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LIGHT AND ELECTRON MICROSCOPIC STUDIES ON MYXOSPOREAN PROTOZOANS OF SOME MARINE FISHES WITH DESCRIPTION OF TWO NEW SPECIES

(With 4 Tables and 15 Figures)

By

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دراسات ميكروسكوبية ضوئية و إليكترونية على أوليات الميكزوسبوريا في بعض الأسماك البحرية مع وصف لنوعين جديدين

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في مسح منتظم على ميكزوسبوريا الأسماك البحرية, تم تجميع ٣٧٠ سمكة مائة من البوري الطازج من البحر المتوسط قرب شواطئ بور سعيد ومائة من البوري المستورد وثمانين من البلطي الزللي من بحيرة المنزلة وأربعون سمكة من القاروس وخمسون من الوقار من أسواق السمك بمدينة بور سعيد. هذه الأسماك تم فحصها فحصا دقيقا داخليا وخارجيا للحصول على حويصلات الميكزوسبوريا. وقد وجد أن النسبة العامة للإصابة ١٨,٦٤ % وكانت نسبة الإصابة في البوري الطازج ٣٨% بينما كانت نسبة الإصابة في البوري المجمد المستورد ٢٠ % وكانت نسبة الإصابة في القاروس ٥ % أعلى من نسبة الإصابة في الوقار (٢ %) واقل من نسبة الإصابة في البلطي الزللى (١٠ %) وقد تم الحصول على ستة أنواع من الميكزوسبوريا نوعين من البوري الطازج ونوع من البوري المجمد ونوع جديد من البلطي الزللى ونوع جديد من القاروس ونوع من الوقار وقد تم وصف هذه الأنواع وصفا دقيقا كما تم تحضير بعض العينات من أحد أنواع البوري الطازج لفحصها بواسطة الميكروسكوب الإلكتروني للتعرف على الخصائص التركيبية الدقيقة لهذا النوع.

SUMMARY

In systematic survey on myxosporea of marine fishes, 370 fishes, 100 *Mugil cephalus*, 100 frozen *Mugil* sp., 80 brackish *Tilapia zilli*, 40 *Moron labrax* and 50 *Epinephelus* sp. were collected from Port-Said Province and examined for myxosporea. The total prevalence of

infection was 18.64% and the prevalence of infection in *Mugil cephalus* was 38% while this of frozen *Mugil* sp. was 20%. The prevalence of infection in *Moron labrax* was 5% slightly higher than this of *Epinephelus* sp. (2%) and lower than this of brackish *Tilapia zilli* (10%). Six myxosporean species were detected, two from *Mugil cephalus*, one from frozen *Mugil* sp., one from *Moron labrax*, one from *Epinephelus* sp. and one from brackish *Tilapia zilli*. The detected myxosporea from *Mugil cephalus* were *Myxobolus mugilis* from gills (18%), *Myxobolus* spinacurvatura from liver and mesenteries (8%) and from brain (2%). *Myxobolus* sp. (20%) was detected from cartilage of the head of frozen *Mugil* sp. *Myxobolus labracis* sp. n. (5%) was recorded from the gill filaments of *Moron labrax* while *Sphaerospora epinepheli* (2%) was recorded from *Epinephelus* sp. In addition, *Myxobolus oreochrome* sp. n. was recorded from internal surface of the operculum of brackish *Tilapia zilli*. Transmission electron microscopy was done on *M. mugilis* of *Mugil cephalus* to recover the ultrastructure characteristics of these small spores.

Key words: *Light and electron microscope, myxosporea, marine fishes*

INTRODUCTION

Myxosporea are considered harmful for their hosts (Woo, 1995). Paperna and Overstreat (1981) described members of the genera *Myxidium, Myxobolus, Sphaerospora* and *Kudoa* from several species of fish. Myxosporea are common gill parasites of fishes. Several species of *Myxobolus, Myxidium* and *Henneguya* were known from the gills of 20 different fish species (Cone and Anderson, 1977; Hoffmann, 1967; Jayasri and Hoffmann, 1982; Komourdjian et al., 1977; Margolis and Arthur, 1979; Price and Mullen, 1980 and Spall, 1974).

