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SUBHASH CHANDRA GHOSH
BUDDHADEV MANNA

ZOOLOGICAL SURVEY OF INDIA

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RECORDS OF THE ZOOLOGICAL SURVEY OF INDIA

Studies on Nematode parasites associated with paddy crop of West Bengal, India

SUBHASH CHANDRA GHOSH
BUDDHADEV MANNA*
Zoological Survey of India, M-Block, New Alipore, Kolkata - 700 053
**Department of Zoology, University of Calcutta, 35, Ballygung Circular Road, Calcutta 700019*

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PREFACE

The importance of phytoparasitic nematodes among the pests is now realised and their role in causing damage to agricultural crops are fully accepted throughout the world. The extensive use of more crops every year, short duration and high yielding varieties, maximum use of fertilizers, increased frequency of irrigation, and monocultivation are responsible for increase of plant parasitic nematode pest problems, all of which are indispensable to meet up the demands of human population.

Extensive work on the management of phytoparasitic nematodes had been done in other countries but such studies in India are limited. The value of crop rotations in the control of root-knot nematodes, *Meloidogyne* spp., cyst nematodes, *Heterodera* spp. and migratory ecto-parasitic nematodes *Helicotylenchus* spp. are well established in India.

Hirschmanniella gracilis (de Man, 1880) Luc and Goodey, 1964 is the most abundant, dominant and serious pest of paddy in rice cultivated districts of West Bengal, India. In absence of any detailed study on the key nematode pests of paddy *H. gracilis* in West Bengal, the present study may contribute to a large extent to the knowledge of the habit, distribution, occurrence, fluctuation of population in different seasons as well as depending on different agricultural practices. The "crop rotation" and "fallowing" would help to stop the use of costly nematicides and inorganic manure as well as to stop the chemical pollution, to find out the cheaper and simple methods for the sustainable management of phytoparasitic nematodes and thereby might help to obtain a greater yield. For the sustainable management of phytonematode pests by crop rotation depends on exact identification of the nematode species.

The present study deals with the systematics of the available soil and plant nematode species infesting the economically important crops like, paddy, wheat and jute etc. grown in different districts of West Bengal, India; Seasonal fluctuation of population of *H. gracilis* and "other nematodes" and their vertical distribution in soil to know the time and depths of availability of the parasitic nematodes; Seasonal crop rotation on the population of *H. gracilis* and "other nematodes" in soil at different selected plots for the management of phytonematodes; Comparison of the effect of fallowing on the population of *H. gracilis* and "other nematodes" in soil of different plots under study and Lastly, the statistical analysis and comparison between different crops, soil moisture, soil temperature and population of *H. gracilis* of different period under study.

The present study reveals, on the basis of high build-up of population of mature females and larvae in August to November, this period is considered as their breeding season. The nematode population in roots is positively correlated with the development of root system of host plant. The cropping sequence of paddy →two months fallow →

Jalmasta jute is more effective than the cropping sequence of paddy → one month fallow → wheat → one month fallow → Disimasta jute for two years, maintaining the low level of population of *H. gracilis* and "other nematodes" Jalmasta jute, *Hibiscus sabdariffa* is the ideal resistant variety or enemy crop for *Hirschmanniella gracilis.*

The soil nematode population does not get annihilated during fallowing. The nematodes develop their own system of survival in the soil under fallowing. The nematodes develop large vacuole in their body during the adverse climatic condition. The population of *H. gracilis*, decline to a manageable level by keeping the plot free from all vegetation for prolonged period and occasional ploughing during hot summer months, May-June.

The present work statistically proves that whatever may be the favourable crop sequence or fallow condition followed, the soil moisture maintained an almost constant correlation with the nematode population, except in Jalmasta jute rotation, an enemy crop. The soil moisture could not help to build-up the nematode population. In monocultivation of paddy, the rise in temperature, maintained a significant correlation with *H. gracilis,* while the soil moisture could not either under the cultivation of Masuiry paddy or Ratna paddy. The temperature, moisture and host plant play important roles in the population fluctuation of nematodes.

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RECORDS OF THE
ZOOLOGICAL SURVEY OF INDIA

OCCASIONAL PAPER

NO. 287 **2008** **1-144**

CONTENTS

PREFACE ..... *iii*

ACKNOWLEDGEMENT ..... *v*

1.0. INTRODUCTION 1-3

2.0. MATERIAL AND METHODS 4-12

2.1. Taxonomic studies 4

2.1.1. Collection of soil samples 4

2.1.2. Extraction of nematodes from the soil samples 4

2.1.3. Fixation and preservations of the nematodes 5

2.1.4. Dehydration of nematodes 6

2.1.5. Preparation of permanent slides of the dehydrated nematodes 6

2.1.6. Measurments of the nematodes 6

2.2. Seasonal fluctuation of population of *Hirschmanniella gracilis*and "other nematodes" and their vertical distribution in soil at plot "D" during 1990-1992 7

2.3. Effect of seasonal crop-rotation on the population of *Hirschmanniella gracilis* and "other nematodes" in soil at plots "A", "B" and "C" during 1990 -1992 8

2.4. Comparison of the effect of fallowing on the population of *Hirschmanniella gracilis* and "other nematodes" at plot "E" in soil with that of other plots "D" and "B" during 1990-992 8

2.5. Statistical analysis of population of *Hirschmanniella gracilis* in soil 8

3.0. OBSERVATIONS 12-111

3.1.0. Taxonomy of nematode parasites associated with paddy crop of West Bengal 12

3.1.1. *Helicotylenchus indicus* Siddiqi 1963 13

3.1.2. *Hirschmanniella gracilis* (de Man, 1880), Luc & Goodey 1964 13

3.1.3. *Dorylaimus innovatus* Jana & Baqri 1982 14

3.1.4. *Calodorylaimus indicus* Ahmad & Jairajpuri 1982 15

3.1.5. *Laimydorus* Siddiqi, 1969 Species 1 *L. siddiqi* Baqri & Jana 1982 16

Species 2 *L. baldus* Baqri and Jana 1982 16

3.1.6. *Sicaguttur sartum* Siddiqi 1971 21

3.1.7. *Aporcelaimellus* Heyns, 1965 Species 1 *A. heynsi* Baqri & Jairajpuri 1968 22
Species 2 *A. tropicus* Jana & Baqri 1981 23
3.1.8. *Laevides laevis* (Thorne, 1939) Thorne 1974 23
3.2.0. Seasonal fluctuation of population of *Hirschmanniella gracilis* and "other nematodes" and their vertical distribution in soil at plot "D" during 1990-1992 24
3.2.1. Male population of *Hirschmanniella gracilis* in soil 32
3.2.2. Female population of *H. gracilis* in soil 39
3.2.3. Adult (male and female) population of *H. gracilis* in soil 39
3.2.4. Larval population of *H. gracilis* in soil 40
3.2.5. Total (male, female and larval) population of *H. gracilis* in soil 40
3.2.6. Population of "other nematodes" in soil 41
3.2.7. Adult (male and female) population of *H. gracilis* in roots 46
3.2.8. Larval Population of *H. gracilis* in roots 46
3.2.9. Total (male, female and larval) population of *H. gracilis* in roots 47
3.2.10. Population of "other nematodes" in roots 47
3.3.0. Seasonal crop rotation on the population of *Hirschmanniella gracilis* and "other nematodes" in soil at plots "A", "B" and "C" 51
3.3.1. Population in plot "A" 51
3.3.2. Population in plot "B" 57
3.3.3. Population in plot "C" 59
3.4. Comparison of the effect of fallowing on the population of *Hirschmanniella gracilis* and "other nematodes" in soil at plot "E" with that of other plots "D" and "B" during 1990-1992 73
3.5.0. Correlation on the population of *Hirschmanniella gracilis* with soil temperature and moisture under different crop rotation at different plots during 1990-1992 82
3.5.1. Correlation in plot "A" 82
3.5.2. Correlation in plot "B" 87
3.5.3. Correlation in plot "C" 91
3.6.0. Correlation of the population of *Hirschmanniella gracilis* with the different crops or same crop during 1990-1992 96
3.6.1. Correlation in plot "A" 96
3.6.2. Correlation in plot "B" 98
3.6.3. Correlation in plot "C" 102
3.7.0. Correlation in plot "D" 104
3.7.1. Correlation in plot "E" 107
4.0. DISCUSSION 112-129
5.0. REFERENCES 130-144

I. INTRODUCTION

Nematodes are most important and highly diversified group of multicellular invertebrate animals. They occur in almost every kinds of climatic conditions, from the arctic to the tropic and from ocean depths to tops of mountains. Most species are free living in soil brackish or marine and fresh waters while others are parasites of animals and plants. The phytoparasitic nematodes cause considerable damage to the agricultural crops. The work on plant parasitic nematodes started rather late, perhaps because of their hidden nature and small size and the technical difficulties for their extraction from the soil and plant tissues. The study of plant parasitic nematodes started in the year 1743 when Needham reported certain chalky malm in red lily, now known as *Anguina tritici*. Later, in Germany a serious sugar-beet disease was reported which caused by a cyst nematode, named by Schmidt (1871) as *Heterodera schactii*. Subsequently, Berkley (1855), Kuhn (1857), Bastian (1865), de Man (1876), Orley (1880), Cobb (1893, 1920), Thorne and Swanger (1936), Thorne (1939, '61), Linford Oliveira (1940), Allen (1955), Golden (1956), Siddiqi (1961, '66, '72, '82,'86), Oostenbrink (1961), Jairajpuri (1962, '89), Coomans (1963), Goodey (1963), Timm (1964), Baqri and his co-workers (1980-1990), Jairajpuri and Baqri (1991), and many others enriched the subject with their valuable contributions.

The important paddy pest nematodes *Ditylenchus angustus* causing "Ufra disease" in rice crop was first reported from Bangladesh by Butler (1913) and another "White-tip" disease caused by *Aphelenchoides besseyi* was reported from Japan in 1940. The report of these two diseases in rice crop attracted the attention of a number of Nematologists throughout the globe. Subsequently, *Haplolaimus indicus* as potential cereal pest in West Bengal was reported by Banerjee and Banerjee (1966). The nematode root-parasites association were recorded by Fortuner(1975) and Fortuner and Mermy (1979). Baqri and his co-workers surveyed different paddy fields in West Bengal, India during 1980-1990 and collected many information (Baqri, 1981, Baqri and Ahmad, 1981, 1984, Jana and Baqri, 1981, 1982, Baqri *et al.*, 1983, Dey and Baqri, 1985, 1986, 1990). Reports on the association of *Hirshmanniella* spp. are available in the rice fields in Vietnam (Khuong, 1987), in Costarica (Lopex and Salazar, 1988) and in Srilanka (Rohini, *et al.*, 1990). The plant and soil inhibiting nematodes associated with paddy crops in three districts of West Bengal Coochbehar, Darjeeling and West Dinajpur were surveyed by Baqri and Das (1991). From deep-water rice in Bangladesh a new nematode *Paralongidorus* sp. was reported by Hunt and Rahman (1991). *H. gracilis* and *H. mucronata* in the rice fields exhibited yellowing, stunting and patchy growth in Ahmedadabad district of Gujarat (Patel *et al.*, 1999). The observations on population of plant nematodes and its fluctuations began in the 2nd half of twentieth century. The vertical distribution and population fluctuation of plant parasitic nematodes in soil are correlated with temperature, moisture and texture of soil and types of available plants (Hollis and Fielding, 1955, Brodie and Quattebaum, 1970, Zuckerman, *et al.*, 1964, Mukhopadhyay and Prasad, 1968, 1970 and Baker, 1968). Simons (1973) observed the nematode survival in relation to soil moisture. The seasonal fluctuation and rhizospherical *Distribution* of population of rice cyst nematode *Heterodera elochista* (Shinizu, 1977), *Hirshmanniella gracilis* (de Man, 1880, Luc and Goodey, 1964) and the vertical distribution of *H. oryzae* in soils of rice field of Assam (Sahu, *et al.*, 1984) are observed. The comparative population build up of *H. oryzae* on Basmati rice cultivars in relation to different date of transplanting and two spacing revealed that there was more building up in crop transplanted in middle June or late July (Randhaway, *et al.*, 1992). Spacing of 15X15 cm and 20X15 cm in Basmati 370 an Pusa 615 had no effect on population build up Population dynamics of *H. mucronata* and *H. oryzae* on *Sesbania rostata*, *Aeschynomeme afraspara* and rice c.v.I.R. 58 were studied by Hendro *et al.* (1992), which declined in Citrus Limettoides (Mukherjee and Dasgupta, 1993). Ibrahim and Perry (1994), however, observed the infectivity and population dynamics of rice stem nematode *Ditylenchus angustus*. The yield loss due to nematode infection also was calculated by many. Panda and Rao (1969) and Rao and Panda (1970) recorded yield loss in rice due to *H. gracilis* infestation. Similarly Ahamad, *et al.* (1984) calculated 18.33 to 19.22% yield loss due o infestation of the same species. Rao (1984) recorded 32% yield loss due to rice root nematode *H. oryzae* infestation.

The idea of management of these rice associated nematodes gradually develops. Routray and Das (1985) observed the population effects of *H. mucronata* on rice and its control by field application of carbofuran at Assam, India, while Baqri, Dey and Ghosh (1987) observed the effect of different sources of nitrogen on the management of *H. gracilis* associated with paddy crop at Rautara village, North 24 Parganas district, West Bengal, India. The effects of crop rotation and fertility management on the root-knot nematodes are known from Peacock (1957), Chawla and Prasad (1973), Khan *et al.* (1975), Handa *et al.* (1975) and Kinloch and Lutrick (1975). The effect of different cropping sequence on the population of plant parasitic nematodes in rice and soil were observed by Khan *et al.* (1976), Kalita and Phukan (1995), Alam, *et al.* (1977, 1980), Prasad and Rao (1978), Prasad, *et al.*(1996), Babatola and Bridge (1979), Lal, *et al.* (1983), Roadriguez and Canullo (1992), Sabova *et al.* (1988), Skiwierez and Wolmy (1988), Tykyani and Khera (1969), Seinhorst (1970) and Mohanty and Das (1985). Laha and Bhattacharya (1984) found *Meloidogyne incognita* in Congo jute *Urena lobata* L. from West Bengal and Bhatta and Dabur (1982) studied the use of wheat as trap crop for the control of *Heterodera avenae*. The crop rotation system for the management of *M. arenaria* in peanut are known from Rodriguez and Ivey (1986). The seasonal population fluctuations of *Heterodera zeae, Rotylenchulus reniformis* and *Tylenchorhynchus vulgaris* in maize – cowpea – wheat rotations were studied (Srivastava and Sethi, 1986). Saikia and Phukan (1986) also studied crop-rotation on the development of root knot nematode *M. incognita* on jute. The susceptibility of *M. incognita* to bast fibre crops *Hibiscus* *subdariffa* was reported by Laha and Pradhan (1987). The integrated approach, the cultural practices followed by crop rotation with paddy and wheat for consecutive two years reduced the root-knot nematode population in the jute fields to the manageable levels (Mishra, *et al.,* 1987). The crop rotation combined with cultural practices and nematodes was reported by Johnson (1988). Mondal and Mishra (1988) observed the soil nematode population influenced by intensive cropping and manuring on long term basis. The influence of non-host plants on population decline of *Rotylenchulus reniformis* was observed by Caswell, *et al.*, (1991). Sukul (1992) recognized some plants antagonistic to plant parasitic nematodes. The longevity of nematodes in the fallow conditions of the cultivated soil is much important in their management. *Tylenchorthynchus claytoni* can survive ten months (Krusberg, 1959), *T. icarus* survive nine months (Wallace and Greet, 1963). *Helicotylenchus* spp. survive eight months (Golden, 1956) and *Radophaolus* sp. survive about three months (Simons, 1973) in fallow land. The population of root-knot nematode larvae declined rapidly under fallow or non-host crops and reached a safe level (Peacock, 1957, Brown, 1961). *Tylenchorhynchus brasicae* population declined when the field remained fallow or wheat was grown (Khan *et al.,* 1969). The temperature and flooding on nematode survival in fallow sandy soil was observed by Overman (1965). The deep summer ploughing showed great declining effect on *Heterodera avenae* in yield of wheat in Rajasthan (Mathur, *et al.,* 1987). The fallowing cause a decrease in adult population in general and larvae of root-knot nematode in particular and fallowing or rotation of non-host crops after host crop resulted in appreciable decrease in the population to a safe level (Khan *et al.,* 1975).

The statistical analysis of population of plant and soil nematodes started in the last decades of this century. The interspecific correlation and regression analysis of population densities of *Tylenchorhynchus* spp., *Rotylenchulus reniformis* and *Heplolaimus indicus* were studied by Gaur and Haque (1986). The *Tylenchorhynchus* spp. and *R. reniformis* populations were usually negatively correlated while *Tylenchorhynchus* spp. and *Hoplolaimus indicus* were positively correlated under wheat and pea in the Rabi season but negatively correlated under mung, okra and fallow in summer. The negative correlations appears to be more due to the differential host and environmental preference than any direct competition for food or space, at the prevalent population levels (Sasser *et al.* 1968). Saeed and Ashrafi (1971) studied the fluctuation of nematode population in banana and tried to correlate them with environmental factors. The population density of nematodes varies considerably due to several factors like availability of host plant, soil type, soil moisture, soil temperature, rainfall and many other extrinsic factors (Norton, 1979). Choudhury and Phukan, 1990, Eapen, 1993 and Ray, *et al.,* 1994. Chatterjee and Sukul (1995) observed the regression coefficient on the rate of growth of Okra plants inoculated with *Meloidogyne incognita* while Chatterjee and Sen (2000) observed positive correlation between the number of host-species and the number of parasitic species. The number of parasitic-species remains directly proportional to the number of host species.

2.0 MATERIAL AND METHODS

2.1. TAXONOMIC STUDIES

For the taxonomic studies of plant and soil nematodes associated with paddy crop in West Bengal, an extensive survey work was conducted during the months of January and February, 1993 at different localities of Nadia district and the nematodes collected around roots of paddy from selected plots during the present study period at Rautara village, North 24-Parganas district, West Bengal, India. Besides, the nematodes collected in 1986-87 from around roots of paddy crop by the author as a member of the tour party led by Dr. Q.H. Baqri, Scientist 'SD' Zoological Survey of India, from Midnapur, Purulia and Bankura districts of West Bengal have also been included in the present study. The methodology comprises with

i) Collection of soil samples

ii) Extraction of nematodes from the soil sample

iii) Fixation and preservations of the nematodes

iv) Dehydration of nematodes

v) Preparation of permanent slides of the dehydrated nematodes

vi) Measurements (de Manian formula) and Photographs of the nematodes

2.1.1. Collection of soil samples

From the rizosphere of paddy plant in the moist fields 5 x 5 cm area soil was taken upto the depth of 15 cm with the help of shovel to make one sub-sample. Five sub-samples were collected from one field. These five sub-samples were mixed thoroughly to form a bulk of soil sample. From that soil sample 200 gms soil was collected to form one sample. In the dry or semidry field the sampling depths were increased upto 20 cm, because most of the parasitic nematodes migrate down to lower depths to avoid high temperature and unfavourable conditions. The soil was then collected in a polythene bag. The opening end of the polythene bag was closed properly with a rubber band incerting relevant data like host, locality, date etc. These soil samples were brought to the laboratory and stored in a fridge to avoid evaporation (Fig. 1).

2.1.2. Extraction of nematodes from the soil sample

The method for the extraction of plant parasitic as well as free living nematodes is based on modified Bearmann funnel technique (Christie & Perry, 1951). To extract the nematodes from the soil samples, approximately 200 gms soil is placed in a bucket (A) of 15 litres capacity of water. One third volume of the bucket is then filled with water. The soil and water are thoroughly mixed by hand to prepare a uniform or homogeneous suspension. Plant debris and large pebbles are removed from the suspension. The lumps are broken with finger tips. The bucket (A) is then left undisturbed for 20-30 seconds to allow the bigger soil particles settle down the bottom while the nematodes are floating or moving on the upper surface of the suspension. This suspension is then filtered through a coarse sieve (2 mm pore) to avoid the plant debris and is collected in another bucket (B). Thus this process is repeated thrice to make the suspension dilute for passing the suspension through fine sieve of 350 mesh. (Fig. 2).

The suspension of bucket (B) being free from stone, leaves and organic matter is also made homogenous solution by hand and allowed to settle for 20-30 seconds. Then the undisturbed homogeneous solution is passed through a fine sieve (350 mesh size). Most of the fine soil particles pass through the sieve while the larger soil particles and the nematodes are retained on this 350 mesh sieve. The entire residue from the sieve is collected in a 250 ml beaker.

The residue collected in the beaker is poured gently on moist double tissue paper placed on a small supporting coarse sieve of 2 mm pores. Air bubbles are avoided between the tissue papers to check the penetration of nematodes through tissue paper. The supporting coarse sieve with residue (aliquot) on the tissue paper is put on a patridish filled with water touching the bottom of the coarse sieve. After 24 hours all the nematodes are penetrated and passed into the fresh water kept in the patridish through the tissue paper. The slow moving nematodes penetrate very slowly through the tissue paper. Hence, more than 24 hours are allowed to extract the slow moving nematodes. The residue on the tissue paper is examined under a stereoscopic binocular for sluggish nematodes and are collected from the soil samples.

2.1.3. Fixation and preservations of the nematodes

The freshwater containing the nematodes was kept in a big test tube and allowed to settle down at the bottom for two hours. Upper level of water of the test tube was removed slowly by a glass dropper of suitable length so that the nematodes settle at the test tube bottom may remain undisturbed. For studying different diagnostic characteristics of the nematodes were fixed in F. a. as fixative (Baqri, 1990). The fixative was prepared as follows

1. Formalin (40% formaldehyde)	–	10 ml.
2. Glacial acetic acid	–	4 ml.
3. Distilled water	–	86 ml.

For killing the nematodes, the fixative (F. a.) was taken in a separate test tube at least double volume of the nematode suspension kept in another test tube. Then the fixative was heated and the hot fixative was quickly poured into the nematode suspension tube. Thus the nematodes are fixed in their characteristic postures and safely preserved in this solution for a long period.

2.1.4. Dehydration of nematodes

The nematodes are transferred from the preservatives to a glycerin-alcohol solution in a glass cavity block. The glycerin-alcohol solution was prepared as follows

1.	30% alcohol	–	95 ml.
2.	Glycerin	–	5 ml.

Small amount of Lacto-phenol is added in the glycerin-alcohol solution to avoid the growth of fungi. From the preserved nematodes mature males and females were picked up under a stereoscopic binocular microscope by a fine needle made by a hair of horse neck to prevent the damage of the nematodes and transferred to the solution of glycerin-alcohol in a glass cavity block. This cavity block is placed in a desiccator at room temperature for dehydration of the nematodes. In dry season 20 days are needed and 30 days are needed in monsoon period for dehydration.

2.1.5. Preparation of permanent slides

The dehydrated nematodes are finally mounted in pure anhydrous glycerin. A small drop of anhydrous glycerin is kept on the glass slide. The dehydrated nematodes near about same thickness and size are selected under stereoscopic binocular microscope which are transferred to glycerin drop kept on the glass slide with the help of a hair needle. Then the nematodes are arranged in the centre of the drop and kept suitable size and thickness of glass wool to avoid any pressure on the nematodes. After arranging the nematodes and glass wool, a clean round glass coverslip, gently warmed over a small flame, is placed over the glycerin drop. Finally "Glyceel" or common nail polish is applied on the outer edges of the round coverslip with the help of a brush to make permanent slide for the taxonomic studies.

2.1.6. Measurements of the nematodes

de Man's formula is followed for identification and measurements of nematodes. All the measurements are in mm unless otherwise mentioned.

L	=	Total body length
a	=	Total length/Maximum body width
b	=	Total length/Distance of oesophagus from anterior tip
c	=	Total length/Distance from anus to tip of tail
G_1 (A.G.)	=	$\frac{\text{Length of anterior gonad x 100}}{\text{Total body length}}$
G_2 (P.G.)	=	$\frac{\text{Length of posterior gonad x 100}}{\text{Total body length}}$

$$V = \frac{\text{Length from anterior end upto vulva x 100}}{\text{Total body length}}$$

$$T = \frac{\text{Distance from cloacal aperture to anterior of testis x 100}}{\text{Body length}}$$

2.2. SEASONAL FLUCTUATION OF POPULATION OF *Hirschmanniella gracilis* AND "OTHER NEMATODES" AND THEIR VERTICAL DISTRIBUTION IN SOIL AT PLOT "D" DURING 1990-1992

To study a population fluctuation of *Hirschmanniella gracilis* in a paddy field during the period from August, 1990 - July, 1992, the plot was selected at Rautara village, North 24-Parganas, West Bengal, India measuring 100 sqm having clayey-loam texture of soil which was referred to as plot "D" The plot has been under cultivation of paddy crop twice in a year, in monsoon and winter seasons, without any manure and pesticide. Kharif paddy was grown during monsoon season, while Rabi or Boro paddy in winter season. The transplanting of Aman paddy seedlings was completed in August and the harvesting was done during third week of November. The seedlings of "Ratna variety" were transplanted in February and the crop was harvested in the middle of May. The rainfall is abundant in West Bengal from June to September. The temperature generally ranges from 19 ^{0} to 34 ^{0}C in different seasons of the year. As and when required, the irrigation facility was availed from the deep tubewell in the area, so that the field could remain moist during the period under crop. The field remained fallow after the harvesting till the transplanting of seedlings of next crop. Since the roots of the rice plants generally spread upto 15 cm in soil, two depths were chosen, 0-10 cm and 10-20 cm depth, for sampling in order to study the vertical *Distribution* of *Hirschmanniella gracilis* and other nematode species. The soil samples were collected once, 1st day of every month. On each date of sampling, five soil samples were collected at random from 0-10 cm and 10-20 cm depths. The soil samples were mixed up separately from both the depths thoroughly with hands to make two soil samples, one from 0-10 cm depth and another from 10-20 cm depth. From these soil samples 200 gms soil was taken separately and kept in polythene bag. To extract the nematodes from the soil samples of two depths, same procedure was followed as in taxonomical studies. The male, female and larvae of *Hirschmanniella gracilis* from soil were counted separately by stereoscopic binocular microscope. The population of *Helicotylenchus,* Dorylaimida, and soil inhabiting nematodes were counted and recorded under the heading "other nematodes" as these are not harmful to the paddy crop. Along with the soil population, root population were also observed. Five plants were uprooted at random from the plot and root samples were collected. From one root samples, all the roots were chopped into small pieces. From that chopped roots, 5 gms root were taken. The root samples were teared with the help of grinder machine for 30 seconds. Lastly, the techniques of extraction and counting of the root nematodes was followed as in the soil nematodes.

2.3. EFFECT OF SEASONAL CROP-ROTATION ON THE POPULATION OF *Hirschmanniella gracilis* AND "OTHER NEMATODES" IN SOIL AT PLOTS "A", "B" AND "C" DURING 1990-1992

Three rice growing plots were selected at Rautara village, North 24 - Parganas, West Bengal, measuring 100 sqm having the history of different sequences of crops. These three plots are being referred to as plots "A", "B" and "C. Plot "A" was monoculture – growing only paddy twice in a year. Plot "B" was rotated paddy with Sonalika variety of wheat *Triticum aestivam* (Fig. 3) and two varieties of jutes, *Corchorus olitorius* (Fig. 4, 5) and *Hibiscus sabdariffa* (Fig. 6, 7) – three crops in a year, while in plot "C" only one paddy crop was grown during monsoon season, which was rotated by Jalmasta variety of jute, *Hibiscus sabdariffa* (Figure 7, 8). The soil and root samples were collected from 0-15 cm depth on the first day of every month during the course of present investigation. The methods of collection of samples, extraction and estimation from 200 gms soil and 5 gms roots were same as mentioned earlier for the study on seasonal fluctuation of population of *Hirschmanniella gracilis* and "other nematodes" and their vertical distribution at plot "D"

2.4. COMPARISON OF THE EFFECT OF FALLOWING ON THE POPULATION OF *Hirschmanniella gracilis* AND "OTHER NEMATODES" AT PLOT "E" IN SOIL WITH THAT OF OTHER PLOTS "D" AND "B" DURING 1990-1992

Effect of fallowing on *H. gracilis* and "other nematodes" were studied at plots "E", "D" and "B" situated at village Rautara, district North 24-Parganas, West Bengal. For this purpose standardized plots measuring 100 sqm were selected at each site. The study was conducted from December, 1990 to December, 1992 in plot "E"

Plot "E" was kept fallow throughout the study period, without any irrigation facility and with periodic weeding out. During summer months (May, June) regular ploughing of the field was also resorted to, for exposure of the top soil to the effect of solar radiation.. The effect of fallowing at this plot was termed as "long period fallowing". In plot "D", the effect of fallowing was studied between two paddy crops which was termed as "short period fallowing" while in plot "B", the fallowing effect was studied in between paddy and wheat or jute and was termed as "very short period fallowing".

200 gms of soil from each sample site were collected at monthly intervals. Extraction of nematodes and their counting were followed according to the standard procedure mentioned.

2.5. STATISTICAL ANALYSIS OF POPULATION OF *Hirschmanniella gracilis* IN SOIL

The data of soil temperature, soil moisture and population of *H. gracilis* were recorded at different plots during the year 1990-1992. The statistical analysis and comparison were

Fig. 1 : Collection of soil sample from the field after harvesting paddy crop at plot 'D' during May, 1991

Fig. 2 : Extraction of nematodes from the soil samples collection from plot 'A'

Fig. 3 : Photograph of Sonalika variety wheat, *Triticum aestivum* at plot 'B' cultivated during March, 1991

Fig. 4 : Cultivation of Disimasta jute, *Corchorus olitorius* and collection of soil sample at plot 'B' during May, 1991

Fig. 5 : Apical part of Disimasta jute, *Corchorus olitorius*

Fig. 6 : Photograph of Jalmasta jute, *Hibiscus sabdariffa* at plot 'C' cultivated during May, 1991

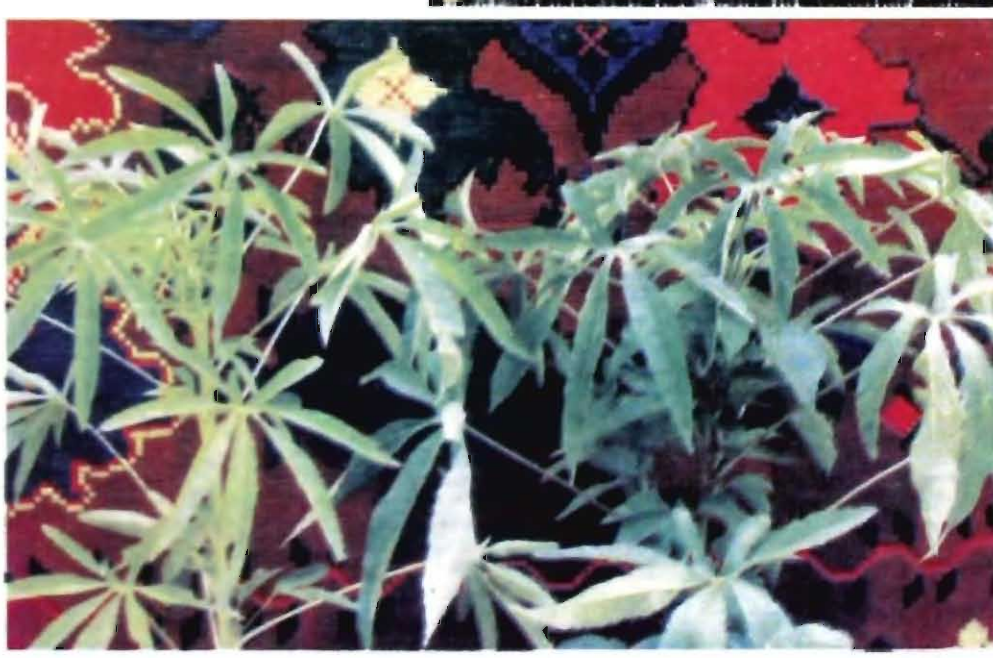


Fig. 7 : Apical part of Jalmasta jute plant *Hibiscus sabdariffa*

made between different crops, soil moisture, soil temperature and populations of *H. gracilis* of different period under study. The level of significance have been calculated and correlation between different physical factors and nematode population were estimated by the following formula :

$$\text{Coefficient of correlation } r = \frac{\sum (x-\bar{x}).(y-\bar{y})}{N\sigma x\sigma y} = \frac{\sum XY}{N\sigma x\sigma y}$$

$$= \frac{\sum XY}{N\sqrt{\frac{\sum x^2}{N}}.\sqrt{\frac{\sum y^2}{N}}} \qquad = \frac{\sum XY}{N\sqrt{\frac{\sum x^2 \sum y^2}{N}}}$$

$$r = \frac{\sum XY}{\sqrt{\sum x^2 \sum y^2}}$$

Where $\bar{x}$ = Mean = $\frac{\sum x}{N}$, $\bar{y}$ = Mean = $\frac{\sum y}{N}$, N = No. of months

Σ = Summation (Total value), σ = Standard deviation = $\frac{\sqrt{\sum x^2}}{\sqrt{N}}$

σx = Standard deviation of x = $\sqrt{\frac{\sum x^2}{N}}$

σy = Standard deviation of y = $\sqrt{\frac{\sum y^2}{N}}$

$X = (x-\bar{x}) \quad Y = (y-\bar{y})$

3.0 OBSERVATIONS

3.1.0. TAXONOMY OF NEMATODES ASSOCIATED WITH PADDY CROP OF WEST BENGAL

The nematodes extracted from the soil associated with paddy crop, collected from some districts of West Bengal, during the study period were studied, measured and their photomicrographs were taken. Only the matured specimens are taken into its account. Their descriptions are as follows :

3.1.1 ***Helicotylenchus indicus*** Siddiqi, 1963

Phylum	NEMATODA
Class	SECERNENTEA
Order	TYLENCHIDA
Family	HOPLOLAIMIDAE Filipjev, 1934
Subfamily	ROTYLENCHUDINAE Whitehead, 1958
Genus	***Helicotylenchus*** (Steiner, 1945) Sher, 1966
Species	***H. indicus*** Siddiqi, 1963
Female 2	L = 0.42 mm–0.51 mm.
	a = 23.33–24.28, b = 4.61–5.31
	c = 42.00–46.36, V = 65.47–66.66

Description : *Female* : (Figure 8 A-D). Body small, stout, spiral-shaped upon fixation. Cuticle with fine transverse striation. Lateral fields with 4 incisures. Lip region continuous with body contour. Stylet measuring 19-20.5 μm long, with rounded basal knobs. Nerve ring 75-79 μm from anterior end. Excretory pore just below the nerve ring. Oesophagus varies from 91-96 μm long, overlaps intestine ventrally. Female reproductive system didelphic, amphidelphic, ovary outstretched. Rectum 5.0-7.5 μm long. Tail measuring 10-11 μm long, more curved dorsally with hemispherical terminus.

Male : Not found.

Locality and Habitat : From soil around roots of Paddy, *Oryza sativa*, from Krishnanagar, Nadia district and Rautara, North 24 Parganas, West Bengal, India.

Distribution : *Helicotylenchus indicus* is commonly found in the soil of rice growing areas, of India.

3.1.2 ***Hirschmanniella gracilis*** (de Man, 1880), Luc & Goodey, 1964.

Family	PRATYLENCHIDAE Thorne, 1949
Sub family	PRATYLENCHINAE Thorne, 1949
Genus	***Hirschmanniella*** Luc & Goodey, 1964
Species	***H. gracilis*** (de Man, 1880), Luc & Goodey, 1964
Female 2	L = 1.88 mm–1.94 mm.
	a = 56.74–58.43, b = 13.28–13.45
	c = 19.23–19.74, V = 51.03–52.01

G_1 = 17.25–19.32, G_2 = 15.92–18.04

Male 2 L = 1.63 mm–1.70 mm.

a = 40.96 – 41.93, b = 11.33 – 11.68

c = 17.81 – 18.09

Description : *Female* : (Figure 9 C, D, E). Body slightly curved posteriorly. Cuticle marked with transverse striations. Lateral fields marked by 4 incisure, occuping about $^1/_4$th of body-width near the middle. Head region continuous with body contour. Stylet 20.7–22.0 μm long, basal knob well-developed, rounded, measuring 4.1–5.0 μm. Oesophagus with a cylindrical procorpus, median bulb and a short slender isthmus encircled by nerve ring. The nerve ring situated at 95 μm or 75% of the oesophageal length from the anterior end. Excretory pore below the oesophago-intestinal junction at 125 mm from the anterior end. Length of vagina 14.9–16.6 μm. Female reproductive system didelphic, amphidelphic Ovaries outstretched, oocytes arranged in a single row except the growth region. Tail cylindrical, measuring about 98.0–98.5 μm, and body width 24.1–26.6 μm. *Male* : (Figure 9 A, B, F). Male similar to female in general morphology except the reproductive system and the tail shape. Spear measuring about 12.4 μm long with rounded basal knobs. Tail slightly curved ventrally, measuring 90.5–95.4 μm long. Gubernaculum curved, 11.6–12.4 mm long. Spicules 33.2–34.9 μm long when measured along the median line; Bursa subterminal.

Locality and Habitat : Soil around the roots of Paddy, *Oryza sativa* from Rautara, District North 24 Parganas, and Jagulia, district Nadia, West Bengal, India.

Distribution : *Hirschmanniella gracilis* are always found in the soil of all the rice-growing areas of West Bengal (Baqri and his co-workers 1981-91), Orissa, India.

H. gracilis is a widely distributed species in the USA, Canada, Netherlands, Germany and many other countries.

3.1.3 ***Dorylaimus innovatus*** Jana and Baqri, 1982.

Class	ADENOPHORA
Order	DORYLAIMIDA
Family	DORYLAIMIDAE de Man, 1876
Subfamily	DORYLAIMINAE, de Man, 1876
Genus	***Dorylaimus*** Dujardin, 1845
Species	***D. innovatus*** Jana and Baqri, 1982
Male 2	L = 4.27 mm–4.29 mm.
	a = 41.63 – 41.86, b = 4.69 – 4.72
	c = 122 – 126

Description : *Female* : Not found. *Male* : (Figure 10 A - E). Body ventrally curved, tapering at both ends. Cuticle finely striated transversely, measuring 5.8–7.5 μm thick at mid body and 6.6–8.3 μm at tail. Lips amalgamated, marked with a slight depression. Amphids stirrup-shaped. Odontostyle 48–51 mm long; its aperture 8.3–10.0 μm long. Guiding ring at 24–29 μm from anterior end. Nerve ring at 215–223 μm from anterior end. Cardia elongated, conoid, measuring 33–36 μm long. Oesophago-intestinal disc present. Spicules 108–110 μm long. Lateral guiding pieces rod-shaped, 20.7–21.5 μm long. 44 contiguous ventromedian supplements present. Copulatory muscles in large number, extended upto the supplement region. Pre-rectum 514–517 μm long. Tail short, bluntly rounded, measuring 33–35 μm long.

Locality and Habitat : From soil around roots of Paddy, *Oryza sativa*, at Midnapur district and Rautara village of North 24-Pargana district, West Bengal, India.

Distribution : The species *Dorylaimus innovatus* is commonly found in soil around the roots of Paddy, *Oryza sativa* at Rasulpur, Burdwan district, West Bengal, India.

3.1.4 ***Calodorylaimus indicus*** Ahmad and Jairajpuri, 1982.

Family	DORYLAIMOIDAE
Subfamily	LAIMYDORINAE, Andrassy, 1969
Genus	***Calodorylaimus*** Andrassy, 1969
Species	***C. indicus*** Ahmad and Jairajpuri, 1982
Male 2	L = 2.65 mm–2.74 mm.
	a = 32.57–33.01, b = 4.07–4.08
	c = 110.04–110.09, T = 64.23–66.03

Description : *Male* : (Figure 11 A - D). Body slightly curved ventrally, cuticle finely striated. Lip region more or less continuous with body contour. Amphids stirrup-shaped. Guiding ring single. Odontostyle measures about 30–32 μm long, Odontophore simple, rod-like structure, 31.5–33.2 μm long. Oesophagus muscular, gradually enlarges near middle, measuring about 650–670 μm long. Cardia elongated, conoid. Nerve ring at 140–145 μm from anterior end. Maximum body width 81.3–3.0 μm. Testis measures about 1750–1760 μm long. Spicule 40–42 μm long. Ventromedian supplements present, 20–23 in number. Anal body width 23– 25 mm. Prerectum measures about 220–258 μm long. Tail short, measures about 24.1–24.9 μm long.

Female : Not found.

Locality and Habitat : Soil around roots of Jute, *Corchorus olitorius*, from Salboni, Bankura district, and Rautara village, North 24-Pargana district of West Bengal, India.

Distribution : The species *Calodorylaimus indicus* is commonly found at Howrah district, West Bengal, India. It is also found in Imphal, Manipur State, India.

3.1.5 ***Laimydorus siddiqii*** Baqri and Jana, 1982.

Genus	***Laimydorus*** Siddiqi, 1969
Species	***L. siddiqi*** Baqri and Jana, 1982
Female 2	L = 2.65 mm–2.90 mm.
	a = 41.42–44.16, b = 4.90–5.17
	c = 7.79–8.05, V = 42.75–45.28
	G_1= 14.48–15.09, G_1= 16.89–17.35

Description : *Female* : (Figure 12 A - E). Body ventrally curved upon fixation, tapering in both ends. Cuticle transversely striated, about 2.5 mm thick at anterior end and 3.32mm thick at tail. Lip region marked from body by a depression. Amphids stirrup-shaped. Odontostyle 27.4–29.5 μm long; its aperture varies from 11.6–12.5 μm. Odontophore 31.5–33.2 μm long; Nerve ring at 155–58 μm from anterior end. Cardia tongue-shaped, measuring 23.2–28.9 μm long. Vulva at 1200–1240 μm from anterior end. Vagina 23.2–25.7 μm long. Female reproductive system amphidelphic, overies reflexed. Anterior genital branch 400–420 μm long and posterior branch 460–490 μm long. Anal body width 26.56 μm long. Prerectum 215–220 μm and rectum 34.9–37.3 μm long. Tail filiform, measuring 340–360 μm long.

Male : Not found.

Locality and Habitats : Collected from soil around the roots of Paddy, *Oryza sativa*, at Rautara village, North 24-Parganas, West Bengal. It is also found in the soil around the roots of paddy, at Purulia district of West Bengal, India.

Distribution : The species is commonly found at Arabindanagar, Pundibari, Coochbehar district, West Bengal, India.

