CHAPTER V

DISCUSSION

5.1. DISTRIBUTION OF THE GENUS *PRATYLENCHUS* IN SUGARCANE TRACTS OF INDIA

5.1.1. ALL INDIA

Spread of different genera and species of plant parasitic nematodes is highly dependent on the climatic and soil conditions of the particular region, cropping sequences and various agricultural practices as observed by earlier authors (Mukopadhyaya and Prasad, 1986; O'Bannon *et al.*., 1972 and Nakagome and Osaki, 1970). Hence there is always a need to survey the distribution of important nematodes of a particular crop based on the location. Such an intensive survey for important plant parasitic nematodes of sugarcane crop was carried out in eight major sugarcane producing states of India (Table 6; Figure 3). Scanning the results it can be concluded that *Pratylenchus* is the predominant plant parasitic nematode identified.

Data presented showed that the genus *Pratylenchus* is at high population levels in all states except Maharashtra. Per cent occurrence of this nematode when compared to all the other important species recorded simultaneously is also higher. Although *Pratylenchus* has been reported from sugarcane fields of India by Nath *et al.*, (1978), Singh and Misra (1974), Darekar & Pokharakar (1979) Varadarajan *et al.*, (1974) and Mehta (1986), there is no clear indication regarding the per cent distribution and widespread occurrence of this genus in comparison with other plant parasitic nematodes. Hence these investigations demonstrated clearly the facts and confirm the economic importance of *Pratylenchus* in sugarcane fields of India. This is in conformity with the earlier findings of Brathwaite (1980) and Pinochet (1987) and Sasser and Freckman (1987) that *Pratylenchus* is the predominant genus in the sugarcane fields of the world.
The other prevalent species that have been identified concurrently in the soil samples analysed were \textit{H.indicus}, \textit{T.annulatus} and \textit{H.dihystera}. The percentage of occurrence of these species in co-existence with \textit{Pratylenchus} varies from zone to zone, where, either one occurs in high population depending on varied bioecological factors.

Tamil Nadu and Haryana have the highest percentage of \textit{Pratylenchus}. This can be attributed to the fact that there is a continuous monoculture of sugarcane in many of the factory zones surveyed which has resulted in the build up of higher population. Also the heavy clay content of the soil of Tamil Nadu is more congenial for a rapid multiplication of population. Such an increase in population with the increase in clay content of the soil has also been reported from Trinidad\textasciitilde South Africa by Singh (1973) and Spaull (1981) respectively. But the State of Haryana showing a high per cent of \textit{Pratylenchus} (38.96) the soil type is sandy loam and not clay. However, in these regions the cropping sequence is generally with wheat, maize and sorghum and other vegetable crops. Probably due to continuous cropping of graminaceous crops which are highly conducive for a rapid multiplication of this nematode and the population is always sustainable at high levels as has also been reported by several authors (Dunn and Mai, 1973; Cuarezama teran \textit{et al.}, 1984; 1985 and Baikabile Motalaote, \textit{et al.}, 1987).

In the state of Andhra Pradesh the distribution trend of nematode genera was almost similar to that of Tamil Nadu. However the percent population of \textit{Pratylenchus} species is lower than in Tamil Nadu with a concurrent increase of \textit{T.annulatus}. Here, although soil type in many of the regions cultivating sugarcane is similar to that of Tamil Nadu, generally the crops cultivated in coastal zones and river beds where the soil is of alluvial type (Sehgal, 1990) thus probably accounting for the increase in \textit{T.annulatus} which prefers a sandy soil.

Gujarat and Madhya Pradesh showed identical trend in percentage distribution of important nematode genera in sugarcane fields with a higher population of \textit{H.indicus} being 23.84 and 23\% respectively followed by \textit{T.annulatus}. Both the states have similar types of soil being medium and black deep soils with red and laterite zones spread out.
The climatic conditions in both the states are sub humid to per humid with equal growing period of 150-180 days (Sehgal et al., 1990). These prevailing factors induce a favourable development of all the three genera viz., *P.zeae*, *H.indicus*, and *T.annulatus*.

In the state of Maharashtra, where there is a great variation in soil types, variety, cropping pattern and climatic conditions, *Pratylenchus* occurs only at a minimum level of 18.08%. On the other hand, *H.dihystera* is found at a high level of 36.06%. Here, the soil is shallow and medium black with a semi arid climatic condition and 90-150 days growing period (Sehgal et al., 1990). Sugarcane variety Co 740 is the ruling variety of this state, cultivated as adsali crop (18 months) followed by two to three ratoon crops. Apparently the soil type, sugarcane variety and cropping system are not favourable for sustaining high populations of *Pratylenchus*. Darekar and Pokharkar (1979) have also reported the dominance of ectoparasites in this region and that *Pratylenchus* is of minor importance in Maharashtra. Apparent symptoms of poor crop due to the nematode infection/damage recorded during the survey is probably due to total synergistic effect of the plant parasitic nematodes of that region.

In Uttar Pradesh also *Pratylenchus* species forms the maximum percent of total plant parasitic nematodes. However the density is lower when compared to other states. This is accompanied by an increase in *H.indicus*. The crop in this area is generally rotated with short term crops like mustard and other pulses probably accounting for low build up of population.

It can be inferred from the above studies that although density of *Pratylenchus* varies from zone to zone and state to state, in comparison with the other plant parasitic nematodes this nematode can be rated as the most economic important plant parasitic nematode in sugarcane tracts of India.

5.1.2. TAMIL NADU

Survey conducted in Tamil Nadu indicated that *Pratylenchus* is the predominant genus found in sugarcane tracts of the state. However, variation in the population
density occurs from location to location as explained by the absolute and relative density and frequency factors. This can be attributed to the fact that climatic conditions, soil type and agronomic practices vary in each district studied.

5.1.2.1. ABSOLUTE AND RELATIVE DENSITY

Absolute density, expresses the population of nematodes found in a specific location, and it varies from region to region. It depends on the various agroclimatic conditions prevailing in a particular region. Study of absolute density *Pratylenchus* in various zones showed maximum absolute density of *Pratylenchus* in National sugars while minimum is observed in Chengalrayan sugar zones. Generally no overlapping is observed in absolute density of *Pratylenchus* spp. in factory zones surveyed.

Minimum absolute density reflects the fact that practices adapted for cultivation of sugarcane are well suited for this crop. Also the soil type and other agronomic practices carried out are more conducive for the better growth of the crop. This reasons for the fact that *Pratylenchus* do not multiply at a very rapid rate and maintains the low density. The lower absolute density ranging from 200 to 400 in the seven factory zones indicates that although the nematode occurs, the number is lower when compared to other zones surveyed. As the areas sampled in different districts of Tamil Nadu fall in the tropical zone, the average temperature being a constant ranging from maximum of 33°C and a minimum of 22°C.

Average rainfall is also constant being 650 mm/year. Hence it can be concluded that soil type and the cropping system are probably the major components that play a very important role in the multiplication of this nematode.

Besides this, the period of sugarcane cultivation in a particular zone also plays an important role. In many cases the sugar factories have been developed only in the recent past and hence the build of the population is slow as in 10 factory zones noted. However regions of EID Parry, Cauvery and National sugars where there is higher absolute density the crop has been cultivated over a period of many decades and hence the zone becomes conducive for the sugarcane nematodes. This attributes to the fact that
absolute density and relative density are higher in such zones. No work has been carried out on these lines in the other sugarcane cultivated zones of the world. However from the literature it can be seen that in Hawaii, Barbados, Puerto Rico, South Africa, Fiji etc. where sugarcane is the principal crop *Pratylenchus* has also been found to occur as an important pest causing immense losses in yield as reported by Pinochet (1987) and Spaull and Cadet (1990).

