V. DISCUSSION
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Flue Cured Virginia (FCV) tobacco is an important revenue and foreign exchange earning crop of India. It is an excellent source of phytochemical which can be converted into value added products beneficial to the mankind. Solenasol an alkaloid from tobacco leaf is found to be an important ingredient in cardiac drug and efforts are going on to harness it commercially. Reports also indicate that tobacco seeds contain 36 to 40 per cent of edible oil rich in polyunsaturated fatty acids. Nicotine sulphate extracted from tobacco leaf is known to be a good pesticide.

Root-knot nematode (*Meloidogyne* spp.) is one of the major constraints in the production of quality FCV tobacco. It has world wide distribution, extensive host ranges and is involved with fungi, bacteria and viruses in disease complexes. A few nematicides are available for the control of nematodes but majority of them have been withdrawn from the market because of their nonecofriendly nature, cost and nonavailability.

On the other hand, there is possibility of adopting few ecofriendly measures like soil solarization, amendment with
organic cakes, poultry and sheep manure, botanical pesticides and screening of germplasm for resistance against nematodes. However, employing any one single method is not effective in minimizing the disease intensity. Therefore, an attempt was made to integrate easily available ecofriendly measures for the effective management of root-knot nematode.

**Soil Solarization**

5.1.1 **Effect of Soil Solarization on Soil Temperature**

It is a hydrothermal process for disinfestations of soil (Stapleton and Devay, 1986). The method of soil solarization was developed in Israel by Katan *et al.* (1976) who achieved solarization by mulching the moist soil during the hottest season of the year with minimum cloud over using transparent polyethylene sheets, thereby increasing soil temperature and killing the pathogens.

According to Baker (1962), Katan (1976), Mahrer (1979) and Stapleton and Devay (1986) the mechanism of soil solarization works on the following principles.

1. Accumulation of heat by transmission of short wave solar radiation but prevention of loss of long wave radiation from
soil, resulting in thermal inactivation at high temperature and production of heat shock proteins, and irreversible heat injury.

2. High soil moisture by intermittent irrigation improves thermal conductivity and the water vapour’s high latent heat.


4. Antagonistic microorganisms have lower thermal sensitivity and faster recolonization capacity enabling shift in favour of biocontrol.

5. Due to physico-chemical and microbiological processes, some toxic gases and minerals are released, and through increased mineralization, some others provide nutrients to crops and induce greater tolerance to them.

6. Prolonged exposure to high temperature weakens the pathogens.
7. Condensed water droplets on the underside of the sheet reduce heat loss and concentrate solar radiation.

8. Concomitant control of weeds and other pathogens possible, some of which may have complex relationship among themselves. Additionally, induced suppressiveness is of long term nature. Solarization is compatible with other methods of control.

Soil temperature increased in solarized beds over unsolarized beds during most part of the solarization process depending on the soil depth and time. While, the upper 5cm. depth showed more fluctuations, at 20cm. depth the temperature fluctuation was not evident (Table-1) (Fig.-3 and 4).

Increase in soil temperature was in the range of 4.0 per cent to 39.9 per cent over that of unsolarized soils at 5cm. depth. Whereas, it was only 1.0 to 6.8 per cent at 20cm. depth. Maximum temperature of 43.8°C was recorded in 8 weeks of solarization at 5cm. depth which was 40 per cent higher compared to unsolarized beds. As compared to check, the increase in temperature was 4.0 per cent in 2 weeks of solarization, 12.5 per cent in 4 weeks of solarization and
Fig. 3: Effect of soil solarization on the soil temperature (5cm depth)

Temperature (°C)

SS 2W | SS 4W | SS 6W | SS 8W | Check

- 2003
- 2004
- 2005
- Mean
Fig. 4: Effect of soil solarization on the soil temperature (20cm depth)

Temperature (°C)
18.2 per cent in 6 weeks of solarization. The temperature peaks of these different solarization periods were attained at 5cm. depth in the afternoon. The effect of solarization in terms of raise in the soil temperature was lowest at 20cm. depth for different solarization periods. These temperature variations and the general trend are in conformity with the findings of Kumar et al. (1993) who reported that the effect of solarization is restricted to 0.5cm. soil layer.

The necessity of longer duration of exposure of the pathogens to heat for effective control of the diseases was observed by Dipon et al. (1987). Accordingly, in the present study, the solarization periods were fixed for 2, 4, 6 and 8 weeks and also because the soil temperature at lower depths was lower than that in the upper layer. This fact is also supported by the findings of Horowitz et al. (1983) who in an experiment on duration of solarization carried out in one of the hottest regions of Israel, observed that soil temperatures are often exceeded 50°C in the upper 5cm. under plastic. They noticed that since increase in temperature attained by solarization at deeper soil layer is lower than at upper once, the period of solarization should be efficiently extended for four weeks or more in order to achieve control in all desired depths.
Aloi and Noviella (1982) and Chauhan et al. (1988) observed that soil temperature of 10cm. depth was less than that of 5cm. depth. This can be due to the decrease in the rate of transmission of solar heat as the depth of the soil increases and most of the solar heat used for heating of the upper layer of the soil.