Species 2	***Laimydorus baldus*** Baqri and Jana, 1982.
Female 4	L = 2.38 mm–2.83 mm.
	a = 31.86–36.27, b = 4.25–4.96,
	c = 8.81–10.10, V = 48.76–57.14,
	G_1= 16.04–18.48, G_2= 16.96–19.32

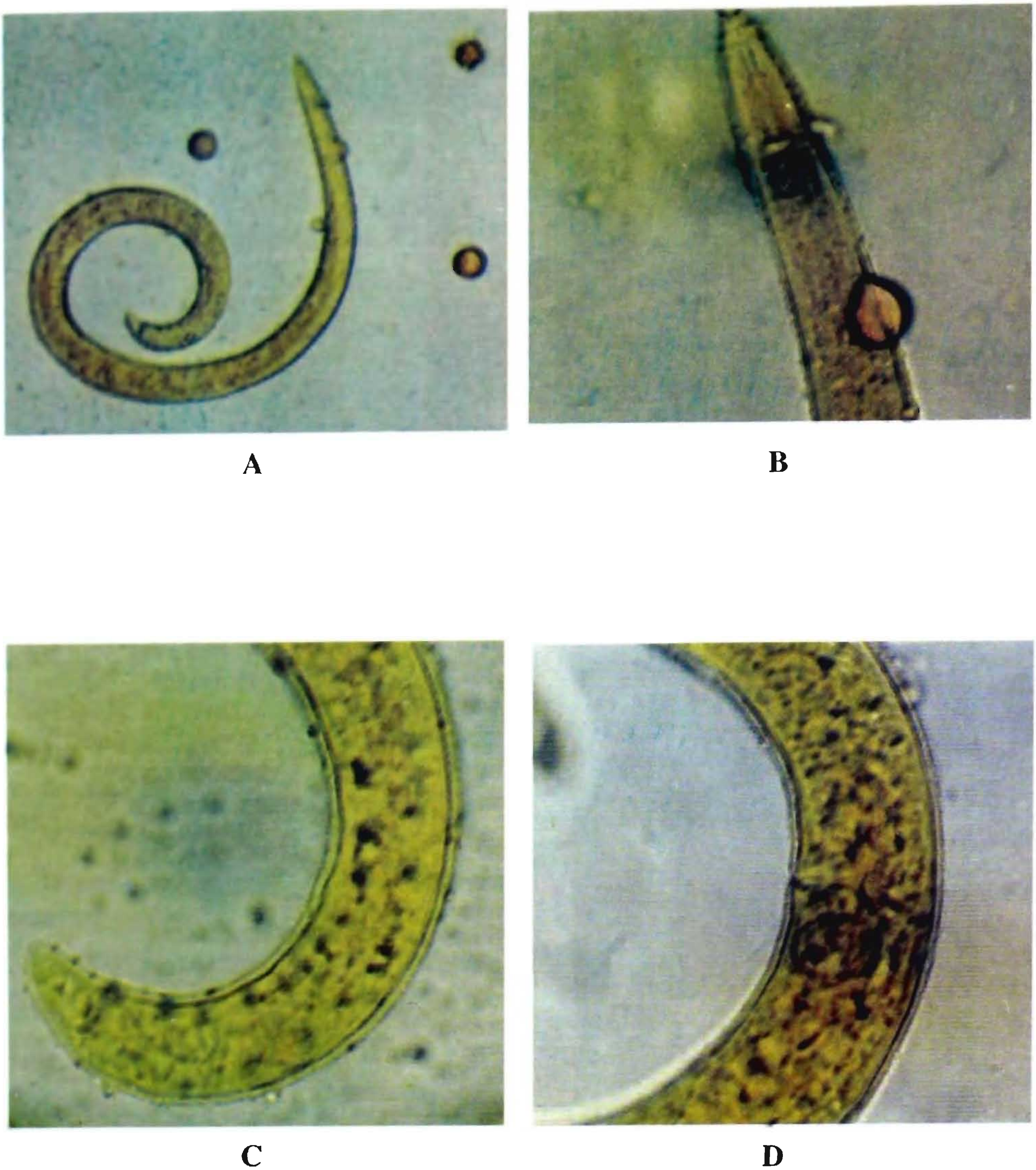


Fig. 8. *Helicotylenchus indicus.* Photomicrographs

A = Entire female X 100; B = Anterior portion showing stylet X 1000
C = Tail region X 1000; D = Vulva region X 1000

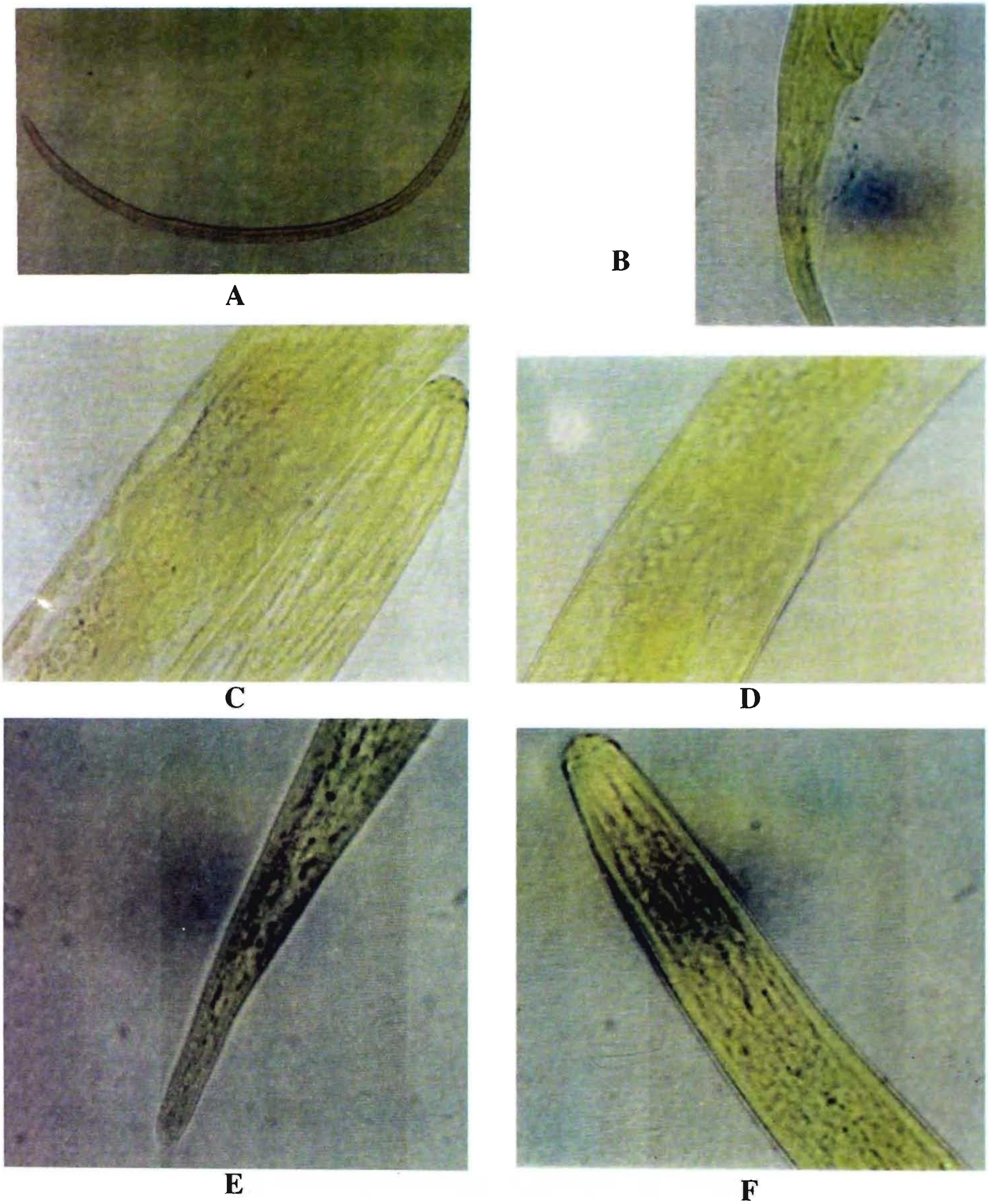


Fig. 9. *Hirschmanniella gracilis.* Photomicrographs
A = Entire male X 100; B = Male tail region with bursa X 1000
C = Female anterior region and vulva region X 1000;
D = Vulva region X 1000 E = Female tail region X 1000; F = Male anterior region X 1000

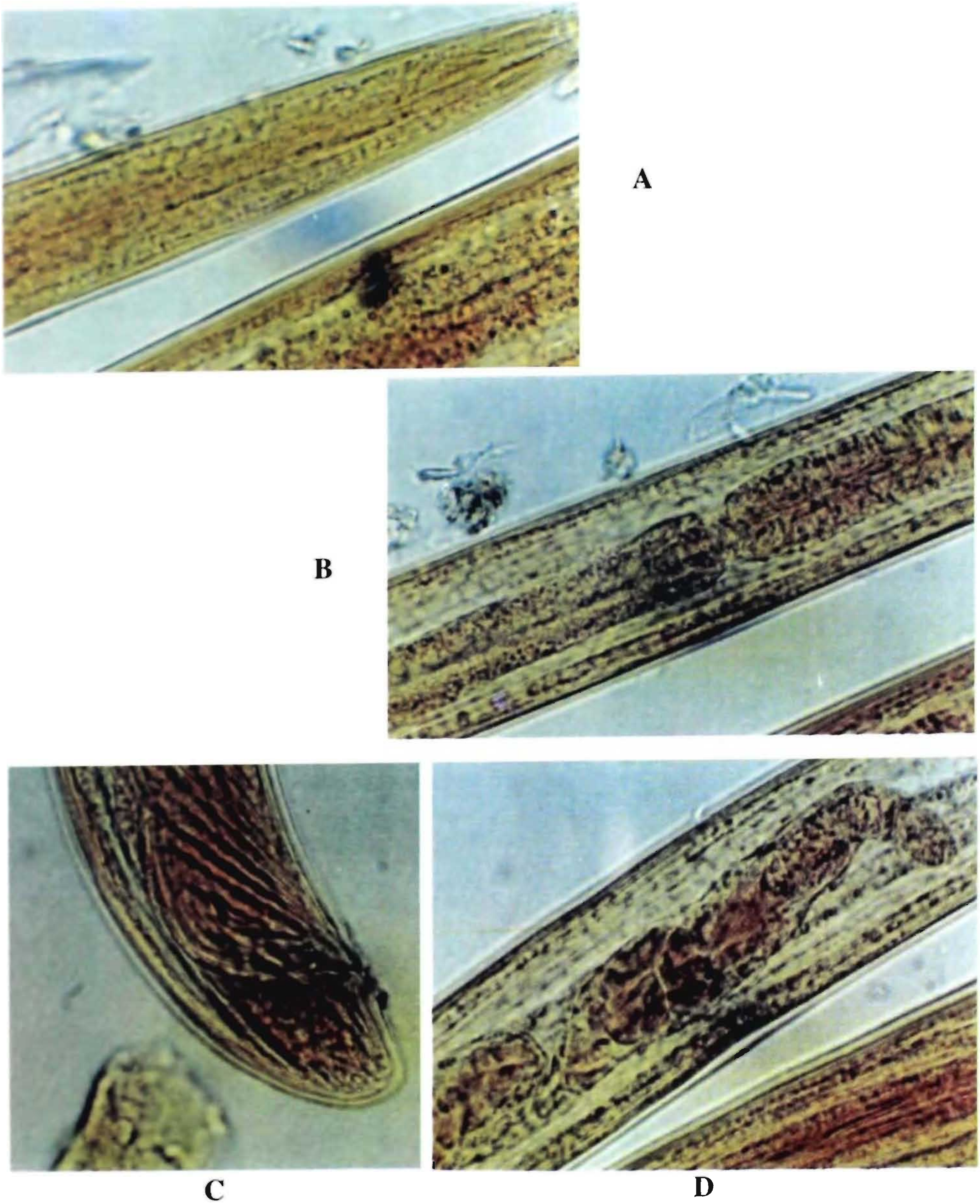


Fig. 10. *Dorylaimus innovatus.* Photomicrographs X 1000
A = Male anterior region; B = Male oesophago-intestinal junction
C = Male tale region with spicule; D = Testis of male

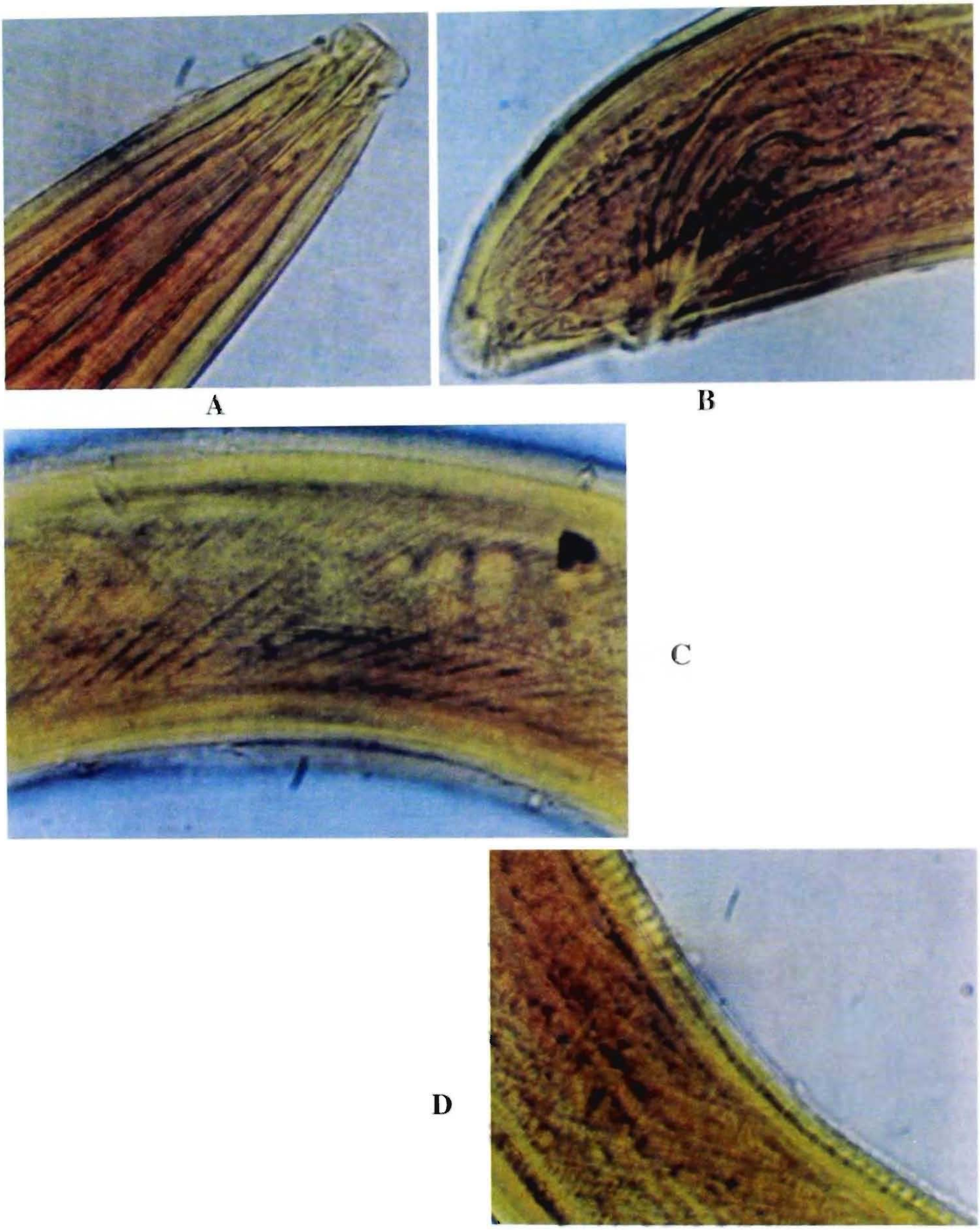


Figure 11 : *Calodorylaimus indicus*. Photomicrographs X 1000
A = Male anterior region with stylet; B = Male tail region with spicule and anus
C = Copulatory muscle of male; D = Supplements and copulatory muscles of male

Male 1 L = 2.39 mm,

a = 33.96, b = 4.64,

c = 82.47, T = 62.60

Description : *Female* : (Figure 13 A - D) Body more or less straight upon fixation, tapering at both ends. Cuticle finely striated, measuring 2.5 µm at anterior end and 3.3 µm at tail. Lip region marked by a depression. Amphids stirrup-shaped. Cardia elongated and rounded, measuring 19–20 µm long. Odontostyle 23.2–25.0 µm long, its aperture varies from 9–11 mm. Odontophore measuring 29.0–29.9 µm long. Guiding ring 14–15 µm from anterior end. Oesophagus 560–570 µm long from anterior end. Nerve ring at 140–150 mm from anterior end. Maximum body width 74.7–78.0 mm. Vulva is a transverse slit, at 680–690 µm from anterior end. Vagina 23–25 µm long. Female reproductive system amphidelphic, anterior gonad ranges from 440–454 mm and posterior gonad 460– 480mm long. Anal body width 33.2–34.8 µm long. Prerectum 120.3–124.5 µm and rectum 39.2–41.5 µm long. Male : Body similar to Female in general morphology except tail shape and male reproductive system. Odontostyle 25mm, Odontophore 29mm long and aperture 10 mm long. Testis 1500 µm long. Supplements consists of an adanal pair and a series of 24 contiguous ventromedians. Spicules 54 mm long, lateral guiding pieces rod-shaped, measuring 9.1 µm. Anal body width 33.2 µm. Tail bluntly rounded, 29.05 µm long.

Locality and Habitat : collected from soil around roots of Paddy, *Oryza sativa*, at Jalanpur, district Bankura; Purulia town, district Purulia and Rautara village, district North 24-Parganas, West Bengal, India.

Distribution : The species *Laimydorus baldus* was first described from Chakchaka, district Coochbehar, West Bengal, India.

3.1.6 ***Sicaguttur sartum*** **Siddiqi, 1971**

Family	THORNENEMATIDAE Siddiqi, 1969
Subfamily	THORNENEMATINAE, Siddiqi, 1969
Genus	***Sicaguttur*** Siddiqi, 1971
Species	***S. sartum*** Siddiqi, 1971
Female 2	L = 1.74 mm–1.79 mm
	a = 33.27–33.36, b = 6.04–6.08
	c = 11.47–12.42, V = 36.64–37.35
	G_1 = 6.25–6.32, G_2 = 8.04

Description : Female : (Figure 14 A - F). Body slightly curved ventrally upon fixation, tapering at both ends. Cuticle striated transversely, 1.7–2.5 µm thick at anterior end and 2.5–3.3 µm thick at tail region. Amphids stirrup-shaped. Odontostyle about 16.5–17.5 µm long, its aperture 5.8mm long. Odontophore varies from 24–25 µm long. Guiding ring at 9 µm from anterior end. Nerve ring ranges from 120–124 µm from anterior end. Cardia tongue-shaped. Oesophagus ranges from 288 to 294mm from its length. Vulva a transverse slit, about 650–656 µm long from anterior end. Vagina 16.5–18.0 µm long. Maximum body width 52.3–53.6 µm long. Anal body width 28.2–29.0. Female reproductive system amphidelphic, anterior gonad ranges from 110–112 µm and posterior gonad 140–144 µm long. Rectum ranges from 31.5 to 32.4 µm long. Pre-rectum length varies from 57.1–58.7 µm. Tail elongated, filiform, measuring 140–156 µm long.

Male : Not found.

Locality and Habitats : The Species was collected from the soil around the roots of Wheat *Triticum aestivum,* at Rautara, village district North 24-Parganas, West Bengal. It was also found in the soil around the roots of paddy *Oryza sativa* at Digha, Midnapur district, West Bengal, India.

Distribution : *Sicaguttur sartum* has also been reported from Narendrapur, South 24-Parganas, West Bengal, India and Saldah, district Burdwan, West Bengal, India.

3.1.7 *Aporcelaimellus heynsi* Baqri and Jairajpuri, 1968

Family	APORCELAIMIDAE Heyns, 1965
Subfamily	APORCELAIMINAE
Genus	***Aporcelaimellus*** Heyns, 1965
Species 1	***A. heynsi*** Baqri and Jairajpuri, 1968
Female 3	L = 1.12 mm–1.27 mm
	a = 26.98–27.82, b = 3.94–4.40
	c = 33.73–35.58, V = 51.96–55.35
	G_1 = 12.59–13.39, G_2 = 7.87–8.03

Description : *Female* : (Figure 15 A - D). Body cylindrical, gradually tapering anterior to bare of oesophagus, and curved in posterior half of its length upon fixation. Cuticle finely striated, its width varies from 1.7 to 2.5 µm (thickest at tail). Lip region well offset from the body. Odontostyle 11.6–12.4 µm long, its aperture measure about 7.5–8.3 µm. Guiding ring at 5.8–6.6 µm from anterior end. Nerve ring at 87–91 µm from anterior end. Oesophagus 284–288 µm long, Oesophago-intestinal disc present. Cardia hemispheroid.

Vulva pore-like, situated at 620–660 µm from anterior end. Vagina 11.6–13.3 µm long. Female reproductive system amphidelphic; anterior and posterior genital branch 150–160mm, and 90–100 µm long respectively. Anal body width 28–22 µm; pre-rectum ranges from 56.1–64.9 µm. Rectum 21.5–23.2 µm long. Tail measures 33.2–35.7 µm, conoid, with rounded terminus.

Male : Not found.

Locality and Habitats : Collected from soil around the roots of Jute *C. olitorious* from Rautara village, North 24-Parganas, West Bengal. It was also collected from the soil around paddy, *Oryza sativa*, from Maliyara, district Bankura of West Bengal, India.

Distribution : *Aporcelaimellus heynsi* was described by Baqri & Jairajpuri (1968) from soil around roots of Cotton (*Gossypium sp.*) at Ajitgunj, Mainpuri district, Mukhtarpur, Bijnor district, and Iglas, Aligarh district of Uttar Pradesh, India. It was also reported from Mayabandar, Andaman.

Species 2 ***Aporcelaimellus tropicus*** Jana and Baqri, 1981

Female 3	L = 1.62 mm–1.78 mm,
	a = 42.89 - 43.37, b = 4.19 - 4.51
	c = 69.70 - 71.78, V = 54.93 - 55.05
Male 2	L = 1.69mm - 1.75mm
	a = 45.24 - 45.83, b = 4.74 - 4.86
	c = 63.62 - 65.88, T= 52.68 - 54.43

Description : *Female* : (Figure 17 D - H). Body cylindrical, tapering anterior to slender part of oesophagus, curved in posterior half of its length upon fixation. Cuticle distinctly striated, 2.5–3.3 μm thick in different region of the body (thick at tail). Lip region offset, wider than adjoining body. Amphids 5.8–6.6 μm wide. Odontostyle 11 to 13 μm long, aperture 6.6–7.5 μm long. Odontophore 17.4–19.1 μm long. Nerve ring at 107.9–116.2 μm from anterior end. Cardia tongue-shaped. Oesophagus varies from 386 to 394 μm in length. Oesophago-intestinal disc absent. Maximum body width 37.3–41.5 μm. Vulva a transverse slit, situated at 890mm from anterior end. Vagina 14.9–18.2 μm long. Female reproductive system amphidelphic. Pre-rectum 70.5–116.2 mm long. Rectum 24.9 to 33.2 μm long. Tail bluntly conoid, measuring 23.2–24.9 μm long

Male : (Figure 16 A - C). Similar to female in general shape and morphology. Spicules 41.5–45.6 μm long. Lateral guiding piece 8.3–9.9 μm long. Copulatory muscles 20–24 μm. Pre-rectum 99.6–161.8 μm long. Tail similar to that of female in shape, measuring 26.5 μm long.

Locality and Habitats : Collected from soil around roots of Paddy *Oryza sativa* at Duttapukur and Rautara, district North 24-Parganas, West Bengal, India.

Distribution : The species was described by Jana & Baqri (1981) from Saldah, Kantapur and Maghlampur, district Burdwan, West Bengal, India.

3.1.8 ***Laevides laevis*** (Thorne, 1939) Thorne, 1974

Family	NYGOLAIMINAE (Thorne,1935)Meyl, 1961.
Subfamily	NYGOLAIMINAE Thorne, 1935
Genus	***Laevides*** Heyns, 1968
	L. laevis (Thorne, 1939)
	Thorne, 1974.
Female 3	L = 1.78mm – 1.86 mm
	a = 45.62 – 45.73, b = 4.04 – 4.13
	c = 64.02 – 67.01, v = 52.68 – 54.49
	G_1 = 12.35 – 12.68, G_2 = 12.92 – 14.51
Male 2	L = 1.66mm – 1.76 mm
	a = 42.55 – 44.17, b = 3.73 – 3.91
	c = 62.5 – 64.25, T= 56.81 – 59.03

Description : *Female* : (Figure 17 F - K). Body more or less straight after fixation, tapering anterior to the base of the oesophagus. Cuticle 1.6–2.5 µm thick at anterior end and 4.1– 4.9 µm on tail. Lip region continuous with body contour, tooth dorylaimoid type, measuring 8.3–10.8 µm. Tooth 9.9–12.4 µm long, its aperture 2.5–3.3 µm. Cardia small, hemispherical, Oesophageal length 440–450 µm. Vulva a transverse slit, situated at 970–980 µm from head region. Vagina 18.3–19.1 µm long. Reproductive system amphidelphic, ovaries reflexed. Maximum body width 39.0–40.7 µm, Anal body width 30.7–31.5 µm Pre-rectum 33.2–37.3 µm long. Rectum 16.6–18.2 µm long. Tail convex-conoid, slightly clavate, 26.6–29.0 µm long.

Male : (Figure 17 A E). Similar to that of female in morphology except the reproductive system and the tail shape. Testis 980–1000 µm long. Tail length measures about 26.6–27.4 µm. Spicules arcuate, 33.2–37.3 µm long. Length of gubernaculum varies from 6.6–7.5 µm. Ventromedian supplements five, spaced regularly/irregularly.

Locality and Habitat : Collected from the soil associated with roots of wheat *Triticum aestivum* at Ichhapur, Gobordanga, and Rautara, North 24-Pargana district, West Bengal, India.

Distribution : The species is cosmopolitan in distribution and commonly found from Pithoragarh, Gola Gokarnath, Lakhimpur kheri, Uttar Pradesh; Joginder Nagar and Malani, Himachal Pradesh, and from Imphal, Manipur, India.

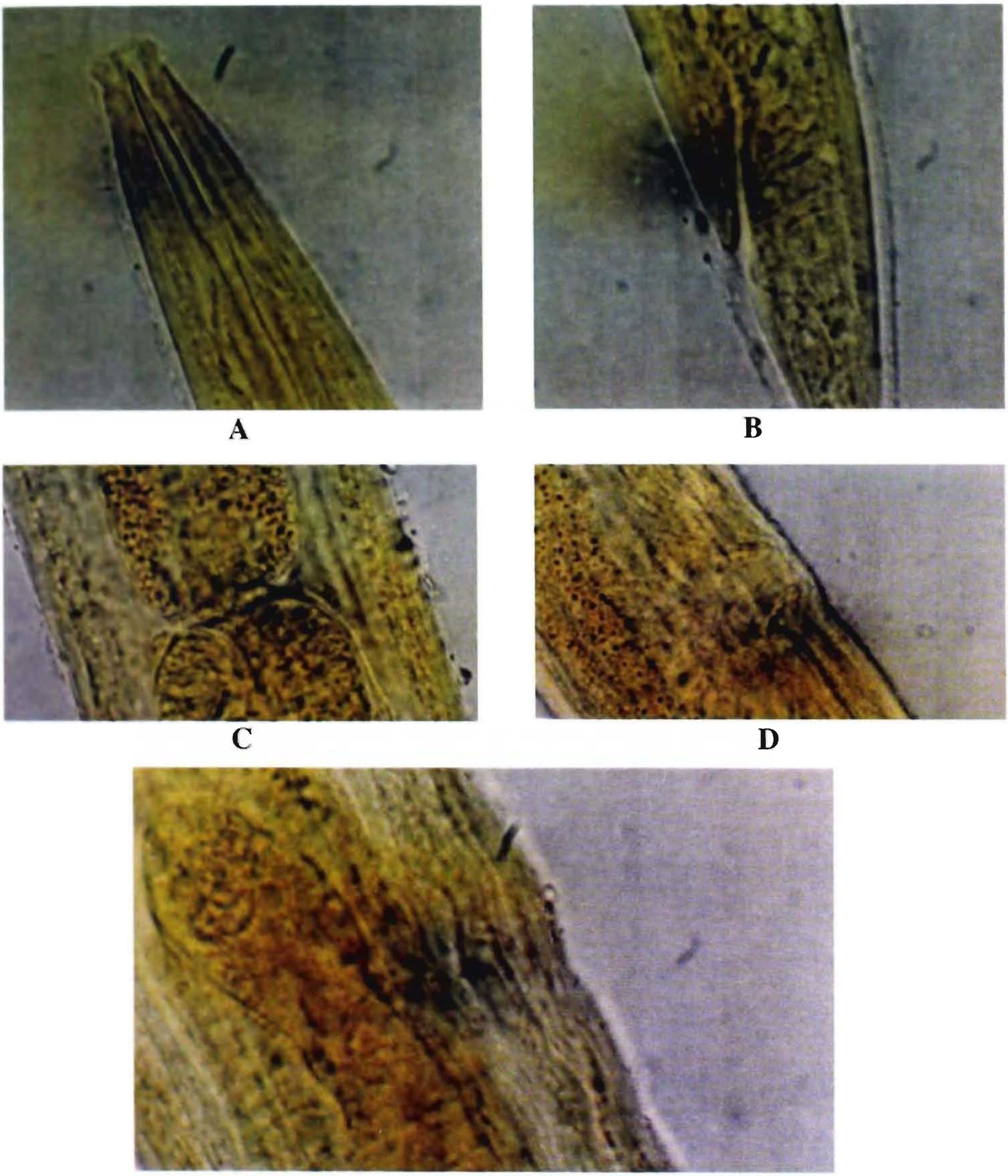


Fig. 12 : *Laimydorus siddiqi.* Photomicrographs X 1000
A= Female anterior region with stylet; B = Female posterior region with anus and rectum
C = Female oesophago-intestinal junction; D = Vulva region of female
E = Female anterior gonad

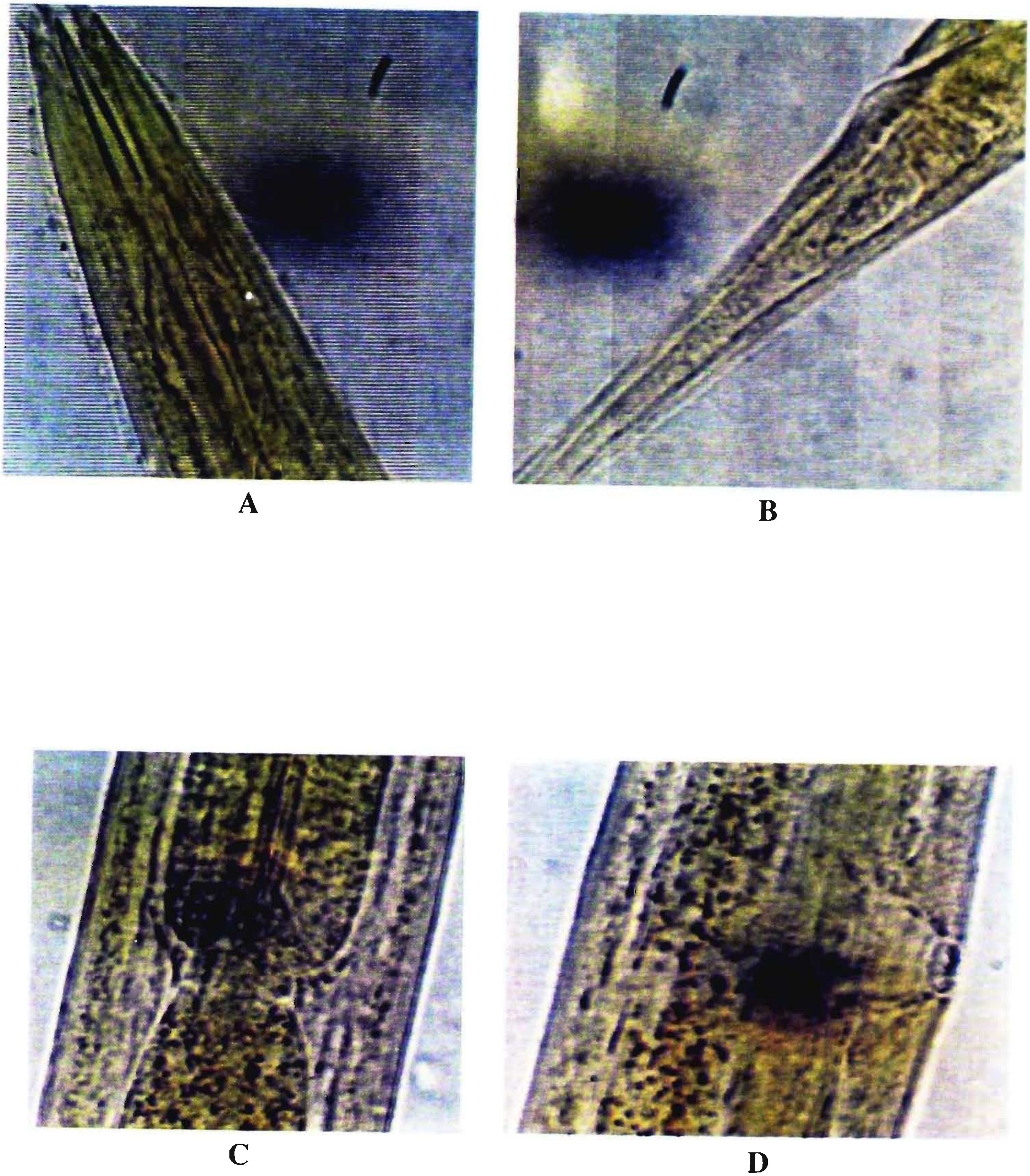
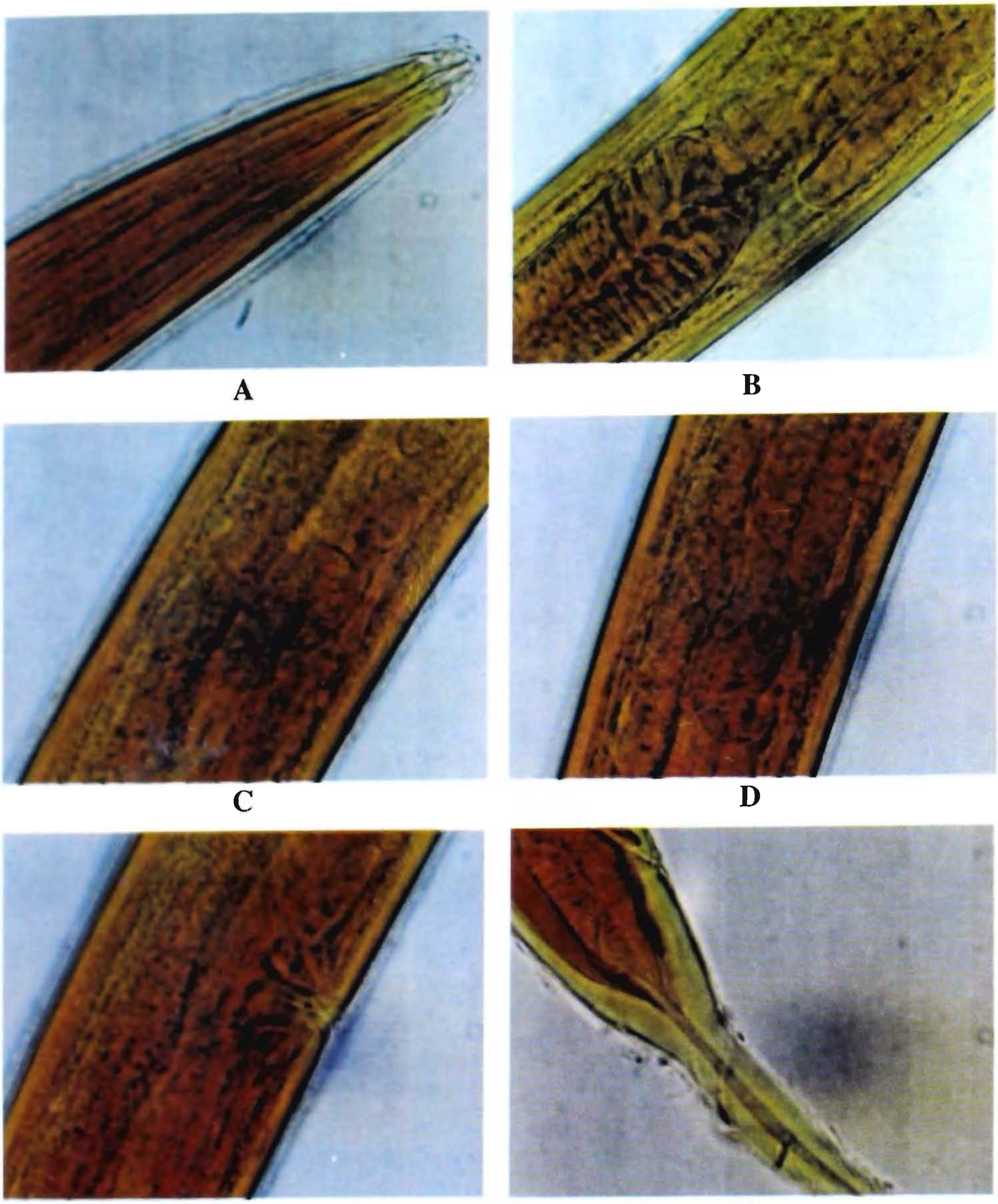


Fig. 13 : *Laimydorus baldus.* Photomicrographs X 1000

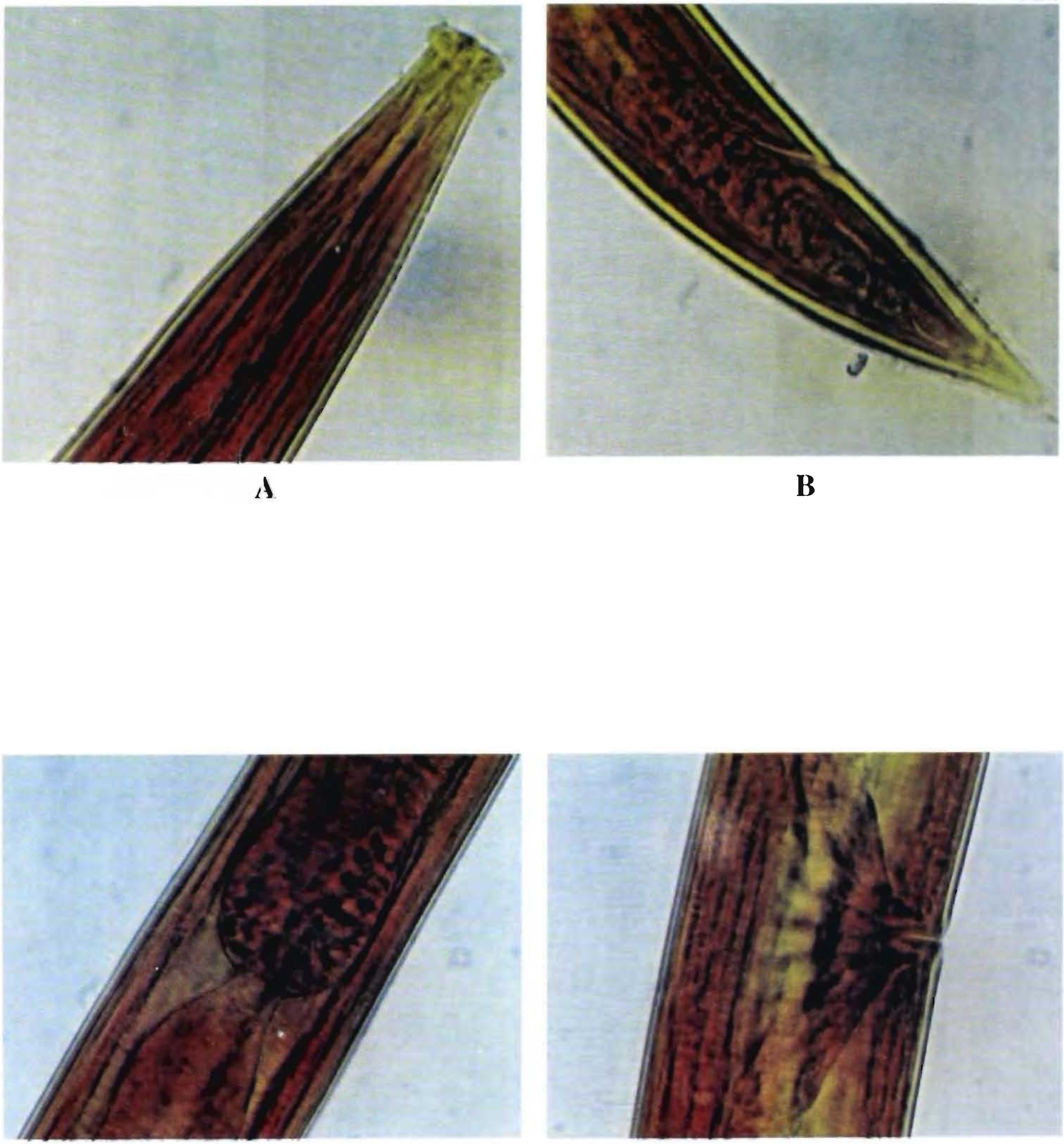
A= Female anterior region with stylet; B = Female posterior region with anus and rectum

C = Female oesophago-intestinal junction; D = Vulva region of female



A B C D E F

Fig. 14 : *Sicaguttur sartum.* Photomicrographs X 1000
A = Female anterior region; B = Female oesophago-intestinal junction
C = Anterior gonad; D = Posterior gonad
E = Vulva region with gonads; F = Tail region with anus and rectum of female



A B C D

Fig. 15: *Aporcelaimellus heynsi.* Photomicrographs X 1000
A = Female anterior region with stylet; B = Female tail region with anus and rectum
C = Female oesophago-intestinal junction; D = Vulva region with gonads

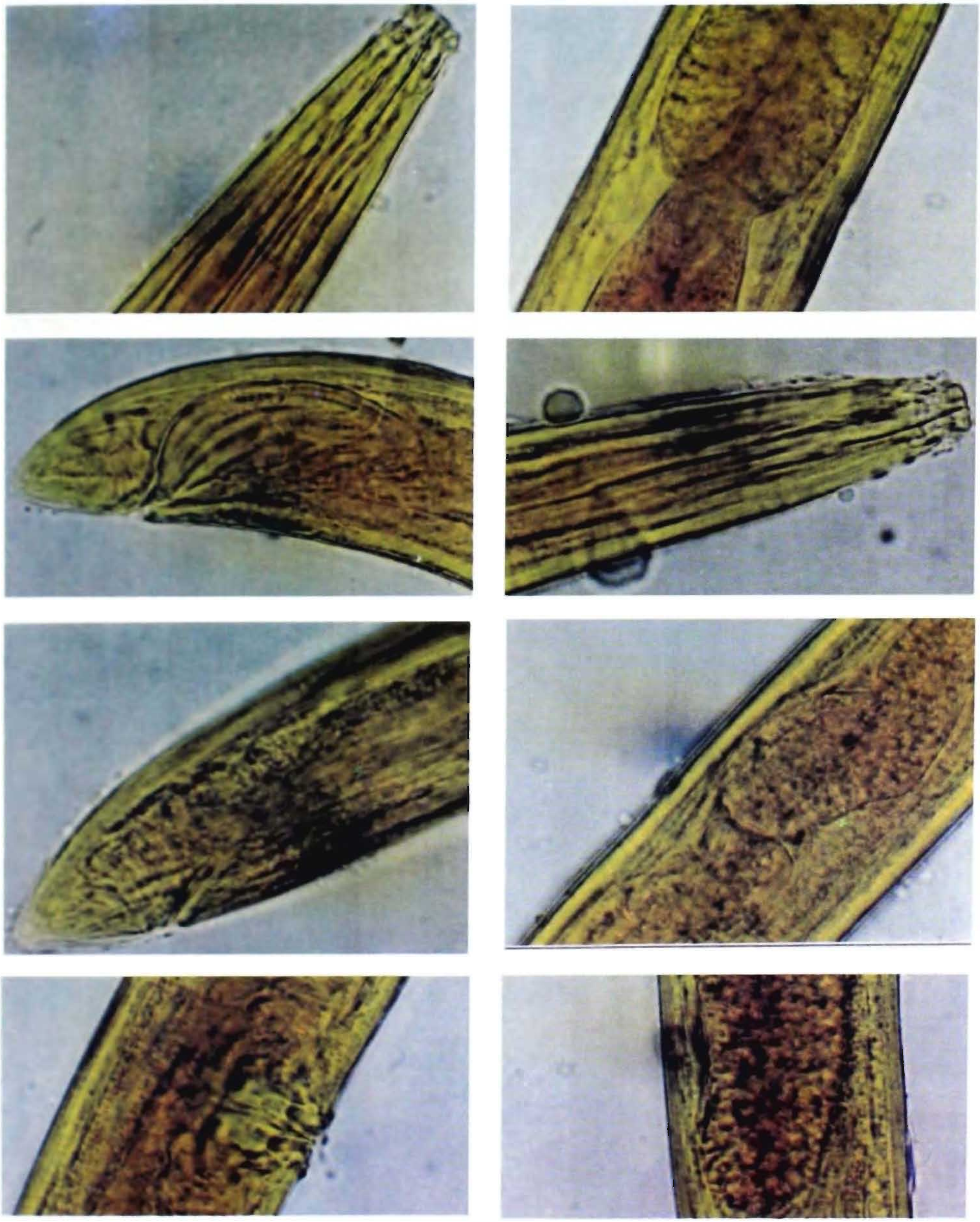


Fig. 16 : *Aporcelaimellus tropicus.* Photomicrographs X 1000
A = Male anterior region; B = Male oesophago-intestinal junction; C = Posterior region with spicule and anus; D = Female anterior region with stylet; E = Female posterior region with anus and rectum; F = Anterior gonad of female; G = Female vulva region; H = Posterior gonad

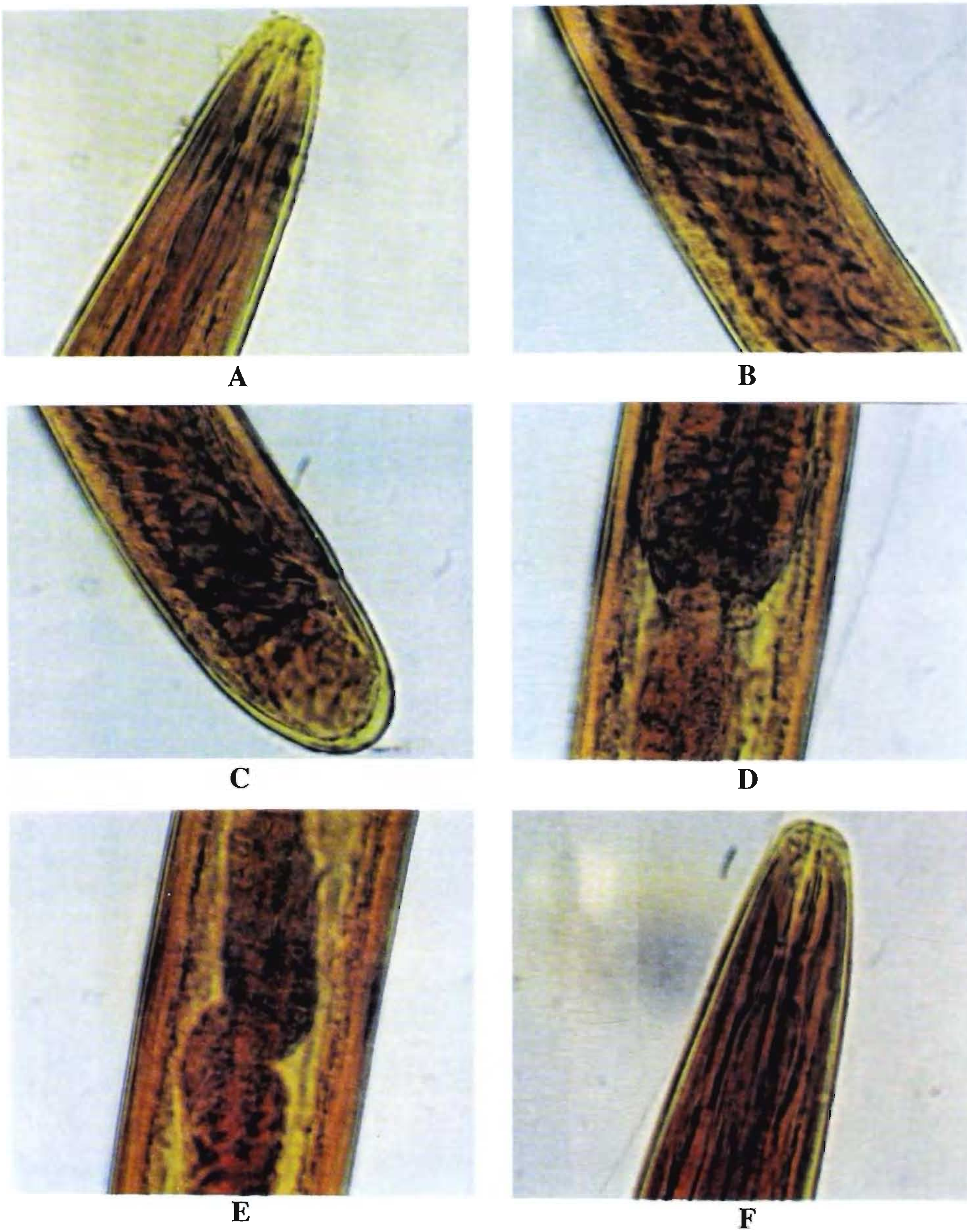
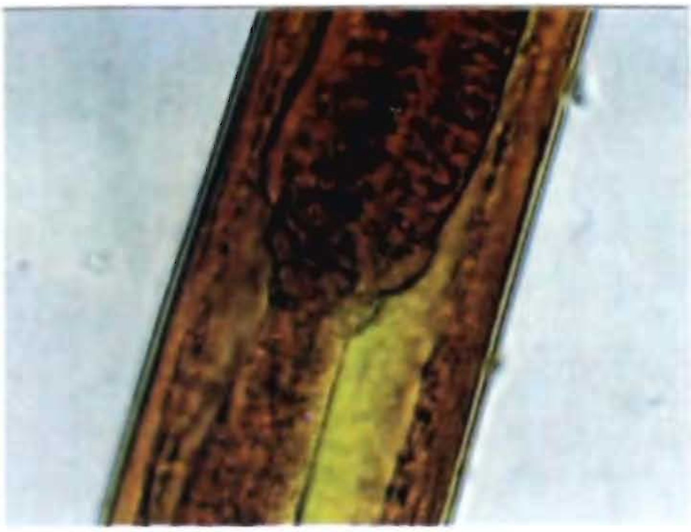
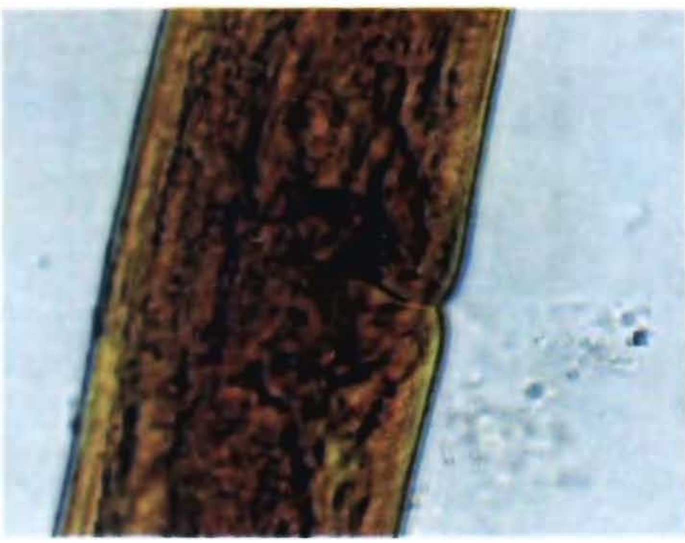


Fig. 17 : *Laevides laevis.* Photomicrographs X 1000
A = Male anterior region and stylet; B = Spicule with coupulatory muscle; C = Tail region with spicule and anus; D = Male oesophago-intestinal junction; E = Showing testis of male; F = Female anterior region with stylet


G


H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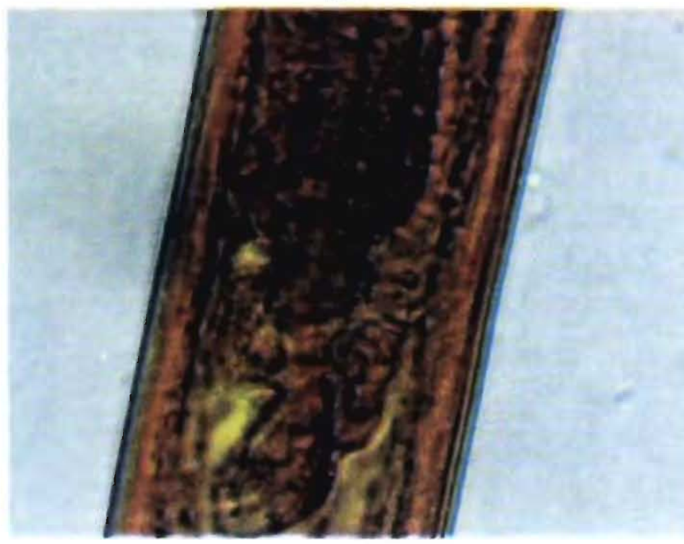

J


K

Laevides laevis. Photomicrographs X 1000
G = Female oesophago-intestinal junction; H = Anterior gonad; I = Female vulva region with gonads; J = Posterior gonad; K = Female tail region with anus

3.2.0. SEASONAL FLUCTUATION OF POPULATION OF *H. gracilis* AND "OTHER NEMATODES" AND THEIR VERTICAL DISTRIBUTION IN SOIL AT PLOT "D" DURING 1990-1992

Seasonal fluctuation of plant parasitic nematodes in both soil and root system is of common occurrence and it gives idea of life cycle pattern of that nematodes. Similar behaviour is shown by nematode parasite of paddy plant *Hirschmanniella gracilis.*

3.2.1. Male population of *Hirschmanniella gracilis* in soil

In the selected plot "D" at Rautara, North 24 Parganas, West Bengal, India, during August, 1990, the first sampling was made when the plot was transplanted with Masuiry variety of paddy. The males of *H. gracilis* were estimated 65.5 and 42.5 per 200 gms soil sample from 0-10 cm and 10-20 cm depths respectively (Table 1, Figure 25, 26, 27). The highest population 77.5 and 45 were in the month of August, 1990 form 0 10 cm and 10 -20 cm depth respectively. From November, 1990, the *Male* population began to decrease gradually and the lowest level was found 20.0 in the month of January, 1991, the plot was kept fallow, for two months. The male population began to increase from February to May, 1991, when the plot was cultivated with Ratna variety of paddy. The highest level of population was observed, 42.5 per 200 gms soil, in 0-10 cm depth during April, 1991, while the lowest level reached to, in 0-10 cm depth in the month of July, 1991 when the plot was kept fallow. The study from 10-20 cm depth reveals that the minimum population was 12.5 per in the month of May, 1991. The male population again began to increase from the month of August, 1991 and the highest number was estimated, 72.5 per 200 gms soil, in the month of October, 1991 from 0-10 cm depth when Masuiry variety of paddy was ready for flowering.

