INTRODUCTION
1. INTRODUCTION

Vegetables are usually defined as edible herbaceous plant parts used for culinary purposes. These are consumed throughout the world. In many areas particularly in the developing countries the entire population largely depend upon vegetables. Because of inadequate production and supply, the vegetables are becoming no longer cheap commodities. Among major constraints responsible for poor productivity of vegetables, pests and parasites occupy paramount position, plant-parasitic nematodes being one of them. Berkeley (1855) was probably the first to have reported nematode injury to vegetables, induced by root-knot nematodes on cucumber in English greenhouse. Most common nematode species reported to be associated with vegetables belong to the genera *Tylenchus* Bastian, 1865; *Ditylenchus* Filipjev, 1936; *Tylenchorhynchus* Cobb, 1913; *Hoplolaimus* Daday, 1905; *Helicotylenchus* Steiner, 1945; *Pratylenchus* Filipjev, 1936; *Rotylenchulus* Linford & Oliveira, 1940; *Hirschmanniella* Luc & Goody, 1964; *Apheelenchoides* Ritzema-Bos, 1891; *Longidorus* Micoletzky, 1922; *Xiphinema* Cobb, 1913; *Radopholus* Thorne, 1949; *Tylenchulus* Cobb, 1913; *Meloidogyne* Goeldi, 1887; *Heterodera* Schmidt, 1871, etc. Although pathogenicity has not been proved for all.

The most common vegetables in India are potato, eggplant, okra, cabbage, cauliflower, cucurbits, immature parts of many legumes, tomato, chilli, etc. These crops are damaged by a number
of plant-parasitic nematodes, the root-knot nematodes (*Meloidogyne* spp.) being most serious damaging pests particularly to the members of Solanaceae, Cucurbitaceae, etc.

**Crop Losses:**

Crop loss is defined as the difference between the attainable yield and the actual yield (Chiarappa, 1971). It is difficult, however, to determine the attainable yield because it depends on many cultural, environmental and pest factors. Actual yield is more easily measured as that obtained under prevailing pest pressure, i.e., without protection. Although, earlier reports on crop losses due to plant-parasitic nematodes thought to be about 5%, whereas, small farmers in the developing countries commonly experience much larger losses (Taylor and Sasser, 1978).

The degree of damage depends upon the population density of nematode(s) species present, host suitability, locality, ecological factors, agronomic practices, control measures adopted, or more likely, a combination of all these conditions. The presence of multiple pathogens makes diagnosis confusing and frequently resulting in under assessment of the damage caused by the nematodes. There are numerous estimates of damage in crop production on worldwide or on country-wise basis. For instance, United States Department of Agriculture (USDA) estimated worth $372,335,000 loss per annum in 16 crops (Taylor, 1967). Earlier, Stapel (1953) estimated an average annual loss of 50,000,000 kroner (12.5 million) resulting from *Heterodera avenae* in Denmark. In other estimates Hutchinson et al. (1961) and Cairns (1955) reported $250 million and $500 million...
respectively annually. According to the Society of Nematologists, which undertook a major crop loss estimation project in 1971, the losses due to nematodes were to the order of 10% extending to 50% in certain situations. Feldmesser et al. (1971) estimated total annual losses to the tune of $159032693 due to nematodes in 16 field crops, 23 fruits and nut crops and 24 vegetable crops; while in vegetables it is estimated to be to the tune of $266,989,100 per year. In England and Wales, *Globodera rostochiensis* alone was responsible for causing losses to the extent of 200,000 tonnes potato annually (Southey and Samuel, 1954).

Recently Sasser & Freckman (1987) have reviewed crop losses on the basis of worldwide survey. They estimated average yield losses of the world's major crops due to plant-parasitic nematodes to about 12.3%. They also reported that monetary losses due to nematodes exceed $100 billion annually.

