0	24.6	40.0	33.0	39.0	33.0	34.5	29.5
29	33.8	25.6	38.0	32.0	38.0	32.0	33.0	29.0
30	32.6	22.7	36.0	31.0	36.5	31.0	32.0	28.5
31	32.1	24.6	41.0	33.0	41.0	33.0	34.5	29.0
June 1986								
1	31.3	24.0	42.0	33.0	41.0	33.0*	34.0	30.0
2	32.1	24.2	42.0	34.0	42.0	34.0	34.0	31.0
3	31.7	24.7	42.0	34.0	42.0	34.0	34.0	31.0
4	31.7	24.5	42.0	34.0	42.0	34.0	34.0	31.0
5	32.3	24.2	42.0	33.0	42.0	33.0	34.5	31.8
6	31.3	23.2	42.0	34.0	41.5	34.0	34.0	31.0
7	31.5	24.6	42.0	34.0	41.0	34.0	34.0	31.0

(Contd...3)

Date	Atmospheric temperature		Soil temperature at 15 cm depth					
	Maximum °C	Minimum °C	Treatments					
			Solarized				Non-solarized	
			Wet		Dry		Wet	Dry
			Open °C	Shade °C	Open °C	Shade °C	Open °C	Shade °C
June 1986								
8	31.2	24.6	42.0	34.0	41.0	34.0	34.0	31.0
9	32.1	24.3	42.0	34.0	41.0	34.0	33.5	31.0
10	31.3	23.8	42.0	34.0	41.5	34.0	33.0	30.0
11	32.8	25.0	42.0	33.0	41.5	33.0	33.0	30.0
12	31.2	24.5	39.0	32.0	38.5	32.0	33.0	28.0
13	31.2	24.0	30.0	30.0	32.0	30.0	30.0	28.0
14	30.4	23.0	39.0	33.0	38.5	33.0	33.0	30.0
15	30.1	22.5	32.5	28.0	32.5	28.0	29.5	26.5
16	29.7	22.5	30.0	30.0	30.0	30.0	30.0	28.0
17	29.0	22.2	38.0	32.0	38.0	32.0	32.0	29.0
18	28.5	22.9	37.5	30.0	37.5	30.0	31.5	28.5
19	31.6	23.0	38.0	31.5	38.0	31.5	32.0	29.0
20	31.0	22.8	32.5	28.0	32.5	28.0	29.5	26.5
21	28.9	24.5	36.0	30.0	36.0	30.0	31.0	27.5

* Indicates the maximum temperature during the period.

and nonsolarized and between open and shaded conditions, similar difference in temperature was not observed between irrigated and nonirrigated soils both in solarized and nonsolarized plots in most of the days, in open and shaded conditions.

In solarized treatments, soil temperature was 0 to 10.8°C above the atmospheric temperature in open while it was almost same as that of atmospheric temperature or slightly less under shaded conditions. However, in open non solarized soils, the temperature increase eventhough was slightly above atmospheric temperature (-1.5 to +6.3°C), it was below the atmospheric temperature in shade nonsolarized soils. In open solarized soils (both irrigated and nonirrigated), soil temperature was 40°C or above for 27 days out of 47 days of solarization. In none of the other treatments temperature reached more than 40°C. In all othar traatments except in shade nonsolarized treatments soil temperature was always above atmospheric temperature. (Table 2, Figure 2).

Soil temperature fluctuations in the nonsolarized and solarized treatments were 10°C (29.5 to 39.5°C) and 12.5°C (30 to 42.5°C) respectively in the open, while in partial shade it was 5.5°C (26.5 to 32°C) in the nonsolarized treatment and 7°C (28 to 35°C) in the solarized treatment.

Table 2

Atmospheric and soil temperature (Weekly mean) during soil solarization (7.5.86 to 21.6.86)

Week	Atmospheric temperature		Soil temperature			
			Treatments			
			Solarised		Non-solarised	
	Maximum °C	Minimum °C	Open °C	Shade °C	Open °C	Shade °C
1st week	33.14	25.55	39.85	33.14	36.92	30.64
2nd week	32.68	25.52	40.35	33.14	37.50	30.35
3rd week	32.87	25.71	40.28	33.50	36.85	30.64
4th week	32.37	24.48	40.14	32.85	33.71	29.71
5th week	31.62	24.18	42.00	33.85	33.85	30.85
6th week	30.62	23.38	35.78	31.14	31.50	28.50
7th week	30.00	23.30	36.00	29.87	31.50	27.87
Maximum temperature recorded	34.2	22.2*	42.5	35.00	39.50	26.50

* Indicates minimum atmospheric temperature.

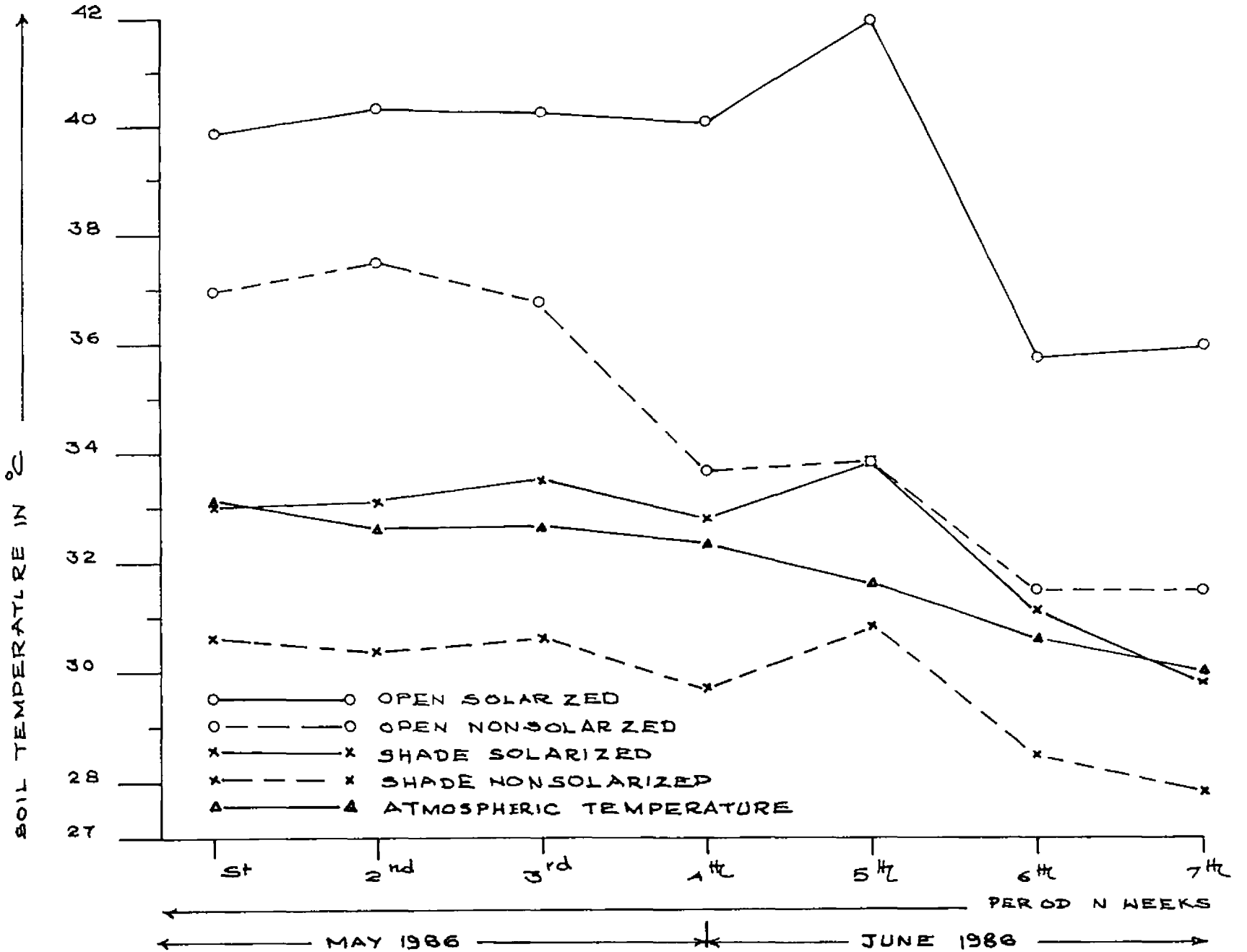


FIG 2 ATMOSPHERIC AND SOIL TEMPERATURE (WEEKLY MEAN) DURING SOIL SOLARIZATION

After mulching, heat build up occurred within 24 to 48 hours. Whenever a heavy rain was obtained the temperature in solarized as well as in nonsolarized soils dropped down. However, in solarized soils within 24 hours the heat build up occurred and normal temperature was regained. This phenomenon was noticed during all the six days in which rain was received. For example, on 13th June, there was a heavy rain and the soil temperature in open irrigated solarized soil dropped from 39°C on 12-6-86 to 30°C. The heat build up took place within 24 hours and on 14th, the temperature was again 39°C.

Based on the soil and air temperature, simple regressions were calculated. The regressions of soil maximum temperature under polythene cover (Y) against maximum air temperature (X) at 15 cm depth were

Open $Y = 4.542 + 1.089 X$

Shade $Y = 14.596 + 0.459 X$

The coefficient of determination under shaded condition was 77.8%. However, it was only 19.18% in open solarized conditions.

Symptoms of the disease

In the experimental plot collar rot phase of the disease was evident. However, web blight phase of the disease was not observed. Infected young seedlings became pale yellow in colour and the cotyledons shrivelled.

Watersoaked areas developed at the collar region and they soon girdled the entire stem resulting in the collapse of the seedlings within 3-5 days. Whitish mycelial growth was visible in the soil near the base of the seedlings. Minute pale yellow microsclerotia were also found to develop at the collar region.

In grown up plants collar rot began as brownish black lesions at the soil level near the collar region. It girdled the basal portion of the stem, soon the leaves turned yellow and many of the leaves dropped off. White mycelial growth often studded with small sclerotia was seen at the affected collar region. In some cases wet root rot symptom was also observed. Root development was inhibited.

Effect of solarization on disease development

Collar rot symptoms appeared in cowpea seedlings on the 5th day of sowing in both solarized and nonsolarized treatments. Pre emergence damping off was not observed in any of the treatments. None of the seeds sown failed to germinate. With the advancement of time substantial difference in the incidence of collar rot of cowpea was observed in different treatments (Table 3, figures 3, 4). In general, incidence of the disease was less in solarized treatments.

Tab e

Effect o so a za ion on Collar rot of owpea
Weekly disease inc dence (ngu ar transfo mat on)
(Mean values)

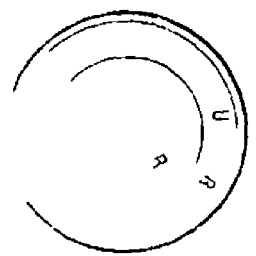
Treatmen	st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week	9th week
T OIC	0 36(3 2)	3 02(5)	8 3 (9 9)	20 25 2 0)	2 96(4 0)	23 08 5 4)	24 45(7)	26 49(9)	28 40(22 6)
T_2 OIS	6 3( )	7 02(5)	7 92(5)	9 0 2 5)	9 0(2 5)	0 00 0)	0 00(3 0)	25(3 8)	3 42(5 4)
T_3 ONIS	6 3( )	6 3( )	6 3( )	7 02(5)	7 02 5)	7 77(5)	7 77 5)	9 42(2 7)	0 93(3 6)
T_4 ONIC	7 93(9)	7 92 9)	9 42(2 7)	08(3 7)	2 09 4 4)	4 76 6 5)	7 02(8 6)	9 62 3)	24 7 (7 5)
T_5 SIC	34(3 9)	4 49(6 3)	6 8(7 8)	8 9 7)	20 67(2 4)	24 34(7 0)	24 49(8 5)	26 55(20 0)	29 30(24 0)
T_6 SNIC	7 93(9)	9 42(2 7)	83(4 2)	6 83 8 4)	8 79(0 4)	22 98(5 2)	23 68(6)	25 99(9 2)	28 47(22 6)
T SIS	5 3(0 8	9 25(2 6)	3 3(5)	4 65 6 4	4 65(6 4)	6 99 8 5)	8 03(9 6)	9 76(4)	23 27(5 6)
8 S IS	7 20 6	9 68 2 8	0 95(3 6)	2 05 4 4)	4 5 6 3)	6 2 8)	6 96 8 5	7 54 9)	7 54 9)
CD at 5%	5 034	5 37	6 94	7 250	7 277	7 658	7 095	6 477	7 77

s week $\overline{T_7T_3T_2T_8T_4T_6\ T\ T_5}$ 2nd week $\overline{T_3T_2T_4\ 7T_6T_8\ T\ T_5}$ 3rd week $\overline{T_3T_2T_4\ T_8T_6\ 7T_5}$

4th week $\overline{T_3T_2T_4T_8\ T_7T_6T_5T}$ 5th week $\overline{T_3T_2T_4\ T_8T_7T_6T_5T}$ 6th week $\overline{T_3T_2T_4\ T_8T_7\ 6\ T_5}$

7th week $\overline{T_3T_2\ T_8T_4T_7T_6\ T_5}$ 8th week $\overline{T\ T_2\ T_8T_4T_7\ T_6T\ T_5}$ 9th week $\overline{T_3T_2T_8\ T_7T_4T\ T_6T_5}$

(The figures in parenthesis a e et ansformed values)



