INTERTRANSMISSIBILITY OF THE COMMON NEMATODE PARASITES OF PIGEON (*Columba livia domestica*) AND DOMESTIC FOWL (*Gallus gallus domesticus*)

BY

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THESIS

Submitted in partial fulfilment of the
requirement for the degree

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Faculty of Veterinary and Animal Sciences
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Department of Parasitology
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DECLARATION

I hereby declare that the thesis entitled **"INTERTRANSMISSIBILITY OF THE COMMON NEMATODE PARASITES OF PIGEON (*Columba livia domestica*) AND DOMESTIC FOWL (*Gallus gallus domesticus*)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled "INTERTRANSMISSIBILITY OF THE COMMON NEMATODE PARASITES OF PIGEON (*Columba livia domestica*) AND DOMESTIC FOWL (*Gallus gallus domesticus*)" is a record of research work done independently by Sri. K. Senthilvel, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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Dedicated to my loving parents and sister

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ABBREVIATIONS USED

ad.an.p.	-	adanal papillae
an.	-	anus
b.c.	-	buccal capsule
b.r.	-	bursal rays
c.i.	-	cuticular inflation
cor.	-	cordons
cu.kn.	-	cuticular knob
d.lip	-	dorsal lip
d.ra.	-	dorsal ray
dev.emb.	-	developing embryo
eg.	-	egg
ex.d.ra.	-	externo dorsal ray
exp.	-	excretory pore
g.oe.	-	glandular oesophagus
g.pr.	-	genital primordium
int.	-	intestine
la.ra.	-	lateral rays
lr.	-	larvae
l.lo.	-	lateral lobe
l.sp.	-	left spicule
m.oe.	-	muscular oesophagus
m.lo.	-	median lobe
mt.	-	mouth terminal
muc.	-	mucron

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ABBREVIATIONS USED

ad.an.p.	-	adanal papillae
an.	-	anus
b.c.	-	buccal capsule
b.r.	-	bursal rays
c.i.	-	cuticular inflation
cor.	-	cordons
cu.kn.	-	cuticular knob
d.lip	-	dorsal lip
d.ra.	-	dorsal ray
dev.emb.	-	developing embryo
eg.	-	egg
ex.d.ra.	-	externo dorsal ray
exp.	-	excretory pore
g.oe.	-	glandular oesophagus
g.pr.	-	genital primordium
int.	-	intestine
la.ra.	-	lateral rays
lr.	-	larvae
l.lo.	-	lateral lobe
l.sp.	-	left spicule
m.oe.	-	muscular oesophagus
m.lo.	-	median lobe
mt.	-	mouth terminal
muc.	-	mucron

n.r.	-	nerve ring
o.op.	-	oral opening
oe.	-	oesophagus
oe.b.	-	oesophagus-bulb
p	-	papillae
pha	-	pharynx
PI	-	Post infection
po.pl.	-	polar plug
po.an.p.	-	post anal papillae
pr.an.p	-	pre anal papillae
rsp.	-	right spicule
seg.emb.	-	segmented embryo
sp.	-	spicule
sp.s.	-	spicule sheath
su.	-	sucker
te.	-	telamon
tee.	-	teeth
tl.	-	tail
tls.	-	tail sheath
u/um	-	microns
ut.	-	uterus
v.lip.	-	ventral lip
va	-	vagina
ve.ra.	-	ventral rays
vu	-	vulva

Introduction

INTRODUCTION

Pigeons of Family Columbidae comprise of nearly 300 species and are encountered except in the polar regions and the colder parts of the temperate zones. Of the 20 species of pigeons in the subcontinent, the Blue rock pigeon (*Columba livia*) is the most common. They live almost entirely on fallen weed seeds and cereals gleaned in harvested fields. The nestlings are fed on 'pigeon milk', a fluid that is secreted in the crop of adults and when the squabs get older this is mixed with predigested grains into a pap. Pigeons produced by selective breeding are trained to fly long distances and are utilized for carrying messages or for the popular sport of pigeon racing.

Pigeon farming is an economically important branch of Animal Husbandry in many civilized countries. In India, the pigeons are reared mainly for meat, eggs and are also used for experimental purposes and for sport by pigeon fanciers. The small farmers in Kerala grow the pigeons as a means of side income, practically spending very little towards feeding, as the birds are let out during the day in search of their food. A profitable pigeon breeding is now known to be impeded by different pathogens like bacteria, virus and parasites. Among parasitic diseases, nematodiasis is most common and could adversely affect the production and even produce acute disease

leading to death of affected birds. Tongson *et al.* (1975) reported that *Ornithostrongylosis* in pigeons caused high mortality in several farms.

In the backyard system of poultry keeping, the pigeons are commonly found mingling with chicken and feeding in and around the poultry yards. The sharing of feeders and waterers by fowls and pigeons result in contamination of the yards by droppings of both birds and cross transmission of parasitic infection is possible. The free flying pigeons also get access to poultry farms. Stabler (1954) stated that wild pigeons play an important role in the transmission of parasitic infections to domestic fowl through contamination of drinking water. A perusal of the available literature revealed only very few reports on nematodes of pigeon and on the cross transmission of nematode parasites of pigeon to chicken and vice-versa.

Hence the present investigation was planned to conduct a systematic study on

1. the prevalence and specific identity of the nematode parasites infecting pigeons
2. the intertransmissibility of nematodes between pigeons and domestic fowl and
3. the biology and pathogenesis of *Ascaridia columbae*, *Syngamus trachea* and *Ornithostrongylus quadriradiatus* in pigeons.

Review of Literature

REVIEW OF LITERATURE

Prevalence and morphological studies of nematode parasites in pigeons

Studies on the prevalence of nematode infection in pigeons are comparatively few when compared to other avian species.

Kamarov and Beaudette (1931) reported the occurrence of *Ornithostrongylus quadriradiatus* in squabs. Roberts (1932) described three species of nematodes namely, *Ascaridia columbae*, *Capillaria obsignata* and *Tetrameres* sp. while examining 128 birds in Brisbane. *O. quadriradiatus* was first reported in Indian domestic pigeons died due to ornithostrongylosis in Muktheswar by Srivastava (1939). Plazikowski (1945) recorded *Heterakis maculosa* in naturally infected pigeons in Germany. Willomitzer (1956) during his survey in Bruno found the pigeons were infected with single or mixed nematode infection. He recorded *A. columbae* (6%), *Capillaria columbae* (5.4%), *Strongyloides* sp. (1.4%) and *Syngamus trachea* (0.2%) in 500 birds examined. He also stated that the incidence of infection was lower in well fed, home bred birds. Intestinal capillariasis caused by *C. obsignata* and *C. caudinflata* was recorded by Jansen (1958) in Netherland. Lindquist (1963) found that the squabs aged 3 to

4 weeks were infected with immature worms of *A. columbae* and mature *C. obsignata* in 83 and 66 birds respectively out of the 92 birds examined. As the squabs does not peck anything at this age, he has suggested that the infection was acquired from mouth feeding of crop milk from their parents.

Dispharynx spiralis in the proventriculus of pigeon was reported by Cotteleer (1964) in Belgium and described its distinctive morphological features. Bhatnagar and Ruprah (1970) and Chauhan *et al.* (1973) reported that none of the nematodes were encountered during their study in pigeons at Hissar and Lucknow Zoo respectively in India. Tongson *et al.* (1975) recorded *O. quadriradiatus* in philippine pigeons with detailed description, clinical symptoms and control of the parasite. Autopsy of a 6 year old carrier pigeon which died of anaemia and dyspnoea revealed 46 specimens of *A. columbae* in small intestine (Takei and Sakurai, 1976). Jha (1977) reported the intestinal capillariasis due to *C. obsignata* in an Indian Jacobin pigeon for the first time at the Biological park, Patna. Gupta and Kazim (1978) recorded the pigeons as the new host for *Oswalostrongylus cruzi* in Lucknow Zoo. Vindevogel and Duchatel (1979) and Kummerfeld and Stove (1981) recorded the parasitic diseases of pigeons caused by *Capillaria* sp., *A. columbae* and *Syngamus* sp. and stated that they were the principal parasites in pigeons.

Al-attar and Aziz (1985) recorded *Hadjelia truncata* for the first time and described it as new host record in pigeons in Baghdad, Iraq. Begum and Shaikh (1987) reported *A. columbae, C. obsignata* and *O. quadriradiatus* as common nematodes encountered during their survey in Bangladesh. Filariasis in pigeons caused by *Eulimdana clava* was described by Eslami (1987) in Tehron. Githkopoulos and liakos (1987) recorded an incidence of 14.5 per cent, 22.7 per cent and 1.8 per cent respectively for *A. columbae, C. obsignata* and *C. caudinflata* in pigeons. Filkovic *et al.* (1989) by examining the faecal samples of 150 pigeons found that 72 were positive and they were infected with *Capillaria* sp. and *A. columbae.* In the same year, Kulisic described three species of nematodes namely *A. columbae, C. columbae,* and *C. gallinae* from 132 pigeons examined in Belgrade.

Muraleedharan *et al.* (1990) recorded *Capillarid, Strongyle* and *Ascarid* infection in pigeons of Mysore Zoo. Boado *et al.* (1992) revealed *A. columbae, C. columbae, C. obsignata, Capillaria* sp., *Strongyloides* sp., *Tropisurus confusus, S. trachea* and an unidentified species of nematode. An outbreak of pigeon malaria due to *Haemoproteus columbae* in association with *O. quadriradiatus* infection at Nehru Zoological park was reported by Rao and Makhekar (1992). Reddy *et al.* (1992) found the pigeons at Bannerghatta National park in Bangalore were infected with single or mixed

infections (38.88%) of *Capillaria* sp., *Strongyle* sp., and *Ascaridia* sp. In the city of Ternii, examination of 85 healthy pigeons by Tacconi *et al.* (1993) recorded the infection of *Dispharynx spiralis* (8%) and *A. Columbae* (3.5%). Venkatesan *et al.* (1996) reported a case of Ascaridiasis in a free flying blue rock pigeon in Kerala.

Egg cultures

Ascaridia galli

Ackert (1919) reported that the infective stage was reached in eggs within 9 days at 28°C, while Deo and Srivastava (1955) found that the eggs normally develop to the embryonated stage under optimum moisture in 6 days and become infective in 8 days at 33 to 33.6°C. Soulsby (1965) observed that the infective second stage was reached within 9 to 10 days, if the satisfactory temperature between 30 to 33°C was provided.

Heterakis gallinae

According to Graybill (1921) eggs reached the infective stage in about 7 to 12 days at 18 to 29°C, While Clapham (1933) reported that development occurred in 14 to 17 days and she regarded 28°C as optimal for development. The eggs become embryonated in about 4 to 5 days at room temperature when

cultured in aerated distilled water to which 5 to 10 drops of 2 per cent formalin were added (Deo, 1964).

Syngamus trachea

Under satisfactory conditions of temperature and humidity, development of third stage infective larvae occurred within 7 days in the egg shell (Wehr, 1937). Ortlepp (1923) claimed that there was only one moult in the egg but Wehr (1937) observed first moult in the egg at 5 days and another moult at 7 days at 24 to 30°C and third stage larvae started hatching from ninth day in the culture. Devada (1987) reported that the infective stage reached within 7 days and hatched from seventh day onwards under room temperature of 27 to 28°C.

Ascaridia columbae

Wehr and Hwang (1964) stated that the first stage larvae appeared in the egg in 12 to 15 days and the infective second stage within 18 to 19 days under room conditions.

Capillaria obsignata

Levine (1937) and Wehr (1939a) reported that the infective stage was developed within 6 to 8 days at room temperature without any moulting inside the eggs.

Ornithostrongylus quadriradiatus

According to Cram and Cuvillier (1931), the larvae reached the infective third stage within 3 days after the eggs were cultured. Eggs developed into first stage larvae in 19 to 24 hours and the first and second moults occurred in 27 and 72 hours respectively. Soulsby (1965) stated that the larvae reached infective stage within 4 to 6 days in culture.

Cross transmission trials

The published literature on the cross transmission experiments of pigeon and poultry nematodes were scanty.

Pigeons

Ascaridia galli

Miller (1937) was unable to infect pigeons with *A. galli* from chicken. Borkakoty and Tewari (1984) also observed that *A. galli* failed to develop in experimentally infected pigeons. Matta (1980) reported that pigeons were susceptible to experimental *A. galli* infection. While Mishra and Sahai (1980) could recover 23 mature worms in one out of four pigeons experimentally infected with *A. galli* and they stated that the resistance of that bird would have been lowered by some unknown factors.

Heterakis gallinae

Miller (1937) found that the pigeons were resistant to *H. gallinae* in experimental infection.

Syngamus trachea

Wehr (1939) reported chickens, guniea-fowl and turkeys were the important hosts of *S. trachea*, but domestic pigeons and ducks were unsuitable hosts for this parasite. He found by experimental infection of pigeons, that the larvae developed to fourth stage in lungs and no worms could be seen in the trachea indicating that these larvae died in the lungs due to a strong host reaction. Willomitzer (1956), Vindevogel and Duchatel (1979), Kummerfeld and Stove (1981) and Boado *et al.* (1992) have recorded the occurrence of natural infection of this parasite in pigeons.

Chicks

Ascaridia columbae

Swett (1910) stated that *A. columbae* could be found in domestic chicken. Miller (1937) exposed young chicks with *A. columbae* and found that the larvae developed for 96 hours and were unable to proceed further. Soulsby (1965) reported that this parasite almost invariably occurs in pigeons and the

reports of it in chickens are likely to be errors of identification. Tverdokhlebov (1967) and Mines and Green (1983) could not infect chickens experimentally with *A. columbae*. Varghese (1990) also reported that domestic fowl was refractory to this parasite.

Capillaria obsignata

Baylis and Daubney (1922) and Anderson (1992) have stated that pigeons were natural hosts of *C. obsignata*. Bhalerao and Rao (1944) and Wakelin (1965) have reported that chicks and turkeys were also natural hosts for this parasite.

Ornithostrongylus quadriradiatus

Cuvillier (1937) was unable to transmit this parasite to chickens, turkeys, Guniea fowls and ducks.

Detailed life cycle studies in pigeons

Ascaridia columbae

Cram (1927) reported that *A. columbae* developed to maturity and eggs appeared in the faeces 17 to 18 days after feeding embryonated eggs to the pigeon. Hwang and Wehr (1958) and Wehr and Hwang (1959) found the larvae of *A. columbae* in the liver as well as in the lungs of experimentally infected birds and suggested that migration through these organs might

be essential for their development. Later Wehr and Hwang (1964) confirmed that the larvae which invaded liver never reached maturity and all parasitic stages were found in the intestine. Detailed study on lifecycle conducted by him revealed that the second moult to third stage larvae occurred between third and sixth days after infection; the third moult to the fourth stage larvae between 11th and 15th days and the fourth moult to fifth stage larvae between 16th and 19th days and the adult worms attained maturity in approximately 35 to 40 days.

Syngamus trachea

Wehr (1939) experimentally infected pigeons with infective eggs and found that the larvae did not develop to maturity in trachea while Willomitzer (1956), Vindevogel and Duchatel (1979), Kummerfeld and Stove (1981) and Boado *et al.* (1992) have reported the presence of mature worms in naturally infected pigeons.

Wehr (1937) experimentally infected chicks with infective eggs and found that the third stage larvae reached the lungs as early as 17 hours. The fourth stage larvae were seen in the lungs from third day onwards and on the seventh day there were immature worms in copulo in the lungs. On the ninth day post infection worms in copulo were seen in trachea. According to Shikhobalov and Rhizhikov (1956) the larvae

reached the liver in two hours, the lungs on the second day, the trachea on the 10th to 12th day and the worms started laying eggs from 17th to 21st day. Fernado *et al.* (1971) reported that the third stage larvae developed to the adult within four to seven days in lungs and attached to the tracheal wall by 11 days. Devada (1987) found that the infective larvae reached lungs within 12 hours after infection and moulting to the fourth and fifth stage occurred on fifth and sixth day of infection respectively. The sexually united pairs as well as the single ones migrated to the trachea from eighth day onwards and the worms matured and started laying eggs from 18 to 22 days post infection.

Ornithostrongylus quadriradiatus

Cram and Cuvillier (1931) and Cuvillier (1937) studied the binomics of free living larval stages and reported the lifecycle to be direct being completed in as little as 7 days under favourable conditions. The only available literature on the morphometry and description of free living and parasitic stages of this parasite appears to be by the above authors.

Binomics of infective larvae of *Ornithostrongylus quadriradiatus*

Phototropism and viability

Cram and Cuvillier (1931) studied the binomics of infective larvae and found that the larvae were viable for 5 to 6 weeks in culture, migrated from faecal matter to water and were negatively geotactic.

Clinical signs and pathogenicity of nematodiasis in pigeons

Ascaridia columbae

Hare (1937) observed the death of pigeons which were extremely emaciated due to heavy infection with *A. columbae* while Deo (1964) considered that this parasite was not pathogenic to pigeons. Death due to parasitic encephalitis in pigeons was reported by Helfer and Dickinson (1972) due to migration of ascarid larvae into the brain. Panigraphy *et al.* (1982) observed that the birds affected with ascaridiasis showed signs of anaemia, emaciation, enteritis and in some cases the intestine was distended and impacted with these parasite. Venkatesan *et al.* (1996) reported a case of ascardidiasis causing death in a blue rock pigeon.

Capillaria obsignata

Deo (1964) and Soulsby (1965) briefly described the clinical signs in pigeons due to capillarid infection. Intestinal capillariasis due to *C. obsignata* was more commonly reported to cause morbidity and mortality in pigeons in certain parts of the world (Biester and Schwarte, 1965). Jha (1977) described the gross and histopathological changes in intestine affected with capillariasis.

Acuaria spiralis

Raggi and Baker (1957) reported the natural outbreak of Tetrameriasis and Acuariasis in pigeons and described the clinical signs caused by them. Deo (1964) and Solusby (1965) also described the clinical signs and pathogenesis of *A. spiralis* infection in pigeons.

Ornithostrongylus quadriradiatus

O. quadriradiatus, a blood sucking parasite was reported as the cause of many deaths in the flocks of pigeons in India and abroad (Komarov and Beaudette, 1931; Srivastava, 1939 and Rao and Makhekar, 1992). Cram and Cuvillier (1931) found that the symptoms were most severe and deaths frequent at 2 to 5 days after infection while the worms were still immature. The clinical symptoms such as inappetance, diarrhoea, ruffled

feathers, anaemia and progressive emaciation were observed by Rose and Kymer (1958), Soulsby (1965) and Tongson *et al.* (1975). Tongson *et al.* (1969) stated that the same symptoms were observed in avian trichomoniasis, but the presence of caseous nodules in upper digestive tract distinguished the latter from ornithostrongylosis. Recently, death of zoo birds due to ornithostrongylosis was reported by Rao and Makhekar (1992) at Nehru Zoological Park in Hyderabad, India.

Materials and Methods

MATERIALS AND METHODS

Prevalence of nematode infections in pigeons

The prevalence of nematode infections were studied from pigeons brought for post-mortem, the viscera obtained from birds purchased from local markets in Thrissur and also from free flying birds caught for experimental purposes. Opportunity was also availed for collection and examination of faecal samples of pigeons from Thrissur zoo, small farms owned by private individuals, local poultry market and from pigeons kept as pets in houses in and around Thrissur.

Different organs and the contents as well as mucosal scrapings of gastro intestinal tract were thoroughly examined for the presence of nematodes. The faecal samples were examined by concentration methods and the morphology of the eggs and the larvae obtained by faecal culture were studied for specific identity. The details regarding the season, age of the birds and their locality were also recorded.

Collection and examination of nematodes

The nematodes collected were washed in normal saline to remove adherent mucus and dirt. Easily identifiable morphological features were studied by preparing temporary

aqueous mounts in normal saline and the detailed morphology by making semipermanent mounts after clearing with lactophenol or carbolic acid and also by making permanent mounts.