Sharma and Nene (1990) recorded soil temperatures higher than 45°C at 5cm. and 10cm. depths in the solarized plots. Maximum temperatures obtained in wet mulched soil at depths of 5 and 20cm. under Israeli climatic conditions, were about 50° and 45°C respectively, which were 7° to 12°C higher than the respective temperatures of an uncovered wet soil (Katan et al., 1976; Grinstein et al., 1979).

Mahrer (1979) opined that the temperature increase is primarily due to the elimination of evaporation and primarily due to greenhouse effect exerted by the polyethylene film. According to Baker (1962), Stapleton and Devay (1986) and Katan (1987), 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 (Plate-12).
Shukla et al. (2000) observed that increase in soil temperature under solarization was due to green house effect at the micro level. Transparent polyethylene allowed the sun’s radiation to pass through but restricted the escape of terrestrial radiation. Accumulation of water vapour inside the polyethylene cover and the absence and evaporational cooling further contributed to heating of the soil. Soil moisture, although known to moderate the temperature, increased the heat conductivity of the soil.

Similarly, increase in soil temperature due to soil solarization using clear or transparent polyethylene sheet is reported by many workers (Katan et al., 1979; Yaelregav and Geverberg, 1979; Rabinovitch et al., 1981 and Rubin & Benjamin, 1983).

The evidence of the raise in soil temperature after second week at upper layer as noticed in the present study also necessitates the extension of mulching period long enough to achieve control of nematode at all depths.

5.1.2 Effects of Soil Solarization on Seed Germination

There was no adverse effect of soil solarization on germination of the seed. Even at the prolonged period of
solarization for 8 weeks, the germination was excellent. There was an increasing trend in seed germination count from 71.67 in 4 weeks, 73.89 in 6 weeks to 84.44 in 8 weeks of solarization (Plate-12. These results are corroborated by the findings of Abdul Wajid et al. (1995) who recorded 28.96 per cent increase of germination in nursery soil collected after solarization over that of nursery soil collected before solarization and 52.86 per cent increase of germination in sick soil after solarization over that of sick soil without solarization. Similar trend was noticed in treatment combination of soil solarization with carbofuran where the seed germination count further improved from 77.22 in 4 weeks, 78.89 in 6 weeks to maximum of 90 in 8 weeks. Interestingly the seed germination was very poor in unsolarized beds.

This increased growth response (IGR) has been attributed to increased mineralization of nutrients in soil and due to the shift in soil microbiota in favour of growth promoting types (Stapleton et al., 1985).

5.1.3 Effect of Soil Solarization on Seedling Production at 60 Days

The seedling production was very meager in unsolarized beds which recorded only 220.33 seedlings. On the other hand,
in all the solarized beds, the seedling production was excellent and thus they were significantly superior to the check. The seedling production increased with the enhanced solarization periods from four to eight weeks, where in it was 418.67, 460.89 and 594.4 seedlings in 4, 6 and 8 weeks, respectively.

The treatment combination of solarization and carbofuran maintained the same trend where the seedling yield further increased from 443.33 in 4 weeks to 529.22 in 6 weeks to maximum of 786.11 in 8 weeks. Thus, the treatment combination of solarization for 8 weeks along with carbofuran (786.11) was significantly superior to all other treatments followed by solarization alone for 8 weeks (594.74) which was significantly superior to the remaining treatments. The results are in conformity with the findings of Abdul Wajd et al. (1995) who reported significant increase in transplantable seedlings in solarized beds compared to nonsolarized beds.

5.1.4 Effect of Soil Solarization on Seedling Production at 75 Days

The seedlings aged between 45 to 60 days will be used for transplanting in the mainfield. However, in the present study, the observation on seedling production was continued upto
75 days with an idea to study the enhanced effect if any of the soil solarization on continued seedling growth and production.

The same trend with respect to seedling production at 60 days prevailed at 75 days also wherein all the treatments were significantly superior to check. Soil solarization for 8 weeks plus carbofuran (860.00) was highly significant over rest of the treatments followed by solarization alone for 8 weeks (695.33). Once again, there was a progressive trend in seedling production from 4 to 8 weeks of solarization wherein 355.89, 413.67 and 695.33 seedlings were recorded in 4, 6 and 8 weeks, respectively.

Similar pattern was noticed in the treatment combination of solarization with carbofuran wherein the seedling yield further increased from 4 to 8 weeks where 413.55 at 4 weeks, 635.00 at 6 weeks and 860.00 seedlings at 8 weeks were harvested respectively. The seedling production was not improved in unsolarized beds which recorded only 205.44 seedlings as that at 60 days. The results are also supported by the findings of Ravindra et al. (1997) who reported significant increase in the production of transplantable seedlings at second pulling (75 days) in all the solarized beds compared to nonsolarized beds.

5.1.5 Effect of Soil Solarization on Total Seedling Production
Total available, healthy and transplantable seedlings were considered for this study wherein the effect of solarization of nursery beds will be reflected in the form of all the available seedlings (Plate-14) (Fig.-5).