In some zones like Chengalrayan zones, both absolute density and relative density are minimum indicating the unsuitability of these zones to *Pratylenchus*. It can be further inferred that in zones of Anna, Dharmapuri, Kallakurichi, Myladudurai and Vellore although relative density is low there is an increase in absolute density. This further proves the fact that through years to come there is a high probability of rapid multiplication of *Pratylenchus* due to the large numbers occurring in the samples. As sugarcane in the recent past, has been cultivated as the primary crop of these regions the higher absolute density can lead to a higher relative density in future.

Such studies on absolute density and relative density gives us a view as to the suitability of zone in influencing faster multiplication of a particular nematode. It can be concluded from this as to whether in time there will be a rapid increase in *Pratylenchus* population and needs to be controlled with immediate effect as by nematicides or the population development will be only gradual and can be controlled by other cultural and management practices.

5.1.2.2. ABSOLUTE FREQUENCY AND RELATIVE FREQUENCY OF *PRATYLENCHUS*

The frequency of particular nematode in the samples analysed gives us an overall view on predicting the prevalence of that particular nematode in the area surveyed. The absolute frequency calculated as a per cent of samples in which the nematodes occur to the total number of samples analysed gives the distribution pattern of that nematodes. From the data (Table 7) it can be seen that frequency of occurrence of *Pratylenchus* is
high being identified in more than 55 to 80% of the samples analysed. This indicates the widespread distribution of the lesion nematodes in sugarcane fields.

The frequency data show the prevalence and widespread distribution of *Pratylenchus* in all sugarcane growing regions of Tamil Nadu although there is a great variation in density figures. As the genus *Pratylenchus* is a well established nematode of the crop and ranks as most important genera for sugarcane (Sasser & Freckman; 1987) it can be presumed that there is a very rapid multiplication of this nematode over a period of years due to the necessity of this crop for the many developing factories, it will be cultivated almost as a perennial crop in future.

5.1.2.3. POPULATION OF *PRATYLENCHUS* AND ASSOCIATED CROP CONDITIONS.

Population levels of *Pratylenchus* should be an indicator to the condition of the crop sampled. When an economic threshold level of particular nematode is established it can be judged as what level of damage can be envisaged in the area correlated with population density. However data recorded during the survey (Table 8) showed that there was a great variation in population of nematode when associated with crop condition. It can be seen from the table that in a crop defined to be the poor condition, the population level of *Pratylenchus* ranges from 165-605/100 cc of soil averaging to 377.41, but in the majority of samples numbers > 200 i.e, higher than the Economic Threshold Level established. Such variation in field condition of the crop is probably due to the fact that the crop is also affected by other biotic and abiotic factors especially other plant parasitic nematodes. However, this poor condition is always associated with a higher population. Like wise, where the crop has been graded fair the range of population is 84-366 nematode per 100 cc of soil averaging to 212.36. Thus there is decline in the overall population when compared that under poor conditions.
The population range of *Pratylenchus* in soils collected from crops of good/normal conditions gives minimum average of 119.27 nematodes, with a range of 45-325.

When we compare each factory zone, it is clearly seen that the population of nematode decreases from poor to good, being maximum in poor and minimum under good conditions of the crop. This explains the fact that in every zone, there is a change in population dynamics and economic threshold level of *Pratylenchus* depending on various factors.

The maximum nematode population under good condition is recorded in Dharmapuri zone being 225. However in the same zone poor crop also records a low population of 252 nematodes only. On the other hand in the Myladudurai zone a good condition of the crop has only 126 *Pratylenchus*/100 cc. while poor condition records a high of 605 nematodes. However, although there is a need to determine an economic threshold level to indicate pathogenicity of *Pratylenchus* to sugarcane, apparently this number does not stand true at the field level always. This is a very good indication that the crop condition alone does not reflect the nematode population and vice versa. However we can conclude, that by regular sampling of apparently healthy and apparently poor clumps in the same field the number of nematodes that can cause economic loss to the crop can be established. Before losses to the crop is judged to be by *Pratylenchus* it is necessary to have a survey of the region concerned to take up any management practices.

5.1.2.4. INTERGENERIC ASSOCIATION

An ecological community has a number of biotic and abiotic factors that act in a synergistic manner controlling the distribution, density, frequency and population level of plant or animal species concerned. This type of an interaction was also observed among the different nematodes species that co-exists together in sugarcane fields. Analysis of the survey samples shows that along with *Pratylenchus*, species of *Hoplolaimus*, *Helicotylenchus* and *Tylenchorhynchus* also occur at high density levels.
Hence when three to four plant parasitic nematodes are found occurring together it indicates that there exists a definite association between *Pratylenchus* and other nematodes. The type of association of *Pratylenchus* with other genera is in turn influenced by the bioecological factors. However, when the factors are conducive for the co-existence of the nematodes together the relationship becomes positive and the influence of such external factors determine the nature of relationship.

*Pratylenchus* indicated a negative association with *H. indicus* in 19 sugar factory zones (Table 9). Since both the respective nematodes are endoparasites and semi endoparasites, depending on internal environment of sugarcane roots for their feeding, reproduction and multiplication there exists a competition for their survival. Though *Pratylenchus* has negative association with *H. indicus* in the above factory zones, the association index (dice index) which is the intensity of association between the two nematodes varied depending on the factory zone, irrespective of the districts from where the samples were collected.

The above data indicates that location of zones surveyed do not form basis for coexistence of the two nematodes species. The zones that are located in different districts with a varied agroclimatic conditions the relationship of the two nematodes in its occurrence is constant. On the other hand, where the zones are located in agroclimatic area of one district the interrelationship between the two nematode varied as shown by different dice index. It can be inferred from these investigations that spread coexistence of two nematode species show a diversification in distribution although they are in same agroclimatic zones.

In three factory zones viz., Madurandagam, Myladudurai, and South India the association of *Pratylenchus* with *Hoplolaimus* is of positive type. This can be attributed to the probability that there is a coordinated rapid multiplication of both the species in the same niche irrespective of each other due to the all factors being very congenial for both the nematodes. In such zones where there exists a positive association it becomes important to take up steps in controlling both the nematodes simultaneously.
Association of *Pratylenchus* with *H. dihystera* in 18 sugar factory regions was positive. Probably the existing soil types, cropping system and agroclimatic factors play a role in this. However, intensity of association is more in Anna followed by Deccan, Vellore and Aruna factory zones. The minimum index is observed in Ambur factory zones. In the case of this nematode also, the rate of multiplication in all probability varies from location to location depending on many factors that plays an important role for their survival.

The positive association between the above two nematodes indicate that it is probably due to differences in the nature of feeding and selection of feeding site. *H. dihystera* is a cortical feeder which feeds mainly on the cortical cells from outside of the root. It lays eggs and completes its life cycle inside the root without entering into it. On the other hand *Pratylenchus* being an endoparasite, penetrates the cortex, lays eggs inside the cortex and completes its life cycle therein. In addition the preferred feeding site for the two nematodes also differ, *H. dihystera*, preferring the root tip region for feeding, where as *Pratylenchus* prefer the region just above the root tip for feeding. Since *Pratylenchus* and *H. dihystera* do not interfere with each other for their feeding or reproduction they are well adopted to the root habitat and the existing interaction between the two nematodes is positive.

Association of *Pratylenchus* with another ectoparasitic nematode *T. annulatus* is of negative type. The negative association is highly significant in Aruna, Anna, Deccan and Vellore zones. Though the two nematodes exhibit different mode of life, being ecto and endoparasitic, both of them compete with each other for their survival, resulting in a negative association.