Preservation

The larvae obtained by faecal culture were preserved in 2 per cent formalin and the eggs and adult worms in 5 per cent formalin for further studies.

Diagram

All diagrams were drawn with the aid of camera lucida.

Photomicrograph

Fresh as well as preserved materials were used for taking photomicrographs.

Measurements

Measurements were made with the aid of an occular micrometer and also from camera lucida drawings. The larvae were killed and straightened by the application of gentle heat before taking measurements.

Harvesting of eggs for setting up of cultures

Ova were obtained direct from the uteri of gravid females by dissection of the worms on a glass slide under a binocular dissection microscope.

Maintenance and study of culture

Filtered aquarium or well water with one per cent formalin was used as the medium for egg cultures. The eggs harvested from gravid females avoiding debris and blood were transferred into a medium sized petridish filled to one fourth of its capacity with filtered medium. The container was then covered by a suitable coverdish inverted over it. The cultures were cleared regularly by carefully pipetting out the supernatant fluid and adding fresh media. Cultures were maintained at room temperature and aeration was done by pumping air into the medium using a pipette. Cultures were examined under a binocular dissection microscope once daily in the morning hours for the first three days and then in the morning and evening hours until the infective second stage developed in the eggs of *A. galli*, *H. gallinae* and *A. columbae*; the infective first stage in the eggs of *C. obsignata* and the infective third stage larvae of *S. trachea* and *O. quadriradiatus*. The hatching time and time of development of infective larvae were also noted. In the case of *O. quadriradiatus* egg cultures were made and

maintained in incubator at various temperatures of 4°C, 12°C, 20°C, 29°C, 38°C and 50°C to note the development of larvae at different temperatures.

Cross transmission trials

In order to find out whether the common nematodes of pigeons were transmissible to chicken and vice-versa, trials were under taken as follows. Pigeons were infected with infective eggs of *Ascaridia galli*, *Heterakis gallinae* and *Syngamus trachea*, the common nematodes of fowl. Chicks were infected with infective eggs of *Ascaridia columbae*, *Capillaria obsignata* and infective larvae of *Ornithostrongylus quadriradiatus*, the common nematodes of pigeons. In both cases chicks or pigeons as the case may be, were infected simultaneously as positive control.

Experimental birds

Ten pigeons and ten chicks were used as experimental birds for each trial. Day old white leghorn chicks were obtained from university poultry farm, Mannuthy. Pigeons aged one and half months were purchased from local poultry markets and were utilised only after maintaining them in the laboratory for such duration as to determine that they were free of any previous infection. All the birds were maintained

in the laboratory in identical conditions and the feed and clean drinking water were provided *ad libitum*.

Standardization of dose for experimental infection

On the day of infection all the infective, viable cultures were pooled together and to obtain a uniform suspension, the samples were homogenized for 10 min. by using a magnetic stirrer. A drop of the sample was taken on a slide and examined to ascertain whether the infective eggs were intact. A pooled culture sample of 0.01 ml was transferred to a glass slide, covered with a coverslip and all the infective eggs therein were counted under the low power of microscope. Three consecutive counts were carried out and the average was taken and then the total number of ova or larvae in the pooled sample was calculated. The infection was done by direct inoculation through mouth into the crop using a fine, long pipette. The infective dose for each species was standardized by conducting preliminary trials with varying doses of infective eggs or larvae. The dose of infective eggs or larvae in each case was as follows:

Pigeons

1. *A. galli* - infective eggs
   Pigeons - 6000
   Chicks - 1000

2. *H. gallinae* - infective eggs

   Pigeons - 3000

   Chicks - 1000

3. *S. trachea* - infective eggs

   Pigeons - 3000

   Chicks - 1000

Chicks

4. *A. columbae* - infective eggs

   Chicks - 3000

   Pigeons - 500

5. *C. obsignata* - infective eggs

   Chicks - 1000

   Pigeons - 500

6. *O. quadriradiatus* - infective larvae

   Chicks - 1000

   Pigeons - 200

When the infection was found successful in pigeons in the first three trials, egg cultures were made from the gravid females collected from pigeons and attempt was made to reinfect the chicken. In all six trials, faecal samples were examined at frequent intervals after infection and one pigeon and one chick were also sacrificed at regular intervals to assess whether the infection was successful or not. The

prepatent period was determined by examining the droppings of infected birds for the presence of eggs. The birds which remained after the prepatent period in each trial except in the case of *O. quadriradiatus* were autopsied to collect the worms and the percentage of establishment was recorded. Four pigeons infected with *O. quadriradiatus* were maintained till 21 days for haematological studies.

Detailed life cycle studies in pigeons

The data on biology of parasitic stages of *A. columbae* and *S. trachea* were collected from the pigeons used in cross transmission studies while in the case of *O. quadriradiatus*, separate birds were used and detailed studies on free living and parasitic stages were made.

Ornithostrongylus quadriradiatus

Twelve one and half months old pigeons constituted the experimental birds for this study. By repeated experiments using different doses of larvae ranging from 100 to 1000, 200 larvae were found to be the optimum dose required to set up infection in pigeons without causing early mortality.

Seven pigeons were infected with 200 infective larvae each and were sacrificed at the rate of one per day from day 1 to 7 post infection. The remaining 5 pigeons were maintained

till 21 days to study the haematology. The entire digestive tract was thoroughly scraped and examined under binocular dissection microscope. Worms, both mature and immature, if present, were collected and transferred to a petridish containing normal saline to remove the mucus and debris. The detailed morphology of the larvae and adult worms were studied.

Binomics of infective larvae of *Ornithostrongylus quadriradiatus*

Phototropism

Faecal sample found positive for *O. quadriradiatus* on coprological examination was collected in sufficient quantities and was divided into two equal subsamples. Each of the subsample was utilised for culturing.

The modified Veglia's method (Sathianesan and Peter, 1970) was followed for coproculture. Clean, dry glass vials measuring 10 cm in height and 3.0 cm in diameter were used for this purpose. Faeces was mixed well and transferred to the vials without soiling the sides. Since the faeces should contain optimum moisture when cultured, excess water was removed by adding charcoal and using blotting paper in case of watery faeces. Then the vials were closed and kept under room temperature. One of the cultures was exposed to light and the

other was covered with a black paper and kept in a dark room to prevent the exposure to light. The former was control for the experiment. Both exposed and unexposed cultures were examined after 5 to 6 days, macroscopically and microscopically to note the movement of larvae on sides of the vials. The distance of vertical migration of larvae from the faecal pad to the sides of vials was measured and compared.

Viability

The larvae washed out with aquarium water from the culture bottles was transferred to a suitable petridish and kept at room temperature. The larvae were examined daily and noted their activity. To replace the evaporated water, sufficient quantity of filtered aquarium water was added whenever required. The observation was continued till all the larvae were found dead and thus longevity of the larvae was determined in dry and wet periods.

Clinical signs and pathogenicity of nematodiasis in pigeons

Clinical signs of naturally and experimentally infected birds were observed. The gross pathology of the affected organs of birds infected with *A. columbae*, *S. trachea*, *O. quadriradiatus*, *C. obsignata* and *A. spiralis* were recorded during the post mortem examination. The tissues showing

lesions utilised for histopathological examination. Sections ranging from four to five microns were prepared from the processed tissues and stained with Haematoxylin and Eosin.

Haematology

This was done only in the case of birds infected with *O. quadriradiatus* since it is known to be a blood sucking nematode. Haematological studies were conducted using nine birds maintained for cross transmission trials and lifecycle studies. Blood samples were collected from the brachial vein which was raised by digital pressure, proximal to the site of collection using a scalp vein set (26 G needle) attached to a 2 ml glass syringe.

Blood was collected from all the above nine pigeons before infecting them with *O. quadriradiatus* for cross transmission and lifecycle studies and the haematological values were determined. After infection three samples from each bird were collected at 7th, 14th and 21st days. Total erythrocyte count, Total leucocyte count and Packed cell volume were determined as per the method described by Sastri (1976). Differential leucocyte count was done with the copper peroxidase method of Sato and Sekiya (1965) and Haemoglobin content was estimated by Sahlis method (Schalm *et al.*, 1975). The results obtained before and after infection were compared by using statistical 't' test.

Results

RESULTS

Prevalence of nematode infections in pigeons

a. As revealed by examination of faecal samples

Eight hundred and fifty four faecal samples were collected from pigeons maintained by private individuals and state museum and Zoo, Thrissur during the period from April 1995 to March 1996. Examination of these samples revealed that 301 samples were positive (35.24%) for ova of single or mixed infections of nematodes belonging to the genera *Ascaris*, *Capillaria*, *Ornithostrongylus* and *Strongyloides*. Single infection due to above genera accounted for 11.29, 14.95, 9.3 and 3.98 per cent respectively and the remaining 60.46 per cent were mixed infections. *Capillaria* sp. had the maximum percentage of infection (38.53%) and the *Strongyloides* sp., the lowest (9.3%) among the positive samples.

Season wise prevalence recorded from the results of faecal examination of 854 samples is given in Table 1. The maximum prevalence of nematode infections was during the cold wet season from June to August (41.72%) and the least during the dry season from December to May (26.92%).

Table 1. Season-wise prevalence of nematode infections in pigeons

Season	Months	Number of samples examined	Number of samples positive	Percentage of infection
Cold wet South west monsoon (heavy rainfall)	June-August	278	116	41.72
Warm wet North west monsoon (low rainfall)	September-November	264	101	38.26
Dry	December-May	312	84	26.92
Whole year	January-December	854	301	35.24

b. As revealed by examination of viscera

Postmortem examination of 92 pigeons revealed that 43 (46.74%) were infected with single or mixed infections of nematodes. The species of nematodes collected with their location and percentage of prevalence were recorded (Table 2). A total of five species namely, *Capillaria obsignata*, *Ascaridia columbae*, *Ornithostrongylus quadriradiatus* and *Strongyloides avium* from the small intestine and *Acuaria spiralis* from the proventriculus were identified. *C. obsignata* had the maximum prevalence of 29 out of 43 infected birds (67.44%) and *A. spiralis*, the lowest (6.98%).

The relative proportion of various species of nematodes in pure infection is given in Table 3. Out of 43 positive birds 21 (48.84%) had infection with a single species. *C. obsignata* was found in 11 birds (25.58%) and was the most common species in pure infection. *Strongyloides avium* was the least common in pure infection (2.33%).

The relative proportion of various combination of species in mixed infections with two, three and four species are given in Table 4. Mixed infection with two species were recorded in 15 (34.88%), three species in 5 (11.63%) and four species in 2 (4.65%) birds. The maximum number of species involved in mixed infections were four from 2 birds and they include *C. obsignata*, *O. quadriradiatus*, *A. columbae* and *S. avium*. It

Table 2. Species of nematodes with their location and percentage of infection in 43 positive pigeons

Sl. No.	Species	Location	Number postive	Percentage
1.	*Capillaria obsignata*	Small intestine	29	67.44
2.	*Ascaridia columbae*	"	18	41.86
3.	*Ornithostrongylus quadriradiatus*	"	17	39.53
4.	*Strongyloides avium*	"	7	16.27
5.	*Acuaria spiralis*	Proventriculus	3	6.98

Table 3. Relative proportion of various species of nematodes in pure infection in 43 positive pigeons

Species	Number of birds postive	Percentage
Capillaria obsignata	11	25.58
Ornithostrongylus quadriradiatus	5	11.63
Ascaridia columbae	4	9.30
Strongyloides avium	1	2.33
Total	21	48.84

Table 4. Relative proportion of various combination of species of nematodes in mixed infections in 43 positive pigeons

Number of species involved	Species	Number encountered		Percentage	
Two	*C. obsignata* + *A. columbae*	6		13.95	
	C. obsignata + *O. quadriradiatus*	5		11.62	
	C. obsignata + *S. avium*	1	15	2.33	34.88
	O. quadriradiatus + *A. columbae*	1		2.33	
	O. quadriradiatus + *A. spiralis*	1		2.33	
	A. columbae + *S. avium*	1		2.33	
Three	*C. obsignata* + *O. quadriradiatus* + *A. columbae*	3		6.98	
	C. obsignata + *S. avium* + *A. spiralis*	1	5	2.33	11.63
	A. columbae + *S. avium* + *A. spiralis*	1		2.33	
Four	*C. obsignata* + *O. quadriradiatus* + *A. columbae* + *S. avium*	2	2	4.65	4.65

was found that *C. obsignata* was the commonest one in mixed infections also.

Pigeons from the age of 10 days to 3 years were examined for helminthic infection in the present study. Birds of different ages were found to have helminthic infection and even eight squabs aged 25 to 28 days were found to be infected with immature *A. columbae* and mature *C. obsignata* and *O. quadriradiatus* in a flock of pigeons.

Description of adult worms

Acuaria spiralis (Molin, 1858)
Syn. *Dispharynx spiralis* (Plate I, Figs.1,2 and 3; Plate II, Figs.1,2,3,4 and 5)

The worms were found in the lumen of proventriculus of pigeons with their heads deeply embedded in the mucosa. Freshly collected worms were white in color and exhibited only slight coiling movements. The sexes were dimorphic in that the females were longer and thicker than males. The mouth was provided with two small lateral lips. The buccal capsule was long, cylindrical and transversely striated. The most striking feature of the worm was the presence of four wavy and recurrent cordons which extend from base of the lips to near about the excretory pore where they are reflected forward to reach nearly two-thirds of length of descending portion of

cordon. The cervical papillae were located in between the recurrence of cordons.

Male

They were readily recognisable, being smaller in size and possessing a spirally coiled tail and measured 5.8 to 6.3 mm in length and 0.29 to 0.34 mm in width. The cordons were 0.81 mm long. The nerve ring and excretory pore were at a distance at 450 and 590 um respectively from head end. The muscular oesophagus which was transparent and 590 um long leads into slightly wider and darker glandular oesophagus measuring 1.70 mm. The spicules were unequal and dissimilar, left spicule being long, slender, curved and 390 to 420 um long while the right was short, boat-shaped and measured 130 to 180 um in length. There were 4 pairs of precloacal and 5 pairs of post cloacal papillae.

Female

They measured 6.70 to 7.48 mm in length and 540 to 580 um in width. The cordons were 1.46 to 1.50 mm long. The nerve ring and excretory pore were at 595 and 687 um respectively from anterior end. The muscular and glandular portions of oesophagus measured 636 um and 2.01 mm respectively in length. The anus was situated at a distance of 152 to 180 um from tail tip. The vulva was located at the posterior part of the body

at a distance of 1.48 mm from the posterior end. The vagina was modified into a muscular ovijector which was shaped like a hook and directed posteriorly. The limiting boundary between the vestibule and sphincter in ovijector was clearly marked by an annular cuticular fold. A small mucron was present at the tip of the tail. The eggs were thick shelled, measuring 84 to 87 x 20 to 23 um in size and had fully developed embryo inside when passed in faeces.

C. obsignata (Madsen, 1945)

Syn. *C. columbae* (Plate III, Figs.1, 2 and 3; Plate IV, Figs. 1-7)

The worms were found in the lumen of small intestine of pigeon. Freshly collected worms were white in colour and hair like in appearance. The cuticle was finely striated transversely. The head was very small and the mouth was indistinct except for a small terminal prominence appearing like a button at the anterior end. The anterior part held the long, non-muscular oesophagus which gradually increases in size as it extended posteriorly.

Male

The males were 7.8 to 14.2 mm in length and 48 to 54 um in width. The oesophagus was more than half as long as the body and measured 4.65 to 6.4 mm in length. The cloaca opened

terminally with a small bursal lobe on either side. The two lobes were connected dorsally by a delicate bursal membrane. The spicule sheath was aspinose, long with transverse folds in fully extruded condition and measured 1.98 to 3.11 mm in length and 8 to 11 um in breadth. The spicule was single and swollen at its proximal region. It was 1.1 to 1.56 mm long and 7 to 10 um broad.

Females

The females measured 9.1 to 18.9 mm in length and 57 to 78 um in breadth. Length of oesophagus was 5.01 to 6.5 mm. The vulva was situated in a slight prominence, 65 to 81 um posterior to the union of oesophagus and intestine. The anus was sub-terminal. The eggs were slightly brownish, thick shelled, operculated at both poles and 46 to 52 x 22 to 28 um in size. The embryo was dark in color.

Strongyloides avium (Cram, 1929)
(Plate V, Figs.1, 2, 3, 4 and 5)

All the worms obtained were only females and were located in the small intestine. The worms were very slender and small, measuring 2.1 to 2.95 mm in length with a maximum thickness of 6 to 7 um. The head end had 3 small well-defined lips and the buccal capsule was indistinct. The oesophagus was filariform and measured 580 to 680 um in length with a

maximum thickness of 23 to 29 um. The vulva was located behind the middle of the body at a distance of 780 to 890 um from tail tip. The uterus contained only a single row of eggs. The anus was at 26 to 33 um from tail tip and the tail terminated into a point. Eggs were oval in shape, thin shelled containing fully developed larvae inside and 40 to 42 x 23 to 26 um in size.

Ascaridia columbae (Gmelin, 1790) Travassos, 1913
(Plate VI, Figs.1,2,3,4 and 5)

The worms were found in the small intestine of pigeons. They were large, white and translucent, thinning towards the ends. Mouth was provided with three prominent subequal lips, one dorsal and two sub-ventral. The distal margin of each lip was again divided into three lobes, one median and two laterals. A transverse fold of cuticle was present just behind the subventral lips.

Male

The males were slightly smaller than females and measured 48 to 59 mm in length and 760 to 920 um in width. The oesophagus was club shaped and measured 2.42 to 2.6 mm in length and 400 um in width at the posterior part. The nerve ring was at a distance of 320 to 360 um from anterior end. The precloacal sucker was circular in shape placed at a

distance of 1.0 to 1.1 mm from the tail tip. The cloaca appeared as transverse slit situated on a distinct prominence at about 735 um from tail tip. The posterior end was truncated and had caudal alae on either side. There were 13 pairs of caudal papillae, of which five pairs were preanal, four pairs adanal and four pairs postanal. The spicules were equal, alate and measured 1.6 mm in length and 82 um in width.

Female

They measured 57 to 60 mm in length and 708 to 856 um in width. The oesophagus was 2.84 to 3.50 mm long and 420 to 450 um wide at the bulbar region. The nerve ring was at 470 to 640 um from head end. The vulva was placed near the middle of the body at 24.1 to 28.8 mm from the anterior end and the anus was at 1.04 mm from the posterior end. The immature and mature eggs were seen in the uterus. The tail was straight. Eggs were oval in shape with thick smooth shell, unsegmented when laid and 69 to 84 by 46 to 53 um in size.

Ornithostrongylus quadriradiatus (Stevenson, 1904)
(Plate VII, Figs.1,2 and 3; Plate VIII, Figs.1,2,3,4 and 5)

The worms were blood suckers, delicate, slender, reddish in color when freshly collected and the coiled anterior ends were partly buried in the mucosa of intestine. The females were longer than males and their body was more or less of

uniform diameter except towards the anterior end. The cephalic cuticular inflation was distinct. The mouth was simple, unarmed and without visible papillae.

Male

The males were 7.9 to 11.1 mm long and 140 to 170 um broad. The cuticular inflation measured 120 to 162 um in length and 54 to 78 um in breadth. The oesophagus was 390 to 460 um long and the excretory pore was at 260 to 290 um from anterior end. The bursa was bilobed and without a distinct dorsal lobe. The ventro-ventral and latero-ventral rays were long, slender and were almost closed together. The antero-lateral was close to medio-lateral proximally but divergent distally. The medio-lateral and postero-laterals were separated. Externo-dorsal rays originated from base of the dorsal ray. The dorsal ray was short, the mainstem showing slight enlargement near its base. It was found to arise from a single stem that divided into two branches, each of which further subdivided into an inner and outer branches, which were bidigitate. Prebursal papillae were present on either side. The spicules were simple, equal 150 to 166 um long and 20 to 30 um wide. Each spicule terminated distally into 3 processes. The telamon was 55 to 70 um long with two longitudinal processes extending backward and forwards along the dorsal wall of the cloaca and two lateral processes

forming a partial ring through which the spicules were protruding out.