After harvesting of the paddy, the lowest level of male population was observed, 12.5 per 200 gms soil, in the month of January, 1992 from 0-10 cm depth, while it increased to 37.5 in 10-20 cm depth during the month of February, 1992. Again high build up *Male* population, 27.5 per 200 gms soil, was found in 0-10cm depth when the Ratna variety of paddy was about 2 months old in the month of April, 1992. The male population from 0 10 cm depth began to decrease gradually in May and the lowest level, 15 per 200 gms soil reached in the month of July, 1992, during the fallow period of the plot. Contrary to that, the population in 10-20 cm depth was increasing gradually and highest population was observed as 40 per 200 gms soil during the same time (Table 1, Figure 25, 26, 27).

Table 1. Seasonal fluctuation of population of *H. gracilis* and "other nematodes" and their vertical *Distribution* in soil at plot "D" during 1990 -1992

1990-1992	(0-10 cm depth)						(10-20 cm depth)						Root population				Physical factors		
Months	M.	F.	A.	L.	T.	O.	M.	F.	A.	L.	T.	O.	A.	L.	T.	O.	S.	%	Crops
Aug. 90	65.5	342.5	410.0	237.5	647.5	847.5	42.5	180.0	222.5	150.0	372.5	807.5	120.0	15.0	135.0	95.0	28°C	30%	Masuiry Paddy
Sep. 90	42.5	282.5	325.0	212.5	537.5	795.0	32.5	102.5	135.0	112.5	247.5	775.0	162.5	72.5	235.0	142.5	33°C	34%	Masuiry Paddy
Oct. 90	77.5	297.5	375.0	192.5	567.5	727.5	45.0	117.5	162.5	80.0	242.5	752.5	158.5	66.5	225.0	122.5	31°C	26%	Masuiry Paddy
Nov. 90	45.0	272.5	317.5	147.5	465.0	707.5	32.5	100.0	117.0	62.5	195.0	717.5	58.0	11.5	67.5	36.5	28°C	25%	Masuiry Paddy
Dec. 90	32.5	232.5	265.0	115.0	380.0	682.5	22.5	75.0	97.5	55.0	152.5	677.5	Nil	Nil	Nil	Nil	21°C	24%	Fallow
Jan. 91	20.0	190.0	210.0	77.5	287.5	482.5	27.5	75.0	102.5	45.0	147.5	510.0	Nil	Nil	Nil	Nil	19°C	22%	Fallow
Feb. 91	30.0	147.5	177.5	57.5	235.0	407.5	37.5	160.0	197.5	140.0	337.5	700.0	Nil	Nil	Nil	Nil	19°C	20%	Ratna Paddy
Mar. 91	30.0	170.0	200.0	72.5	272.5	492.5	27.5	95.0	122.5	97.5	220.0	585.0	91.0	6.5	97.5	80.0	25°C	32%	Ratna Paddy
Apr. 91	42.5	200.0	242.5	55.0	297.5	552.5	15.0	75.0	90.0	77.5	167.5	510.0	97.5	20.0	117.5	90.0	30°C	26%	Ratna Paddy
Maay 91	37.5	215.0	252.5	42.5	295.0	577.5	12.5	65.0	67.5	60.0	127.5	500.0	40.0	6.0	46.0	55.0	30°C	27%	Ratna Paddy
June 91	22.5	182.5	205.0	27.5	232.5	512.5	22.5	65.0	87.5	37.5	125.0	547.5	Nil	Nil	Nil	Nil	34°C	15%	Fallow
July 91	15.0	127.5	142.5	17.5	160.0	377.5	32.5	87.5	120.0	17.5	137.5	592.5	Nil	Nil	Nil	Nil	30°C	22%	Fallow
Aug. 91	57.5	307.5	365.0	285.0	650.0	777.5	37.5	147.5	185.0	172.5	357.5	777.5	95.0	10.0	105.0	70.0	30°C	35%	Masuiry paddy

1990-1992	(0-10 cm depth)						(10-20 cm depth)						Root population				Physical factors		
Months	M.	F.	A.	L.	T.	O.	M.	F.	A.	L.	T.	O.	A.	L.	T.	O.	S.	%	Crops
Sept. 91	37.5	275.0	312.5	287.5	600.0	810.0	27.5	135.0	162.5	142.5	305.0	795.0	140.0	67.5	207.5	100.0	31°C	33%	Masuiry Paddy
Oct. 91	72.5	252.5	325.0	247.5	272.5	750.0	27.5	122.5	150.0	97.5	247.5	762.5	135.0	50.0	185.0	87.5	29°C	31%	Masuiry Paddy
Nov. 91	32.5	262.5	295.0	205.0	500.0	757.5	32.5	97.5	130.0	70.0	200.0	776.5	70.0	22.5	92.5	52.5	26°C	27%	Masuiry Paddy
Dec. 91	20.0	245.0	265.0	167.5	432.5	690.0	27.5	75.0	102.5	72.5	175.0	702.5	Nil	Nil	Nil	Nil	23°C	23%	Fallow
Jan. 92	12.5	207.5	220.0	135.0	355.0	570.0	27.5	67.5	95.0	47.5	142.5	607.5	Nil	Nil	Nil	Nil	20°C	21%	Fallow
Feb. 92	22.5	167.5	190.0	102.5	292.5	412.5	37.5	137.5	175.0	162.5	337.5	717.5	Nil	Nil	Nil	Nil	20°C	35%	Ratna Paddy
Mar. 92	17.5	192.5	210.0	107.5	317.5	505.0	32.5	82.5	115.0	95.0	210.0	685.0	120.0	12.5	132.5	87.5	25 °C	32%	Ratna Paddy
Apr. 92	27.5	190.0	217.5	77.5	295.0	580.0	20.0	75.0	95.0	75.0	170.0	622.5	107.5	15.0	122.5	82.5	28 °C	25%	Ratna Paddy
May 92	22.5	232.5	255.0	62.5	317.5	632.5	17.5	60.0	77.5	42.5	120.0	547.5	77.5	9.0	66.5	52.5	30 °C	19%	Ratna Paddy
June 92	15.0	207.5	222.5	50.0	272.5	572.5	30.0	67.5	102.5	45.0	147.5	617.5	Nil	Nil	Nil	Nil	30 °C	15%	Fallow
July 92	15.0	157.5	172.5	27.5	200.0	435.0	40.0	85.0	125.0	22.5	147.5	567.5	Nil	Nil	Nil	Nil	30 °C	27%	Fallow

Abrivations used in the Table : M = Male; F = Female; A = Adult; L = Larva; T = Total *H. Gracilis*; O = Other Nematodes; S = Soil temperature; % of soil moisture.

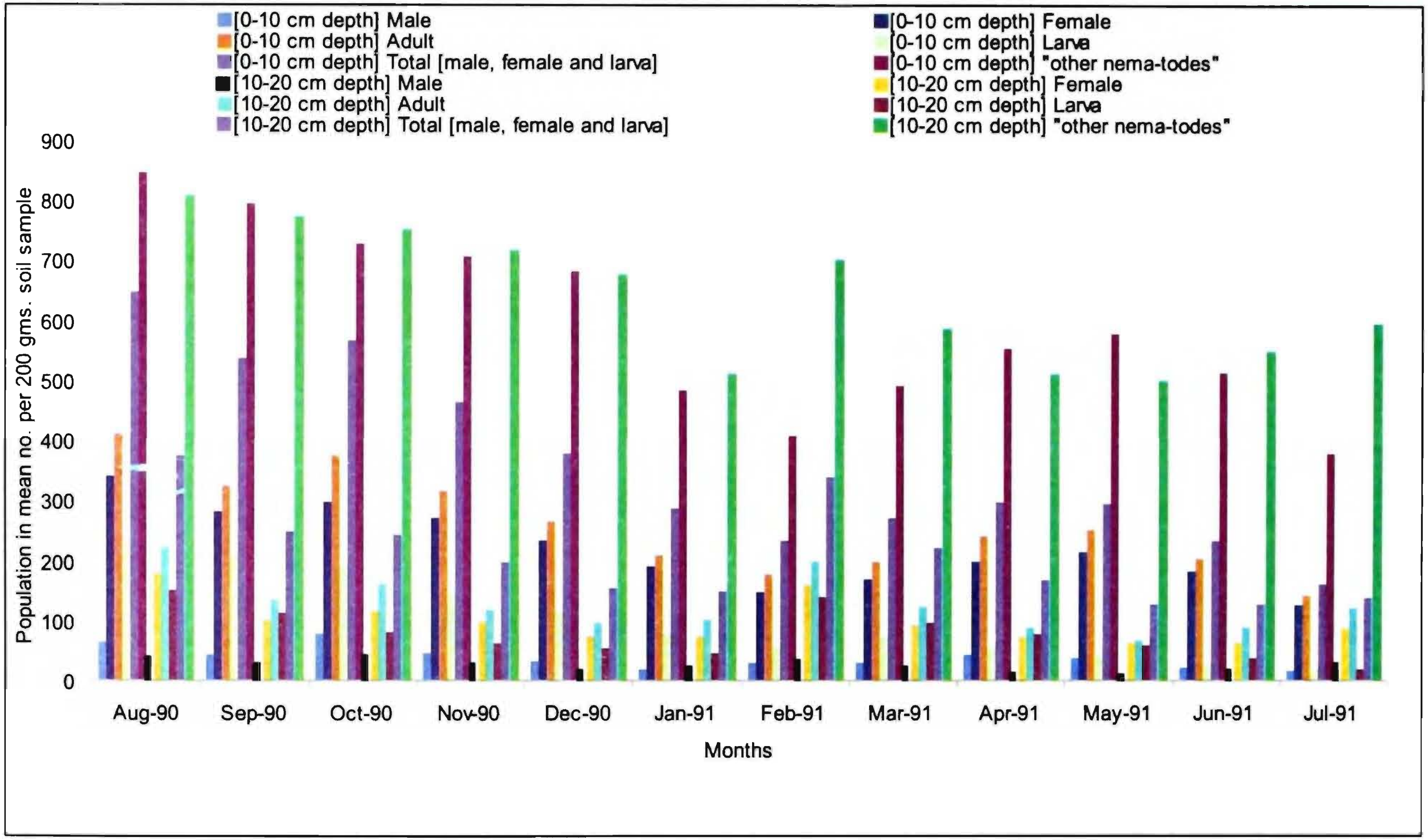


Fig. 25. Seasonal fluctuation of population of *H. gracilis* and "other nematodes" and their vertical distribution in soil at plot "D" during August 1990 - July 1991

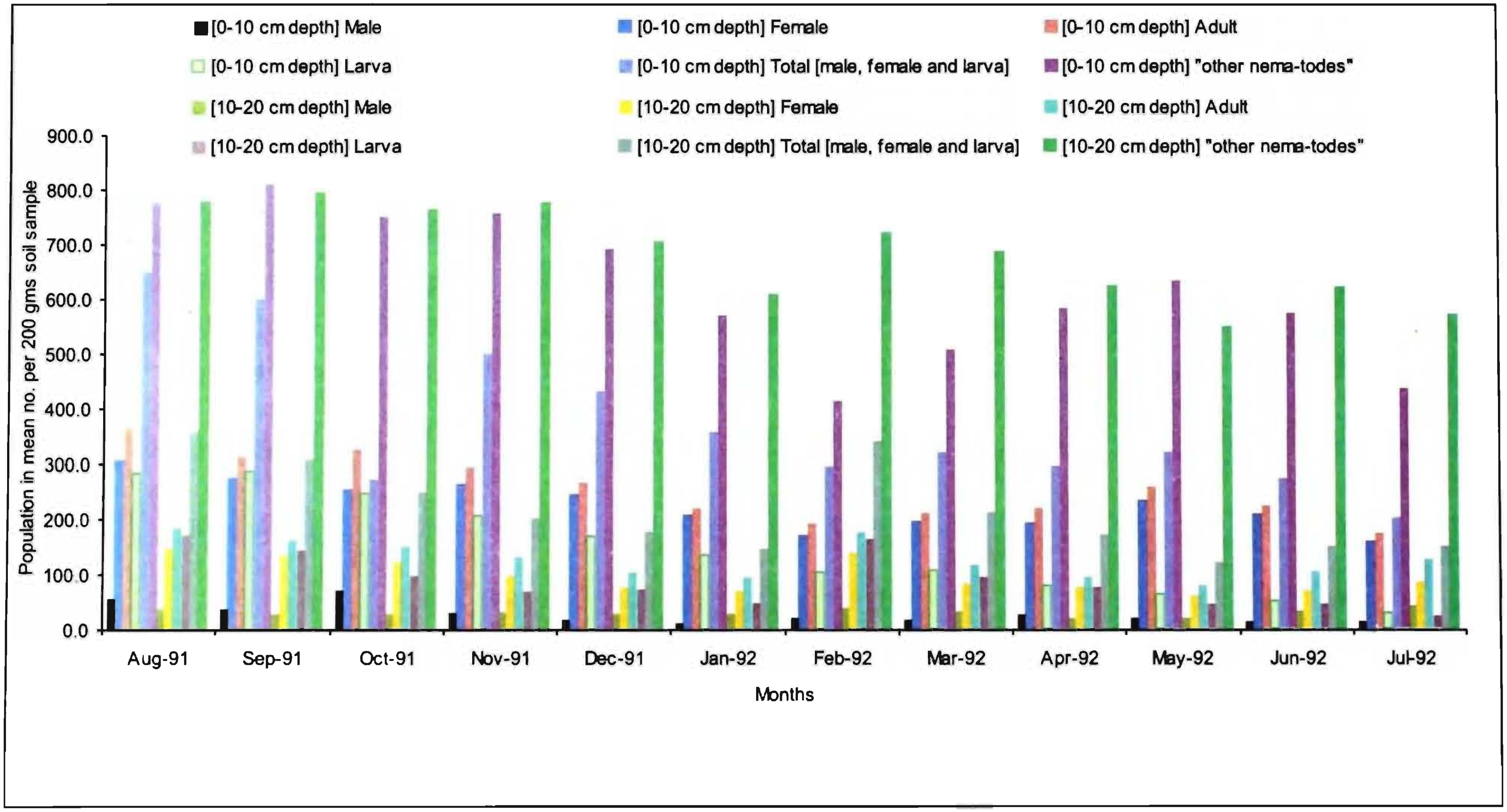


Fig. 26. Seasonal fluctuation of population of *H. gracilis* and "other nematodes" and their vertical distribution in soil at plot "D" during August 1991 - July 1992

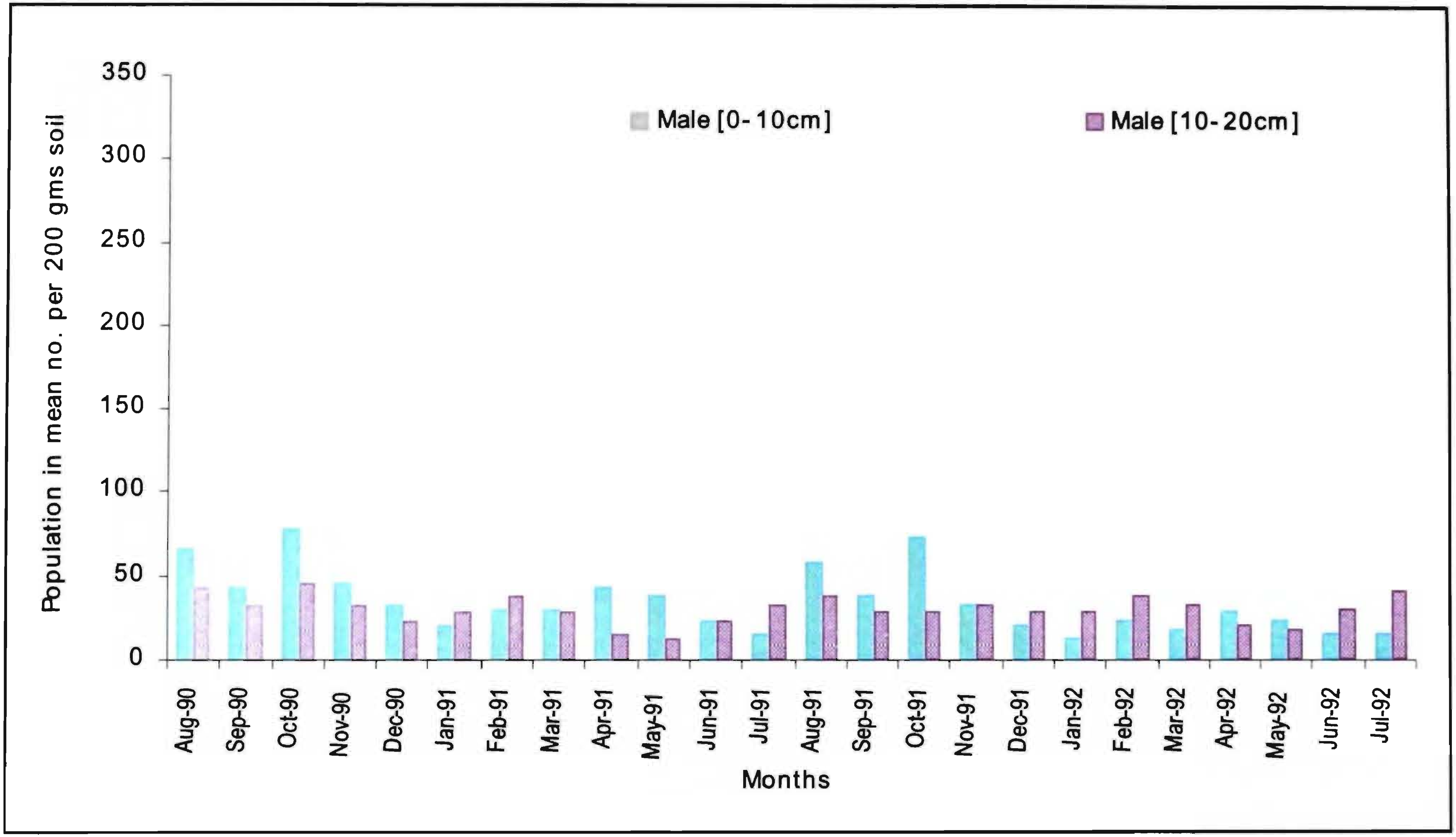


Fig. 27. Seasonal fluctuation of *Male* population of *Hirschmanniella gracilis* and their vertical distribution in soil at plot "D" during 1990-1992 (0-10 cm and 10-20 cm depth)

Fig. 28. Seasonal fluctuation of female population of *Hirschmanniella gracilis* and their vertical distribution in soil at plot "D" during 1990-1992 (0-10 cm and 10-20 cm depth)

3.2.2. Female population of *Hirschmanniella gracilis* in soil

All the data collected during August, 1990 to July, 1992 has been furnished in Table 1. During the month of August, 1990 when the plot was transplanted with Masuiry variety of paddy seedlings under 28°C soil temperature, and 28% soil moisture, the female population of *H. gracilis* was 342.5 per 200 gms soil in 0-10 cm depth, while at 10-20 cm depth the population was 180 (Table 1, Figure 25, 26, 28). Thereafter, the population declined in September, 1991 in both the depths. The population gradually decreased from September to February, 1991, when it was estimated only 147.5 per 200 gms soil in 0-10 cm depth (Table 1 and Figure 28). While in 10-20 cm depth, the lowest level, 75 per 200 gms soil, was observed in the month of January, 1991 and the highest level 160 in February, 1991.

In August, 1991, the population was different but the trend was more or less similar to the results obtained during the year 1990 -1991. The high build up of female population was found in both the depths, 0-10 cm and 10-20 cm, 307.5 and 147.5 respectively under 30°C soil temperature and 35% soil moisture. The female population in 0-10 cm depth continued to decline from September, 1991 to February, 1992 and lowest level of population was observed as 167.5 in the month of February, 1992 and the soil temperature and moisture was recorded 20°C and 35% respectively. On the contrary, the female population was found to increase to 137.5 in the lower depth (10-20 cm) in the same month, February, 1992. Again the female population began to increase from March, 1992 when the plot was transplanted with Ratna variety of paddy and highest number achieved as 232.5 per 200 gms soil in 0-10 cm depth in May, 1992 while the lowest level of female population was found 157.5 per 200 gms soil in 0-10 cm depth in July, 1992 during the fallow period of the plot. The minimum female population from lower depth was found as 60 in the month of May, 1992.

3.2.3. Adult (Male & female) population of *Hirschmanniella gracilis* in soil

In the selected plot "D" at Rautara village, North 24-Parganas, West Bengal, India, the adult population of *H. gracilis* was observed 410 and 222.5 per 200 gms of soil sample in 0-10 cm and 10-20 cm depth respectively (Table 1, Figure 29), in August, 1990 when Masuiry variety of paddy was transplanted, at the soil temperature and moisture of 28°C and 30% respectively. In September, 1990 the adult population increased in both the depths, 0-10 cm and 10-20 cm, to 325.0 and 135.0 respectively. In October, 1990, the adult population again increased, in both the depths, to 375.0 and 162.0 respectively, during the flowering period of the Masuiry paddy. From November, 1990 the adult population gradually to decrease. The lowest level of adult population, was recorded as 177.5 in 0-10 cm depth in the month of February, 1991 while in the same month from 10-20 cm dept, the highest population was recorded as 197.5.

The adult population of *H. gracilis* was found to increase in the months April and May, 1991 when the plot was transplanted with Ratna variety of paddy at 30°C soil temperature and 27% soil moisture. The highest level of adult population was recorded as 252.5 per

200 gms soil sample in the month of May, 1991 in 0-10 cm depth, while in 10-20 cm depth the population was found at its lowest level, 67.5 per 200 gms soil sample. In July, 1991 when the plot was fallow under 30 °C soil temperature and 22% soil moisture, the adult population of *H. gracilis* was found to decrease considerably to 142.5 in 0-10 cm depth, but at that period in 10-20 cm depth, the number was found to increase to 120. Further, the adult population is significantly increased to 365 and 185 per 200 gms soil in both the depths 0-10 cm and 10-20cm, in August, 1991 respectively when the plot was transplanted with Masuiry variety of paddy under 30°C soil temperature and 35% moisture. From November, 1991 to February, 1992 the adult population in both the depths began to decline gradually. The minimum number of adult *H. gracilis* was 190 in upper depth in the month of February, 1992 but in lower depth the high build-up population, 175 of adult *H. gracilis* was recorded in the same month.

The adult population was further increased from the month of March, 1992 and maximum number of adults were 255.0 from upper depth during the flowering period of Ratna paddy. From June, 1992 the adult population began to decline and lowest level of adult population was 172.5 in upper depth in the month of July, 1992. On the other hand, in the lower depth the minimum number of adult population was observed as 77.5 in the month of May, 1992 when the plot was cultivated with Ratna variety of paddy. During the fallow period, in the month of July 1992, maximum number of adult *H. gracilis* were noted as 125.0 from the lower depth.

3.2.4. Larval population of *Hirschmanniella gracilis* in soil

In August, 1990, when the plot was transplanted with Masuiry variety of paddy under soil temperature 28°C and soil moisture 30% , the larval population was 237.5 and 150 per 200 gms soil in 0-10cm and 10-20 cm depth respectively (Table 1, Fig. 30). From September, 1990 to July, 1991, gradual decline in larval population was observed in upper depth and lowest level of larval population was observed as 17.5 per 200 gms soil in 0–10 cm depth in the month of July, 1991. But in February, 1991 the larval population in 10–20 cm depth suddenly increased to 140 per 200 gms soil sample when the plot was transplanted with Ratna variety of paddy. In August, 1991, the larval population of *H. gracilis* significantly increased in both the layers 0–10 cm and 10–20 cm, to 285 and 172.5 respectively, where plot was cultivated with Masuiry variety of paddy under 30 °C soil temperature and 35% moisture respectively. From September, 1991 to July, 1992, the larval population in both the depths gradually decreased and the lowest level of 27.5 and 22.5 per 200 gms of soil sample in 0-10 cm and 10-20 cm depth reached in the month of July, 1992 when the plot was fallow at 30°C and 27% soil temperature and moisture respectively.

3.2.5. Total population (male, female and larval) of *Hirschmanniella gracilis* in soil

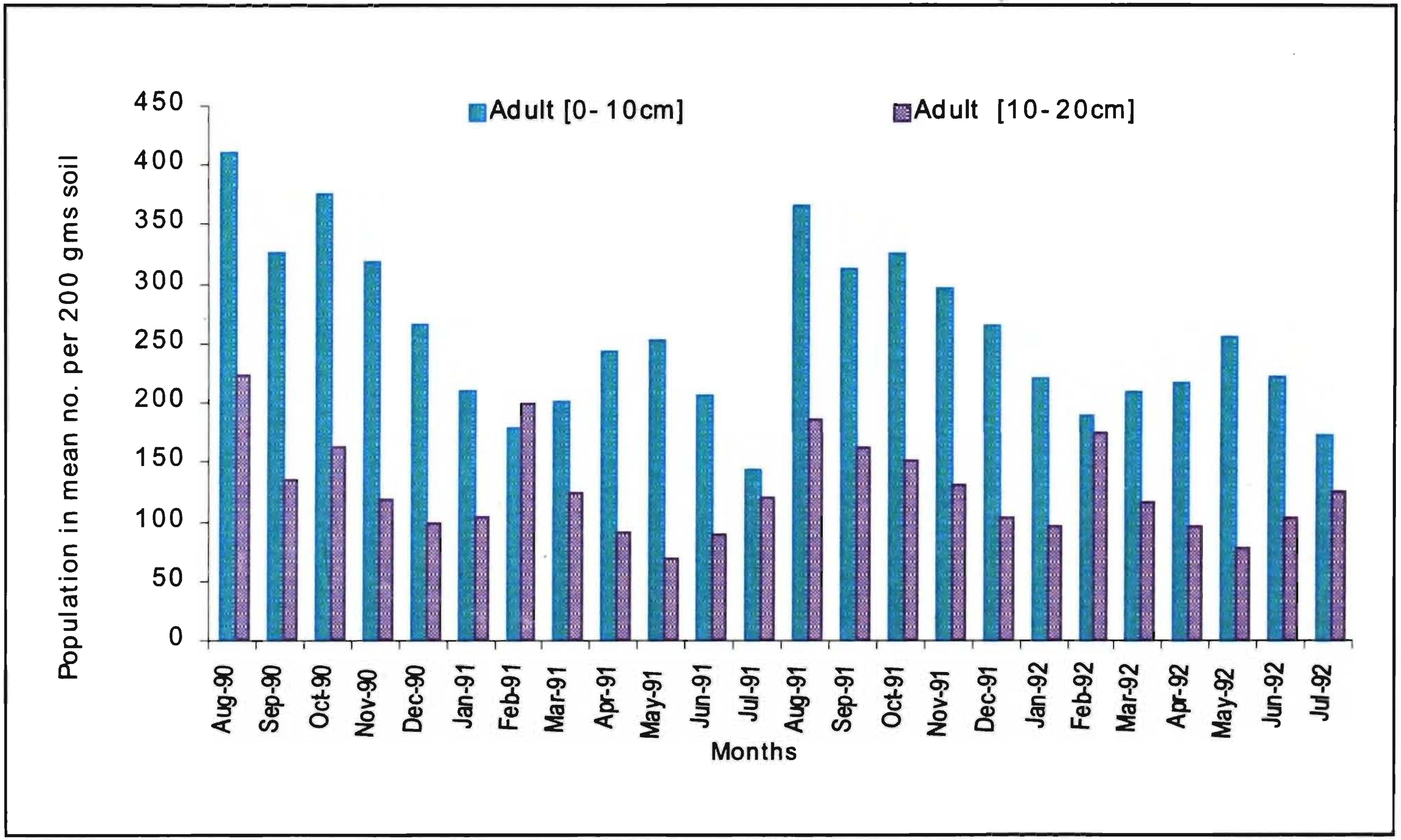
In August, 1990, when the plot was transplanted with Masuiry variety of paddy under 28 °C soil temperature and 30% soil moisture, the population of total *H. gracilis* was found in high build up of 647.5 per 200 gms soil sample in 0-10 cm depth, while in 10-20 cm depth the population was 372.5 per 200 gms soil sample (Table 1, Figure 31). From November, 1990 to February, 1991, a gradual decline of total population was observed in 0-10 cm depth and lowest level of population was observed as 235.0 per 200 gms soil sample in the month of February, 1991. The gradual decline in total population of *H. gracilis* was observed also in lower depth which suddenly increase in the month of February, 1991 to 337.5 per 200 gms soil. From March, 1991, the total population was found increasing when the plot was transplanted with Ratna variety of Paddy and the maximum total population was 297.5 in upper layer in the month of April, 1991 during the flowering period of Ratna paddy. The minimum number of total population of *H. gracilis* from upper depth was recorded as 17.5 in the month of July, 1991 during the fallow period of the plot, whereas in lower depth the population was found at its highest level as 120.0 in the month of July 1991.

Further, the high build up, 650 and 357.5 per 200 gms of soil in the month of August, 1991, in both the depths, 0-10 cm and 10-20 cm respectively was found when the plot was transplanted with Masuiry variety of paddy under 30°C soil temperature and 33% soil moisture. From September, 1991 to July, 1992, the population gradually declined and the lowest level was observed as 292.5 per 200 gms soil sample in 0-10 cm depths in the month of February, 1992 while the plot was transplanted with Ratna variety of paddy.

Again the total population of *H. gracilis* was found to increase from March, 1992 and highest level of population was observed as 317 in the month of May, 1992. The lowest level of population was observed as 120 per 200 gms soil in 10-20 cm depth in the month of May, 1992 when the plot was cultivated with Ratna variety of paddy under 30 °C soil temperature and 19% of moisture. The total population *H. gracilis* was found at its highest level as 337.5 at lower depth in the month of February, 1992, when the plot was transplanted with Ratna variety of paddy under 20°C soil temperature and 35% of moisture.

3.2.6. Population of "other nematodes" in soil

A large number of other nematodes were recovered during this study period and was considered as "other nematodes" as they are harmless for paddy plants and some are free-living or ectoparasitic. Of the other nematodes most prominent are *Helicotylenchus* sp. (Figure 8), *Laimydorus* sp. (Figure 12), *Sicaguttur* sp. (Figure 14), *Laevides* sp. (Figure 17), *Colodorylaimus* sp. (Figure 11), *Aporcelaimellus* sp. (Figure 15) and *Dorylaimus* sp. (Figure 10), etc. The highest number 847.5 in 0 -10 cm and 807.5 in 10-20 cm depth per 200 gms soil sample of "other nematodes" was observed in August, 1990 (Table 1, Figure 32). From September to December, 1990 no remarkable decline in population was observed in both the depths. In January, 1991, the decline of population of "other nematodes" was observed as 482.5 and 510 from 0-10 cm and 10–20 cm depth respectively. In February, 1991, the lowest level of "other nematodes" population was observed as 407.5 per 200 gms soil sample in 0-10 cm depth while in 10–20 cm depth the population increased to 700 when the plot was ploughed for next crop Ratna paddy.



29. Seasonal fluctuation of adult (male and female) population of *Hirschmanniella gracilis* and their vertical distribution in soil at plot "D" during 1990-1992 (0-10 cm & 10-20 cm depth)

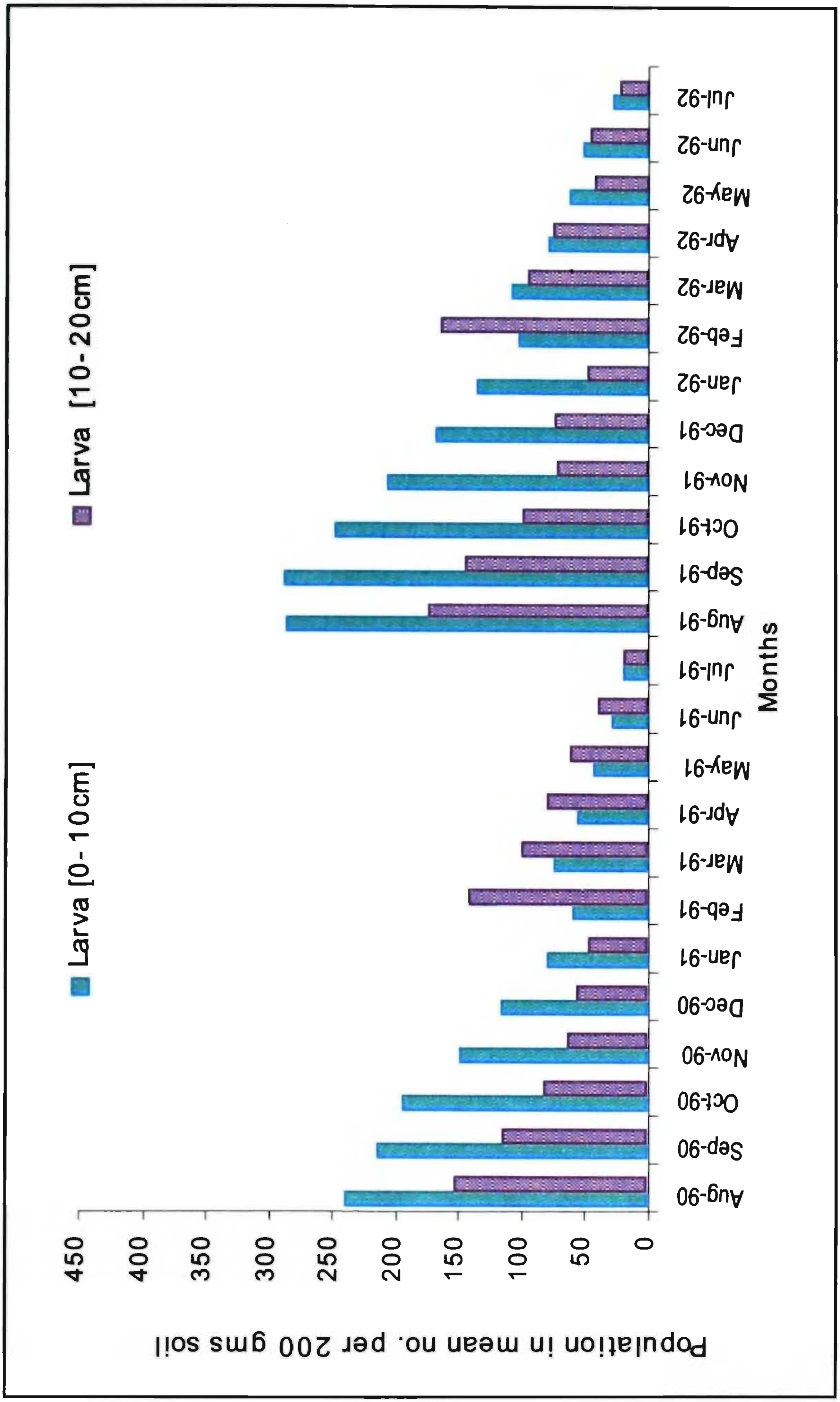


Fig. 30. Seasonal fluctuation of larval population of *Hirschmanniella gracilis* and their vertical distribution in soil at plot "D" during 1990-1992 (0-10 cm & 10-20 cm depth)

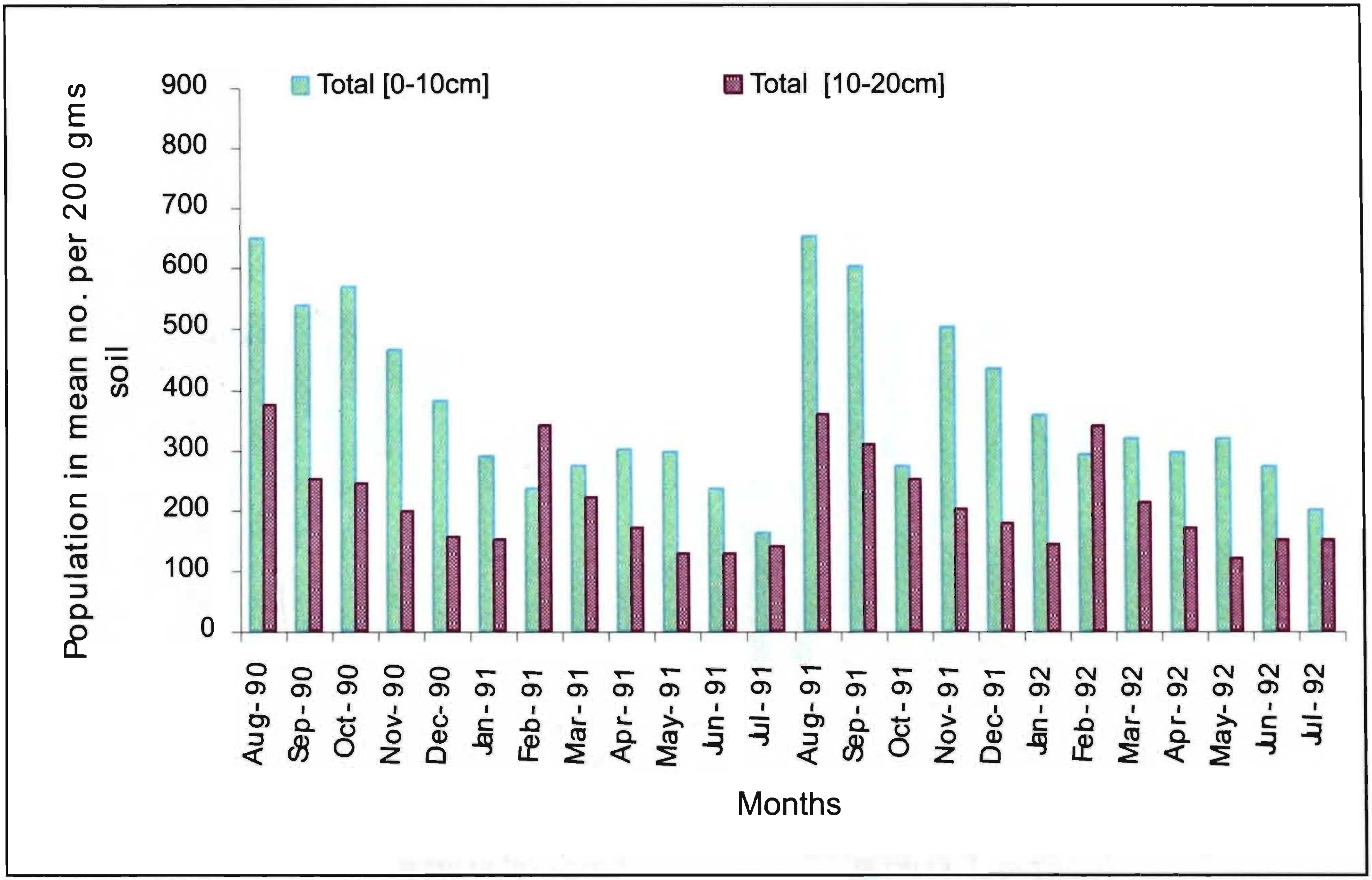


Fig. 31. Seasonal fluctuation of total (male, female and larval) population of *Hirschmanniella gracilis* and their vertical distribution in soil at plot "D" during 1990-1992 (0-10 cm & 10-20 cm depth)

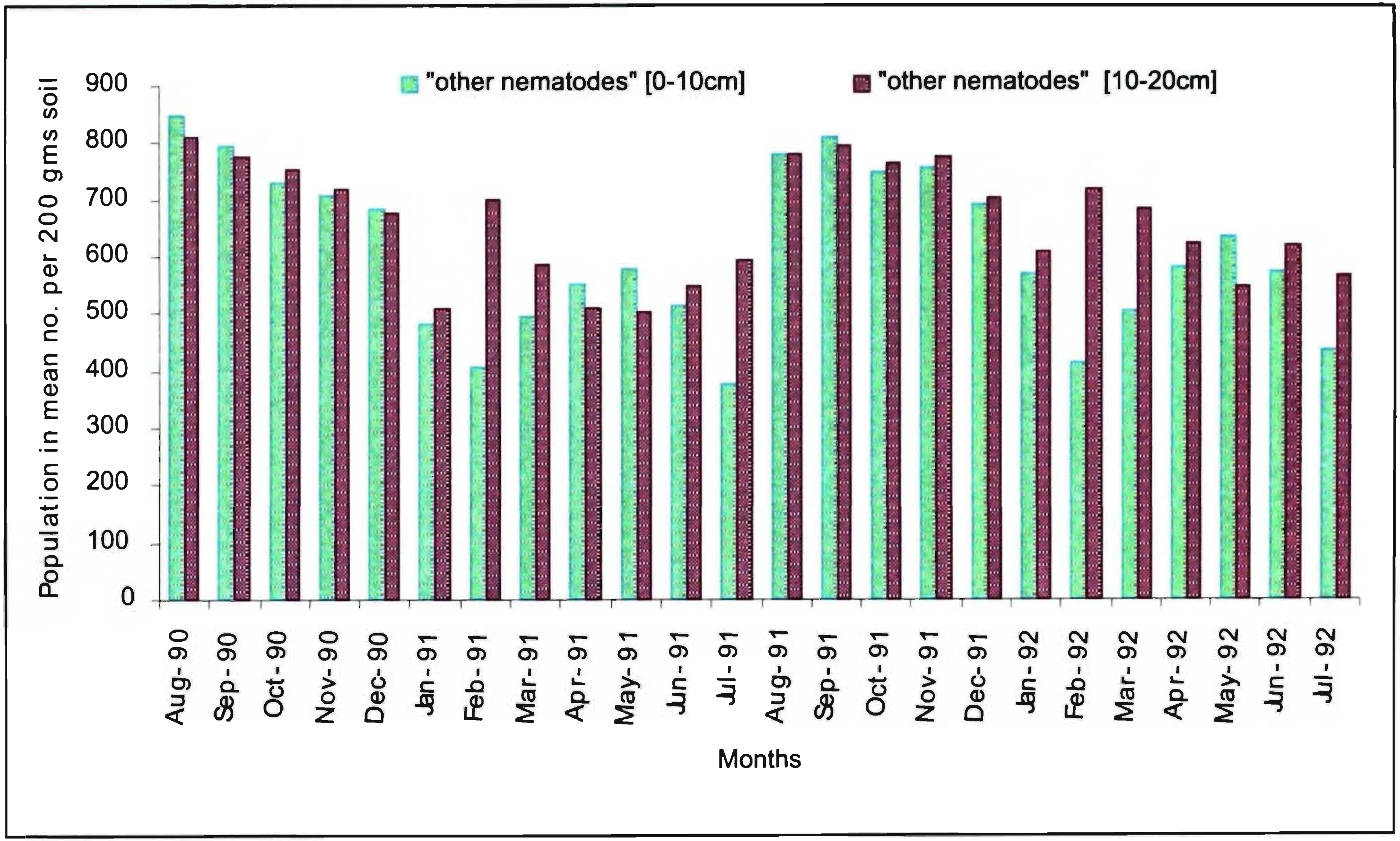


Fig. 32. Seasonal fluctuation of population of "other nematodes" and their vertical distribution in soil at plot "D" during 1990-1992 (0-10 cm & 10-20 cm depth)

Further, in February, 1992, the population of "other nematodes" in 0-10 cm depth was found to decline to 412.5 per 200 gms soil sample while in 10-20 cm depth, the same population increased to 717.5 per 200 gms soil when the plot was transplanted with Ratna paddy. In August, 1991, the high build up of population, 777.5 per 200 gms soil samples, was observed in both the depths when the plot was cultivated with Masuiry variety of paddy. In July, 1992, the lowest level as 435 per 200 gms soil sample, was observed in 0 -10 cm depth while in 10-20 cm depth, it increased to 567.5, during the fallow period of the plot at 30°C soil temperature and 24% soil moisture.

