II. REVIEW OF LITERATURE
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2.1 Soil Solarization

2.1.1 What is soil solarization?

Soil solarization is a method of heating the surface soil by using plastic sheets placed on moist soil to trap the solar radiation. Other terms such as solar heating, plastic or polyethylene tarping and polyethylene or plastic mulching are also used. The term solar pasteurization is also justified, since the method involves repeated daily heating.

It has been pointed out that the farmers of the Deccan plateau in India have long exploited a form of solar heating of soil, by plowing the soil so as to expose sub soil prior to the hot summer period (April – June), when maximum daily air temperatures usually exceed 40°C, and leaving it fallow Chauhan et al. (1988).

2.1.2 Possible mechanism involved in soil solarization

Katan, et al. (1976) were the first to conduct scientific and concerted investigations on utilization of soil solarization against soil borne plant pathogen and weeds.
The temperature increase by transparent polyethylene mulching is primarily due to the elimination of evaporation and partially due to the green house effect exerted by the polyethylene film (Mahrer 1979).

Maximal temperatures obtained in wet mulched soil at depths of 5 and 20 cm, under Israeli conditions, were about 50 and 45°C, respectively, which are 7 to 12°C higher than the respective temperatures of an unmulched wet soil (Katan et. al. 1976; Grinstein et.al., 1979, Mahrer 1979).

Rubin and Benjamin (1983) have shown that mulching (from July 7th to August 11th) of the wet soil with transparent polyethylene leads to an increase in the soil temperature of the upper layer by 10° to 18°C to a maximum of 51° to 56°C. With increasing soil depth, maximal soil temperature decreased.

In an experiment on duration of solarization carried out in one of the hottest regions of Israel, Horowitz et al. (1983) observed that soil temperatures often exceeded 50° in the upper 5 cm under plastic. No weeds emerged under the plastic, but control plots were heavily infested when carrot crop was raised shortly after the removal of the sheets.
Soil heating may result in the release of soil volatiles, many of which are biocidal. Among the volatiles known to increase after solarization is ammonia (NH₃), generated from ammonium nitrogen (NH₄ N) under conditions of reduced soil oxygen or alkaline pH (Stapleton, 1990). Besides this, soil solarization also increases levels of ammonium (NH₄-H) and nitrate nitrogen (NO₃-N) as well as other mineral nutrients such as K⁺, P, Ca²⁺, Mg²⁺, Cl⁻ etc., (Chen and Katan, 1980; Katan, 1987; Stapleton and Devay, 1986; Stapleton et al., 1990; Weir et al., 1989; Black and Greb, 1962, Park 1988).

Backer, 1962; Katan, 1987; Stapleton and Devay, 1986 observed that soil moisture assists the solarization process by conducting heat energy to target pathogens and pests, which when moist are often actively metabolizing and thus more susceptible to lethal dosages of heat.

Chen and Katan (1980) reported that tomato seedlings growth on extract of heated soil showed an enhanced growth compared to extracts of untreated soil.

Improvement in plant or seedling growth following soil solarization in peach, walnut, radish, pepper and Chinese
cabbage has been reported by Stapleton and Devay (1982) and Stapleton et al (1985).

Stapleton and Garza-lopes (1988) and Yaduraju (1993) reported the reduction in weed population following soil solarization.

In India, use of soil solarization in tobacco nurseries is of recent origin. Patel et al (1991a) studied the effect of five plastic films viz., LDPE black (Lines low density poly ethylene black 400 gauge) Clear (400 gauge), HM HDPE (High molecule high density polyethylene, (150 gauge) milky (150 gauge) and PP (Poly propylene, 100 gauge) for 2 months (April 15 to June 15) during the summer in bidi tobacco nursery. They reported that all the treatments significantly increased the number of transplants and over control. Beds tarped with LDPE clear (400 gauge) film yielded 215 and 152 percent higher number of transplants and total surviving seedlings, respectively. It also reduced root-knot disease and weed population to the tune of 58 and 77 percent over control with an incremental cost benefit ratio of 1:1.97.