The competition may be either for food or shelter. It has been observed that since *Tylenchorhynchus* is an ectoparasite with browsing mode of habitat it usually prefer the region just behind the root tip for their feeding. The population of *Pratylenchus* increases rapidly after location of favourable environment for feeding. Consequently there is an increase in phenolic oxidation of sugarcane roots. Lesions formed by feeding
of *Pratylenchus* turns brown in colour due to phenols and may inhibit the feeding site of *T.annulatus* which is a surface feeder on most hosts as has been reported by Zuckerman (1961), Klinkenberg (1963) and Bridge and Hague (1974). It was further observed that feeding sites of one nematode was always a competent place for other nematodes and in this competition the nematode which is able to adopt better to that particular feeding site is in turn capable of multiplying rapidly. Also the heavy clay content of soil in the factory zones do not favour the rapid multiplication of *T. annulatus* but is highly favourable for species of *Pratylenchus*.

This results in a negative association between *Pratylenchus* and *T.annulatus* where probably endoparasite multiplies rapidly under favourable soil conditions and the multiplication of the ectoparasite is suppressed. Thus *Pratylenchus* shows a positive association with *H.dihystera* and is capable of coexisting together, but a negative association with the competing *H.indicus* and *T.annulatus* where each species increase/decrease depending upon its own adaptability.

5.2. POPULATION DYNAMICS OF *PRATYLENCHUS* IN SUGARCANE FIELDS

5.2.1. EFFECT OF MONOCULTURE OF SUGARCANE ON THE POPULATION OF *PRATYLENCHUS*

From the data on population dynamics (Table 11-14) and meteorological records (Fig. 5) it can be noted that there was a regular fluctuation in the monthly population of *P.zeae* at a two depths and three distances within the one crop year (Fig. 6, 7 and 8). However, the fluctuation in the annual meteorological data was not significant.

The maximum peak of nematode population was reached between 9 to 10 months of crop period at both the depths studied except in second year of study where the maximum peak was at eighth month. Hence it can be concluded that population of *P.zeae* is more dependent on age of the crop rather than climatic factors. In sugarcane crop the crop growth period between 180-240 days is generally referred to as the "Grand
Growth Period" of the crop. It is during this period that the crop stabilizes itself with well formed root system and fully developed shoot system. This is also the period when there is a beginning in formation of sucrose in the stem which reaches its peak at about 12th month. The Pi of \( P.zeae \) thus gradually increases along with the growth of the crop roots reaching Pmax at 9th to 10th month. Hence this age of the crop can be considered as the most optimum sampling period when maximum population can be recorded.

These data also illustrate that the Pmin gradually increases over period of 9-10 months to Pmax. This fact indicates that there is a successful feeding and multiplication of nematode during the course of the period. Consequent to such a vigorous establishment of any nematode under consideration, there should be an intense damage to the root system as there must be an accompanied entry and feeding of root by the endoparasite like \( P.zeae \). Thus it is during this period that there is a maximum loss to the crop concerned. Even the survey results have indicated that wherever there is a high population of nematode at later stage of crop it is accompanied by poor condition of the crop. This built up must have been from a Pmin in the early stages eventually causing considerable crop damage.

These field investigations were carried out at two depths and three distances within the sugarcane rhizosphere. Fluctuation in population at three distances when sampled at same depth (Fig. 7) indicated that maximum population of \( P.zeae \) incurred at 0 cm away from the clump i.e at the base of the clump. Further it can be seen that depth of 20 cm from the soil surface is more congenial zone for the nematode than 40 cm depth (Fig. 8). Hence sampling at base of the clump at 20 cm depth can be considered as the favourable site for sampling nematodes in sugarcane fields. This can be attributed to the fact that sugarcane root system is more luxuriant in this area. As we go deeper beyond 20 cm, there is a gradual thinning of root mass. Also as the distance from the base of the clump increases the root mass spreads and reduces. Hence the nematodes are found to occur in the area where there is thick root mat. It has been reported by Martin, (1967) that population \( P.zeae \) in the soil is greater beneath the cane row than in
the inter row. This may also be dependent on the fact that there is a continuous production of new roots in this zone. As the sugarcane roots mature and elongates probably the nematodes do not move to this distance. *P.zeae* being an endoparasite and able to complete its life cycle within the root, released in the soil as the roots decay, they immediately attack the freshly formed roots at the base of the clump. This gives them little chance to move away from their feeding site as newly formed roots are readily available. Probably this is one of the prime reason why there is greater loss to the crop as the developing root system is always infected rapidly. Hence the zone at base of the cane 20 cm deep in sugarcane fields should be regarded as the most optimum area for nematode sampling.

The data in table 13 also prove that though there is a fluctuation in nematode population during the five year period, there has always been a progressive increase in the population level from year to year. The population shows a tendency of two peaks in earlier years of cropping i.e., first three years, which gradually merge to a single peak by the fifth year (Fig. 12 and 13).

Intensive investigations undertaken to study the population dynamics also proved that a continuous monoculture of sugarcane in the same field for a period of five consecutive years significantly increased population of *P.zeae* at all depths and distances studied. Population observed in the 20 cm depth is higher when compared to that observed at 40 cm depth. It was further observed that increase in population of *P.zeae* for every year is more at the 20 cm than at 40 cm. This indicates that ecosystem of sugarcane influences the population of *P.zeae* in the soil, since availability of root system at 20 cm depth is more favourable for the multiplication of *P.zeae* maximum population is observed in this depth. However there is a decrease in the population at fifth year as compared to the first year at respective depths. This may be due to the fact that nematode population has reached a peak and remains at a plateau of sigmoid curve.

Population of *P.zeae* in the soil at three different distances away from the sugarcane clump indicated that maximum population is observed at the rhizosphere (0
cm) than the other two distances. In addition, population increase observed at the two distances are same as that observed in the rhizosphere of sugarcane clump. It can be concluded from this though the root system increases the population of \textit{P.zeae}, possible involvement of other environmental factors are also not excluded. These details explain the build up of population of \textit{P.zeae} and its wide spread distribution in the sugar factory zones.

The total rainfall showed no effect on the population build up of \textit{P.zeae}. This can be attributed to the reason that sugarcane is always cultivated as well as irrigated crop and has no dependance on the rainfall for its growth. Hence the available soil moisture is always within range suitable for maintenance of nematode population, and they do not have to depend on the natural rainfall for its existence. This makes the sugarcane ecosystem all the move influential in maintaining and increasing the nematode population over a period of years.

However working out the correlation between the environmental factors and population dynamics (Table 14) it can be seen that the rainfall has a positive correlation with the population of nematodes at lower depth. The samples taken at the base of the clump and at 25 cm away from the clump at a depth of 40 cm, there was an increase in population. This was probably due to the fact that inspite of sugarcane field being regularly well irrigated the moisture reaching to a lower strata are not sufficient for the rapid multiplication of nematode. Also it can be due to the rapid movement of water downwards the nematodes from the surface level being carried down thus increasing the population. Probably when there is an increase in the seasonal rainfall period it can be predicted that there can be a higher multiplication in the lower strata also.