3.2.7. Adult (Male and female) population of *Hirschmanniella gracilis* in roots

During the present course of investigation, the population of adult *Hirschmanniella gracilis* in roots was observed. The highest number 162 from 5 gm of chopped root, was observed in the month of September, 1990 when the Masuiry variety of paddy was 50 days old (Table 1, Figure 33). From October, 1990, the root population of *H. gracilis* began to decrease and the lowest level of adult population was observed 56 from 5 gms chopped roots in the month of November, 1990, the pre-harvesting period of the paddy crop (Table 1, Figure 33). After two months fallowing the plot was again transplanted with Ratna variety of paddy. Another high build-up of the root population, 97.5 of adult *H. gracilis* in the month of April, 1991 during the flowering period of the Ratna variety of paddy. During May, 1991 *H. gracilis* was found at its lowest level and recorded as 40 from 5 gms of chopped roots.

Next year the plot was again transplanted with Masuiry variety of paddy. Further increase in root population of adult *H. gracilis* was found and recorded as 140 in the month of September, 1991 when the root system of Masuiry paddy was well-developed. During preharvesting time, in November, 1991, the adult *H. gracilis* was found declined to 70 from 5 gms chopped roots. Finally the plot was cultivated with Ratna variety of paddy in the month of February, 1992. High build-up in root population of adult *H. gracilis* was observed as 120 from 5 gms roots in the month of March, 1992. During May, 1992, the preharvesting time, the lowest level of adult *H. gracilis* was observed as 77.5 (Table 1, Figure 33) from 5 gms chopped roots.

3.2.8. Larval Population of *Hirschmanniella gracilis* in roots

The root population of larval *H. gracilis* associated with Masuiry variety of paddy was found to have poor concentration in the month of August, 1990 and was recorded as 15 from 5 gms of chopped roots. At that time the root system of Masuiry paddy was not well-developed while in September, 1990, the root system of paddy crop was mature and well developed, the maximum larvae of *H. gracilis* estimated as 72.5 per 5 gms chopped roots. Minimum level of root population of larval *H. gracilis* was recorded as 11.5 per 5 gms roots in the month of November, 1990, the preharvesting period of paddy crop. During February to May, the plot was cultivated with Ratna variety of paddy, the highest larval population was observed as 20 per 5 gms root in the month of April, 1991. While the lowest root population was recorded as 6 per 5 gms roots in the month of May, 1991 (Table 1, Figure 37).

Next year, when the plot was again cultivated with Masuiry variety of paddy, the same trend of larval population of *H. gracilis* was observed. The highest root population was observed as 67.5 per 5 gms chopped root in the month of September, 1991. Gradual decline in root population was observed from October, 1991 and the minimum number of root population was estimated as 22.5 per 5 gms chopped roots in the month of November, 1991. During February, 1992, the plot was again transplanted with Ratna variety of paddy. At that period, the larval population of *H. gracilis* was found at its highest peak which was recorded as 15 from 5 gms roots in the month of April, 1992 while in pre-harvesting period of Ratna paddy, the population was found to decline to 9 per 5 gms root sample in the month of May, 1992 (Table 1, Figure 37).

3.2.9. Total population (male, female and larvae) of *Hirschmanniella gracilis* in roots

During two years of observations from August 1990 – July 1992, the total population of *H. gracilis* was found at its highest peak in the root in the month of September, 1990 and 1991 which was recorded as 235 and 207.5 per 5 gms chopped roots when the Masuiry variety of paddy was six weeks old with their well developed roots system (Table 1, Figure 36). In the same cropping sequence and period the lowest level of total *H. gracilis* population 67.5 and 92.5 per 5 gms chopped roots of Masuiry paddy respectively was found in the month of November, 1990 and 1991, the pre-harvesting time of the crop. Further, the plot "D" was cultivated with Ratna variety of paddy in the month of February, 1991 and 1992. Two months fallow period was maintained before transplantation of the plot, with occasional ploughing in the hot summer days. In this cropping sequence of Ratna paddy, the highest population of total *Hirschmanniella gracilis* 117.5 and 132.5 per 5 gms roots was observed in the month of April, 1991 and March, 1992 respectively. While the lowest level of population was observed as 46 and 66.5 in the months of May, 1991 and 1992 respectively (Table 1, Figure 36). During two years of observations, it was noted that the total population of *Hirschmanniella gracilis* was always more in the roots of Masuiry variety of paddy than the roots of Ratna variety of paddy.

3.2.10. Population of "other nematodes" in roots

During the present course of investigation from August, 1990 to July, 1992, the root population of "other nematodes" were also observed. In September, 1990 when the Masuiry variety of paddy was about six weeks old, the maximum number of population was observed as 142.5 per 5 gms root sample (Table 1, Figure 33). After that the population of "other nematodes" began to decline and the lowest level was recorded as 36.5 in the month of November, 1990, the pre-harvesting time of the crop. Again the plot "D" was transplanted with Masuiry variety of paddy in the month of August, 1991. The high build-up population of "other nematodes" was observed as 100 per 5 gms chopped roots in the month of September, 1991 and lowest level of population was observed 52.5 in the month of November, 1991. Further, the plot D was transplanted with Ratna variety of paddy in the month of February, 1991 and the high-build up population of 90 per 5 gms. root was observed in the month of April, 1991 and lowest level of 55, in the month of May, 1991. Again in March, 1992 when the Ratna variety of paddy of 40 days old, "other nematodes" population was recorded at its highest peak, 87.5, while lowest level of

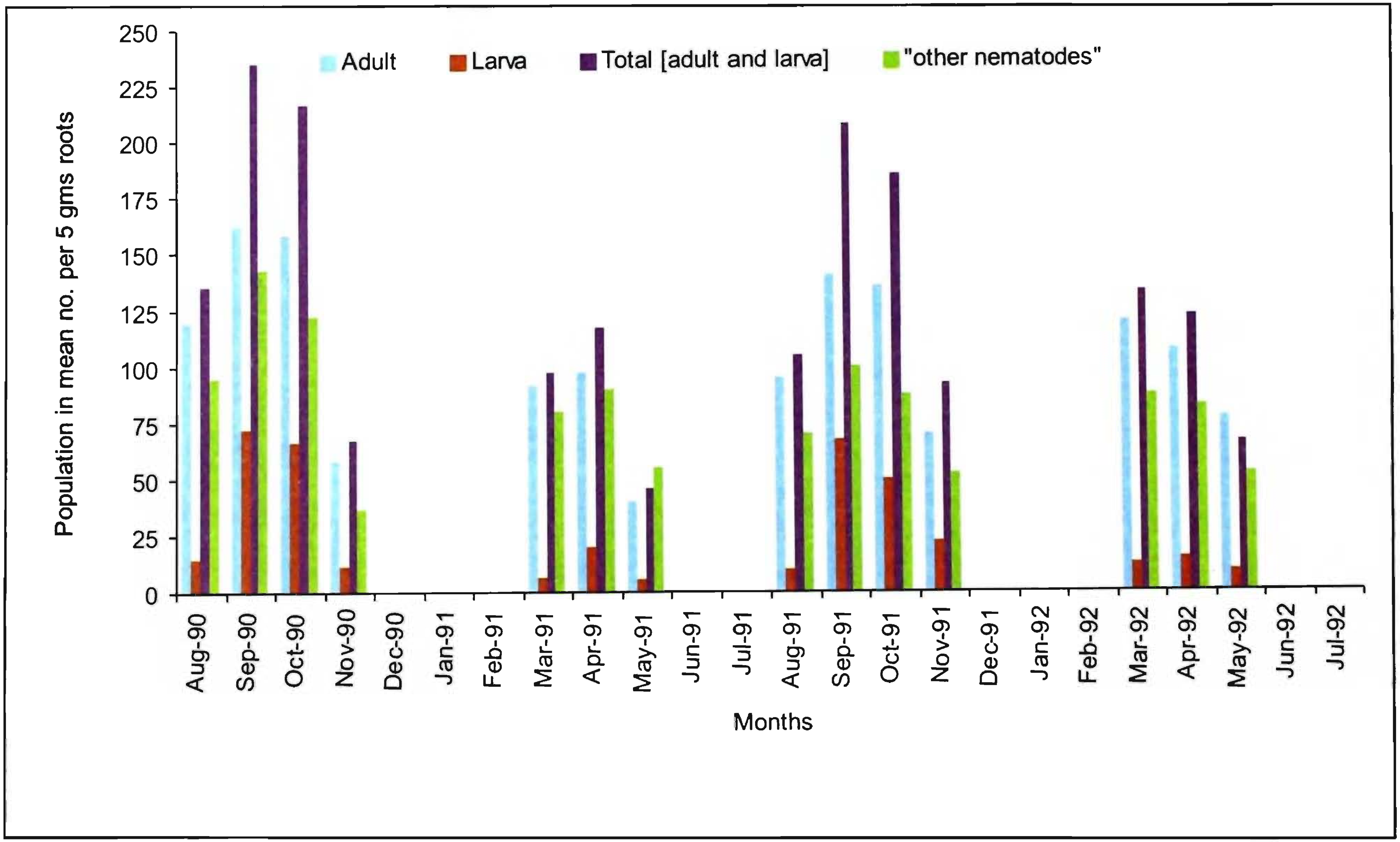


Fig. 33. Seasonal fluctuation of population of *H. gracilis* and "other nematodes" in roots [5 grams] at plot "D" during 1990 - 1992

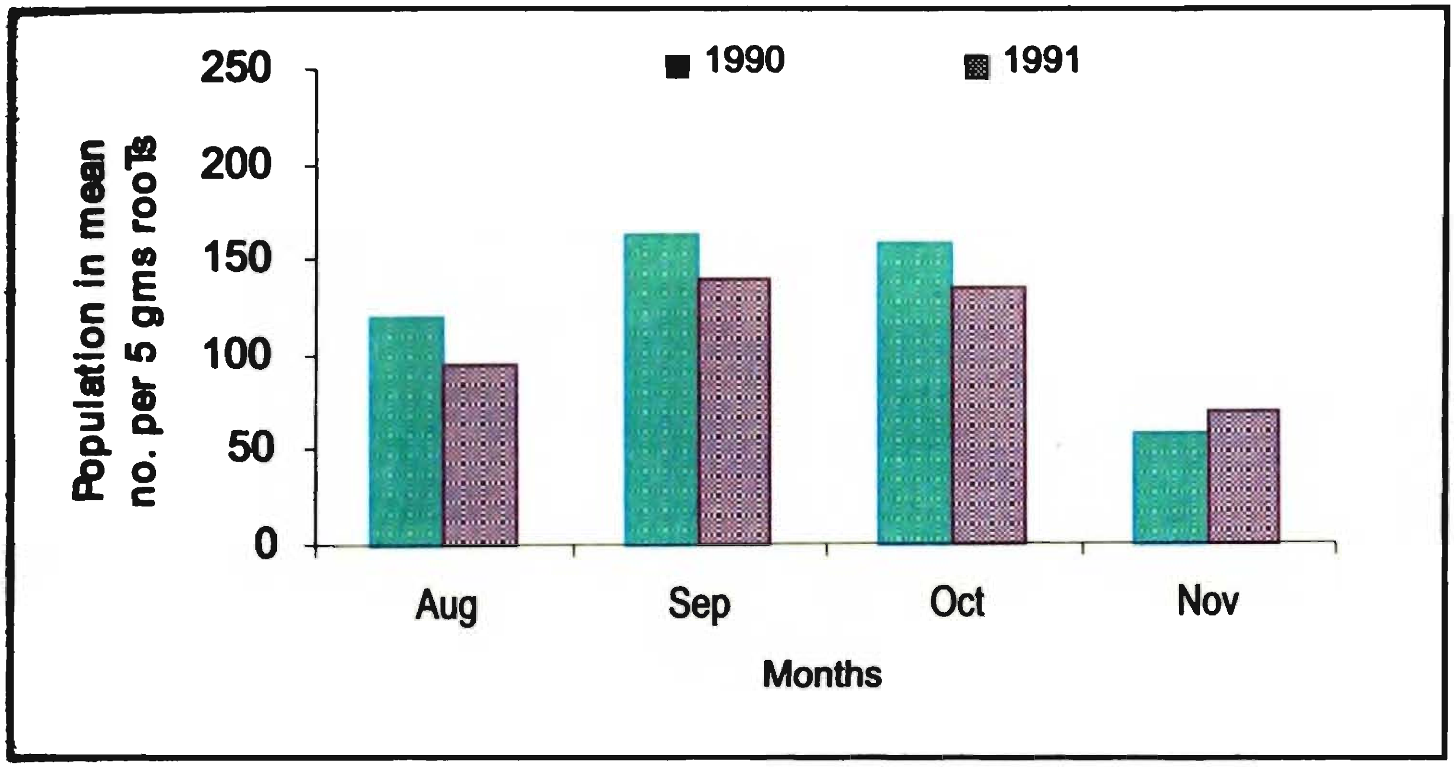


Fig. 34. **Seasonal fluction of adult (male and female) population of *Hirschmanniella gracilis* in roots [5 grams] of Masuiry Paddy at plot - "D" during 1990-1992.**

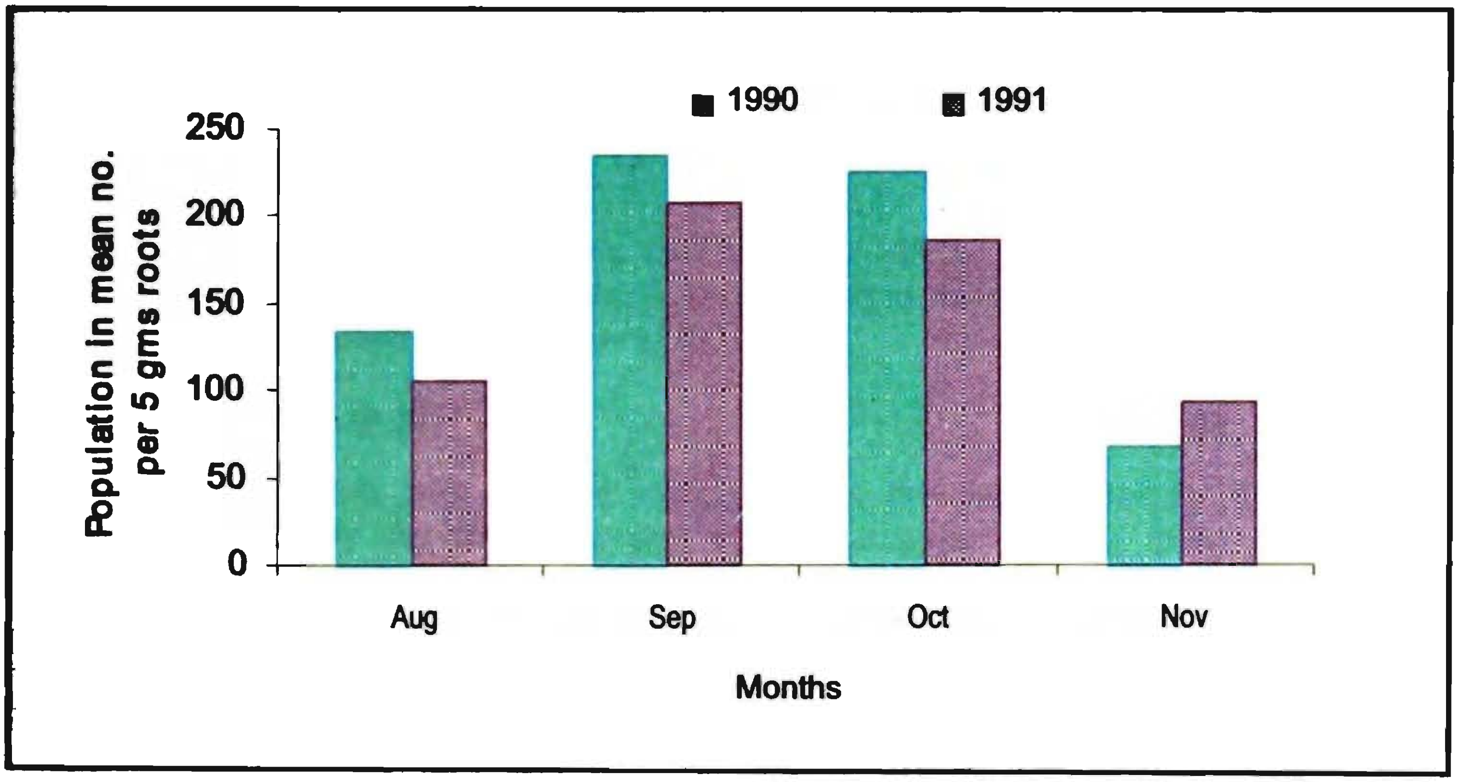


Fig. 35. **Seasonal fluction of total (male, female and larvae) population of *Hirschmanniella gracilis* in roots [5 grams] of Masuiry Paddy at plot - "D" during 1990-1992.**

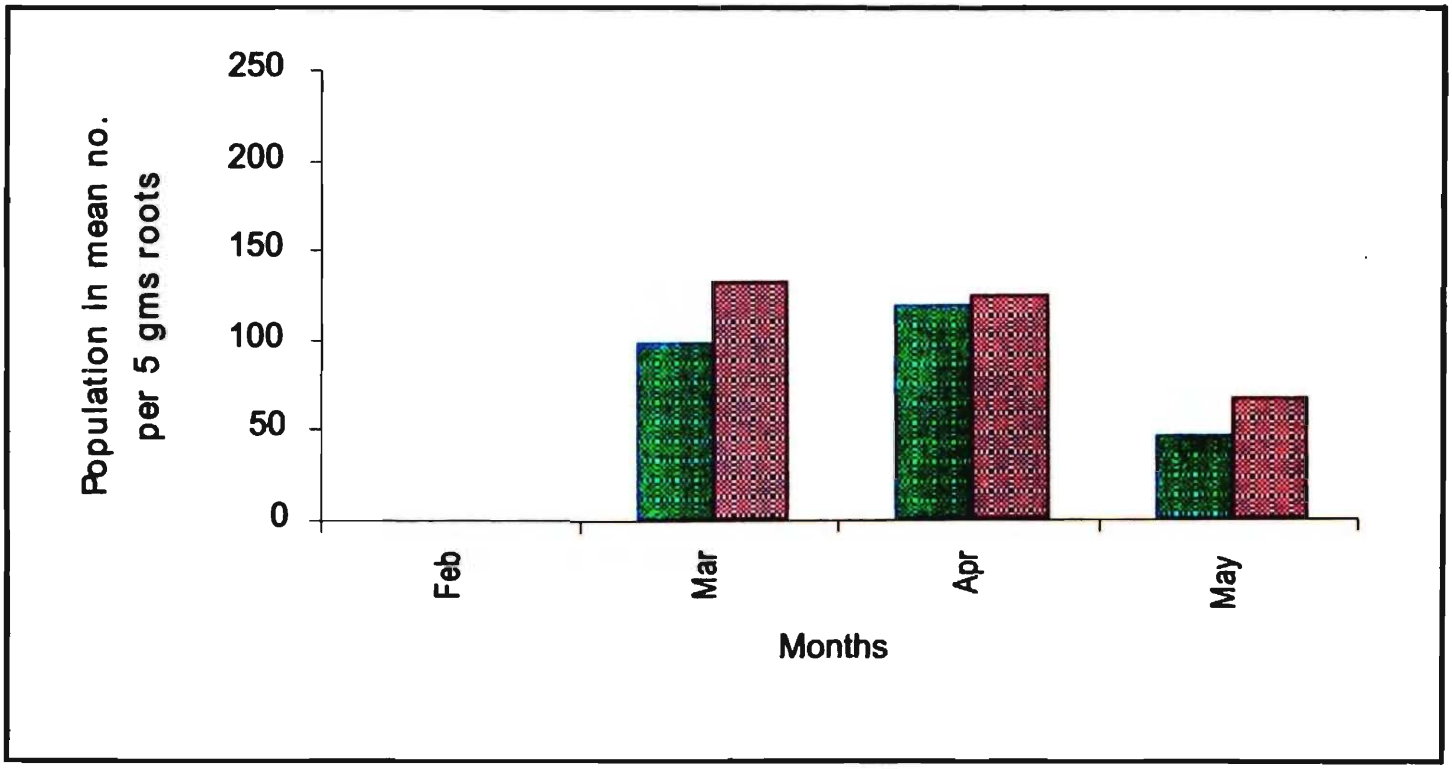


Fig. 36. Seasonal fluction of total (male, female and larvae) population of *Hirschmanniella gracilis* in roots [5 grams] of Ratna Paddy at plot - "D" during 1990-1992.

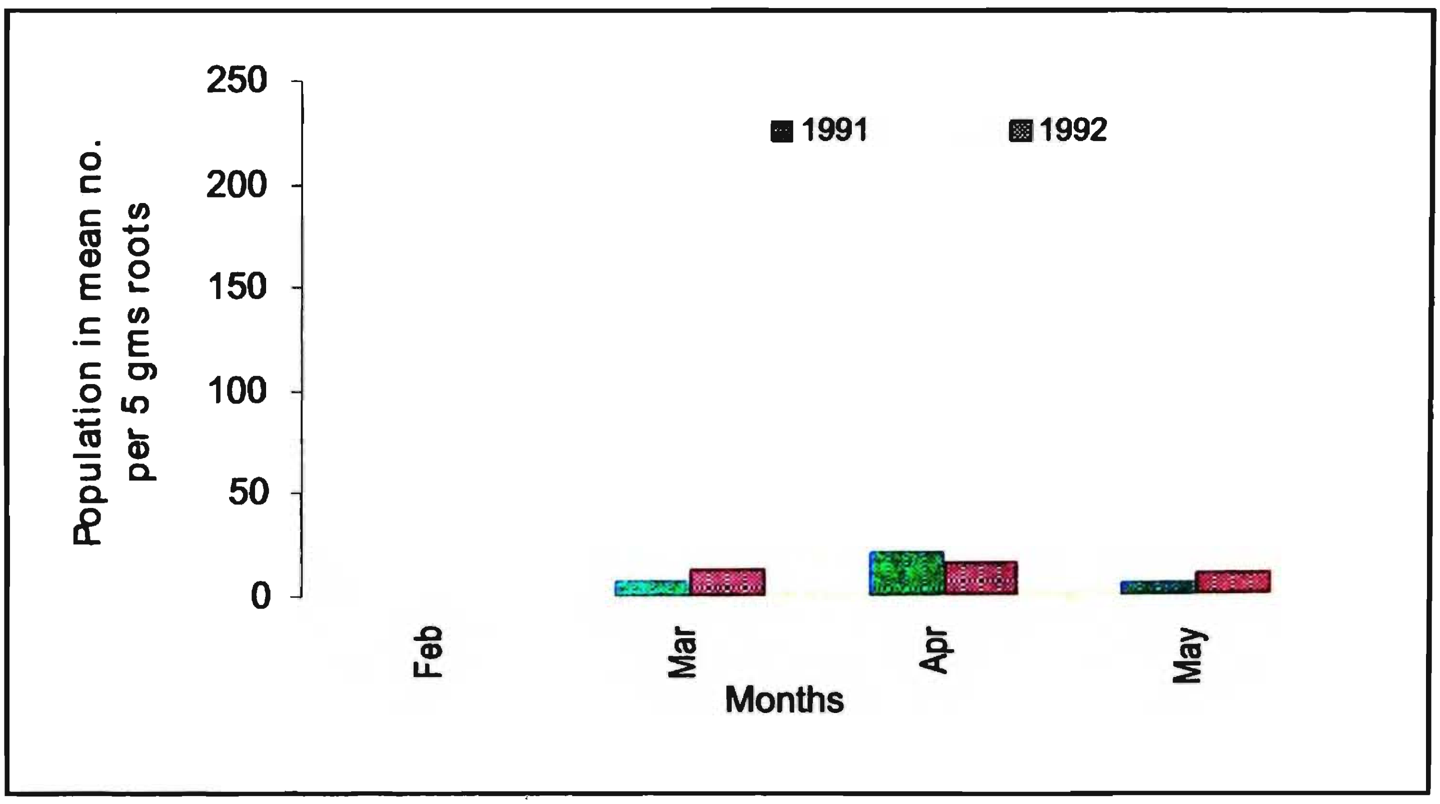


Fig. 37. Seasonal fluction of larval population of *Hirschmanniella gracilis* in roots [5 grams] of Ratna Paddy at plot "D" during 1990-1992.

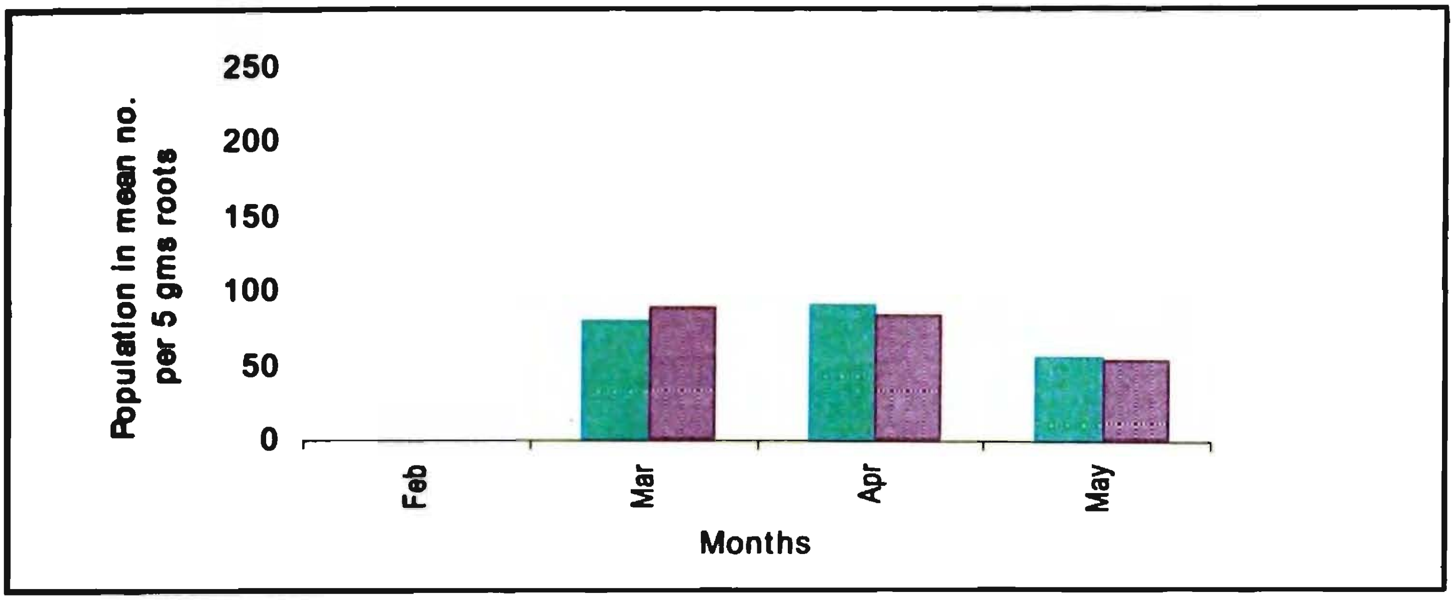


Fig. 38. Seasonal fluction of population of "other nematodes" in roots [5 grams] of Ratna Paddy at plot - "D" during 1990-1992.

population, 52.5 from 5 gms roots, was observed in the month of May, 1992, just prior to harvesting the crop (Table 1, Figure 38). It was observed that the root invasion by the "other nematodes" belonging to different groups such as Tylenchids, Dorylaimid and other saprophagus were considered less significant because of their non-parasitic nature or less in number.

3.3.0. SEASONAL CROP ROTATION ON THE POPULATION OF *Hirschmanniella gracilis* AND "OTHER NEMATODES" IN SOIL AT PLOTS "A", "B" AND "C" DURING 1990-1992

The Crop rotation with non-hosts, fallowing and drying up is the usual practice to reduce the nematode population in the field followed in different parts of the globe. In the present study following results are observed.

3.3.1 Population in plot "A"

Before starting the crop rotation experiment in the paddy field at plot "A" was naturally infected by the nematode pest *Hirschmanniella gracilis* heavily. The field showed gradual yellowing and stunted growth of Pankoj paddy in May, 1990 (Figure 19, 20). After one year crop rotation with Pankoj paddy → fallow for 2 months → Jalmasta jute → fallow for 2 months → Pankoj paddy, improvement of paddy field was observed in November, 1991 (Figure 21, 22). After two years crop rotation with same cropping sequence, further improved and the paddy yield was higher during December, 1992 (Figure 23, 24).

Plot "A" was selected at Rautara village, District 24-Parganas, West Bengal, India to study the effect of seasonal crop rotation on *Hirschmanniella gracilis* and "other nematodes" population.

Table 2. Effect of crop rotation on the population of *Hirschmanniella gracilis* and "other nematodes" at plot "A" during 1990-1992

1990-1992	Soil population		Root population		Physical factor		
Months	***H. gracilis***	**Other Nematodes**	***H. gracilis***	**other Nematodes**	**Soil Temperature**	**% of soil moisture**	**Crops**
Aug. 1990	405	570	210	80	29 °C	37%	Pankoj Paddy
Sep. 1990	350	555	185	65	30 °C	34%	Pankoj Paddy
Oct. 1990	300	500	175	50	28 °C	34%	Pankoj Paddy
Nov. 1990	235	500	110	30	24 °C	26%	Pankoj Paddy
Dec. 1990	210	485	60	15	23 °C	25%	Pankoj Paddy
Jan. 1991	145	360	Nil	Nil	20 °C	21%	Fallow
Feb. 1991	100	350	Nil	Nil	19 °C	20%	Fallow
Mar. 1991	90	340	Nil	Nil	22 °C	28%	Jalmasta Jute
April 1991	85	325	Nil	Nil	27 °C	16%	Jalmasta Jute
May 1991	55	325	Nil	Nil	30 °C	14%	Jalmasta Jute
June 1991	45	300	Nil	Nil	30 °C	12%	Jalmasta Jute
July 1991	95	330	Nil	Nil	29 °C	30%	Jalmasta Jute
Aug. 1991	295	415	120	40	29 °C	36%	Pankoj Paddy
Sep. 1991	270	490	125	30	31 °C	33%	Pankoj Paddy
Oct. 1991	240	470	100	25	29 °C	32%	Pankoj Paddy
Nov. 1991	220	455	55	20	26 °C	27%	Pankoj Paddy
Dec. 1991	185	430	20	5	24 °C	23%	Pankoj Paddy
Jan. 1992	130	400	Nil	Nil	19 °C	18%	Fallow
Feb. 1992	110	365	Nil	Nil	19 °C	16%	Fallow
Mar. 1992	75	310	Nil	Nil	21 °C	26%	Jalmasta Jute
April 1992	60	250	Nil	Nil	26 °C	19%	Jalmasta Jute
May-1992	35	205	Nil	Nil	29 °C	15%	Jalmasta Jute
June 1992	35	200	Nil	Nil	29 °C	13%	Jalmasta Jute
July 1992	25	185	Nil	Nil	30 °C	12%	Jalmasta Jute

Fig. 19 : Photograph of the paddy field "A" *Hirschmanniella gracilis* infection with yellowing and stunted growth of Pankoj paddy plant before starting crop rotation in May, 1990

Fig. 20 : Photograph of the paddy field "A" *Hirschmanniella gracilis* infection with yellowing and patchy growth of Pankoj paddy plant before starting crop rotation in May, 1990

Fig. 21 : Photograph of the paddy field "A" one year after starting crop rotation "Pankoj paddy – fallow for 2 months – Jalmasta jute – fallow for 2 months – Pankoj paddy" with improvement during November, 1991

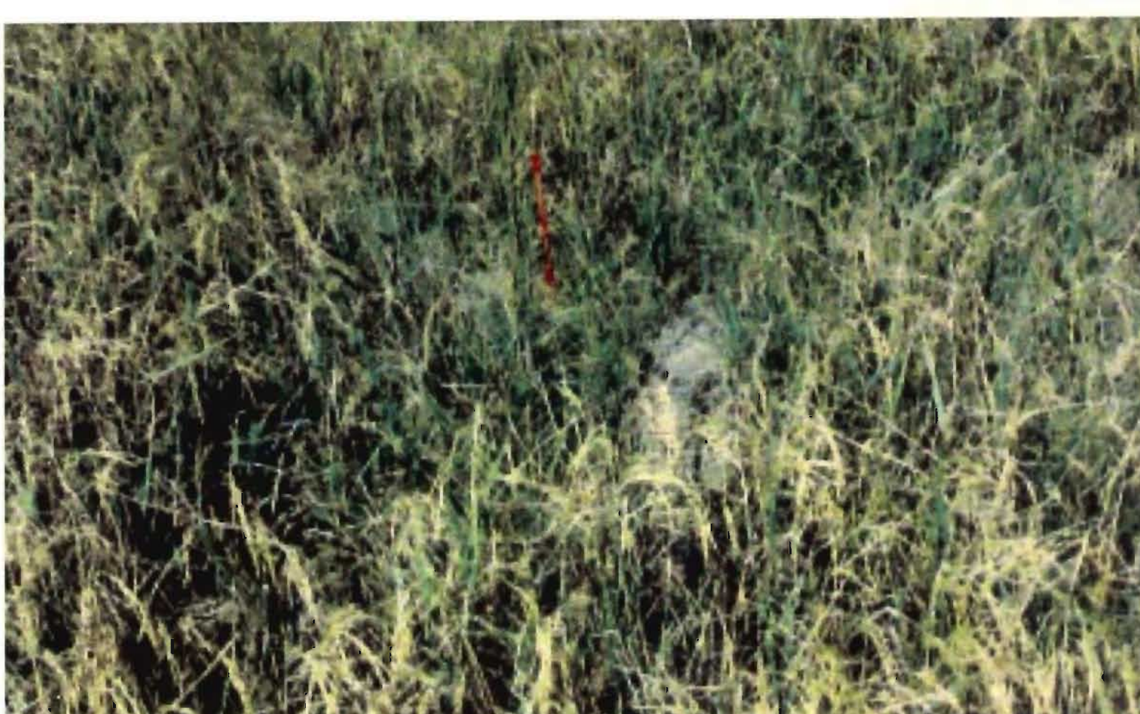


Fig. 22 : Photograph of the paddy field "A" one year after starting crop rotation "Pankoj paddy – fallow for 2 months – Jalmasta jute – fallow for 2 months – Pankoj paddy" in another site during November, 1991

Fig. 23 : Photograph of the paddy field "A" two years after starting crop rotation as in Figure 22, with further improvement of paddy yield during December, 1992

Fig. 24 : Photograph of the paddy field "A" as in Figure 23, in another site during December, 1992

Pankoj variety of paddy and Jalmasta variety of jute were rotated with two months fallow in between. After the transplantation of paddy seedlings, the population of *H. gracilis* was found to be maximum which was recorded 405 per 200 gms soil and 210 per 5gms of chopped roots in the month of August, 1990, at 29^{0}C soil temperature and 37% moisture. Both soil and root populations of *H. gracilis* began to decline gradually and the lowest level of population was observed 210 per 200 gms soil and 60 per 5 gms of chopped roots in the month of December, 1990 at the time of harvesting when the soil temperature and moisture were 23 ^{0}C and 25% respectively (Table 2, Figure 39, 44).

In the year 1991, similar trend was observed from August to December, 1991 with gradual decline of the population from the maximum 295 in August to a minimum 185 in December per 200 gms soil while the roots population was observed declining from a maximum of 125 per 5 gms roots in September to a minimum 20 per 5 gms chopped root in the month of December, (Table 2, Figure 39, 44). During these months, August and December, 1991, the soil temperature and percentage of soil moisture at plot "A" were recorded as 29^{0}C, 36% while in September was recorded as 31^{0}C, 33% respectively.

Hirschmanniella gracilis exhibited a moderate population of 145 and 100 per 200 gms soil in January and February, 1991 respectively during the fallow period of the plot. In another fallow period, during the month of January and February, 1992, the population of *H. gracilis* was recorded as 130 and 110 per 200 gms soil respectively. Soil temperature and soil moisture were recorded 20^{0}C and 21% in January, 1991 and 19^{0}C and 20% respectively in February, 1991, while in January and February, 1992 the soil temperature and moisture were recorded as 19^{0}C, 18% and 19^{0}C, 16% respectively (Table 2, Figure 39).

During the cultivation of Jalmasta variety of jute from March, 1991 to July, 1991, gradual decline of population of *H. gracilis* was evident. During the period, the lowest level of *H. gracilis* population was observed as 45 per 200 gms soil in the month of June, 1991, at the soil temperature and moisture of 30^{0}C and 12% respectively. Next year from March to July, 1992, the same trend of decline of population was found and lowest level of population was recorded as 25 per 200 gms soil sample in the month of July, 1992 at 30^{0}C soil temperature and12% soil moisture. No nematodes, either *H. gracilis* or "other nematodes", were present in the roots when the plot "A", was cultivated with Jalmasta variety of jute (Table 2, Figure 39).

"Other nematodes" in soil samples was in more concentration during cultivation of paddy crop. The highest number of "other nematodes" population was observed as 570 per 200 gms soil in the month of August, 1990 when the plot "A" was cultivated with Pankoj variety of paddy. On the day of sampling, the soil temperature was 29^{0}C and soil moisture

37%. The population of "other nematodes" gradually declined from September up to December, 1990. The lowest level of population was observed as 485 per 200 gms soil during the preharvesting period of paddy crop in the month of December, where the soil temperature was 23 °C and 25% soil moisture. A similar trend of increasing and declining soil population of "other nematodes" was also observed in the next year (1991) when the plot was under Pankoj variety of paddy cultivation with a maximum number being recorded as 490 per 200 gms soil sample in the month of September, 1991 which gradually decreased to a minimum of 430 per 200 gms soil sample in the month of December, 1991 at 31°C and 24°C soil temperature and 33% and 23% soil moisture respectively (Table 2, Figure 39).

The root population of "other nematodes associated with Pankoj paddy was found to have a poor concentration but a similar trend of gradual decrease from transplanting to harvesting was noticed with a maximum of 80 per 5 gms chopped root sample to a minimum of 15 per 5 gms of root sample during the months of August and December, 1990 respectively. Similar trend of decline in the next year with a maximum of 40 per 5 gms chopped root sample in August, 1991 to a minimum of 5 per 5 gms root sample in December, 1991 was recorded (Table 2, Figure 44).

During the cultivation of Jalmasta variety of jute, the population of "other nematodes" gradually came down from a maximum of 340 per 200 gms of soil sample in the month of March, 1991 to the minimum of 300 per 200 gms soil sample during the month of June, 1991 at the soil temperature and soil moisture 22°C, and 30°C, 28% and 12% respectively. In the consecutive year, same trend was observed during the cultivation of Jalmasta jute with a maximum of 310 per 200 gms soil in March, 1992 to a minimum of 185 per 200 gms soil sample in July, 1992 when the soil temperature and moisture were of 21°C and 30°C, 26% and 12% respectively (Table 2, Figure 39).

During the fallow period, number of "other nematodes" was recorded as 360 and 350 per 200 gms soil sample in the month of January and February, 1991 and 400 and 365 per 200 gms soil in the month of January and February, 1992 respectively. The soil temperature and moisture was 20°C, 21% and 19°C, 20% in the month of January and February, 1991 and 19°C, 16% in the month of January and February, 1992 respectively (Table 2, Figure 39).

The root population either of *Hirschmanniella gracilis* or "other nematodes" were absent in Jalmasta variety of jute from 5 gms of chopped root sample.

3.3.2. Population in plot "B"

In Plot "B", paddy, wheat and Disimasta variety of jute were cultivated alternately with one month fallow in between. One month after the transplanting of Pankoj variety of paddy seedlings, the population of *H. gracilis* and "other nematodes" were found to be maximum, which were recorded as 340 and 450 per 200 gms of soil sample respectively in the month of September, 1990 while the population were found to be maximum, 55 and 35 per 5 gms of chopped root sample at the soil temperature and moisture 32°C and 30% respectively. Both *H. gracilis* and "other nematodes" populations gradually decreased and came to its minimum 285 and 360 per 200 gms soil respectively in the month of November, 1990 during the pre harvesting time of Pankoj paddy at 26°C soil temperature and 20% soil moisture. Lowest level of root population of *H. gracilis* and "other nematodes" were recorded as 35 and 20 per 5 gms chopped root respectively in the month of November, 1990 when the roots became older (Table 3, Figure 40, 45).

Next year, under Ratna variety of paddy cultivations, a similar trend was obtained from September to November, 1991, with gradual decline of the population of *H. gracilis* and "other nematodes" from maximum 170 and 400 to minimum 155 and 350 per 200 gms soil sample in the month of September and November respectively. During this period, in both the populations, gradual decline of root population was recorded as maximum 50 and 30 in the month of September, 1991 to a minimum 30 and 15 in the month of November, 1991 per 5 gms root sample respectively (Table 3, Figure 40, 45).

During January to March, 1991 when the plot was cultivated with wheat, the population of *H. gracilis* and "other nematodes" were found to be maximum 225 and 300 per 200 gms soil respectively in the month of January, 1991 when the soil temperature and moisture were 18°C and 28% respectively. The number in root population were observed to be maximum 15 and 20 per 5 gms of roots respectively in the month of February, 1991 when the root system of wheat was well developed. The population of *H. gracilis* and "other nematodes" gradually declined to a minimum of 120 and 225 per 200 gms from soil and 5 and 15 per 5 gms from roots respectively in the month of March, 1991 at the time of harvesting when the soil temperature and moisture were 23°C and 19% respectively (Table 3, Figure 40, 45).

In the year 1992 under wheat cultivations, a similar trend was obtained from January to March, 1992. The gradual decline of the two populations, *H. gracilis* and "other nematodes" was observed from maximum 110 and 285 to a minimum 80 and 255 per 200 gms soil in the months of January and March, respectively. The maximum root population of *H. gracilis* and the "other nematodes" was 16 and 28 in the month of February and minimum 10 and 15 in March respectively. During this period, January to March, 1992, the soil temperature and moisture were recorded as 20°C, 20°C, 21°C and 21%, 19%, 18% respectively (Table 3, Figure 40, 45).