Hussaini (1983) reported yield reduction in FCV tobacco in both nursery and field crop which was estimated to the tune of 59.4 per cent and 52.9 per cent respectively.
Similar results in bidi tobacco and tomato nursery were obtained by Patel and Makwana (1992) and Patel et al (1991 b) respectively.

2.1.3 Utilization of soil solarization for disease management

Katan (1981) used the practice to effectively control verticillium and fusarium diseases in vegetables and *Verticillium dahliae* in pistachio.

Other beneficial effects of soil solarization, such as control of weeds and insect pests, release of certain plant nutrients and increased soil moisture accumulation were demonstrated by Horiuchi (1984) and Stapleton et al. (1986).

The heating process causes complex changes in soil which are deleterious to most pathogens and pests, while stimulating antagonistic micro organisms and crop growth (Katan 1987; Stapleton and Devay 1986).

Iglesias et al (1998) demonstrated that a 45 day exposure period to soil solarization reduced the infestation of *Meloidogyne* spp. to non detectable levels, and a 30 day exposure eliminated more than 70% of the nematode population. Weeds were also controlled, except *Cyperus rotundus*.
Plastic film thickness had no effect on germination, plant growth, number of root-knot nematodes or weed growth. There was very little difference between the untreated and carbofuran treated plots. Economic analysis showed that an annual soil solarization of tobacco nurseries during the hottest period of summer with 100 gauge film for 15 days gave an incremental cost benefit ratio of 1:6.93 and enabled the film to be used on another site (Patel et al 1995).

Soil solarization by tarping the bidi tobacco nursery beds with clear plastic film of 400 gauge for two months starting from 15th April alone or in combination with bajra husk and carbofuran was economical and effective in management of stunt, root-knot and reniform nematodes as well as weeds (Patel and Makwana, 1995).

Diphon et al (1987) have made a detailed study on the tobacco seed bed sterilization through solar heating in connection with control of damping-off disease in naturally infested soil.

Reduction in root-knot infection in FCV tobacco nursery was achieved progressively as the period was increased from
2 to 8 weeks. A minimum of 4 weeks was found effective (Hussaini et al., 1993).

Hussaini et al. (2001) demonstrated that root-knot infection in FCV tobacco nursery was significantly reduced with al gauge and period upto 80 days. Nut grass was significantly decreased with solarization using 50 and 400 gauge sheets for 6 to 8 weeks or 100 and 200 for 8 weeks. Other weeds were controlled with all gauges and periods in the first weeding. Increase in transplants was obtained except for 100 g for 2 to 4 weeks in respect of all gauges and periods over check.

Combination of soil solarization with neem cake has been found effective in increasing the yield of transplants with significant reduction in root-knot infection (Hussaini, 1995).

Ravindra et al. (1997) reported that soil solarization of FCV tobacco nursery beds with transparent polyethylene sheets during hot summer months of March and April, significantly reduced root-knot index and recorded maximum yield of transplants with an incremental cost benefit ratio of 1:6.8.

Combination of soil solarization of FCV tobacco nursery beds for 2 weeks along with application of neem cake @
200 g/m² resulted in highest number of transplants with drastic reduction in root-knot disease and weeds with an incremental cost benefit ratio of 1:3.20 (Ravindra et al., 2001).

Ravindra et al. (2003) observed that soil solarization of FCV tobacco nursery beds for 4 weeks with incorporation of poultry manure at 100 g/m² resulted in maximum yield of transplants with minimum root-knot index with an incremental cost benefit ratio of 1:7.30.

Integration of botanicals such as neem, pongamia, eucalyptus, marigold and ipomea along with soil solarization of FCV tobacco nursery beds for 2 weeks registered minimum root-knot index with maximum production of transplants (Ravindra et al. 2003).