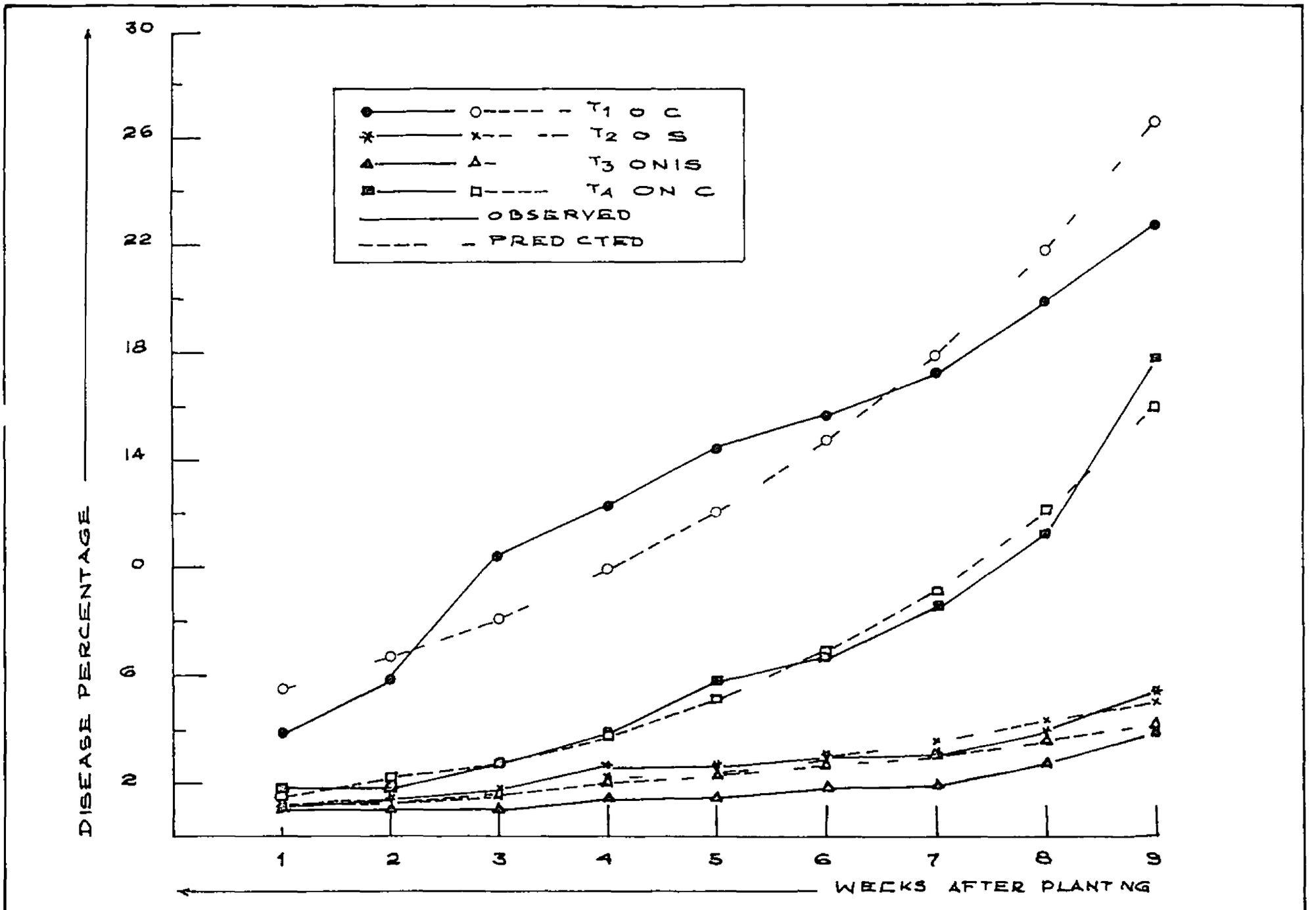


FIG 3 NOCULUM POTENTIAL OF *R solani* IN SOILS

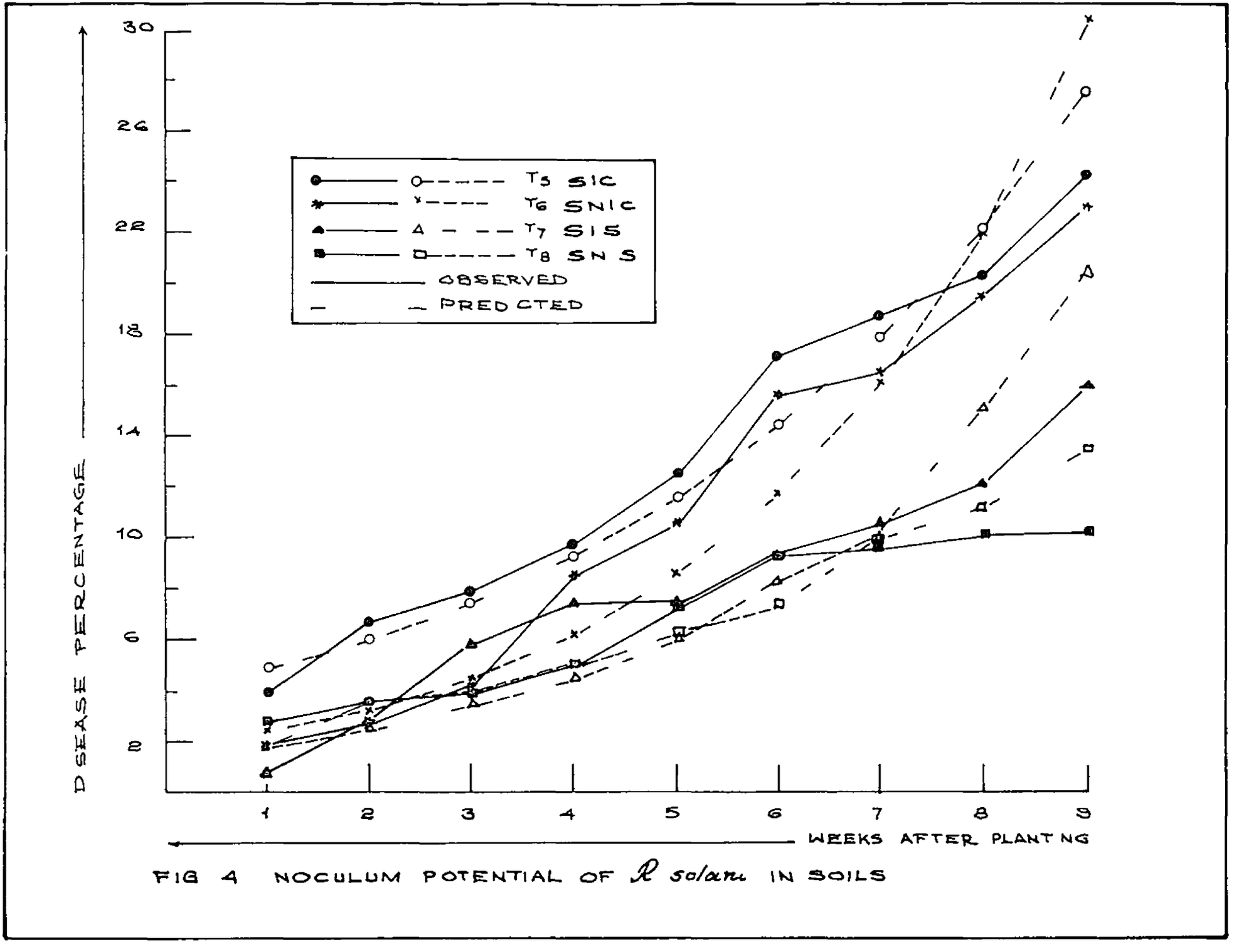


FIG 4 NOCULUM POTENTIAL OF *R solani* IN SOILS

There was marked difference in the disease incidence at the time of harvest. Maximum (24.0%) plants were killed in shade irrigated control, followed by open irrigated control (22.6%). While least incidence of the disease was noticed in open nonirrigated solarized (3.6%), followed by open irrigated solarized treatment (5.4%).

Eventhough there was significant difference among the various treatments at the time of harvest, it was not so, during the early stages of plant growth. During the first week, in the shade irrigated control, only 3.9% of the plants were diseased, which was on par with open irrigated control. All other treatments were not significantly different from one another. The same trend was noticed during the second week also. In the third week both open irrigated solarized and open nonirrigated solarized treatments showed no increase in the disease development. During this period, maximum increase in the incidence of disease, over the previous week, (table 4) was in open irrigated control (4.8%) followed by shade irrigated solarized treatment (2.5%). In the fourth week, shade nonirrigated control gave the maximum increase of disease over the previous week (4.2%). The trend was similar till the end of sixth week. However, from seventh week onwards the influence of solarization was noticeable. The solarized treatments in open were

Table 4

Effect of solarization on incidence of Collar rot of Cowpea
Per cent increase of collar rot over the previous week
(Retransformed values)

Treatment		Collar rot during 1st week	Increase over previous week							
			2nd week	3rd week	4th week	5th week	6th week	7th week	8th week	9th week
T_1	OIC	3.2	1.9	4.8	2.1	2.0	1.4	1.7	2.0	3.5
T_2	OIS	1.1	0.4	0	1.0	0	0.5	0	0.8	1.6
T_3	ONIS	1.1	0	0	0.4	0	0	0	1.2	0.9
T_4	ONIC	1.9	0	0.8	1.0	0.7	2.1	2.1	2.7	6.2
T_5	SIC	3.9	2.4	1.5	1.9	2.7	4.6	1.5	1.5	4.0
T_6	SNIC	1.9	0.8	1.5	4.2	2.0	4.8	0.9	3.1	3.4
T_7	SIS	0.8	1.8	2.5	1.3	0	2.1	1.1	1.8	4.2
T_8	SNIS	1.6	1.2	0.8	0.9	1.9	1.5	0.7	0.6	0

on par and were superior to other treatments. This trend was more noticeable in the last week, when the percentage of diseased plants in all the solarized treatments were less compared to nonsolarized ones (Figure 5). Neverthless, shade irrigated solarized treatment was not significantly different from the control treatments both in open and shade conditions. On examining the general trend of disease development in open, (figure 3) it is clear that the development pattern of the disease is similar for solarized and nonsolarized treatments. A similar picture was not observed under shaded conditions (Figure 4).

In the present study, the influence of shade, irrigation and solarization on the incidence of collar rot of cowpea was investigated. In order to find out the efficacy of these factors, independently the data was analysed using a 2^3 factorial experiment in RBD. The retransformed values obtained are presented in the table 5. A significant and effective control was noticed in solarized treatments (16.29%) compared to nonsolarized treatments (27.72%). However, such an influence was not observed when the factor irrigation was taken into account. The incidence of disease in irrigated (23.6%) and nonirrigated (20.41%) treatments were not statistically significant. The intensity of sun light