Soil temperature showed a significant negative correlation with nematode population at top depth of 20 cm, at two distances of 25 and 40 cm away from the clump. The leaf canopy of sugarcane being very thick probably keeps the temperature immediately beneath it a constant low and with accumulation of adequate moisture in the root zone may also serve to protect the nematode moisturizing it at high levels. At the
distance of 25 and 45 cm there is a gradual thinning of leaf canopy and root system and hence, the population decreased as there was an increase in temperature. This influence was not envisaged at the depth of 40 cm. Also the air temperature showed a negative correlation with the population at all depths distance except at the lower depth of 40 cm and maximum distance of 45 cm. It can be explained by the fact that thinning of the leaf canopy and loss of moisture at the depth influences the drop in population levels. However the minimum air temperature showed no correlation as in this sub-tropical zone there is apparently no sudden fall in the night temperatures and average minimum temperature being fairly constant.

The relative humidity recorded during the morning hours has no effect on the population dynamics of *Pratylenchus*. However as the temperature cools down the relative humidity showed a positive correlation at all distances of 20 cm depth and at base of the clump i.e., only 0 cm at 40 cm depth. As the temperature reduces and relative humidity increases the situation is highly congenial for maintaining a good nematode population. This is reflected by the positive correlation recorded. But at lower depth and away from the sugarcane canopy this influence is in all probability not effective on the population of nematodes.

It can be thus concluded from these studies that rainfall, soil temperature and air temperature are important in increase/decrease of nematode population in the sugarcane ecosystem being accentuated also by the relative humidity.

5.2.2. VARIETAL EFFECT OF SUGARCANE ON THE POPULATION *PRATYLENCHUS*

Data on the population dynamics of *P.zeae* in the sugarcane field planted with 40 varieties of sugarcane are presented in the table 15. It can be observed from the table that population varied in different months from variety to variety. Among all varieties tested eight varieties viz., Co 527, Co 1107, Co 1307, Co 7318, Co 7717, Co 7527, Co 1287, and Co 8215 showed a maximum peak population at seventh month after planting
of canes. However no maximum peak population was observed at eleventh month after planting.

These findings suggest that though sugarcane variety also play an important role in influencing the population of nematodes in the soil it is the growth period, i.e seven to eight months after planting that induces a peak in nematode population. However sugarcane variety is also a limiting factor for maximum peak population of \( P.zeae \), as mean population varied from variety to variety. Maximum population of nematode was observed in the soil planted with variety Co 8338. However minimum population was recorded in the variety Co 6304. These preliminary investigations show that varieties influences the population of \( P.zeae \), breeding programme can be taken up to raise nematode resistant varieties.

5.3. PATHOGENICITY STUDIES

5.3.1. PATHOGENICITY OF \( PRATYLENCHUS \) TO SUGARCANE

Determination of yield loss and economic threshold level of any nematode to a specific crop need to estimated by conducting trials under control conditions. Results of such trials of \( P.zeae \) to sugarcane crop carried out for a plant crop as well as ratoon crop indicated that yield loss in the plant crop was more accentuated than in the ratoon crop, with no significant losses in the quality cane.

The greater per cent loss in crop yield due to nematode infection in both the varieties indicated that the losses caused to the root system is more in the plant crop than in the ratoon crop. Such losses of the plant cane has also been reported by Cadet and Spaull (1985) who remarked that this was probably due to the fact that cane plant largely depend on the sett root system during the period of tiller development.

The yield loss in the plant cane of both the varieties were directly proportional to the inoculum levels (Table 16). The maximum yield loss is noted at inoculum level of \( 10^5 \) nematodes. However, loss in yield is envisaged from low inoculum level of \( 10^2 \) nematodes/pot. Consequently, in variety Co 6304 there is an increase in the nematode
population in the pot being 78 nematodes/100 cc of soil which is approximately 0.78 nematodes/100 cc of soil i.e 1 nematode/cc of soil. In case of variety CoC 671 also a significant yield loss is noted at the inoculum level of \(10^2\) nematodes/pot. In this case increase in the nematode population is 92.3/100 cc of soil or 0.9 nematodes/cc of soil. Hence it can be concluded that one nematode/cc of soil is economic threshold level of *P.zeae* to sugarcane crop to cause a significant loss of yield.

Analysis of the root population showed that the economic threshold level is apparently similar, to the soil level at the inoculation level of 100 nematodes/pot the population was 21 and 23/10 g of root in the varieties Co 6304 and CoC 671 respectively averaging to two nematodes/g of root. However in the ratoon crop there is a rapid increase in the root population increasing to three nematodes/g of root. This increase in the root population can be explained due to the fact that soon after harvest of the plant crop the initial young shoots are dependent upon the roots of the previous crop (stool roots) before being replaced by new roots (Spaull and Cadet, 1990). Hence there are chances of intense entry of the soil nematodes into the existing root system causing such an increase of root population.

Besides loss in yield the effect of inoculation of nematodes on the quality of sugarcane were also analysed. The losses in the brix, sucrose and purity levels of the cane are not statistically significant in the plant crop. In the ratoon crop of the variety CoC 671 there is a significant reduction in brix, sucrose and CCS% only at highest inoculum level (Table 17). Thus it can be concluded that the *P.zeae* alone do not directly affect the quality of sugarcane at the economic threshold level. If only the levels do rise beyond this limit, a drop in the quality can be expected. But in the cane crop as the CCS% involves both yield and quality the significant loss in yield consequently results in a loss in the total CCS%.

Koike and Roman (1970) have also reported extensive damage to sugarcane by *P.brachyurus*. They also mentioned that the apparent damage is to the length and mass of the stalks. However although there has been reports on loss to sugarcane by many
workers (Khan, 1963; Harris, 1974 and Valle-Lambey and Ayala, 1980) there is no report on the pathogenicity of \textit{P.zeae} alone and the economic threshold level to sugarcane crop. Working out the average yield loss it can be seen that there is a loss of 23\% in Co 6304 and 30\% in the variety CoC 671. However as the experiment was only with few stalks in the pot and no tillering the ensuring yield loss is probably lower.

It can be concluded that \textit{P.zeae} do cause an economic damage to sugarcane crop and that basic economic threshold level is one nematodes/cc of soil and two nematodes/g of root with a consequent loss in yield of cane. Further it can be said that losses caused by nematodes vary depending on the variety and Pi in the soil.

\textbf{5.3.2. SYNERGISTIC ACTION OF \textit{P.zeae} WITH \textit{H.indicus} AND \textit{T.annulatus}}

Data presented (Table 18) indicates that in variety Co 6304 yield was reduced at all inoculation levels of both the nematodes. Inoculation of \textit{P.zeae} with \textit{H.indicus} at higher inoculation level causes more reduction in the yield that with \textit{T.annulatus} at same level. In CoC 671 inoculation of \textit{P.zeae} with \textit{H.indicus} at higher inoculation level (T3) cause more reduction in yield than the reduction at low inoculation level and at both the inoculum level of \textit{T.annulatus}. However the yield differences due to the treatments T2 was on par with the control pot.

These results prove that synergistic interaction exists between the three nematodes in the sugarcane ecosystem. Further it was observed that synergistic action of both the nematodes on the sugarcane variety CoC 671 is more compared to Co 6304 since the loss caused by \textit{P.zeae} in combination with two nematodes on sugarcane variety CoC 671 is high as compared to Co 6304.

Since the nematodes are found in polyspecific communities (Oostenbrink, 1966) they interact with each other and alter the damage caused by another nematodes.

Spaull and Cadet (1990) reported that roots of sugarcane are normally attacked simultaneously by number of nematode species, some or all of which cause serious
damage. To understand the importance of nematodes to sugarcane and to explain the mechanisms of damage it is necessary to consider the different components of the community, *P.zeae* being an endoparasite enters the root for feeding and completion of life cycle. However, of the two nematodes studied for the synergistic action, *H.indicus* is a migratory endoparasite while *T.annulatus* is an ectoparasite.