Ramakrishnan et al (2005) found that the application of neem cake at 400 g/m², poultry manure at 300 g/m² and vermin compost at 1.0 kg/m² in combination with soil solarization of FCV tobacco nursery beds recorded 62.5, 72.0 and 73.4 percent increase in healthy transplants yield respectively over untreated check along with root-knot index of 1.97, 1.90 and 2.00 respectively compared to 3.80 in check.
In a study to know the efficacy of time of application of organic amendments prior or after soil solarization, it was revealed that soil solarization of FCV tobacco nursery beds for 2 weeks followed by the application of neem cake at 100 g/m² was significantly superior in registering highest germination (82%) and maximum yield of transplants with least root-knot index and weeds (Ravindra et al, 2005).

2.3 Role of neem cake in nematode management

Even though, the scientific investigation on use of neem derivatives against insect pests began much earlier, concerted efforts regarding their utilization against nematodes, fungi, bacteria and viruses started only during mid – 1960’s.

The first report on bioactivity of neem cake against root-knot nematodes on tomato and okra was made by Singh and Sitaramaiah (1966). Since, then large numbers of reports have come up confirming its nematode controlling potential.

Alam and Khan (1975) reported highest reduction in the population of stylet bearing nematodes with neem cake followed by mahua, mustard, groundnut and castor.

Certain non-edible oil cakes such as neem (Azadirachta indica), karanj (Pongamia glabra), mahua (Mahuca indica),
castor (*Ricinus communis*) etc., have shown special potential (Swarup and Das Gupta, 1986).

Comparative efficacy of various organic amendments in the control of root-knot nematode, *M. incognita* was studied by Gowda and Setty (1973). They found that application of groundnut, honge, neem and castor cakes each at 10 g per pot improved the growth in terms of height and fresh weight of the shoot and the roots and also reduced the nematode population in terms of galling and egg masses per plant. Among, these neem and honge were found to be the best.

Rao *et al.* (1985) studied the effect of plant products on egg hatch and larval mortality of *M. incognita*. All leaf and oil cake extracts were toxic to *M. incognita*. *M. incognita* Juveniles, Karanj and neem cake extracts inhibited egg hatch by 34 per cent and 23.55 per cent respectively. While castor and gingelly cake extracts showed little effect. The root exudates of *Tagetes erecta* recorded the highest larval mortality of 59.32 per cent after 48 hr of exposure.

Alam *et al.* (1980) observed that soil amended with oil cakes of *Mahua indica*, *Ricinus communis*, *Brassica compestris*,
*Azadiracta indica* and *Arachis hypogea* were found to be effective in reducing nematode penetration and gall formation in tomato, chilli and egg plant against *M. incognita*.

Combination of saw dust with mustard or neem cake was most effective in reducing *M. incognita* and improving plant growth of tomato (Singh *et al.*, 1985).

The most significant increase in tomato plant growth and reduction in root galling as well as root and soil population of *M. incognita* were obtained with the application of neem oil cake at 4 per cent (w/w). However, dosages above 4 per cent were found to be phytotoxic (Bhattacharya and Goswami, 1989).

Vijayalakshmi and Goswami (1989) studied the effect of different dosages of neem and groundnut oil cakes on plant growth characters and *M. incognita* population in tomato. Significant increase in plant growth and reduction in root galling as well as root and soil populations of *M. incognita* was obtained with neem oil cake at 4 kg per ha while the higher dosage were phytotoxic.

Singh *et al.* (1990) found that neem cake was an effective amendment for the control of *M. incognita* on tomatoes than
mustard and castor. However, a mixture of neem plus mustard and neem plus castor were more effective than neem alone.

Both decomposed and undecomposed extracts of neem cake and leaves as bare root dip treatment significantly reduced root-knot development in pre-infected tomato seedlings as well as those inoculated with $J_2$ of *M. incognita* after root dip treatment. Inhibition of root-knot development was more pronounced in pre-infected seedlings than in seedlings inoculated after dip treatment. Further, decomposed extracts were comparatively more effective than undecomposed extracts (Akhtar and Mahmood, 1994).