The enhanced effect of solarization on seedling production was clearly depicted in the form of maximum availability of healthy transplantable seedlings in the treatment combination of solarization for 8 weeks along with carbofuran which was significantly superior over rest of the treatments. The fact that solarization of beds contribute to the increased production of seedlings was clearly evident as all the solarization treatments were significantly superior to the check. The same trend of seedling production prevailed here also wherein 883.89, 952.78 and 1138.78 seedlings were recorded in 4, 6 and 8 week of solarization alone and 656.00, 1027.22 and 1294.55 seedlings were observed in 4, 6 and 8 weeks of solarization with carbofuran, respectively, but increase in availability of seedlings was not observed in the unsolarized beds (536.67). The results are in conformity with the findings of Patel and Makwana (1992) who observed significantly higher number of transplantable as well as total seedlings compared to control were obtained with clear plastic as well as bajra husk rabbing in bidi tobacco
Fig. 5: Effect of soil solarization on total seedling production.
nursery. According to Ravindra et al. (1997), soil solarization of FCV tobacco nursery beds significantly increased the number of transplantable and total healthy seedlings in all the solarized beds but not in the nonsolarized beds (Plate-15 and 16).

5.1.6 Effect of Soil Solarization on Root-Knot Nematode at 60 Days
The effect of increased temperature on root-knot nematode was clearly observed as all the solarized beds were significantly superior to unsolarized beds in minimizing the root-knot index. The fact that the prolonged period of solarization upto 8 weeks has added advantage was clearly depicted as solarization for 8 weeks alone and with carbofuran were significantly superior to rest of the treatments. Further, between these two treatments, solarization for 8 weeks with carbofuran was significantly superior to solarization alone wherein the root-knot index of 1.34 and 1.63 were recorded, respectively. Maximum root-knot index of 4.63 was observed in the unsolarized beds.

5.1.7 Effect of Soil Solarization on Root-knot Nematode at 75 Days
Usually, the seedlings will be collected from the nursery beds upto 75 days for transplanting or for gap filling in the main field. Hence, there was every chances of root-knot nematode to
increase its population which will be reflected in the form of multiple galling. This study was conducted to know the enhanced and accumulated effect of solarization of nursery beds if any on root-knot nematode at 75 days (Fig.-6).

The trend observed at 60 days of solarization prevailed at 75 days also wherein solarization of nursery beds with or without carbofuran was significantly superior to the unsolarized beds. Here also, it is witnessed that solarization of 8 weeks along with carbofuran minimized the root-knot index (1.37) followed by solarization for 8 weeks without carbofuran (1.57). Both these treatments were on par and significantly superior to rest of the treatments.

Once again, unsolarized beds exhibited maximum root-knot index (4.60) (Plate-21). The results are in conformity with the findings of Patel and Makwana (1992) and Hussaini et al. (1993) who have used the technique for the control of root-knot nematode in the nurseries of bidi and FCV tobacco, respectively. Similar results with plastic tarping and rabbing in bidi tobacco nursery were obtained by Patel et al. (1987, 1990 and 1995) who reported the efficacy of plastic tarping in reducing the root-knot index and weeds with more than 100 per cent healthy
Fig.-6: Effect of soil solarization on root-knot nematode in FCV tobacco nursery at 75 days
transplantable seedlings. Ravindra et al. (1997) reported significant difference between tarped and non tarped beds and observed non significant difference in root-knot index among the different tarping periods in FCV tobacco nursery. This reduction in root-knot index may be due to sublethal heating of the nematodes in the soil profile resulting in reduced pathogenic potential, lower subsequent reproduction of egg hatching, and possibly induced bio control (Katan, 1981; Stapleton and Devay, 1983; Stapleton and Devay, 1986, Sharma and Nene, 1990).

Chen and Katan (1980) observed that steaming of the soil resulted, in phytotoxicity due to the release of manganese or other substances in certain cases. Such negative side effects were less pronounced, however, when soil was heated at relatively lower temperatures of 60 to 70°C. In the experiments with solar heating, soil temperatures did not exceed 46°C. Indeed, phytotoxicity effects were not observed in any of the soil solarization experiments including the present study.

### 5.1.8 Effect of Soil Solarization on Weed Surveillance

Weeds are a major problem for production of healthy FCV tobacco seedlings in Karnataka Light Soils (KLS). They come up rapidly due to frequent irrigations and cause enormous losses to
the seedlings in nursery beds besides escalating the cost of manual weeding. The over dependence and over use of herbicides for weed management in agriculture in developed countries resulted in development of herbicide resistance, herbicide residues and environmental pollution (Sudha et al., 1998). Weed suppression is also important for the disease control as number of weeds act as hosts for root-knot nematodes in KLS region (Hussaini and Wajid, 1981). The predominant weeds in tobacco nurseries are *Cyperus rotundus*, *Cynodon dactylon*, *Commelina bengalensis*, *Erogrostis biflora*, *Euphorbia hirta*, *Leucas aspera*, *Tridax procumbens* and *Bidens pilosa*.