After nine months, paddy followed by wheat, the plot "B" was cultivated with Disimasta variety of jute when the soil temperature was 30°C and moisture 14% in the month of May, 1991 a trend of rapid decline in both the population of *H. gracilis* and "other nematodes" from 90 and 200 in the month of May, 1991 to 35 and 185 in the month of June, 1991, respectively, was observed. During the month of July, 1991, the population of *H. gracilis* and "other nematodes" suddenly increase and recorded as 70 and 250 respectively from soil. In the month of June and July, 1991, the "other nematodes" were found as 35 and 45 respectively per 5 gms root, while no *H. gracilis* population was recorded in the root sample of Disimasta variety of jute. During this period the temperature and soil moisture varies from 30°C–34°C and 14%–27% respectively (Table 3, Figure 40, 45).

The plot "B" again was cultivated next year, 1992 with Disimasta variety of jute. The same declining trend was observed with a maximum population of *H. gracilis* and "other nematodes", 70 and 240 in the month of May and July, 1992 respectively, while maximum root population of "other nematodes" was observed as 40 per 5 gms chopped root sample of Disimasta jute in the month of July, 1992. No *H. gracilis* was found in the root sample of Disimasta jute (Table 3, Figure 40, 45) at that time.

During the fallow period, *H. gracilis* and "other nematodes" population exhibited a moderate number 265 and 335 respectively in the month of December, 1990. However, in the fallow period of April, 1991, these population declined to 110 and 215 respectively per 200 gms soil. Again the number in population was observed as 175 and 435 in the month of August, 1991 per 200 gms soil, while in the fallow period of December, 1991 and April, 1992, the population of *H. gracilis* and "other nematodes" were observed to decrease to 130, 300 and 70, 235 respectively per 200 gms soil sample (Table 3, Figure 40, 45).

3.3.3 Population in plot "C"

Pankoj variety of paddy and Jalmasta variety of jute were cultivated alternately with two months fallow period in Plot "C" After transplantation of the paddy seedlings, maximum population of *Hirschmanniella gracilis* was observed to be 385 per 200 gms soil and 195 per 5 gms of roots in the month of August, 1990. The population gradually went on decreasing and was recorded as 245 in soil and 75 in roots in the month of December, 1990 after the paddy was harvested. During these months, the range of soil temperature and soil moisture were 30°C–24°C and 36%–26% respectively (Table 4, Figure 41, 46).

In the year 1991, a similar declining trend of soil population as well as root population was observed from August to December, 1991. In August, 1991, the maximum population of *H. gracilis* was observed and recorded as 195 and 105 per 200 gms soil sample and 5 gms root sample respectively whereas the minimum level of population was observed as 105 in soil and 15 in roots during the month of December, 1991 (Table 4, Figure 41, 46). It was also observed that after one year, the plot "C" being crop-rotated with paddy and Jalmasta jute, the population of *H. gracilis* declined rapidly and lowered down to half of the initial population of the plot.

Table 3. Effect of crop rotation on the population of *Hirschmanniella gracilis* and "other nematodes" at plot "B" during 1990-1992.

1990-1992	Soil population		Root population		Physical factor		
Months	*H. gracilis*	other Nema-todes	*H. gracilis*	Other Nema-todes	Soil Tempe rature	% of soil moisture	Crops
Aug. 1990	325	400	35	20	30 °C	32%	Pankoj Paddy
Sep. 1990	340	450	55	35	32 °C	30%	Pankoj Paddy
Oct. 1990	310	390	40	25	29 °C	29%	Pankoj Paddy
Nov. 1990	285	360	35	20	26 °C	20%	Pankoj Paddy
Dec. 1990	265	335	Nil	Nil	21 °C	18%	Fallow
Jan. 1991	225	300	10	15	18 °C	28%	Wheat
Feb. 1991	185	250	15	20	18 °C	25%	Wheat
Mar. 1991	120	225	5	15	23 °C	19%	Wheat
Apr. 1991	110	215	Nil	Nil	26 °C	27%	Fallow
May 1991	90	200	Nil	Nil	30 °C	14%	Disimasta Jute
June 1991	35	185	Nil	35	34 °C	17%	Disimasta Jute
July 1991	70	250	Nil	45	30 °C	27%	Disimasta Jute
Aug. 1991	175	435	Nil	Nil	30 °C	30%	Fallow
Sep. 1991	170	400	50	30	30 °C	32%	Ratna Paddy
Oct. 1991	165	380	45	25	28 °C	26%	Ratna Paddy
Nov. 1991	155	350	30	15	25 °C	19%	Ratna Paddy
Dec. 1991	130	300	Nil	Nil	23 °C	27%	Fallow
Jan. 1992	110	285	13	25	20 °C	21%	Wheat
Feb. 1992	90	270	16	28	20 °C	19%	Wheat
Mar. 1992	80	255	10	15	21 °C	18%	Wheat
Apr. 1992	70	235	Nil	Nil	27 °C	28%	Fallow
May 1992	70	225	Nil	15	30 °C	20%	Disimasta Jute
June 1992	55	220	Nil	25	30 °C	14%	Disimasta Jute
July 1992	55	240	Nil	40	29 °C	24%	Disimasta Jute

During the fallow period, January and February, 1991, *H. gracilis* exhibited a moderate population of 200 and 120 per 200 gms soil sample respectively. During January and February, 1992 when, the plot was fallow, the population showed its minimum level 80 and 70 per 200 gms soil sample respectively.

The *H. gracilis* population went down to lowest level when the plot was cultivated with Jalmasta variety of jute. During this period, the maximum population was 105 in March, and minimum was 45 in the month of July, 1991 per 200 gms soil sample. Next year, in 1992, when the plot was again cultivated with Jalmasta variety of jute, a drastic decrease of *H. gracilis* population was observed with maximum number being 55 in the month of March and minimum 20 in the month of July per 200 gms soil. No nematodes either *H. gracilis* or "other nematodes" population was observed in 5 gms chopped roots of Jalmasta jute (Table 4, Figure 41, 46).

In soil samples, "other nematodes" population also exhibited more concentration during cultivation of paddy crop than jute crop. The other nematodes population observed to be a maximum 550 per 200 gms soil initially during the month of August, 1990. Their population in soil gradually declined to 400 in the month of December, 1990. In the next year under paddy cultivation, "other nematodes" population was 475 per 200 gms soil during August, 1991 while a similar declining trend in soil population was also recorded as 385 in the month of December, 1991 (Table 4, Figure 41, 46).

The root population of "other nematodes" associated with paddy crop was found low. In the month of August, 1990, their maximum population was observed as 70 per 5 gms root sample. Like root population of *H. gracilis*, a similar trend of gradual decrease from transplanting to harvesting was observed and minimum root population was recorded as 20 per 5 gms in the month of December, 1990. Next year, the same declining trend was found with a maximum of 35 in September, 1991 to a minimum of 10 per 5 gms root sample in the month of December, 1991 (Table 4, Figure 41, 46).

While the plot "C" was cultivated with Jalmasta variety of jute under soil temperature ranging from 20 °C – 33 °C and percentage of soil moisture ranging from 10% – 36%, gradual decrease of the soil population of "other nematodes", was found from a maximum level of 330 in the month of March, 1991 to a minimum 255 per 200 gms soil in the month of July, 1991. In March 1992, the plot was again cultivated with Jalmasta jute and maximum level of population was recorded as 325 while the minimum was observed as 225 in July, 1992 (Table 4, Figure 41).

In January and February, 1991, during the fallow period, the soil population of "other nematodes" were observed as 380 and 350 per 200 gms soil sample respectively while in another fallow period of the plot, in the month of January and February, 1992 respectively the number in population were observed as 370 and 340 per 200 gms soil sample (Table 4, Figure 41).

The root population of neither *H. gracilis* nor "other nematodes" were found when the plot was cultivated with Jalmasta variety of jute.

Table 4. Effect of crop rotation on the population of *Hirschmanniella gracilis* and "other nematodes" at plot "C" during 1990-1992.

1990-1992	Soil population		Root population		Physical factor		Crops
Months	*H. gracilis*	other Nema-todes	*H. gracilis*	other Nema-todes	Soil Tempe rature	% of soil moisture	
Aug. 1990	385	550	195	70	29°C	36%	Pankoj Paddy
Sep. 1990	325	500	170	55	30°C	30%	Pankoj Paddy
Oct. 1990	285	485	155	40	28°C	35%	Pankoj Paddy
Nov. 1990	265	465	120	25	24°C	27%	Pankoj Paddy
Dec. 1990	245	400	75	20	24°C	26%	Pankoj Paddy
Jan. 1991	200	380	Nil	Nil	20°C	19%	Fallow
Feb. 1991	120	350	Nil	Nil	20°C	18%	Fallow
Mar. 1991	105	330	Nil	Nil	23°C	26%	Jalmasta Jute
Apr. 1991	100	300	Nil	Nil	28°C	18%	Jalmasta Jute
May 1991	85	280	Nil	Nil	31°C	12%	Jalmasta Jute
June 1991	55	270	Nil	Nil	33°C	10%	Jalmasta Jute
July 1991	45	255	Nil	Nil	30°C	29%	Jalmasta Jute
Aug. 1991	195	475	105	Nil	30°C	35%	Pankoj Paddy
Sep. 1991	190	455	90	35	31°C	33%	Pankoj Paddy
Oct. 1991	165	425	75	30	29°C	30%	Pankoj Paddy
Nov. 1991	135	400	50	15	25°C	30%	Pankoj Paddy
Dec. 1991	105	385	15	10	23°C	25%	Pankoj Paddy
Jan. 1992	80	370	Nil	Nil	20°C	17%	Fallow
Feb. 1992	70	340	Nil	Nil	20°C	15%	Fallow
Mar. 1992	55	325	Nil	Nil	21°C	27%	Jalmasta Jute
Apr. 1992	50	300	Nil	Nil	26°C	21%	Jalmasta Jute
May 1992	35	280	Nil	Nil	29°C	17%	Jalmasta Jute
June 1992	25	245	Nil	Nil	29°C	14%	Jalmasta Jute
July 1992	20	225	Nil	Nil	30°C	26%	Jalmasta Jute

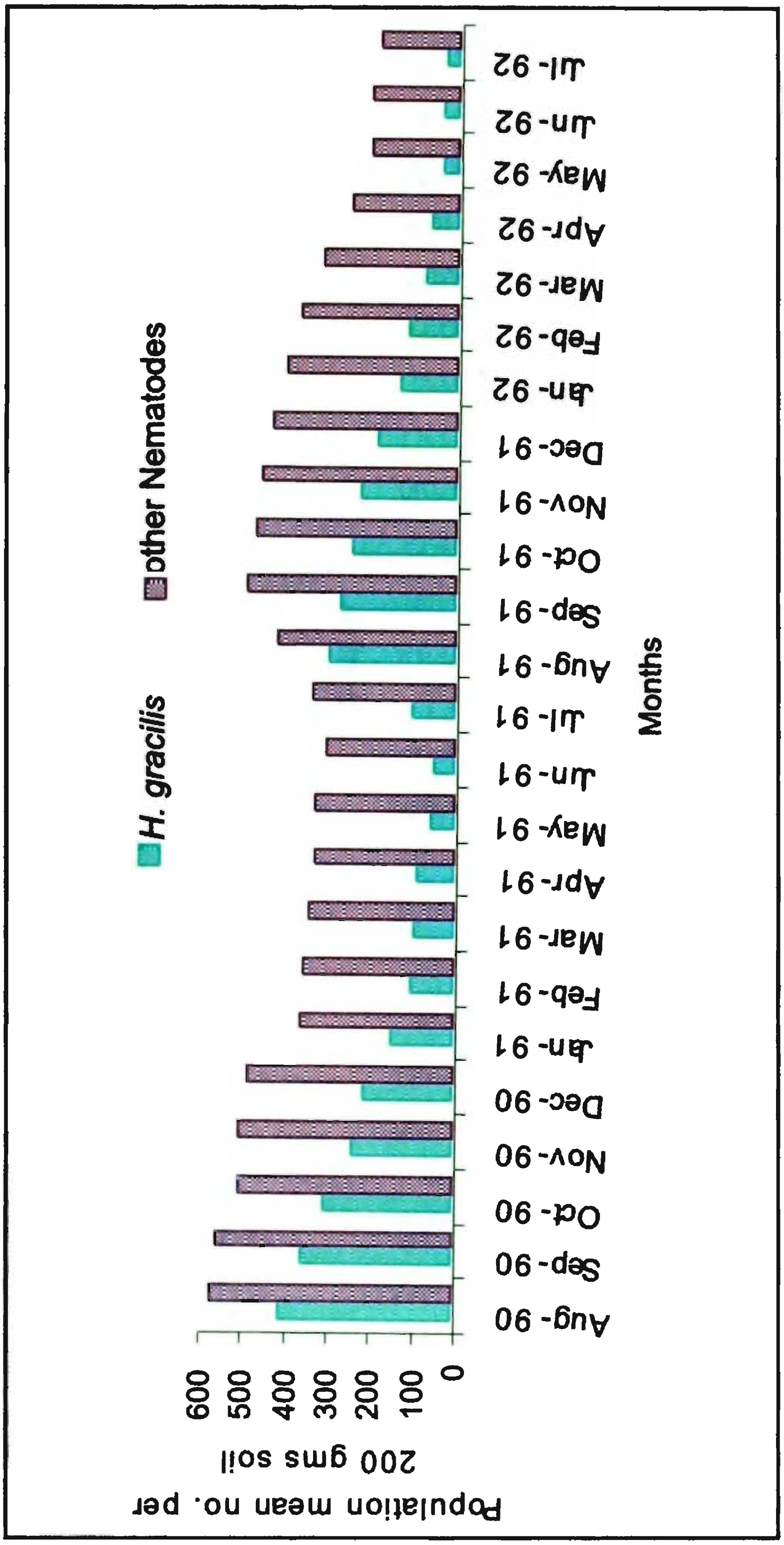


Fig. 39. Effect of seasonal crop-rotation on the population of *Hirschmanniella gracilis* and other nematodes in soil at plot - "A" during 1990-1992.

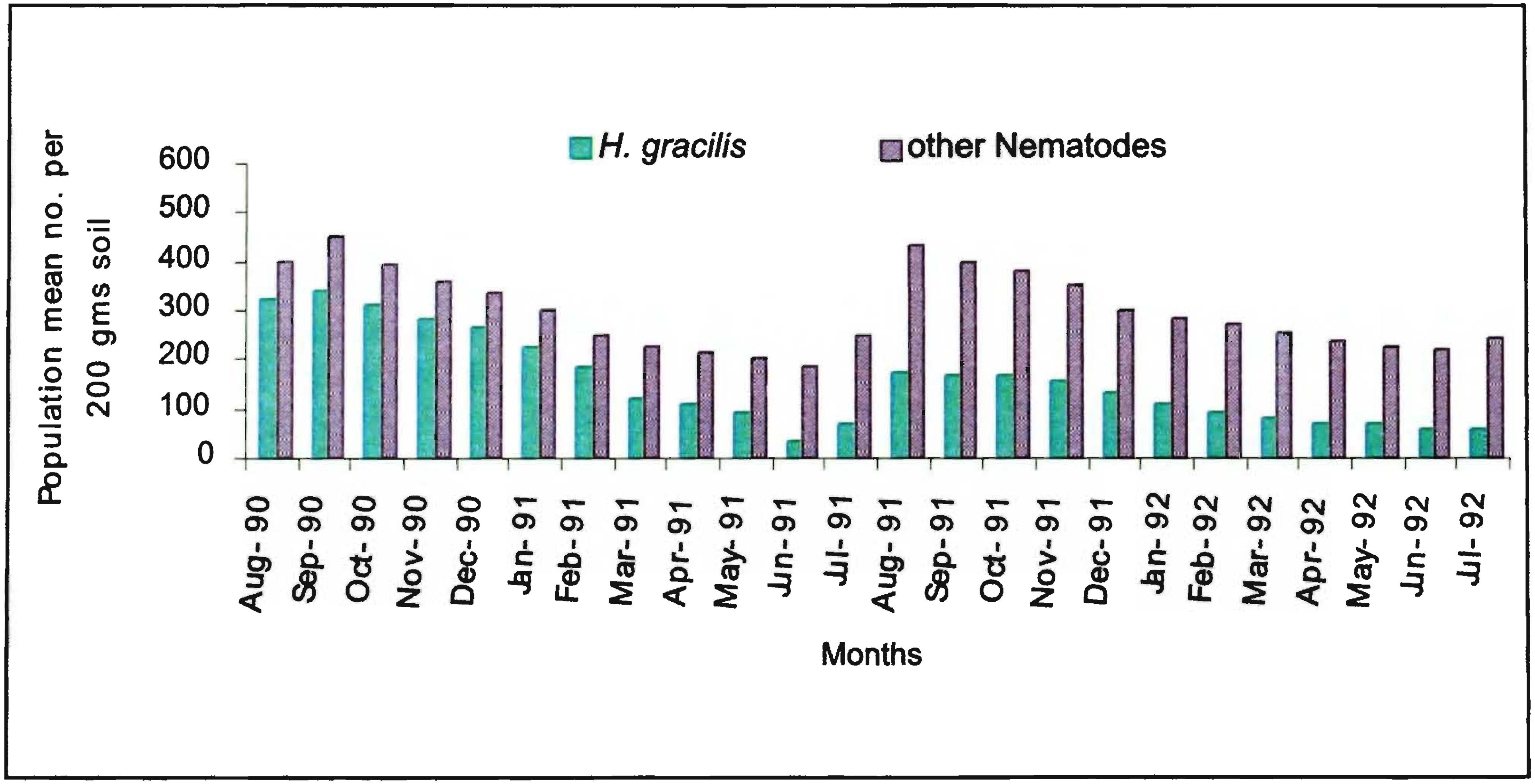


Fig. 40. Effect of seasonal crop-rotation on the population of *Hirschmanniella gracilis* and other nematodes in soil at plot - "B" during 1990-1992.

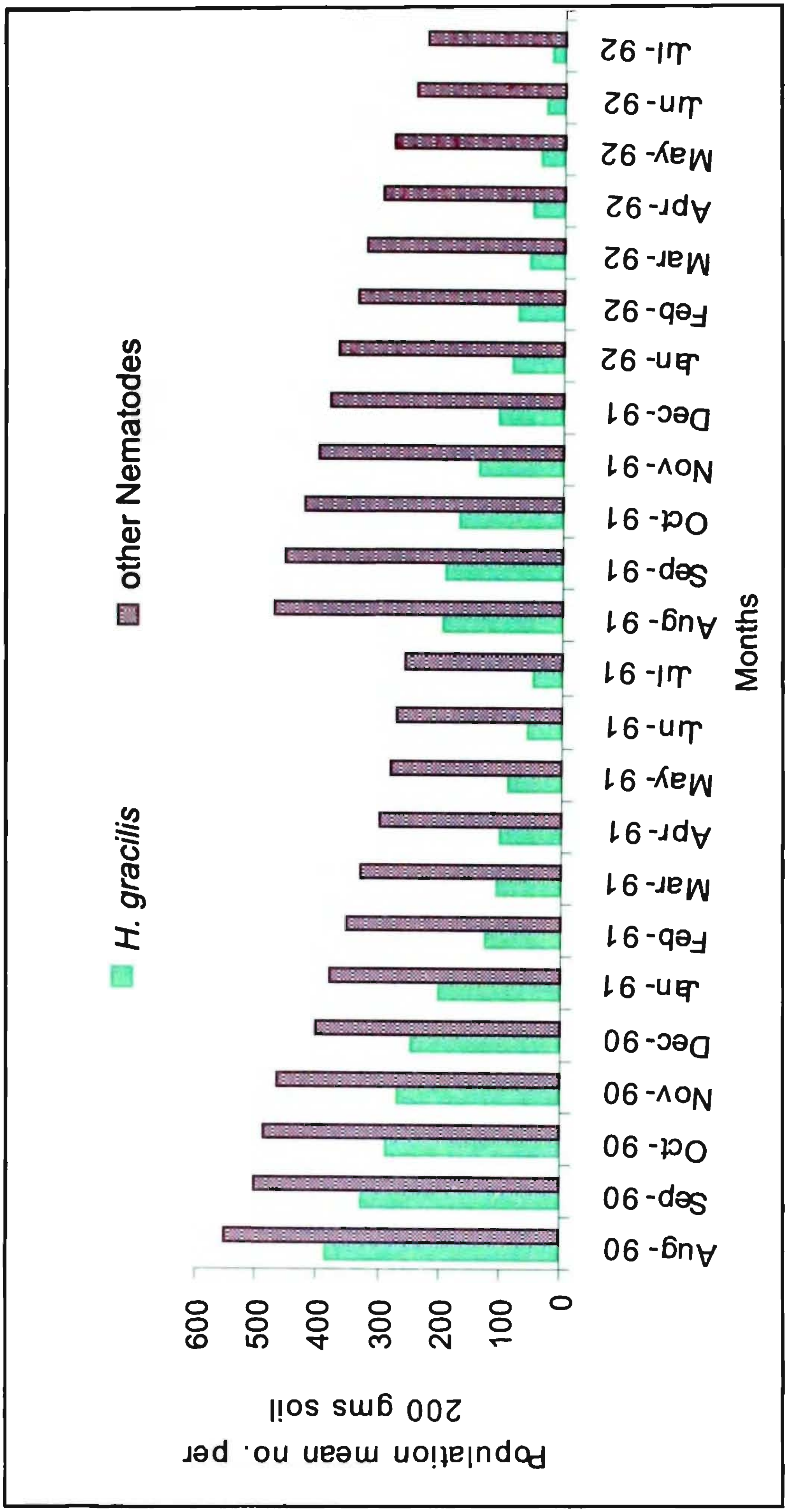


Fig. 41. Effect of seasonal crop-rotation on the population of *Hirschmanniella gracilis* and other nematodes in soil at plot - "C" during 1990-1992.

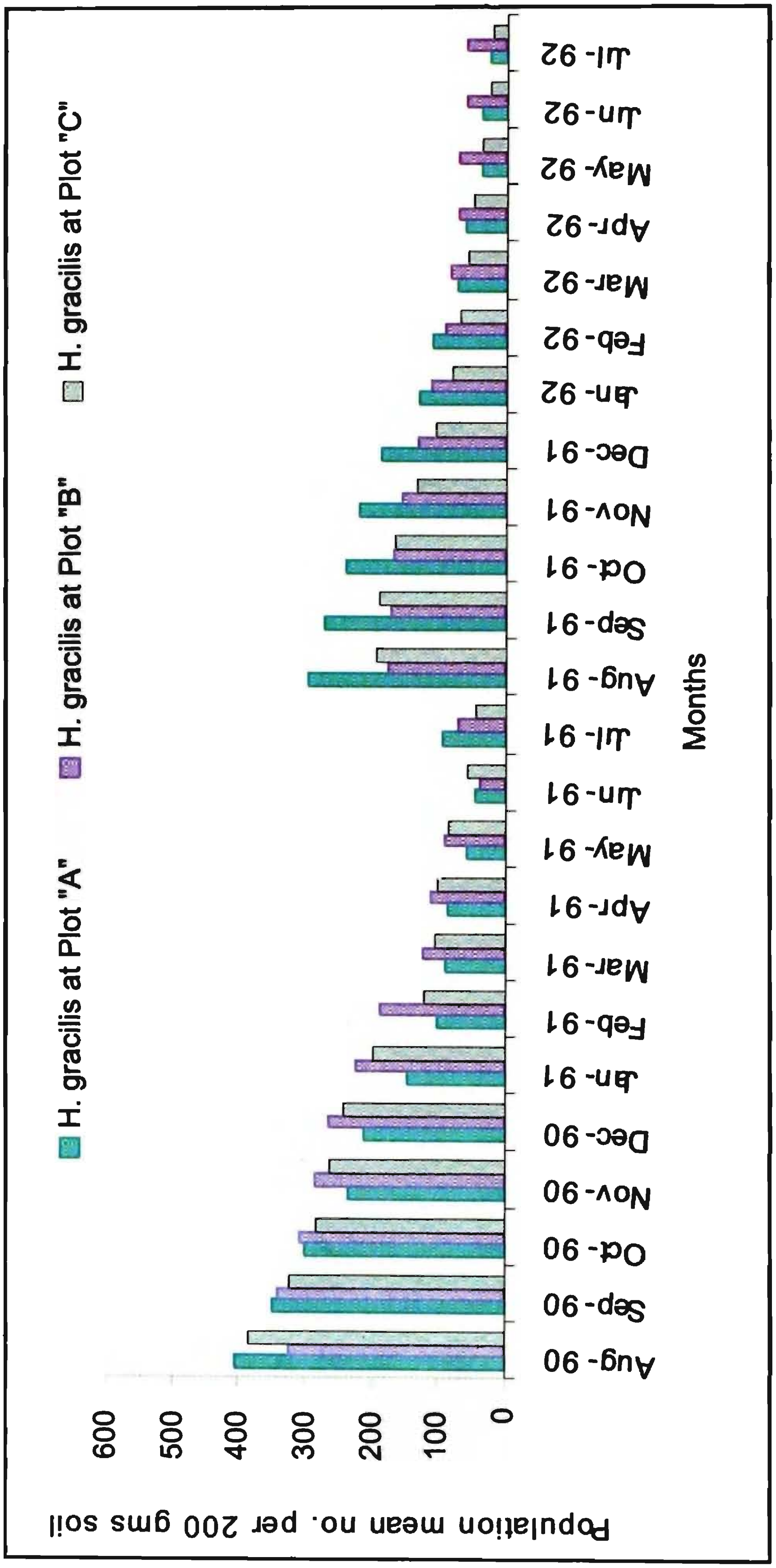


Fig. 42. Effect of seasonal crop-rotation on the population of *Hirschmanniella gracilis* in soil, comparative at plot - "A", "B" and "C" during 1990-1992.

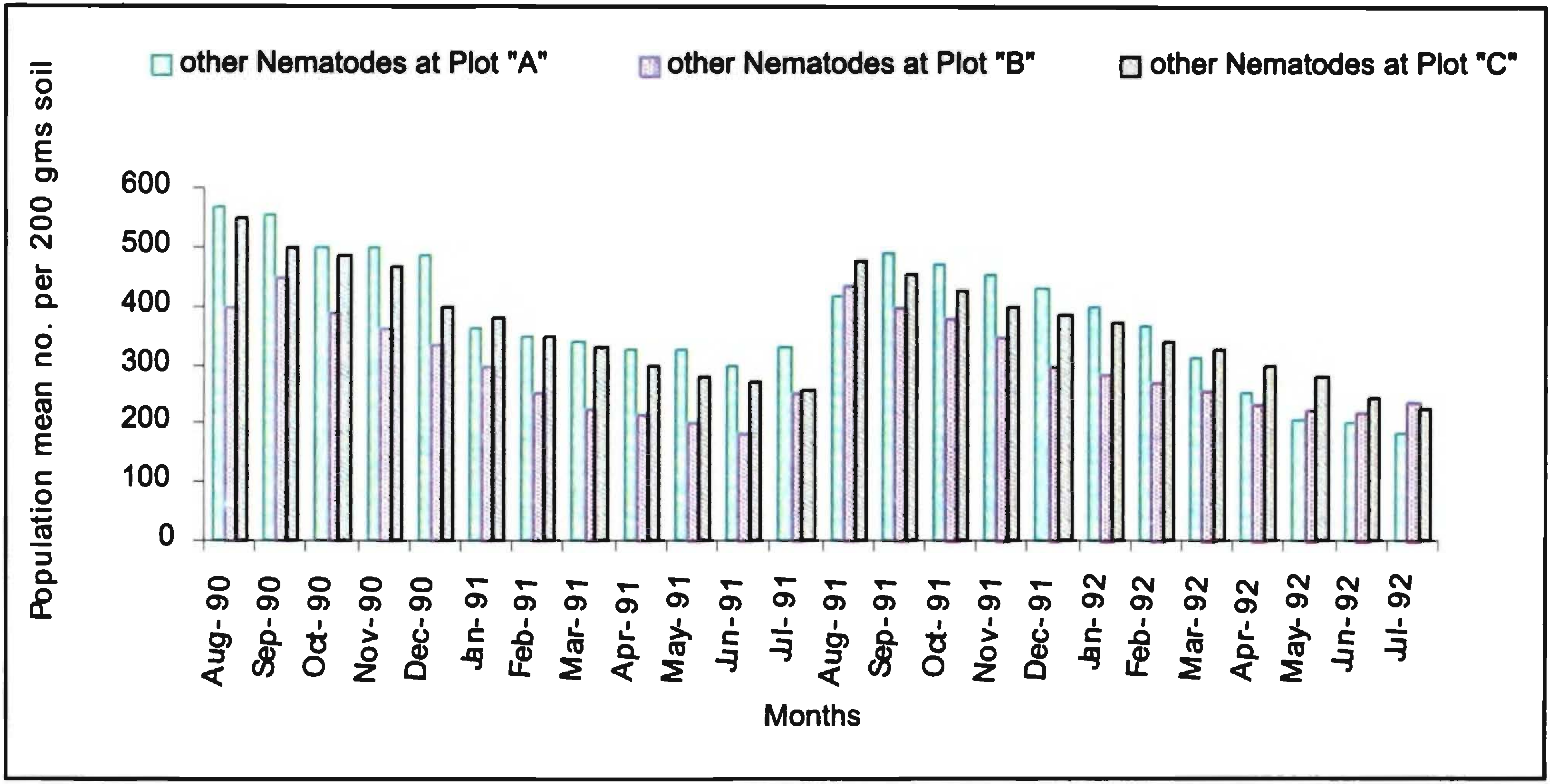


Fig. 43. Effect of seasonal crop-rotation on the population of other nematodes in soil, comparative at plot - "A", "B" and "C" during 1990-1992.

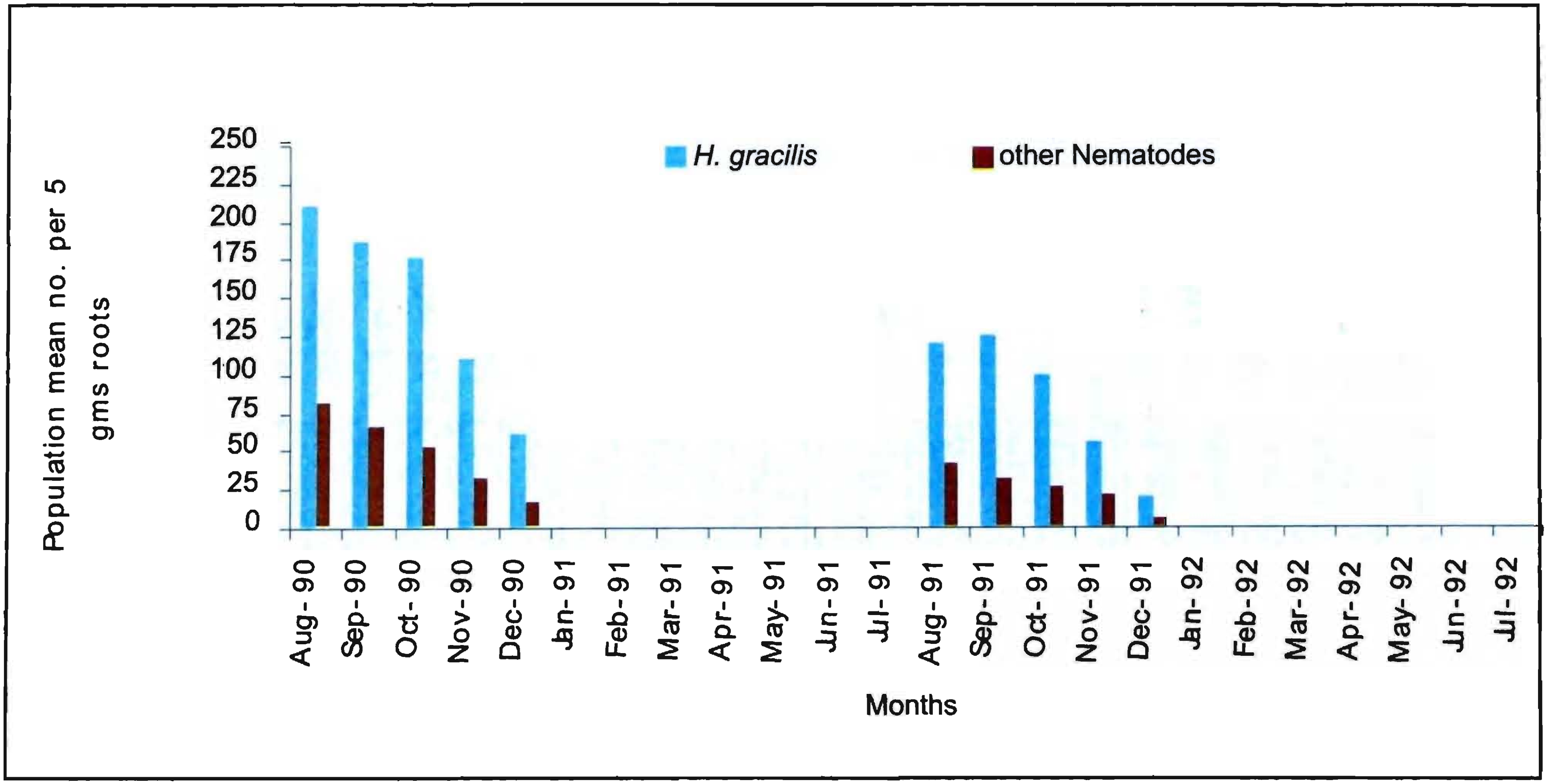


Fig. 44. Effect of seasonal crop-rotation on the population of *Hirschmanniella gracilis* and other nematodes in root [5 gms] at plot "A" during 1990-1992.

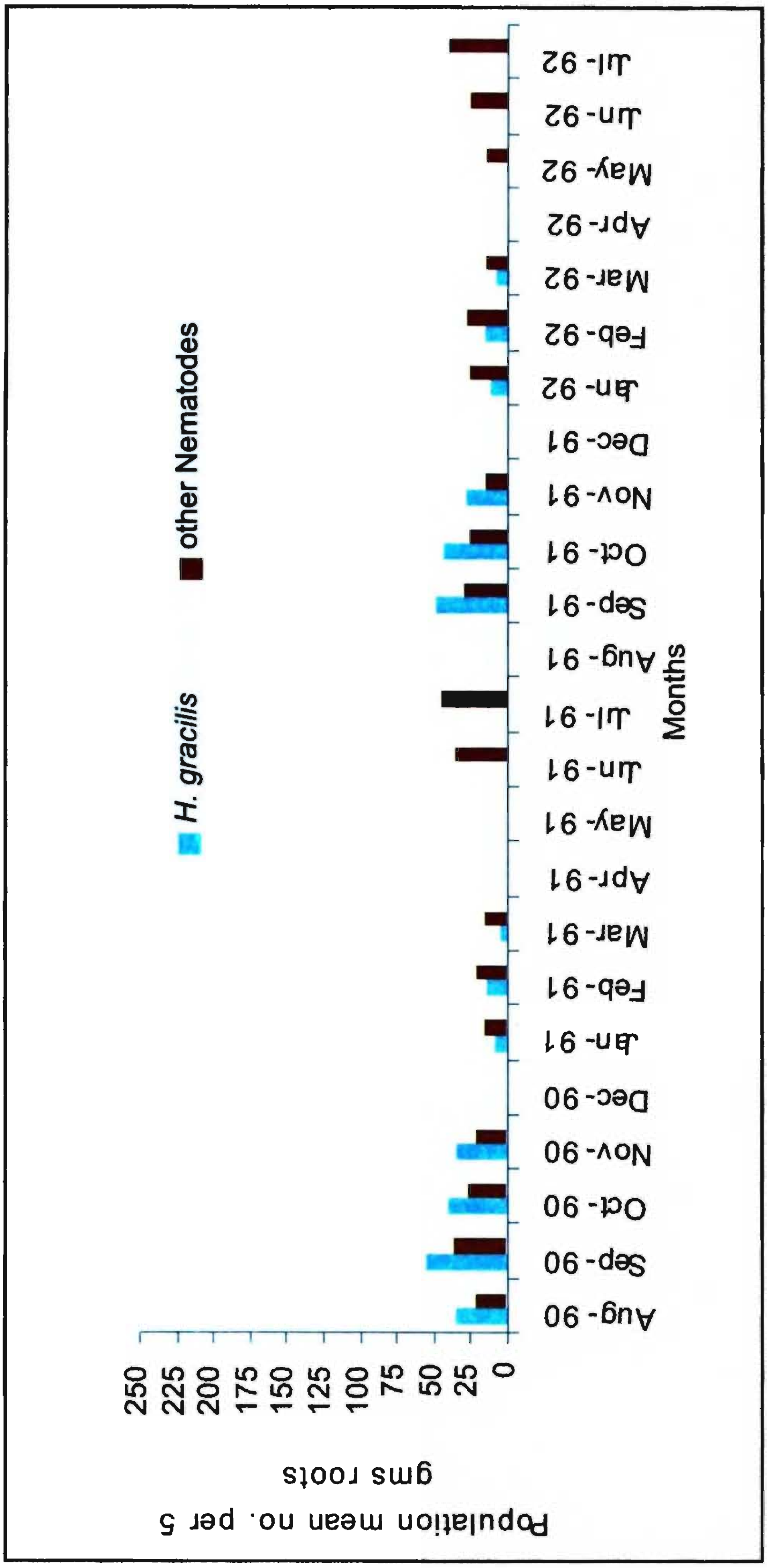


Fig. 45. Effect of seasonal crop-rotation on the population of *Hirschmanniella gracilis* and other nematodes in root [5 gms] at plot "B" during 1990-1992.

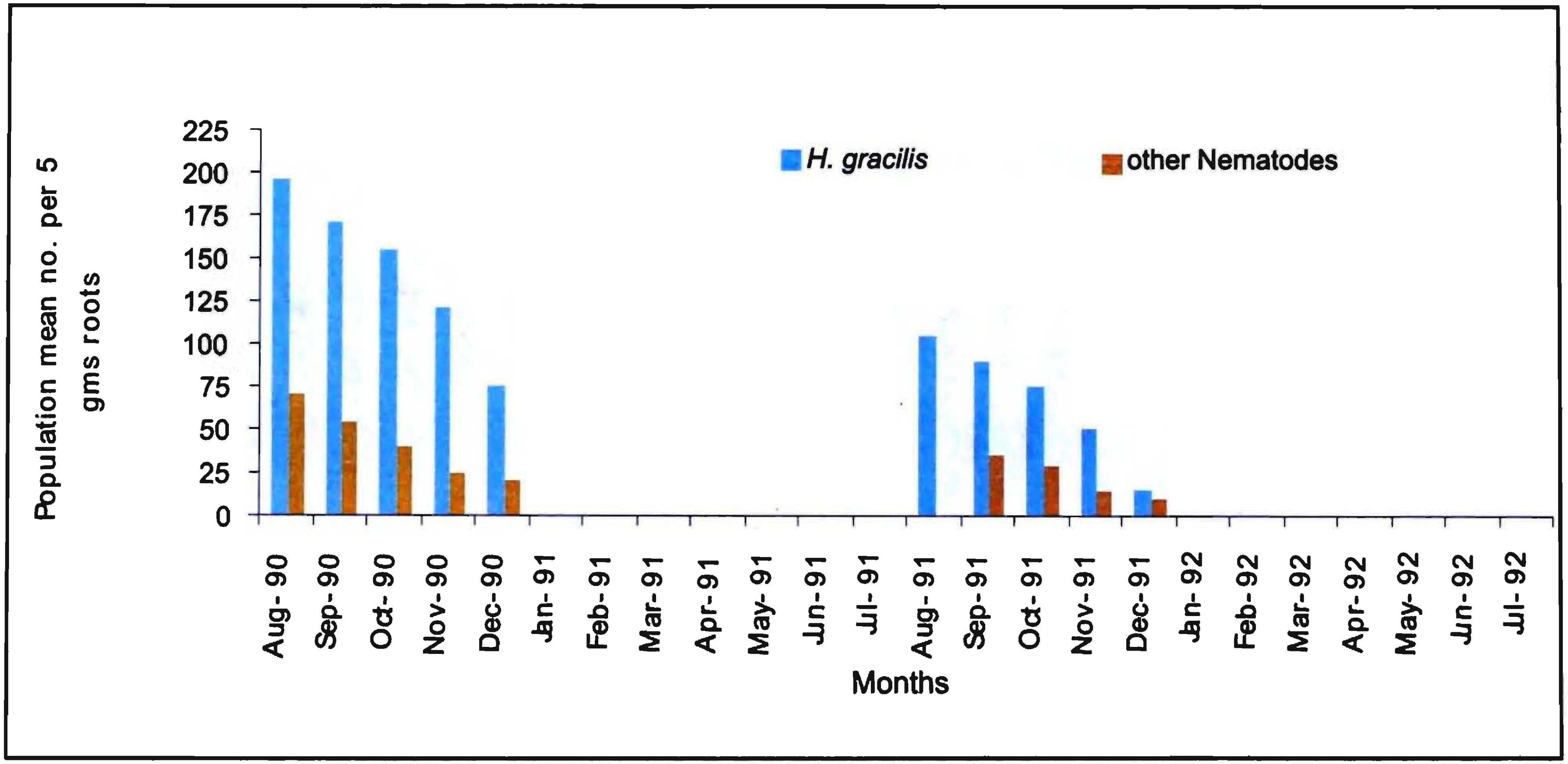


Fig. 46. Effect of seasonal crop-rotation on the population of *Hirschmanniella gracilis* and other nematodes in root [5 gms] at plot - "C" during 1990-1992.

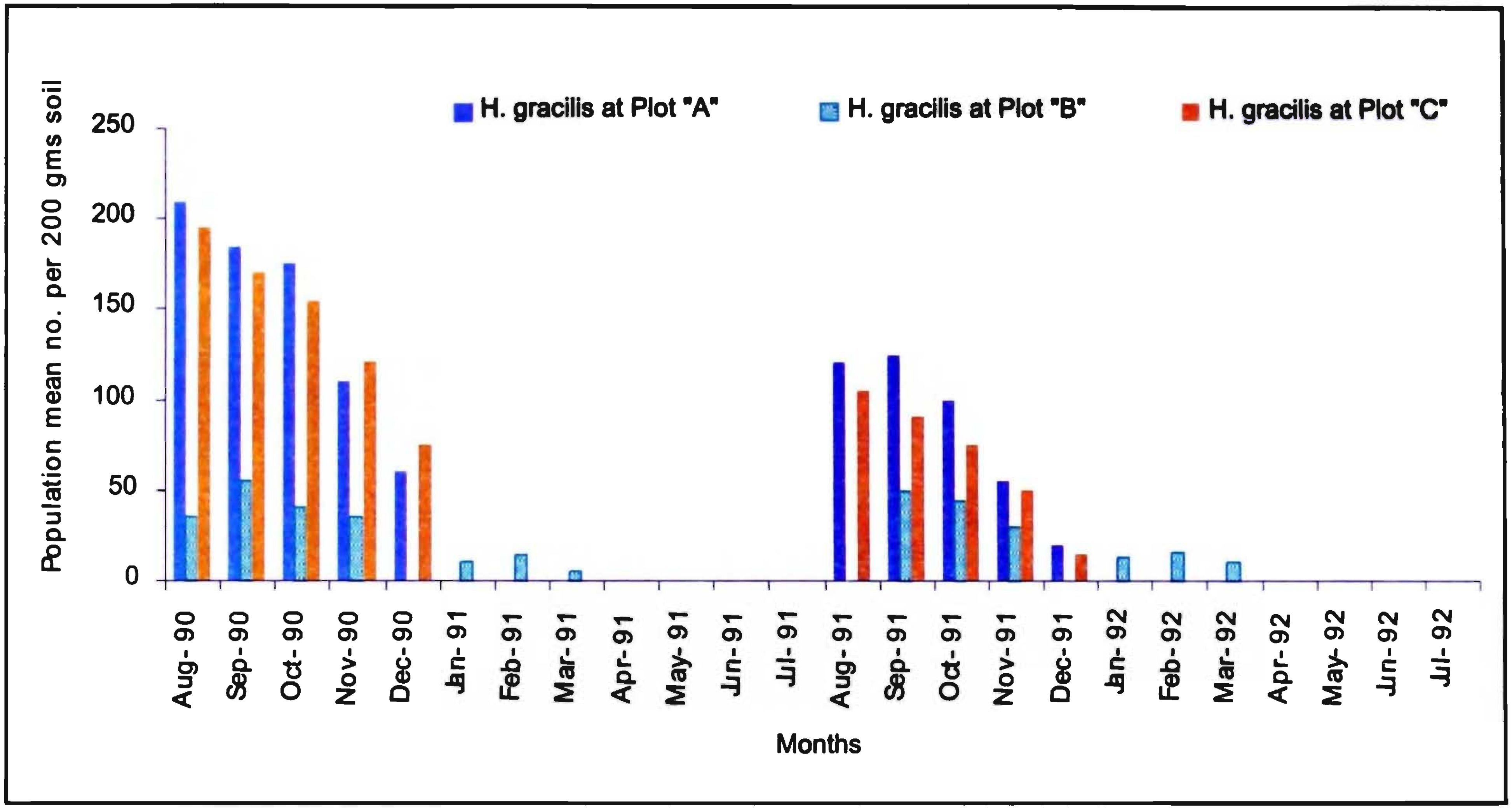


Fig. 47. Effect of seasonal crop-rotation on the population of *Hirschmanniella gracilis* in soil comparative at plot - "A", "B" and "C" during 1990-1992.