Application of castor, bean, mustard and neem oil cakes each at 125 g per furrow and 15 g per spot were found to be effective for the management of *M. incognita* and increase in the plant growth of tomato (Deka and Phukan, 1997).

Jain and Gupta (1997) reported that neem cake application at 80 kg per ha was more effective than carbofuran at 2 kg a.i per ha, in reducing root-knot nematode population and improving tomato yield under pot culture.

Efficacy of four neem products (neem bitter 0.5 per cent, pepelin 1 per cent, well grow one percent and neem seed kernel
extract 2.5 per cent) against *M. incognita* infesting tomato cv. Pusa Ruby was compared by Byomakesh and Padhi 1998). Seed treatment, bare root dip and foliar spray proved to be effective in reducing root-knot galls and increasing growth of pants. Neem exhibited better performance in all the three methods.

Mohammad Akhtar (2000) showed that root galls produced by *M. incognita* were significantly low in bare root dip treatment of tomato seedlings with neem based commercial products and also aqueous extracts of neem seeds with all concentrations at various periods. Improvements in plant weight and height were correlated to reduction in nematode infestation.

The aqueous extracts of neem seed, neem cake and achook and root dip treatments (1.0, 2.5 and 5.9 per cent w/v) were effective in reducing *M. incognita* infestation in tomato cv. Pusa Ruby under green house conditions (Vijayalakshmi, 2000).

The effect of organic soil amendments against root-knot nematode, *M. incognita* was studied by Singh *et al.* (1988). They found that oil cakes of castor, mustard, neem, mahua and groundnut were effective in reducing nematode population on eggplant.
Lingaraju and Goswami (1993) studied the effect of two organic amendments, mustard (*Brassica juncea*) and neem (*Azadirachta indica*) oil cakes with an interaction involving a plant parasitic nematode, *Rotylenchulus reniformis* and *G. fasciculatum* on cowpea. *G. fasciculatum* + amendment had shown highest plant growth response in the presence of nematodes with least nematode number per gram of root.

Gupta and Kaliram (1981) reported that irrespective of soil types application of neem leaves increased plant growth and reduced number of galls per plant.

### 2.2 Botanical pesticides for nematode management

Many plants (wild or cultivated) are known to contain nematicidal principles and are being preferred for nematode control. The leaf extracts generally contain many chemical compounds, some of which might be toxic or repellant to nematodes. However, very few of them have been identified for their nematicidal property and the results of few investigators showed that marigold (*Tagetes* spp) as intercrop is effective in inhibiting the egg hatching of root-knot nematode, *Meloidogyne* spp.
Maijenke and Oostenbrink (1958) studied the effect of growing *Tagetes* in the soil infested with certain nematodes and reported that *Tagetes* not only reduced population of root-knot nematode and cyst-forming nematodes but also certain migratory nematodes like *Tylenchorhynchus* species.

Several recent investigations have revealed its scientific basis and it has now been demonstrated that the marigold cultivation reduced the population of plant parasitic nematodes to non-injurious levels resulting in better crop production (Alam and Masood, 1975).

Trap crops such as marigold, spinach, bottle gourd and ridge gourd suppressed the build up of some plant parasitic nematodes either due to non-host nature which may be due to the particular nematode species or to the mild antagonistic effect (Khan et al. 1975).

*Tagetes patula* was 27 per cent more effective in reducing *M. incognita* than peanut. Marigold acted as a trap crop. The juveniles (J2) penetrated marigold roots but failed to develop or to initiate giant cell formation due to hypersensitive necrotic reaction in the cells around the anterior end of larvae (Belcher and Hussey, 1977).
Bakker and Gommer (1979) studied the photo activation of nematicidal compound, a-terthienyl from roots of *Tagetes* species. They observed the photo activation of a-terthienyl under aerobic conditions, which enhanced the killing of nematodes.

Gupta and Kaliram (1981) reported that irrespective and soil types, application of leaves increased plant growth and reduced number of grass per plant.