Female

They were 13 to 17 mm long and 125 to 180 um wide. The culticular inflation was 115 to 168 um long and 65 to 94 um broad. The oesophagus was 440 to 540 um long and the excretory pore was at 290 to 340 um from head end. The vulva was situated at 490 to 590 um from tail tip and the vagina was very short, followed by two powerful muscular ovijectors. The tail tapers to narrow blunt end which had a short spine. The anus was at 130 to 172 um from tail tip. Eggs were thin smooth shelled, segmented when laid and 70 to 82 x 38 to 45 um in size.

Egg cultures

The egg cultures of different species of nematodes for cross transmission and/or lifecycle studies were made and maintained at room temperature (27-33°C) till they developed to their respective infective stage. The development of culture for each species was as follows.

Ascaridia galli

The eggs incubated at the room temperature of 28 to 33°C undergone the series of clevage of cells and developed to the moru la stage in 4 to 5 days; first stage larvae in 7 to 8 days and the infective second stage in the egg was reached within 9 to 10 days. The infective larvae showed active movements inside the egg.

Heterakis gallinae

The eggs showed the morula stage in 3 to 4 days; the first stage larvae in 5 to 6 days and the infective second stage in the egg by 7 to 8 days after incubation at the room temperature of 29 to 32°C.

Syngamus trachea

On culturing eggs, it was observed that the eggs had undergone development and reached infective, sheathed third stage larvae on seventh day at room temperature of 27 to 29°C. There were two moults inside the eggs; the first occurred on day 4 and the second during 6 to 7 days after incubation. The larvae started hatching from seventh day onwards in cultures.

Ascaridia columbae

Under room temperature of 31 to 33°C, the first stage larvae appeared in the egg in 12 to 13 days. This larvae moulted to infective second stage in the egg in another 3 to 4 days.

Capillaria obsignata

The unsegmented eggs on incubation developed to first stage larvae within 9 to 10 days at 30 to 32°C. There was no moulting inside the eggs and the eggs containing first stage were infective.

Ornithostrongylus quadriradiatus

Under the room temperature of 29 to 30°C and moisture, the eggs developed into the first stage larvae which hatched out within 15 to 16 hours. The first and second moult occurred on 25 to 27 and 72 hrs respectively after incubation. The sheathed infective third stage larvae were seen from 72 hrs in the culture.

On culturing the eggs of *O. quadriradiatus* in different temperature (4°C, 12°C, 20°C, 29°C, 38°C and 50°C) revealed that the temperature had a significant role and optimum development was recorded at 29°C, whereas no development was observed at 4°C, 38°C and 50°C. The infective larvae were

observed from day 8 to 9 at 12°C, 6 to 7 at 20°C and 3 at 29°C.

Egg cultures of *S. trachea* and *O. quadriradiatus* failed to develop to their infective stage at room temperatures above 30°C but in the case of *A. columbae*, *C. obsignata* and *H. gallinae*, cultures kept at temperatures above 33°C showed disintegration and degeneration of eggs.

Cross transmission trials

Pigeons

Ascaridia galli

Ten pigeons and 10 chicks were infected with 6000 and 1000 infective eggs per bird respectively. One pigeon and one chick were sacrificed on day 2, 6, 10, 15, 20, 25 and 30 post infection. The remaining 3 pigeons and 3 chicks were sacrificed on day 42 PI.

The droppings of all infected pigeons showed the presence of unhatched infective eggs during the first 3 hours after infection. Hatched out live larvae of *A. galli* were seen from 4 hrs to 3 days after infection. Chicks also showed the presence of live hatched out infective larvae in droppings but were relatively few in number.

Day 2 PI

Forty two and 74 numbers of hatched out second stage larvae of *A. galli* were recovered from intestine of the pigeon and chick respectively and were similar in morphological details.

Day 6 PI

On sacrificing the pigeon and chick, 12 and 63 second stage larvae respectively could be obtained from the intestine. Some larvae in chicks were in the moulting stage.

Day 10 PI

No larvae could be collected from pigeons but 66 third stage larvae were collected from the intestine of a chick.

Day 15 PI

Sixty eight third stage larvae obtained from the intestine of a chick and majority of them were in the third moulting stage. No larvae could be collected from the pigeons.

Day 20 PI

Pigeon was found negative for any larvae and 74 fourth stage larvae could be collected from the chick.

Day 25 PI

No larvae could be seen in the pigeon but 68 fifth stage larvae were recovered from the chick.

Day 30 PI

The chick yielded 64 immature worms and the pigeon was negative for any worms.

Day 42 PI

The droppings of all the remaining three chicks showed eggs on 42nd day after infection and on autopsy a total of 118 worms could be recovered from these chicks. Three pigeons which remained on 42nd day were found negative for infection. The details of worms recovered and the percentage of infection are presented in Table 5.

From the above experiment it was observed that the pigeons were relatively resistant to *A. galli* infection. The second stage larvae persisted upto day 6 in the intestine and

Table 5. Susceptibility of pigeons and chicks to infective eggs of *A. galli*

Day	Number of pegions and chicks autopsied	Pigeons*		Chicks**	
		Number of larvae recovered	Percentage of infection	Number of larvae/ worms recovered	Percentage of infection
2	1 each	42	0.7	74	7.4
6	1 each	12	0.2	63	6.3
10	1 each	-	-	66	6.6
15	1 each	-	-	68	6.8
20	1 each	-	-	74	7.4
25	1 each	-	-	68	6.8
30	1 each	-	-	64	6.4
42	3 each	-	-	118	3.9

* Infective dose - 6000 eggs

** Infective dose - 1000 eggs

subsequently got eliminated. No larval stages could be seen after 10 days of infection.

Heterakis gallinae

Of the 10 pigeons infected with 3000 infective eggs per bird and 10 chicks infected with 1000 infective eggs per bird, one each was sacrificed on day 2, 5, 9, 12, 16, 20, 25 and 30 PI and 2 each on 33rd day.

The droppings of all infected pigeons were found to contain unhatched infective eggs from 5 hrs to 2 days after infection whereas in chicks only few infective eggs and hatched out live and dead larvae were seen. Hatched out larvae could not be seen in the droppings of pigeons.

The pigeon sacrificed on day 2 onwards harboured no larval stages and the entire infective eggs have been found to be eliminated by 2 days of PI as evidenced in the faecal examination. In the case of chicks, various developmental stages of worms could be collected from the caecum at different days intervals and the percentage recovery of immature and mature worms in chicks were 11, 8.4, 9.3, 6.4, 3.2, 2.1, 1.4, 1.2 and 0.9 on day 2, 5, 9, 12, 16, 20, 25, 30 and 33 PI respectively. Fully viable eggs were detected in the faeces of chicks from day 33 PI onwards.

It was thus observed that the pigeons were completely resistant to *H. gallinae* infection and this parasite was not transmissible to pigeons.

Syngamus trachea

Of the 10 pigeons infected with 3000 infective eggs per bird and 10 chicks infected with 1000 infective eggs per bird, one each was sacrificed on day 2, 6, 9, 13, 18 and 21 PI.

The droppings of all infected pigeons were found to be positive for the presence of infective eggs and hatched out live larvae of *S. trachea* from 9 to 24 hrs after infection while in chicks comparatively fewer eggs and hatched out larvae were noticed.

Day 2 PI

Thirty seven third stage larvae could be recovered from the intestine and lung of the pigeon and 57 from the lung of the chick. No third stage larvae could be seen in the intestine of the chick.

Day 6 PI

On day 6, the lung of pigeon and the chick were found to harbour third stage larvae, their moulting stage and the

fourth stage larvae. The total number of larvae collected from pigeon was 32 as against 52 in chicks.

Day 9 PI

Thirteen larvae including fourth stage, their moulting stage and fifth stage were collected from the lung of the pigeon whereas 21 fifth stage larvae and young copulating forms were recovered from lung and trachea of the chick. No copulating forms were seen in the pigeon.

Day 13 PI

Autopsy of pigeon yielded a total of 9 juveniles including single and copulatory ones while the chick yielded 17 copulatory immature worms from the lung and the trachea. Majority of the young copulating forms were seen in the lung of the pigeon while in the chick they were in the trachea.

Day 18 PI

The faecal sample of one of the remaining chick was found positive for eggs on 18th day following infection. Autopsy of the pigeon yielded 6 immature worms in the lung and trachea while in the positive chick 10 mature worms in the trachea were found and no worms were present in the lung.

Eggs could be detected in the droppings of all the remaining chicks on day 20 PI onwards.

Day 21 PI

The pigeon and the chick sacrificed on 21st day yielded 8 young adults and 12 adult worms respectively from the trachea. No worms could be seen in lungs in both cases. The chicks were continued to void the eggs while in pigeons no eggs could be detected till 27 days.

Day 28 PI

Fully matured eggs were detected in the droppings of all the remaining pigeons. The remaining chicks also continued to show the eggs in their droppings. On autopsy a total of 21 adult worms from pigeons and 36 adult worms from chicks were recovered from the trachea.

From the above experiment it was established that *S. trachea* in pigeons could develop to maturity and pass viable eggs from day 28 PI. The difference in the time required for the development of various stages and their relative location in the lungs and trachea of pigeons and chicks are given in Table 6. It could be seen that there was a delay in the fourth moulting, development of fifth stage

Table 6. Developmental stages of *S. trachea* with their location in pigeons and chicks at various intervals

Day	Piegons		Chicks	
	Lungs	Trachea	Lungs	Trachea
2	Third stage	Nil	Third stage	Nil
6	Third, fourth and moulting forms	Nil	Third, fourth and moulting forms	Nil
9	Fourth, fifth and moulting forms	Nil	Fifth stages in single and in copulo	Fifth stages in single and copulo
13	Juveniles in single and copulo	Juveniles in single and copulo	Immature worms in copulo	Immature worms in copulo
18	Immature worms in copulo	Immature worms in copulo	Nil	Mature worms in copulo*
21	Nil	Young adults in copulo	Nil	"
28	Nil	Mature worms in copulo*	Nil	"

* Eggs in faeces

larvae, juveniles in copula and mature worms in pigeons compared to chicken.

The worms collected from pigeons and chicks at each interval were studied in detail to note the differences, if any, in their body size and morphological details. The comparative mean length of worms of different ages and the percentage of worm recovery in pigeons and chicks are presented in Table 7. It was found that the worms collected at each interval from the pigeons were markedly smaller than those obtained from the chicks eventhough no appreciable morphological differences could be detected.

Five chicks were infected with 700 infective eggs each obtained from the worms of pigeon origin in order to find whether there was any difference in the development of the worms in chicken infected with worms of chicken origin. It was found that the worms developed to maturity and eggs could be detected in the droppings of these birds by 20 days. The worms collected on 21st day at autopsy of all the chicks were similar in morphology to those collected from chicks infected with the infective eggs of chicken origin.

Table 7. Comparative mean length of different stages of *S. trachea* of pigeons and chicks at various intervals

Day	Number of pigeons and chicks autopsied	Pigeons*			Chicks**		
		Average size of worms (mm)		Percentage of infection	Average size of worms (mm)		Percentage of infection
		Male	Female		Male	Female	
2	1 each	0.406 (Male/Female)		1.23	0.435 (Male/Female)		5.7
6	1 each	0.870	0.820	1.06	1.000	0.863	5.2
9	1 each	0.980	1.540	0.43	1.200	1.800	2.1
13	1 each	1.040	2.370	0.30	1.500	3.060	1.7
18	1 each	1.900	8.300	0.20	2.800	11.400	1.0
21	1 each	2.200	9.600	0.26	3.400	13.100	1.2
28	4 each	2.900	11.100	0.17	4.100	16.200	0.9

* Infective dose - 3000 eggs

** Infective dose - 1000 eggs

Chicks

Ascaridia columbae

Ten chicks and 10 pigeons were infected with 3000 and 500 infective eggs per bird respectively. One chick and one pigeon were autopsied on day 2, 6, 12, 17, 25, 36 and 42 PI. The remaining 3 chicks and 3 pigeons were sacrificed on day 46 PI.

All the infected chicks were found to pass unhatched infective eggs in their droppings from 5 hours to 36 hours after infection, while the pigeons passed comparatively fewer infective eggs. Hatched out larvae were seen in droppings of pigeons only.

Autopsy of the chicks on day 2 PI onwards revealed that they were completely refractory to *A. columbae* as evidenced by the absence of worms in the intestine at all intervals. In pigeons various developmental stages were collected at different intervals and the percentage of worm recovery was 14.0, 11.6, 8.2, 5.0, 5.8, 3.4, 4.4 and 3.8 on day 2, 6, 12, 17, 25, 36, 42 and 46 PI respectively. The worms reached sexual maturity and started passing fully viable eggs in the faeces of pigeon from day 46 PI.

From the result of the above experiment it was found that the infective eggs of *A. columbae* did not hatch in intestine of chicken and this nematode of pigeon was not transmissible to chicken.

Capillaria obsignata

Of the 10 chicks infected with 1000 infective eggs per bird and 10 pigeons infected with 500 infective eggs per bird were autopsied one each on day 2, 6, 10, 14, 20 and 24 PI. The remaining 4 chicks and 4 pigeons were sacrificed on 26th day PI.

The droppings of all infected chicks and pigeons showed the presence of only a few infective eggs and hatched out larvae from 6 to 36 hrs after infection.

Autopsy of chicks and pigeons at different days intervals after infection revealed that both birds picked up the infection and the developmental stages of worms collected from chicks were similar in size and morphology to those recovered from pigeons. The worms collected in both cases were measuring an average size of 0.32, 0.68, 1.5, 3.2, 5.9, 8.8 and 10.9 mm in the respective days of collection. The percentage recovery of worms in chicks were 15.1, 9.6, 6.4, 3.9, 1.8, 1.1 and 1.4 on days 2, 6, 10, 14, 20, 24 and 26 PI. The worms reached sexual maturity and passed viable eggs in the faeces of chicks from day 26 PI onwards. In the case of

pigeons, the percentage recovery of worms were 17.2, 10.8, 6.6, 3.6, 2.4, 2.8 and 3.4 on the respective days but the eggs were passed in the faeces from day 24 PI.

It would be seen from this experiment that *C. obsignata* could be transmitted between chicks and pigeons.

Ornithostrongylus quadriradiatus

Ten chicks and 10 pigeons were constituted the experimental birds for this study. One chick and one pigeon each infected with 1000 and 200 infective third stage larvae respectively were sacrificed on day 1, 3, and 5. The remaining 7 chicks and 3 pigeons out of 7 were autopsied on 7th day PI. Four pigeons were maintained till 21 days for haematological studies.

It was observed that all the infected chicks passed the dead infective larvae in faeces from 3 hrs to one day after infection beyond which no larvae could be detected in the droppings.

Chicks sacrificed at different days interval were found negative for infection whereas in pigeons different developmental stages of worms could be collected at various intervals and the percentage recovery of worms were 32, 26, 21 and 17 on day 1, 3, 5 and 7 PI. The worms reached its maturity and eggs could be detected in droppings from day 7 PI in pigeons.

Chicks were thus found to be completely refractory to infection with *O. quadriradiatus*.

Detailed life cycle studies in pigeons

Ascaridia columbae (Plate IX, Figs.1-6; Plate X, Figs.1-6)

The life history of pigeon ascarid, *A. columbae* was studied in detail and the morphology of various stages were presented as follows.

Egg

The eggs were oval, thick with smooth shell and contained unsegmented embryo when laid. They measured 69 to 84 by 46 to 53 um.

First stage larva

These larvae were developed inside the egg on day 12 to 13 after incubation at 31 to 33°C. They had an average length of 290 um. The oesophagus was 88 to 96 um long and 8 to 9 um wide and the intestine contained mass of granules. The nerve ring and excretory pore were at 41 and 64 um respectively from the anterior end. The first moulting occurred within the eggs on 15 to 17 days after incubation.

Second stage or infective larva

The infective larvae developed in the egg were 324 to 428 um in length. After infection they were collected from washings of small intestine of the pigeon autopsied on day 2 PI. They measured in 360 to 510 um in length and 10 to 14 um in width. A small cuticular knob was present on the head. The oesophagus and the intestine were more distinct. The oesophagus had a posterior bulb and measured 114 to 130 um in length and 12 um in width at posterior bulb region. The nerve ring and excretory pore were located at 84 and 97 um respectively from the anterior end. The well defined intestinal canal filled with dark intestinal contents measured 184 to 296 um in length and the anus was at 62 to 84 um from tail tip.

Third stage larva

Larvae collected from lumen and scrapings of small intestine on day 6 PI had already developed to the third stage. Transition to third stage had apparently taken place between 3rd and 5th day PI. In fully grown specimens, sexes were distinguishable. The males could be distinguished by the presence of swelling situated just anterior to the cloaca indicating the formation of pre-cloacal sucker and the tail of females were longer and more gradually tapering.

Male

The males measured 1.6 mm in length and 45 um in width. Lips were weakly developed and the cuticular knob was absent. The oesophagus with distinct bulbar portion in the posterior part measured 290 to 300 um in length. Nerve ring and excretory pore were at 160 and 252 um respectively from head end. The intestine had a length of 1.05 to 1.18 mm and anus was located at 131 to 145 um from tail tip.

Female

They measured 1.78 mm in length and 48 um in width. The oesophagus was 301 to 322 um long. Nervering and excretory pore were present at a distance of 174 and 278 um respectively from head end. The intestine was 1.2 to 1.4 mm long and the anus was at 180 to 195 um from tail tip.

Fourth stage larva

These larvae were collected from the lumen of small intestine on day 12 and 17 PI. On the day 12, majority were third stage and the fourth stage larvae and moulting forms were few but on day 17 majority were fourth stage. The third moulting apparently occurred between 11 to 16 days PI.

Male

The male worms were 6.7 mm long and 120 um wide. The lips were distinct and the clubshaped oesophagus was 680 to 710 um long. Precloacal sucker was distinct but not completely developed and situated at a distance of 294 um from tail tip. The rudiments of caudal papillae and spicules were visible. The anus was at 135 um from hind end.

Female

They measured 7.0 mm in length and 134 um in width. The club shaped oesophagus was 698 to 734 um long. The vulva was placed on a distinct prominence at a distance of 3.8 mm from anterior end. The short curved vagina and uterine coils were also visible. The anus was at 230 to 270 um from hind end.

Fifth stage larva (Juvenile)

A few moulting forms of fourth stage larvae were collected on day 17 PI and many fifth stage larvae were seen on day 25 PI indicating that final moult occurred after 16 days and completed before 24 days.

Male

The males measured 11.60 to 12.0 mm in length and 280 um in width. Lips were distinct, three in number and cervical

alae extended from base of the lips to oesophagus. The oesophagus was 1.1 to 1.2 mm long. Precloacal sucker and anus were at an average distance of 390 and 261 um respectively from tail tip. Spicules were equal and 374 um long. There were 13 pairs of caudal papillae of which five pairs were preanal, four pairs adanal and four pairs postanal.

Female

They were 13.1 to 13.8 mm long and 288 um wide. Lips and cephalic alae were seen as in males. The oesophagus was 1.2 to 1.4 mm long and clubshaped. Vulva was placed in the middle of the body, 6.7 to 6.9 mm from anterior end. Anus was at 470 um away from tail tip.

Immature worms

They were collected from small intestine on day 36 PI. These worms were twice as long as the juveniles collected on day 25 PI and similar in morphology with adult worms already described. The males measured a length of 24.64 to 31.4 mm and 370 um in width and the females were 29 to 35.4 mm long and 540 um wide.