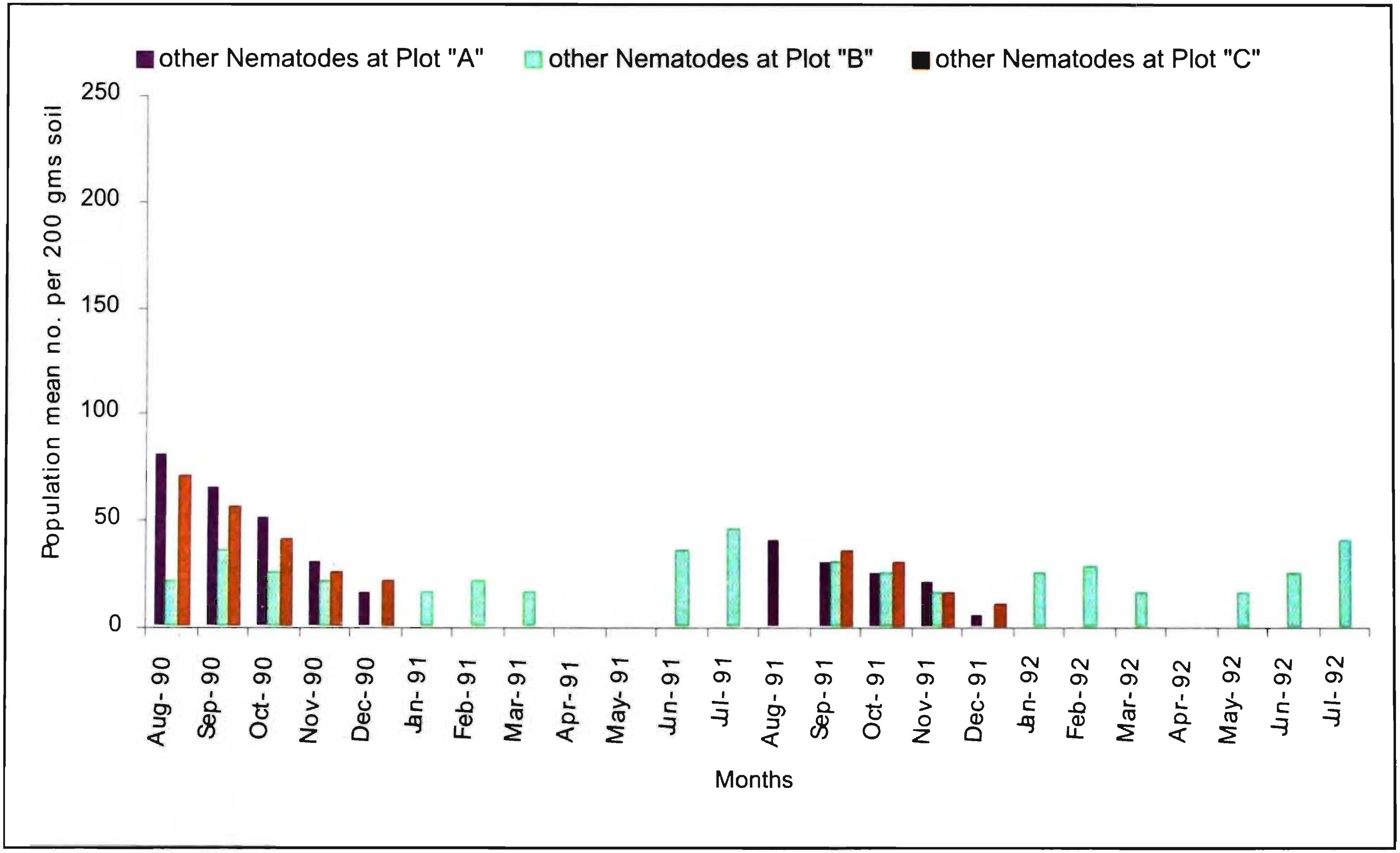


Fig. 48. Effect of seasonal crop-rotation on the population of other nematodes in soil comparative at plot - "A", "B" and "C" during 1990-1992.

3.4. COMPARISON OF THE EFFECT OF FALLOWING ON THE POPULATION OF *Hirschmanniella gracilis* AND "OTHER NEMATODES" IN SOIL AT PLOT "E" WITH THAT OF OTHER PLOTS "D" AND "B" DURING 1990-1992

During these fallow periods, the population of *H. gracilis* and "other nematodes" in plots "E", "D" and "B" are shown in the tables and figures (Table 5, 6, 7, 8, 9, 10, 11; Figures 49, 50, 51, 52 and 53)

The mean population of *H. gracilis* and other "nematodes" were observed as 255, 225 and 485, 460 and 400 per 200 gms soil sample in the month of December, 1990 and January, 1991 respectively at plot "E" kept for long period fallowing (Table 5, Figure 49) where the soil temperature and percentage of soil moisture of the plot was recorded as 22 °C, 20 °C, and 17%, 20% and 18% respectively. While the mean no of population of *H. gracilis* and "other nematodes" was observed as 380, 287.5 and 682.5, 482.5 per 200 gms soil sample in December, 1990 and January, 1991 respectively in plot "D", when the soil temperature and percentage of soil moisture was 21 °C, 19 °C and 24%, 22% (Tables 6, 8). The plot "B" was kept fallow only in December, 1990 under 21 °C soil temperature and 18% soil moisture. The mean population of *H. gracilis* and "other nematodes" was observed as 265 and 335 respectively (Table 7). During June and July, 1991, under "long period fallow" at plot "E" (Table 5, Figure 49), the mean no. of *H. gracilis* and "other nematodes" population was found to be 30, 45 and 310, 320 per 200 gms soil sample where the soil temperature and soil moisture of the plot was recorded as 34 °C, 30 °C and 11%, 26% respectively while in plot "D" during the same period (i.e. June, July 1991) under "short period fallowing (Table 6, Figure 51), the mean no. of *H. gracilis* and "other nematodes" were recorded as 232.5, 160 and 512.5, 377.5 at 34 °C and 30 °C soil temperature and 15%, 22% soil moisture respectively. In April and August, 1991 under "very short period fallowing" at plot "B" the mean no. of *H. gracilis* and "other nematodes" were 110, 175 and 215, 435per 200 gms soil sample at soil temperature and soil moisture 26 °C, 27% and 30 °C, 30% respectively (Tables 7, 9, Figure 51).

During the months of December and January, 1991 and 1992 at plot "E" under "long period fallowing" under soil temperature and soil moisture of 24 °C, 20 °C and 16%, 15%, the mean population of *H. gracilis* and "other nematodes" were observed as 125, 105 and 485, 300 respectively (Table 5, Figure 49). At plot "D", during the months December, 1991 and January, 1992 under "short period fallowing" the soil temperature and moisture were recorded as 23 °C, 20 °C and 23%, 21%, respectively. The mean population of *H. gracilis* and "other nematodes" were noted as 432.5, 355 and 690, 570, respectively (Table 6, Figure 52) whereas in the month of December, 1991 under "very short period fallowing" at plot "B" the soil temperature and moisture were recorded as 23 °C and 27%. The mean number of population of *H. gracilis* and "other nematodes" were observed as 130 and 300 respectively. A decline in active population of *H. gracilis* observed as 25 with rise of soil temperature to 30 °C and low soil moisture 8% were noted in the month of May, 1992 under long period fallowing at plot "E" (Table 5, Figure 49). The large

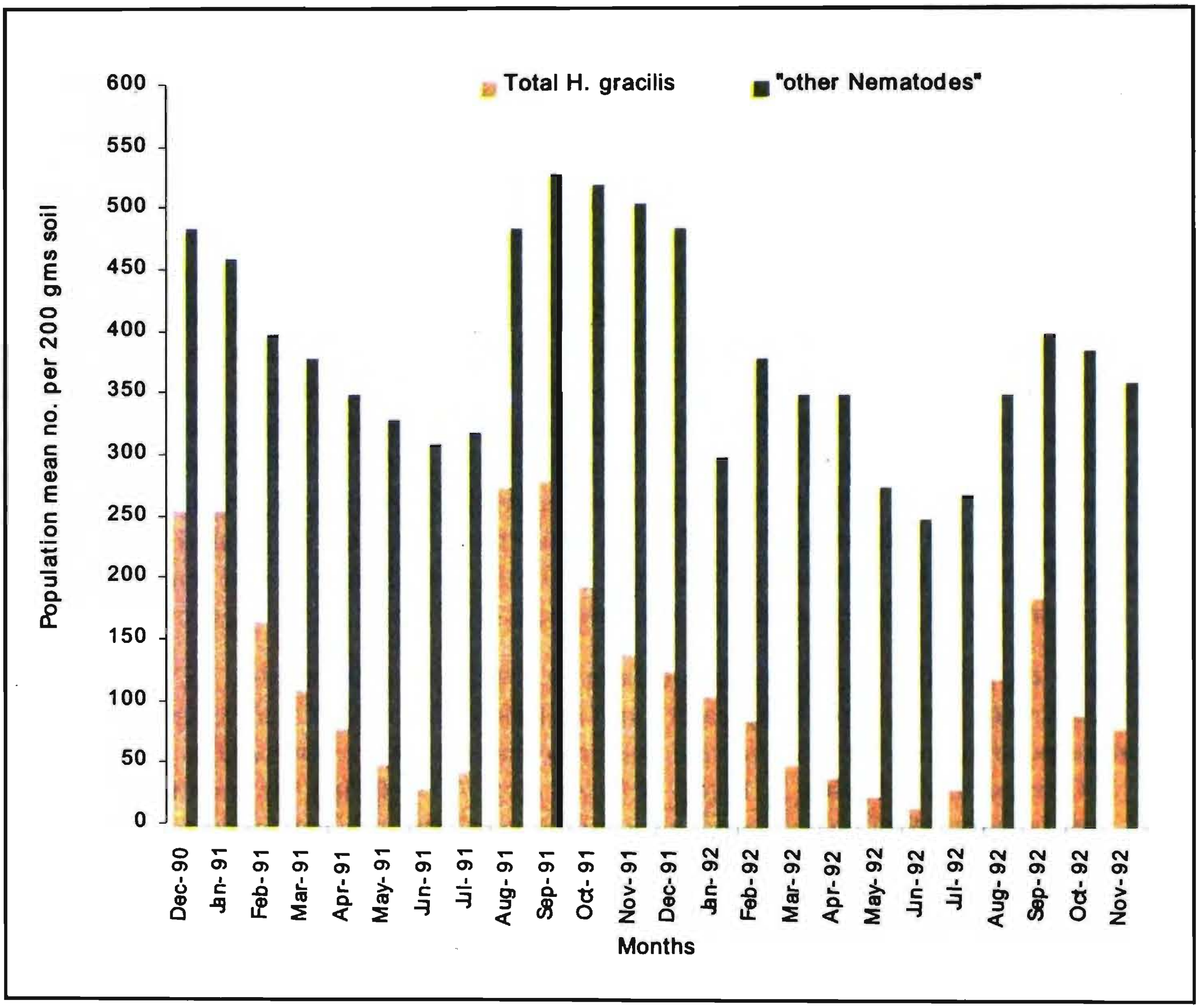

Population mean no. per 200 gms soil
600
550
500
450
400
350
300
250
200
150
100
50
0
Total H. gracilis
"other Nematodes"
Dec-90
Jan-91
Feb-91
Mar-91
Apr-91
May-91
Jun-91
Jul-91
Aug-91
Sep-91
Oct-91
Nov-91
Dec-91
Jan-92
Feb-92
Mar-92
Apr-92
May-92
Jun-92
Jul-92
Aug-92
Sep-92
Oct-92
Nov-92
Months

Table 5. Effect of "long period fallowing" on *Hirschmanniella gracilis* and "other nematodes" in soil at plot "E" during 1990-1992.

Months	**Total *H. gracilis***	**other Nematodes**	**Soil Temperature**	**% of soil Moisture**	**Crops**
Dec. 1990	255	485	22 °C	17%	Fallow
Jan. 1991	225	460	20 °C	20%	Fallow
Feb. 1991	165	400	19 °C	18%	Fallow
Mar. 1991	110	380	23 °C	16%	Fallow
Apr. 1991	80	350	27 °C	16%	Fallow
May. 1991	50	330	27 °C	14%	Fallow
June. 1991	30	310	34 °C	11%	Fallow
July. 1991	45	320	30 °C	26%	Fallow
Aug. 1991	275	485	29 °C	24%	Fallow
Sep. 1991	280	530	30 °C	21%	Fallow
Oct. 1991	195	520	29 °C	18%	Fallow
Nov. 1991	140	505	25 °C	18%	Fallow
Dec. 1991	125	485	24 °C	16%	Fallow
Jan. 1992	105	300	20 °C	15%	Fallow
Feb. 1992	85	380	20 °C	13%	Fallow
Mar. 1992	50	350	22 °C	10%	Fallow
Apr. 1992	40	350	27 °C	10%	Fallow
May. 1992	25	275	30 °C	8%	Fallow
June. 1992	15	250	30 °C	13%	Fallow
July. 1992	30	270	30 °C	25%	Fallow
Aug. 1992	120	350	29 °C	28%	Fallow
Sep. 1992	185	400	30 °C	32%	Fallow
Oct. 1992	90	385	28 °C	29%	Fallow
Nov. 1992	80	360	24 °C	19%	Fallow

Table 6. Effect of "short period fallowing" between the two crops (Paddy) on *Hirschmanniella gracilis* and "other nematodes" in soil at plot "D" during 1990-1992.

Months	**Total *H. gracilis***	**other Nematodes**	**Soil Temperature**	**% of soil Moisture**	**Fellow/Crops**
Aug. 1990	647.5	847.5	28 °C	30%	Masuiri Paddy
Sep. 1990	537.5	795.0	33 °C	34%	Masuiri Paddy
Oct. 1990	567.5	727.5	31 °C	26%	Masuiri Paddy
Nov. 1990	465.5	707.5	28 °C	25%	Masuiri Paddy
Dec. -1990	380.0	682.5	21 °C	24%	Fallow
Jan. 1991	287.5	482.5	19 °C	22%	Fallow
Feb. 1991	235.0	407.5	19 °C	20%	Ratna Paddy
Mar. 1991	272.5	492.5	25 °C	32%	Ratna Paddy
Apr. 1991	297.5	552.5	30 °C	23%	Ratna Paddy
May. 1991	295.0	577.5	30 °C	21%	Ratna Paddy
June. 1991	232.5	512.5	34 °C	15%	Fallow
July. 1991	160.0	377.5	30 °C	22%	Fallow
Aug. 1991	650.0	777.5	30 °C	33%	Masuiri Paddy
Sep. 1991	600.0	810.0	31 °C	29%	Masuiri Paddy
Oct. 1991	272.5	750.0	29 °C	26%	Masuiri Paddy
Nov. 1991	500.0	757.5	26 °C	26%	Masuiri Paddy
Dec. 1991	432.5	690.0	23 °C	23%	Fallow
Jan. 1992	355.0	570.0	20 °C	21%	Fallow
Feb. 1992	292.5	412.5	20 °C	35%	Ratna Paddy
Mar. 1992	317.5	505.0	25 °C	32%	Ratna Paddy
Apr. 1992	295.0	580.0	28 °C	20%	Ratna Paddy
May. 1992	317.5	632.0	30 °C	19%	Ratna Paddy
June. 1992	272.5	572.5	30 °C	15%	Fallow
July. 1992	200.0	435.0	30 °C	27%	Fallow

Table 7. Effect of "very short period fallowing" between three crops (Paddy, Jute/Wheat, and Paddy) on *Hirschmanniella gracilis* and "other nematodes" in soil at plot "B" during 1990-1992.

Months	Total *H. gracilis*	other Nematodes	Soil Temperature	% of soil Moisture	Crops
Aug. 1990	325	400	30 °C	32%	Pankoj Paddy
Sep. 1990	340	450	32 °C	30%	Pankoj Paddy
Oct. 1990	310	390	29 °C	29%	Pankoj Paddy
Nov. 1990	285	360	26 °C	20%	Pankoj Paddy
Dec. 1990	265	335	21 °C	18%	Fallow
Jan. 1991	225	300	18 °C	28%	Wheat
Feb. 1991	185	250	18 °C	25%	Wheat
Mar. 1991	120	225	23 °C	19%	Wheat
Apr. 1991	110	215	26 °C	27%	Fallow
May. 1991	90	200	30 °C	14%	Disimasta Jute
June. 1991	35	185	34 °C	17%	Disimasta Jute
July. 1991	70	250	30 °C	27%	Disimasta Jute
Aug. 1991	175	435	30 °C	30%	Fallow
Sep. 1991	170	400	30 °C	32%	Pankoj Paddy
Oct. 1991	165	380	28 °C	26%	Pankoj Paddy
Nov. 1991	155	350	25 °C	19%	Pankoj Paddy
Dec. 1991	130	300	23 °C	27%	Fallow
Jan. 1992	110	285	20 °C	21%	Wheat
Feb. 1992	90	270	20 °C	19%	Wheat
Mar. 1992	80	255	21 °C	18%	Wheat
Apr. 1992	70	235	27 °C	28%	Fallow
May. 1992	70	225	30 °C	20%	Disimasta Jute
June. 1992	55	220	30 °C	14%	Disimasta Jute
July. 1992	55	240	29 °C	24%	Disimasta Jute

Table 8. Comparison of the effect of fallowing on the population of *H. gracilis* and "other nematodes"in soil at plot "E" with that of other plots "D" and "B" under fallow period of December, 1990 and January, 1991.

	Long period fallow				Short period fallow				Very short period fallow			
	Plot - "E"				Plot - "D"				Plot - "B"			
Months	*H.* gracilis	other Nema- todes	Soil Tempe- rature	% of soil Moist.	*H.* gracilis	other Nema- todes	Soil Tempe rature	% of soil Moist.	*H.* gracilis	other Nema- todes	Soil Tempe rature	% of soil Moist.
Dec. 1990	255	485	22°C	17%	380	682.5	21°C	24%	265	335	21°C	18%
Jan. 1991	225	460	20°C	20%	287.5	482.5	19°C	22%				

Table 9. Comparison of the effect of fallowing on the population of *H. gracilis* and "other nematodes" in soil at plot "E" with that of other plots "D" and "B" under fallow period of June, July, April, and August, 1991.

	Long period fallow				Short period fallow				Very short period fallow			
	Plot - "E"				Plot - "D"				Plot - "B"			
Months	*H.* gracilis	other Nema- todes	Soil Tempe- rature	% of soil Moist.	*H.* gracilis	other Nema- todes	Soil Tempe rature	% of soil Moist.	*H.* gracilis	other Nema- todes	Soil Tempe rature	% of soil Moist.
June. 1991	30	310	34°C	11%	232.5	512.5	34°C	15%				
July. 1991	45	320	30°C	26%	160	377.5	30°C	22%				-
Apr. 1991			-						110	215	26°C	27%
Aug. 1991									175	435	30°C	30%

Table 10. Comparison of the effect of fallowing on the population of *H. gracilis* and "other nematodes" in soil at plot "E" with that of other plots "D" and "B" under fallow period of December, 1991 and January, 1992.

	Long period fallow				Short period fallow				Very short period fallow			
	Plot - "E"				Plot - "D"				Plot - "B"			
Months	***H.* gracilis**	**other Nema-todes**	**Soil Tempe-rature**	**% of soil Moist.**	***H.* gracilis**	**other Nema-todes**	**Soil Tempe rature**	**% of soil Moist.**	***H.* gracilis**	**other Nema-todes**	**Soil Tempe rature**	**% of soil Moist.**
Dec. 1991	125	485	24°C	16%	432.5	690	23°C	23%	130	300	23°C	27%
Jan. 1992	105	300	20°C	15%	355	570	20°C	21%				
Feb. 1992	85	380	20°C	13%	292.5	412.5	20°C	35%				

Table 11. Comparison of the effect of fallowing on the population of *H. gracilis* and "other nematodes" in soil at plot "E" with that of other plots "D" and "B" under fallow period of June, July, and April, 1992.

	Long period fallow				Short period fallow				Very short period fallow			
	Plot - "E"				Plot - "D"				Plot - "B"			
Months	***H.* gracilis**	**other Nema-todes**	**Soil Tempe-rature**	**% of soil Moist.**	***H.* gracilis**	**other Nema-todes**	**Soil Tempe rature**	**% of soil Moist.**	***H.* gracilis**	**other Nema-todes**	**Soil Tempe rature**	**% of soil Moist.**
June. 1992	15	250	30°C	13%	272.5	572.5	30°C	15%			-	-
July. 1992	30	270	30°C	25%	200	435	30°C	27%				
Apr. 1992						-			70	235	27°C	28%

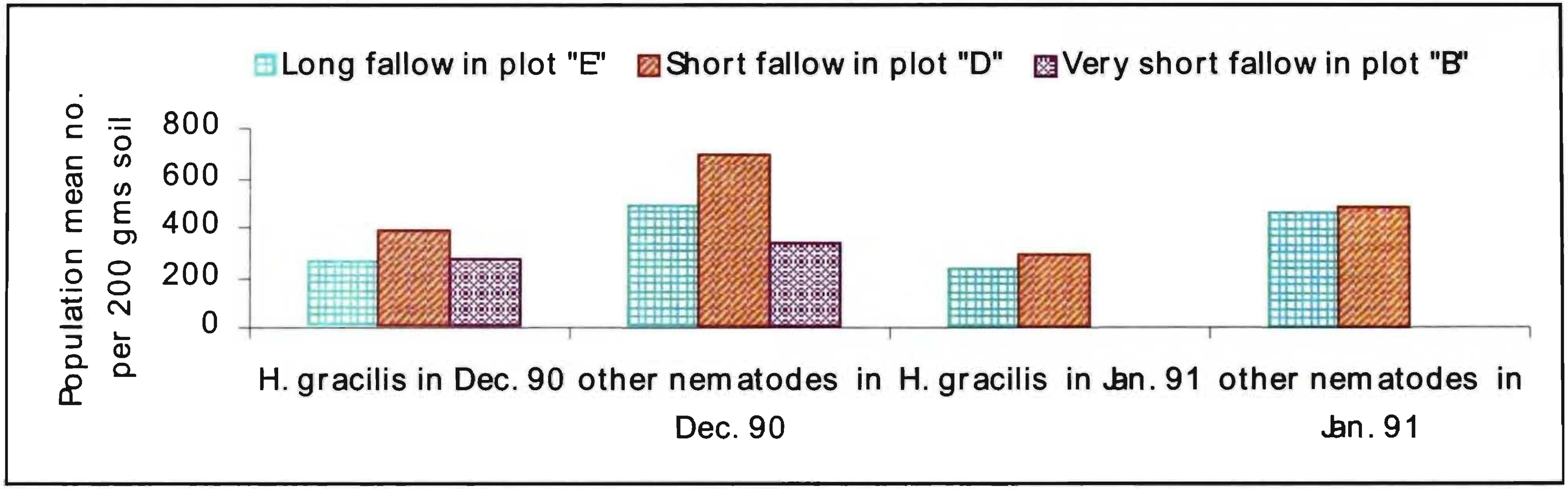


Fig. 50. Comparison of the effect of fallowing on the population of *Hirschmanniella gracilis* and "other nematodes" at plot - "E" with that of other plots "D" and "B" under fallow period of Dec., 1990 and Jan., 1992.

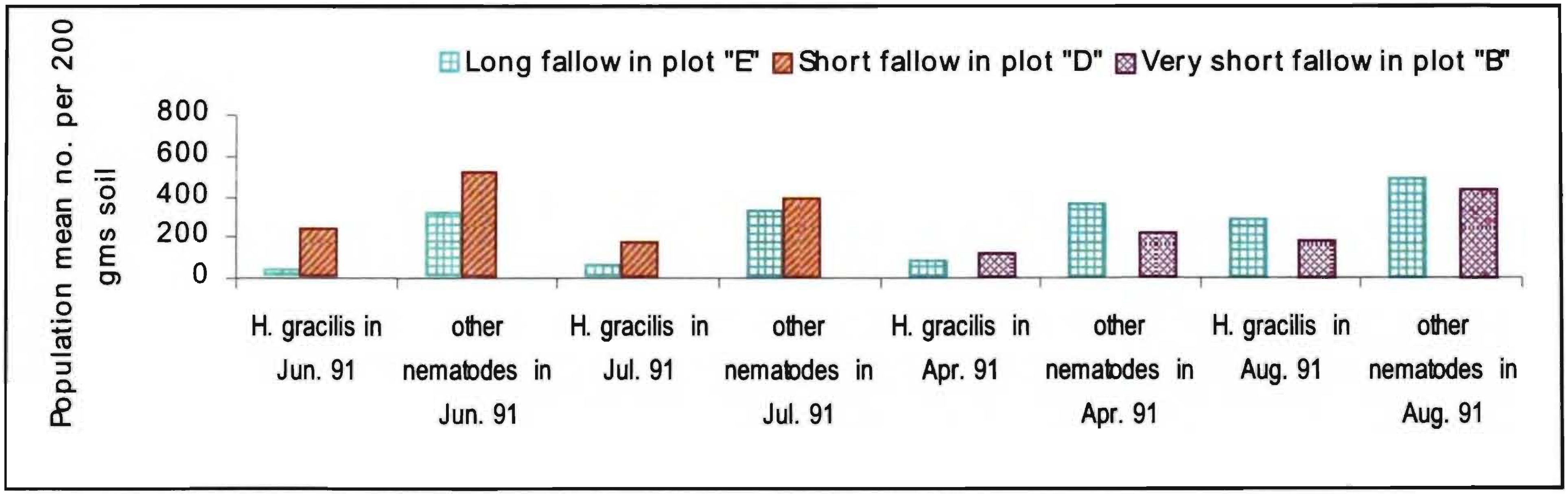


Fig. 51. Comparison of the effect of fallowing on the population of *Hirschmanniella gracilis* and "other nematodes" at plot - "E" with that of other plots "D" and "B" under fallow period of June, July April, and August, 1991.

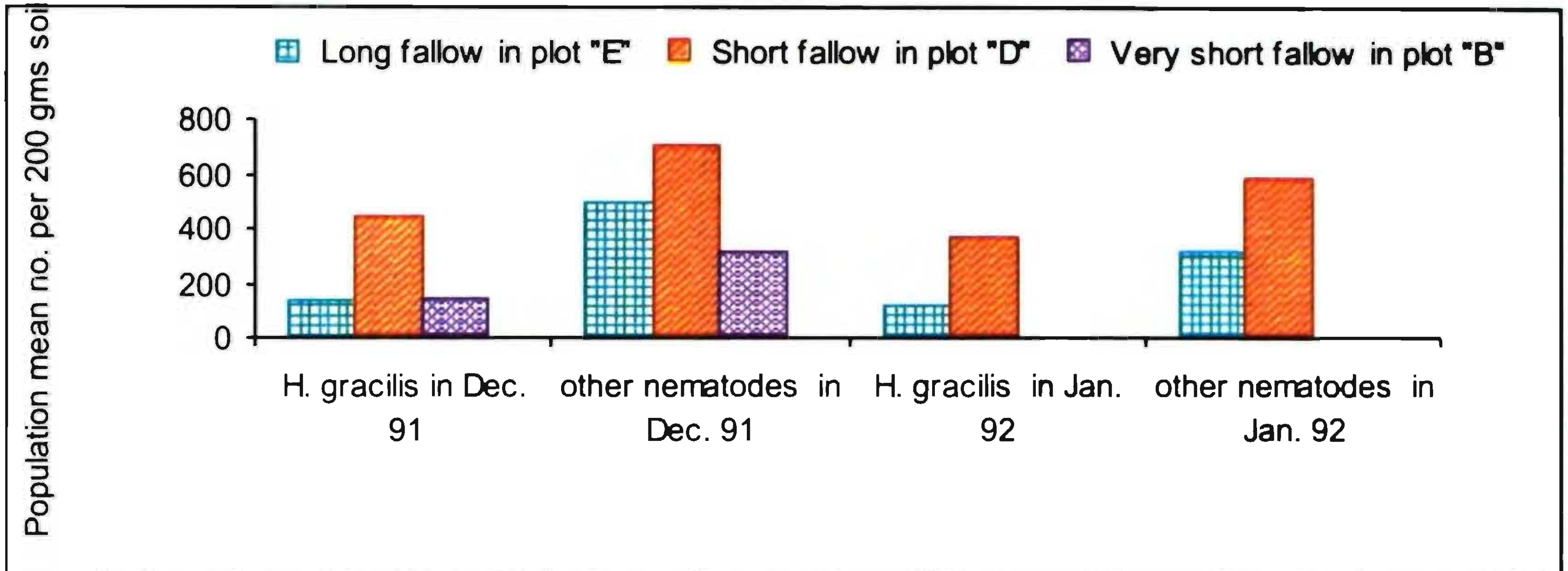


Fig. 52. Comparison of the effect of fallowing on the population of *Hirschmanniella gracilis* and "other nematodes" at plot - "E" with that of other plots "D" and "B" under fallow period of Dec., 1991 and Jan., 1992.

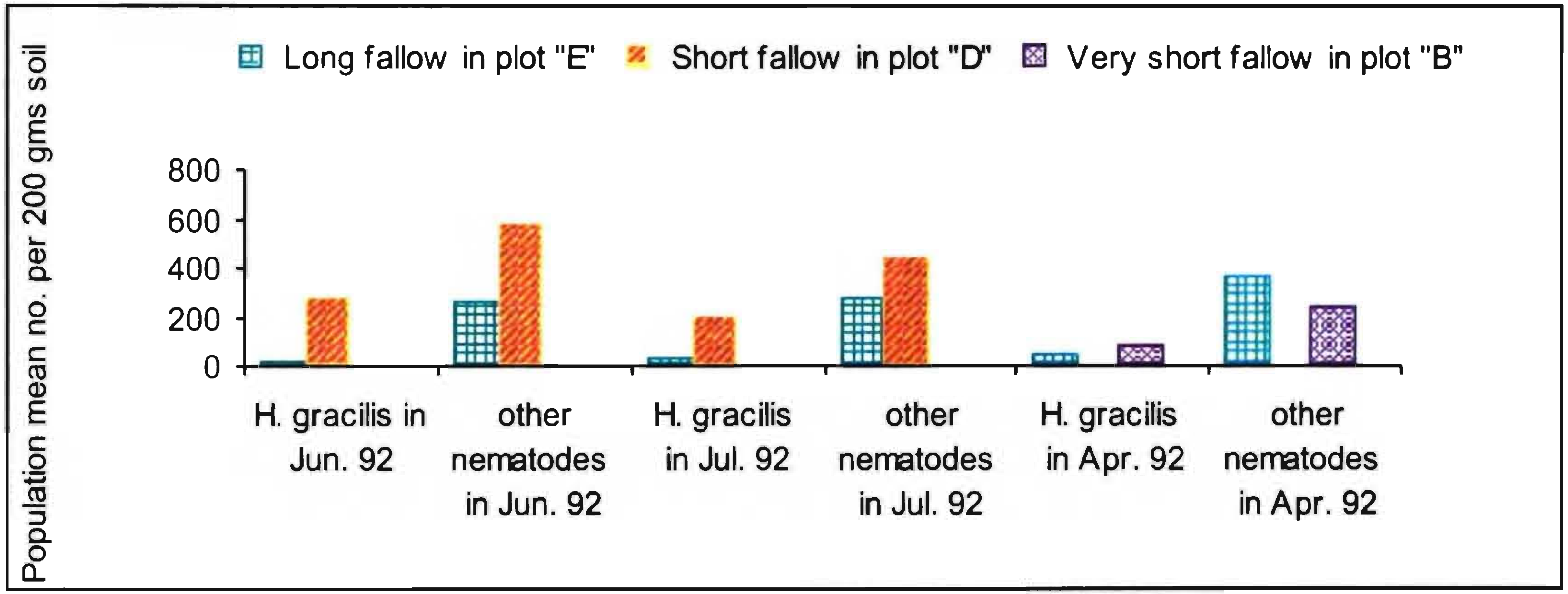


Fig. 53. Comparison of the effect of fallowing on the population of *Hirschmanniella gracilis* and "other nematodes" at plot - "E" with that of other plots "D" and "B" under fallow period of June, July, and April, 1992.

3.5.0 CORRELATION ON THE POPULATION OF *Hirschmanniella gracilis* WITH SOIL TEMPERATURE AND MOISTURE UNDER DIFFERENT CROP ROTATION AT DIFFERENT PLOTS DURING 1990-1992

The correlation coefficient on the soil population of *Hirschmanniella gracilis* with soil temperature and soil moisture under different crop rotation in different plots were subjected to statistical analysis.

3.5.1. Correlation in plot "A"

The mean population of *H. gracilis* and mean soil temperature during the cropping season of Pankoj paddy were recorded 300 and 26.8 respectively (Table 12). The correlation coefficient (= r) were calculated 0.914 indicates strong and positive correlation (significant at 0.01 level) between nematode population and temperature.

Similarly, during the fallow period in the same plot, the mean soil population and soil temperature (Table 13) shows a little decline, yet the correlation coefficient (r) has been calculated 1, indicating an absolute correlation between the two factors.

Now, instead of Pankoj paddy when these two factors i.e. soil population and soil temperature in the Jalmasta jute cultivation in the same Plot "A", (Table 14) are considered, we get "r" value = -0.602, which denotes insignificant correlation between the two.

Table 12. Correlation between the soil population of *H. gracilis* and soil temperature under Pankoj paddy cultivation during the months August - December, 1990 in Plot "A"

1990	Soil population	Temperature	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT. of $X^2.Y^2$ = 1001.4888	Remarks
	X	Y							
Aug.'90	405	29	105	2.2	231	11025	4.84		
Sep.'90	350	30	50	3.2	160	2500	10.24	r=0.9136	Significiant at 0.01 level
Oct.'90	300	28	0	1.2	0	0	1.44		
Nov.'90	235	24	-65	-2.8	182	4225	7.84		
Dec.'90	210	23	-90	-3.8	342	8100	14.44		
Total	**1500**	**134**	**0**	**-3.55**	**915**	**25850**	**38.8**		

Table 13. Correlation between the soil population of *H. gracilis* and soil temperature under Fallow period during the months January - February, 1991 in Plot "A"

1991	Soil population	Soil Temperature	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT. of $X^2.Y^2$ = 22.5	Remarks
	X	Y							
Jan. '91	145	20	22.5	0.5	11.25	506.25	0.25	r = 1	Absolutely Significiant
Feb.'91	100	19	-22.5	-0.5	11.25	506.25	0.25		
Total	**245**	**39**	**0**	**0**	**22.5**	**1013**	**0.5**		

Table 14. Correlation between the soil population of *H. gracilis* and soil temperature under Jalmasta jute cultivation during the months March - July, 1991 in Plot "A"

1991	Soil population	Soil temperature	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT. of $X^2.Y^2$ = 302.1655	Remarks
	X	Y							
Mar.' 91	90	22	16	-5.6	-89.6	256	31.36	r = 0.6023	Not significant
Apr. '91	85	27	11	-0.6	-6.6	121	0.36		
May '91	55	30	-19	2.4	-45.6	361	5.76		
June '91	45	30	-29	2.4	-69.6	841	5.76		
July '91	95	29	21	1.4	29.4	441	1.96		
Total	**370**	**138**	**0**	**-7.1E-15**	**-182**	**2020**	**45.2**		

Table 15. Correlation between the soil population of *H. gracilis* and soil temperature under Pankoj paddy during the months August - December, 1991 in Plot "A".

1991	Soil population	Soil Temperature	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT. of $X^2.Y^2$ = 1034.4950	Remarks
	X	Y							
Aug. '91	295	29	53	6	318	2809	36	r = 0.3934	Not significant
Sep. '91	270	31	28	8	224	784	64		
Oct. '91	240	29	-2	6	-12	4	36		
Nov. '91	220	26	-22	3	-66	484	9		
Dec. '91	185	24	-57	1	-57	3249	1		
Total	**1210**	**115**	**0**	**24**	**407**	**7330**	**146**		

Table 16. Correlation between the soil population of *H. gracilis* and soil temperature in Fallow period during the months January - February, 1992 in Plot "A"

1992	Soil population	Temperature	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT. of $X^2.Y^2$ = 0	Remarks
	X	Y							
Jan. '92	130	19	10	0	0	100	0	r = 0	Not significant
Feb. '92	110	19	-10	0	0	100	0		
Total	**240**	**38**	**0**	**0**	**0**	**200**	**0**		

Table 17. Correlation between the soil population of *H. gracilis* and soil temperature under Jalmasta jute cultivation during the months March - July, 1992 in Plot "A"

1992	Soil population	Soil Temperature	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT. of $X^2.Y^2$ =304.7622	Remarks
	X	Y							
Mar. 92	75	21	29	-6	-174	841	36	r = 0.9679	Significant at 0.01 level
Apr. 92	60	26	14	-1	-14	196	1		
May. 92	35	29	-11	2	-22	121	4		
June. 92	35	29	-11	2	-22	121	4		
July. 92	25	30	-21	3	-63	441	9		
Total	**230**	**135**	**0**	**0**	**-295**	**1720**	**54**		

Table 18. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under Pankoj paddy cultivation during the months August December, 1990 in Plot "A"

1990	Soil population	% of Soil Moist.	X=x-x	M=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ =1722.6665	Remarks
	X	M							
Aug. '90	405	37	105	5.8	609	11025	33.64	r = 0.9549	Significant at 0.01 level
Sep. '90	350	34	50	2.8	140	2500	7.84		
Oct. '90	300	34	0	2.8	0	0	7.84		
Nov. '90	235	26	-65	-5.2	338	4225	27.04		
Dec. '90	210	25	-90	-6.2	558	8100	38.44		
Total	**1500**	**156**	**0**	**0**	**1645**	**25850**	**114.8**		

Table 19. Correlation between the soil population of *H. gracilis* and percentage of soil moisture in Fallow period during the months January February, 1991 in Plot "A"

1991	Soil population	% of Soil Moist.	X=x-x	Y=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ = 22.5	Remarks
	X	M							
Jan. '91	145	21	22.5	0.5	11.25	506.25	0.25	r = 1	Absolutely significant
Feb. '91	100	20	-22.5	-0.5	11.25	506.25	0.25		
Total	**245**	**41**	**0**	**0**	**22.5**	**1013**	**0.5**		

Table 20. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under Jalmasta jute during the months March July, 1991 in Plot "A"

1991	Soil population	% of Soil Moist.	X=x-x	Y=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ = 4647.8704	Remarks
	X	M							
Mar. '91	90	28	71	22	1562	5041	484	r = 0.9660	Significant at 0.01 level
Apr. '91	85	16	66	10	660	4356	100		
May '91	55	14	36	8	288	1296	64		
June '91	45	12	26	6	156	676	36		
July '91	95	30	76	24	1824	5776	576		
Total	**370**	**100**	**275**	**70**	**4490**	**17145**	**1260**		

Table 21. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under Pankoj paddy cultivation during the months August December, 1991 in Plot "A"

1991	Soil population	% of Soil Moist.	X=x-x	M=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ =1900.1022	Remarks
	X	M							
Aug. '91	295	36	93.3333	10.833333	1011.1	8711.1	117.36	r = 0.9883	Significant at 0.01 level
Sep. '91	270	33	68.3333	7.8333333	535.28	4669.4	61.361		
Oct. '91	240	32	38.3333	6.8333333	261.94	1469.4	46.694		
Nov. '91	220	27	18.3333	1.8333333	33.611	336.11	3.3611		
Dec. '91	185	23	-16.6667	-2.166667	36.111	277.78	4.6944		
Total	**1210**	**151**	**201.67**	**25.16667**	**1878**	**15464**	**233.5**		

Table 22. Correlation between the soil population of *H. gracilis* and percentage of soil moisture in Fallow period during the months January 1992- February, 1992 in Plot "A"

1992	Soil population X	% of Soil Moist. M	X=x-x	Y=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ = 20	Remarks
Jan. '92	130	18	10	1	10	100	1	r = 1	Absolutely significant
Feb. '92	110	16	-10	-1	10	100	1		
Total	**240**	**34**	**0**	**0**	**20**	**200**	**2**		

Table 23. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under Jalmasta jute cultivation during the months March July, 1992 in Plot "A"

1992	Soil population X	% of Soil Moist. M	X=x-x	Y=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ = 472.8636	Remarks
Mar. '92	75	26	29	9	261	841	81	r = 0.9727	Significant at 0.001 level
Apr. '92	60	19	14	2	28	196	4		
May '92	35	15	-11	-2	22	121	4		
June '92	35	13	-11	-4	44	121	16		
July.'92	25	12	-21	-5	105	441	25		
Total	**230**	**85**	**0**	**0**	**460**	**1720**	**130**		

Let us consider the correlation between these two factors in the same plot in the next year in 1991-1992 in the same cropping sequence of Pankoj paddy, next fallow period and then Jalmasta jute (Tables 15, 16 and 17 respectively). The "r" values being 0.393, 0, and -0.967 respectively do indicate that either the two factors have no correlation or negatively correlated.

When we do concentrate on the correlation between soil population and soil moisture in the same plot "A" in the same sequence of cropping seasons in the two consecutive years 1990-1991 and 1991-1992 (Tables 18, 19, 20 and 21, 22, 23), the correlation either become very much (mostly at 0.01 level) significant or even absolute (during fallow period) in both the seasons and in all the crops.

3.5.2 Correlation in plot "B"

The observations available from another plot "B", where the cropping sequence were Pankoj paddy, Ratna paddy, wheat and Disimasta jute in both the years 1990 -1991 and 1991-1992. The observations (Table 24, 25, 26 and 27, 28, 29) show that the soil temperature is very much correlated at 0.001 and 0.01 level respectively with that of nematode population when either Pankoj or Ratna variety of paddy were grown but when the crops were wheat or Disimasta jute, the temperature showed a negative correlation at 0.01 and 0.10 level with nematode population in 1991, or no correlation in 1992.

Further, when we do concentrate on the correlation between soil population and soil moisture in the same plot "B" in the same sequence of cropping seasons like paddy (Pankoj or Ratna variety), wheat and Disimasta jute in the same two consequtive year 1990-1991 and 1991-1992 (tables 30, 31, 32 and 33, 34, 35), the correlation either become significant at 0.10 level (Table 30) and 0.02 level (Table 33) during two varieties of paddy cultivation or very much significant at 0.01 level (Table 31), even absolute (Table 34) during wheat cultivation in both the seasons. As a consequence, when cultivation of an unfavourable crop like Disimasta jute followed (second time in the series), the nematodes had to face adverse condition and as an impact the correlation turned reverse and we got a negative correlation between the two factors soil population and soil moisture. (r = - 0.065, table 32 and r = -0. 114, Table 35).

Table 24. Correlation between the soil population of *H. gracilis* and soil temperature under Pankoj paddy cultivation during the months August- November, 1990 in Plot "B"

1990	Soil population	Soil Tepmerature	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT. of $X^2.Y^2$ = 175.8905	Remarks
	X	Y							
Aug.'90	325	30	10	0.75	7.5	100	0.5625	r = 0.9949	Significant at 0.001 level
Sep.'90	340	32	25	2.75	68.75	625	7.5625		
Oct.'90	310	29	-5	-0.25	1.25	25	0.0625		
Nov.'90	285	26	-30	-3.25	97.5	900	10.5625		
Total	**1260**	**117**	**0**	**0**	**175**	**1650**	**18.75**		

Table 25. Correlation between the soil population of *H. gracilis* and soil temperature under wheat cultivation during the months January - March, 1991 in Plot "B"

1991	Soil population	Soil Temperature	X=x-x	M=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ =305.9593	Remarks
	X	M							
Jan.'91	225	18	48.33333	-1.666667	-80.5556	2336.111	2.7777	r = 0.9260	Significant at 0.01 level
Feb.'91	185	18	8.333333	-1.666667	-13.8889	69.44444	2.7777		
Mar.'91	120	23	-56.66667	3.3333333	-188.889	3211.111	11.111		
Total	**530**	**59**	**0**	**-3.6E-15**	**-283.33**	**5616.67**	**16.6667**		

Table 26. Correlation between the soil population of *H. gracilis* and soil temperature under Disimasta jute cultivation during the months May July, 1991 in Plot "B"

1991	Soil population	Soil Temperature	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT. of $X^2.Y^2$ = 128.5820	Remarks
	X	Y							
May' 91	90	30	25	-1.3333	-33.3333	625	1.7777	r = 0.9332	Significant at 0.10 level
June '91	35	34	-30	2.66666	-80.0000	900	7.1111		
July '91	70	30	5	-1.3333	-6.66667	25	1.7777		
Total	**195**	**94**	**0**	**0**	**-120**	**1550**	**10.6667**		

Table 27. Correlation between the soil population of *H. gracilis* and soil temperature under Ratna paddy cultivation during the months September November, 1991 in Plot "B"

1991	Soil population	Soil Temperature	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT. of $X^2.Y^2$ = 38.4418	Remarks
	X	Y							
Sep. '91	170	30	6.6666	2.33333	15.5556	44.44444	5.4444	r = 0.9971	Significant at 0.01 level
Oct. '91	165	28	1.6666	0.33333	0.55556	2.777778	0.1111		
Nov. '91	155	25	-8.3333	-2.6666	22.2222	69.44444	7.1111		
Total	**490**	**83**	**0**	**0**	**38.333**	**116.667**	**12.6667**		

Table 28. Correlation between the soil population of *H. gracilis* and soil temperature under wheat during the months January March, 1992 in Plot "B"

1992	Soil population	Soil Temperature	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT. of $X^2.Y^2$ = 17.6383	Remarks
	X	Y							
Jan. '92	110	20	16.66667	-0.3333	-5.55556	277.77	0.1111	r = 0.7559	Not significant
Feb. '92	90	20	-3.33333	-0.3333	1.11111	11.111	0.1111		
Mar. '92	80	21	-13.3333	0.66666	-8.88889	177.77	0.4444		
Total	**280**	**61**	**0**	**0**	**-13.333**	**466.667**	**0.66667**		

Table 29. Correlation between the soil population of *H. gracilis* and soil temperature under Dishimasta jute cultivation during the months May July, 1992 in Plot "B"

1992	Soil population	Soil Temperature	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT. of $X^2.Y^2$ = 10	Remarks
	X	Y							
May. 92	70	30	10	0.33333	3.33333	100	0.1111	r = 0.5	Not significant
June '92	55	30	-5	0.33333	-1.66667	25	0.1111		
July '92	55	29	-5	-0.6666	3.33333	25	0.4444		
Total		**180**	**89**	**0**	**0**	**5**	**150**	**0.66667**	

Table 30. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under Pankoj paddy cultivation during the months August November, 1990 in Plot "B"

1990	Soil population	% of Soil Moist.	X=x-x	Y=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ = 373.9485	Remarks
	X	M							
Aug. '90	325	32	10	4.25	42.5	100	18.0625	r = 0.8691	Significant at 0.10 level
Sep. '90	340	30	25	2.25	56.25	625	5.0625		
Oct. '90	310	29	-5	1.25	-6.25	25	1.5625		
Nov. '90	285	20	-30	-7.75	232.5	900	60.0625		
Total	**1260**	**111**	**0**	**0**	**325**	**1650**	**84.75**		

Table 31. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under wheat cultivation during the months January March, 1991 in Plot "B"

1991	Soil population	% of soil moist.	X=x-x	M=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ =485.6954	Remarks
	X	M							
Jan. '91	225	28	48.3333	4.0000	193.3333	2336.111	16.0000	r = 9986	Significant at 0.01 level
Feb. '91	185	25	8.3333	1.0000	8.3333	69.444	1.0000		
Mar. '91	120	19	-56.6667	-5.0000	283.3333	3211.111	25.0000		
Total	**530**	**72**	**0.0000**	**0.0000**	**485.0000**	**5616.666**	**42.0000**		

Table 32. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under Disimasta jute cultivation during the months May July, 1991 in Plot "B"

1991	Soil population	% of soil moist.	X=x-x	M=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ = 10	Remarks
	X	M							
May '91	90	14	25.0000	-5.3333	-133.333	625.000	28.4444	r = 0.8691	Not significant
June '91	35	17	-30.0000	-2.3333	70.000	900.000	5.4444		
July '91	70	27	5.0000	7.6667	38.333	25.000	58.7778		
Total	**195**	**58**	**0**	**0**	**-25.000**	**1550.000**	**92.6667**		

Table 33. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under Ratna paddy cultivation during the months September November, 1991 in Plot "B"

1991	Soil population	% of soil moist.	X=x-x	M=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ = 99.3870	Remarks
	X	M							
Sep. '91	170	32	6.6667	6.3333	42.2222	44.4444	40.1111	r=0.9894	Significant at 0.02 level
Oct. '91	165	26	1.6667	0.3333	0.5556	2.7778	0.1111		
Nov. '91	155	19	-8.3333	-6.6667	55.5556	69.4444	44.4444		
Total	**490**	**77**	**0.0000**	**0.0000**	**98.3333**	**116.6667**	**84.6667**		

Table 34. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under wheat cultivation during the months January March, 1992 in Plot "B"

1992	Soil population	% of soil moist.	X=x-x	M=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ = 46.6667	Remarks
	X	M							
Jan. '92	110	21	16.6667	1.6667	27.7778	277.7778	2.7778	r =1.0000	Absolutely significant
Feb. '92	90	19	-3.3333	-0.3333	1.1111	11.1111	0.1111		
Mar. '92	80	18	-13.3333	-1.3333	17.7778	177.7778	1.7778		
Total	**280**	**58**	**0.0000**	**0.0000**	**46.6667**	**466.6667**	**4.6667**		

Table 35. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under Disimasta jute cultivation during the months May July, 1992 in Plot "B"

1992	Soil population	% of soil moist.	X=x-x	M=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ = 87.1780	Remarks
	X	M							
May '92	70	20	10	0.6667	6.6667	100.0000	0.4444	r =0.1147	Not significant
June '92	55	14	-5	-5.3333	26.6667	25.0000	28.4444		
July '92	55	24	-5	4.6667	-23.3333	25.0000	21.7778		
Total	**180**	**58**	**0**	**0**	**10.0000**	**150.0000**	**50.6667**		

3.5.3. Correlation in plot "C"

From the Table 36, the correlation coefficient (= r) calculated 0.796, indicates the positive correlation (significant at 0.10 level) between nematode population and soil temperature under Pankoj paddy cultivers. This may indicate that the higher soil temperature is a favourable force to build-up the soil nematode population.