Egusa *et al.*, (1990) described *Myxobolus episquamalis* that infected the scales of mullets *(Mugil cephalus)*. Maeno et al. (1990) described *Myxobolus spinacurvatura* from deformed mullets (*Mugil cephalus*). Bahri and Marques (1996) recorded four *Myxobolus* spp. namely *M. episquamalis, M. spinacurvatura, M. bizerti* and *M. ichkeulensis* from scales, mesenteric vessels, gill filaments and gill arch of *M. cephalus* respectively. Negm El-Din et al. (1999) described new species, *Myxobolus mugilis* from gills of *Mugil cephalus* in Delta, Egypt.

Abolarin (1974) and Abdel Ghaffar et al. (1995) described *Myxobolus tilapae* and *Myxobolus* sp. from the gill filaments, mouth,

eye and operculum of *Tilapia* sp. in Nigeria and Egypt respectively. Imam et al. (1987) and Abu El-Wafa (1988) described *Myxobolus* sp. and *Myxobolus occularis* from eye of *Tilapia* spp. in Giza and Behera, Egypt respectively.

Since Arthur and Lom (1985) reviewed the genus *Sphaerospora*, several new species had been described from freshwater fishes (Li and Desser, 1985; Lom and Desser, 1985; Lom et al., 1989; Fisher-Scheri et al., 1986; Landsberg, 1986 and Baska, 1990). *Sphaerospora* spp. parasitizing marine fishes were *S. epinepheli* of *Epinephelus malabaricus* from Thailand (Supamattaya et al., 1991) and *S. dicentrarchi* of sciaenid fish *Dicentrarchus labrax* (Sitja-Bobadilla and Alvarez-Pellitero, 1992). Electron microscopic observation and ultrastructure of myxo-sporea were studied by El-Matbouli *et al.*, (1995) and Sitja-Bobadilla and Alvarez-Pellitero (1992 & 1993) for *Myxobolus, Sphaerospora and Zschokkella.* The work on myxosporea of marine fishes is scarce in Egypt. The aim of this work is to survey myxosporean parasites of some marine fishes at Port Said province and to through the light on the new species from fishes in this area.

MATERIALS and METHODS

Three hundred seventy fishes were submitted for examination. One hundred *Mugil cephalus* were obtained immediately after fishing from Mediterranean sea along the coastal margin of El-Gameel district, Port Said by aid of fishermen. Forty *Moron labrax* and fifty *Epinephelus* sp. were obtained from Port-Said fish-market. Eighty brackish *Tilapia zilli* were obtained from El-Manzala Lake at El-Gameel area. In addition one hundred imported frozen *Mugil* sp. were submitted for examination. The fishes were transferred to Vet. Lab. at El-Gameel district whereas the samples were examined externally and internally for presence of myxosporean cysts. Also, impression smears were done from brain, gall bladder and kidney. Any suspected cysts were squashed between two slides. The squashed preparations and impression smears were air-dried, fixed in absolute methanol and transferred to Parasitology Department, Faculty of Vet. Med., Suez Canal University for staining and further investigation. The fixed smears were stained with Giemsa stain and 5% Lugol's iodine and examined under oil immersion lens for presence of myxosporean spores (Narasimhamurti and Kalavati, 1979).

Selected cysts of small size were fixed in 2.5 % glutaraldehyde in phosphate buffer, post fixed in 1% osmium tetraoxide, dehydrated

through graded ethanol series and embedded in epoxy resin (Spurr, 1969). Semithin sections were stained with toluidine blue and examined by light microscope to localize the proprite part of cyst. Ultrathin sections were double stained with uranyl acetate and lead citrate (Reynolds, 1963) and examined in JEOL EM A35 at National Cancer Institute, Cairo. The size, shape, and other morphological criteria of spores were described. Also microphotos were taken.

RESULTS

Table (1) explains the prevalence rates of myxosporea in some marine fishes at Port-Said province. The total prevalence of myxosporean infection was 18.64%. The prevalence of infection in *Mugil cephalus* was (38%) higher than this of frozen *Mugil* species (20%). The prevalence of infection in brackish *Tilapia zilli* was (10%) higher than this of *Moron labrax* (5%) and *Epinephelus* sp. (2%). Six myxosprean species were detected from 4 marine fish species and brackish *Tilapia zilli*, two from *Mugil cephalus*, One from frozen *Mugil* sp. One from Moron *labrax*, one from *Epinephelus* sp. and one from brackish *Tilapia zilli*.