Rajavanshi *et. al.* (1985) screened several species of *Tagetes* for their nematicidal properties and reported that *T. patula* having strong nematicidal effect with extreme resistance to polyphagous nematodes such as *Pratylenchus* and *Meloidogyne* species.

Good *et. al.* (1995) reported that *Tagetes* and *Crotalaria* species were more efficient crops for reducing wide range of soil nematodes based on rotational trials and also reported that marigold was highly susceptible to *M. arenaria* and *M. hapla* but was resistant to other species of root-knot nematodes.

Mateeva (1995) examined the effectiveness of some nematicidal plants like *Tagetes patula* and *Cannabis sativa*
against *Meloidogyne* spp. in greenhouse experiments and found that some of these alternative plant protection methods increased plant growth and yield.

Growing *Tagetes* in alternate rows of tomato, okra and other *solanaceous crops* reduced the stylet bearing nematodes species of *Meloidogyne* and *Tylenchorhynchus* in the soil (Khan *et al.*, 1971). Population of *M. incognita* and *Pratylenchus ulnii* from tomato intercropped with marigold was significantly fewer than tomato cultivated alone. In combination of *G. fasciculatum* + neem cake + FYM accounting to 65.08 per cent reduction over control (706.66). Thus, from the above results it may be opined that better reduction in nematode population was obtained in combination treatments (12.44 to 65.09 per cent) compared to individual treatments (4.54 to 53.77 per cent) at all the intervals after transplanting. However, among various combination treatments, *G. fasciculatum* + neem cake + FYM had showed maximum reduction of nematode population compared to other treatments and inoculated check.

Similarly, application of neem products help in reducing nematode population by releasing of alkaloids which is toxic to nematodes and prevent the penetration of roots which was
confirmed by the findings on brinjal (Siddiqui and Alam, 1998; Siddiqui and Alam, 1990) tomato (Bhattacharya and Goswami, 1987; Zaki and Bhatti, 1989; Mukhtar et al (1994); Rama (1995); Kiran Kumar, 2004) okra (Wani, 1992; Abid et al., 1995) and chickpea (Majumder and Mishra, 1993).

2.4 Role of poultry manure in nematode management

Chindo and Khan (1990) reported that poultry manure has tremendous potential for the control of root-knot nematodes. Both the growth and fruit yield of tomato increased significantly with levels of poultry manure at 4 t/ha and above.

The addition of chicken litter to soils suppressed *Meloidogyne* spp., restricted root galling caused by the nematode, and stimulated plant growth (Miyan and Rodrigue – Kabana, 1992).

Kaplan and Noe (1993) observed that amendment of soil with chicken litter suppressed *Meloidogyne arenaria* and may provide practical control of root-knot nematodes as part of an integrated management system.

Poultry manure plus carbofuran 3G as spot application before transplanting is most effective in reducing the severity of
root-knot disease and is an economically viable alternative to poultry manure alone in managing root-knot nematode in bidi tobacco nursery is (Hundekar et al. 2005).

2.5 Screening of germplasm to identify source of resistance / tolerance against root-knot nematode

In India, *Meloidogyne incognita* and *M. javanica* are the dominant species causing root-knot on tobacco although *M. arenaria* is also found associated in some pockets.

Gopalachari (1984) reported that there is no resistance in any of the *Nicotiana tabacum* or *N. rustica* tested at Rajahmundry. He observed that NC 95 was the first flue cured variety developed resistant to most prevalent *M. incognita* and *M. incognita* var. *acrita* in U.S.A. But N.C. 95 was found susceptible to *Meloidogyne* species at Rajahmundry and at Anand. Out of 31 *Nicotiana* species tested for resistance to *M. javanica* at Rajahmundry, *N. repanda*, *N. amplexicaulis*, *N. nudicaulis* and *N. plumbaginifolia* showed high resistance. *N. tabacum* strains resistant to *M. javanica* was successfully developed by adopting interspecific bridge cross by using *N. repanda* and *N. sylvestris* (Burk 1957) and by using *N. longitolona* and *N. repanda* as sources of resistance (Scheweppenhauses, 1968).
Milne (1972) observed that there is no commercial variety of tobacco which is resistant to *M. javanica*.