The prolonged period of solarization upto 8 weeks along with carbofuran had deleterious effect on weed population as this treatment was significantly superior in minimizing the weed (7.78) to other treatments. Eight weeks of solarization alone was the next best treatment and was significantly superior to rest of the treatments except solarization for 6 weeks plus carbofuran which drastically reduced weed intensity (13.55 and 21.00 respectively) (Plate-22). However, there was significant difference between the remaining solarized beds and nonsolarized beds. Maximum weeds were observed in nonsolarized beds (176.67) (Plate-17).
The results are corroborated with the findings of Ravindra et al. (2001) who reported lowest number of weeds in the treatment combination of soil solarization plus neem cake followed by solarization alone for 4 weeks in FCV tobacco nursery. Similar results with soil solarization plus neem cake was obtained by Hussaini (1995) who reported an increase in growth and production of FCV tobacco seedlings with reduction in weeds due to solarization. This increasing trend in seedling production was attributed to increased availability of nutrients in solarized beds along with neem cake (Stapleton and Devay, 1982) and Gruenzweig et al. (1993) observed that soil solarization with transparent polyethylene sheet for 30 days was found effective in increasing the seedlings dry matter production which was due to more weed suppression owing to raised temperature of soil in transparent polyethylene. Sudha et al. (1998) reported that, soil solarization with transparent polyethylene for 30 days effectively controlled the weeds, increased the dry matter production of seedlings and C.B. ratio.

Horowitz et al. (1983) observed that weed emergence within the carrot crop was reduced in proportion to the time of solarization. During the first month of crop growth, weed emergence was reduced by 60, 80 and 90 per cent of the control,
after 1, 2 and 4 weeks of solarization, respectively. Carrot yields were found to increase after solarization. According to Hosamani (1991), the response to solarization varies with weed species. Although many annual species common to warm regions are sensitive, most perennials are resistant. In perennials, with an established underground system of deep roots, rhizomes of tubers, failure of solarization is probably due to its effectiveness to a limited soil depth that is 10cm. where the temperature reaches lethal levels. Among annual species, the response is differential, presumably due to their specific sensitivity to high temperature. Solarization was found to be effective against imbibed but dormant seeds.

5.2.1 Effect of Integration of Botanicals and Soil Solarization on the Production of Transplantable Seedlings at 60 Days

The exploitation of plants and their parts in nematode management has attracted much attention of late owing to low cost, easy availability and the environment safety. The plant that possesses nematicidal properties, either induces nematode larval mortality or inhibits larval hatching (Phillip et al., 1993; Ramakrishnan et al., 1995). Biopesticides of botanical origin have become the focus of attention today for facing the nematode
problems especially when we think for an ecofriendly approach for evolving ecology based low cost input technology for providing safe food and clean environment worth living (Mishra, 1998). Since soil solarization increases temperature, enhanced decomposition of botanicals may take place. Keeping this in view, an attempt was made to test the integrated effect of botanicals and soil solarization on root-knot index and yield of transplants.

In the present investigation, it was observed that solarization for 4 weeks and above was found to be quite longer periods as the plastic film turned opaque and hence transparency was lost. Since, continuous exposure to sun light, the sheet also became brittle and not reusable. Moreover, difficulty in protecting from trampling by animals and human and damage by wind (Ravindra et al., 2001).

Hence, attempts were made to reduce the solarization period from 4 weeks to 2 weeks plus different combinations with botanicals organic amendments poultry manure and so on to maintain the same efficacy of 4 weeks of solarization in 2 weeks of solarization. Such combinations have been reported to prolong the efficacy of solarization (Shoemaker, 1985). This attempt was
carborated by the findings of Patel et al. (1995) who reported that tarping the nursery beds with clear LDPE plastic of 100 gauge (25µm) for two weeks during hot summer was equally effective with bajra husk and carbofuran in getting more number and healthy transplants with effective management of root-knot, stunt and reniform nematodes and weeds in bidi tobacco nursery.

All the individual botanical treatments and the treatments having solarization component for 2 weeks were significantly superior to the check.

Soil solarization along with marigold leaves was significantly superior to other treatments with maximum increase in seedling production (180). Soil solarization along with neem leaves (1.0kg/m²) was found to be the next best treatment as it was significantly superior to rest of the treatments with 140 seedlings and closely followed by solarization alone (125) and neem leaves alone (120). Seedling production was least in the check (50).

5.2.2 Effect of Integration of Botanicals and Solarization on Production of Transplantable Seedlings at 75 Days
The idea behind this experiment was to study the affect of enhanced decomposition of botanicals up to 75 days on seedling production. The treatments viz., solarization with neem leaves, neem leaves alone, solarization with marigold leaves and solarization with pongamea leaves were at par with each other and significantly superior to rest of the treatments. Highest number of transplantable seedlings were observed in solarization with neem leaves (238) followed by neem leaves alone (225), solarization with marigold leaves (220) and solarization with pongamea leaves (215) respectively. Seedling production was lowest in the check (160) (Fig.-7). The results are in conformity with the findings of Ravindra et al. (2003) who observed that marigold leaves in conjunction with soil solarization yielded maximum member of transplantable seedlings at 60 days followed by neem leaves plus soil solarization and neem leaves alone.