Adult worms

Adult worms were collected from small intestine on day 42 and 46 PI. The detailed description was given already under the title 'Description of adult worms'.

Prepatent period

Eggs were first observed in the droppings of pigeons on day 46 PI.

Syngamus trachea (Plate XI, Figs.1-5; Plate XII, Figs.1-6; Plate XIII, Figs.1-5)

Cultures were made from the eggs collected from gravid females of *S. trachea* of fowl origin and were used for the present study. The infective third stage larvae developed within 6 to 7 days in cultures maintained at room temperature (27-29°C) were utilised for infecting the pigeons.

Description of larvae and adults

Third stage larva

The larvae collected from lung and intestine of the pigeon sacrificed on day 2 PI had an average length of 406 um and width of 16.4 um. Buccal capsule was distinct with an average depth and width of 5.1 um. Pharynx was indistinct and

measured 9.6 um in length and the oesophagus had an average length of 101.4 um. The intestine had an average length of 253.8 um and filled with blood. The genital primordium was at a distance of 164 to 182 um from head end. The anus was at an average distance of 41 um from tail tip.

Fourth stage larva

The larvae were collected from the lung on day 6 and 9 PI. Majority of the fourth stage larvae and a few third stage and their moulting forms were recovered on day 6 PI but on day 9 PI, very few fourth stage larvae were collected. Transition from third to fourth stage had apparently taken place between day 3 to 7 PI.

Male

It had an average length of 870 um and width of 37 um. The buccal capsule was oval in shape measuring 12.1 to 13.9 um in length and depth of 11.8 to 12.9 um. Oesophagus showed bulbous posterior portion with a length of 158 to 181 um. Intestine was 656.8 um long and filled with food granules. The anus was located at a distance of 45 to 54 um from tail tip. The tail was truncated with a short pointed tip. Bursal rays were found posteriorly but not quite prominent.

Female

The female larvae had an average length of 820 um and width of 49.4 um. Buccal capsule was cylindrical in shape with a depth of 8.4 to 9.6 um and width of 9.8 to 11.4 um. Oesophagus had a slight swelling at the posterior end and measured 148 um in average length. The intestine was filled with blood and 620 to 634 um in length. Vulva appeared as a prominence and situated at an average distance of 498.4 um from the anterior end. The tail measured an average length of 43.1 um.

Fifth stage larva (Juvenile)

They were collected from both lungs and trachea on day 9 and 13 PI and included both singles and in copulo. Few fifth stage larvae and many fofurth moulting forms were seen on day 9 PI but on day 13 PI, only fifth stage were collected from infected birds indicating that the final moult occurred between day 8 to 12 PI.

Male

The males measured a length ranging from 0.98 to 1.04 um and an average width of 42.6 um. The buccal capsule was large, conical in shape measuring on an average of 19.2 um in depth and 16.4 um in width. The oesophagus and intestine

Immature worms

These worms were collected from the lung and the trachea on day 18 and 21 PI. The males measured 1.9 to 2.2 mm in length and 58 to 66 um in width and the females were 8.3 to 9.6 mm long and 210 to 242 um wide. The worms were similar in morphology with adult worms described below.

Adult worms

The adults were found in the trachea on day 28 PI.

Male

The male was 2.8 to 3.0 mm long and 125 um wide at the anterior end. The buccal capsule was deep, thick walled, semi circular having a depth of 0.12 to 0.37 mm and a width of 0.19 to 0.41 mm. The mouth on enface view, revealed three pairs of teeth opposite to each other. The oesophagus measured 0.40 to 0.58 mm in length and with a width of 64 um at the posterior region. The intestine was 2.1 to 2.29 mm long and filled with blood. The bursa was obliquely truncated and inserted into the vulva of female. Bursal rays were 109 to 126 um long and visible but difficult to distinguish the bursal formula.

Females

The females were large and moving freely in the lumen of trachea. They were 10.6 to 12.0 mm long and 0.51 mm wide at the middle. The buccal capsule was deep with a depth of 0.28 mm and width of 0.35 mm. Enface view of mouth revealed three pairs of teeth with fine processes, arranged in a circular fashion at the base. The oesophagus was 0.620 to 0.680 mm long with the thickness of 190 um in the posterior part. The vulval prominence was located at a distance of 1.88 to 2.64 mm from the anterior end and the intestine was filled with food granules. The uterus was twisted around the intestine and contained both immature and mature eggs. The tail was conical with a pointed process and 0.38 mm long.

Egg

The eggs collected from the adult worms of pigeon origin were oval, thin shelled, operculated at both poles with segmenting embryo and measured 60 to 78 x 41 to 46 um in size.

Prepatent period

The mature eggs of the parasite were detected in the droppings from day 28 PI.

Ornithostrongylus quadriradiatus (Plate XIV, Fig.1; Plate XV, Figs.1 and 2; Plate XVI, Figs.1,2 and 3; Plate XVII, Figs.1-5; Plate XVIII, Figs.1,2 and 3; Plate XIX, Figs.1,2 and 3; Plate XX, Figs.1,2 and 3; Plate XXI, Figs.1,2 and 3).

Egg

The eggs were oval, thin smooth shelled, measuring 70 to 82 x 38 to 45 um in size and segmented when laid. They hatched within 15 to 16 hrs at room temperature of 29 to 30°C.

First stage larva

They measured 320 to 390 um in length and 12 to 15 um in width. The mouth tube had a length of 5 to 7 um. The rhabditiform oesophagus was 74 to 88 um long. The nerve ring and excretory pore were at an average distance of 47 and 58 um respectively from head end. The genital primordium was at 184.8 um from anterior end. The intestinal cells were indistinct and the lumen appeared wavy. The anus was located at a distance of 40 to 48 um from tail tip.

The active movements and feeding lasted for about 16 to 19 hours and the lethargy for 8 to 9 hrs and the first moult occurred within 25 to 27 hrs after hatching.

measured 162 to 184 and 664 to 846 um respectively. Bursal rays were seen clearly and engulfing the vulval projection of the female while it was in copulation. Spicules were similar in size, broad and fused posteriorly with an average length of 54 um.

Female

The female worms measured 1.54 to 2.37 mm in length and maximum width of 59 um at the anterior end. The buccal capsule had three pairs of teeth at its base and 32 um deep and 42.4 um broad. The oesophagus and intestine had an average length of 211 and 1689 um respectively. The vulva appeared as a clear prominence, located near the middle of the body, 580 to 690 um away from the head end. The tail was short, pointed and 74 to 92 um long.

Pairing of worms

Non copulating and copulatory worms were recoverable from the lungs as well as from trachea on 13th day. This suggested that the copulation of worms started in the lungs and also occur after reaching the trachea. By the 18th day after infection, males and females were in copulo and no non-pairing worms were obtained from trachea.

Second stage larva

The larvae measured 520 to 585 um in length and 16 to 18 um in width. The mouth tube was 8 to 10 um long. The less rhabditiform oesophagus measured 102 to 108 um in length. The nerve ring and excretory pore were located at 60 to 64 and 70 to 74 um respectively from the anterior end. The genital primoridium was at 265 to 274 um from head end and the intestinal cells were indistinct. The tail was 65 um long.

The active movements and feeding lasted for about 26 to 29 hrs and the lethargy for 16 to 21 hrs. The second moulting occurred on day 3 after hatching and meanwhile the cuticle got separated and the oesophagus assumed a new form.

Third stage larva

These larvae retained their old cuticle in the form of a sheath all around its body and measured 594 to 655 um in length and 22 to 26 um in breadth. The filariform oesophagus was 140.4 to 156 um long. The nerve ring, excretory pore and genital primoridium were at 75 to 84, 88 to 96 and 320 to 366 um respectively from anterior end. The intestinal cells were distinct, 16 in number and the anus was at 82 to 92 um from tail tip. The tail ended in a terminal point and had a pair of lateral, asymmetrical subterminal spines. The tail sheath measured 26 to 31 um from tail tip.

The exsheathed third stage larvae were recovered from proventriculus and duodenum after 24 hrs PI but only very few moulting stages could be collected at this time indicating that the third moulting was initiated.

Fourth stage larva

On day 2 PI, all the larvae developed to 4th stage and on day 3 PI many of these larvae started fourth moulting and were embedded on the surface of the mucosa of proventriculus and duodenum.

Male

They had a length of 1.0 to 1.3 mm and a width of 41 um. The oesophagus was 190 to 261 um long. The nerve ring and excretory pore were at a distance of 120 and 138 um respectively from the head end. The intestine measured a length of 810 to 968 um and was filled with food and refractile granules. Tail was truncated and was 64 to 71 um long. Bursal rays were not prominent.

Female

The females were similar to the male except for the long and slender posterior extremity and measured 1.5 mm in length and 49 um in width. The oesophagus was 240 to 278 um long.

The nerve ring and excretory pore were located at 134 and 151 um respectively from head end. Intestine had 1.0 to 1.2 mm in length and was filled with blood. The vulval region appeared at the posterior third of the body and the tail was 68 to 81 um long.

Fifth stage larva (Juvenile)

The larvae were collected on day 4 and 5 PI from lumen of duodenum.

Male

The males measured a length of 2.0 to 2.4 mm and 61 um width. A cephalic cuticular inflation was present. The oesophagus was 254 to 284 um long. The nerve ring and excretory pore were at 140 and 154 um respectively from head end. The intestine was filled with dark granules. Bursal rays and spicules could be seen clearly. The spicules were equal in size measuring 62 to 74 um. Prebursal papillae and telamon were also present.

Female

The females were longer than males and had a length of 3.0 to 3.4 mm and 69 um in width. the cuticular inflation was seen on the head. The oesophagus was 270 to 290 um long. The nerve ring and excretory pore were at 146 and 165 um

respectively from head end. The intestine was filled with blood. The vulva and anus were placed at 270 to 294 and 80 to 96 um respectively from tail tip. The tail tapered to a narrow blunt end and had a short spine at the tip.

Immature worms

These worms were collected from lumen of duodenum on day 5 and 6 PI. They were twice as long as the juveniles collected on day 4 and similar in morphology to adult worms described already. Males measured a length of 4.9 to 7.1 mm and a width of 80 um and the females were 6.9 to 8.9 mm long and 88 um wide. Immature eggs were seen in the uteri of the females.

Adult worms

A few mature worms on day 6 and many on day 7 PI were collected from duodenum. The detailed morphology of adult worms was discussed under the title 'Description of adult worms'.

Prepatent period

Eggs were first observed in the faeces on day 7 PI onwards.

The details of developmental stages collected at different days intervals are presented in Table 8.

Table 8. Developmental stages of *O. quadriradiatus* collected at different days intervals

Day	Stages of development of larvae/worms obtained	Location
1	Third stage and few moulting forms	Proventriculus and duodenum
2	Fourth stage	"
3	Fourth stage and mounting forms	"
4	Fifth stage	Duodenum
5	Juveniles and immature	"
6	Immature and adult	"
7	Adult	"

Binomics of infective larvae of *Ornithostrongylus quadriradiatus*

Phototropism

A total of six experiments were conducted by culturing faecal samples of infected pigeons and the cultures were kept in vials as described in materials and methods. The cultures exposed and unexposed to light were examined after 5 to 6 days and found that the larvae were seen migrating into the water droplets formed in the vials and were at some distance from the faecal pad. The distance of vertical migration of larvae to the sides of vials was measured and presented in Table 9. The presence of light had influence on the migration of larvae as evidenced by a greater distance of migration in exposed cultures compared to the unexposed ones.

Another observation made in the present study was that the infective larvae were seen migrated to the water droplets formed in the vials above the faecal pad indicating that the larvae were also hydrotactic.

Viability

To know the viability of larvae in dry and wet season, five cultures were set up at each season and the larvae in the cultures were examined at periodical intervals to note their

Table 9. Results of experiments for phototropism of infective larvae of *Ornithostrongylus quadriradiatus*

Expt. No.	Date of faecal culture	Date of larval migration	Upward migration of larvae in cultures (cm)	
			Unexposed	Exposed
1.	1.7.95	6.7.95	1.6	6.2
2.	3.7.95	8.7.95	1.4	5.8
3.	20.7.95	25.7.95	1.8	6.1
4.	7.8.95	12.8.95	1.4	5.6
5.	16.8.95	22.8.95	1.7	5.9
6.	22.9.95	27.9.95	1.6	6.0

activity till all the larvae were found dead. The viability was 60 to 67 days (ave. 63) in wet as against 47 to 52 days (ave. 49) in dry, beyond which the intestinal cells of the larvae got gradually exhausted, they became pale, shrunken and the sheath was lost and ultimately died and floated in water.

Clinical signs and pathogenicity of nematodiasis in pigeons

The clinical signs of infection due to *Acuaria spiralis* could be observed only in natural infection and that of *Ornithostrongylus quadriradiatus* and *Syngamus trachea* in experimental infection. In the case of *Ascaridia columbae* and *Capillaria obsignata*, the symptoms were recorded in both natural as well as experimental infection. The gross lesions and histopathological examination of affected organs were also studied.

Ascaridia columbae

Pigeons infected with a moderate number of worms were invariably poor in condition than the uninfected ones and exhibited dullness, inappetance, emaciation, progressive anaemia and diarrhoea from 25th day PI. No mortality was recorded during the period of observation.

Postmortem examination of affected birds revealed mild congestion and edema of intestinal mucosa. Moderate number of mature worms were seen in the intestinal lumen. Microscopically, desquamation of glandular epithelium and infiltration of inflammatory cells in the lamina propria were observed. A few goblet cells were seen at the tip of villi.

Capillaria obsignata

Infected birds showed symptoms of emaciation, droopiness and greenish diarrhoea from day 15 PI.

Sacrificed birds showed mild congestion and edema of small intestinal mucosa. On microscopical examination, infiltration of mononuclears comprising predominantly of lymphocytes and macrophages in the lamina propria was observed. A few goblet cells were also seen in the villi.

Acuaria spiralis

The infection with *A. spiralis* appeared to be very mild and the affected birds were apparently normal. The gross lesions in proventriculus included congestion and edema of the mucosa. Microscopically, desquamation of glandular epithelium and infiltration of inflammatory cells in the mucosa of proventriculus were characteristic.

Ornithostrongylus quadriradiatus

The symptoms observed were droopiness, inappetance, diarrhoea, ruffled feathers, progressive emaciation and anaemia from day 5 PI. The droppings were greenish in color and the birds showed a gradual reduction in weight. One bird died on 5th day after infection.

The gross lesions observed at necropsy were severe dehydration of the carcass, palor of muscles and mucous membrane and thickening with petechial haemorrhage of the duodenal mucosa. The worms were seen entangled in the greenish coagulated mucus mixed intestinal contents. Histopathologically, intestine revealed necrosis and desquamation of glandular epithelial cells and mild focal infiltration of inflammatory cells. A few goblet cells were seen in the villi.

Syngamus trachea

In the present experimental trial the affected birds did not exhibit any characteristic symptoms of the disease and it was found that the establishment of infection was very low.

Grossly the lungs were congested and fragile. The trachea showed petechial haemorrhage at the site of attachment of worms. The tracheal contents on examination were found to

be mixed with mucus, tissue debris and ova of worms. Microscopically, the lung tissue showed isolated areas of congestion with haemosiderin pigmentation. Cross section of migrating larva could also be seen in the connective tissue around the parabronchi (Plate XXII, Fig.1). Inflammatory reaction was not evident around the larva.

Haematology

The haematological changes in pigeons infected with *O. quadriradiatus* were studied on day 7, 14 and 21 PI and the data obtained were compared with the values of the same birds recorded before infection (Table 10). A significant reduction in haemoglobin, packed cell volume, red blood corpuscles and lymphocytes ($P<0.01$) was observed. The leucocyte and heterophils showed a regular increase ($P<0.01$) at all intervals. Eosinophils were found to increase from 14th day ($P<0.05$) and was highly significant at 21st day ($P<0.01$) post infection.

Table 10. Haemogram in pigeons infected with *O. quadriradiatus*

Day of collection	Hb gm%	PCV (%)	RBC M/cu.m.m.	WBC x10³/mm³	Differential Count (%)				
					H	E	B	L	M
0***	16.56	41.04	3.69	14.65	25.74	2.30	2.80	62.76	6.40
7	15.67 *	38.60 **	3.11 *	15.60 **	27.28 **	2.41	2.65	61.40 **	6.26
14	14.57 **	36.12 **	2.83 **	16.80 **	28.94 **	2.81 *	2.77	59.19 **	6.29
21	13.80 **	33.90 **	2.12 **	17.90 **	30.55 **	3.01 **	2.90	57.32 **	6.22

* - Significant at P<0.05

** - Highly significant at P<0.01

*** - Before infection

Plates

PLATE I

Fig.1. *Acuaria spiralis* - head end (x400)

Fig.2. *Acuaria spiralis* - female, vulval region (x400)

Fig.3. *Acuaria spiralis* - female, tail end (x400)

Fig.1

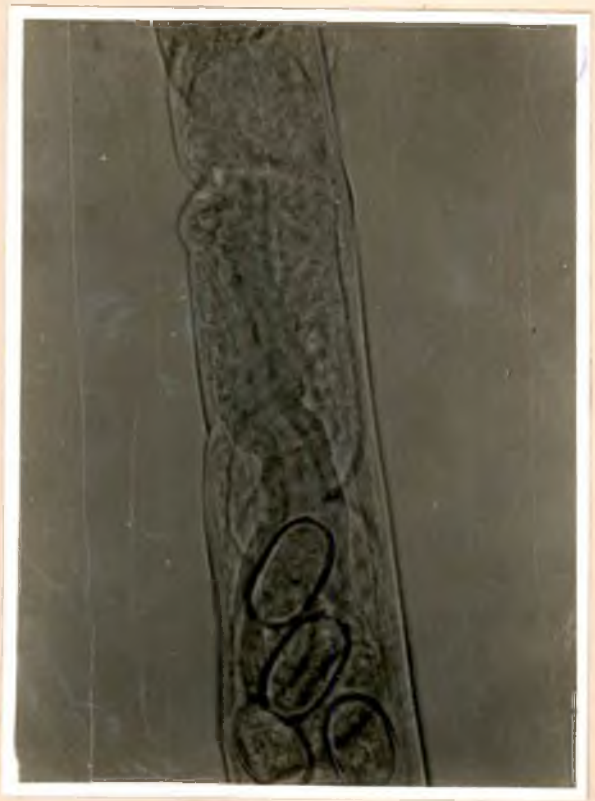


Fig.2

Fig.3

PLATE II

Fig.1. *Acuaria spiralis* - head end

Fig.2. *Acuaria spiralis* - male, tail end

Fig.3. *Acuaria spiralis* - female, tail end

Fig.4. *Acuaria spiralis* - female, ovijector

Fig.5. *Acuaria spiralis* - egg

(Camera lucida drawings)