Okinava 6 and Okinava 12 were found to be resistant to *M. javanica* in Japan (Fukudome and Yamaguchi 1976). However, Shah *et al.* (1985) reported their susceptibility under Gujarat conditions to the same species. Perhaps Gujarat populations is a different pathotype.

Florida 22 and RK 70 were found resistant to *M. incognita* (Milne, 1972).

Moore *et al.* (1962) reported that No.95 was released in USA in 1962 as the first flue cured variety, resistant to *M.incognita*.

Under nurseries and controlled conditions in glass house with *M. incognita*, varieties Va 145, FCH 6005 and Coker 254 showed low root-knot index at 60 days after inoculation. Similar controlled tests were done with *M. arenaria* and *M. javanica*, while VA 770 is the only variety promising against *M. arenaria*, FCH 6005 has low root-knot index against *M. janica* (Hussaini, 1986).
Gull et al. (1993) reported that out of 10 tobacco varieties tested against *Meloidogyne juvanica* KHG 12 was found moderately resistant, Speight G-28, Coker-176, Coker-206, NC-88, KHG-10 and KHG-11 were susceptible and NC-13 and Coker-51 were highly susceptible.

Amongst the 65 entries of tobacco evaluated for resistance to *Meloidogyne incognita* race 1 and *M. javanica* in the greenhouse, 16 entries were resistant to *M. incognita* race 1 and 25 entries were moderately resistant to *M. incognita* race 1. Only Va 102 was moderately resistant to *M. javanica*. Among the 10 entries evaluated for resistance to *M. arenaria* races 2, in field experiments, only CF 954 was moderately resistant (Wang-Nian et al., 2000).

Ramakrishnan et al. (2005) reported that among the 45 FCV tobacco germplasm screened against root-knot nematodes under sick field conditions, only 6 accessions namely Cy-149, Burley-1, B-1000-1, KST-27, KST-28 and N-98 were found promising with RKI = 1.5 on 0-5 scale. CY-1185C1, Leca 10, Spanish Burley, Burley 21, Hy burley, VA 528, BSRB-2 and 754-2-1 were found highly susceptible with RKI > 3.5. The cultivars Swarna and Bhavya served as susceptible and resistant checks, respectively.
Resistance of 19 tobacco cultivars to *M. incognita* race 1, *M. arenaria* race 2 and *M. javanica* was studied by means of cluster and variance analysis. Results showed that NC 95, K 326(U), G 28, V2, 3027, Qiansuoz, 317, K 326 (Y), 3040, 4072 were resistant to *M. incognita* race 1. All tobacco cultivars in this study were susceptible to *M. arenaria* race 2 and *M. javanica*, but 871 had some tolerance to *M. arenaria* race 2 and 317 had tolerance to *M. javanica*. At the same time, the resistance of K 326 (T) which had been cultivated in Yunnan province for about 10 years was consistent with that of K 326 (V) which was introduced from the USA in 1994, they both were resistant to *M. incognita* race 1 and susceptible to *M. arenaria* race 2 and *M. javanica* (Yu – ShengFu et al. 1999).

Ramakrishnan *et al* (1999) demonstrated that among sixty flue cured Virginia tobacco germplasm accessions along with the variety Bhavya as resistant check and varieties FCV special and Swarna as susceptible checks which were screened for their reaction to root-knot nematode, *Meloidogyne* spp. in sick plot, the lines varieties exhibited varying degrees of reaction to root-knot nematodes ranging from highly susceptible to resistant. Among the lines screened, six varieties / lines viz., FCH-124, FCH-176, FCH-178, FCH-179, Gold streak and ILTD special were found promising with root-knot index ranging from 1.1 to 1.5.