5.2.3 Effect of Integration of Botanicals and Soil Solarization on Root-knot Nematode at 60 Days

The fact that solarization of nursery beds alone and incorporation of botanicals to the nursery beds alone had deleterious effect on root-knot nematode is clearly evident. Hence, this study was initiated to study the combined effect of both on root-knot index at 60 days. All the botanicals with or
Fig.-7: Effect of integration of botanicals and soil solarization on the production of transplantable seedlings in FCV tobacco nursery at 75 days
without solarization component were significantly superior to check. Marigold leaves along with solarization recorded least root-knot index (1.70) followed by solarization alone (1.75), marigold leaves (1.78), neem leaves alone (1.95), pongamea leaves alone (2.00) solarization with neem leaves (2.00) and eucalyptus leaves alone (2.15). Highest root-knot index was noticed in the check (3.75). The results are supported by the findings of Linford et al. (1938) who reported that incidence of root-knot nematode could be significantly reduced by incorporating chopped pineapple leaves at 50 to 200 tons per acre in soil. Singh (1965a) applied chopped leaves of Karanj to soil infected with *Meloidogyne javanica* and obtained 50 per cent reduction in tomato root-knot gall intensity. Singh and Sitaramaiah (1967) reported that application of 5 to 10 per cent (w/w) of leaves of *Azadirachta indica*, *Melia azadirach*, *Cassia fistula*, *Crotolaria juncea* and *Sesbania aculeate* to infested soil reduced incidence of root-knot on tomato and okra.

**5.2.4 Effect of Integration of Botanicals and Soil Solarization on Root-knot Nematode at 75 Days**

At 75 days also the same trend continued wherein all the botanicals with or without solarization were significantly superior to the check clearly indicating the enhanced effect of
solarization in decomposition of botanicals. The treatments of neem leaves alone and solarization along with marigold leaves were significantly superior to rest of the treatments in minimizing the root-knot index. Both these treatments registered root-knot index of 1.75. While, maximum root-knot index was noticed in the check (4.00) (Fig.-8).

The results are corroborated by the findings of Hameed (1970) who reported the control of *Meloidogyne incognita* using decomposed leaves of Margosa, Tagetes, Datura, Nerium and Chrysanthemum. Leaf extract of *Tagetes patula* contains an alkaline water soluble nematostatic chemical was suggested by Rajavanshi *et al.* (1985) constituent that kills *Xiphinema basiri*.

Ravindra *et al.* (2003) who reported that marigold leaves in conjunction with solarization registered least root-knot index followed by soil solarization for 2 weeks alone which were on par at 60 days while neem leaves alone recorded minimum root-knot index at 75 days followed by marigold leaves plus solarization.

5.3.1 Effect of Integration of Oil Cakes and Poultry Manure with Soil Solarization on the Production of Transplantable Seedlings at 75 Days
Fig. 8: Effect of integration of botanicals and soil solarization on root-knot nematode in FCV tobacco nursery at 75 days.
It is now well established that plant damage by nematodes invariably decreases whenever some organic matter is incorporated into the soil. However, the efficacy of organic additives varies. It depends mainly on the nature of amendment, prevailing soil temperature / moisture, kind of other soil biota, species and stage of the target nematode and type of the host. The fact that the incorporation of oil cakes like neem, pongamea to the nursery beds will have increased production of seedlings was clearly evident as these treatments alone and in combination with solarization were significantly superior to over check (Fig.-9). Apart from this, all the treatments in general were significantly superior to check. However, among the treatments, soil solarization for 2 weeks along with neem cake, soil solarization alone for 4 weeks, soil solarization for 2 weeks in conjunction with poultry manure and soil solarization for 2 weeks plus carbofuran were found to be significantly superior to rest of the treatments and were on par. Solarization for 2 weeks along with neem cake recorded highest seedling production (422) followed by solarization alone for 4 weeks (395), solarization for 2 weeks with poultry manure (390) and solarization for 2 weeks plus carbofuran (375). Seedling production was lowest in the check (210). These results are in conformity with the findings of Hussaini (1995) who obtained similar results in combination of
Fig.-9: Effect of integration of oil cakes and poultry manure with soil solarization on seedling production in FCV tobacco nursery at 75 days
soil solarization with neem cake and reported an increase in growth and production of transplants. This increasing trend was attributed to increased availability of nutrients in solarized beds along with neem cake. Alam et al. (1977, 1980) also described changes in physico chemical properties of the soil due to decomposition products of the additives, and their toxic effects. Besides this, soil solarization was also reported to increase levels of ammonium (NH₄N) and nitrate nitrogen (NO₃N) as well as other mineral nutrients such as K⁺, P, Ca²⁺, Cl⁻ etc. (Chen and Katan, 1980 and 1987; Stapleton and Devay, 1986; Stapleton et al., 1990; Weir et al., 1989; Black and Greb, 1962 and Park, 1988). Thus, increased available nutritional status of solarized soil may boosts up the per cent growth.