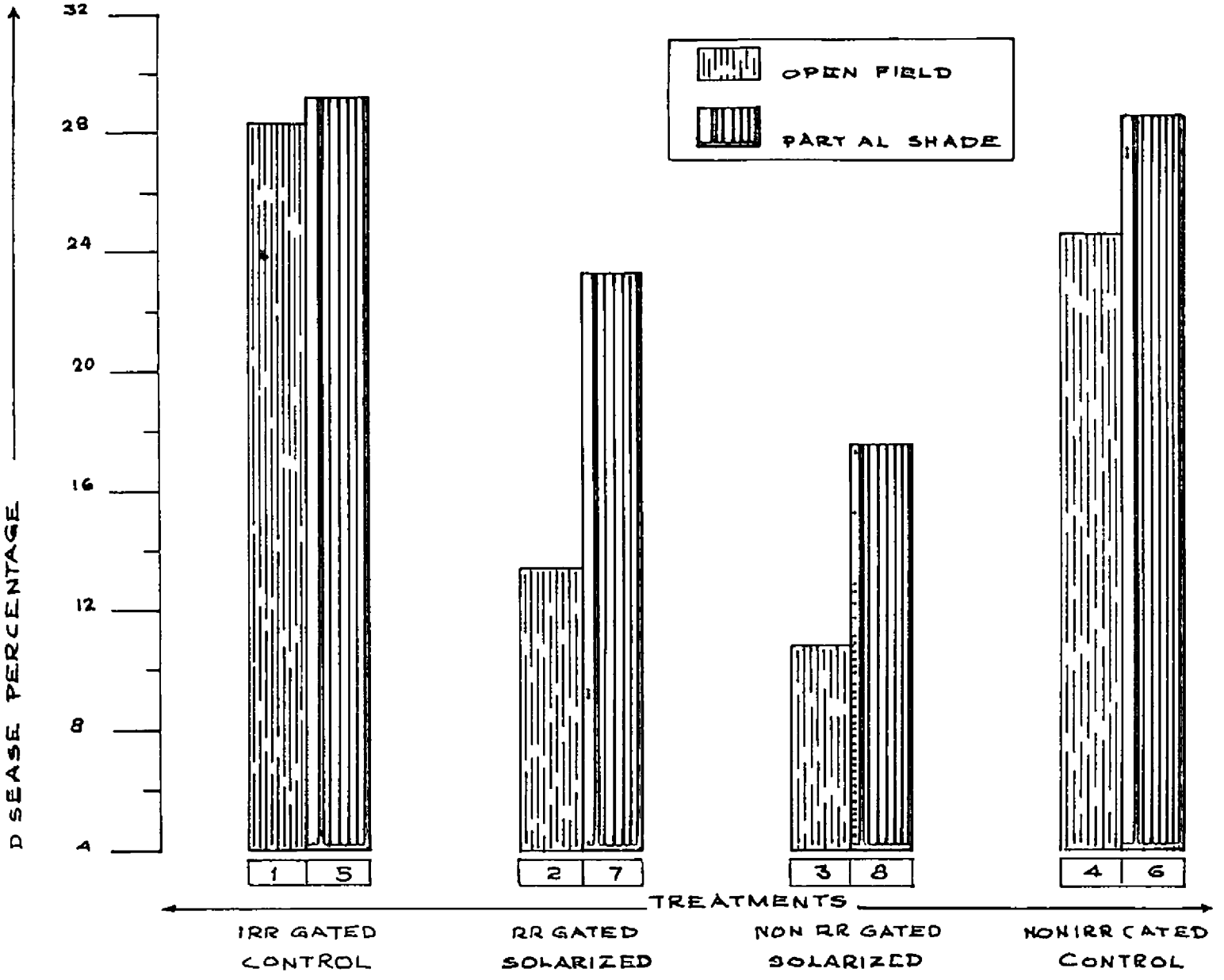


FIG 5 EFFECT OF SOLARZATON ON NCIDENCE OF COLLAR ROT OF COWPEA

Table 5

Effect of Shade, irrigation and solarization on collar rot of cowpea

Treatments and factors used for 2^3 factorial analysis

Treatments		Factors		Mean values (Retransformed)
T_1	Open irrigated nonsolarized	A - Shade	Open sun	19.37 Y**
T_2	Open irrigated solarized		Partial	24.64 Y
T_3	Open nonirrigated nonsolarized	B - Irrigation	Irrigated	23.60
T_4	Open nonirrigated solarized		Nonirrigated	20.41
T_5	Shade irrigated nonsolarized	C - Solarization	Solarized	16.29 Y**
T_6	Shade irrigated solarized		Nonsolarized	27.72 Y
T_7	Shade nonirrigated nonsolarized	C D for comparison of A, B and C at 5 per cent = 3.588		
T_8	Shade nonirrigated solarized	C D for comparison of A, B and C at 1 per cent = 4.884		
		$\overline{T_4T_2T_8}$ $\overline{T_6T_3}$ $\overline{T_1T_7T_5}$		

** Significantly different at 1 per cent level

greatly influenced the disease development. Significant control was obtained in the open (19.37%) compared to that under partial shade (24.64%). The interaction effect of the three factors was not statistically significant. (Appendix - II)

Disease prediction

From the data on the intensity of disease in the different treatments, an exponential model $Y = AB^t$ was developed for predicting collar rot of cowpea. In this model A & B two constants, t time in weeks and Y percentage of disease (Table 6). Coefficient of determination ranged from 78.66 to 98.30% in the various treatments (Figures 3, 4).

The rate of disease development (i) is given in table 6. From this it is evident that the rate of disease development in nonirrigated solarized treatment is the minimum (15.43%) while it is maximum in shade nonirrigated control (37.37%). Under open sun the percentage of disease development is less than 20% in both irrigated and nonirrigated solarized plots.

Soil microflora

Effect of solarization on fungal population

Solarization influenced the population of fungi in soil (Table 7, Appendix III). In order to arrive at

Table 6

Prediction of collar rot of cowpea

Treatments	Prediction equation	Coefficient of determination (%)	i
T_1 OIC	$Y = 4.48905(1.2187)^t$	87.35	31.87
T_2 OIS	$Y = 1.13432\ (1.18114)^t$	93.99	18.11
T_3 ONIS	$Y = 1.16624(1.15425)^t$	89.66	15.43
T_4 ONIC	$Y = 1.26369(1.32678)^t$	98.30	32.68
T_5 SIC	$Y = 3.94974(1.24137)^t$	95.73	24.14
T_6 SNIC	$Y = 1.74461(1.37373)^t$	93.74	37.37
T_7 SIS	$Y = 1.38467(1.34896)^t$	78.66	34.90
T_8 SNIS	$Y = 2.21431(1.22321)^t$	87.91	22.32

Y = Percentage of diseases.

i = Rate of disease development in per cent.

Tab e 7

Effect of solarization on soil mycoflora
($\sqrt{x}$ transformation)
(Mean values)

Treatments	Initial population	After solarization/ exposure	0 days after solarization	month after solarization	2 months after solarization	at final harvest
T OIC	6 33	4 846(22 48)	8 797(76 38)	6 475(40 93)	6 924(46 94)	6 768(44 81)
T_2 OIS	6 33	5 253(26 59)	2 256(49 2)	6 567(42 3)	6 665(43 42)	4 252(7 08)
T_3 ONIS	6 33	5 0(25 1)	8 035(63 57)	9 23(82 24)	6 222(37 7)	4 593(20 09)
T_4 ONIC	6 33	5 673(3 9)	8 43 (70 09)	8 570(72 44)	7 529(55 68)	5 975(34 70)
T_5 SIC	20 00	6 768(44 8)	9 950(98 0)	9 884(96 68)	9 692(92 94)	9 026(80 47)
T_6 SNIC	20 00	6 793(45 2)	8 443(70 29)	0 003(99 07)	9 485(88 96)	7 25(49 76)
T_7 SIS	20 00	7 857(60 73)	7 68 (58 0)	0 458(08 38)	10 320(05 50)	7 25 (5 58)
T_8 SNIS	20 00	8 28 (67 57)	8 520(7 58)	8 993(79 88)	9 4 0(87 54)	8 493(7 3)
CD at 5%	0 75 4 9		36855	0 83304	44505	3472
Ranking		$\overline{T\ T_3T_2T_4T_5T_6T_7T_8}$	$\overline{T_7T_3T_4T_6T_8T\ T_5T_2}$	$\overline{T\ T_2T_4T_8T_3T_5T_6T_7}$	$\overline{T_3T_2T\ T_4T_8T_6T_5T_7}$	$\overline{T_2T_3T_4T\ T_6\ 7T_8T_5}$

(Figures in parenthesis are retransformed values)

reliable conclusions, due weightage was given to the population of fungi that were present in each plot before the commencement of the experiment. In general, the fungal population was more in open field compared to the partially shaded condition and the effect of irrigation was not marked. The pattern of fluctuations of fungal population in various treatments were similar - A gradual increase in the population was noticed initially and then there was a decline (figures 6, 7). Immediately after solarization the least number of fungal colonies were noticed in the open irrigated nonsolarized (22.48) soil. While in shade maximum number of colonies was in nonirrigated solarised (67.57) treatment. On 10th day after solarization, however, all the different treatments except open irrigated solarized (149.21) and shade irrigated control (98.01) were on par. One month after solarisation, fungal population was least in open irrigated control (40.93), whereas it was maximum in the shade irrigated solarized treatment (108.38).

A reduction in the population of fungi in the open field is apparent from second month after solarisation. During this period the different treatments in open were on par and in partial shade also the different treatments did not show significant difference. The number of fungal

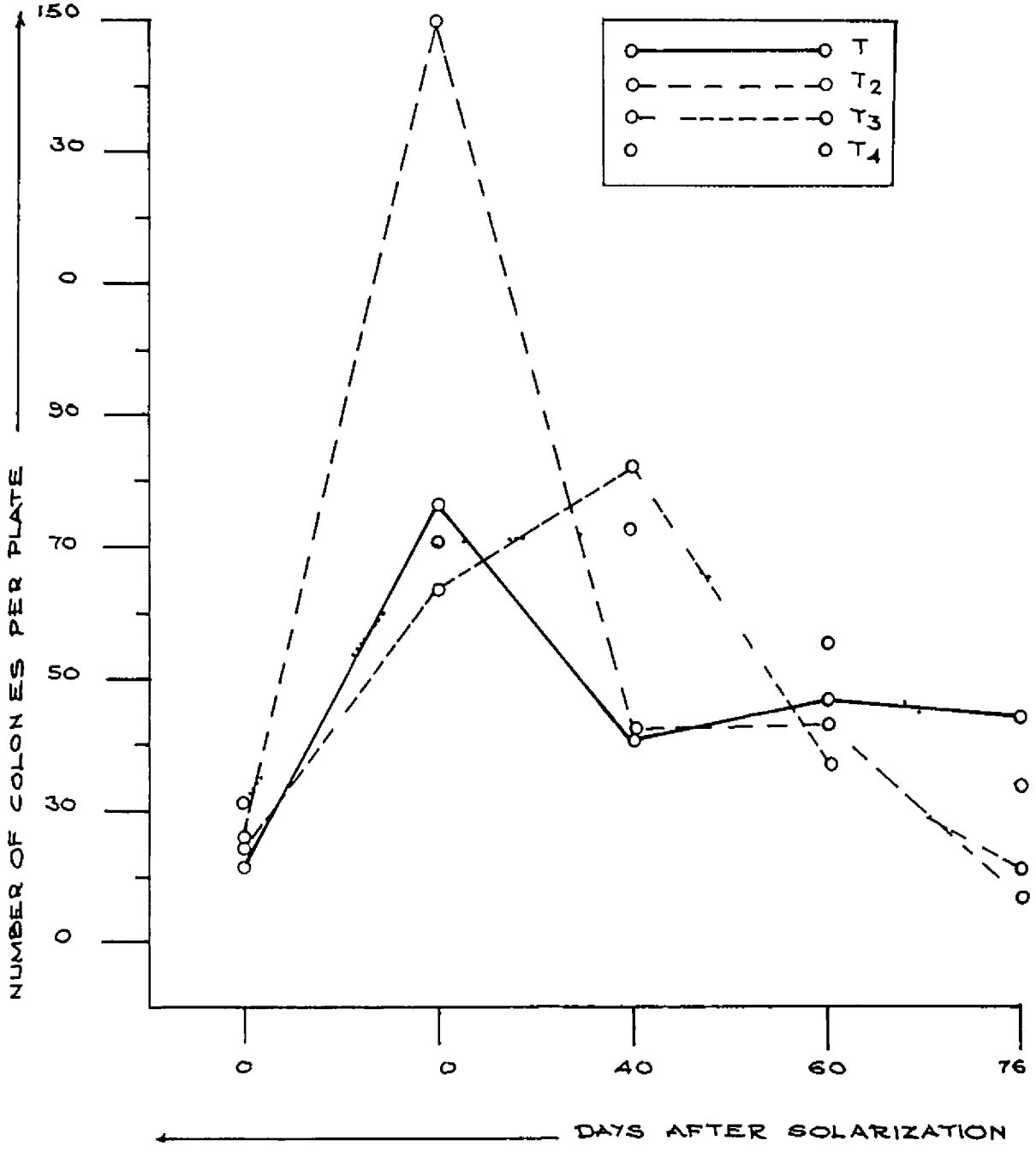


FIG 6 EFFECT OF SOLARIZATION ON SOIL MYCOFLORA IN OPEN FIELD

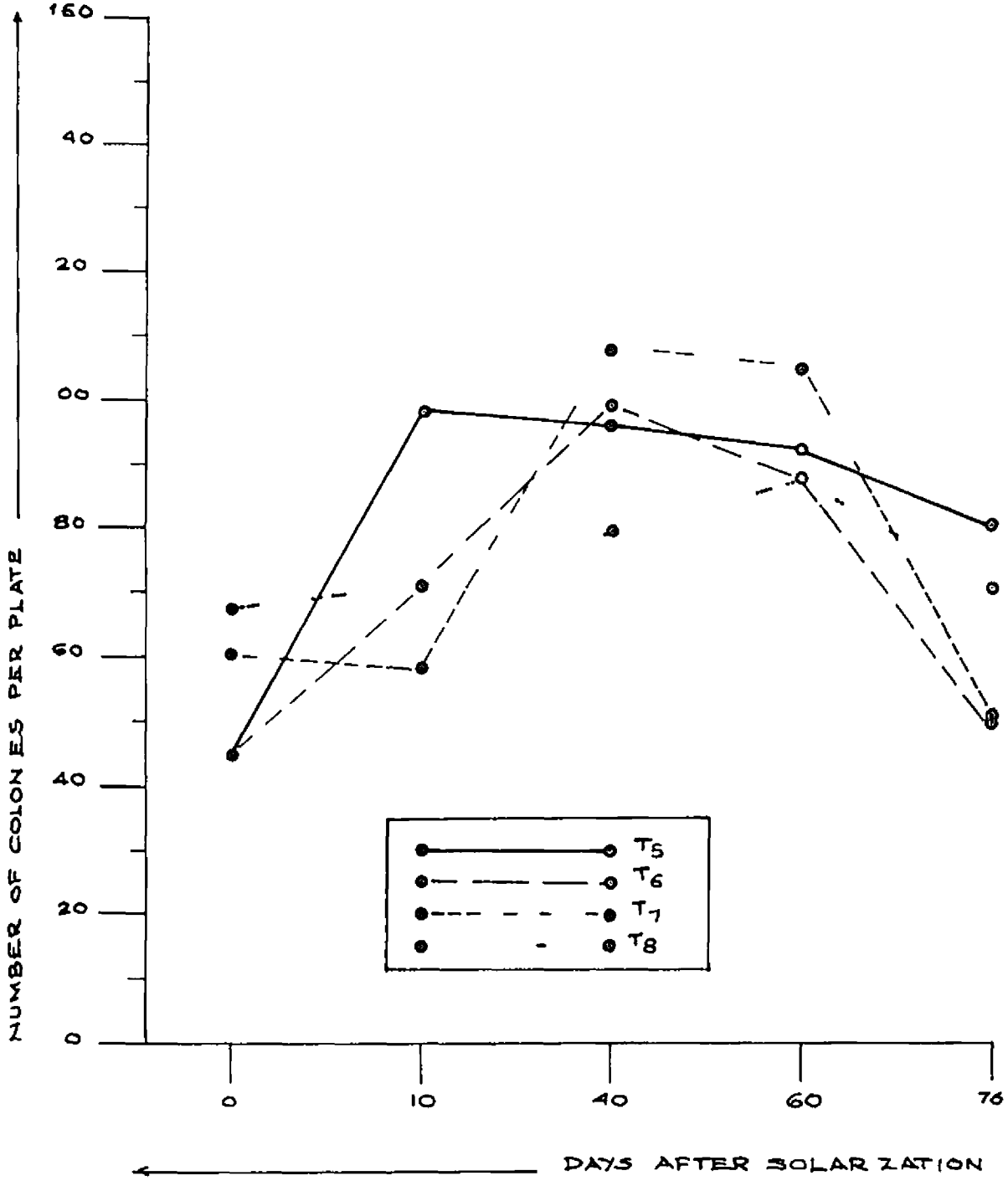


FIG 7 EFFECT OF SOLARIZATION ON SOIL MYCO-FLORA IN PARTIAL SHADE

propagules observed in open were significantly more then in shade. At harvest, solarized treatments in the open (irrigated and nonirrigated) harboured less number of fungal population (17.08 and 20.09). Under partial shade fungal population in irrigated non solarized treatment(80.47) and non irrigated solarized treatment (71.13) did not differ significantly.