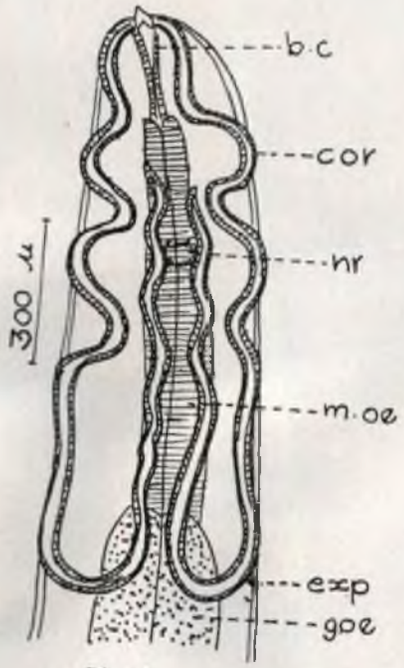


Fig: 1

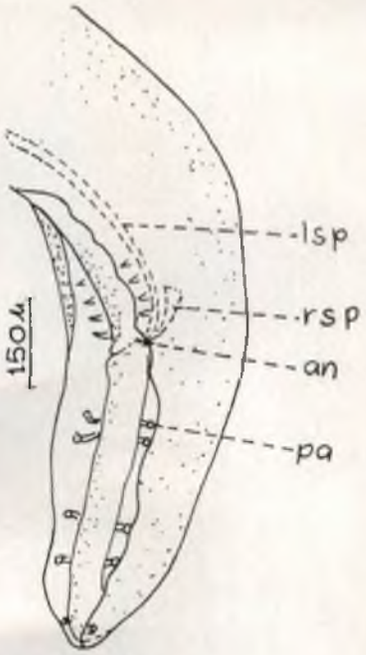


Fig: 2

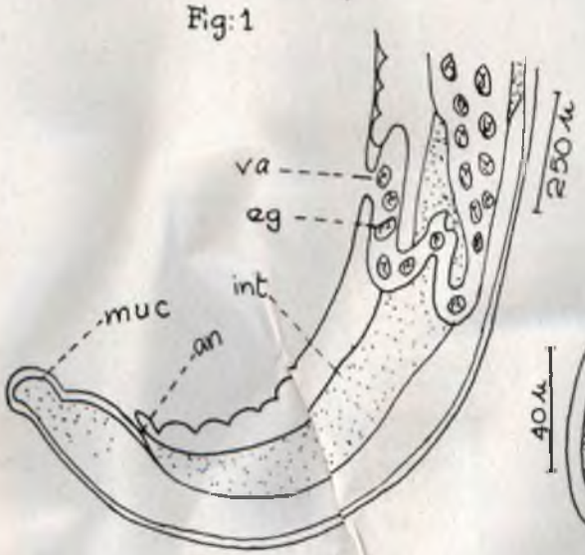


Fig: 3

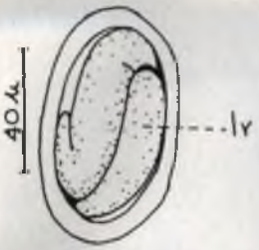


Fig: 5

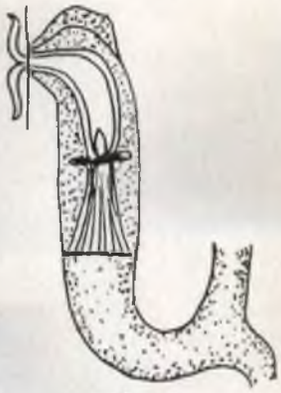


Fig: 4

PLATE III

Fig.1. *Capillaria obsignata* - head end (x160)

Fig.2. *Capillaria obsignata* - female, vulval region (x250)

Fig.3. *Capillaria obsignata* - male, tail end (x250)

Fig.1

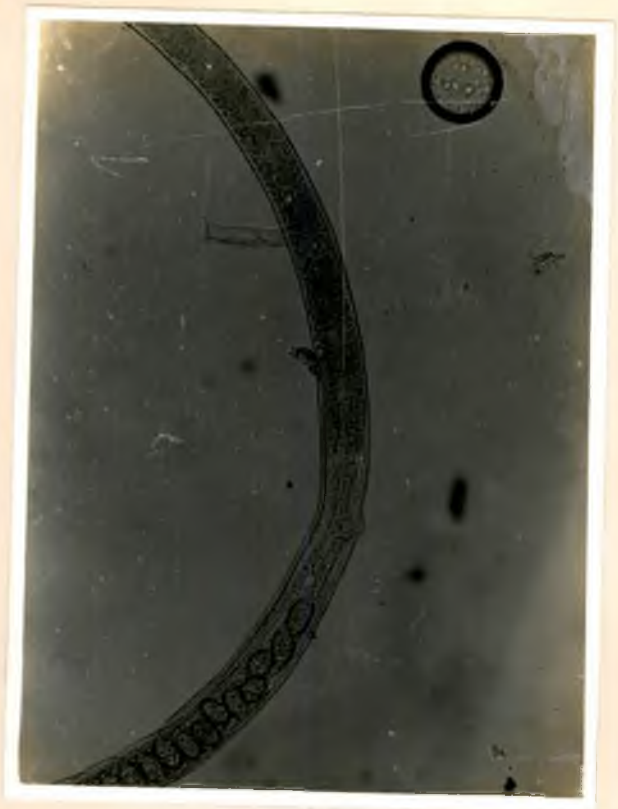


Fig.2

Fig.3

PLATE IV

Fig.1. *Capillaria obsignata* - head end

Fig.2. *Capillaria obsignata* - female, vulval region

Fig.3. *Capillaria obsignata* - female, tail end

Fig.4. *Capillaria obsignata* - male, tail end, lateral view

Fig.5. *Capillaria obsignata* - male tail end, dorsal view

Fig.6. *Capillaria obsignata* - male, spicule, proximal region

Fig.7. *Capillaria obsignata* - egg

(Camera lucida drawings)

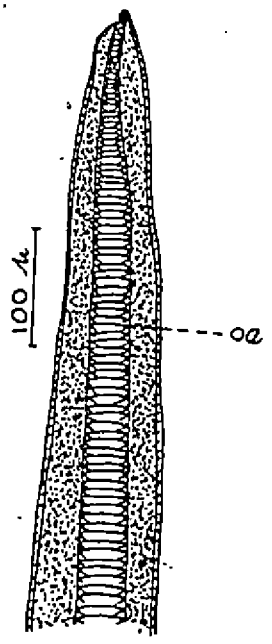


Fig: 1

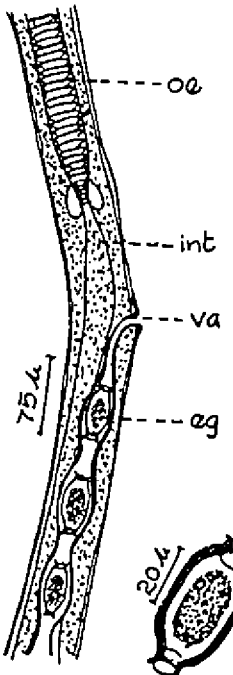


Fig: 2

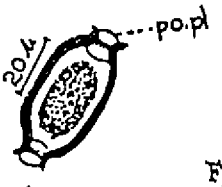


Fig: 7

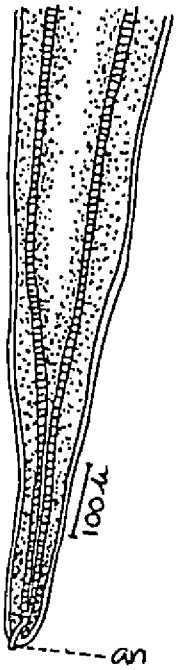


Fig: 3

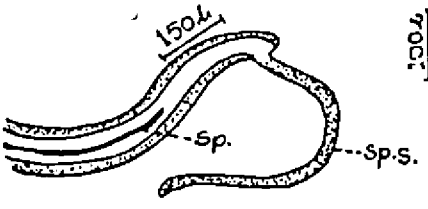


Fig: 4

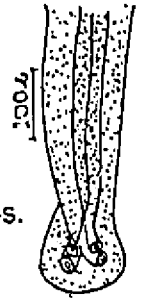


Fig: 5.

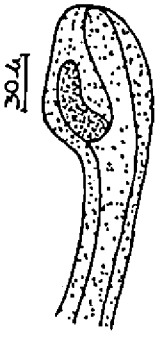


Fig: 6

PLATE V

Fig.1. *Stronglyloides avium* - female, anterior end

Fig.2. *Stronglyloides avium* - female, head end

Fig.3. *Stronglyloides avium* - female, tail end

Fig.4. *Stronglyloides avium* - female, hind end

Fig.5. *Stronglyloides avium* - egg

(Camera lucida drawings)

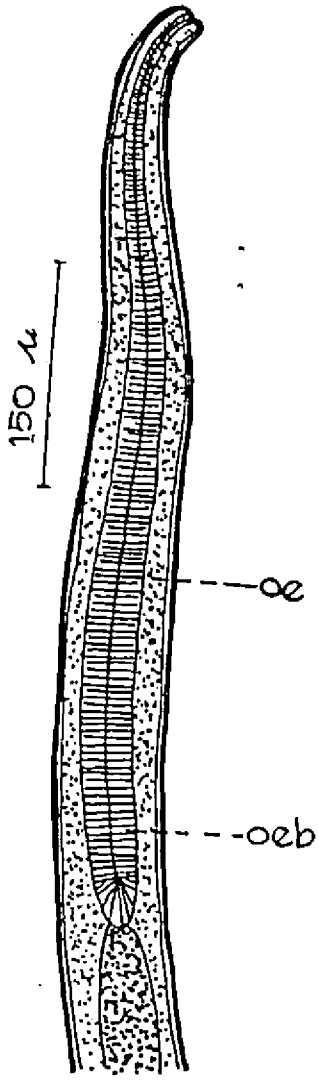
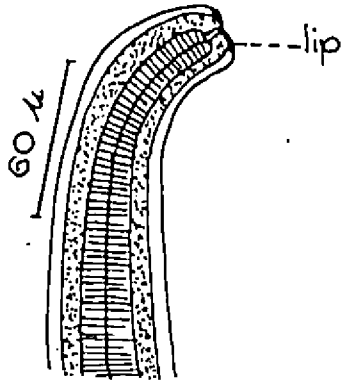


Fig: 1



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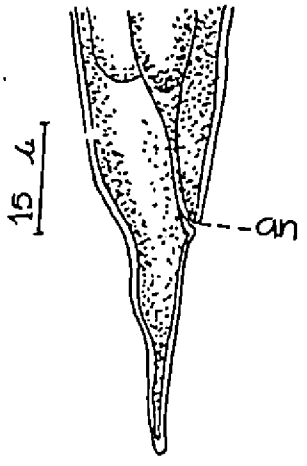
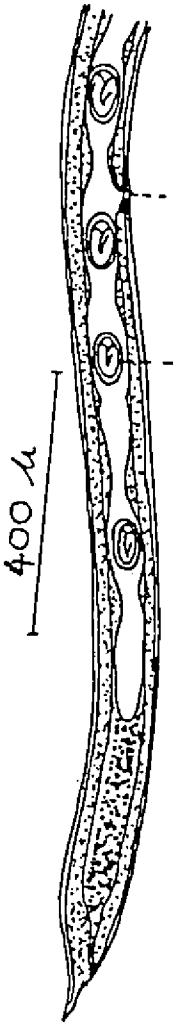


Fig: 3



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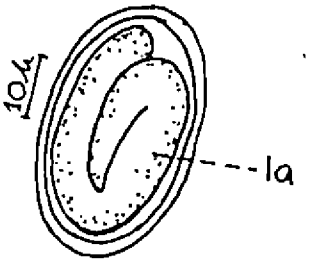


Fig: 5

PLATE VI

Fig.1. *Ascaridia columbae* - head end

Fig.2. *Ascaridia columbae* - anterior end, enface view

Fig.3. *Ascaridia columbae* - male, tail end

Fig.4. *Ascaridia columbae* - female, vulval region

Fig.5. *Ascaridia columbae* - egg

(Camera lucida drawings)

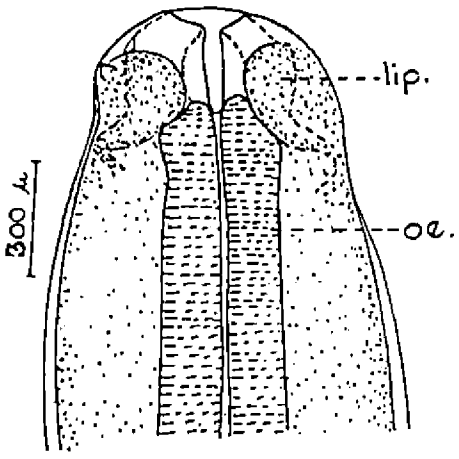
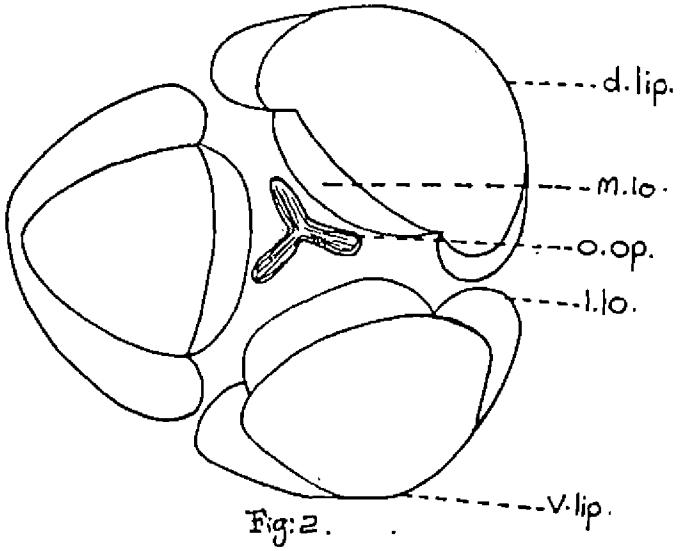


Fig: 1.



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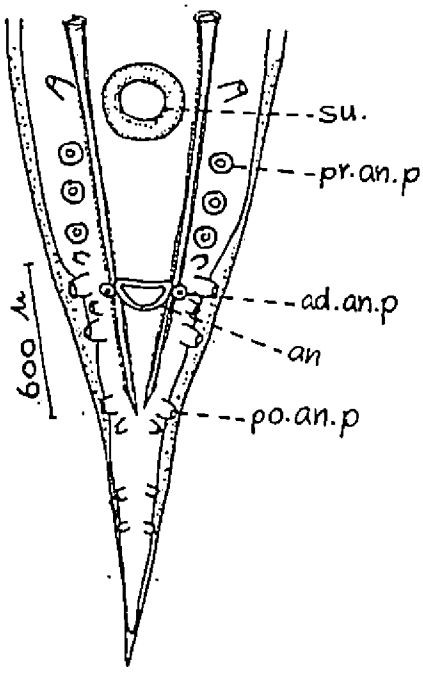

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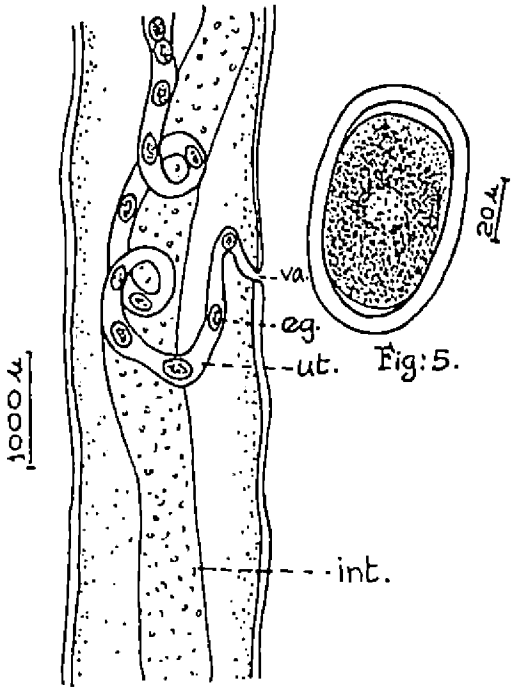


Fig: 4.

Fig: 5.

PLATE VII

Fig.1. *Ornithostrongylus quadriradiatus* - head end (x400)

Fig.2. *Ornithostrongylus quadriradiatus* - female, tail end (x400)

Fig.3. *Ornithostrongylus quadriradiatus* - male, bursa (x400)

Fig.1

Fig.2

Fig.3

PLATE VIII

Fig.1. *Ornithostrongylus quadriradiatus* - head end

Fig.2. *Ornithostrongylus quadriradiatus* - male, bursa

Fig.3. *Ornithostrongylus quadriradiatus* - male, telamon

Fig.4. *Ornithostrongylus quadriradiatus* - female, tail end

Fig.5. *Ornithostrongylus quadriradiatus* - egg

(Camera lucida drawings)

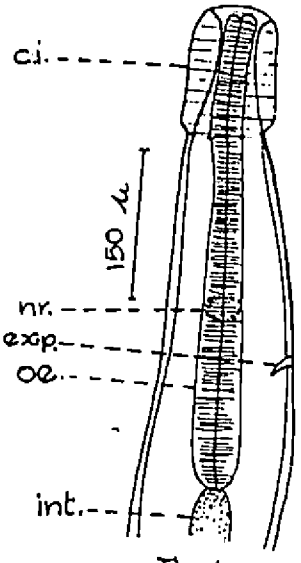


Fig: 1.

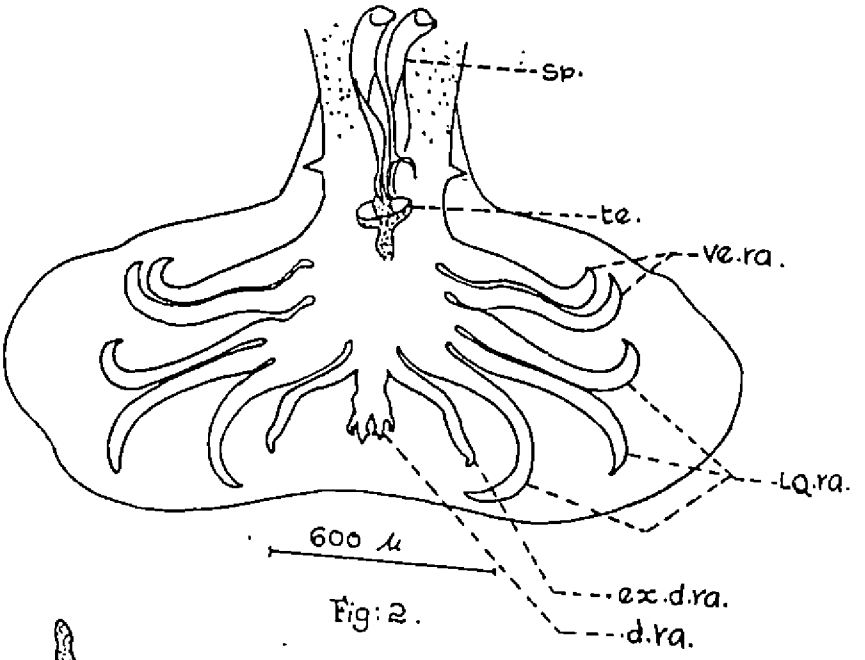


Fig: 2.

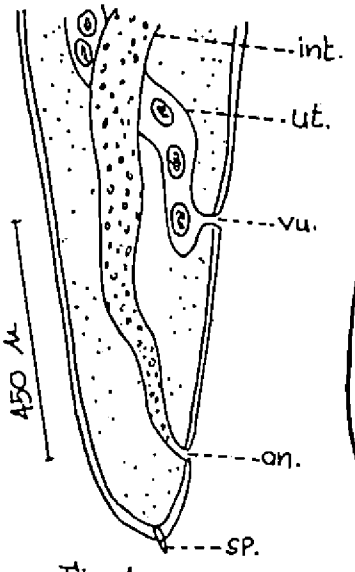


Fig: 4.

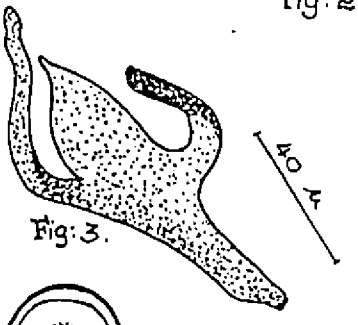


Fig: 3.

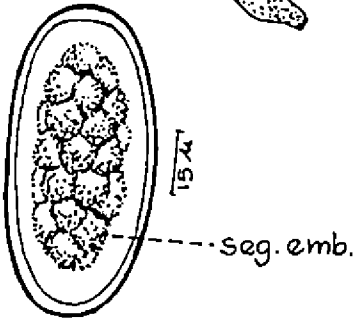


Fig: 5.