Similarly, during the fallow period in the same plot (Table 37 and 40), the mean soil nematode population and soil temperature shows little decline, the correlation coefficient (= r) has been calculated 0, indicates the correlation not significant between the two factors.

Now instead of Pankoj paddy when these two factors i.e. soil nematode population and soil temperature in the Jalmasta jute cultivation in the same plot "C" (Table 38) are considered, the "r" value = -0.721, denotes the negative correlation (significant at 0.10 level).

Now if the correlation between the same two factors in the same plot "C" in the next year, 1991-1992, in the same cropping sequence Pankoj paddy – fallow period – Jalmasta jute (Tables 39, 40, 41), is considered, the "r" values being 0.978, 0, and -0.967 respectively, indicate that the favourable host like Pankoj paddy influence the nematodes and correlation significant at 0.001 level between the two factors, whereas in fallow period and in Jalmasta variety of jute, either the two factors show no correlation or negatively correlated with the nematode population respectively.

The correlation between the soil population and soil moisture in the same plot "C" in the same sequence of cropping like Pankoj paddy, fallow period and Jalmasta jute in the two consecutive years 1990-1991 and 1991-1992 (tables 42, 43, 44 and 45, 46, 47), either become significant at 0.10 level (Table 42) and 0.01 level (Table 45) during paddy cultivation or very much significant or absolute (Table 43 and 46) during fallow period. But when the plot "C" was cultivated with Jalmasta jute in March-July, 1991, the "r" was -0.005 (Table 44) or correlation was not significant between the two factors, soil population and soil moisture. The same result was obtained from the same plot which was followed by Jalmasta jute next year 1992 and the same result (Table 47) ("r" = -0.335) obtained and the correlation was not significant between the two factors.

Table 36. Correlation between the soil population of *H. gracilis* and soil temperature under Pankoj paddy cultivation during the months August December, 1990 in Plot "C"

1990	**Soil population**	**Temperature**	**X=x-x**	**Y=y-y**	**XY**	**X^2**	**Y^2**	**SQRT. of $X^2.Y^2$ = 627.8853**	**Remarks**
	X	**Y**							
Aug. '90	385	29	84	2	168	7056	4	r =0.7963	Significant at 0.10 level
Sep. '90	325	30	24	3	72	576	9		
Oct. '90	285	28	-16	1	-16	256	1		
Nov. '90	265	24	-36	-3	108	1296	9		
Dec. '90	245	24	-56	-3	168	3136	9		
Total	**1505**	**135**	**0**	**0**	**500**	**12320**	**32**		

Table 37. Correlation between the soil population of *H. gracilis* and soil temperature under Fallow period during the months January February, 1991 in Plot "C"

1991	Soil population X	Soil Temperature Y	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT. of $X^2.Y^2$ = 0	Remarks
Jan. '91	200	20	40	0	0	1600	0	r = 0	Not significant
Feb. '91	120	20	-40	0	0	1600	0		
Total	**320**	**40**	**0**	**0**	**0**	**3200**	**0**		

Table 38. Correlation between the soil population of *H. gracilis* and soil temperature under Jalmasta jute cultivation during the months March July, 1991 in Plot "C"

1991	Soil population X	Soil Temperature Y	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT. of $X^2.Y^2$ = 408.7053	Remarks
Mar. '91	105	23	27	-6	-162	729	36	r =0.7218	Significant at 0.10 level
Apr. '91	100	28	22	-1	-22	484	1		
May '91	85	31	7	2	14	49	4		
Jun '91	55	33	-23	4	-92	529	16		
July '91	45	30	-33	1	-33	1089	1		
Total	**390**	**145**	**0**	**0**	**-295**	**2880**	**58**		

Table 39. Correlation between the soil population of *H. gracilis* and soil temperature under Pankoj paddy cultivation during the months August December, 1991 in Plot "C"

1991	Soil population X	Soil Temperature Y	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT. of $X^2.Y^2$ = 522.3179	Remarks
Aug. '91	195	30	37	2.4	88.8	1369	5.76	r =0.9783	Significant at 0.001 level
Sep. '91	190	31	32	3.4	108.8	1024	11.56		
Oct. '91	165	29	7	1.4	9.8	49	1.96		
Nov. '91	135	25	-23	-2.6	59.8	529	6.76		
Dec. '91	105	23	-53	-4.6	243.8	2809	21.16		
Total	**790**	**138**	**0**	**0.00**	**511**	**5780**	**47.2**		

Table 40. Correlation between the soil population of *H. gracilis* and soil temperature under Fallow period during the months January February, 1992 in Plot "C"

1992	Soil population	Soil Temperature	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT. of $X^2.Y^2$ = 0	Remarks
	X	Y							
Jan. '92	80	20	5	0	0	25	0	r = 0	Not significant
Feb. '92	70	20	-5	0	0	25	0		
Total	**150**	**40**	**0**	**0**	**0**	**50**	**0**		

Table 41. Correlation between the soil population of *H. gracilis* and soil temperature under Jalmasta jute cultivation during the months March July, 1992 in Plot "C"

1992	Soil population	Soil Temperature	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT. of $X^2.Y^2$ = 304.7622	Remarks
	X	Y							
Mar. '92	55	21	18	-6	-108	324	36	r =0.9680	Negative correlation significant at 0.0 level
Apr. '92	50	26	13	-1	-13	169	1		
May '92	35	29	-2	2	-4	4	4		
Jun '92	25	29	-12	2	-24	144	4		
July '92	20	30	-17	3	-51	289	9		
Total	**185**	**135**	**0**	**0**	**-200**	**930**	**54**		

Table 42. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under Pankoj paddy cultivation during the months August December, 1990 in Plot "C"

1990	Soil population	% of Soil Moist.	X=x-x	Y=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ = 1009.9980	Remarks
	X	M							
Aug. '90	385	36	84	5.2	436.8	7056	27.04	r =0.7485	Significant at 0.10 level
Sep. '90	325	30	24	-0.8	-19.2	576	0.64		
Oct. '90	285	35	-16	4.2	-67.2	256	17.64		
Nov. '90	265	27	-36	-3.8	136.8	1296	14.44		
Dec. '90	245	26	-56	-4.8	268.8	3136	23.04		
Total	**1505**	**154**	**0**	**0**	**756**	**12320**	**82.8**		

Table 43. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under Fallow period during the months January- February, 1991 in Plot "C"

1991	Soil population	% of Soil Moist.	X=x-x	Y=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ = 40	Remarks
	X	M							
Jan. '91	200	19	40	0.5	20	1600	0.25	r = 1	Absolutely significant
Feb. '91	120	18	-40	-0.5	20	1600	0.25		
Total	**320**	**37**	**0**	**0**	**40**	**3200**	**0.5**		

Table 44. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under Jalmasta jute cultivation during the months March July, 1991 in Plot "C"

1991	Soil population	% of Soil Moist.	X=x-x	Y=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ = 897.9978	Remarks
	X	M							
Mar. '91	105	26	27	7	189	729	49	r = 0.0056	Not significant
Apr. '91	100	18	22	-1	-22	484	1		
May '91	85	12	7	-7	-49	49	49		
June '91	55	10	-23	-9	207	529	81		
July '91	45	29	-33	10	-330	1089	100		
Total	**390**	**95**	**0**	**0**	**-5**	**2880**	**280**		

Table 45. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under Pankoj paddy cultivation during the months August December, 1991 in Plot "C"

1991	Soil population	% of Soil Moist.	X=x-x	Y=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ = 574.9922	Remarks
	X	M							
Aug. '91	195	35	37	4.4	162.8	1369	19.36	r = 0.9496	Significant at 0.01 level
Sep. '91	190	33	32	2.4	76.8	1024	5.76		
Oct. '91	165	30	7	-0.6	-4.2	49	0.36		
Nov. '91	135	30	-23	-0.6	13.8	529	0.36		
Dec. '91	105	25	-53	-5.6	296.8	2809	31.36		
Total	**790**	**153**	**0**	**0**	**546**	**5780**	**57.2**		

Table 46. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under Fallow period during the months January February, 1992 in Plot "C"

1992	Soil population	% of Soil Moist.	X=x-x	Y=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ = 30	Remarks
	X	M							
Jan. '92	370	17	15	1	15	225	1	r = 1	Absolutely significant
Feb. '92	340	15	-15	-1	15	225	1		
Total	**710**	**32**	**0**	**0**	**30**	**450**	**2**		

Table 47. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under Jalmasta jute cultivation during the months March July, 1992 in Plot "C"

1992	Soil population	% of Soil Moist.	X=x-x	Y=m-m	XM	X^2	M^2	SQRT. of $X^2.M^2$ = 342.3156	Remarks
	X	M							
Mar. '92	55	27	18	6	108	324	36	r =0.3359	Not significant
Apr. '92	50	21	13	0	0	169	0		
May '92	35	17	-2	-4	8	4	16		
June '92	25	14	-12	-7	84	144	49		
July '92	20	26	-17	5	-85	289	25		
Total	**185**	**105**	**0**	**0**	**115**	**930**	**126**		

3.6.0. CORRELATION OF THE POPULATION OF *Hirschmanniella gracilis* WITH DIFFERENT CROPS OR SAME CROP

3.6.1 Correlation in plot "A"

The correlation between soil population of *H. gracilis* in Pankoj paddy and Jalmasta jute (Table 48) in the plot "A" has not become significant but when these population are compared between the two paddy crops (Table 50) grown in different years (1990-1991, 1991-1992) shows highly significant result (r = 0.982). The data proves that the population under different crops are not correlated but when the host is common, the two populations show strong correlation.

Correlation of soil nematode population available from cultivation of paddy and Jalmasta jute in the next season in the same plot (Table 49) has become significant at 0.01 level but the same has not become significant when population in Jalmasta jute grown in

1991 is compared with that of the same grown in 1992 (Table 51). The Jalmasta jute being the unfavourable host has little impact on the population build-up and the resultant population built under this crop has not shown any correlation.

Table 48. Correlation of the soil population of *H. gracilis* with Pankoj paddy and Jalmasta jute cultivation during the months August, 1990 July, 1991 in Plot "A"

Pankoj Paddy	**Jalmasta Jute**	**X = x-x**	**Y = y-y**	**XY**	**X^2**	**Y^2**	**SQRT of $X^2.Y^2$ = 7226.1331**	**Remarks**
x	**y**							
405	90	105	16	1680	11025	256	r =0.3079	Not significant
350	85	50	11	550	2500	121		
300	55	0	-19	0	0	361		
235	45	-65	-29	1885	4225	841		
210	95	-90	21	-1890	8100	441		
1500	**370**	**0**	**0**	**2225**	**25850**	**2020**		

Table 49. Correlation of the soil population of *H. gracilis* with Pankoj paddy and Jalmasta jute cultivation during the months August, 1991- July, 1992 in Plot "A"

Pankoj Paddy	**Jalmasta Jute**	**X = x-x**	**Y = y-y**	**XY**	**X^2**	**Y^2**	**SQRT of $X^2.Y^2$ = 3550.7182**	**Remarks**
x	**y**							
295	75	53	29	1537	2809	841	r =0.9547	Significant at 0.01 level
270	60	28	14	392	784	196		
240	35	-2	-11	22	4	121		
220	35	-22	-11	242	484	121		
185	25	-57	-21	1197	3249	441		
1210	**230**	**0**	**-3.55**	**3390**	**7330**	**1720**		

Table 50. Correlation of the soil population of *H. gracilis* with Pankoj paddy and Pankoj paddy cultivation during the months August, 1990 December, 1991 in Plot "A"

Pankoj Paddy 1990	**Pankoj Paddy 1991**	X = x-x	Y = y-y	XY	X^2	Y^2	**SQRT of $X^2.Y^2$ = 3765.1916**	**Remarks**
x	y							
405	295	105	53	5565	11025	2809	r =0.9826	Significant at 0.001 level
350	270	50	28	1400	2500	784		
300	240	0	-2	0	0	4		
235	220	-65	-22	1430	4225	484		
210	`185	-90	-57	5130	8100	3249		
1500	**1210**	**0**	**-3.55**	**13525**	**25850**	**7330**		

Table 51. Correlation of the soil population of *H. gracilis* with Jalmasta jute and Jalmasta jute cultivation during the months March, 1991- July, 1992 in Plot "A"

Jalmasta Jute 1991	**Jalmasta Jute 1992**	X = x-x	Y = y-y	XY	X^2	Y^2	**SQRT of $X^2.Y^2$ = 1863.9742**	**Remarks**
x	y							
90	75	16	29	464	256	841	r =0.3782	Not significant
85	60	11	14	154	121	196		
55	35	-19	-11	209	361	121		
45	35	-29	-11	319	841	121		
95	25	21	-21	-441	441	441		
370	**230**	**0**	**-3.55**	**705**	**2020**	**1720**		

3.6.2 Correlation in plot "B"

In plot "B" the crop like paddy, wheat and Disimasta jute grown in succession in two consecutive years (1990-1991 and 1991-1992) are shown in (Tables 52, 53, 54 and 55, 56, 57). The correlation has been calculated between paddy–wheat, paddy–Disimasta jute and wheat–Disimasta jute. These results proved that either they have no correlation or very weakly correlated, viz. between wheat and Disimasta (r = 0.944) significant at 0.10 level or between Ratna paddy and wheat (r = 0.928) significant at 0.10 level.

But when the nematode population of the same crop grown in different years, i.e. paddy nematode population (Table 58) and wheat nematode population (Table 59) of 1991-1992, grown in different seasons are compared and similarly the Disimasta nematode population (Table 60) is compared with the same, grown in different seasons, the correlation shows either insignificant or very little significant (wheat 1991 and wheat 1992; r = 0. 947) at 0.10 level.

Table 52. Correlation of the soil population of *H. gracilis* with Pankoj paddy and wheat cultivation during the months August, 1990 March, 1991 in Plot "B"

Pankoj Paddy	**Wheat**	**X = x-x**	**Y = y-y**	**XY**	**X^2**	**Y^2**	**SQRT of $X^2.Y^2$ = 1589.8113**	**Remarks**
x	**y**							
325	225	0	48.3333	0	0	2336.1111	r =0.6133	Not significant
340	185	15	8.3333	125.00	225.00	69.4444		
310	120	-15	-56.6667	850.00	225.00	3211.1111		
975	**530**	**0**	**0.0000**	**975.00**	**450.00**	**5616.6667**		

Table 53. Correlation of the soil population of *H. gracilis* with Pankoj paddy and Disimasta jute cultivation during the months of August, 1990 July, 1991 in Plot "B"

Pankoj Paddy	**Disimasta Jute**	**X = x-x**	**Y = y-y**	**XY**	**X^2**	**Y^2**	**SQRT of $X^2.Y^2$ = 835.1647**	**Remarks**
x	**y**							
325	90	0	25	0	0	625	r =0.6286	Not significant
340	35	15	-30	-450	225	900		
310	70	-15	5	-75	225	25		
975	**195**	**0**	**0**	**-525**	**450**	**1550**		

Table 54. Correlation of the soil population of *H. gracilis* with wheat and Disimasta jute cultivation during the months January, 1991- July, 1991 in Plot "B"

Wheat	Disimasta Jute	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT of $X^2.Y^2$ = 2950.5649	Remarks
x	y							
225	90	48.3333	25	1208.3333	2336.11	625.00	r =0.2288	Not significant
185	35	8.33333	-30	-250.0000	69.44	900.00		
120	70	-56.667	5	-283.3333	3211.11	25.00		
530	**195**	**0**	**0**	**675.0000**	**5616.66**	**1550.00**		

Table 55. Correlation of the soil population of *H. gracilis* with wheat and Disimasta jute cultivation during the months January, 1992- July, 1992 in Plot "B"

Wheat	Disimasta Jute	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT of $X^2.Y^2$ = 264.5751	Remarks
x	y							
110	70	16.6667	10.0000	166.6667	277.7778	100.0000	r =0.9449	Significant at 0.10 level
90	55	-3.3333	-5.0000	16.6667	11.1111	25.0000		
80	55	-13.3333	-5.0000	66.6667	177.7778	25.0000		
280	**180**	**0.0000**	**0.0000**	**250.0000**	**466.6667**	**150.0000**		

Table 56. Correlation of the soil population of *H. gracilis* with Ratna paddy and wheat cultivation during the months September, 1991 March, 1992 in Plot "B"

Ratna Paddy	Wheat	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT of $X^2.Y^2$ = 233.3333	Remarks
x	y							
170	110	6.6667	16.6667	111.1111	44.4444	277.7778	r =0.9286	Significant at 0.10 level
165	90	1.6667	-3.3333	-5.5556	2.7778	11.1111		
155	80	-8.3333	-13.3333	111.1111	69.4444	177.7778		
490	**280**	**0.0000**	**0.0000**	**216.6667**	**116.6667**	**466.6667**		

Table 57. Correlation of the soil population of *H. gracilis* with Ratna paddy and Disimasta jute cultivation during the months September, 1991 July, 1992 in Plot "B"

Ratna Paddy	Disimasta Jute	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT of $X^2.Y^2$ = 132.2875	Remarks
x	y							
170	70	6.66667	10	66.6666	44.4444	100	r =0.75592	Not significant
165	55	1.66667	-5	-8.33333	2.77777	25		
155	55	-8.3333	-5	41.6666	69.4444	25		
490	**180**	**0**	**0**	**100**	**116.6667**	**150**		

Table 58. Correlation of the soil population of *H. gracilis* with Pankoj paddy and Ratna paddy cultivation during the months August, 1990 November, 1991 in Plot "B"

Pankaj Paddy	Ratna Paddy	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT of $X^2.Y^2$ = 229.1288	Remarks
x	y							
325	170	0	6.66667	0	0	44.4444	r =0.6547	Not significant
340	165	15	1.66667	25	225	2.7778		
310	155	-15	-8.3333	125	225	69.4444		
975	**490**	**0**	**0.00**	**150**	**450**	**116.6667**		

Table 59. Correlation of the soil population of *H. gracilis* with wheat and wheat cultivation during the months January, 1991 March, 1992 in Plot "B"

Wheat 1991	Wheat 1992	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT of $X^2.Y^2$ = 1618.9846	Remarks
x	y							
225	110	48.3333	16.6667	805.5556	2336.1111	277.7778	r =0.9471	Significant at 0.10 level
185	90	8.33333	-3.3333	-27.7778	69.4444	11.1111		
120	80	-56.667	-13.3333	755.5556	3211.1111	177.7778		
530	**280**	**0**	**0.0000**	**1533.3333**	**5616.6667**	**466.6667**		

Table 60. Correlation of the soil population of *H. gracilis* with Disimasta jute and Disimasta jute cultivation during the months May, 1991 July, 1992 in Plot "B"

Disimasta Jute	Disimasta Jute	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT of $X^2.Y^2$ = 482.1825	Remarks
x	y							
90	70	25	10	250	625	100	r =0.7777	Not significant
35	55	-30	-5	150	900	25		
70	55	5	-5	-25	25	25		
195	**180**	**0**	**0**	**375**	**1550**	**150**		

3.6.3 Correlation in plot "C"

In case of a third plot, i.e. "C", only two types of crops were grown, Pankoj paddy and Jalmasta jute. The population under Pankoj paddy and that with Jalmasta jute, in both the years 1990-1991 and 1991-1992 (Table 61 and 62), are compared. A significant correlation is apparent in both the seasons (r = 0.899 and 0.968) respectively. But when the population associated with the same crop, i.e. either Pankoj paddy with Pankoj paddy (Table 63) or Jalmasta jute with Jalmasta jute (Table 64) are compared, the correlation between them also proved to be significant (r = 0.895 and 0.974 respectively).

Table 61. Correlation of the soil population of *H. gracilis* with Pankoj paddy and Jalmasta jute cultivation during the months August, 1990 July, 1991 in Plot "C"

Pankaj Paddy	Jalmasta Jute	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT of $X^2.Y^2$ = 5956.6434	Remarks
x	y							
385	105	84	27	2268	7056	729	r =0.8998	Significant at 0.02 level
325	100	24	22	528	576	484		
285	85	-16	7	-112	256	49		
265	55	-36	-23	828	1296	529		
245	45	-56	-33	1848	3136	1089		
1505	**390**	**0**	**0**	**5360**	**12320**	**2880**		

Table 62. Correlation of the soil population of *H. gracilis* with Pankoj paddy and Jalmasta jute cultivation during the months August, 1991- July, 1992 in Plot "C"

Pankaj Paddy	**Jalmasta Jute**	**X=x-x**	**Y=y-y**	**XY**	**X^2**	**Y^2**	**SQRT of $X^2.Y^2$ = 2318.4909**	**Remarks**
x	**y**							
195	55	37	18	666	1369	324	r =0.9683	Significant at 0.01 level
190	50	32	13	416	1024	169		
165	35	7	-2	-14	49	4		
135	25	-23	-12	276	529	144		
105	20	-53	-17	901	2809	289		
790	**185**	**0**	**-3.55**	**2245**	**5780**	**930**		

Table 63. Correlation of the soil population of *H. gracilis* with Pankoj paddy and Pankoj paddy cultivation during the months August, 1990 July, 1992 in Plot "C"

Pankaj Paddy 1990	**Pankaj Paddy 1991**	**X=x-x**	**Y=y-y**	**XY**	**X^2**	**Y^2**	**SQRT of $X^2.Y^2$ = 8438.5781**	**Remarks**
x	**y**							
385	195	84	37	3108	7056	1369	r =0.8959	Significant at 0.02 level
325	190	24	32	768	576	1024		
285	165	-16	7	-112	256	49		
265	135	-36	-23	828	1296	529		
245	105	-56	-53	2968	3136	2809		
1505	**790**	**0**	**-3.55**	**7560**	**12320**	**5780**		

Table 64. Correlation of the soil population of *H. gracilis* with Jalmasta jute and Jalmasta jute cultivation during the months August, 1991- July, 1992 in Plot "C"

Jalmasta Jute 1991	Jalmasta Jute 1992	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT of $X^2.Y^2$ = 1636.5818	Remarks
x	y							
105	55	27	18	486	729	324	r =0.9746	Significant at 0.001 level
100	50	22	13	286	484	169		
85	35	7	-2	-14	49	4		
55	25	-23	-12	276	529	144		
45	20	-33	-17	561	1089	289		
390	**185**	**0**	**-3.55**	**1595**	**2880**	**930**		

3.7.0. CORRELATION IN PLOT "D"

The correlation between soil population of *H. gracilis* and soil temperature has been assessed at plot "D" under cultivation of Masuiry paddy (Table 65) and Ratna paddy (Table 66) in two consecutive years 1990-1991 and 1991-1992 (Tables 67 and 68). The correlation between the two factors under Masuiry paddy is not significant in both the years but the same under Ratna paddy (1990-1991) is highly significant (r = 0.996) at 0. 001 level but insignificant in 1991-1992.

When we do concentrate on the correlation between soil population and soil moisture in the same plot "D", in the same sequence of cropping season in the same two consecutive years of 1990-1991 and 1991-1992 (Tables 69, 70, 71 and 72), the soil moisture could not maintain significant correlation with the nematode population either under the cultivation of Masuiry paddy or Ratna paddy.

Table 65. Correlation between the soil population of *H. gracilis* and soil temperature under Masuiry paddy cultivation uring the months August November, 1990 at 0-10 cm depth in Plot "D"

1990	Soil pollu-tion	Soil Tempe-rature	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT of $X^2.Y^2$ = 555.0760	Remarks
	x	y							
Aug.'90	647.5	28	93.125	-2	-186.3	8672.3	4	r =0.0811	Not significant
Sep.'90	537.5	33	-16.875	3	-50.63	284.77	9		
Oct.'90	567.5	31	13.125	1	13.125	172.27	1		
Nov.'90	465	28	-89.375	-2	178.75	7987.9	4		
Total	**2217.5**	**120**	**0**	**0**	**-45**	**17117**	**18**		

Table 66. Correlation between the soil population of *H. gracilis* and soil temperature under Ratna paddy cultivation during the months February May, 1991 at 0-10 cm depth in Plot "D"

1991	Soil pollution	Soil Temperature	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT of $X^2.Y^2$ = 453.8998	Remarks
	x	y							
Feb.'91	235	19	-40	-7	280	1600	49	r =0.9969	Significant at 0.001 level
Mar.'91	272.5	25	-2.5	-1	2.5	6.25	1		
Apr.'91	297.5	30	22.5	4	90	506.25	16		
May '91	295	30	20	4	80	400	16		
Total	**1100**	**104**	**0**	**0**	**452.5**	**2513**	**82**		

Table 67. Correlation between the soil population of *H. gracilis* and soil temperature under Masuiry paddy cultivation during the months August November, 1991 at 0-10 cm depth in Plot "D"

1991	Soil pollution	Soil Temperature	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT of $X^2.Y^2$ = 1085.2721	Remarks
	x	y							
Aug.'91	650	30	144.375	1	144.38	20844	1	r =0.3225	Not significant
Sep.'91	600	31	94.375	2	188.75	8906.6	4		
Oct.'91	272.5	29	-233.125	0	0	54347	0		
Nov.'91	500	26	-5.625	-3	16.875	31.641	9		
Total	**2022.5**	**116**	**0**	**0**	**350**	**84130**	**14**		

Table 68. Correlation between the soil population of *H. gracilis* and soil temperature under Ratna paddy cultivation during the months February May, 1992 at 0-10 cm depth in Plot "D"

1991	Soil pollution	Soil Temperature	X=x-x	Y=y-y	XY	X^2	Y^2	SQRT of $X^2.Y^2$ = 179.4098	Remarks
	x	y							
Feb.'91	292.5	20	-13.125	-5.75	75.469	172.27	33.0625	r =0.5191	Not significant
Mar.'91	317.5	25	11.875	-0.75	-8.906	141.02	0.5625		
Apr.'91	295	28	-10.625	2.25	-23.91	112.89	5.0625		
May '91	317.5	30	11.875	4.25	50.469	141.02	18.0625		
Total	**1222.5**	**103**	**0**	**0**	**93.13**	**567.2**	**56.75**		

Table 69. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under Masuiry paddy cultivation during the months August November, 1990 at 0-10 cm depth in Plot "D"

1990	Soil pollu-tion	% of Soil moisture	X=x-x	M=m-m	XY	X^2	M^2	SQRT of $X^2.M^2$ = 932.0393	Remarks
	x	y							
Aug.'90	647.5	30	93.125	1.25	116.4063	8672.266	1.5625	r =0.3507	Not significant
Sep.'90	537.5	34	-16.875	5.25	-88.5938	284.7656	27.5625		
Oct.'90	567.5	26	13.125	-2.75	-36.0938	172.2656	7.5625		
Nov.'90	465	25	-89.375	-3.75	335.1563	7987.891	14.0625		
Total	**2217.5**	**115**	**0**	**0**	**326.875**	**17117.2**	**50.75**		

Table 70. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under Ratna paddy cultivation during the months February May, 1991 at 0-10 cm depth in Plot "D"

1990	Soil pollu-tion	% of Soil moisture	X=x-x	M=m-m	XY	X^2	M^2	SQRT of $X^2.M^2$ = 427.5329	Remarks
	x	y							
Feb.'91	235	20	-40	-6.25	250	1600	39.0625	r =0.5731	Not significant
Mar.'91	272.5	32	-2.5	5.75	-14.375	6.25	33.0625		
Apr.'91	297.5	26	22.5	-0.25	-5.625	506.25	0.0625		
May '91	295	27	20	0.75	15	400	0.5625		
Total	**1100**	**105**	**0**	**0**	**245**	**2512.5**	**72.75**		

Table 71. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under Masuiry paddy cultivation during the months August November, 1991 at 0-10 cm depth in Plot "D"

1990	**Soil pollution**	**% of Soil moisture**	X=x-x	M=m-m	XY	X^2	M^2	**SQRT of $X^2.M^2$ = 1715.9659**	**Remarks**
	x	**y**							
Aug.'91	650	35	144.375	3.5	505.3125	20844.14	12.25	r =0.4597	Not significant
Sep.'91	600	33	94.375	1.5	141.5625	8906.641	2.25		
Oct.'91	272.5	31	-233.125	-0.5	116.5625	54347.27	0.25		
Nov.'91	500	27	-5.625	-4.5	25.3125	31.64063	20.25		
Total	**2022.5**	**126**	**0**	**0**	**788.75**	**84129.7**	**35**		

Table 72. Correlation between the soil population of *H. gracilis* and percentage of soil moisture under Ratna paddy cultivation during the months February May, 1992 at 0-10 cm depth in Plot "D"

1990	**Soil pollution**	**% of Soil moisture**	X=x-x	M=m-m	XY	X^2	M^2	**SQRT of $X^2.M^2$ = 296.2638**	**Remarks**
	x	**y**							
Feb.'92	292.5	35	-13.125	7.25	-95.1563	172.2656	52.5625	r =0.4029	Not significant
Mar.'92	317.5	32	11.875	4.25	50.46875	141.0156	18.0625		
Apr.'92	295	25	-10.625	-2.75	29.21875	112.8906	7.5625		
May '92	317.5	19	11.875	-8.75	-103.906	141.0156	76.5625		
Total	**1222.5**	**111**	**0**	**0**	**-119.38**	**567.188**	**154.75**		

3.7.1. CORRELATION IN PLOT "E"

The observations available from another plot "E" where the plot was kept fallow for continuous two years. The data (Table 73) shows that the two factors, soil population and soil temperature, have no correlation or negatively insignificant.

But when we do consider the correlation between soil population and soil moisture in the same plot "E", under same fallow period of continuous two years, December 1990-November 1992, the correlation become significant (r = 0.384, Table 74) at 0.05 level.

Table 73. Correlation between the soil population of *H. gracilis* with soil temperature in Fallow period during the months December, 1990 November, 1992 in Plot "E"

Months -years	Soil population x	Soil temperature t	X = x -x	T = t-t	XT	X^2	T^2		Remarks
Dec. '90	255	22	137.083	-4.208	-576.9	18791.8	17.7		Not significant
Jan. '91	255	20	137.083	-6.208	-851.1	18791.8	38.5	SQRT of $X^2.T^2$ = 12365.9742	
Feb. '91	165	19	47.0833	-7.208	-339.4	2216.84	52		
Mar. '91	110	23	-7.9167	-3.208	25.399	62.6736	10.3		
Apr. '91	80	27	-37.917	0.7917	-30.02	1437.67	0.63		
May '91	50	27	-67.917	0.7917	-53.77	4612.67	0.63		
June '91	30	34	-87.917	7.7917	-685	7729.34	60.7	r value for soil population & temperature = -0.227	
July '91	45	30	-72.917	3.7917	-276.5	5316.84	14.4		
Aug. '91	275	29	157.083	2.7917	438.52	24675.2	7.79		
Sep. '91	280	30	162.083	3.7917	614.57	26271	14.4		
Oct. '91	195	29	77.0833	2.7917	215.19	5941.84	7.79		
Nov. '91	140	25	22.0833	-1.208	-26.68	487.674	1.46		
Dec. '91	125	24	7.08333	-2.208	-15.64	50.1736	4.88		
Jan. '92	105	20	-12.917	-6.208	80.191	166.84	38.5		
Feb. '92	85	20	-32.917	-6.208	204.36	1083.51	38.5		
Mar. '92	50	22	-67.917	-4.208	285.82	4612.67	17.7		
Apr. '92	40	27	-77.917	0.7917	-61.68	6071.01	0.63		
May '92	25	30	-92.917	3.7917	-352.3	8633.51	14.4		
June '92	15	30	-102.92	3.7917	-390.2	10591.8	14.4		
July '92	30	30	-87.917	3.7917	-333.4	7729.34	14.4		
Aug. '92	120	29	2.08333	2.7917	5.816	4.34028	7.79		
Sep. '92	185	30	67.0833	3.7917	254.36	4500.17	14.4		
Oct. '92	90	28	-27.917	1.7917	-50.02	779.34	3.21		
Nov. '92	80	24	-37.917	-2.208	83.733	1437.67	4.88		
Total	**2830**	**629**	**0**	**0**	**-1835**	**161996**	**400**		

Table 74. Correlation between the soil population of *H. gracilis* with percentage of soil moisture in Fallow period during the months December, 1990 November, 1992 in Plot "E"

Months -years	Soil population x	% Soil moisture t	X = x -x	T = t-t	XT	X^2	T^2		Remarks
Dec. '90	255	17	137.08	-1.2083	-166	18791.8	1.46		significant at 0.05 level
Jan. '91	255	20	137.08	1.7917	245.6	18791.8	3.21	SQRT of $X^2.T^2$ = 12365.9742	
Feb. '91	165	18	47.083	-0.2083	-9.81	2216.84	0.043		
Mar. '91	110	16	-7.917	-2.2083	17.48	62.6736	4.877		
Apr. '91	80	16	-37.92	-2.2083	83.73	1437.67	4.877		
May '91	50	14	-67.92	-4.2083	285.8	4612.67	17.71		
June '91	30	11	-87.92	-7.2083	633.7	7729.34	51.96	r value for soil population & soil moisture = -0.384	
July '91	45	26	-72.92	7.7917	-568	5316.84	60.71		
Aug. '91	275	24	157.08	5.7917	909.8	24675.2	33.54		
Sep. '91	280	21	162.08	2.7917	452.5	26271	7.793		
Oct. '91	195	18	77.083	-0.2083	-16.1	5941.84	0.043		
Nov. '91	140	18	22.083	-0.2083	-4.6	487.674	0.043		
Dec. '91	125	16	7.0833	-2.2083	-15.6	50.1736	4.877		
Jan. '92	105	15	-12.92	-3.2083	41.44	166.84	10.29		
Feb. '92	85	13	-32.92	-5.2083	171.4	1083.51	27.13		
Mar. '92	50	10	-67.92	-8.2083	557.5	4612.67	67.38		
Apr. '92	40	10	-77.92	-8.2083	639.6	6071.01	67.38		
May '92	25	8	-92.92	-10.2083	948.5	8633.51	104.2		
June '92	15	13	-102.9	-5.2083	536	10591.8	27.13		
July '92	30	25	-87.92	6.7917	-597	7729.34	46.13		
Aug. '92	120	28	2.0833	9.7917	20.4	4.34028	95.88		
Sep. '92	185	32	67.083	13.7917	925.2	4500.17	190.2		
Oct. '92	90	29	-27.92	10.7917	-301	779.34	116.5		
Nov. '92	80	19.00	-37.92	0.7917	-30	1437.67	0.627		
Total	**2830**	**437**	**0.00**	**0.0000**	**4760**	**161996**	**944**		

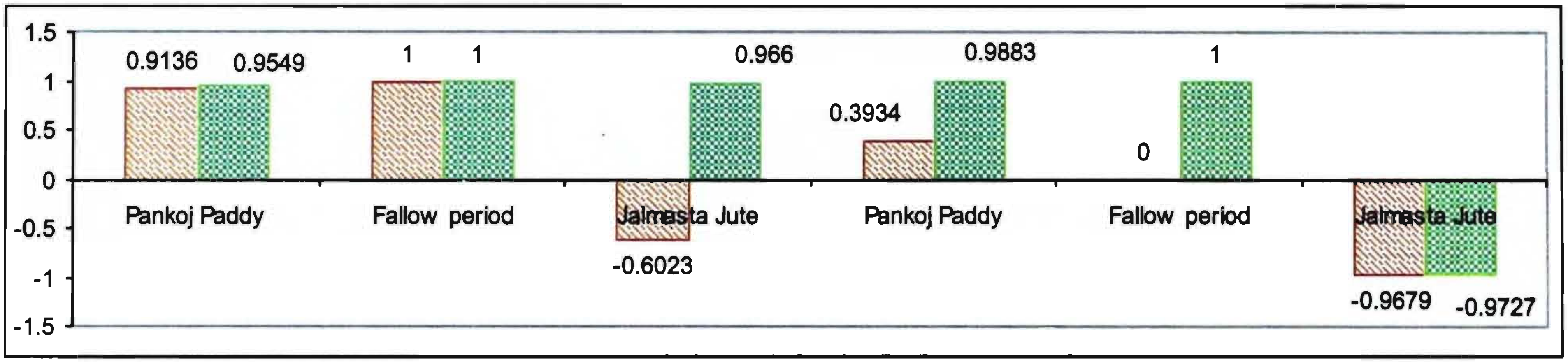


Fig. 54. Correlation on the population of *H. gracilis* with soil temperature & % of soil moisture at Plot "A" during 1990 -1992.

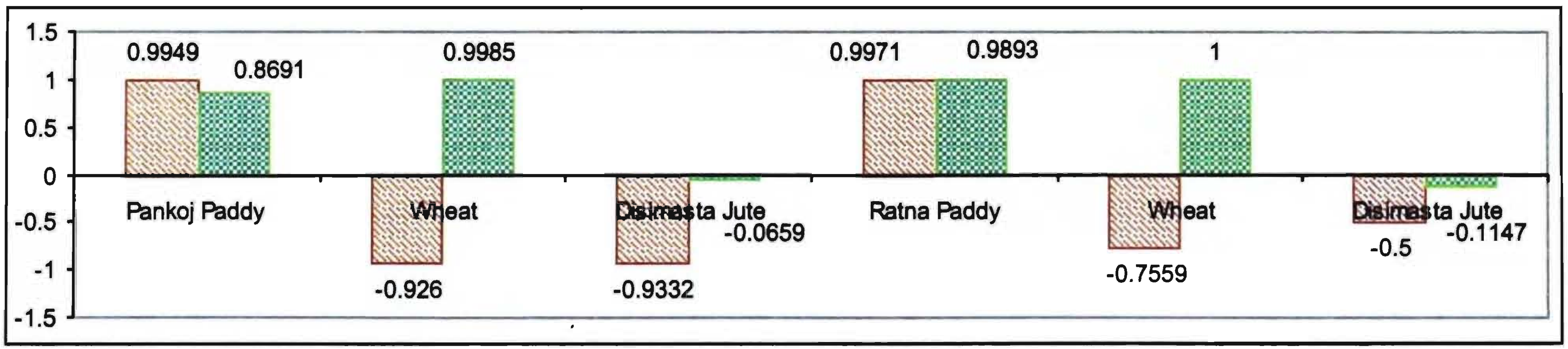


Fig. 55. Correlation on the population of *H. gracilis* with soil temperature & % of soil moisture at Plot "B" during 1990-1992.

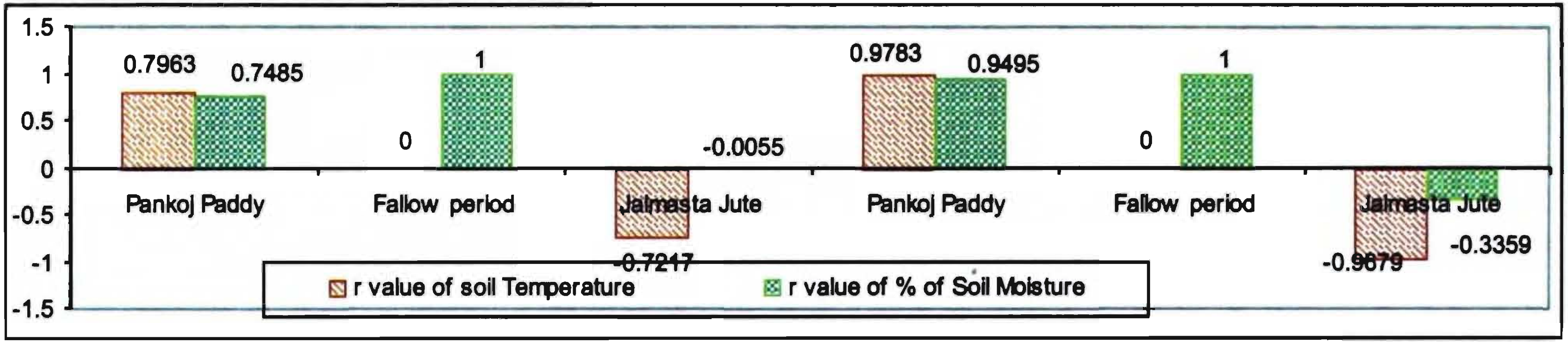


Fig. 56. Correlation on the population of *H. gracilis* with soil temperature & % of soil moisture at Plot "C" during 1990-1992

4.0. DISCUSSION

Paddy wheat and jute are the main cash crop of India. These crops are very much affected by the phytonematodes. However, our knowledge is very meagre on nematodes associates with paddy crop. Thirty five nematode species so far are recorded from the soil associated with paddy crop in india (Baqri and Das, 1990). The quantitative study reveals that the frequency of occurrence of *Hirschmanniella gracilis* is the highest about, 83% in the soil sample of paddy field. This nematode is considered as the key nematode pest of paddy and is most abundant and dominant species (Baqri *et al.* 1983) in West Bengal, India.

The present work reports ten species of phytonematodes, *Helicotylenchus indicus, Hirschmanniella gracilis, Dorylaimus innovatus, Calodorylaimus indicus, Laimydorus siddiqii, L. baldus, Sicaguttur sartum, Aporcelaimellus heynsi, A. tropicus* and *Laevides laevis,* from the soil samples associated with paddy, wheat and jute crop in five selected plots at Rautara village of West Bengal, India. Other than *H. gracilis,* all the nematodes described here, are placed under "other nematodes" to focus on the importance of *H. gracilis*. although some parasites are also available in the soil samples growing wheat and jute.

The genus *Helicotylenchus* (Steiner 1945) Sher, 1966 shows the main features as (i) shape of lip region (ii) perperesente or absence of annuls on the lips, (iii) shape of stylet knobs, size of stylet, (iv) shape of tail, number of tail annuls and (v) position of plasmid in relation to anus. Sher (1966), after examining topotypes, described the lip region to be truncted and stylet knob with sloping interior surfaces. In case of *H. cavelessi* Sher, 1966, the lip region is usually hemispherical. Sher (1966) stated that lip region sometimes appears to be flattened anteriorly. In *H. lobus* Sher, 1966 and *H. exallus* Sher, 1966 the tail shape and shape of stylet knob are variable from rounded to flattened or slightly indented anteriorly.

Considering different characters and comparing them, the present forms are identified and fits well with *Helicotylenchus indieus* Siddiqi, 1963.