Effect of solarization on bacterial population

The fluctuations in the population of bacteria in the different treatments in open and in shade showed a definite pattern. Under open conditions, in all treatments, bacterial population did not exhibit marked fluctuation till the end of two months after solarization. However, at the time of harvest there was a sudden increase (Figure 8). While under shade, in all the treatments, the bacterial count decreased till 10 days after solarization and since then there was a gradual increase in the count till the harvest (Figure 9).

Statistical analysis of the data (Table 8) immediately after solarization revealed that there was no significant difference among the different treatments in the open. Under partial shade also the effect was the same. However, the bacterial population in open treatments was less than in shaded soil. The bacterial

Table 8

Effect of solarization on Soil Bacteria
($\sqrt{x}$ transformation)
Mean values

Treatment		Initial population	After solarization	0 days after solarization	month after solarization	2 months after solarization	at final harvest
T_1	OIC	33	2 109(3 45)	959(2 84	8 8(2 30)	2 003(3 0)	4 030(5 24)
T_2	OIS	33	973(2 89)	805(2 26)	8 8(2 30)	2 53(3 63)	3 278(9 75)
T_3	ONIS	33	6 0(59)	854(2 44)	1 907(2 636)	2 303(4 30)	3 066(8 40)
T_4	ONIC	33	2 09(3 45)	2 353(4 54)	2 430(4 90)	2 368(4 6)	4 435(8 67)
T_5	SIC	4 00	2 816(6 93)	1 912(2 65)	3 052(8 32)	3 073(8 44)	4 97(6 6)
T_6	SNIC	4 00	2 830(7 0)	735(2 0)	2 6 (3 67)	2 894(7 37)	3 758 3 2)
T_7	SIS	4 00	2 776(6 7)	2 75(3 73)	2 082(3 34)	2 7 7(6 38)	4 97(6 6)
T_8	SNIS	4 00	2 770(6 67)	567 45)	2 54(3 64	3 063(8 38)	4 065(5 63)
CD at 5%		=	09978	24657	0 55400	0 50 82	0 9756
Ranking			$\overline{T_3T_2T\ T_4T_8T_7T_5T_6}$	$\overline{T_8T_6T_2T_3T_5T\ T_7T_4}$	$\overline{T\ T_2T_3T_7T_8T_6T_4T_5}$	$\overline{T\ T_2\ _3T_4T_7T_6T_8T_5}$	$\overline{T_3T_2T_6T\ T_8T_5T_7T_4}$

(Figures in parenthesis are retransformed values)

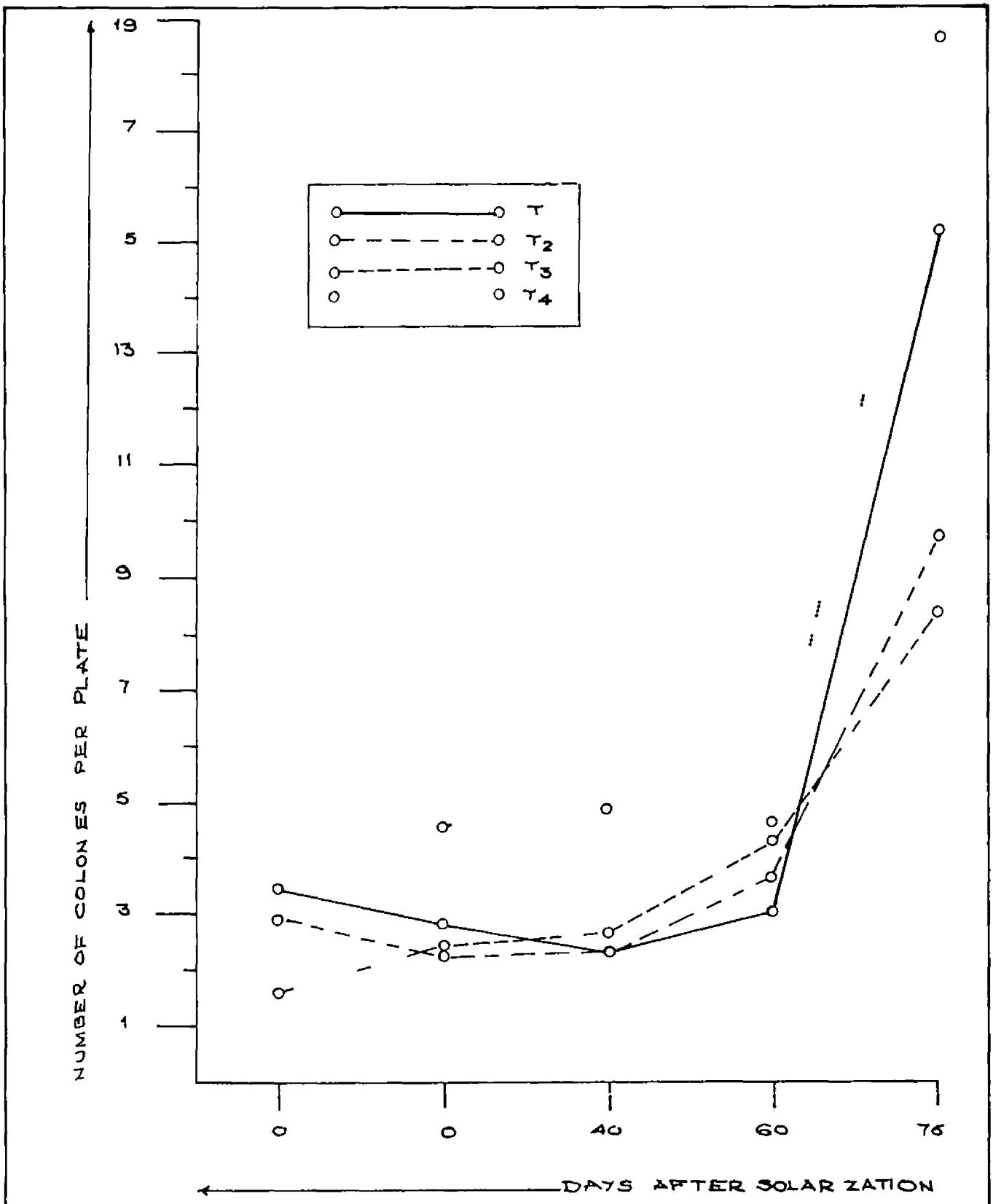
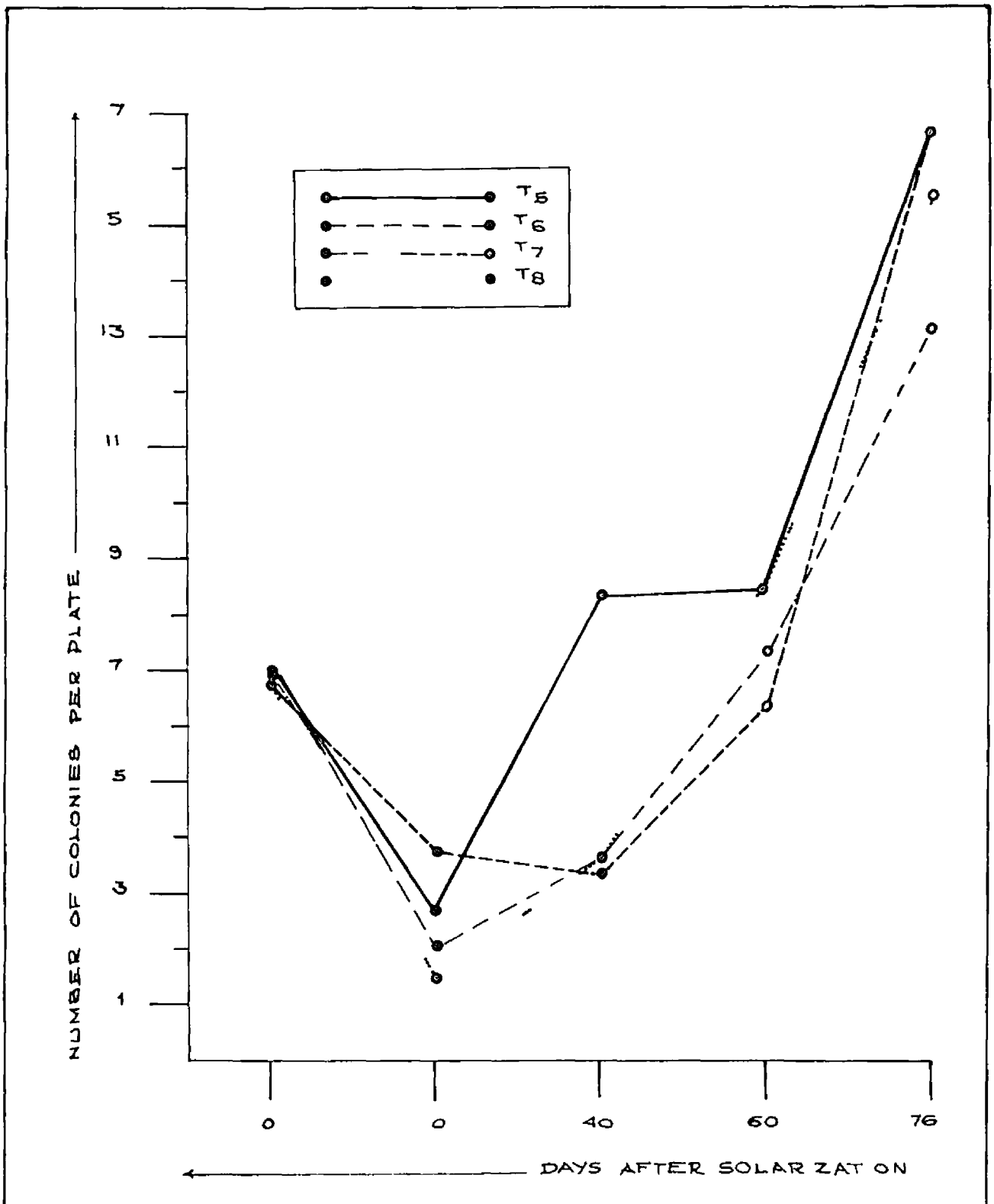


FIG 8 EFFECT OF SOLARZATION ON SOIL BACTERIA IN OPEN FIELD



FG 9 EFFECT OF SOLAR ZAT ON ON SOIL BACTERIA IN PART AL SHADE

population ranged from 1.59 to 3.45 in the open, while in shade it ranged from 6.67 to 7.01. On the tenth day after solarization, there was no significant difference among all the treatments under open and partial shade. One month after solarization, non-irrigated control, in shade supported the least bacterial population (8.32). As was observed at the end of 10 days after solarization, the bacterial count at the end of two months after solarization also did not differ significantly in open and in the shade. The bacterial population in different treatments at the time of harvest did not show any particular trend.

Effect of solarization on actinomycetes

The changes in actinomycetes population in open followed a definite trend. The actinomycetes population of all the treatments decreased slightly during the first ten days of solarization (Figure 10) and then from 10 day till one month, there was a gradual increase followed by a decrease till the end of two months after solarization. Then the population in all the treatments rapidly increased till the harvest.