PLATE IX

Fig.1. *Ascaridia columbae* - first stage larva

Fig.2. *Ascaridia columbae* - second stage larva

Fig.3. *Ascaridia columbae* - second stage larva, head end

Fig.4. *Ascaridia columbae* - third stage larva, head end

Fig.5. *Ascaridia columbae* - third stage larva, male, tail end

Fig.6. *Ascaridia columbae* - third stage larva, female, tail end

(Camera lucida drawings)

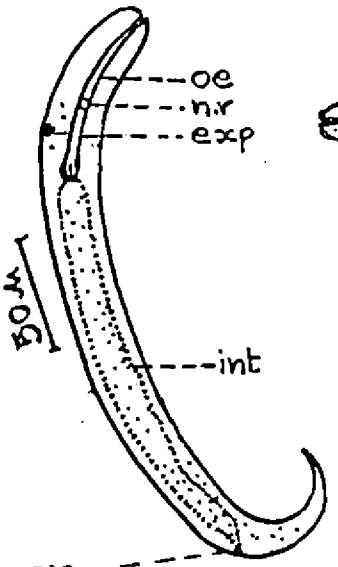


Fig:1

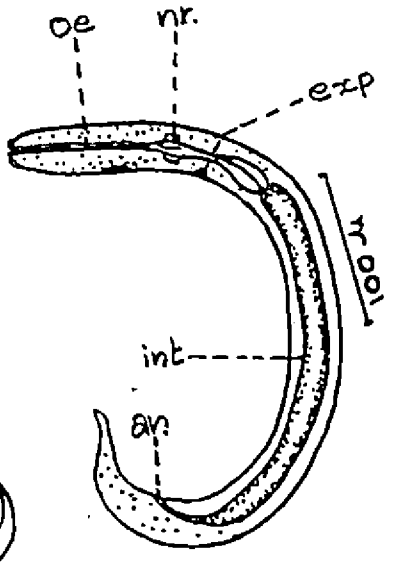


Fig:2.

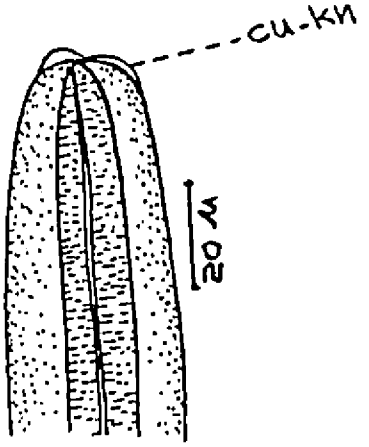


Fig:3

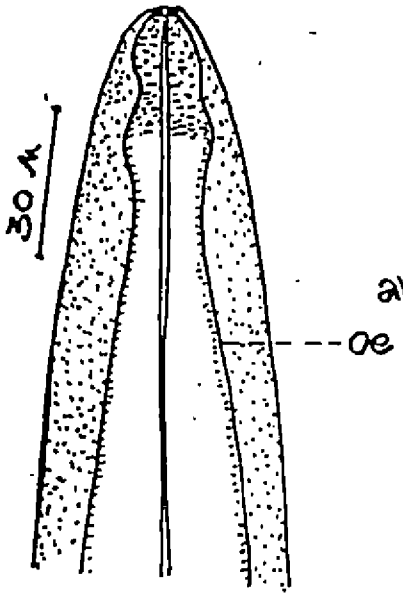


Fig:4

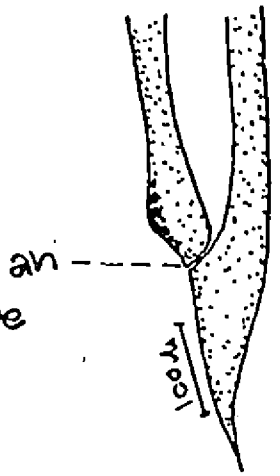


Fig:5

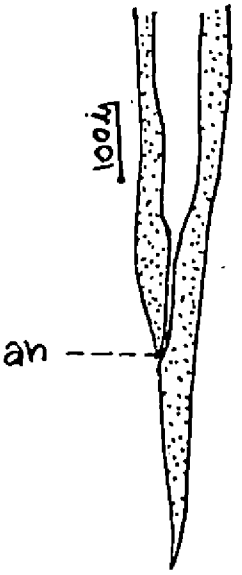


Fig:6

PLATE X

Fig.1. *Ascaridia columbae* - fourth stage larva, head end

Fig.2. *Ascaridia columbae* - fourth stage larva, male, tail end

Fig.3. *Ascaridia columbae* - fourth stage larva, female, tail end

Fig.4. *Ascaridia columbae* - fifth stage larva, head end

Fig.5. *Ascaridia columbae* - fifth stage larva, male, tail end

Fig.6. *Ascaridia columbae* - fifth stage larva, female, tail end

(Camera lucida drawings).

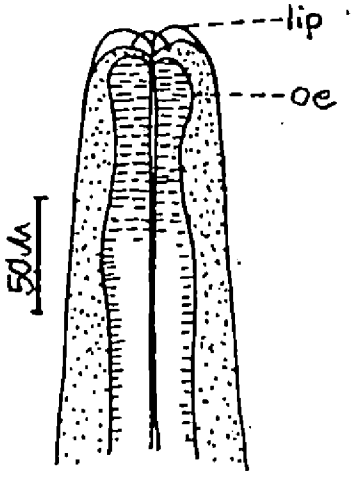
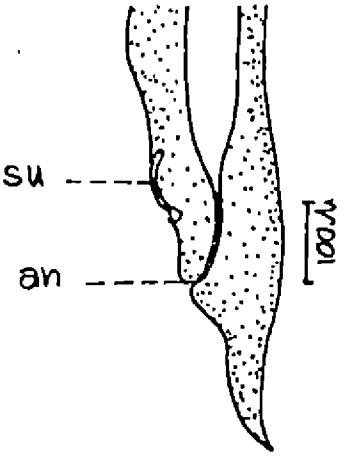


Fig: 1



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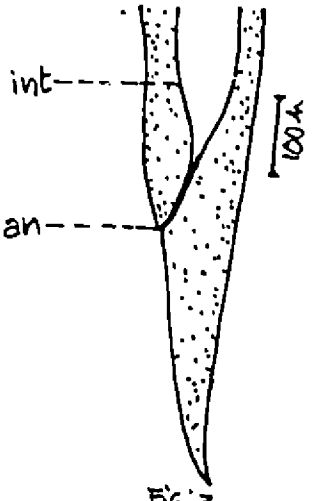
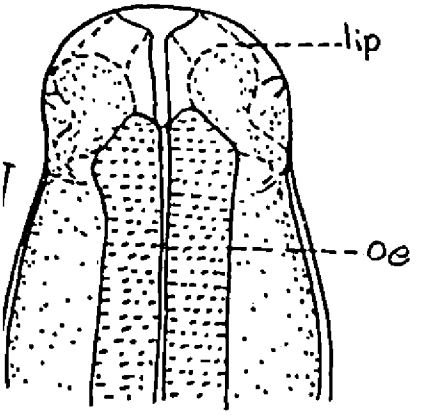


Fig: 3



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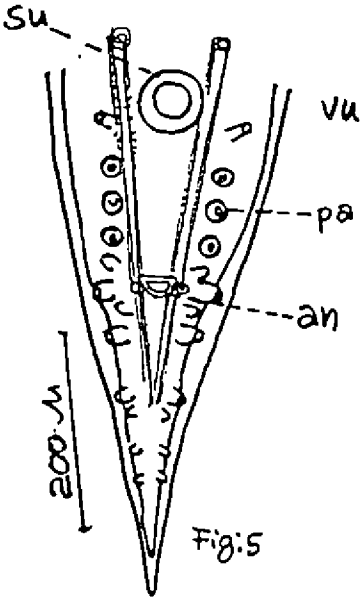


Fig: 5

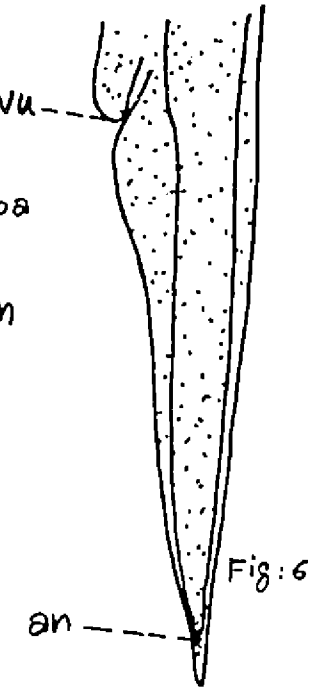


Fig: 6

PLATE XI

Fig.1. *Syngamus trachea* - third stage larva

Fig.2. *Syngamus trachea* - fourth stage larva, male, head end

Fig.3. *Syngamus trachea* - fourth stage larva, male, tail end

Fig.4. *Syngamus trachea* - fourth tage larva, female, head end

Fig.5. *Syngamus trachea* - fourth stage larva, female, vulval, region

(Camera lucida drawings)

PLATE XII

Fig.1. *Syngamus trachea* - fifth stage larva, male, head end

Fig.2. *Syngamus trachea* - fifth stage larve, male, bursa

Fig.3. *Syngamus trachea* - fifth stage larve, female, head end

Fig.4. *Syngamus trachea* - fifth stage larva, female, tail end

Fig.5. *Syngamus trachea* - adult, male, enface view

Fig.6. *Syngamus trachea* - adult, female, enface view

(Camera lucida drawings)

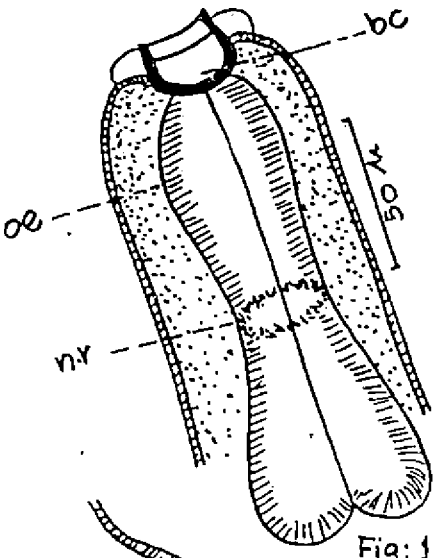


Fig: 1

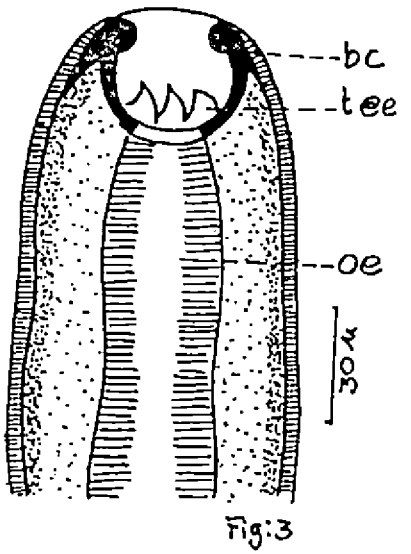


Fig:3

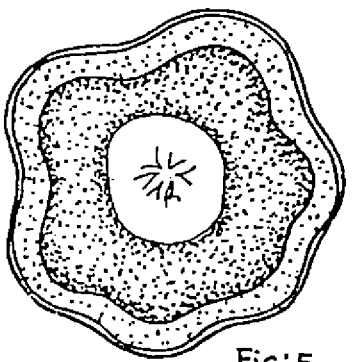


Fig:5

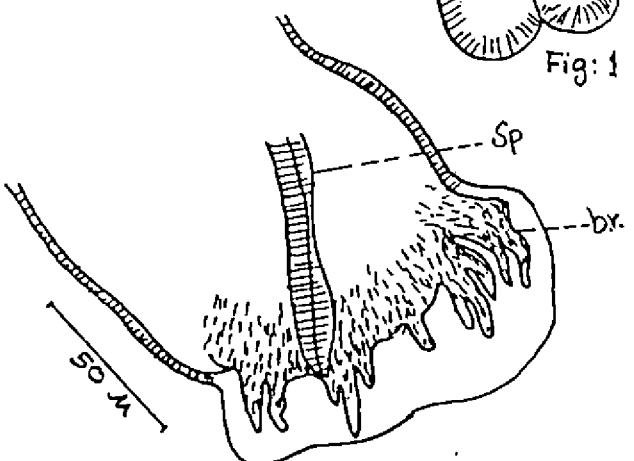


Fig:2

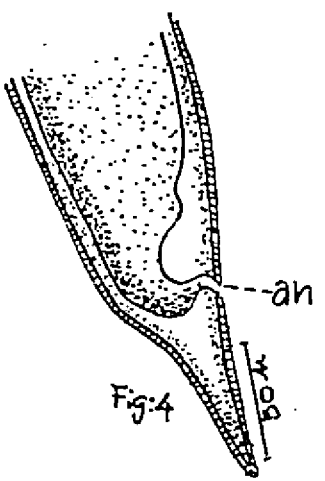


Fig:4

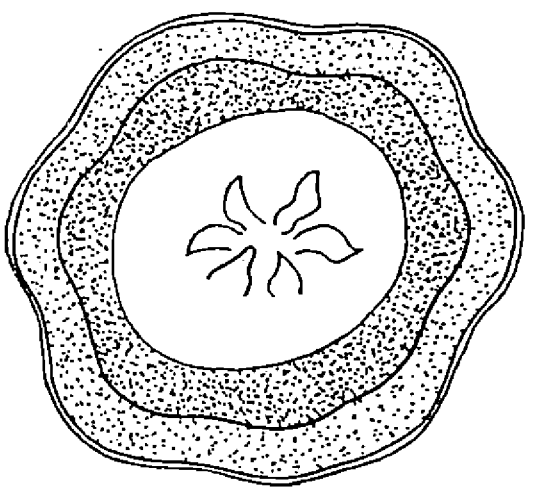


Fig:6

PLATE XIII

Fig.1. *Syngamus trachea* - adult, female, head end

Fig.2. *Syngamus trachea* - male, head end

Fig.3. *Syngamus trachea* - male, tail end

Fig.4. *Syngamus trachea* - female, tail end

Fig.5. *Syngamus trachea* - worms in copulo

(Camera lucida drawings)

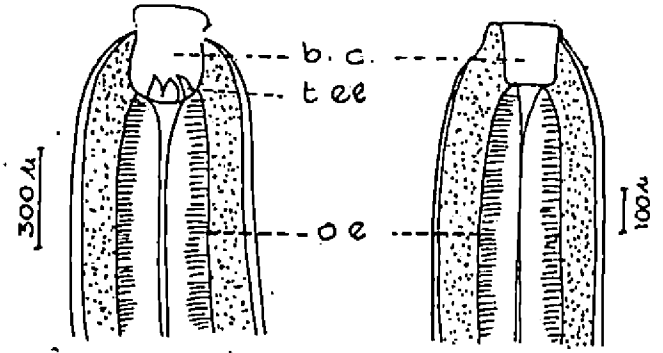
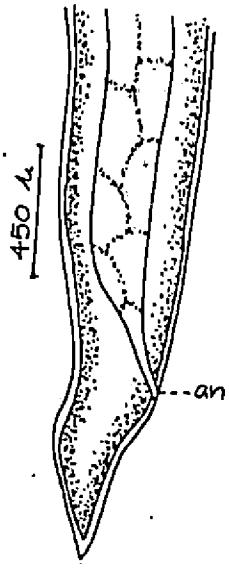


Fig: 1

Fig: 2



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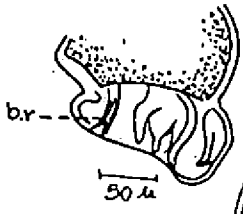

Fig: 3

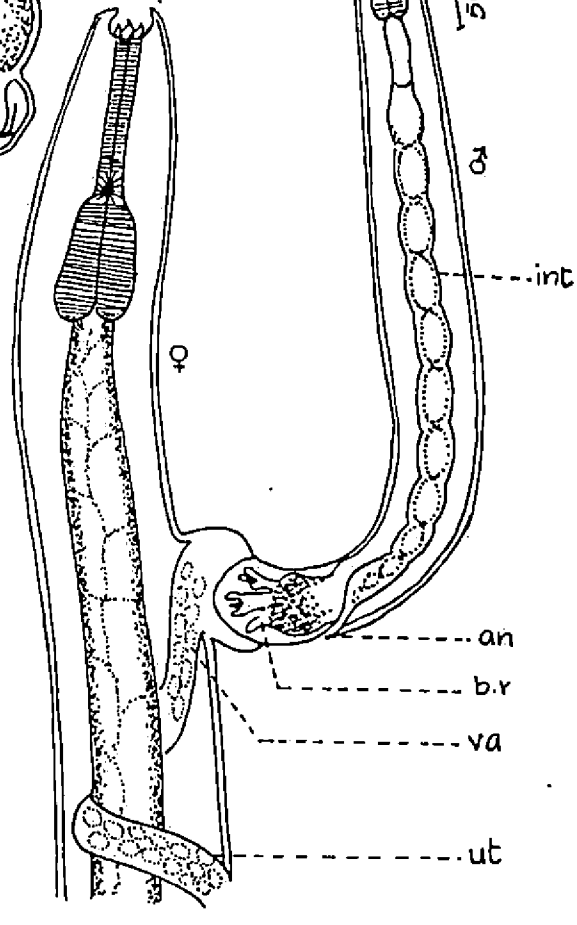

Fig: 5

PLATE XIV

Fig.1. *Ornithostrongylus quadriradiatus* - eggs, developmental stages

Camera lucida drawings

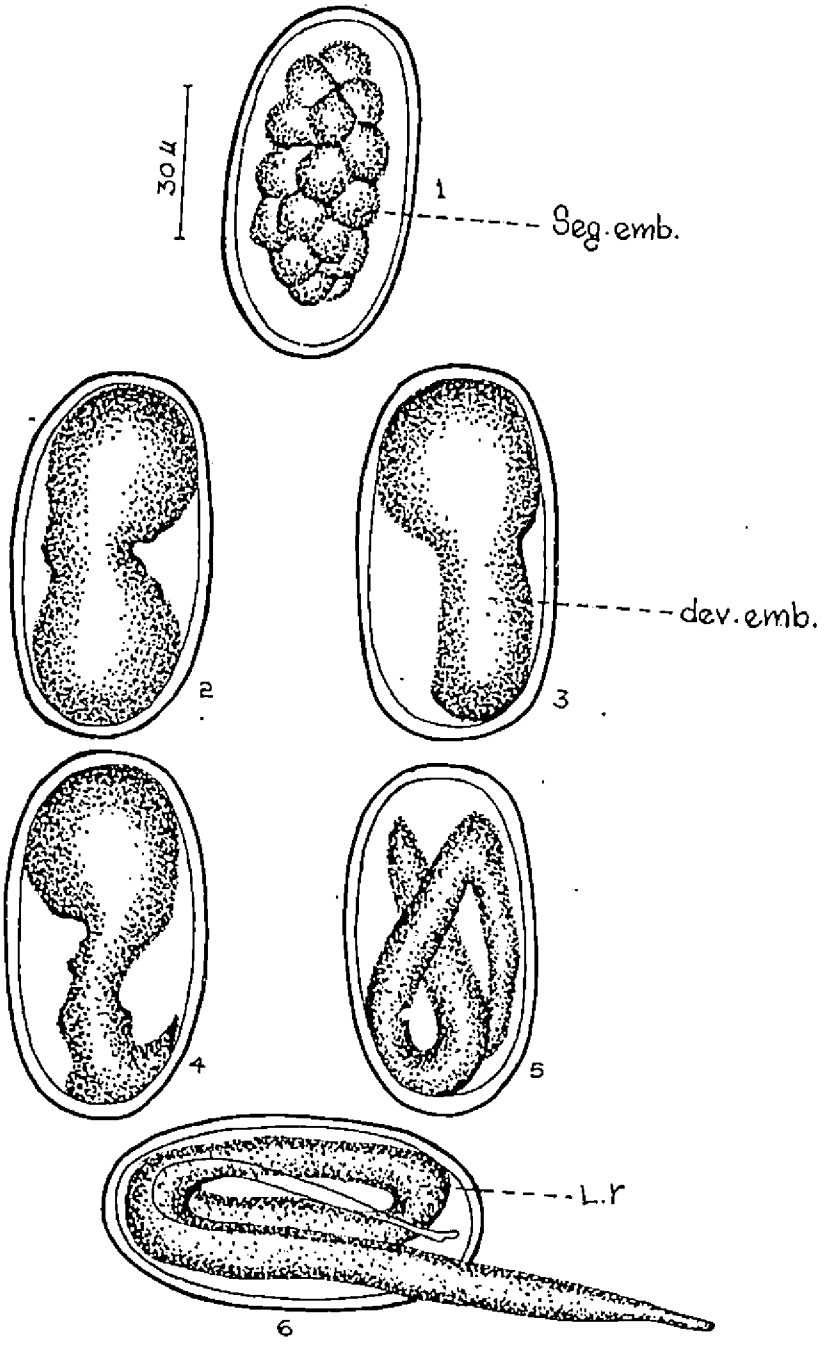

Fig. 1

PLATE XV

Fig.1. *Ornithostrongylus quadriradiatus* - first stage larva (x250)