Both the nematodes are dependent on the root proliferation for invasion at same time thereby increasing damage to root system. These pot culture studies show that when both nematodes crop is more than when only *P.zeae* is inoculated alone. Both the nematodes are capable of restricting the normal growth and development of root system as reported by Singh and Misra (1976) from India and Astudille and Birchfield (1980). Poor development of the root growth in turn affects the growth of stalks resulting in magnified yield loss.

In case of the ectoparasite *T.annulatus*, it is a well-established fact that feeding of this nematode is on the epidermal cells and root hairs. Root system of cane becomes sparse with signs of necrosis and severe stunting of growing roots has been reported with the presence of *T.annulatus* (Birchfield and Martin, 1956; Gargantiel and Davide, 1973 and Harris, 1974). Hence the presence of this nematode along with *P.zeae* increases the root damage markedly, thereby causing a further loss in yield. Such an increase in loss of yield is clearly seen in these studies. A similar type of interaction was observed by Sikoro et al. (1972) in Bentgrass. He found that single inoculation of *T.agri* or *P.penetrans* inhibited plant growth but shoot growth was suppressed only when combined inoculation of the two nematodes species was made.

*P.zeae* with both the nematodes exhibit positive interaction in the sugarcane ecosystem as both of them together cause yield loss. But the interaction observed between *P.zeae* and *H.indicus* to cause loss is more accentuated than between *P.zeae* and *T.annulatus*, since the former combination of nematodes cause more reduction in yield than the latter one.
Increased yield loss in one variety compared to the other may be due to an increase in susceptibility to invasion or to some other factors that brings about a physiological reaction in the plant to a greater or total susceptibility as reported earlier by Powell (1979).

A significant difference in the quality characters due to the synergistic action of \textit{P.zeae} and \textit{H.indicus} can be noted at a higher inoculation level. However minimum differences were noted when \textit{P.zeae} is inoculated along with \textit{T.annulatus}, which compared to the losses caused by higher level of \textit{P.zeae} alone, the differences are not significant. It can be concluded that when \textit{P.zeae} and \textit{H.indicus} are present in high population simultaneously in the soil the damage caused to the crop is more intensified than caused by even higher level of \textit{P.zeae} alone. Thus there exists an interaction between the three important genera of sugarcane nematodes, which in turn magnify the losses in yield than presence of \textit{P.zeae} alone.

5.4. STUDIES ON SUGARCANE ROOTS INFECTED BY \textit{PRATYLENCHUS}

5.4.1. ROOT PENETRATION STUDIES

Pathogenicity studies of \textit{P.zeae} on sugarcane proved that this nematode is a true pathogen of sugarcane plant as it can penetrate, develop, multiply and damage root in the absence of other organisms. Examination of roots where the nematodes penetrated show that there is a formation of lesions at the point of penetration (Plate 5A). These lesions were clearly seen as the nematode was surrounded by one or two are formed as a result of nematode invasion and darkened gradually over a period of 7 to 8 days. Such lesions formation have also been described by Klinkenberg (1963) in \textit{Poa annua} roots after feeding by \textit{P.crenatus}. She further observed that in \textit{Stellaria media} roots when infected by \textit{P.crenatus} in some cases there was no necrosis where many specimens of \textit{P.penetrans} lived in the root for three weeks. Similarly, Nandakumar and Khera (1973) reported feeding at the same site by \textit{P.mulchandi} did not cause any necrosis on pearl
millet roots. Some necrotic spots were noticed on the roots of *Cicer arietinum* seedlings after continued feeding by *P.mulchandi* (Nandakumar et al., 1969).

As in the case of other lesion nematodes *P.zeae* also do cause visible lesions on sugarcane root but there can also be penetration into the root cells without lesion formation. In may instances it is very difficult to locate the lesions on sugarcane roots. But when the roots are processed for nematode extraction, *Pratylenchus* population could be recovered from the same. Hence the formation of lesions need not be taken as a major symptom for the presence or absence of *Pratylenchus* sp. When a population of *Pratylenchus* is extracted from the soil, it can be concluded that nematode being an endoparasite, the root penetration would have taken place and followed by consequent losses.

*P.zeae* penetrated the sugarcane roots both intra and inter cellullarly. Similar type of damage due to *Pratylenchus* infection have been reported in other crops (Acedo and Rohde, 1971). All stages of nematodes from egg to adult stage have been located inside the sugarcane roots (Plate 5D-5G). When the population in soil was high the meristem was damaged or completely destroyed and root elongation is completely inhibited. As a result the nutrient uptake by the plant reduced and probably leads to yellowing and stunting of sugarcane. *P.zeae* penetrated the stellar region also and causes damage to the vascular tissue (Plate 5G). After the penetration of vascular tissue a feeding site was established and eggs were laid within the vascular tissue. Larvae also were found in the cells, indicating that *P.zeae* is capable of completing its life cycle in sugarcane roots and thus the multiplication is completed in the root tissues.

### 5.4.2. HISTOPATHOLOGY

Microscopic examination of the stained sections of the *P.zeae* infected sugarcane roots showed that endodermal damage was rarely observed and occurred only when large number of nematodes entered en masse at a single location. Though the nematode penetrated into the endodermis, no endodermal necrosis occurs as that of cortical
necrosis. Hence endodermal cells do not form any barrier for the penetration of nematodes (Plate 6E).

*P.zeae* was found to be capable of penetrating into the stellar region also (Plate 6F). However, apparent damage to the stellar region was not seen. The damage was very minor and does not lead to cell break down or occlusion of cells. Severe damage to the stellar region have been reported in other crops (Godfrey 1929; Graham, 1951 and Inagaki and Powell, 1969). Lindsey (1969) also found that *P.brachyurus* invaded vascular tissues of soybean roots without causing necrosis. Root damage caused by *P.zeae* in sugarcane resembled that caused by *P.penetrans* in *Crypteneria japonica* (Mamiya, 1971) and in cabbage (Acedo and Rohde, 1971). But in the vascular tissues of maize both *P.brachyurus* and *P.zeae* caused extensive browning and occlusion of xylem vessels.

Hence these studies have clearly indicated that there is brown lesion formation, break down of cell wall and thickening of the cells in sugarcane roots. Entry into endodermis and vascular tissues also occur but no apparent damage is visible. Concluding, it can be reported that damage to the cortical cells form the main reason for losses caused to the root system and consequently to the crop.

5.4.3. EFFECT OF TEMPERATURE, SOIL TYPE AND VARIETIES ON PATHOGENICITY OF *PRATYLENCHUS* TO SUGARCANE.

Temperature has long been considered a primary factor in nematode activity, reproduction and in the host-parasite relationship (Bergeson, 1959 and Elmiligy, 1971). Data of the present studies indicated that maximum penetration of *P.zeae* into the sugarcane root, irrespective of soil type, occurred at the range of 26-28°C. However the data showed that variety of sugarcane used in these studies also influence the rate of penetration of the nematode along with the temperature. Four varieties tested, CoC 671 was more susceptible to *P.zeae* as can be seen by the maximum number of nematode penetrating into roots, (Table 19) seven days after inoculation. Whereas in variety Co 6304, CoC 85061 and Co 8021 the rate of penetration of nematodes was reduced.
Variety CoC 671 showed a minimum penetration was at lowest temperature with a gradual increase reaching the maximum penetration at 28°C (Fig 23 and 24). Earlier studies proved that optimum temperature for penetration of two Pratylenchus species varies within the root of the same plants. Townshend (1973) described 20°C as optimum temperature for Pratylenchus penetration into maize roots but for P.minyus 30°C was found optimum in the same host. The fact that the same nematode may behave differently in different environment was illustrated by Faulkner and Bolander (1969), who found that P.neglectus reproduced best at different temperatures depending on the presence or absence of Verticillium dahliae.