The pattern of population fluctuation in shade, however, was entirely different. In all the treatments except in shade nonirrigated solarized, the population change was similar. In shade nonirrigated solarized

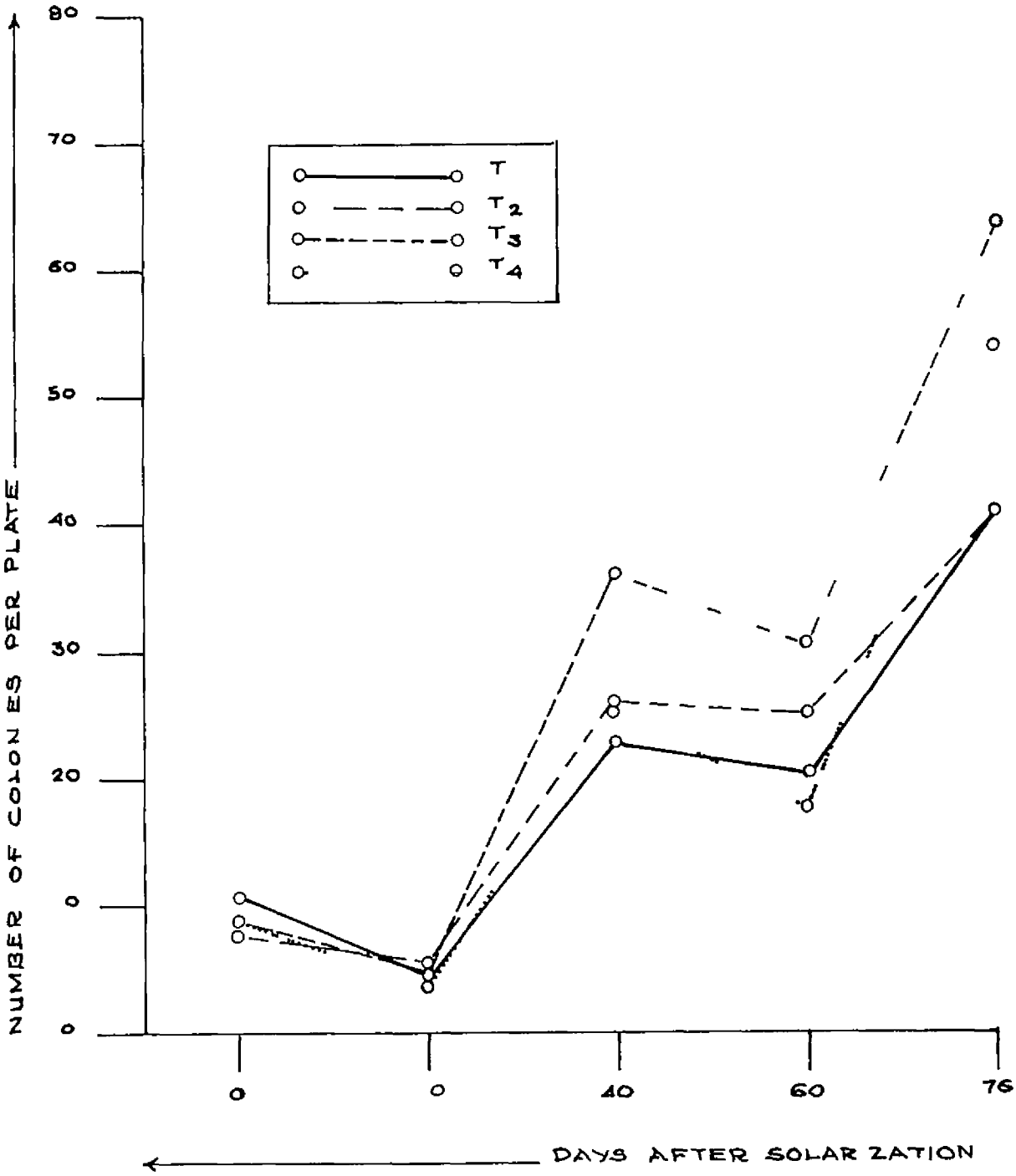


FIG 0 EFFECT OF SOLAR ZATON ON SOIL ACTINO-MYCETES IN OPEN FIELD

treatment the actinomycete count gradually increased till the harvest. While in other treatments the population increased till the first month and then there was a decline. (Figure 11).

Analysis of the data showed that solarization and irrigation had not much influence on the population of actinomycetes (Table 9). Immediately after solarization all the treatments in open except irrigated control supported lesser number of actinomycetes compared to the treatments in shade. This reduction in the population count of actinomycetes in open was pronounced till the end of two months after solarization. However, at the time of harvest shade irrigated control and shade nonirrigated control gave the least actinomycete count (21.16 and 24.11), while the treatment open nonirrigated solarized and shade nonirrigated solarized supported the maximum population (63.81 and 73.74).

Effect of solarization on nematode population of soil

Nematode population differed significantly among the various treatments at the time of harvest (Table 10). Nematode count was nil prior to solarization in all the plots. Immediately after solarization also only saprophytes were encountered, in all treatments. Population of nematodes in open nonirrigated solarized and open irrigated solarized treatments was less than in other

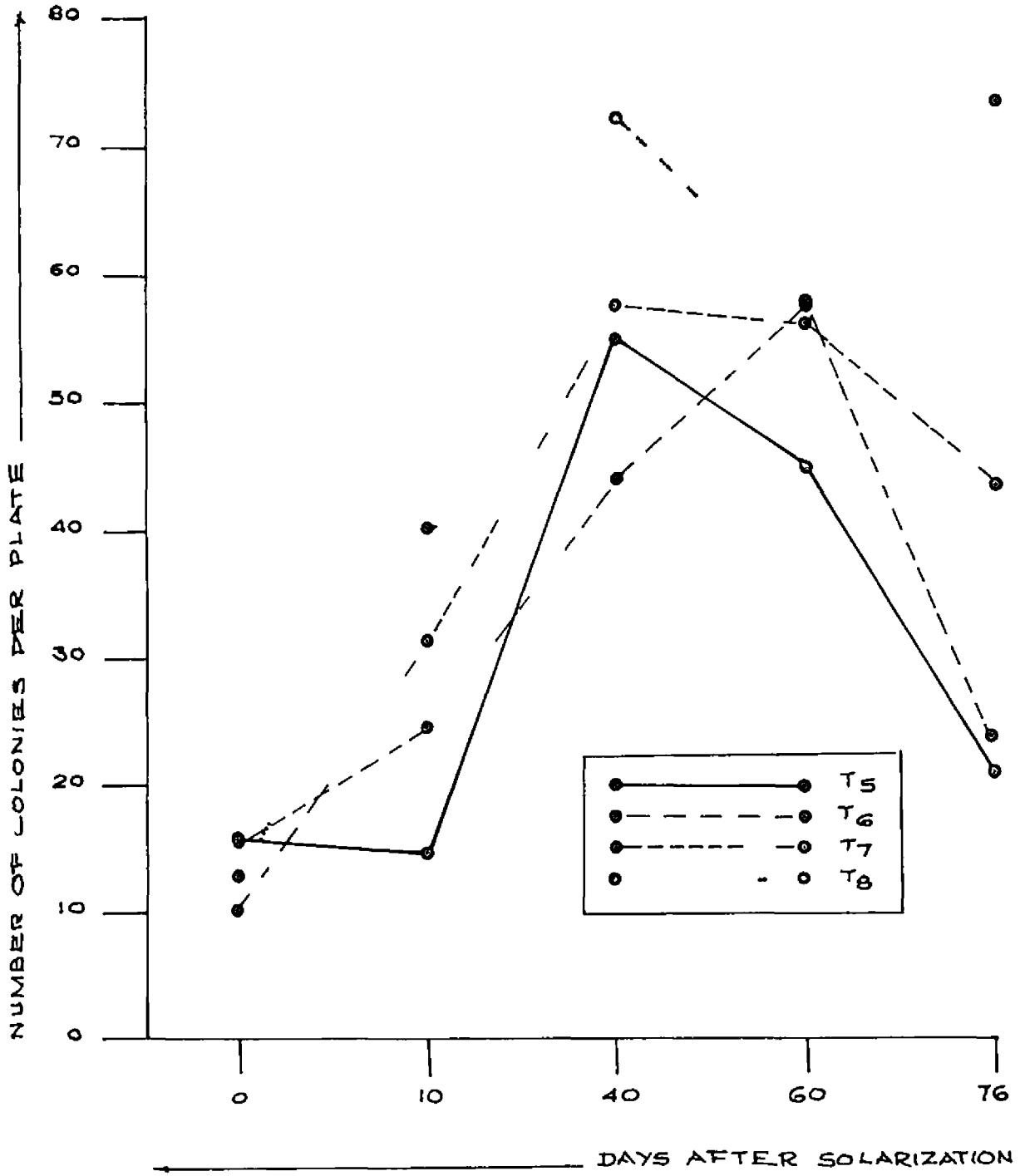


FIG 11 EFFECT OF SOLARIZATION ON SOIL ACTNOMY-CETES N PARTIAL SHADE

Table 9

Effect of solarization on Soil Actinomycetes

($\sqrt{x}$ transformation)

(Mean values)

Treatment	Initial popu ation	After solarization	0 days after solarization	month after solarization	2 months after solarization	at final harvest
T OIC	3 66	3 967(10 54)	2 458(5 04)	4 940(23 40)	4 643(20 56)	6 495(4 9)
T_2 OIS	3 66	2 997(7 97)	2 576(5 64)	5 208(26 2)	5 25(25 27)	6 485(41 06)
T_3 ONIS	3 66	3 60(8 99)	2 524(5 37)	6 05(36 27)	5 6 7(30 55)	8 050(63 8)
T_4 ONIC	3 66	3 207(9 28)	2 243(4 03)	5 75(25 78)	4 304(7 53)	7 429(54 8)
T_5 SIC	0 66	4 28(6 04)	3 996(4 97)	7 483(55 00)	6 8 5(45 44)	4 707(2 6)
T_6 SNIC	0 66	4 09(5 75)	5 079 24 80)	6 7 7(44 2)	7 657(57 62)	5 0 (24 1)
T_7 SIS	0 66	3 368(0 34)	5 698(3 47)	7 676(57 92)	7 60 (56 77)	6 699(43 88)
T_8 SNIS	0 66	3 70 (12 70)	6 4 4(40 4)	8 573(72 49)	7 688(58)	8 645(73 74)
CD at 5%	=	0 46713	0 68402	0 787 0	1 05449	0 98577
Ranking		$\overline{T_2T_3T_4T_7T_8T_1T_6T_5}$	$\overline{T_4T_1T_3T_2T_5T_6T_7T_8}$	$\overline{T\ T_4T_2T_3T_6T_5T_7T_8}$	$\overline{T_4T\ T_2T_3T_5T_7T_6T_8}$	$\overline{T_5T_6T_2T_1T_7T_4T_3T_8}$

(Figures in parenthesis are retransformed values)

Table 10

Effect of solarization on nematode population of soil ($\sqrt{x}$ transformation)

(Mean values)

Treatments	After solarization	At harvest
T_1 OIC	6.48(42.33)	10.06(101.33)
T_2 OIS	1.38(2.0)	3.39(11.33)
T_3 ONIS	1.15(2.0)	2.81(8.0)
T_4 ONIC	6.70(45.0)	7.94(63.33)
T_5 SIC	8.69(75.67)	10.39(111.33)
T_6 SNIC	8.62(74.33)	4.10(17.0)
T_7 SIS	8.03(64.67)	5.19(26.33)
T_8 SNIS	8.25(68.33)	7.11(51.33)
CD at 5%	0.7980	0.7039
Ranking	$\overline{T_3 T_2 T_1 T_4 T_7 T_8 T_6 T_5}$	$\overline{T_3 T_2 T_6 T_7 T_8 T_4 T_1 T_5}$

(Figures in parenthesis are retransformed values)

treatments (2.0) and were on par. There was no significant difference among solarized and nonsolarized treatments under partial shade immediately after solarization.

At harvest, saprophytic and parasitic nematodes were noticed in all the treatments. The parasitic species included Helicotylenchus, Tylenchorynchus, Hoplolaimus and Xiphenema. The least number of nematodes at harvest, was noticed in open nonirrigated solarized (8.0) followed by open irrigated solarized treatment (11.33) and both these were on par, but were significantly different from all other treatments. However nonirrigated control was superior to the solarized treatments, in partial shade.