Fig.2. *Ornithostrongylus quadriradiatus* - second stage larva (x250)

Fig.1

Fig.2

PLATE XVI

Fig.1. *Ornithostrongylus quadriradiatus* - third stage larva (x160)

Fig.2. *Ornithostrongylus quadriradiatus* - third stage larva, head end (x250)

Fig.3. *Ornithostrongylus quadriradiatus* - third stage larva, tail end (x250)

Fig.1

Fig.2

Fig.3

PLATE XVII

Fig.1. *Ornithostrongylus quadriradiatus* - first stage larva

Fig.2. *Ornithostrongylus quadriradiatus* - second stage larva

Fig.3. *Ornithostrongylus quadriradiatus* - third stage larva

Fig.4. *Ornithostrongylus quadriradiatus* - third stage larva, head end

Fig.5. *Ornithostrongylus quadriradiatus* - third stage larva, tail end

(Camera lucida drawings)

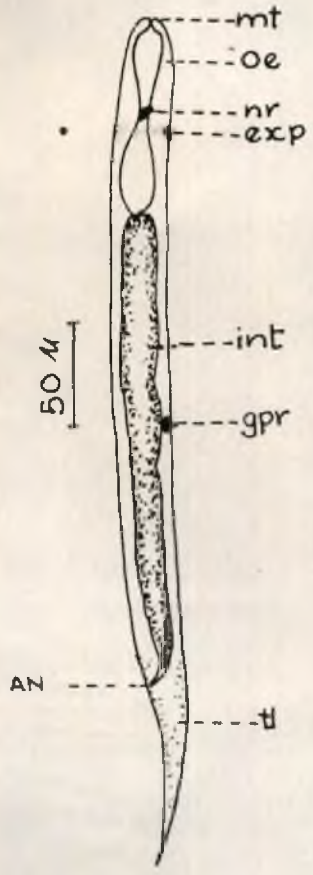

Fig: 1.

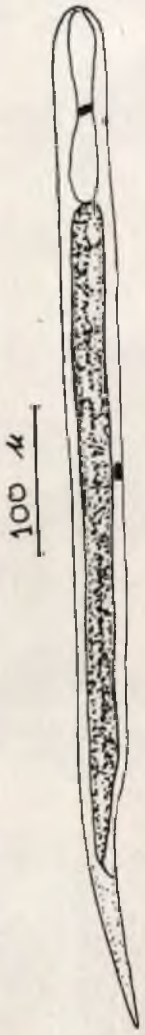

Fig:2.

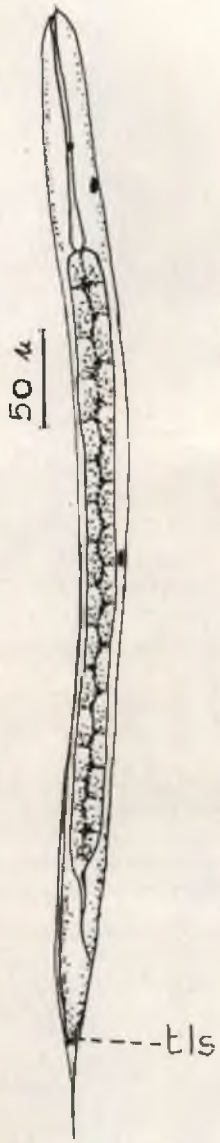

Fig:3

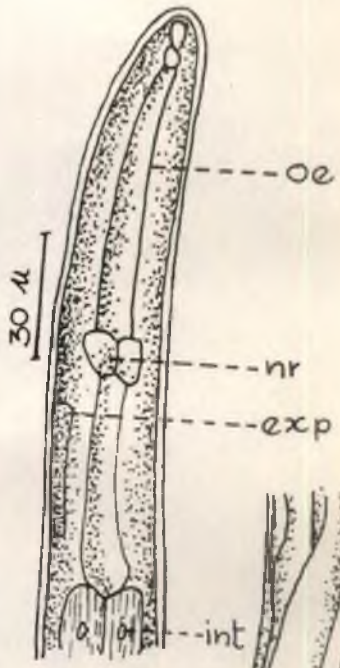

Fig: 4.

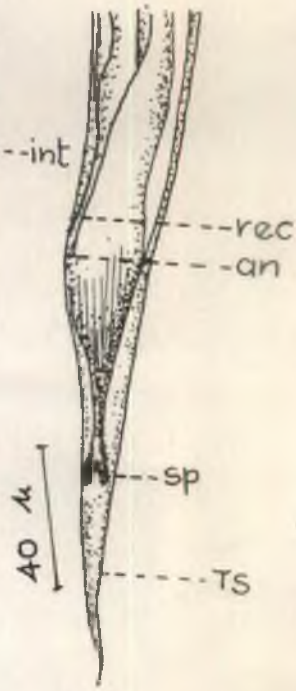

Fig:5.

PLATE XVIII

Fig.1. *Ornithostrongylus quadriradiatus* - fourth stage larva, head end (x250)

Fig.2. *Ornithostrongylus quadriradiatus* - fourth stage larva, female, tail end (x250)

Fig.3. *Ornithostrongylus quadriradiatus* - fourth stage larva, male, tail end (x250)

Fig.1

Fig.2

Fig.3

PLATE XIX

Fig.1. *Ornithostrongylus quadriradiatus* - fourth stage larva, head end

Fig.2. *Ornithostrongylus quadriradiatus* - fourth stage larva, male, tail end

Fig.3. *Ornithostrongylus quadriradiatus* - fourth stage larva, female, tail end

(Camera lucida drawings)

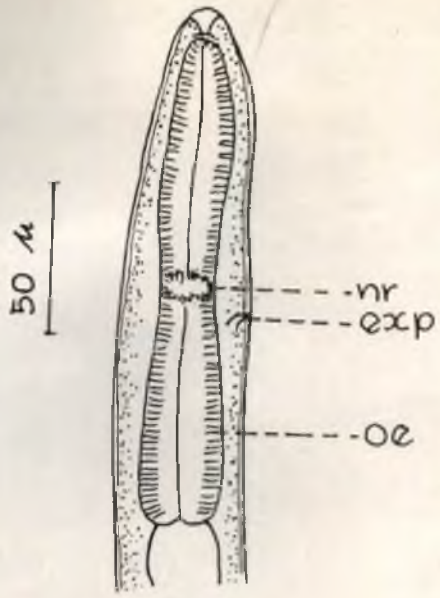

Fig:1

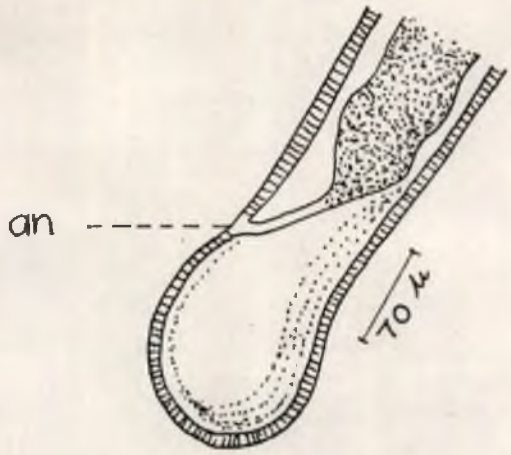

Fig:2

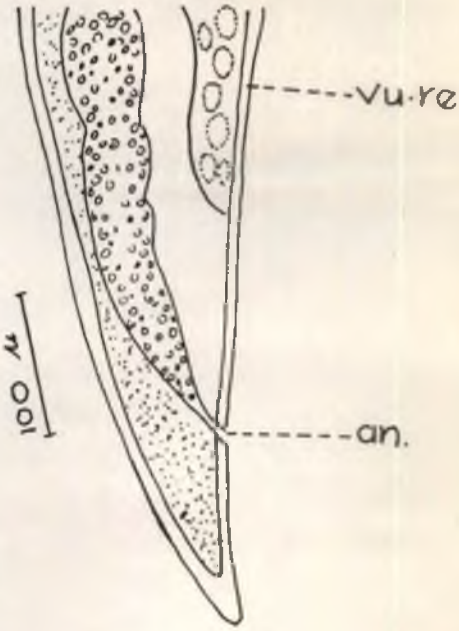

Fig:3

PLATE XX

Fig.1. *Ornithostrongylus quadriradiatus* - fifth stage larva, head end (x250)

Fig.2. *Ornithostrongylus quadriradiatus* - fifth stage larva, female, tail end (x250)

Fig.3. *Ornithostrongylus quadriradiatus* - fifth stage larva, male, tail end (x250)

Fig.1

Fig.2

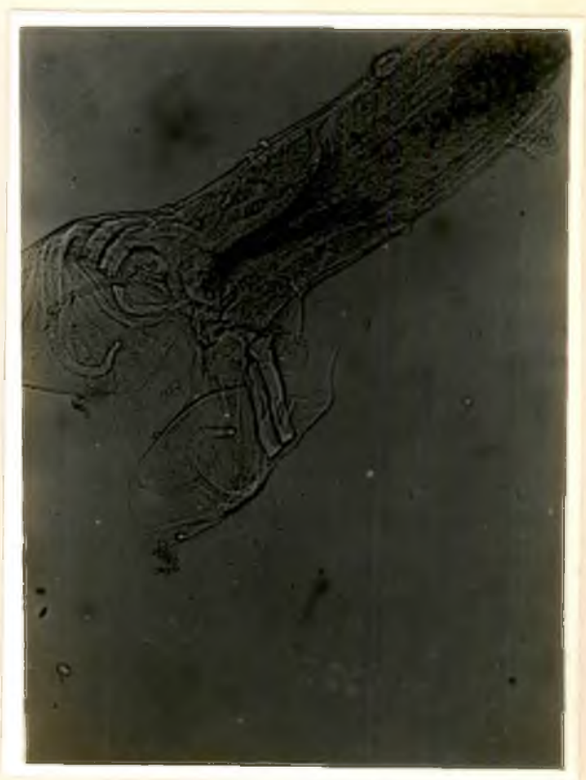

Fig.3

PLATE XXI

Fig.1. *Ornithostrongylus quadriradiatus* - fifth stage larva, head end

Fig.2. *Ornithostrongylus quadriradiatus* - fifth stage larva, male, tail end

Fig.3. *Ornithostrongylus quadriradiatus* - fifth stage larva, female, tail end

(Camera lucida drawings)

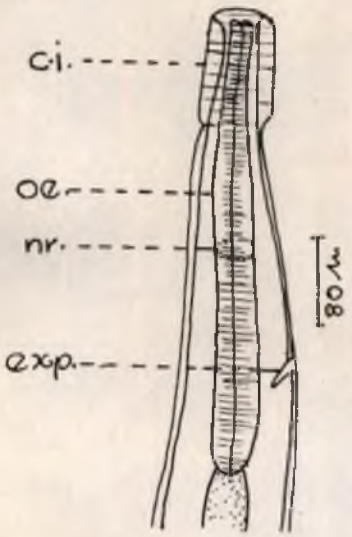

Fig: 1

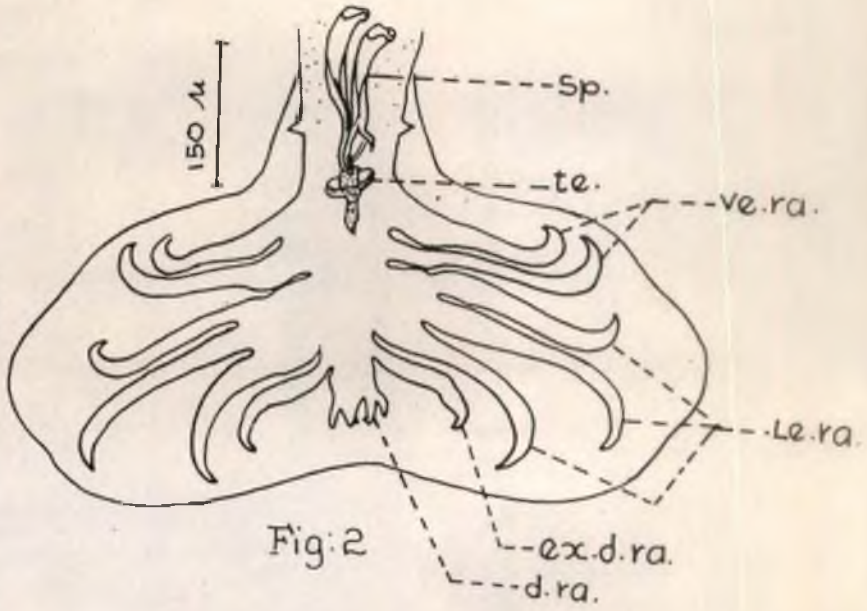

Fig: 2

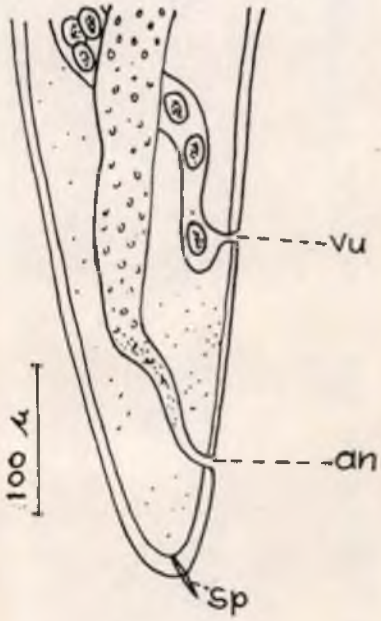

Fig: 3

PLATE XXII

Fig.1. Syngamiasis - Section of lung (H&E) (x400)

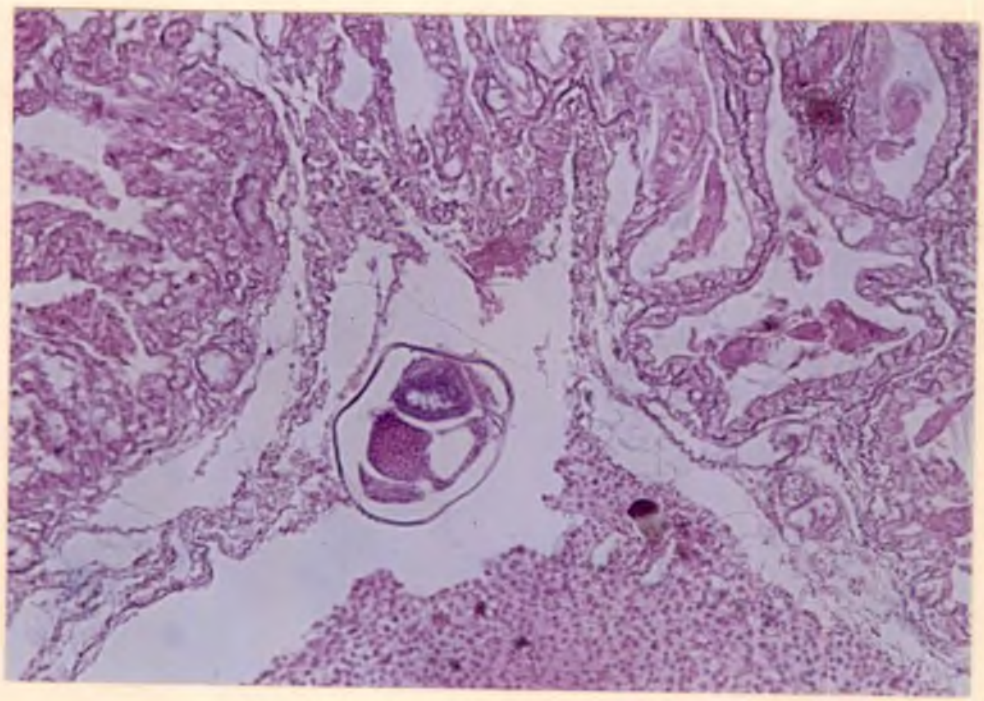

Fig.1

Discussion

DISCUSSION

Prevalence of nematode infections in pigeons

During the period of an year (1995 April to 1996 March) it was found that the prevalence of nematode infections in pigeons by faecal examination was 35.24 per cent as against 48 per cent reported by Filkovic *et al.* (1989) and 38.88 per cent by Reddy *et al.* (1992). The above authors also found that the pigeons were infected with single or mixed infections of nematodes of genera *Capillaria*, *Ascaridia* and *Ornithostrongylus*. In addition to the above, *Strongyloides* was also recorded in the present investigation. According to Reddy *et al.* (1992) *Capillaria* sp. was more predominant (42.85%) in single infection and the mixed infections of nematodes were more common (57.14%) than the single infection. The present finding is concurring with the higher prevalence of *Capillaria* in single infection though the percentage prevalence was only 15 per cent and the mixed infections were found to be more (60.46%) than that observed by the above authors. *Capillaria* sp. had the maximum percentage of infection (38.53%) among the positive samples in the present investigation which is concurring with the findings of Filkovic *et al.* (1989) and Reddy *et al.* (1992) except that the prevalence reported by the latter authors was higher (66.9%).

The lowest prevalence was seen in the case of *Strongyloides* sp. (3.94%) and no comparison could be made due to lack of literature on the prevalence of *Strongyloides* sp. by faecal examination.

In the present study, a seasonal influence was found to be present in the nematode infection of pigeons which was higher in the cold wet season (41.72%) than in the summer season (26.92%). Failure of development of nematode eggs to their infective stage at higher temperatures as observed in the present study might be a factor for the lesser incidence of nematode infections in summer season. No authors were seen to have reported on this aspect.

The prevalence of infection found by examination of viscera of 92 pigeons was 46.74 per cent in the present investigation as against 57.47 per cent reported by Kulisic (1989) and 11.76 per cent by Tacconi *et al.* (1993).

The species of nematodes collected from pigeons in this study were *Capillaria obsignata* (67.44%), *Ascaridia columbae* (41.86%), *Ornithostrongylus quadriradiatus* (39.53%), *Strongyloides avium* (16.27%) and *Acuaria spiralis* (6.98%). The first three species were the common parasites in pigeons and is in agreement with the findings of Begum and Shaikh (1987) at Bangladesh. *Capillaria obsignata* was found to be the commonest species in pigeons which is also observed by

Biester and Schwarte (1965) and Jha (1977) while only 5.4 per cent was reported by Willomitzer (1956) and 22.7 per cent by Githkopoulos and Liakos (1987). The lowest prevalence was seen in the case of *A. spiralis* which is almost comparable with that of 8 per cent reported by Tacconi *et al.* (1993).