In India, it is not fully known as to how much losses nematodes cause by way of damage to vegetables crops. However, Bhatti and Jain (1977) and Jain and Bhatti (1978) observed losses worth 91%, 46% and 27% in okra, tomato and brinjal respectively due to root-knot nematodes. Reddy (1985) pointed out that the yield of tomato was reduced by 39.77% at a population of 20 larvae of root-knot per gram of soil. Van Berkum and Seshadri (1970) estimated the loss of $10 million in wheat from 'Ear cockle' disease caused by *Anguina tritici* and $8 million due to 'Molya' disease in wheat and barley caused by *Heterodera avenae* in Rajasthan State alone. Moreover, crop losses in coffee caused by *Pratylenchus coffeae* worth $3 million was also assessed.
NEMATODE MANAGEMENT STRATEGIES:

Nematode management can be defined as a practice whereby populations of plant-parasitic nematodes are maintained at levels that do not cause economic losses in crops. There are two broad means for the management of nematodes: chemical and non-chemical. The different nematode management strategies are briefly described below.

Chemical Method:

For chemical means of nematode management, basically two types of chemicals are used: fumigant and non-fumigant nematicides. Soil fumigation began to be used extensively since the discovery of DD by Carter in 1943. Thereafter, EDB and DBCP in 1945 and 1954 respectively, were formulated as efficient soil fumigants for nematode management. Non-fumigant chemicals are usually carbamates or organophosphates; these are mostly water soluble, so rely on water to move through soil profile. In general, non-fumigants are economical and easier in application, besides being less phytotoxic. Many of them have good systemic activity in plants against nematodes (Hague and Gowen, 1987).

Chemical control still remains to be one of the most outstanding methods in terms of immediate results, but phytotoxic effects sometime pose difficulties. Furthermore, many nematicidal chemicals have been found to have contaminated the ground-water. Thus potentially causing toxicity to human beings. Some of the chemicals are equally hazardous to live-stocks, plants and also to the beneficial fauna and flora of the soil. Unacceptable chemical residues may occur in fruits due to translocation of material in the
plant. Thomason (1985) has pointed out that the environmental risks with nematicides warrant the development and adoption of alternative practices. In our country, not a long time ago, we have experienced a catastrophe in the infamous Bhopal tragedy of 1984 due to leakage of MIC (methyl isocynide) gas which was meant for the manufactures of some kind of pesticides (Alam and Jairajpuri, 1990a). The recent removal of key nematicides from use in several developed countries through regulatory action has triggered a search for alternative nematode management strategies.

**Regulatory Method:**

Numerous attempts have been made to prevent the introduction of nematodes into countries or provinces by means of plant quarantine. Plant quarantine is a restriction, imposed by duly constituted authorities, whereby the production, movement, or existence of plants or plants products, is brought under regulation, or in order that the introduction or spread of nematode may be prevented or limited, or in order that a pest already introduced may be controlled or eradicated. Thereby avoiding or reducing losses that would otherwise occur through damage by the pest or through a continuing cost of control measures (Leiby, 1932). Regulatory methods have some obstacles in their implementations, because one material which is restricted for a disease, may be infected by other pathogen(s). Therefore to check the entry of one causal organism may bring menace of another pest.
Physical Method:

In physical means of control, basically nematodes are eradicated through heat treatment, steam sterilization and pasteurization of soil, electrical soil heating, short wave diathermy, peak heating and 'cooking out' of mushroom composts, hot water treatment, radiation treatment, ultrasonics, washing process, seed cleaning, etc. (Alam and Jairajpuri, 1990a). These aspects have been reviewed by Jenkins (1960), Southey (1965, 1978) and Maas (1987). Christie (1959) has pointed out that plant-parasitic nematodes can be killed at 44-48°C. Soil solarization is a recently developed and most effective technique when carried out during hottest season of the year (Heald and Robinson, 1987; La Mondia and Brodie, 1984). The thermal death of nematodes is quite difficult for particular nematode species. Therefore, temperature regimes has got much importance for effective treatments. Though these practices are effective for diseased material like propagating tuber, shoot or root, but temperature regulation is quite difficult. Besides, there are some problems for large scale infestations.

Cultural Method:

Basically, cultural practices involve depriving the nematodes of a suitable host and thereby reducing nematode population by starvation. There are many cultural practices used in nematode control, viz., prevention of spread, fallowing, flooding, selection of healthy propagating material, sanitation, winnowing, time of planting, harvesting, nutrition, general care of host crops, cropping, manuring, etc. The last named category is sometimes treated as biological
method of nematode control because organic wastes are remains of once living organisms.