Effect of solarization on weed population

The field where the experiment was conducted, had 12 different species of weeds (Table 11), of which nine belonged to the dicots. Population of weeds were more in partially shaded conditions. The mean weed population before solarization in the open ranged from 11.25 to 16.25 in the different plots. In open no weeds were noticed immediately after the removal of polythene sheets in solarized treatments as against 23.25 and 31 weeds in the control treatments. One month after solarization also there was absolute weed control in solarized plots

Tab e

Effect of solar zation on weed population
(Mean values)

Weeds*	Treatments (In open)															
	Treatment (T)				Treatment 2 (T_2)				Treatment 3 (T_3)				Treatment 4 (T_4)			
	B/S**	A/S	IA/S**	H**	B/S	A/S	IA/S	H	B/S	A/S	IA/S	H	B/S	A/S	IA/S	H
	7	0 25		5	5			0 75	7 5			25	8 5			
2		5		4 75				6				2 25			25	0 75
3	2 5	2 5		0 75	8 5			2	6 5			5	3	3 25	0 5	75
4	1 75	2 25	0 5	5				0 75	2 25			1 5	2 5	1 5	0 75	75
5		0 25										3 5	75			
6		10 5		33				6 75				8 5		3	2	25
7																
8		3 75	0 75											3 5	0 5	
9				2 75											2	
0				2				5				0 25				25
2															0 75	
	11 25	3 00	2 25	46 25	4 5			7 75	6 25			18 75	5 75	23 25	3 00	4 50

(Contd 2)

eeds	Treatments (In shade)															
	Treatment 5 (T_5)				Treatmen 6 (T_6)				Treatment 7 (T_7)				Treatment 8 T_8)			
	B/S *	A/S	IA/S	H	B/S	A/S	IA/S	H	B/S	A/S	IA/S	H	B/S	A/S	IA/S	H
	25			3	3 5	0 25		5	0 75			3 75	5	25		75
2	7 5	6 25	0 75		3	2			2 25	2 5		2 75	5	5 75		5
3								0 25								
4	75		0 75	0 25	2 25		0 25	75					75			
5	5 25			0 5				0 25		3		0 5		0 5		0 75
6	20 25	49 00		8 5	93	43 5		7 25	70	29		2 75	00 75	4 75		7 25
	3 75	2		3		25		3 75		25		0 25	6 25	0 75		0 5
8		5	0 5			3 5										
9				2 75				4		2755				466 5		
0				0 5												
		25				3 5		7 75				3				25
2				3				25				4 25				2 5
Total	39 75	60 00	2 00	3 50	02 75	65 00		25 38 75	94 00	28 3 75		0 27 25	75	489 50	0	25 50

Name of weeds

	sachne miliacea	2	Brachia ia ramosa	3	erremia t dentata	B/S Before solar zation
4	Hem desmus indicus	5	Desmodium tr fo ium	6	Alteranthe a sessilis	A/S = Afte Solar zation
7	Cur u igo orchioides	8	Sebastina chamaelea	9	Linde a rustacea	IA/S month afte Solarization
0	Oldenlandia corymbosa		Ageratum conyzoides	2	Emilia sonetrifolia	H At harvest

**

in the open while two to three weeds were observed in the nonsolarized plots. At the time of harvest also the total weed population in solarized treatments was less than 50% of that observed in nonsolarized treatments. The number of weeds ranged from 17.75 in open irrigated solarized to 18.75 in open nonirrigated solarized against 41.5 in open nonirrigated control to 46.25 in open irrigated control treatments.

In partial shaded condition the total weed population before solarization ranged from 102.75 to 194. During solarization the weed Lindernia crustacea (Sacrophulariaceae) germinated profusely and a thick growth of the weed appeared as a pale green carpet under the cover in the solarized treatments. It decayed even before the removal of the polythene cover. This weed was successfully controlled in the solarized plots during the crop season. Apart from this there was not much difference in the total weed population among the solarized and nonsolarized treatments in the shaded conditions at harvest.

Effect of solarization on plant growth

The results of the observations are presented in table 12. In general, plants in partial shade were taller compared to open treatments. The plants in open

Table 12

Effect of solarization on growth paramaters
Height of plants
(Mean values)

Treatments	Days after planting			
	20th	40th	60th	at harvest
T_1 OIC	8.5	20.62	29.56	30.68
T_2 OIS	8.25	18.68	39.50	41.37
T_3 ONIS	7.59	14.00	30.43	31.87
T_4 ONIC	7.62	11.68	18.18	19.43
T_5 SIC	10.81	19.50	34.12	35.87
T_6 SNIC	11.31	28.93	35.68	37.25
T_7 SIS	13.12	56.50	70.00	68.06
T_8 SNIS	12.06	49.12	70.50	74.06
CD at 5%	1.168	22.881	26.51	26.647
Ranking	$\overline{T_7 T_8 T_6 T_5 T_1 T_2 T_4 T_3}$	$\overline{T_7 T_8 T_6 T_1 T_5 T_2 T_3 T_4}$	$\overline{T_8 T_7 T_2 T_6 T_5 T_3 T_1 T_4}$	$\overline{T_8 T_7 T_2 T_6 T_5 T_3 T_1 T_4}$

nonirrigated control were shorter compared to plants in other treatment.

Solarization has exerted some influence on leaf production in open solarized treatments whereas it was not so under partial shade. However, irrigated solarized treatment and nonirrigated solarized treatment in open were on par and superior in leaf production, though open irrigated control treatment was not inferior to the above two treatments. This trend was seen throughout the crop period. In partial shade solarized treatments though ranked better were on par with other treatments.(Table 13)

Nodulation

More number of nodules were noticed under partial shade than in open conditions. The influence of solarization was evident both in open and partially shaded conditions. However there was no significant difference between irrigated and nonirrigated solarized treatments either under shade or open conditions (Table 14). The least number of nodules were observed in open irrigated control (2.4) while the maximum was noticed in shade irrigated solarized treatment (10.36).

Yield

A significant increase in the yield of cowpea was observed in solarized plots (Table 15). This was more evident in the open solarized field. Open nonirrigated

Table 13

Effect of solarization on growth parameters
Number of leaves
Mean values
($\sqrt{x}$ transformation)

Treatments		Days after planting → 20th	40th	60th	at harvest
T_1	OIC	2.38(5.67)	3.77(14.75)	4.63(21.48)	4.85(23.55)
T_2	OIS	2.27(5.18)	4.00(16.18)	5.26(27.76)	5.52(30.53)
T_3	ONIS	2.20(4.87)	3.61(13.12)	4.66(21.80)	4.87(23.73)
T_4	ONIC	2.19(4.80)	3.22(10.56)	3.71(13.78)	3.95(15.62)
T_5	SIC	2.13(4.55)	3.01(9.18)	3.60(12.97)	3.72(13.86)
T_6	SNIC	2.16(4.68)	3.15(10.12)	3.77(14.26)	3.94(15.56)
T_7	SIS	2.19(4.81)	3.57(12.87)	4.12(17.06)	4.12(18.05)
T_8	SNIS	2.13(4.56)	3.16(10.06)	3.89(15.17)	4.02(16.17)
CD at 5%		0.136	0.663	0.706	0.675
Ranking		$\overline{T_1 T_2 T_3 T_7 T_4 T_6 T_8 T_5}$	$\overline{T_2 T_1 T_3 T_7 T_4 T_8 T_6 T_5}$	$\overline{T_2 T_3 T_1 T_7 T_8 T_6 T_4 T_5}$	$\overline{T_2 T_3 T_1 T_7 T_8 T_4 T_6 T_5}$

(Figures in parenthesis are retransformed values)

Table 14

Effect of solarization on nodulation in cowpea ($\sqrt{x}$ transformation) (Mean values)

Treatments		Mean values
T_1	OIC	1.54 (2.40)
T_2	OIS	1.75 (3.07)
T_3	ONIS	1.86 (3.49)
T_4	ONIC	1.72 (2.99)
T_5	SIC	2.42 (5.90)
T_6	SNIC	2.76 (7.66)
T_7	SIS	3.21 (10.36)
T_8	SNIS	3.18 (10.17)
CD at 5%		0.262
Ranking		$\overline{T_7\ T_8}\ T_6\ T_5\ \overline{T_3\ T_2\ T_4\ T_1}$

(Figures in parenthesis are retransformed values)

Table 15

Effect of solarization on yield in cowpea

Treatments		Mean yield (g)	
		Treatment	Percentage increase on control
T_1	OIC	126.08	-
T_2	OIS	152.94	21.30
T_3	ONIS	154.71	21.69
T_4	ONIC	127.13	-
T_5	SIC	126.45	-
T_6	SNIC	129.25	-
T_7	SIS	140.42	11.00
T_8	SNIS	139.11	7.62
CD at 5%	= 15.160		
Ranking		$\overline{T_3T_2T_7}\ \overline{T_8T_6T_4T_5T_1}$	

solarized treatment gave the maximum yield (154.71) per plot followed by open irrigated solarized treatment (152.94 g) and irrigated solarized treatment under partial shade (140.42 g). All these three treatments were on par and significantly different from other treatments. Nonirrigated solarized treatments under shade (139.11 g) was on par with irrigated solarized treatment in shade. The yield recorded in all the nonsolarized plots were poor and the lowest yield of 126.08 g per plot was recorded in the open irrigated nonsolarised treatment.

The influence of solarisation was not evident when yield per plant was compared. The yield per plant varied from 2.42 g in Open nonirrigated control to 2.62 g in open irrigated solarized and shade nonirrigated control treatments.

Statistical analysis of the data revealed that yield was negatively corelated with collar rot of cowpea.

Effect of solarization on the availability of plant nutrients

Solarization has been found to influence the availability of nutrients. Table (16). Small fluctuations in nitrogen level were observed in different treatments as a result of solarization. In open solarized treatments the available nitrogen increased from 0.039% (before solarization) to 0.042% and under partial shade it increased from 0.033% to 0.045%.

Table 16

Effect of solarization on nutrient status pH and Electrical conductivity o soil
(Mean values)

	Treatments (in open)											
	T			T_2			T_3			T_4		
	B/S	A/S*	H*	B/S	A/S	H	B/S	A/S	H	B/S	A/S	H
Avai able nitrogen %)	0 039	0 039	0 039	0 039	0 042	0 04	0 039	0 042	0 04	0 039	0 040	0 043
Available phosphorus (%)	0 0009	0 00	0 0025	0 0009	0 00 3	0 00 0	0 0009	0 00 5	0 00 3	0 0009	0 00 0	0 00 8
Exchangeab e potassium (%)	0 0089	0 0 52	0 0 00	0 0089	0 0 52	0 0094	0 0089	0 0 60	0 0086	0 0089	0 0 76	0 0092
Exchangeable calcium (%)	0 00425	0 002 2	0 04880	0 00425	0 00595	0 03039	0 00425	0 00532	0 02577	0 00425	0 00457	0 0378
Exchangeab e magnesium (%)	0 0082	0 0099	0 00622	0 0082	0 0082	0 00483	0 0082	0 00907	0 00357	0 0082	0 00852	0 00478
O ganic Carbon (%)	0 435	0 472	0 472	0 435	0 5	0 50	0 435	0 5	0 458	0 435	0 48	0 52
p^H	4 8	4 8	5 2	4 8	4 8	4 8	4 8	4 8	4 7	4 8	4 9	4 7
Electrical conductivity (mmhos/cm	0 2	0 2	0 2	0 2	0 2	0 2	0 2	0 2	0 2	0 2	0 2	0 2

(Contd 2)

	Treatments (in shade) (Mean values)											
	T_5			T_6			T_7			T_8		
	B/S	A/S	H	B/S	A/S	H	B/S	A/S	H	B/S	A/S	H
Available nitrogen %)	0 033	0 036	0 04	0 033	0 03	0 036	0 033	0 045	0 042	0 033	0 038	0 040
Available phosphorus (%)	0 00	0 00 4	0 002	0 00	0 00 6	0 00 7	0 00 1	0 0022	0 0019	0 00	0 0020	0 0024
Exchangeable po assium (%)	0 0 94	0 0 72	0 0076	0 0 94	0 0 0	0 0072	0 0 94	0 0 92	0 0088	0 0 94	0 0 86	0 008
Exchangeable calc um (%)	0 00277	0 00972	0 02500	0 00277	0 00953	0 03358	0 00277	0 00809	0 0402	0 00277	0 00789	0 05 8
Exchangeable magnesium (%)	0 0 0	0 00628	0 00468	0 0 0	0 00634	0 0083	0 0 00	0 0099	0 00560	0 0 00	0 00752	0 00489
Organic Carbon (%	0 0435	0 465	0 49	0 435	0 472	0 435	0 435	0 495	0 505	0 435	0 487	0 483
p^H	6 0	5 9	5 8	6 0	5 9	5 8	6 0	5 9	5 7	6 0	6 0	5 6
Elect ical conductivity (mmhos/cm)	0	0 5	0 3	0	0 2	0	0	0 2	0 5	0	0 5	0

* B/S = Before Solarization A/S = After Solarization H = At Harvest

Changes in the status of available phosphurus in solarized treatments both in open and shade were similar to that observed in the case of available nitrogen. In all nonsolarized treatments there was an increase of available phosphurus in both open and partial shade immediately after solarization.

The effect of solarization on the availability of potassium in open and partial shade was different. In open, an increase in potassium level was noticed in all plots, both solarized and nonsolarized. In shade, availability of potassium in solarized and non-solarized treatments declined, but the decrease was more in nonsolarized treatments.

The status of exchangeable calcium both in open end shade, immediately after solarization, was slightly influenced by solarization.

All treatments (solarized and nonsolarized) in shade immediately after solarization showed a decrease in magnesium level where as such decrease was not noticed in open treatments.

Solarization exerted marked influence on the organic carbon content of soil. Immediately after solarization, organic carbon increased from 0.435 to 0.510% in open solarized treatments, where as it increased

from 0.435 to 0.495% in shade solarized treatments. In nonsolarized treatments both in open and shade, the increase was not marked as was observed in solarized treatments.

The soil pH level in general was not altered markedly as a result of solarization. However, pH ranged from 5.6 to 6.0 in shade compared to 4.7 to 5.2 in open. The results indicated no marked change in E.C due to solarization (Table 16).

DISCUSSION

DISCUSSION

Soil borne fungal pathogens (Katan 1981, Martyn and Hartz (1985) and other soil organisms (Stapleton and De Vay (1982, 1984) have been reduced in population following solarization. Solarization has also been found to be very effective in reducing parasitic nematodes (Katan 1981, Stapleton and De Vay 1983) and weeds (Rubin and Benjamin 1983, Horowitz et al.,1983, Egley 1983). This in turn helps to increase the yield of the plants considerably.