5.3.2 Effect of Integration of Oil Cakes and Poultry Manure with Soil Solarization on Root-knot Nematode at 60 Days

Incorporation of oil cakes and poultry manure had a deleterious effect on root-knot nematode which was reflected in the form of least gall index both in individual treatments and combination treatments with solarization (Plate-18). Hence, all the treatments were significantly superior compared to check. Soil solarization alone for 4 weeks, soil solarization for 2 weeks,
soil solarization for 2 weeks with poultry manure and soil solarization for 2 weeks along with pongamea cake plus carbofuran were found to be significantly superior over rest of the treatments and were on par. Least root-knot index was observed in solarization alone for 4 weeks (1.25) followed by solarization for 2 weeks alone (1.90), solarization for 2 weeks along with poultry manure (1.94) and solarization for 2 weeks along with pongamea cake and carbofuran (1.95). Highest root-knot index was observed in the check (3.54).

5.3.3 Effect of Integration of Oil Cakes and Poultry Manure with Soil Solarization on Root-knot Nematode at 75 Days

The result (Table-14) indicated the same trend as that of 60 days where all the treatments were significantly superior to the check. Among the treatments, solarization for 4 weeks, solarization for 2 weeks along with neem cake and solarization for 2 weeks plus poultry manure were found to be on par and significantly superior to other treatments. Once again, solarization for 4 weeks registered least root-knot index (1.53) followed by solarization for 2 weeks plus neem cake (1.55) and solarization for 2 weeks along with poultry manure (1.60). Maximum root-knot index of 4.50 was observed in the check.
These results are corroborative with the findings of Hussaini (1995) who reported effective reduction in root-knot index due to combination of soil solarization and neem cake. According to Rodriquez (1986), the increased microbial activity in the amended soil leads to release of wide variety of chemically different substances which are directly toxic to phytonematodes. Patel and Makwana (1992) reported that soil solarization of bidi tobacco nursery beds for 2 weeks along with neem cake resulted in highest number of transplants with drastic reduction in root-knot disease.

Solarization of soils amended with neem cake will be more effective. Neem cake amendment without soil solarization was found to be less effective. Thus, the two non chemical methods work synergistically (Abdul Wajid et al., 1995). Singh (1983); Narendra Singh and Singh (1982) have reported that organic amendments work excellently at higher concentration and higher temperature caused maximum suppression of fungi. Attri and Ravi Prasad (1981), reported that application of neem cake before solarization helped its degradation and release of phenolic compounds under higher temperature. Neem cake, besides reducing pathogen propagules also promotes rapid, luxuriant
growth of seedlings to overcome disease attack and also regulates nitrogen nutrition.

According to Sharma and Nene (1990) soil solarization reduced the preplant nematode population densities in the vertisol and thus incurred less crop damage from plant parasitic nematodes, but solarization may not result in long term nematode control. Solarization should be combined with other treatments such as application of neem cake or other organic amendments and (or) planting of resistant cultivars or non hosts after solarization to determine if there are interactive effects on the population densities of plant parasitic nematodes.

Khan et al. (1974) reported the least proliferation of nematodes in the plots treated with neem cake due to liberation of ammonia. According to Sitramaiah and Singh, 1978 it is due to liberation of fatty acid during decomposition which is detrimental for the development of nematode. Apart from this, neem cake itself contained formaldehyde (0.25%) which is another factor responsible for nematode control.

5.3.4 Effect of Integration of Oil Cakes and Poultry Manure with Soil Solarization on Surveillance of Weeds
At the outset, all the treatments were significantly superior to check. However, amongst the treatments, solarization for 4 weeks alone, solarization for 2 weeks alone, solarization for 2 weeks along with neem cake, solarization for 2 weeks plus pongamea cake, poultry manure alone and solarization for 2 weeks plus poultry manure were on par with each other and found to be significantly superior to rest of the treatments. Solarization for 2 weeks plus neem cake recorded lowest weed intensity (22) followed by solarization for 4 weeks (25), solarization for 2 weeks alone (34), solarization for 2 weeks plus pongamea cake (35), solarization for 2 weeks plus poultry manure (35) and poultry manure alone (40). Maximum weeds were noticed in the check (165). The results are in conformity with the findings of Hussaini (1995) who obtained similar results in combination of soil solarization with neem cake and reported drastic reduction in weeds.

5.4.1 Effect of Integration of Sheep and Poultry Manure with Soil Solarization on Transplantable Seedling Production at 60 Days

Farm Yard Manure (FYM) and compost have been reported to suppress populations of many plant parasitic nematodes when used in large quantities (Adeniji, 1977). However, reports
are also available which indicate that these materials do not cause significant suppression of nematode populations. It is agreed that these materials are already decomposed hence lack nematicidal principles which are normally released during the process of decomposition. It means that the organic matter should decompose at the site of nematode activity (Alam, 1976). Of late, poultry manure / litter is being used for the effective control of plant parasitic nematodes. The addition of chicken litter to soils suppressed *Meloidogyne* spp., restricted root galling caused by the nematode, and simulated plant growth (Mian and Kabana, 1982) (Plate-24) (Fig.-10).