Hirschmanniella gracilis (de Man, 1880) Luc & Goodey, 1964 is the key pest of paddy crop in West Bengal which is one of the major rice producing states in India (Baqri *et al.*, 1983 Dey and Baqri, 1985, Baqri & Das 1991). Sivakumar and Khan (1982) in their key to species of *Hirschmanniella* have reported *H. gracilis* from *H. oryzae* (Soltwedel, 1889) Luc & Goodey, 1963 basing on the characters (i) Lateral fields completely or incompletely areolated and excretory pore opposite to oesophago-intestinal valve in *H. gracilis* against lateral fields incompletely areolated or not and excretory pore posterior to oesophago-intestinal valve in *H. oryzae.* Dey and Baqri (1986) showed the position of excretory pore varies from anterior to posterior of oesophago-intestinal valve and stated that the position of excretory pore should not be used as a key characters in the identification of *H. gracilis* and the visibility of areolation in the lateral fields depends upon the fixation and thus can not be used to differentiate the species from closely related species, and the stylet length should always be used as a key or main character to differentiate *H. gracilis* from *H. oryzae* (stylet length 20-23 mm in *H. gracilis* against 15-19 mm in *H. oryzae*). They also reveals that the males of *H. gracilis* can further be differentiated from *Male H. gracilis* in having bigger spicules (27-38 mm long against 18-26 mm in *H. oryzae*).

Comparing them and considering the different characters, the present form is identified and fit well with *Hirschmanniella gracilis* (de Man 1880), Luc & Goodey, 1964.

The present form *Dorylaimus innovatus* Jana and Baqri, 1982 comes closer to *D. stagnalis* Dujardin 1845. Jana and Baqri (1982) stated that it differs in having differently shaped in lip region marked by a depression and longer spicules and subventral papillae extending up to intestine-pre-rectum junction in *Male* whereas in *D. stagnalis,* the lips prominent, spicules 100 mm and subventral papillae restricted up to ventromedian supplement region. Jana and Baqri (1982) shows some important features as odontostyle 47-52 mm, guiding ring at 25-30 mm from anterior end, odontophore 47-52 mm, spicules 110 mm long, copulatory muscle in large number, extending above the supplement region. Pre-rectum 520 mm long. Tail short, bluntly rounded, 34 mm long.

Comparing and considering the different characters the present form, fits well with and identified as *Dorylaimus innovatus* Jana and Baqri, 1982.

Calodorylaimus indicus Ahmad and Jairajpuri, 1982 differs from its closer species *C. oclo* Andrassy, 1969 in having smaller body, in the shape of the lip region, in having shorter odontostyle, longer oesophagus, posterior vulva and smaller spicules (L = 3.0-3.6 mm; b = 6.0, V = 36-37, odontostyle = 32-35 and spicules = 57-60 mm in *C. oclo*).

The present form is identified and fits well as *Calodorylaimus indicus* Ahmad and Jairajpuri, 1982.

The species *Laimydorus siddiqii* Baqri and Jana, 1982 comes close to *L. finalis* Thorne, 1975 and *L. thornei* Andrassy, 1969. It is shorter than *L. finalis*, with a longer tail and shorter odontostyle (L = 3.8 mm, c = 17). Odontostyle is 45 mm in *L. finalis.* The present form has a more anteriorly situated guiding ring than *L. thornei* and a shorter tail and longer pre-rectum (guiding ring 1.5 lip region-width, C = 4.5 and pre-rectum as long as the rectum in *L. thornei*).

The main features of the present species odontostyle 29-31 mm long, odontophore 31-37 mm long; Nerve-ring at 137-159 mm from anterior end cardia tongue-shaped, 20-25 mm long. Prerectum 177-208 mm and rectum 33-35 mm long, filiform, 322-363 mm long, tail are similar to and fits well with *Laimydorus siddiqii* Baqri and Jana, 1982.

The species *Laimydorus baldus* Baqri and Jana, 1982 under report resembles *L. gazella* Andrassy, 1970 and *L. stenopygus* (Andrassy, 1968) Siddiqi, 1969. It differs from

L. gazella in having amalgamated lips, marked by a slight depression and narrower than adjoining body, shorter odontostyle, and the *Male* having 53 mm long spicules, lips distinct, lip region marked by a constriction and wider than adjoining body, odontostyle 28-29 mm. The *Male L. gazella* possesses 58 mm long spicules. The present species differs from *L. stenopygus* in having amalgamated lips, marked by a depression and narrower than adjoining body, differently shaped amphids and a shorter oesophagus. In *L. stenopygus* the lips distinct, lip region marked by a constriction and wider than adjoining body, and b = 4.0 - 4.3.

The present form shows the important features as odontostyle 24-25 mm, guiding ring 14-15 mm from anterior end, odontophore 29-30 mm long, nerve ring at 137-147mm from anterior end, cardia 18-20 mm, elongated with rounded terminus, pre-rectum 122-157 mm, rectum 40-45 mm long, spicules 53 mm, male tail bluntly rounded, 29 mm long which is similar and fits well with the species described by Baqri and Jana (1982). Thus the present form, is identified as *Laimydorus baldus* Baqri and Jana, 1982.

The species *Sicaguttur sartum* Siddiqi 1971, in the present observation, shares all the morphological features as described by Siddiqi (1971). In view of the dissimilar tails found in two sexes of *Sicaguttur sartum* Siddiqi, 1971 from West Bengal, males being reported for the first time, diagnosis of the genus *Sicaguttur* Siddiqi, 1971 is emended by Baqri and Jana (1980). *Mehdinema prabhae* n. gen., n. sp. is proposed for *S. sartum* by Ali and Prabha, 1974. *Mehdinema* Ali and Prabha, 1974 differs from *Sicaguttur* Siddiqi, 1974 mainly in having similar tails in both sexes *Mehdinema indicum* (Ali and Prabha, 1974) n. comb. is proposed for *Sicaguttur indicum. Mehdinema coomansi* Baqri and Jana, 1980 is also described from West Bengal and is compared with *M. prabhae* and *M. indicum*. After comparing the paratype females of *Thornenema wickeni* Yeates, 1970 with the Indian specimens having similar tails in the sexes which were identified as *T. wickeni* by Ali and Prabha (1974). They proposed a new genus *Indodorylaimus*. But Baqri and Jana (1980) concluded that Ali and Prabha misidentified the Indian specimens *T. wickeni* and is well placed under *Thornenema*.

Baqri and Jana shows the important features of *Sicaguttur sartum* as odontostyle 14 - 17 mm, Odontophore 22 - 27 mm long, guiding ring 9 -10 mm, nerve ring 114 -125 mm from anterior end. Pre-rectum 50 - 90 mm and rectum 31-39 mm long. Tail ranges from 97-279 mm long.

Aporcelaimellus heynsi comes close to *Aporcelaimellus paraconicaudatus* (Meyl, 1956) Heyns, 1965 but differs in having a shorter spear, 16m in *A. paraconicaudatus*, slender body a = 21-22 in *A. paraconicaudatus* and differently shaped tail. *A. heynsi* Baqri and Jairajpuri, 1968, also comes close to *Aporcelaimellus tropicus* Jana and Baqri, 1981.

Baqri and Jairajpuri (1968) shows the important features in having longer body (L = 0.98 - 1.22 mm in *A. heynsi*), longer odontophore, 17-19 mm, pre-rectum 52-75 mm, rectum 21-24 mm long, shorter and bluntly conoid tail, 29-41 mm long in *A. heynsi*.

Comparing and considering the characteristics present specimen fits well and identified as *Aporcelaimellus heynsi* Baqri and Jairajpuri, 1968.

Another species of the genus *Aporcelaimellus* Heyns, 1965 resembles *A. heynsi* Baqri and Jairajpuri 1968 and *A. paraconicaudatus* (Meyl, 1956) Heyns, 1965. From the former it differs in having longer body (L = 0.98 - 1.22 mm in *A. hensi*), larger odontophore (odontophore 17-19 mm in *A. hensi*), differently shaped vagina, no oesophago-intestinal disc, shorter and bluntly conoid tail (tail 29-41 mm long and conoid in *A. heynsi*). From *A. paraconicaudatus* the present species differs in shorter odontostyle (odontostyle 16 mm in *A. paraconicaudatus*), longer and differently shaped tail (c = 25, and conoid tail in *A. paraconicaudatus*); shorter spicules and 3 to 5 ventromedian-supplements in males (spicules more than 50 mm and 14-16 ventromedian supplements in *A. paraconicaudatus*).

The present species (*A. tropicus*), fits well with *Aporcelaimellus tropicus* Jana and Baqri, 1981 in all respects and identified as *A. tropicus* Jana and Baqri, 1981.

The species of genus *Laevides* Heyns, 1968 described here agrees fairly well with those described by Thorne (1939) and Heyns (1968) except in having a slightly longer tooth, differently shaped tail and in having posterior vulva.

Thorne (1974) showed the features of *Laevides laevis* as lip region continuous with body contour, tooth measuring 8 -10 mm, oesophagus = 39 - 520 mm, pre-rectum 40 - 60 mm, rectum 20 -25 mm, tail 26 -27 mm long, spicules 35 - 42 mm long, and gubernaculum 6-8 mm long.

The present species fits well and indentified as Laevides laevis (Thorne, 1939) Thorne 1974.

The maximum number of male population of *H. gracilis* in the present study, was found in the upper depth (0-10 cm) in October in both the years, 1990 and 1991, under Masuiry variety of paddy cultivers whereas at the same depth the lowest number was noted during January, 1991 and 1992 when the plot was kept fallow. On the other hand, in the depth of 10-20 cm, the number of males are less than upper layer during the study period. The soil temperature and soil moisture varies from 19-34 ^{0}C and 15-35% respectively during the study period.

The seasonal variations in the population of plant and soil nematodes discussed by many scientists like Oostenbrink (1960), Scinhorst, (1967, 68), Feris and Bernard (1967), Wallace (1969), Brodie *et al.* (1970a, 1970b, 1970c), Khan *et al.* (1971), Szczygiet and Hasior (1972), Chaturvedi and Khera (1979) and Ahmad and Jairajpuri (1982). However, the report on the seasonal variation on the nematodes associated with paddy crop is almost nil from India, except one such report of Das *et al.* (1984). The qualitative and quantitative studies of nematodes of paddy crops at Burdwan District, west Bengal, India made by Baqri *et al.* (1983) revealed that *Hirschmanniella gracilis* (de Man, 1880) Luc & Goodey, 1964 is the most abundant and dominant species in the area surveyed. During random survey of paddy crop at Chinsurah, District Hooghly, West Bengal, India, they confirmed that the same species is dominant over the other parasitic nematodes. Ahmad *et al.* (1984) confirmed the yield losses up to 12.05 to 13.61% in 1979 and 18.33 to 19.22% in 1981 in the rice crop due to *H. gracilis.* However, in the present study, in the month of October, 1991 Masuiry variety of paddy crop remains in the field where occasional irrigation is made. So presence of the suitable host, temperature and moisture is available in the 1st layer at that time where as in the 2^nd^ layer the root system of paddy is very ill developed and temperature is lower, although soil moisture remains same as in upper layer. For this reason the male population in the lower layer always remains lower than the upper layer. So variation in soil temperature plays one of the vital role in distribution of male *H. gracilis*. Similar report is available from Ahmad and Jairajpuri (1982) who worked on another type of plant *Litchi chinensis* Sonn with *P. shakili.* The sharp decline in the population of *P. shakili* during late July and its subsequent increase in August at the upper layer can be attributed to water logging. Further, the migration of nematodes from upper layer to the lower from October to April is due to corresponding decrease in soil moisture in the upper layer. During May, after irrigation, their migration to the upper layer is again due to the soil moisture (Ahmad and Jairajpuri, 1982). Inspite of having moisture (21-22 %) at the upper layer in the month of January and February each year the *Male* population remains very low but become higher in the lower layer. During this period the field remains fallow, ploughing occurs, and the temperature remains low, ploughing cause desiccation of the soil and host crop remains absent in the upper layer. The *Male* nematodes thus migrate to the comparatively undisturbed lower layer and increase the number in male population.

The female and larval population of *H. gracilis* shows almost same pattern of seasonal variations in the soil layers of the plot under paddy cultivation. The *FeMale* and larval population were highest in number in the month of August, 1990 and 1991 at 0-10 cm depth when the plot was transplanted with Masuiry variety of paddy. From December onwards decline in female and larval population was observed upper layer.

In lower depth, the females and larval population showed the gradual decline except in the month of February after two months fallow and ploughing for the next crop and the lowest level of female population was observed in the month of June, 1991 and May, 1992, while high build up of both female and larval population was observed in the month of August, 1990 and 1991 and February, 1991 and 1992. It was also observed that gravid female and larvae were recovered maximum in both the depths from August to November each year under study.

The present study supports the findings of Das *et al.* (1984). The adults and larval populations in soil in their report fluctuate nearly in the similar fashion except in June, September and October. Though in June the adult population was found at its highest peak, but larvae were at its low level. They also noted low level of the adult and larval population during February, about one month after harvesting. On the basis of the high build-up of larval population and occurrence of gravid female, the breeding season has been considered from September to November. In our observation, the Masuiry variety of paddy was transplanted during early August. The root system begins to grow and gradually develops, and tillering (flowering) occurs through October. This is being the optimum condition for growth of nematodes highest peak is shown in this period. Obviously, the lower depth shows lesser number of both female and larvae of *H. gracilis*.

The total number of male, female and larval population of *H. gracilis* becomes optimum in August, 1990 and 1991 at the upper depth under the cultivation of Masuiry variety of paddy. The population was maintained upto November in both the years under study. From December the total number of *H. gracilis* population began to decline and lowest number of population was observed in February and July, 1991 at the upper layer. Sudden decline of total population was observed in the month of October, 1991 at the upper layer. Again the lowest level of total population was observed in the month of July, 1991 and 1992 in this layer.

On the other hand, fluctuation in the said nematode numbers at lower depth, did not show remarkable variation except in the month of August, 1990 and 1991 and February, 1991 and 1992. Similar fluctuation pattern in *H. gracilis* population was reported by Das *et al.* (1984). Mathur and Prasad (1972) also reported from North India that the gravid females of *H. oryzae* occur in highest number during September which is the peak period of growth of paddy. Das *et al.* (1984) mentioned that the high build-up in total population was always been noticed when the field remains moist either by irrigation or the rain fall.

In the present observation, from August to November the field remained watery due to rainy season and occasional irrigation during Autumn. Thus the field condition remains favourable to the heavy growth of paddy root system as well as the season being favourable the adult males and gravid females of *H. gracilis* become higher. Higher number of larvae are observed in this season also. From November to February, after harvesting of paddy crop the field remains fallow, dry and occassional ploughing makes the upper layer unsuitable for parasitic nematodes to thrive well. Obviously they shift to the lower level and thus increase the number of nematode population in the lower depth at this time.

There was no remarkable variation in occurrence of the "other nematodes" population in both the layers in present study. They maintain high build-up in their population from August to December in both the layers in two years observations. Drastic decline was observed in February, 1991, 1992 at the upper layer, while high build-up is evident in the same period at lower layer. Again the decline in number in population was observed on July, 1991, 1992 at the upper depth, whereas in the same time higher population at the lower depth is evident.

The present study, considers tylenchid, dorylaimids and other soprophagus nematodes, as the "other nematodes" which are less significant either because of their reported non-parasitic nature or less common in occurrence. *Hirschmanniella oryzae* is also included under this group in the present study, for their parasitic nature but less in occurrence. Similar grouping is also available from Das *et al.* (1984).

The population fluctuation of "other nematodes" in upper and lower depth also depends on the availability of moisture in the rainy season or by irrigation and fallowing, thus showing their nature of fluctuation similar to that of *H. gracilis* population.

The adult population of *H. gracilis* in the roots of Masuiry variety of paddy in the present investigation, began to increase from August, 1990 and 1991. Maximum number of adult population were recovered in the roots of Masuiry variety of paddy in the month of September, 1990 and 1991 and minimum number in the month of November, 1990 and 1991 during the preharvesting period.

During cultivation of Ratna variety of paddy, in the present study, the highest root population was observed in April, 1991 and March, 1992 but this number was nearly half the root population found in September, 1990 and 1991 in Masuiry variety of paddy. This was happened probably due to the host specificity of *H. gracilis* to that particular paddy plant.

As the root system of paddy grows, the adult population of *H. gracilis* also grow, because, the host root, temperature and moisture remained favourable for the growth of this nematode. The highest root population was recorded during the pre-flowering and flowering periods of Masuiry and Ratna paddy respectively when the root system becomes highly developed. The root population immediately comes down during pre harvesting period when the roots starts degenerating because of advance age. Thus growth of the root population has direct correlation with the development of the root system of paddy. The favourable host helps to maintain high buildup of *H. gracilis* population in soil as well as in the roots of paddy.

The previous study of Das *et al.* (1984), stated that the low number of nematodes recovered from roots during the first 2-3 weeks of crop and later a gradual increase in the root population prove the direct correlation with the development of the root system. The maximum population was encountered during the flowering periods of both the crops when the root system becomes highly developed. The root population immediately comes down when the roots start degenerating just before the crop is harvested because of advance age. The present study also supports the findings of many workers working on different crops (Wihmut, 1957; Mukhopadhyay and Prasad, 1968; and Szczygiel and Hasior, 1972).

Likewise, maximum larval population was found in the month of September, 1990 and 1991 under Masuiry variety of paddy cultivation in the present work. Under the cultivation of Ratna variety of paddy, the highest larval population was recorded in April, 1991 and 1992 which was also less than one third the highest population observed in September, 1990 and 1991 under Masuiry paddy cultivers. This observation also indicates the variety specificity of *H. gracilis*. The lowest level of larval root population was observed in

November, 1990 under Masuiry variety of paddy and May, 1991 and 1992 under Ratna variety of paddy. Here also the increase and decrease of larval population was followed like that of the adult population in roots. The present observation highlights on the breeding season of *H. gracilis* as September and October because in these months maximum number of larval population as well as gravid females were found in the soil and roots during both the years under study.

The present work agrees with the findings of Das *et al.* (1984), where the nematode population in the roots was also positively correlated with the development of root system of host plant. On the basis of high build-up of juvenile population, the breeding period of the nematode is considered from September to November.

As far as the effect of crop rotation is concerned, the trend of the *Distribution* of both *H. gracilis* and "other nematodes" in soil as well as root (Tables 2, 3 and 4), clearly depicts more increase in number during transplanting season and gradually reducing during harvesting in all the plots in the present study. This is probably due to the fact that from transplanting onwards the penetration inside the roots became gradually difficult as the plant grew older and as well as due to gradual slowdown of root exodus seeping out from the root into the soil. It is apparent that the population of *H. gracilis* and "other nematodes" both in soil as well as in root were directly dependent on the easy availability of the food material, from the roots of the standing crop. The present work corroborated with the observation of Naidu *et al.* (2000), studied the management of "Kalahasti Malady" (*Tylenchorhynctus brevitingatus*). Rabi groundnut proceeded by summer rice and Kharif rice recorded maximum decrease in nematode population, disease severity and increase in pod yield. This was closely followed by the two cropping sequence viz. Rabi groundnut preceded by summer rice and kharif sun hemp and rabi groundnut preceded by kharif rice. Blackgram, greengrant and Maize proved to be susceptible host for nematode. The present work also supports the finding of Chawla and Prasad (1973). The population was higher at harvest than at sowing indicates that the crops under study were in the host range of these nematodes which were polyphagus in nature. The saprozoic nematodes also were more at harvest probably because the cultural operations were limited to the period in between two crops. *Pratylenchus* population was mostly higher in bojra rotations, conversely, *Tylenchorhynchus* and *Helicotylenchus* were found in higher number in sorghum rotation than in bojra rotations indicating that not only the crop being grown but the previous crop also had some influence in nematode population build up. Oostenbrink (1964) also stated that the composition of the population is markedly influenced by the last grown crop or crops. It is this principle which, probably, contributes more towards the utility of crop rotation in nematode control. Similar observations on population fluctuations on plant nematodes have been made by Azmi (1990). Nematode population, under other crops studied, increased at a slower rate in the beginning the early vegetative stage of the host crop, at a faster rate during the late vegetative stage when the population reached its peak and then declined at harvest.

However, such a trend of decline in population might also had a relation with soil temperature and soil moisture which also gradually decline from sowing or transplanting to harvesting and statistically the relationship of the nematode population with the soil temperature and soil moisture were found to be significantly correlated in the present study. During rice cultivation such relationship were positively correlated in plots "A", "B" and "C" (Table 2, 3 and 4).

It is also evident that at plots "A" and "C" where the rotation of crop involved paddy and jute interspaced with short fallow period of two months remarkably reduced the soil population of *H. gracilis* in both these plots, where the roots of Jalmasta jute were found to contain no nematode at all. During cultivation of Jalmasta jute the population of soil nematodes became markedly low and well below 50% population of *H. gracilis,* in particular, had went down to a manageable level.

At plot "B" cropping were done with the rotation of Pankoj paddy followed by wheat and then Disimasta jute interspaced by very short fallow of one month. Here, Disimasta jute did not farvour *H. gracilis* at all, whereas wheat was favoured as alternate intermediate host. However, infestation in wheat by *H. gracilis* was found to be considerably low in comparison to paddy.

The present work supports the findings of Ray *et al.* (1995) stated that recovery of *Tylenchorhynchus mashoodi* and *Hoplolaimus indicus* from paddy, wheat, jute and sugarcane demonstrated that the species are polyphagus. Host plant belonging to the family Graminae, especially paddy and sugarcane supported more numbers than jute though no appreciable difference in numbers existed between wheat and jute, the former supporting a fewer more. Rotations containing wheat and paddy had also fairly large number of nematodes (435 and 611) respectively. A fallow, in between two crops is capable of reducing nematode population. So in a nematode infested field, proper exploitation of the knowledge of crop rotation can play a significant role in the integrated pest management programme.

In this plot also the population of *H. gracilis* was found to be highly influenced by soil temperature and moisture and their relationship were found to be highly significant, positively or negatively as indicated in.

The monoculture of paddy is, found to encourage *H. gracilis* to increase enormously which might go beyond a manageable level and therefore, cause remarkable damage to the crop. Similar observations are available from Alam *et al.* (1980) and Lal and Mathur (1983).

The rotation of paddy cropping with other crops in the present study causes marked decrease of *H. gracilis* population in the soil. The earlier observations of Shivakumar and Marimuthu (1986), and Kalika and Phukan (1995). Ray *et al.* (1994 and 1995) supports the present study indicating that the inclution of non-host (mustard), moderate host (maize) and fallow in rotation had effectively checked *Meloidogyne graminicola.* Saikia and Phukan (1986) have also reported similar effect of fallow and non-host and poor host crops on nematode reproduction.

Of the two different types of crop rotations observed, it appeared that the pattern of rotation of paddy and Jalmasta jute interspaced by short fallow at plot "A" and "C" were found to be more effective in bringing down the population of *H. gracilis* below the threshold level. It is evident, from the plots "A" and "C" in the present study, (Tables 2, 4), that the high build up of population of *H. gracilis* and "other nematodes" was found during the period of paddy cultivation and decline in number when the plots were cultivated with Jalmasta variety of jute (*Hibiscus sabdariffa*). It was also observed that after two years crop rotation with paddy and Jalmasta jute interspaced by two months fallow, the phytoparasitic nematode *H. gracilis* reached to its manageable level. During the cultivation of Jalmasta variety of jute (*Hibiscus sabdariffa*) in plot "A" and "C", it was noted that not a single nematode either *H. gracilis* or "other nematodes" was found from the 5 gms roots of Jalmasta jute (Table 2 and 4). From these observation it may be concluded that the Jalmasta jute is a non-host crop or enemy crop or antagonistic crop of *H. gracilis*.

The previous work of Laha and Bhattacharyya (1984) reported similar behaviour of *Meloidogyne incognita* on *Urena lobato L.* from India (congo jute). The cultural practices followed by crop rotation with paddy and wheat for two years reduced the root-knot nematode population in jute fields to a manageable levels (Mishra, Singh and Laha, 1987) and Laha and Pradhan (1987) also reported the *Hibiscus sabdariffa* being free from root knot nematode *Meloidogyne incognita* completely.

Fallowing is the most effective method for the management of the phytoparasitic nematodes. It is a practice of keeping the land free from all vegetation for a stipulated period by occasional ploughing of the soil during the hot summer days. The nematodes present in the deeper layers can also be killed by giving frequent turning of soil. Our knowledge regarding the longevity of nematodes in fallow soil is of much importance in their control. *Tylenchorhynchus* has got maximum longevity in fallow condition. *T. claytoni* is reported to survive for ten months in fallow fields (Krusberg, 1959) and *T. icarus* for nine months (Wallace and Great, 1963). *Helicotylenchus* can survive for eight months in fallow condition (Golden, 1956). *Rodopholus* an allied genus of *Hirschmanniella* can survive about three months in fallow condition (Simons, 1973). Chaturvedi and Khera (1979) reported two fallow periods, first from the middle of September to early November and second, from the middle of February to the second week of April. The populations of all the three species, *Tylenchorhynchus claytoni*, *T. icarus*, and *Radopholus* sp. declined greatly. Very hot and dry soil conditions, essential for rapid desiccation during fallow period, were however, not available because of frequent rains and the population of nematodes resurrected itself with the reapproaching of suitable conditions.

The present study reveals that the population of *Hirschmanniella gracilis*, was reduced considerably under both "long period fallowing" & "short period fallowing" in the months of December, 1990 & January, 1991. The change during "very short period fallowing" in the month of December, 1990 is negligible (Table 8).

No remarkable decline in the population of "other nematodes" in the three categories of fallow periods during the months December, 1990 and January, 1991 is observed (Table 8) and the decline of *H. gracilis* population is more pronounced than that of "other nematodes" Probably it happened due to ploughing of the plots and non-availability of host plants which has direct effect on phytoparasitic nematode *H. gracilis*.

During the fallow period of June and July, 1991 at plot "E", "D" and fallow period of April and August, 1991 at plot "B", the population of *H. gracilis* declined more under long period fallow than that of short period and very short period fallow, whereas the rate of decline of "other nematodes" population is more or less same in all the categories of fallow periods. It happened perhaps due to the migration of *H. gracilis* from upper to lower depth to avoid the extreme adverse condition and non-availability of host plants due to continuous fallowing at plot "E" (Table 9).

The present observation gets support from the previous observations of Chaturvedi and Khera (1979). Similarly, Khan *et al.* (1969) reported that *Tylenchorhynchus brassicae* remained very low when the field remained fallow. In another observation Khan, *et al.* (1975) reported a general decrease of nematode population during fallow period and the larvae of root-knot nematode in particular. Similar results were observed by Brown (1961) and Peacock (1957) where population of root-knot larvae declined rapidly under fallow period and reached a safe level.

In continuance of the observation of the fallow periods for the next year, 1992, in the present observation, the rate of decline of population of *H. gracilis* was more than that of the fallow period of 1991. The population of *H. gracilis* with rise of soil temperature and low soil moisture was decreased drastically in the month of May and June, 1992 at plot "E" under long period fallow (Table 5), but there was no remarkable fluctuation of "other nematodes" during this period. In this adverse climatic condition and long fallow period a few inactive parasitic nematodes (*H. gracilis*) was recorded with large vacuoles in their body. This indicates that they develop vacuoles in their body.

Nielsen (1949) suggested that in moist soils, nematodes are probably constantly active whereas in dry habitats they must be periodically inactive. Wallace (1963) concluded that dry conditions may inhibit activity of nematodes. Dropkin *et al.* (1958) found that although hatching of *Heterodera rostochiensis, Meloidogyne arenaria* and *Ditylenchus dipsaci* may be reduced in dry conditions, the eggs survive and are able to hatch when moisture increases. Bosher and Mc Keen (1954) found large vacuoles in the body of *Ditylenchus dipsaci* after it was subjected to freezing for 20 min. at 80 ^{0}C. Tikyani and Khera (1969) also observed that the nematodes were found with vacuoles in their body and believe that unfavourable conditions induce vacuole formation in the body of the nematodes. They also stated that in the fallow field the average number of nematodes decrease with the rise of atmospheric temperature. A decrease in number of nematodes in the month of April followed by a very sharp reduction in the month of May and June indicates that the atmospheric temperature beyond 30 °C is not favourable for nematode activity in the fallow field at 15 cm depth. The recovery of nematodes in May from field below 15 cm depth may be attributed to the capacity of nematodes to migrate into the deeper soil levels, where sufficient moisture exists. It is therefore, likely that the reappearance of the nematodes after the soil being moist and subjected to low temperature may be due to reactivation of the nematodes. In fallow field, the nematode migrate to deeper soil or adopt quiescent state at 15 cm depth. In their opinion, the nematodes in soil become active again after the rain in July when the temperature goes down and soil gets cooler. Bare fallow has been suggested to be useful in controlling nematode pests. During the hottest months (May and June) the temperature, rather than food may play a dominant role in the longevity of this nematode. The present study also is in fair conformity with the observations made by Wallace (1963) when he stated that the high temperature range for nematode activity is 30-40 °C and the temperature beyond 40°C is lethal for nematodes.

The influx of population of *H. gracilis* in September, 1992 in the present observation is low as compared to that in September, 1991. This is probably due to non-availability of host plants for a prolonged period and migration of parasitic nematode to the lower depth to avoid the adverse conditions. On the contrary, it was observed that the population fluctuation of "other nematodes" in the same plot during the two years of study was insignificant. This is probably because of the fact that the influence of host plant did not affect the population of "other nematodes" as they do not depend on host plants. Thus it can be concluded that *Hirschmanniella gracilis* is host-specific. The observations of Tikyani and Khera (1969) of the recovery of nematodes in the month of May from fallow field below 15 cm depth may be attributed to the capacity of nematodes to migrate into the deeper soil levels, where moisture exists, as in the present study.

The population of *H. gracilis* may be checked upto a manageable level by fallowing the plot for a long period of time as well as by frequent ploughing during hot summer days. It may be mentioned here that the soil nematode population does not get annihilated during fallowing. The nematode develops their own system of survival in the soil under fallowing.

The observations of Chaturvedi and Khera (1979) stated that very hot and dry soil conditions, essential for rapid desiccation during fallow period were however, not available because of frequent rains and the population of nematodes resurrected itself with the reapproaching of suitable conditions. However, Tikyani and Khera (1969) suggested that the bare fallow is very useful in controlling nematode pests.

From the present study it is evident that the association of the population of the plant-parasitic nematode, *H. gracilis* with paddy, wheat and jute crop in different selected plots at Rautara village fluctuates in different seasons of two years study. In general, populations were affected by soil temperature, moisture and the rate of plant growth.

The findings from the tables 12, 13 and 14 may easily be interpreted that even the rise of temperature to a favourable condition is not sufficient for survival of the population in absence of their favourable host, paddy plant. Instead of Pankoj paddy when these two factors i.e. soil population and soil temperature in the Jalmasta jute cultivation in the same plot "A" (Table 14) are considered, we get "r" value= -0.602 which denotes insignificant correlation between the two and thus the temperature alone could not contribute to the population build up.

Let us consider the correlation between the two factors in the same plot in the next season, 1991-1992, in the same cropping sequence, Pankoj paddy – fallow period – Jalmasta jute (Tables 15, 16, 17 respectively). The "r" values being 0.393, 0 and -0.967 respectively do indicate that either the two factors have no correlation or negatively correlated. The cultivation of Jalmasta jute, an unfavourable host at the end of previous year had severely affected the nematode population in such a low level that even after getting their attractive host (Pankoj paddy), the nematodes could not made up the population to the original level. The fallow period further had cut down the population in the minimum. As a consequence, when cultivation of an unfavourable crop like Jalmasta jute followed, the nematodes had to face a very unfavourable condition and as an impact the correlation turned reverse and a negative correlation is observed between the two factors (r = -0.967).

The present study supports the observation of Ray, Shah and Mukhopadhyay (1995), who stated that the host plants belonging to the family Graminae, especially paddy and sugarcane supported more numbers than jute though no appreciable difference in numbers existed between wheat and jute, the farmer supporting a fewer more. The rotations containing wheat and paddy had also fairly large number of nematodes (435 and 611) respectively as like present investigation. A fallow, in between the two crops is capable of reducing nematode number. When correlation coefficient was calculated between sugarcane yields and nematode numbers from the fields under study, in the work of Ray *et al.* (1995) there exists a significant negative relationship between the two variables.

When concentrated on the correlation between soil population and soil moisture in the same plot "A" in the same sequence of cropping season in the same two consequtive years of 1990-1991 and 1991-1992 (Tables 18, 19, 20 and 21, 22, 23), in the present study, the correlations either become very much (at 0.01 level) significant or even absolute (during fallow period) in both the seasons and in all the crops. The results may be interpreted that what ever the favourable crop sequence or fallow are being followed, the soil moisture maintains almost constant correlation with nematode population. It is evident from the table 20 and 23 during the two consequitive years, the correlation significant at 0.01 and 0.001 level respectively between the soil population and soil moisture. The result happened due to frequent irrigation of the plot in the present study.

The present work supports the findings of Azmi (1995). Three plant-parasitic nematodes associated with Carribean stylo in Jhansi, showed different population fluctuation behaviour during the various season of the year. In general, the population fluctuations were also affected by temperature, moisture and plant growth. *Basiriolaimus seinhorstii* is least affected by environmental stresses, *Pratylenchus thornei* multiplied better in highly moist conditions whereas *Tylenchorhynechus vulgaris* was adversely affected by moisture (Azmi, 1995).

It is evident from another plot "B", in the present study, where the cropping sequence were Pankoj paddy, Ratna paddy, wheat and Disimasta jute in both the seasons 1990-1991 and 1991-1992. The soil temperature is very much correlated at 0.001 (Table 24) and 0.01 (Table 27) levels respectively with that of nematode population when either Pankoj or Ratna variety of paddy were grown. But the temperature had shown negative correlation with nematode population at 0.01 (Table 25) and 0.10 (Table 26) levels in 1991 or no correlation in 1992 when the crops were wheat and Disimasta jute (table 28 and 29).

Further, the correlation between the nematode population and soil moisture in the same plot "B" under same sequence of cropping like paddy (Pankoj or Ratna variety), wheat and Disimasta jute in the same two consecutive year 1990-1991 and 1991-1992, the correlation either become significant at 0.10 (Table 30) and 0.02 (Table 33) levels during the two varieties of paddy cultivation or very much significant at 0.01 (Table 31) level, even absolute (Table 34) during wheat cultivation in both the seasons.

Paddy being the favourable host of *H. gracilis* has responded favourably to temperature whereas in wheat and Disimasta jute, the temperature had little impact to bring a positive correlation. Likewise, soil moisture also influence the nematode population and the correlation either become significant during two varieties of paddy cultivation or very much significant during wheat cultivation in both the seasons may be attributed to irrigation and other agricultural practices in the two different years under study. As a consequence, when cultivation of an unfavourable crop like Disimasta jute had followed (second time in the series), the nematode had to face adverse condition and as an impact the correlation turned reverse and we got a negative correlation between the two factors i.e. nematode population and soil moisture which were not significant, ($r = -0.065$, Table 32 and $r = -0.114$, Table 35).

The present work supports the findings of Ray *et al.* (1995). The host plants belonging to the family Graminae, especially paddy and sugarcane supported more numbers than jute though no appreciable difference in numbers existed between wheat and jute, the former supporting a fewer more. Rotations containing wheat and paddy had also fairly large number of nematodes (435 and 611) respectively. A fallow, in between two crops is capable of reducing nematode number. So in a nematode infested field, proper exploitation of the knowledge of crop rotation can play a significant role. Nematodes suppressing effect of other crops against many other nematode species have been reported by Mukhopadhyaya and Chakraborty (1985), Gaur and Haque (1986), Sethi and Gaur (1986) and Sukul (1992). When correlation coefficient was calculated between sugarcane yields and nematode numbers, it was observed that there exist a significant negative relationship between the two variables. Calculated value of "r" became as high as -0.964, but in our observation, insignificant negative relationships were obtained (r = -0.065, r = -0.114 under tables 32, 35 respectively). It was happened due to the unfavourable crop Disimasta jute in the crop rotation series. Soil moisture alone could not maintain the high build-up population.

As evidence from Plot "C", in which the cropping sequence were Pankoj paddy – fallow for 2 months – Jalmasta jute – Pankoj paddy – fallow – Jalmasta jute during two years under study, it is evident from table 36 and 39, the correlation between Pankoj paddy and temperature were significant at 0.10 and 0.001 level respectively in both the years. The correlation between Pankoj paddy and soil moisture were also significant at 0.10 level in 1990 and 0.01 level in 1991 (Table 42, 45). This may indicate that the higher soil temperature is a favourable condition to build-up the soil nematode population of *H. gracilis*. During the fallow period of plot "C" during two years under study (Table 37, 40), the mean soil nematode population of *H. gracilis* and soil temperature shows little decline. The correlation coefficient (= r) has been calculated as '0', indicates that the correlation is not significant between the two factors, while in same two years under same fallow period (Table 43, 46), the correlation between nematode population of *H. gracilis* and soil moisture was found absolutely significant.

Now instead of Pankoj paddy, when these factors i.e. soil nematode population with soil temperature and soil moisture, in the Jalmasta jute cultivation in the same plot "C" are considered (Tables 38, 41, 44 and 47), it was observed that correlation between population of *H. gracilis* and soil temperature indicates negative correlation, significant at 0.10 level in 1991 and 0.01 level in the year 1992 while the soil moisture shows the correlation with *H. gracilis* negatively insignificant.

This antagonistic results may be due to the cultivation of Jalmasta jute, an unfavourable host and fallow period at the end of previous season, had severely affected the nematode population in such a low level that soil temperature alone could not contribute to the population build-up. Thus when cultivation of an unfavourable crop like Jalmasta jute, the nematode had to face an adverse condition and as an impact the correlation turned reverse and a negative correlation between the two factors (r = -0.721, Table 38) was observed. The nematode population had affected in such a low level that even after getting their favourable host (Pankoj paddy), the nematodes could not made up the population in the original level. The fallow period also helps to decline the population to the minimum level. Crop rotation by Jalmasta jute in the next year, again creates more adverse condition for *H. gracilis* and as a result the correlation again turned reverse leading to the negative correlation between the two factors, soil population and soil temperature (r = -0.967, Table 41).

Thus the results may be interpreted in the way, whatever may be the favourable crop sequence or fallow condition are being followed, the soil moisture maintained an almost constant correlation with the nematode population, except in Jalmasta jute rotation (unfavourable crop, tables 44and 47). It may be concluded that due to enemy crop (Jalmasta jute), the soil moisture could not help to build-up the nematode population and the correlation was negatively insignificant in both the years under study (r = -0.005 and -0.335 in 1991 and 1992 respectively).

The present work corroborates with the findings of Ray *et al.* (1994). A fallow, in between the two crops is capable of reducing nematode number but the population build up happens again on availability of suitable crop. This was observed in Bolpur-I where a brief period of fallow was allowed between paddy and sugarcane. On the contrary, if a fallow is succeeded by an antagonistic crop like sesame showed its best performance in controlling *Tylenchorhynchus mashhoodi* whereas in case of *Hoplolaimus indicus*, sesame, garlic and corn powder exhibited nematicidal activity of the same order. Hence, in a nematode infested field, proper knowledge of crop rotation can play a significant role. Nematode suppressing effect of plants have been reported by Mukhopadhyaya and Chakraborti (1985), Gaur and Haque (1986), Sethi and Gaur (1986) and Sukul (1992). When correlation coefficient was calculated between sugarcane yield and nematode numbers from the fields under study, it was observed that there exists a significant negative relationship between the two variables. Calculated value of "r" became as high as -0.964. The present study also supports the findings of Azmi (1995) who stated that the three plant parasitic nematodes associated with Carribean stylo in Jhansi, showed different population fluctuation behaviour during the various seasons of the year. In general, their population fluctuations were affected by temperature, moisture and plant growth. However, *Basiriolaimus seinhorstii* is least affected by environmental stresses, *Pratylenchus thornei* multiplied better in highly moist conditions wheras *Tylenchorhynchus vulgaris* was adversely affected by moisture.

In plot "A", the correlation of the population of *H. gracilis* with the different crops or the same crop were studied in the present work. It is evident from table 48 and 50, that the population under different crops are not correlated but when the host is common, the two population shows strong correlation (Table 50, significant at 0.001 level). But in case of Pankoj paddy and Jalmasta jute (Table 49) the relationship was found significant at 0.01 level. Table 51, shows the correlation of the soil population of *H. gracilis* with same variety of Jalmasta jute as insignificant (r = 0.378). This result was happened due to the unfavourable host of *H. gracilis*.

In plot "B" crop like paddy, wheat and Disimasta jute grown in succession in two consecutive years, 1990-1991 and 1991-1992 are shown in tables 52, 53, 54 and 55, 56, 57. The results shows that either they have no correlation or very weakly correlated between wheat and Disimasta jute (Table 55; r = 0.944) which was significant at 0.10 level. Correlation of the soil population of *H. gracilis* with Ratna paddy and wheat (Table 56; r=0.928) also significant at 0.10 level. But when the population of the same crop grown in different years are compared i.e. Pankoj paddy with Ratna paddy (Table 58), wheat and wheat (Table 59) and Disimasta jute with Disimasta jute (Table 60), the correlation shows either insignificant or very little significant (r = 0.947) at 0.10 level when compared with wheat and wheat (Table 59).

From the results it is apparent that except paddy, practically two other crops were unfavourable host for the nematodes. So a correlation between the population under these crops can not be expected.

In case of a third plot, i.e. "C" only two types of crops were grown, Pankoj paddy and Jalmasta jute. It is evident from the tables 61, 62, though a positive correlation is apparent between nematode population with Pankoj paddy and Jalmasta jute, yet the mean population in Jalmasta jute remains always significantly in low level, because Jalmasta jute acts as an unfavourable host for *H. gracilis*. But when the population in the same crop between different seasons are compared, they also show significant correlation but the populations in 1992 has always remained significantly low. This has happened for cultivating unfavourable host Jalmasta jute between the two paddy crop, which has cut down the population of *H. gracilis*.

The correlation between the soil population of *H. gracilis* and soil temperature has been assessed at plot "D" under cultivation of Masuiry paddy and Ratna paddy in two consecutive years 1990-1991 and 1991-1992 (Tables 65, 66 and 67, 68respectively). The correlations under Masuiry paddy has not become significant in both the years while in 1991 the Ratna paddy shows significant correlation at 0.001 level (Table 66; r = 0.996) between the two factors, soil population and temperature, but in 1992, insignificant correlation was obtained.

The finding leads to interpret that Masuiry paddy is favourable host of *H. gracilis*. The cultivation of paddy crop in both the years and well developed root system of Masuiry paddy influenced the nematodes to allow them to invade the roots. The temperature alone could not maintain the population of *H. gracilis*, as a result an insignificant correlation between the two factors is observed, while incase of Ratna paddy (Table 66, 1991), with less developed root system, less invasion to the roots and rise of temperature during its cultivated period, maintained a significant correlation at 0.001 level (Table 66; r = 0.996).

Similarly, the correlation between soil population of *H. gracilis* and soil moisture in the same cropping sequence during the two years, 1990-1991 and 1991-1992 (Tables 69, 70and 71, 72 respectively), the soil moisture could not maintain significant correlation with the nematode population either under the cultivation of Masuiry paddy or Ratna paddy.

The result may be interpreted that though the soil moisture maintain an almost constant correlation with nematode population but interestingly under paddy or different variety of paddy cultivation, the mean population of *H. gracilis* shows insignificant correlation with soil moisture. This was happened perhaps due to the monocultivation of paddy in two consecutive years (1990-1991 and 1991-1992) at plot "D" The suitable host influenced the nematode to invade into the roots, as a result, the soil moisture could not maintain the nematode population and shows insignificant correlation.

The present work corroborated with the observation of Chawla and Prasad (1973), who reported that the population was higher at harvest than at sowing. *Pratylenchus* population was mostly higher in bojra rotations. Conversely, *Tylenchorhynchus* and *Helicotylenchus* were found in higher number in sorghum rotations than in bojra rotations indicating that not only the crop being grown but the previous crop also had some influence in nematode population build up (Chawla and Prasad, 1973). Oostenbrink (1964) also stated that the composition of the population is markedly influenced by the last grown crop or crops. The population of nematodes is influenced by different cropping sequence (Alam *et al.* 1980). No simple rotation sequence can be recommended for all the nematodes. Monoculture builds up the population of nematodes. The present work also corroborated with the findings of Azmi (1995), who reported that the population fluctuation were affected by temperature, moisture and plant growth. *Basiriolaimus seinhorstti* is least affected by environmental stresses. *Pratylenchus thornei* multiplied better in highly moist condition whereas *Tylenchorhynchus vulgaris* was adversely affected by moisture. The temperature, moisture and host play important roles in the population fluctuation of nematodes.

The observation available from another plot "E" where continuous two years was kept fallow (Table 73). The "r" value -0.227 does indicate that the two factors have no correlation or negatively insignificant. The correlation between soil population and soil moisture in the same period in plot "E" become significant at 0.05 level (Table 74; r = 0.384).

Though the rise of temperature is favourable to build-up the nematode population but continuous fallow period had cut down the nematode population to the minimum level. During fallow period or without any host, the nematodes had to face adverse condition and temperature alone unable to maintain the original level of population. Thus the correlation turned reverse and we got a negative insignificant correlation between the two factors, soil population and soil temperature (Table 73; r = -0.227).

The soil moisture maintained almost a constant correlation with the nematode population even in the continuous fallow period of the plot "E" probably due to the frequent rainfall in West Bengal and the *H. gracilis* population does not move down to a vanishing level, clearly indicating that these nematode have developed their own system of survival in the soil during fallow period.

The present work supports the findings of Saikia and Phukan (1986). The "fallow" appeared to be quite effective in checking the development of nematode population. Peacock (1957), Roy (1978) and Khan *et al.* (1979) have also reported similar effect of fallow and non-host crops on nematode reproduction. Naidu (2000) also reported the reduction in nematode population due to land "fallowing" and absence of any host plants. The present work also corroborated with the findings of Chaturvedi and Khera (1979). The very hot and dry soil conditions, essential for rapid desiccation during fallow period, were however, not available because of frequent rains and the population of nematodes resurrected itself with the re-approaching of suitable condition (Chaturvedi and Khera, 1979).

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