In Co 6304 maximum penetration of 7.48 occurred at 27°C but minimum penetration of 5.19 occurred at 15°C. In this variety nematode penetration increased in the temperature ranging from 15 to 18°C but decreased from 19 to 21°C and again increased from 23 to 27°C. Hence two peaks of nematode penetration could be recorded, first at 15 to 18°C and second at 23 to 27°C. However the number decreases both at 28°C and 29°C. This occurrence of two maximum peaks has also been reported earlier by Thomason and O'melia (1962) for P.scribneri. There was no constant increase in rate of penetration with respect to increase in temperature as noted in the variety CoC 671. Influence of temperature is probably dependent directly or indirectly on the varieties. This has been reported by Griffin and Elgin (1977) who found that rate of penetration of nematodes into the roots of two varieties of a single species are affected by temperatures. Penetration into resistant seedlings was similar to that of susceptible seedlings but at later stage nematode failed to establish and develop in root tissues. Similarly number of P.penetrans and P.crenatus in alfalfa and timothy increased as the temperature increased from 10 to 30°C. However, P.crenatus in alfalfa decreased in number as temperature increased (Kimpinski and Willis, 1981).

In CoC 85061 maximum nematode penetration occurred at 26°C and the minimum penetration at 16°C. In this variety nematode penetration increased at all the temperatures except at 20°C, 21°C and 27°C.
Maximum penetration of 6.7 nematodes occurred at 28°C in the variety Co 8021 but minimum (3.32) penetration occurred at 21°C. In some instances smaller number of nematodes cause more damage at one temperature than larger numbers at another. Ferris (1970) found that 100 \textit{P. penetrans} per gram of root could cause damage at 7-13°C but over 400 nematodes per gram of root were required to cause similar damage at 16-25°C. However, Vangundy and Rackham, (1961) reported that some nematodes as \textit{Hemicycliophora arenaria} and \textit{Longidorus africanus} favoured high temperature of 30°C for their activity. Number of nematodes in the roots increased progressively in all the soil types as the temperature increases from 15 to 29°C. In the clay soil penetration was minimum of 4.9 at 15°C whereas maximum penetration of 7.1 is observed at 28°C. In the sandy and red soil nematode penetration was minimum of 5.02 (21°C) and 4.3 (21°C) and maximum of 7.3 (28°C) and 6.6 (26°C).

Trend in penetration of nematode into the roots differed with three soil types. A progressive linear increase of nematode population in root was observed in the clay soil with increase in temperature. In the sandy soil population increased at lower temperature it decreased at 23°C and again increased at higher temperature. In red soil, root penetration was reverse to that found in clay soil, the population remained constant at the temperature range of 15 to 19°C, decreased at 20°C and 21°C, followed by a progressive increase with increase in temperature.

Ouden and Beuzenberg (1971) also reported that soil type at an early stage of growth modify the infection of \textit{Pratylenchus} on plants. They found the damage by \textit{P. vulnus} to roses growing in soil with little organic matter was initially less than in clay soil with much organic matter. But this difference became less over a time and eventually disappeared. Thus the soil type influences the penetration of nematode in co-ordination with the temperature and the variety.
5.5. STUDIES ON HOST RANGE OF PRATYLENCHUS

Evaluating the 20 economic crops for resistance susceptibility to *P.zeae* it can be concluded that nematode had a definite host preference. This was indicated by the rate of multiplication of nematode both in soil and roots and also the differentiated loss in shoot weight and root weights. It can be concluded that crops like mustard, tomato, chillies are poor hosts for *P.zeae*.

Data also (Table 21) indicated that there was a significant loss of shoot weight in different crops due to the infection of *P.zeae*. However, no significant difference has been observed in the root weight of the crops studied. But the soil and root population of the nematode increased significantly at 1% level.

The shoot weight loss was maximum in pearl millet when compared to other crops. However soil population was maximum in the fox tail millet planted pots. Among the three millet crops tested minimum population level of *P.zeae* was observed in the pearl millet roots. Dunn and Mai (1973) also reported that among seven plants assessed for their host range studies, Japanese millet showed was a net increase in nematode number after eight weeks of growth.

It is well known fact that graminaceous crops are good host for the lesion nematodes especially *P.zeae*. Kumar (1971) listed finger millet to be the best host of *P.coffeae*. These studies also proved that among 20 crops tested the three millet crops show maximum increase in nematode population and loss in yield of shoot weight further proving the importance of graminaceous crop being suitable host for the nematode under study. Avoiding of such crops on the nematode infested area will help to enhance the control practices of crop rotation.

Among four oil seed crops tested, namely, soybean, mustard, groundnut and sesame for their pathogenicity to *P.zeae*, soybean prove to be the most favourable host than the other three crops. This can be envisaged by increased loss in shoot weight with the high soil and root population of nematodes. Studying the pathogenicity of soybean, Scotto et al.,(1981) also found that *P. convallariae* and *P.thornei* reproduced well on
soybean whereas *P.crenatus* and *P.vulnus* could not maintain their population. Further studies confirmed that soybean was also a host for *P.brachyurus* (Charchar and Huang, 1980). *P.thornei* (Obrien, 1982) and *P.hexincisus* (Zirakparwar, 1982).

These studies also indicate that soybean is good host for *P.zeae*. Mustard showed a minimum shoot weight loss accompanied by a low multiplication rate of nematode, proving that this crop is tolerant to nematode infection. Johnson et al., (1983) reported that *Brassica rapa* were most effective in suppressing nematode population. Also mustard oilcake has been successfully used in control of nematodes. Mustard is probably more resistant to *P.zeae* than other crops tested. Sesame also supported a low population of *P.zeae* although yield loss was higher. In his trials on crop rotation in sugarcane field Govindarajan et al., (1978) also reported that sesame is very successful in reducing nematode population in increasing the yield of succeeding crops.

There was a low multiplication of nematode in groundnut crop also. Groundnut cake has also been used successfully in reducing nematode population hence probably this crop also had antagonistic effect on *P.zeae*. Thus as against graminaceous crops showing maximum nematode population oil seeds crops except soybean sustain a low population and hence their field use in rotation with sugarcane as and when required can be administrated. Soybean has to be avoided where sugarcane is to be the succeeding crop in order to safe guard built up of *Pratylenchus* species population.

Among the three legumes tested, blackgram showed moderate root and soil population although maximum loss in shoot weight was observed. In greengram shoot weight loss, soil and root population were minimum when compared to other crops. While in redgram shoot weight loss was medium and root and soil population were maximum than the other two legumes. Endo (1959) reported that most legumes are non-hosts for *P.zeae* and depends on the type of legume used for the study because *P.brachyurus* multiplied better on legumes than on graminaceous crops. Among the three common legumes tested blackgram can be advocated for reducing the nematode population though there was a subsequent loss in yield. But all the legumes can be
successfully used for reducing the population as either intercropping or short duration rotation crop with sugarcane to bring down the population level below economic threshold level.

Among the six vegetable crops tested for their host range reaction to *P.zeae* the maximum significant shoot weight loss occurred in okra followed by cabbage and brinjal. However no significant difference in shoot weight loss was observed in turnip, chillies and tomato. Nematode populations in soil and root were significantly increased in brinjal, cabbage and okra while only soil population was increased significantly in chillies and turnip. However no significant difference in root weight have been observed in vegetables. Experiments conducted by Race and Hutchinson (1959) proved that among 14 plant species tested for their host range reaction to *P.penetrans*, turnip was a fair host for the lesion nematode.