Soil temperature is increased by mulching with polythene sheets in the process of solarization. In the present experiment soil temperature was upto 10.8^{o}C above the atmospheric temperature in open and it was almost similar or slightly higher than atmospheric temperature under shaded condition. Increase in soil temperature as a result of plastic mulching has been reported by earlier workers (Katan et al. 1976, 1980, Grinstein et al.,1980). In the present experiment increase in temperature in open solarized soil (over the atmospheric) was lesser than that reported elsewhere (Grinstein et al., 1979, Katan et al. 1981, Pullman et al. 1979). In most of the places where solarization was tried, the atmospheric temperature was higher than what was observed here.

Further, in most of the studies, thinner polythene sheets (25-30 μm) were used. In the present study comparatively thicker polythene sheet (50 μm) was used. Thinner sheets are more efficient in increasing the soil temperature than thicker ones. (Katan 1980, Pullman et al. 1981). In most of the trials conducted elsewhere soil temperature was recorded at 5 cm below the soil. In the present study soil temperature was observed only at 15 cm depth. With increasing soil depth, maximal soil temperature decreased as a result of the soil's high thermal capacity and poor conductivity.

Under partial shade, increase in temperature in solarized soil was less than in open. Low air temperature due to the canopy of coconut leaves may be responsible for this. Reduction in the penetration of solar radiation to the soil by covering with black polythene caused a significant decrease in soil temperature elevation (Rubin and Benjamin 1983). The increase in soil temperature in mulched soil is due to the "green house effect" caused by polythene and it varies with air temperature, humidity, radiation, wind velocity and soil characteristics. (Katan 1981, Mahrer 1979). Temperature of soil mulched with black polythene is usually less than that in open nonmulched soil (Katan et al. 1976, Kodama et al. 1979). The role of coconut leaves

in partial shaded condition may be similar to black polythene. The canopy of coconut leaves also prevents the sunlight directly reaching the soil. This indicates that plastic mulching of soil under a coconut canopy is not effective in increasing soil temperature.

Mulching with polythene sheets, reduced the collar rot of cowpea, caused by Rhizoctonia solani (Table 3, Appendix I). Maximum number of plants were killed in shade irrigated control (24.0%) followed by open irrigated control (22.6%). Lowest number of diseased plants (3.6%) was in open nonirrigated solarized treatment followed by open irrigated solarized treatment (5.4%).

R. solani survives unfavourable climatic conditions and non crop periods in the form of sclerotia. Effective control of the disease could be achieved only when the resting structures of the fungus are killed. Maximum soil temperature recorded in solarized soil at 15 cm depth was only 42.5^{o}C which is below the lethal temperature of sclerotia of the fungus, (Pullman et al.,1981). This temperature though not lethal could injure sclerotia. The injured sclerotia are easily attacked by soil microorganisms (Baker Cook 1974, Katan 1980).

The propagules of pathogenic fungi become more vulnerable to other soil microorganisms, when exposed to sublethal dosages of temperature. This has already been

suggested as a tool for achieving an integrated control through a synergestic effect (Katan 1981). This has been demonstrated in the case of Armillaria mellea (Munnecke et al. 1976) and in Sclerotium rolfsii (Lifshitz et al., 1983, Elad et al.,1980).

The effectiveness of sublethal temperature in reducing the population of the sclerotia might be due to either the direct cumulative effect on sclerotia (Katan et al. 1976) or to a combination of thermal and biological factors. On a perusal of the data, on disease incidence recorded at weekly intervals, (Table 2) it is clear that the number of diseased plants in solarized treatments in open was less initially. During the 8th and 9th weeks there was a sudden increase in the number of infected plants in open solarized plots. Sublethal temperature causes delay in germination of sclerotia of R. solani. This varied with temperature and duration of exposure. The germination delay was the longest when the organism was exposed to high temperature. The longer a propagule was heated, the longer it required to germinate indicating that heat damage accumulated gradually to a point beyond which propagule cannot recover (Pullman et al.,1981). A partially viable propagule may recover and resume its course of development, if given normal conditions and sufficient time. The build up of inoculum from survived sclerotium takes time to reach a

level to initiate the disease. Increase in the incidence of disease in solarized plots during later periods in the experiment (Table 3) may be due to one of the above factors. Similar effects of heat, on Armillaria mellea (Munnecke et al.,1976) Botrytis cinerea (Smith 1923) Verticillium dahliae, Thielaviopsis basicola, Pythium ultimum and Rhizoctonia solani (Pullman et al., 1981). Under field conditions the recovery of the partially viable propagules may be further restricted by different stress factors including the activity of other soil microorganisms. (Katan 1981, Pullman et al., 1981).

Apart from decreasing the viability of propagules, solarization may also reduce the capacity of the propagule to incite disease. Even if the same number of viable propagules taken from solarized and nonsolarized treatments are allowed to infect the same number of plants, the probability that solarized viable propagules causing the disease is less compared to viable propagules from the nonsolarized treatments (Pullman 1979).

Baker (1962) opined that solarization may create a shift in microbial population in the soil in favour of heat resistant saprophytes. This is expected as most pathogens are less resistant to heat than saprophytes (Baker 1962). Injury caused to selerotia by solarization

might also increase leakage of sugar and aminoacids (Lifshitz et al.,1983). This attracts other microorganisms to the sclerotial surface and may kill the sclerotia through the production of toxic metabolites.

Under normal conditions free exchange of gases takes place in soil and whatever volatiles produced escapes to the air. Permeability of polythene to gases is low. The lethal effect of increased quantities of soil volatiles is more on parasitic fungi than on saprophytes in the soil, (Peethambaran 1975). Thus the accumulation of volaties under polythene mulch might have also helped in inactivating or killing the sclerotia of R. solani in the soil and thereby reducing the disease incidence.

Maintenance of fairly high moisture is necessary for getting better control of soil pathogens using solarization (Katan et al.,1976, Elad et al. 1980). In the present study significant control was obtained in the irrigated solarized plot. This is in agreement with the results obtained by Katan (1981) and Horiuchi (1984). However it may be mentioned that significant disease control was noticed in the nonirrigated plots also. This could be due to the effect of heavy rainfall received in the area 3 days before polythene mulching.

Under partially shaded conditions disease control was not effective as that noticed in solarized and nonsolarized treatments in open, (Table 3). As is clear from table 1, soil temperature in nonsolarized partially shaded treatments is less than the air temperature recorded under open condition while soil temperature in solarized partially shaded treatments is almost equal to open air temperature or slightly higher. Thus temperature might not have played any role in reducing the population of pathogenic fungi in shaded conditions.

Shade, irrigation and solarization are the three variables studied in the present investigation. A 2^3 factorial analysis of the data (Table 5, Appendix II) shows that there is significant reduction of the disease in the open sun compared to the shade and in solarized treatment compared to nonsolarized treatment. The result of the analysis on the effect of irrigation on disease control requires further confirmation because the present study was not conducted under controlled conditions and even the nonirrigated plots received ample moisture as a result of the rainfall three days before mulching. Even in the same treatment disease control is more effective when the field is fully exposed to sun, rather than in an area under perennial crop like coconut. Solarization

independently or coupled with other factors is found to be superior to nonsolarized treatments.

From the data on atmospheric temperature, soil temperature and intensity of disease, two models were developed. (1) Simple regression equation $Y = (A+B)\ x$ (Where Y = Soil temperature under polythene cover at 15 cm depth, X = air temperature, A and B constants). Using this equation it is possible to calculate soil temperature under plastic mulch provided air temperature is known. (2) An exponential model $Y = (AB)^t$, (where Y = percentage of disease, t = time in weeks, A and B constants). This could be used to predict the per cent incidence of disease at different intervals after planting.

Thermal death point of different pathogenic microorganisms has been worked out (Pullman et al. 1981). Thus using model (1), it is possible to find out the period of solarization required for obtaining satisfactory control of the disease by knowing the air temperature. The coefficient of determination of the model is low (19.18%) for open treatments while it is fairly high (77.8%) for partial shade. Studies under different agroclimatic conditions are required to increase the accuracy of prediction by the model.

The exponential model $Y = (AB)^t$ is useful for predicting the incidence of collar rot of cowpea under solarized and nonsolarized conditions. The coefficient of determination ranges from 78.66 to 98.37%. Thus the accuracy of prediction that could be made by this model is fairly high (fig. 3, 4). Similar models can be developed for areas under different agroclimatic situations. This is the first time a model for predicting disease under solarized condition is developed.

Solarization in general reduced fungal population in open conditions. But an increase was observed in both solarized and nonsolarized plots ten days after removal of polythene mulches, in open and shade. Since cowpea seeds were sown immediately after removal of polythene mulches, the presence of the seedlings would have contributed to the increase in fungal population. The bacterial population in the various treatments was not significantly different. The population of actinomycetes increased gradually in solarized and nonsolarized plots in both open and shade till one month after solarization and the increase was more in solarized treatments. Further studies are required to establish the exact effect of solarization on soil microflora.

Nematodes were not noticed in any of the plots at 15 cm depth in the pretreatment observation. This could be due to the migration of nematodes to deeper layers of soil having sufficient levels of moisture. After solarization, nematodes were observed in both solarized and nonsolarized plots. Irrigation and rain received during the period raised the moisture level of the soil. This could have helped the movement of nematodes to the upper layers of the soil. The nematode population in open solarized plots was the least immediately after solarization and also at the time of harvest of the crop. Higher temperature coupled with gaseous components, accumulated in the polythene mulched plots, might have killed those nematodes that migrated to the upper soil layers. In the partially shaded plots, reduction in nematode population was not appreciable - possibly because of the lower soil temperature and presence of coconut roots.

Solarization reduced weed population in the open while under partial shade, no substantial reduction was noticed. However, Lindernia crustacea was effectively controlled in partial shade.

Solarization has two complimentory effects - 1) inducing the emergence of dormant propagules and

foliar scorching of emerged plants under plastic cover and 2) decreased weed emergence after removal of the polythene sheets. (Horowitz et al. 1983). Induction of secondary dormancy by relatively high temperature has been reported (Koller 1972, Mayer and Polyakoft - Mayber 1975). Heating seeds to temperature above optimum for germination resulted in a reduction of the germination rate, possibly due to denaturation of functional protein (Levitt 1980, Taylorson and Hendricks 1977). Hendricks and Taylorson (1976) reported that heating weed seeds from 30 to 35°C modified the membrane permeability which resulted in leakage of endogenous aminoacids. Leakage from the seed will attract soil microflora which inturn will reduce germination. Since the increase in temperature as a result of solarization is more pronounced at the upper layers, only those weeds which have their vegetative parts or seeds present in the upper layers of the soil are effectively controlled by solarization.

Soil oxygen concentration under plastic sheets do not differ appreciably from uncovered control while the concentration of carbondioxide increases upto 30 times or more (Rubin and 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 enhancing germination. Such germinated seeds are killed as a result of the increase in temperature under the polythene mulches. In the present study Lindernia crustacea was induced to germinate in mulched soil under partially shaded conditions. Since there was no marked increase in the soil temperature or moisture level in mulched soils in shaded condition, the factor which induced germination of the seeds might be the gaseous agents accumulated in mulched soil. The seedlings thus emerged got decayed eventually under the polythene mulch. The reduction in weed population noticed in solarized plots may be due to direct thermal killing of the seeds, inducing secondary dormancy, thermal breaking of seed dormancy through the production of CO_2 and other gases in soil, altering seed metabolism or action of soil micro organisms on weakened seeds (Rubin and Benjamin 1983, 1984, Hendricks and Taylorson 1976, Pavlica et al. 1978).

The nodulation was found to be poor in all the treatments. Among the treatments, higher number of nodules was observed in shaded condition compared to open. Under shaded condition plants in solarized plots had more nodules. In the present study all the seeds

sown were inoculated with rhizobial culture. Hence, the population of rhizobacteria on the seed surface was uniform in all the treatments. Whatever changes observed later may be due to native rhizobia or the effect of solarization on plant. Further detailed studies are required to examine the role of solarization on rhizobial population.

Growth parameters like height of plants and number of leaves were not markedly influenced by solarization. However, there was an increase in the yield of the crop in solarized treatments. But the increase in yield, on per plant basis was not significant. Thus the higher plant population has contributed to the increased yield in solarized plots.

The results from soil nutrient assays following solarization showed, though slight, an increase in the status of available nitrogen, phosphurus, organic carbon, a decrease in magnesium (especially under partial shade), while there was no marked change in the levels of potassium and calcium (Table 16). Other soil properties like pH and electrical conductivity were not influenced by solarization.

The increase in nitrogen and phosphurus in solarized soils might be due to increase in soil temperature. During day time more evaporation takes place

in solarized soil and these varpours are not lost but blocked by polythene. During night time these vapours condense and drips down to the soil. This process is repeated throughout the period of solarization and might have helped in a greater mineralization leading to an increase in the status of available nitrogen and phosphurus. The increased CO_2 content in solarized soil (Rubin and Benjamin 1984) also might have influenced the availability of nutrients by making the soil reaction more acidic which helps in a greater solubilisation especially of phosphurus. The increase in temperature is known to catalyse the chemical and biological process that takes place in a soil which may further lead to the increase in the status of available nutrients.

The increase in organic carbon in solarized soil is noteworthy. The partial anaerobic condition (Rubin and Benjamin 1984) and the decay of germinated weeds in the solarized soils might be responsible for the increase in the organic carbon under solarized conditions. A partial anaerobic condition reduces the decomposition of organic matter to an extent, while in nonsolarized soils a gradual reduction in organic matter takes place. Organic carbon content generally decreases with increase in temperature. But the accumulation of organic matter

by the germination and decay of weeds might have compensated the losses so occurred and has resulted in accumulation of organic carbon in solarized plots.