The occurrence of *S. avium* and *A. spiralis* reported in the present study constitutes new host records of these parasites in pigeons in India.

It was observed that the squabs aged 25 to 28 days were naturally infected with mature worms of *C. obsignata* and *O. quadriradiatus* and immature worms of *A. columbae*. Since the squabs does not peck anything inquisitively upto 28 to 30 days of age, the infections to the squabs might have occurred from their parent birds by mouth feeding; the possibility of which has been reported in the case of 'mouth canker' caused by *Trichomonas gallinae*. Lindquist (1963) collected *A. columbae* and *C. obsignata* from squabs aged about 3 weeks and suggested that the above mode of infection was possible in this early nematode infections. Kamarov and Beaudette (1931) have also recorded *O. quadriradiatus* in squabs.

Capillaria obsignata and *O. quadriradiatus* requires 20 to 24 and 6 to 7 days respectively for development to mature worms but *A. columbae* requires 42 to 48 days to reach the mature stage. From this it could be inferred that the squabs

would have acquired infections during the first two weeks of age and subsequently developed to mature worms in the case of *C. obsignata* and *O. quadriradiatus* and immature worms in *A. columbae*. Hence the early transmission of nematode infections from parent birds to the squabs through mouth feeding is possible.

Description of adult worms

All the nematodes were identified based on the description given by previous authors; Tubangui (1926), Varghese (1966) and Sundaram (1971) for *A. spiralis*; Graybill (1924), Madsen (1945) and Wakelin (1965) for *C. obsignata*; Cram (1927) and Varghese (1966) for *S. avium* and Skrjabin (1954), Soulsby (1965) and Tongson *et al.* (1975) for *O. quadriradiatus*. The characters noted for these nematodes were in full agreement with the respective authors.

The morphological details of *A. columbae* were similar to the details given by Wehr and Hwang (1964) but differed from the findings of Bhalerao (1934) and Kung (1949) in respect of the number of caudal papillae which were 14 and 12 pairs respectively as against 13 pairs in the present specimens.

Egg cultures

Ascaridia galli

The time taken for the development of egg to its infective stage in the present study was 9 to 10 days at room temperature of 28 to 33°C, which is similar to the findings of Ackert (1919) and Soulsby (1965), while a lesser period of 8 days at 33 to 33.6°C was reported by Deo and Srivastava (1955).

Heterakis gallinae

The infective stage was reached within 7 to 8 days at 29 to 32°C in the present study. But Graybill (1921) and Clapham (1933) reported a longer period of 7 to 12 days at 18 to 29°C and 14 to 17 days at 28°C respectively and Deo (1964) observed a shorter period of 4 to 5 days at room temperature.

Syngamus trachea

On culturing the eggs, they developed to infective third stage larvae in 6 to 7 days at 27 to 29°C which is agreeable with the observation of Wehr (1937) and Devada (1987). The hatching started by seventh day of setting culture as was observed by Devada (1987) but Wehr (1937) reported that the hatching never occurred earlier than nineth day. Ortlepp

(1923) stated that the hatched out larvae were in the second stage and that they were also the infective stage. While in the present study the larvae that hatched out were found to be third stage and this is in agreement with the findings of Wehr (1937) and Devada (1987).

Ascaridia columbae

The days required to develop the infective stage was found to be 15 to 17 at 31 to 33°C during this investigation. Deo (1964) reported 17 days and Wehr and Hwang (1964) 18 to 19 days at room temperature for the development to infective stage.

Capillaria obsignata

The infective first stage larva was developed inside the egg without any moulting in 9 to 10 days at the room temperature of 30 to 32°C. This observation is similar to that of Levine (1937) and Wehr (1939a) who also could not observe any moulting inside the egg but the period to reach the infective stage reported by them was 7 to 8 days.

Ornithostrongylus quadriradiatus

During this investigation the eggs hatched out to first stage larvae in 15 to 16 hrs under the room temperature of 29 to 30°C but Cram and Cuvillier (1931) found that the hatching

started in 19 to 24 hrs after incubation. The first and second moult occurred in 25 to 27 and 72 hrs respectively in the present study and the infective third stage larvae were seen from 72 hrs onwards in the cultures. This finding agrees with that of Cram and Cuvillier (1931) but disagrees with the observation of Soulsby (1965) who reported that the infective larvae were developed in 4 to 6 days.

Cross transmission trails

Pigeons

Ascaridia galli

In the present trial it was observed that the pigeons were relatively resistant to *A. galli* infection and the hatched out infective second stage larvae persisted only upto 6 days. The present observation is in concurrence with that of Miller (1937) and Borkakoty and Tewari (1984) who stated that the pigeons were unsuitable hosts and unable to transmit *A. galli* from chicken but contradictory to the findings of Matta (1980) who reported that pigeons were susceptible to experimental infection of *A. galli* and Mishra and Sahai (1980) who could recover 23 mature worms from one out of 4 experimentally infected pigeons.

Heterakis gallinae

Cross transmission experiment during the present study indicated that pigeons were totally resistant to *H. gallinae* infection as observed by Miller (1937).

Syngamus trachea

The present experimental trial indicated that the pigeons were susceptible to fowl origin of *S. trachea* but the prepatent period was longer in pigeons (28 days) when compared to chicks (18-20 days). This finding is in total disagreement with that of Wehr (1939) who found that the pigeons were unsuitable hoststo this parasite as the infective third stage larvae developed only to the fourth stage in lungs and died in the lungs due to strong host reaction. Willomitzer (1956), Vindevogel and Duchatel (1979), Kummerfeld and Stove (1981) and Boado *et al*. (1992) have reported that they could collect *S. trachea* from naturally infected pigeons and thus supports the finding of the present work.

It was observed that there was a definite delay in the development of various stages in pigeons compared to those in chicks and the size of worms collected from pigeons at different intervals after infection were comparatively smaller than those of chicks. The similarity in size of the worms collected from pigeons and chicks could be seen only at the

time of the respective prepatent periods, which was 10 days longer in pigeons indicating that more time is required for the growth and development of *S. trachea* in pigeons compared to chicken. The percentage establishment of the worms in pigeons (0.42%) was lesser compared to chicks (2.05%). Whether some unknown host factor exist in pigeons and contributed this size difference could not be understood during this study.

Chicks could also be successfully infected with eggs collected from the pigeon strain of *S. trachea* and the maturity of adult worms were found to be similar to those of chicks infected with chicken strain.

Chicks

Ascaridia columbae

The result of the trial showed that the chicks were completely refractory to *A. columbae* infection which is in conformity with the findings of Soulsby (1965), Tverdokhlebov (1967), Mines and Green (1983) and Varghese (1990) but disagrees with the observation of Sweet (1910) who reported that this parasite could occur in chicken. Miller (1937) found that the larvae developed for 96 hrs and were unable to proceed further in the chicks but the present study revealed that the infective eggs did not even hatch in the intestine.

Capillaria obsignata

By cross infection trial, it was found that *C. obsignata* of pigeon origin could be successfully transmitted to chickens and the development and morphology of different stages were similar except that the prepatent period in chicks was reached 2 days later compared to pigeons. Bhalerao and Rao (1944) and Wakelin (1965) recorded the prevalence of this parasite in chicks and hence it is established that *C. obsignata* of pigeon is transmissible to chicks.

Ornithostrongylus quadriradiatus

Chicks were completely refractory to infection of *O. quadriradiatus* and this finding is in confirmity with that of Cuvillier (1937).

From the above six trials it was found that *S. trachea* from fowl and *C. obsignata* from pigeons are transmissible to pigeons and chicks respectively. Hence it is possible that the pigeons reared under mixed farming system and the free flying ones infected with these parasites can act as a source of infection to the chicks and vice versa.

The occurrence of *A. spiralis* and *S. avium* in chicks and pigeons was reported by earlier workers and it was found that the pigeons in the present study were also infected with these

parasites. Though the morphological details of worms collected from pigeons in the present study were similar to those of chicken described by earlier workers. Further studies are required to establish the cross transmissibility of these parasites between chicken and pigeons.

Detailed lifecycle studies in pigeons

Ascaridia columbae

The egg cultures showed the development of first stage larvae in 12 to 13 days and they moulted to the infective second stage in the egg by 15 to 17 days after incubation. In the infected pigeons, the second, third and fourth moult occurred between day 3 to 5; 11 to 16 and 17 to 24 PI respectively and the worms attained maturity in 42 to 46 days. These findings are comparable to that of Wehr and Hwang (1964) except the difference in the period reported by them for fourth moult and prepatent period which were 16 to 19 days and 35 to 40 days respectively. A lesser prepatent period of 17 to 18 days was reported by Cram (1927) and a longer prepatent period of 50 days by Whitney (1961) and such a wide variation as reconciled by Madsen (1962) may be due to the different degrees of interplay between resistance and viability of the larvae.

Hwang and Wehr (1958) and Wehr and Hwang (1959) stated that migration through liver and lungs might be essential for the development of *Ascaridia columbae*. But later in 1964 Wehr and Hwang conducted detailed studies and proved that larvae of *A. columbae* were found in liver of infected pigeons but such larvae failed to develop beyond second stage and all stage in the development of the parasitic larvae were found in the intestine. In the present study none of the larvae could be found in the liver and lungs of infected birds and all stages were seen in the small intestine which indicate that the larval migration is not required for the development of adult worms in the intestine.

The morphological features of various developmental stages were similar to that described by Wehr and Hwang (1964).

Syngamus trachea

The infective third stage larvae of *S. trachea* developed within 7 days in egg cultures maintained at the room temperature of 27 to 29°C. In the pigeons infected with third stage larvae, the third and fourth moult occurred between day 3 to 7 and 8 to 12 PI respectively in lungs. The copulatory and non-copulatory worms were present in the lung and trachea from day 13 to 18 and by the 18th day all worms were in copulo and no non pairing worms were present. This suggest that the

copulation of the worms would occur both in the lungs and the trachea. The worms attained maturity and started to lay eggs on day 28 PI onwards.

Though there are reports on natural infection of pigeons with *S. trachea*, the literature on the life history of this parasite in pigeons appears to be that of Wehr (1939), who found that the infective larvae did not develop beyond the fourth stage in lungs of pigeons. Hence the present report of successful experimental infection in pigeons with *S. trachea* and the description of its parasitic stages is an additional information on this aspect.

In the present study, the third and fourth moults was found to occur on day 3 to 7 and 8 to 12 PI respectively in pigeons, while in chicks they were recorded as 3 and 6 days PI and 5 and 6 days PI by Wehr (1937) and Devada (1987) respectively. Copulation of the worms in chicken also was reported to occur in the lungs and trachea (Devada, 1987). The prepatent period of 28 days in pigeons was found to be longer than that of 17 to 21 and 18 to 22 days reported by Shikhobalov and Rhizhikov (1956) and Devada (1987) respectively in chicken.

Ornithostrongylus quadriradiatus

In egg cultures the eggs hatched to first stage larvae in 15 to 16 hrs under room temperature of 29 to 30°C. Larval moulting to second stage occurred in 25 to 27 hrs after incubation and the ensheathed third stage larvae were seen from 72 hrs in culture after the second moulting.

Experimental infection of pigeons revealed that the third and final moults occurred on day 1 and 3 PI respectively and the worms reached to maturity on day 6 and started to lay eggs from day 7 PI. The present observation of morphometry of developmental stages of parasite, moulting periods and the prepatent period were almost similar to those observed by Cram and Cuvillier (1931) and Cuvillier (1937). They found that some of the fourth stage larvae were deeply penetrated into the glands of proventriculus, but in the present study the larvae were seen closely adherent to the mucosal surface with their anterior extremity burried in between the glands of proventriculus.

Binomics of infective larvae of *Ornithostrongylus quadriradiatus*

Phototropism

In the present study, the infective larvae were found to migrate to a greater distance in cultures exposed to light and

they also preferred to remain in the water droplets formed on the sides of culture vials indicating that they are positively phototropic and hydrotactic. Cram and Cuvillier (1931) have also observed that the larvae were hydrotactic and negatively geotactic but they have not mentioned the tropism of the larvae towards light.

Viability

The viability of the infective larvae as reported by Cram and Cuvillier (1931) was 5 to 6 weeks, but they have not stated whether there was any seasonal variation. In the present study it was found that the larvae were viable for a longer period even in dry season (47-52 days) and in the wet it was still greater (60-67 days) than the period reported by the above authors.

Clinical signs and pathogenicity of nematodiasis in pigeons

Ascaridia columbae

The clinical signs observed in the present investigation are in agreement with the findings made by Panigraphy *et al.* (1982). Deo (1964) considered this parasite as non pathogenic to pigeons, while Hare (1937) and Venkatesan *et al.* (1996) reported deaths of pigeons due to ascardiasis. In the present

study, the infected birds showed morbidity, but no mortality was recorded.

Capillaria obsignata

The current observation on clinical signs is similar with that of Deo (1964) and Soulsby (1965). The gross and histopathological changes in the intestine are also in concurrence with the observations made by Jha (1977) in *C. obsignata* infected intestine of pigeons.

Acuaria spiralis

The gross and histopathological changes observed in the present investigation are in concurrence with the findings made by Deo (1964) and Soulsby (1965).

Ornithostrongylus quadriradiatus

The clinical signs and gross lesions noticed in the present study are comparable with the reports of Rose and Kymer (1958), Soulsby (1965), Tongson *et al.* (1975) and Rao and Makhekar (1992). Cram and Cuvillier (1931) found that symptoms were severe and deaths frequent at 2 to 5 days after infection. The infected birds in the present study exhibited symptoms from day 5 PI and one of the infected birds died on 5th day following infection.

Syngamus trachea

There was no characteristic symptom of syngamiasis exhibited by the infected pigeons in the current study. Deo (1964) also reported the absence of clinical signs in pigeons infected with *S. trachea*.

Although the pigeons infected with *A. columbae*, *C. obsignata* and *O. quadriradiatus* were showing clinical signs of infection, the inflammatory changes as evidenced by histopathological examination were not severe. However they were found to cause morbidity in infected birds.

Goblet cell hyperplasia has been reported in *A. galli* infection in fowls and in many other nematode infection in animals, but in the present study this was not found in any of the nematode infections. This is in agreement with Mimori *et al.* (1982) who reported that all nematode infectionsdo not induce goblet cell hyperplasia.

Haematology

The values for haemoglobin, packed cell volume, total red blood corpuscles, total white blood corpuscles and differential leucocyte count recorded before infection with *O. quadriradiatus* in pigeons were almost similar to the normal values given by Sturkie (1976) and Wallach and Boever (1983).

The reductions in Hb, PCV and RBC count in infected pigeons were related to the anaemic changes produced by *O. quadrirdiatus*, which is a blood sucking parasite. This finding agrees with the reports of Soulsby (1965) and Jubb *et al.* (1993), who observed similar haematological changes in animals infected with *Ancylostoma caninum* and *Haemonchus contortus*. Chandrasekaran (1977) also found similar changes in ducklings infected with *Tetrameres anatis*. The above authors also observed leucocytosis and heterophilia in Ancylostomiasis, Haemonchosis and Tetrameriasis. The findings in the present study support the view that eosinophilia is a characteristic clinical feature of parasitic infections.

Summary

SUMMARY

1. An investigation into the prevalence of nematode infections in pigeons was made during April 1995 to March 1996 by faecal and postmortem examinations. Examination of 854 faecal samples revealed that 35.24 per cent of birds were infected with nematodes either as single or mixed infection. *Capillaria* sp. had the maximum percentage (38.53%) of infection and the *Strongyloides* sp. the lowest (9.3%) among the positive samples. From the postmortem examination of 92 birds, the prevalence was found to be 46.74 per cent. *Capillaria obsignata* had the highest prevalence (67.44%) and *Acuaria spiralis*, the lowest (6.98%) among the positive cases.

2. A total of five species of nematodes namely; *Capillaria obsignata*, *Ascaridia columbae*, *Ornithostrongylus quadriradiatus*, *Acuaria spiralis* and *Strongyloides avium* were encountered during the present study. The occurrence of *A. spiralis* and *S. avium* in pigeons reported during the present investigation constitutes new host records of these parasites in India.

3. Egg cultures of nematodes for experimental studies were made and maintained at room temperature revealed that the infective stage of *Ascaridia galli* developed in 9 to 10

days at 28 to 33°C; that of *Heterakis gallinae* by 7 to 8 days at 29 to 32°C; *Syngamus trachea* by 6 to 7 days at 27 to 29°C; *Ascaridia columbae* by 15 to 17 days at 31 to 33°C; *Capillaria obsignata* by 9 to 10 days at 30 to 32°C and *Ornithostrongylus quadriradiatus* by 3 days at 29 to 30°C.

4. The cross transmission trials of *A. galli*, *H. gallinae* and *S. trachea* from chicks to pigeons and *A. columbae*, *C. obsignata* and *O. quadriradiatus* from pigeons to chicks indicated that *S. trachea* was transmissible from chicks to pigeons and *C. obsignata* from pigeons to chicks. The prepatent period of *S. trachea* was found to be 28 days in pigeons and 18 to 20 days in chicks. Cross infection of chicks with pigeon origin of *S. trachea* yielded positive result and the worms developed to maturity by 21 days.

5. The detailed lifecycle of *A. columbae*, *S. trachea* and *O. quadriradiatus* in pigeons were elucidated with description of various developmental stages. The prepatent period of the above species was determined to be 46, 28 and 7 days respectively.

6. Binomics of infective larvae of *O. quadriradiatus* such as phototropism and viability were studied and the larvae were found to be phototropic and hydrotactic. The

viability was 47 to 52 and 60 to 67 days in dry and wet seasons respectively.

7. The clinical signs and pathogenicity of nematodiasis in pigeons were studied in detail from naturally and experimentally infected birds. Dullness, inappetance, progressive anaemia, emaciation and diarrhoea were found to be the general symptoms of nematode infections. Birds infected with *S. trachea* did not exhibit any characteristic symptoms of the disease. The gross and histopathological lesions produced by the worms encountered were also studied. Haematological studies in pigeons infected with *O. quadriradiatus*, indicated that there were anaemic changes in moderate infections.

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INTERTRANSMISSIBILITY OF THE COMMON NEMATODE PARASITES OF PIGEON (*Columba livia domestica*) AND DOMESTIC FOWL (*Gallus gallus domesticus*)

BY

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ABSTRACT OF A THESIS

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ABSTRACT

An investigation was made on the prevalence of nematode infections in pigeons for a period of one year by faecal and postmortem examinations and the percentage prevalence was 35.24 and 46.74 respectively. The species of nematodes collected from pigeons were *Ascaridia columbae*, *Capillaria obsignata*, *Ornithostrongylus quadriradiatus*, *Acuaria spiralis* and *Strongyloides avium*. *Capillaria obsignata* had the highest prevalence.

The development of egg and the time taken to reach the infective stage in egg cultures of *Ascaridia galli*, *Heterakis gallinae*, *Syngamus trachea*, *Ascaridia columbae*, *Capillaria obsignata* and *Ornithostrongylus quadriradiatus* maintained at different room temperature were studied and recorded.

The cross transmission trials with fowl nematodes; *A. galli*, *H. gallinae* and *S. trachea* and pigeon nematodes; *A. columbae*, *C. obsignata* and *O. quadriradiatus* were conducted in pigeons and chicks respectively. *Syngamus trachea* and *C. obsignata* were found to be transmissible between pigeons and chicks.

The detailed life cycles of *A. columbae*, *S. trachea* and *O. quadriradiatus* in pigeons were worked out in detail. The

prepatent period for these species was 46, 28 and 7 days respectively.

The infective larvae of *O. quadriradiatus* were seen to be phototropic and hydrotactic. They remained viable for 47 to 52 and 60 to 67 days in dry and wet seasons respectively.

The clinical signs, gross and histopathological lesions produced by the nematodes in pigeons were recorded. Moderate infections of *O. quadriradiatus* produced anaemic changes in pigeons.