Similarly Hirling (1980) found that cultivation of oil radish as a catch crop reduced the population of *P.neglectus* in soil and roots to about 20% of that control pots. In addition natural decrease in nematode was accelerated by oil radish but delayed by other two plants. Charchar and Huang (1981) in Brazil reported that cabbage was non-host where the reproduction was very low when compared to other crops studied. However, the above studies show that cabbage is probably a favourable host for *P.zeae* as is brinjal and okra. Hence there is a need to avoid the planting of these crops in sugarcane fields infested with *P.zeae*. Although turnip and chillies are a tolerable host showing no root population build up tomato is apparently the most suitable crop to be utilized for a safe crop rotation, where *P.zeae* is a problem.

Among the spice crops tested soil population build-up was maximum in the fennel while soil and root population levels were maximum in fenugreek. Coriander recorded minimum shoot weight loss consequent to a minimum root population. In general, the population build up was at a minimum level in all the spices tested when compared with the other crops. It is possible that root exudates of these plants may have repellant or nematicidal action (Jenkins and Taylor, 1967) or the plants lack some
chemicals essential for the nutrition of parasite (Wallace 1963). It may also be due to the internal environment being non favourable for growth and multiplication of the nematode or the defence mechanism of the host may have detrimental effect on the nematode.

Sunhemp showed minimum loss in green matter as well as build up of nematode in soil and root. This being a very advantageous crop, it can be used as intercrop followed by usage as green manure. It can be recommended as one of the best short duration crops to reduce the population level of *P.zeae* below economic threshold level.

Thus it can be concluded from the present studies that since shoot weight loss as well as soil and root population build -up are noted at a maximum level in brinjal, cabbage, okra, soybean and pearl millet than other crops, these crops are most favourable hosts for the multiplication of *P.zeae* and hence their planting in sugarcane fields need to be avoided. Chillies, turnip, sesame, blackgram, redgram and fennel are less favourable for the multiplication of *P.zeae* and these planting of these crops need to be judiciously managed in sugarcane fields. On the other hand tomato, groundnut, greengram, fenugreek and coriander are non favourable hosts for the multiplication of *P.zeae*, since all the parameters as shoot and root weight loss and rate of multiplication of the nematode in soil and root are minimum. Hence these plants can be conveniently used for suitable crop rotations/ intercropping where this nematode is a problem. As sunhemp proves to be the best suited crop, this crop can be recommended as a safe crop for the management of the nematodes in sugarcane fields.

In order to further accentuate the host preference and rate of multiplication of this nematode on sugarcane crop, subsequent to harvest the soil in pots of ten selected crops were planted with sugarcane and data on soil and root nematode population yield and quality of sugarcane recorded (Table 21). From the data it can be seen that in all the crops there was a significant increase in the yield of the cane in control pots when compared to inoculated pots. Maximum increase in yield was in the cane potted after
mustard followed by green gram and red gram while yield of cane planted after turnip, and coriander are on par.

The presence of nematode in the soil also affect the quality of sugarcane. Brix values in the juice was maximum in the cane planted after sunhemp, mustard, green gram and tomato.

Decrease in sucrose content of the juice was also significant in the inoculated pots, the maximum sucrose level being in mustard and minimum in red gram as preceding crops. The sucrose content of cane planted after harvest of turnip, ground nut and finger millet ranged to a minimum. The maximum purity of the juice was recorded in the cane planted after the harvest of mustard.

Evaluating the CCS/pot, the crop following mustard recorded the highest CCS/pot with a minimum being in the crop planted after red gram. Pots with green gram, sunhemp, tomato and coriander showed a CCS value on par while chillies, fox tail millet, turnip and ground nut had CCS value on par.

Working out a simple correlation between the soil and root population of nematode with yield and quality parameters of sugarcane it was seen that there exists a significant negative correlation between the nematode population and quality of sugarcane i.e., decrease in the quality subsequent to an increase in the nematode population. Recommendation of planting mustard as the previous crop of sugarcane is thus favourable and need to be taken up as a necessity where this nematode is a problem.

5.6. BIOCHEMICAL CHANGES

5.6.1. ENZYMES

The major biochemical changes caused by the nematode in its host is the changes in the enzyme level. The enhanced or decreased activity of the enzyme soon after the entry of the nematode is either because of enzymes in the nematode exudates or it may be due to the de novo synthesis of enzyme in the host itself. The increased or decreased
activity of enzymes causes some major metabolic, physiological and cytological changes in the host (Zacheo et al., 1987).

Increased activity of hydrolases [cellulase, protease and acid phosphatase] in sugarcane root infected by *Pratylenchus* may be due to the synthesis of some endohydrolases by the host, due to the metabolic disturbance caused by the nematode (Bird, 1974).

Because of the increased activity of protease there is a degradation in the cell wall protein as has been reported earlier by Malik and Singh (1980). This must be the same in the *P.zeae* infected roots also, resulting in an increase in amino acids. Abeles (1969) had reported that the breakage in cell wall resulted in production of ethylene, which in the infected tissue caused lesions due to breakage of cell walls. This resulted in increased cellulase in the infected tissue. Also an increase in the acid phosphatase activity was seen in the *P.zeae* infected tissue. This increased activity changes the inorganic phosphorous levels in plant cell activity and has been reported by Malik and Singh (1980).

Because of the higher peroxidase activity in *Pratylenchus* infected tissue mRNA was destroyed in the presence of a glucose. Glasziou et al. (1967) have also found this activity and reported that it may be the reason for decreasing activity of RNA-ase. The main function of RNA-ase is to degrade the RNA in to nucleoside monophosphate and oligonucleotide. It was observed that in infected tissue RNA level was high compared with low RNA-ase activity uninfected tissue.

The oxidases caused changes in physiologically active host components such as phenol, auxin and amino acid. Giebel (1982) also found these components involved in the cell-differentiation and maturation in sugarcane. Such physiological changes can be the reasons for loss in yield and quality of the infected cane.

After the entry of nematode, higher peroxidase activity occurs in the cavity of the cortex, especially the cortical cells around necrotic epidermal cells (Hussey and Krusberg, 1970). Nematode extracts does not contain peroxidase, so the increase peroxidase activity in *Pratylenchus* infected root may be due to the increasing in existing
peroxidase levels and synthesis of new peroxidase isozyme as response of nematode infestation. It was also observed that the glucose present in sugarcane destroy the mRNA which in turn induced the activity of peroxidase as noted earlier by Glasziou et al., (1967) and Gayler et al., (1968).

Peroxidase activity was known to be high in the wound meristem, and the enzyme is capable of oxidizing many mono and diphenols and aromatic amines to quinone in the presence of hydrogen peroxide (Bonnar, 1950). The quinones are toxic to extracellular enzymes produced by pathogens and pathogen itself, thereby inducing the host resistance. Cellwall thickening is also induced by the peroxides. It also caused the oxidation of IAA, ethylene biosynthesis and proline hydroxylation (Ridge and Osborne, 1970). Such cellwall thickening was observed in *P.zeae* infected sugarcane roots and may be attributed to the same biochemical changes noted above.

Increase in polyphenol oxidase after the entry of nematode may be due to activation of latent enzymes by peptic enzyme produced by the pathogen. Maraite (1973) reported that one of the isoenzymes of the host was of pathogen origin. Polyphenol oxidase oxidise the phenolic compounds into quinone and semiquinone, and it remains in the oxidized state in the region of parasitation to be effective and resulting in formation of local lesion. The browning of the *P.zeae* infected root may be due to the accumulation of products of the action of these enzymes (Ahuja and Ahuja, 1980). It has been reported by Ganguly and Dasgupta (1984) that the phenolics and their oxidation products are toxic to invading pathogens and also causes tissue necrosis, thereby involving disease resistance.