The results from soil nutrient assays following solarization in the present study is not always consistant with those reported for soils in Israel and California. (Chen and Katan 1980, Stapleton and DeVay 1982, 1985). This variation is probably due in part to climatic conditions, vegetation, soil type and other factors.

SUMMARY

The study "Influence of soil solarization on soil microflora, plant growth and incidence of diseases" was conducted during 1985-87 at the Department of Plant Pathology, College of Agriculture, Vellayani. The field experiments on the effect of solarization on Rhizoctonia solani Kuhn causing collar rot of cowpea, were conducted in a farmer's field at Madavoor, 35 Km from Trivandrum. The effect of solarization was studied in the open and in partially shaded conditions in a coconut garden using 0.05 mm thick transparent polythene sheets. Before the commencement of the experiment one bulk crop of cowpea was raised in the experimental plot and it was ploughed in. Then the plot was uniformly inoculated with R. solani be ore covering it with polythene sheet.

The atmospheric temperature of the experimental area during the period of solarization ranged from 28.5°C to 34.2°C. The soil temperature, at 15 cm depth, in solarized treatments was 0 to 10.8°C above the atmospheric temperature in the open while under the partially shaded condition, temperature was almost the same as that of atmospheric temperature. Maximum soil temperature (42.5°C) at 15 cm depth was recorded in open solarized soil. In all the solarized plots in open, the soil

temperature was 40°C or above for 27 days (out of 47 days of solarization), while in nonsolarized plots, the temperature was below 40°C throughout this period.

Soil temperature variations in nonsolarized and solarized treatments were 10°C and 12°C respectively in the open while it was 5.5°C and 7°C in the partially shaded plots. However, such a variation was not observed among irrigated and nonirrigated treatments both in open and partially shaded conditions.

Collar rot occured both in solarized and nonsolarized fields. Marked reduction in the number of collar rot affected plants was observed in solarized plots. Least incidence of the disease (3.6%) was noticed in open nonirrigated solarized treatments followed by open irrigated solarized treatment (5.4%), while the maximum incidence of 24.0% was observed in shade irrigated control plots. The interaction effect of shade, solarization and irrigation was not significant.

Based on the soil and air temperature recorded, a simple regression equation was developed. By this it was possible to predict the soil temperature under polythene mulch at known atmospheric temperatures.

An exponential model $Y = AB^t$ was developed for predicting collar rot of cowpea. The coefficient of

determination of this equation ranged from 78.66 to 98.30% in the various treatments.

Solarization reduced fungal population in open conditions while the population of bacteria was not significantly affected. A slight increase in the actinomycetes population was noticed in solarized plots. The nematode population was the least in open solarized plots.

In open solarized plots there was absolute weed control till one month after solarization. Even at the time of harvest weed population was significantly lower in solarized plots compared to the control. No marked difference in the total weed population was observed among solarized and nonsolarized treatments in partial shade. However, the weed Lindernia crustacea was effectively controlled by solarization even under shaded conditions.

Growth parameters like height and number of leaves per plant were not significantly influenced by solarization. However, the solarized plots had more number of plants throughout the period. Nodulation, in general, was poor in all the treatments. Maximum number of nodules was obtained in irrigated solarized treatment, under partial shaded condition. Number of nodules was less in open treatments compared to those in partial shade.

Significant increase in yield was obtained in solarized treatments. In the solarized treatments in open, the yield recorded was 21.6 per cent more than that in control while under partially shaded conditions, the increase ranged from 7.6 to 11 per cent. Herein, when per plant yield was compared there was no significant difference between plants given under solarized and nonsolarized treatments.

Solarization influenced the availability of soil nutrients. Available nitrogen, phosphorus and organic carbon were increased in solarized soils both in open and partially shaded conditions, while there was no marked difference in the case of potassium and calcium. Soil p^H and electrical conductivity were not altered by solarization.

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* Original not seen.

APPENDICES

Appendix I

Analysis of variance table
Effect of solarization on collar rot of cowpea

Source	Sum of squares	D.F.	Mean sum of squares	F calculated
Total	1990.42	31	-	-
Block	46.01	3	15.34	0.64
Treatments	1444.24	7	206.32	8.66**
Error	500.16	21	23.81	-

CD at 0.05 level = 7.177

**Significant at 0.01 level

Ranking - $\overline{T_3\ T_2\ T_8}$ $\overline{T_7\ T_4\ T_1\ T_6\ T_5}$

Appendix II

Analysis of variance table
Effect of Shade, Irrigation and Solarization on collar rot of cowpea

Source	Sum of squares	D.F.	Mean sum of squares	F calculated
Total	1990.38	31	-	-
Block	46.03	3	15.34	0.64
A	222.57	1	222.57	9.35**
B	81.10	1	81.10	3.41
C	1045.31	1	1045.31	43.89**
A x B	0.0722	1	0.0722	0.0030
B x C	6.89	1	6.89	0.289
A x C	69.56	1	69.56	2.92
A x B x C	18.67	1	18.67	0.78
Error	500.15	21	23.82	-

**Significant at 0.01 level

Appendix III

Analysis of Variance and Analysis of Covariance table
(Effect of solarisation on fungal population at planting)

Source	SSx	SPxy	SSy	SSadj	df.	MS	F calculated
Total	4.54	4.63	31.59	-	23	-	-
Block	2.01	0.16	0.007	-	2	-	-
Treatments	1.00	4.82	29.64	17.52	7	2.50	19.31
Error	0.62	-0.356	1.89	1.60	13	0.129	-
Treatments + Error	1.62	4.47	31.52	19.20	20	-	-

CD at 0.05 level = 0.7514

Ranking - $\overline{T_1\ T_3\ T_2}\ \ T_4\ \ \overline{T_5\ T_6}\ \overline{T_7\ T_8}$

Appendix IV

Analysis of Variance and Analysis of Covariance table
Effect of solarization on fungal population at harvest

Source	SSx	SPxy	SSy	SSadj	df.	MS	F calculated
Total	4.54	4.86	54.32	-	23	-	-
Block	2.91	-0.003	0.06	-	2	-	-
Treatments	1.00	5.44	49.94	35.67	7	5.09	17.24
Error	0.62	-0.54	4.32	3.84	13	0.296	-
Treatments + Error	1.62	4.89	54.26	39.51	20	-	-

CD at 0.05 level - 1.1347

Ranking - $\overline{T_2\ T_3}\ \overline{T_4\ T_1\ T_6}\ T_7\ \overline{T_8\ T_5}$

Appendix V

Anova and Ancova table

Effect of solarization on bacterial population of soil at planting (after solarization)

Source	SSx	SPxy	SSy	SSadj	df.	MS	F calculated
Total	1.53	1.96	6.74	-	23	-	-
Block	0.68	0.23	0.42	-	2	-	-
Treatments	0.77	1.75	4.49	0.90	7	0.13	0.916
Error	0.007	-0.0007	1.82	1.82	13	0.14	-
Treatments + Error	0.85	1.74	6.31	2.73	20	-	-

CD at 0.05 level = 1.099

Ranking - $\overline{T_3\ T_2\ T_1\ T_4}\ \overline{T_8\ T_7\ T_5\ T_6}$

Appendix VI

Anova and Ancova Table

Effect of solarization on bacterial population of soil at harvest

Source	SSx	SPxy	SSy	SSadj	df.	MS	F calculated
Total	1.53	0.40	6.02	-	23	-	-
Block	0.68	-0.18	0.005	-	2	-	-
Treatments	0.77	0.60	4.54	4.14	7	0.59	5.35
Error	0.007	-0.001	1.43	1.44	13	0.11	-
Treatments + Error	0.85	0.58	5.98	5.57	20	-	-

CD at 0.05 level = 0.975

Ranking - $\overline{T_3\ T_2\ T_6\ T_1}\ \overline{T_8\ T_7\ T_5\ T_4}$

Appendix VII

Anova and Ancova table

Effect of solarization on actinomycetes in soil at planting (after solarization)

Source	SSx	SPxy	SSy	SSadj	df.	MS.	F calculated
Total	2.49	-0.95	3.99	-	23	-	-
Block	0.11	-0.003	0.11	-	2	-	-
Treatments	0.99	-1.28	3.06	2.80	7	0.40	7.18
Error	1.38	0.36	0.82	0.72	13	0.005	-
Treatments + Error	2.37	-0.92	3.88	3.53	20	-	-

CD at 0.05 level = 0.467

Ranking - $\overline{T_2\ T_3\ T_4\ T_7}\ \overline{T_8\ T_1\ T_6\ T_5}$

Appendix VIII

Anova and Ancova table

Effect of solarization on actinomycetes in soil at harvest

Source	SSx	SPxy	SSy	SSadj	df.	MS.	F calculated
Total	2.48	1.63	41.77	-	23	-	-
Block	0.11	0.10	0.211	-	2	-	-
Treatments	0.99	1.84	38.25	37.34	7	5.33	21.46
Error	1.38	-0.32	3.30	3.23	13	0.248	-
Treatments + Error	2.37	1.53	41.55	40.57	20	-	-

CD at 0.05 level = 0.985

Ranking - $\overline{T_5\ T_6}\ \overline{T_2\ T_1\ T_7\ T_4}\ \overline{T_3\ T_8}$

Appendix IX

Analysis of variance table

Effect of solarisation on nematode population of soil at planting (after solarisation)

Source	Sum of squares	D.F.	Mean sum of squares	F calculated
Total	210.13	23	-	-
Block	1.14	2	0.57	2.75
Treatments	206.07	7	29.43	141.78**
Error	2.90	14	0.207	-

CD at 0.05 level = 0.798

**Significant at 0.01 level

Ranking - $\overline{T_3\ T_2\ T_8\ T_7}\ \overline{T_4\ T_1\ T_6\ T_5}$

Appendix X

Analysis of variance table

Effect of solarisation on nematode population of soil at harvest

Source	Sum of squares	D.F.	Mean sum of squares	F calculated
Total	185.95	23	-	-
Block	9.88	2	4.94	3.06
Treatments	183.67	7	26.24	162.4**
Error	2.26	14	0.161	-

CD at 0.05 level = 0.703

**Significant at 0.01 level

Ranking - $\overline{T_3\ T_2}\ T_6\ T_7\ T_8\ T_4\ \overline{T_1\ T_5}$

Appendix XI

Analysis of variance table

Effect of solarization on nodulation in cowpea

Source	Sum of squares	D.F.	Mean sum of squares	F calculated
Total	13.725	31	-	-
Block	0.008	3	0.002	0.843
Treatments	12.973	7	1.853	58.04**
Error	0.670	21	3.193	-

CD at 0.05 level = 0.2628

**Significant at 0.01 level

Ranking - $\overline{T_7\ T_8}\ \ T_6\ T_5\ \ \overline{T_3\ T_2\ T_4}\ \ T_1$

Appendix XII

Analysis of variance table

Effect of solarization on yield in cowpea

Source	Sum of squares	D.F.	Mean sum of squares	F calculated
Total	6234.18	31	-	-
Block	114.50	3	38.16	0.359
Treatments	3888.50	7	555.50	5.228**
Error	2231.18	21	106.24	-

CD at 0.05 level = 15.160

**Significant at 0.01 level

Ranking - $\overline{T_3\ T_2\ T_7}\ \ \overline{T_8\ T_6\ T_4\ T_5\ T_1}$

INFLUENCE OF SOIL SOLARIZATION ON SOIL MICROFLORA, PLANT GROWTH AND INCIDENCE OF DISEASES

by

C R CHANDRAN

ABSTRACT OF A THESIS

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ABSTRACT

The influence of solarization on soil microflora, plant growth and incidence of disease was studied during 1985-87 at Madavoor on collar rot of cowpea caused by Rhizoctonia solani Kuhn. The effectiveness of solarization was tested in open and partially shaded conditions in coconut garden using 0.05 mm transparent polythene sheets as the mulch.

The atmospheric temperature during the period of solarization ranged from 28.5°C to 34.2°C. The increase in soil temperature, as a result of solarization was more in open field than in partial shade. The soil temperature variation in open nonsolarized treatments was 10°C while it was 12.5°C in solarized plots. Corresponding figures for partially shaded conditions were 5.5°C and 7°C respectively. Maximum soil temperature recorded at 15 cm depth in open solarized soil was 42.5°C. Based on the experimental data two statistical models (1) for predicting soil temperature under polythene mulch and (2) for predicting collar rot of cowpea were developed during the study.

Soil solarization significantly reduced collar rot of cowpea. Least incidence of the disease (3.6%) was noticed in open nonirrigated solarized treatments

while maximum incidence (24%) was recorded in shade irrigated control. The interaction effect of shade, solarization and irrigation was not significant.

Solarization reduced the total fungal population in open conditions while the population of bacteria was not significantly changed. In the case of actinomycetes population, a slight increase was noticed in solarized plots. The nematode population was significantly reduced by solarization in open field. Eventhough solarization substantially reduced weed population in open, it was less effective under partially shaded conditions.

Growth parameters like height and number of leaves per plant were not significantly influenced by solarization. But it improved the stand of the crop and yield. An yield increase ranging from 7.62 to 21.69 per cent was obtained in solarized plots over the control.

Availability of nitrogen, phosphorus and organic carbon was improved by solarization while there was no change in the level of potassium, calcium, pH and electrical conductivity.