All the treatments were significantly superior to check (Table-17). The treatment combination of poultry manure and solarization was found to be significantly superior to rest of the treatments in yielding highest number of transplantable seedlings. Among the other treatments, neem cake with solarization, sheep manure with solarization and poultry manure alone were on par and significantly superior to rest of the treatments. Maximum seedlings were obtained in solarized beds along with poultry manure (185) and followed by solarization
Fig. 10: Effect of integration of sheep and poultry manure with soil solarization on seedling production in FCV tobacco nursery at 60 days.
with neem cake (142), solarization with sheep manure (140) and poultry manure alone (96). Whereas, least number of seedlings were procured in the check (60). The present results are mostly in line with the findings of above authors indicated.

5.4.2 Effect of Integration of Sheep and Poultry Manure with Soil Solarization on Transplantable Seedling Production at 75 Days

At 75 days also, the same trend continued where all the treatments were significantly superior to the check. Once again, poultry manure in conjunction with solarization was significantly superior to other treatments. This was followed by solarization with neem cake and solarization with sheep manure which were on par and significantly superior to rest of the treatments. Maximum seedling production was observed in solarized beds along with poultry manure (210) (Plate-25) followed by solarization with neem cake (170), solarization with sheep manure (165) and poultry manure alone (160). Lowest number of seedlings were recorded in the check (75) (Plate-26). These results are in conformity with the findings of Chindo and Khan (1990) who reported significant increase in growth and yield of tomato with different levels of poultry manure (4t/ha and above). This could be ascribed to a number of factors viz., increased
nutrient availability to the plant (Druzina et al., 1983) improvement in the soil condition resulting in greater root growth there by enhancing the utilization of soil nutrients as a consequence of which the nematode damage is markedly minimized (Vander Lean, 1956), and changes in biotic and abiotic environment of plants due to poultry manure which ultimately altered the host parasitic relationships (Van der Laan, 1956).

5.4.3 Effect of Integration of Sheep and Poultry Manure with Soil Solarization on Root-knot Nematode at 60 Days

At the outset all the treatments were significantly superior to the check (Table-18). Poultry manure along with soil solarization was significantly superior to other treatments except neem cake with solarization and poultry manure alone. It recorded root-knot index of 1.75 followed by solarization with neem cake (2.00) and poultry manure alone (2.10). The check registered highest root-knot index (3.25).

5.4.4 Effect of Integration of Sheep and Poultry Manure with Soil Solarization on Root-knot Nematode at 75 Days

The trend observed at 60 days regarding the reduction of root-knot index was repeated at 75 days. All the treatments were
significantly superior over the check (Table-19). Poultry manure with solarization, neem cake with solarization and poultry manure alone were significantly superior over rest of the treatments and were on par with each other. Least root-knot index (2.40) was noticed in poultry manure with solarization followed by neem cake with solarization (2.50) and poultry manure alone (2.70). Sheep manure along with solarization registered higher root-knot index (3.25) followed by carbofuran alone treated beds (3.20). Maximum root-knot index was observed in the check (4.00) (Plate-27).

Similar results were obtained by Chindo and Khan (1990) with poultry manure who reported remarkable reduction in the nematode population with a concomitant increase in growth and yield in tomato. These results are also corroborated by the findings of Ramakrishnan et al. (2005) who showed that application of neem cake at 400g/m², poultry manure at 300g/m² and vermicompost at 1.0kg/m² in combination with soil solarization recorded root-knot index of 1.97, 1.90 and 2.00, respectively compared to 1.72 in phenamiphos and 3.80 in control. They also recorded 62.5, 672.0 and 73.4 per cent increase in healthy transplants yield, respectively over untreated check as against phenamiphos (85.9%).
The fact that there was a remarkable reduction in nematode damage suggests that some toxic substances might have been released during decomposition of poultry manure (Johnson, 1959; Singh and Sitaramaiah, 1966; Jagadale et al., 1985). A dual mechanism of suppression may be operating for chicken litter, with an immediate effect from NH₄ and other toxic compounds, followed by long term suppression due to the microbial activity associated with organic amendments. Lowering of pH in amended soils due to addition of ammonia might also have contributed to observed decrease in nematode activity (Kaplan and Noe, 1993). The nematode suppressive effects of chicken litter have been attributed to nitrogen content, and most importantly to the release of ammonical nitrogen from the soil amendment (Rodriguez-Kabana, 1986).