The quinone produced by the polyphenol oxidase was found to inhibit sucrose synthetase activity, which helps in the conversion of sucrose to sugar. Usually quinone accumulation was observed in the endodermis of infected roots in advance of actual nematode feeding and necrotic reactions mainly occurred in the cortical, epidermal and endodermal tissues thereby inducing host resistance (Acedo and Rhode, 1971).
Ascorbic acid oxidase mainly occur in cell-wall and in resistant tissues enhanced ascorbic acid oxidase activity was generally seen (Malik and Singh, 1980). The enhanced ascorbic acid oxidase activity in inoculated root may be due to the denovo synthesis of the enzyme in the host itself soon after the entry of nematode. Enhanced ascorbic acid oxidase activity may be lowering the nematode penetration and reproduction in the cell wall.

After the entry of nematode, increased dehydrogenase activity was observed in Meloidogyne infected cotton tissue (Giebel, 1982). Glucose 6 phosphate dehydrogenase mainly helps in the regulatory role in phosphate-pathway, which supplies the building blocks for the bio-synthesis of nucleic acids (Malik and Singh, 1980). The glucose 6 phosphatase activity was similar in both infected and control tissues and so there are no changes in the nucleic acid synthesis by nematode attack. Enhanced activity of both GDH and MDH, in Pratylenchus infected tissue may be due to some metabolic changes in the host and production of new isoenzymes in the infected tissue, GDH mediate the production of glutamic acid, alanine and aspartic acid. MDH has been reported to mainly involve the respiration and carboxylation of plants (Malik and Singh, 1952). As the biochemical changes in the enzymes of the infected tissue show similarity to the changes reported earlier. It can be concluded that such changes also occur in P.zeae infected sugarcane root tissues.

5.6.2. AMINO ACIDS

One of the bio-chemical alterations in host plants due to the nematode infection was significant increase in amino acid and protein (Owens and Novotony, 1960). Obviously increase in proteins and amino acids in nematode infected plants appear to be disease related. The changes in amino acid in infected tissue may be due to interconversion of one amino acid to another (Steward and Bidwell, 1962) or due to hydrolysis of plant proteins by nematode enzymes as in Meloidogyne infected tomato roots (Myuge, 1956).
Increase in amino acid in *Pratylenchus* infected root may be due to the increase in nitrogen metabolism of the host, since the free amino acids are increased or indirectly from oxidation of certain phenols by the host to form quinones that combine and thereby inactivate net increase in protein synthesis (Feldman and Hanks, 1964).

In sugarcane it was found that high concentration of glutamic acid inhibit the peroxidase activity (Glaszio et al., 1967). So the absence of glutamic acid in *Pratylenchus* infected root may cause the enhanced activity of peroxidase in the control lesser peroxidase activity may be due to the presence of glutamic acid. It was observed that in respond to wounding and nematode number hydroxy proline and proline quantity was increased (Zacheo et al., 1988). In infected tissue more accumulation of proline occurred through ornithine cycle (Mohanty and Pradhan, 1989), it may be the reason for the presence of ornithine in infected tissues.

The presence of methionine in *P.zeae* infected root was enhanced by the initiation of protein synthesis and production of ethylene which helps in the cellulase activation as has been reported by Giovanelli et al., (1980). Serine present in control roots may combine with homocystine and form pyruvate via cistothione in infected roots. This pyruvate may form the precursor of leucine in non-inoculated tissues (Bryan, 1980).

Thus the changes in amino acid content in the inoculated can be said to be triggered by the feeding of *P.zeae*. Such changes in the complete cycle of amino acid can be one of the major cause in reducing the quality parameters in sugarcane.

5.7. MANAGEMENT PRACTICES IN SUGARCANE CROP FOR CONTROL OF *PRATYLENCHUS*

Usage of different management practices in a nematode infested sugarcane field has always helped in improving yield and quality of sugarcane. However the effect necessarily varies from field to field and variety to variety. This then results in the need for changing various practices over a period of time to suit a particular field. From the data presented in the tables 27 and 28 it can be seen that in both the varieties all the
treatments have influenced the yield increase over the control plot. In the variety Co6304 and CoC 85061 the maximum yield was recorded where all the management practices were followed in combination. Even the individual treatments have showed a significant increase in the yield in the variety CoC 85061.

When there is a combination of all the treatments the total effect normally becomes magnified. However it is not always possible to practice all the varied parameters of the management at one time. Evaluating the individual parameters, the data showed that maximum yield increase was recorded in the plots treated with press mud (filter cake) in both the varieties. Dick and Harris (1975) and Reyes and Beguico (1978) have also recorded that incorporation of filter cake (press mud) to the sugarcane soil reduced the number of plant parasitic nematodes. Further Martin (1967) has also reported an increase in yield consequent to application of filter cake.

The same results have been recorded from these trials. The reduction in nematode population can be explained by the fact that residues in the press mud, such as phenols and aldehydes are toxic to the nematodes resulting in the natural decrease of nematode population leading to an increase in the yield of crop. Addition of press mud to the soil also increased the antagonistic micro-organisms like fungi, bacteria and nematophagous nematodes which in turn reduces the population of plant parasitic nematodes of the soil. Since press mud cake is easily accessible to the farmers in and around the sugar factory zones application on a regular basis to all the sugarcane fields at the rate of 40 t/ha would helping to maintain the low economic threshold level of parasitic nematodes. Also it would help the factories in a easy disposal of this waste.

The application of nematicide carbofuran had also increase the yield with a significant reduction in the nematode population. In such sugarcane fields where the nematode problem is detected after planting the cane and no other management practices can be easily taken up, advocating the application of carbofuran becomes a necessity. Also in fields where there is a immediate need to reduce high population levels of nematodes this practice becomes a must. It has been further proved by the
investigations that delay in application of nematicides gives good yield and control of nematodes as it was applied in furrows 45 days after planting of cane. Chandler (1978), Bull (1981) and Donaldson (1987) had also experiment on delay in application of chemicals like aldicarb and have reported better yields. Application of carbofuran 45 days after planting can be followed for an immediate control of nematodes in sugarcane yields.

From the data in table 25 and 26 it can be seen that when there was a combination of treatments there was a further increase in yield. Practices like intercropping of sunhemp and application of press mud is in general a simple practice for the farmers and do not involve any monitory inputs. Hence, regular manipulation of such simple practices in the sugarcane ecosystem need be taken up as a regular practice.

It can be further seen from the results that when press mud and carbofuran are added as a single, treatments there is a reduction in yield in both the varieties when compared to application of press mud or carbofuran alone. Such a depression in yield is probably due to the fact that the residual chemicals in press mud plays a role in depressing the effect of nematicide. Further studies on this aspect need to be taken up, before a combination of both can be advised.

Although the yield increase was significant in CoC 85061 there was no consequent increase in the quality characters. However the variety Co 6304 responded more to the practices with the significant increase of brix, sucrose and purity levels. This has resulted in the significant increase in the CCS/ha.

It can thus be concluded that manipulation of different management practices, not involving much inputs can be recommended for control of plant parasitic nematodes of sugarcane fields. These practices individually or in combination plays an active role in reducing the nematode population followed by increase in yield and quality of sugarcane. However there is a definite need to select the management practices to suit the field, the variety, agronomic practices followed and mainly the nematode population in the field.
vary judiciously there by decreasing the inputs to control nematodes giving a highly profitable gain to both the farmers and industry.