The detected myxosporea from *Mugil cephalus* were *Myxobolus mugilis* from gill filaments (18%), *Myxobolus spinacurvatura* from liver & mesenteries (18%) and from brain (2%). Frozen *Mugil* sp. was infected with *Myxobolus* sp. in cartilage of the head (20%).

Brackish *Tilapia zilli* was infected with *Myxobolus oreochrome* sp. n. on the internal surface of operculum (10%). *Myxobolus labracis* sp. n. was detected from gills of *Moron labrax* (5%) and *Sphaerospora epinepheli* from intestinal wall of *Epinephelus* sp. (2%).

Myxobolus mugilis (Fig. 1):

The host of this species was *Mugil cephalus*. The site of infection was the gill filaments. The spores were spherical or subspherical measuring 6-8 m in diameter. The polar capsules were ovoid and sub-equal measuring 3-3.5 X 2-2.5 m for large and 2.5-3 X 1.8-2 m for small. The length of the polar filaments was about 40-47 m. The iodinophilous vacuole was present.

Myxobolus spinacurvatura (Fig. 2, 3 & 4):

The host of this species was *Mugil cephalus*. The site of infection was liver, mesenteries and brain in which a small white cysts 1-2 mm were present. The spores were ovoid measuring 9-11 X 11-13 m. The polar capsules were pear-shaped and equal measuring 3.5-4.5 X 2.5-3

m. The polar filament was 30-32 m in length. The iodinophilous vacuole was absent.

Myxobolus sp. (Fig., 5):

The host of this species was imported *Mugil* sp. The site of infection was the cartilage of the head in which several small cysts were firmly attached. The spores were spherical or sub-spherical measuring 11-12 m in diameter. The polar capsules were fusiform and equal measuring 3-4 X 2-2.5 m. The iodinophilous vacuole was present.

Myxobolus oreochrome sp.n. (Fig. 6):

The host of this species was brackish *Tilapia zilli*. The site of infection was the internal surface of operculum in which cysts 2-3 mm were attached. The spores were large oval in shape slightly pointed anteriorly measuring 17-19 X 9-10 m. The polar capsules were fusiform and equal measuring 4-5 X 2.5-3 m occupying almost the third of spore. The polar filament was 25-27 m in length. The iodinophilous vacuole was absent.

Myxobolus labracis sp.n. (Fig. 7):

The host of this species was *Moron labrax* (Karoos). The site of infection was the gill filament in which small cysts were attached. The spore was ovoid, slightly pointed anteriorly and measured 11-12 X 9-10 m. The polar capsules were relatively large, occupying almost the half of spore, pear-shape and equal measuring 5-6 X 3-4 m. The polar filament was 15-20 m in length.

Sphaerospora epinepheli (Fig., 8):

The host of this species was *Epinephelus* sp. (Wakar). The site of infection was the wall of intestine in which the cysts were embedded resulting in thickening in the intestinal wall. The spores were sub-spherical, with slightly flattened base. Bluntly pointed anterior pole, measuring 11-12 X 10-11 m. The spore surface was rough with mucous envelope. The polar capsules were pyriform and equal measuring 6-7 X 4-5 m reaching the anterior apex of spore. Coils of polar filament not visible by light microscopy.

Transmission electron microscopy:

In each spore of *Myxobolus mugilis*, a remnant layer of valvogenic cells enclosed capsulogenic cells and sporoplasm (sporoplasmic cells). Each valvogenic cell forms half of spore valve (Fig. 13). The valvogenic cells meet forming thickened crest, which are joined forming the sutural ridge and suture line (Fig. 13). During the spore maturation the valvogenic cells forms a narrow layer around the spore (Fig. 13 & 14) and their organelles degenerate and become

incorporated into the valves (Fig.13). Two capsulogenic cells (Fig. 11) each contains two polar capsules (Fig.11 &15). Each polar capsule contains electron dense substance (Fig. 14) and well-organized polar filament (Fig. 10 & 11) which is helically arranged coils running internally. The filament was 6 to 7 coils (Fig. 11 & 12). Lipid inclusions and glycogen vacuoles were found around the polar capsules (Fig. 12 &14). Binucleat sporoplasm was recognized easily beneath the polar capsule (Fig. 13& 14) and contained electron dense bodies, sporoplasmosomes, (Fig. 14).