5.5.1 Screening of Germplasm for Resistance / Tolerance against Root-knot Nematode

Control of root-knot nematode in tobacco by use of nematicides is neither desirable nor economical due to the health hazards and high cost. Use of resistant varieties as an alternative to chemical control is most desirable for nematode
management since it is cost effective and eco friendly. In India, *Mecoidoyne incognita* and *M.javanica* are the dominant species causing root-knot dominant species causing root-knot disease on tobacco although *M.arenaria* is also found associated in some pockets.

A total 111 of FCV tobacco breeding materials comprising germplasm, lines or varieties were used for screening against root-knot nematode. The variety FCV special was used as susceptible check. The results indicated that screening breeding materials revealed different type of reactions against root-knot nematode which reflected in the form of root-knot index recorded by them. The entries viz., KST-17, KST-19, KST-20, KST-21, KST-25, KST-28, Bhavya JL-53-12, FCH-144, FCH-145, FcH-148, FCH-184, Bigorinica, delcrust-P, 94-3-6-1-5-1, 95-1-3-6-4, 95/4, V-4080, II 1624, ILTD Spl., V-4056, cm-12, Gold line, KGC-1, 1308, 86-4-1-1-1-9, 86-8-3-2-1, 1099/2/2, F-210, PCT-16, L-621 and CTRI spl. MR x MDC-57 recorded root-knot index varying between 1 and 2 indicating that the disease intensity is very mild to mild. Thus these 32 entries are highly resistant to root-knot nematode. The entries, KST-26, KST-27, CY-133, CY-135, JL-5-97, JL-19-96, JL-32-95, JL-52-78, JL-52-36, PCT-7, FCH-6523, FCH-164, Cocker-140, 95-3-1-2-5-1, 95-1-3-6-2-1,
95/13, V-4064, 48/54, II1623, Gold streack, NLS-4, 86-8-3-2-1-2, 86-8-3-2-1-3, 1294/4, 1117, L-1031, 1127, Blackshank resistant, Bhavya x PCT-7 and Bhavya x Delcrust showed root-knot index varying from 2 to 3. Here, the disease intensity is mild to moderate indicating that these 30 entries are moderately resistance to root-knot nematode.

Root-knot index varying from 3 to 4 was observed in the entries, KST-18, KST-29, Ratna, CY-139, CY-146, CY-118-5C-1, CY-142, FCH-154, FCH-172, FCH-187, FCH-188, VA-116, L-1358, L-1366, L-1359, 94-10-7-1-9-3, 95/5, V-3884, V-4076, II-1619, 1204/4, II-1308, V-3543, V-3643, 88-15-5-1-7, 88-15-5-1-4, Swarna, Kanakaprabha, MDC-57 and Bhavya x MDC-57 indicating the disease intensity from moderate to severe. Thus, these 30 entries are found to be susceptible to the root-knot nematode while, the other entries, KST-22, KST-23, CY-149, JL-32-96, FCH-177, N-98, V-4219, 94-5-8-5-2-1, V-3703, 134/4, NLS-5, V-3571, 1099/214, 1099, 117/2, 86-4-1-1-1-7, FCV Special and Navile-1 recorded root-knot index varying between 4 and 5 indicating the disease intensity from severe to very severe and therefore these 18 entries are highly susceptible. Moreover, such plants also exhibited clear symptoms of leaf yellowing, rimfiring and day wilting in the hotter periods of the day. Similar relative reaction to root-knot nematode in germplasm collection
of tobacco was widely reported (Nagarajan et al., 1998). The present investigations are in conformity with the findings of Ramakrishnan et al. (1998) who screened FCV tobacco germplasm accessions numbering 60 along with variety Bhavya a resistant check and varieties FCV special and Swarna as susceptible checks 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-174, FCH-176, FCH-178, FCH-179, Gold streack and ILTD special were found promising with root-knot index ranging from 1.1 to 1.5. Further Ramakrishna et al. (2005) subjected to screening of 45 tobacco germplasm accessions against root-knot nematodes under sick field conditions. Six accessions namely, CY-149, Burley-1, B-1000, KST-27, KST-28 and N-98 were found promising with RK1=1.5 on a 0.5 scale CY-118.5C1, Leca 10, Spanish burley, burley 21, hyburley, VA528, BSRBV-2 and 754-2-1 were found highly susceptible with RK1 more than 3.5.

The 32 germplasm which have exhibited highly resistant reaction against root-knot nematode can be exploited in breeding programame aiming at developing root-know resistant varieties.
Plate-1: FCV Tobacco-Trupti
Plate-2: Tobacco Barn
Plate-3: Inside of Tobacco Barn
Plate-4: Ventury furnace
Plate-5: Female of root knot nematode
Plate-6: Male of root-knot nematode
Plate-7: Juveniles inside the host tissue

Plate-8: Life cycle of root knot nematode

Plate-9: Root-knots in root system

Plate-10: Root-knot affected plant

Plate-11: Experimental Site and solarized beds

Plate-12: Vapour condensation inside the solarized bed
Plate-13: Germination of FCV tobacco
Plate-14: Transplantable seedlings
Plate-15: Check
Plate-16: Check
Plate-17: Weeds in unsolarized beds
Plate-18: Application of Poultry Manure