**Cropping:** Though, it appears simple method but it has many problems when all aspects are taken into consideration. The most important disadvantage is the fact that when a nematode species is controlled by a particular cropping sequence some non-significant species may attain noxious level thereby crumbling the whole system. Moreover, in such a control method some of the low value crops to be recommended may not be acceptable to farmers for obvious reasons. However, this type of control may be recommended in certain cases especially those concerning with vegetables.

**Use of Nematode-Free Planting Stock:** The use of nematode-free planting stock and other sanitation procedures are effective means of nematode control. Even though the cost of such practices is relatively low but growers continue to use nematode infected transplant and seed pieces into infested field. Apparently this is due to the ignorance of farmers about the importance of plant-parasitic nematodes.

**Sanitation:** The term covers a wide range of cultural practices, including weed/crop-residue destruction and disinfestation of farm implements. These practices are cumbersome and time consuming.

**Fallowing:** With fallowing, in addition to starvation the nematode is also affected by soil desiccation and direct heat from the sun. Most plant-parasitic species probably do not survive in upper soil layers
for more than 12-18 months, and their population densities are greatly reduced in first 6 months. However, some problems occur to implement these practices: (i) the mechanical operations necessary to maintain lands completely free of vegetation are difficult and expensive, (ii) fallow lands do not contribute to farm income, and (iii) fallow is poor conservation practice.

**Flooding:** The principle of control involved in flooding are not fully understood. Most probably, flooding decreases the oxygen content of soil and may kill nematodes by asphyxiation (Brown, 1933). The disadvantages of flooding are the same as those listed above for fallowing. Also, an adequate source of inexpensive water should have to be available for this strategy.

**Time of Planting:** Some parasitic nematodes become inactive during the winter season because low temperature inhibit their activities. By planting crops when soil temperature is favourable for crop growth and unfavourable for nematode development, it is often possible to obtain relatively high yields despite the presence of nematodes.

**Biological Method:**

Garrett (1965) has defined biological control of plant diseases as "any condition under which, or practice whereby, survival or activity of a pathogen is reduced through the agency of any other living organism (except man himself) with the result that there is a reduction in incidence of the disease caused by the pathogen". Several predacious or parasitic organisms such as fungi, bacteria, protozoans, viruses, nematodes, tardigrades, turbellarians,
collumbolans, mites, enchytraeids, etc. have been reported as effective biocontrol agents of many plant-parasitic nematodes (Kerry, 1987). There are few fungi and bacteria which have shown much promise in such a control, though their potential for wider use has still to be achieved. Some times scientists also included organic amendment, antagonism and host resistance/tolerance in the broader sense of biological control of plant-parasitic nematodes, while some treat them separately or as a part of cultural method of nematode control.

Organic Amendments: Application of organic matter into soil for crop improvement by farmers has been practised since the advent of agriculture, but beneficial effects of organic amendments against nematode control became known only recently (Singh and Sitaramaiah, 1970; Sayre, 1971; Alam, 1976, 1990; Muller and Gooch, 1982). In addition to nematicidal activity on the part of decomposition products, the addition of organic matter stimulates microbial population of actinomycetes, bacteria, and fungi, elements of which might be antagonistic to nematodes (Badra et al., 1979; Godoy et al., 1983a).

Antagonistic Plants: Several plant species are antagonistic to plant-parasitic nematodes (Alam and Jairajpuri, 1990b), e.g., marigold, Tagetes spp. (Tyler, 1938); mustard, Brassica spp. (Ellenby, 1945, Alam et al., 1976); rocket-salad, Eruca sativa (Alam et al., 1976); Asparagus officinalis (Rohde and Jenkins, 1958); neem, Azadirachta indica (Alam et al., 1977d); Persian lilac, Melia azedarach (Siddiqui and Saxena, 1987a,b), etc.
Biological control is in fact, a skilful manipulation of biosphere against nematodes for obtaining maximum benefits. In the modern era of research, bio-control has shown to be a successful means of control but it appears rather difficult to artificially raise and introduce nematode antagonists, yet it is feasible to create conditions which will increase environmental resistance against nematodes. Organic amendments and interculture of antagonistic crop plants would probably hold the key in such endeavours. These two aspects constituting the main theme of the present thesis have been reviewed and discussed in the next chapter.