DISCUSSION

The detected myxosporea in this study were placed in two genera *Myxobolus* and *Sphaerospora* depending upon the morphological characters of spores (Woo, 1995). Walliker (1968) synonymized the genus *Myxosoma* and *Myxobolus* because of the variability of occurrence of iodinophilous vacuole. Lom (1969) endorsed the view of walliker, thus abolishing the family myxosomatidae. Myxosporea, in general are considered to be highly host specific (Sitja-Bobadilla and Alvarez-Pellitero, 1993).

The detected *Myxobolus* species from gills of *Mugil cephalus* was identified as *Myxobolus mugilis* according to Negm El-Din et al., (1999) who recorded this species from gills of *M. cephalus* in Egypt This species was larger than *Myxobolus microspora* which previously recorded from gills of M. *cephalus* in India (Narasimhamurti et al., 1980).

Myxobolus species from the liver, mesenteries and brain of *M. cephalus* was varied in size from *Myxobolus mugilis* and *M. microspora*. In addition this species varied in size from *Myxobolus* spp. that recorded from other genera and species of mugilidae; *Myxobolus intestinalis* from *Mugil waigensis* (Narasimhamurti, 1970) and *Myxobolus lairdi* from *Liza macrolepis* (Narasimhamurti and Kalavati, 1979) (Table, 4). This species was similar in size and habitat to *Myxobolus spinacurvatura*, which recorded from *M. cephalus* (Maeno et al., 1990 and Bahri and Marques, 1996).

Matching *Myxobolus* species from the internal surface of the operculum of *Tilapia zilli* with other recorded *Myxobolus* spp. from *Tilapia* in Egypt and Africa (Table, 3), it appeared clear that this species was similar in size and habitat to *Myxobolus* sp-1 from gills, mouth and operculum of *Oreochromis niloticus* and *O. aureus* (Abdel Ghaffar et

al., 1995). Since this species was found in three species of *Oreochromis (Tilapia)*, it was worth to nominate according to it. The name *M. tilapae* was previously used (Abolarin, 1974), so the name *Myxobolus oreochrome* sp.n. was proposed for this species from *Oreochromis (Tilapia)* spp.

Myxobolus species from *Moron labrax* was varied in size of spore and polar capsules from other species of *Myxobolus* detected from marine fishes during this study and varied from other myxosporea detected from sciaenid fish (Sarker, 1996). The name *Myxobolus labracis* sp. n. was proposed for this species from *Moron labrax*.

Myxosporean species from intestinal wall of *Epinephelus* sp. was identified as *Sphaerospora* because of its characteristic shape of spore in which one surface was spherical and the other was slightly flat beside the shape and position of the polar capsules (Sitja-Bobadilla and Alvarez-Pellitero, 1992). This species varied from the previous recorded *Sphaerospora* spp. from freshwater fishes (Arthur and Lom, 1985 and Lom et al., 1985 & 1989). Also, this species varied in size from S. *dicentrarchi* of sea bass *Dicentrarchus labrax* (Sitja-Bobadilla and Alvarez-Pellitero, 1992) while it was similar in shape, size and host genus to *Sphaerospora epinepheli* of *Epinephelus malabaricus* (Supamattaya et al., 1991).

The ultrastrucure of spores of *Myxobolus mugilis* from *Mugil cephalus* was in line with this of *M. cerebralis* (El-Matbouli et al., 1995) with the exception of the size of spore organelles and the number of coils of the polar filament. This means that the sporogenesis and spore formation was probably similar within the genus of myxosporea.

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FIGURES

Fig. 1: *Myxobolus mugilis* spores from gill filaments of *M. cephalus*. Spore with unequal polar capsules (arrowhead), bar = 10 m.

Fig. 2: *Myxobolus spinacurvatura* spores from liver of *M. cephalus*, bar = 10

Fig. 3: *M. spinacurvatura* spores from brain of *M. cephalus*, bar = 10 m.

Fig. 4: *M. spinacurvatura* spores from mesenteries of *M. cephalus*, bar = 10

Fig. 5: *Myxobolus* sp. spores from cartilage of the head of imported *Mugil* sp., bar = 10

Fig. 6: *Myxobolus oreochrome* sp. n. spores from the internal surface of the perculum of *T. zilli*, mature spore with two polar capsules (arrow), bar = 10

Fig. 7: *Myxobolus labracis* sp. n. spores from the gill filaments of *Moron labrax*, bar = 10

Fig. 8: *Sphaerospora epinephcli* spores from intestinal wall of *Epinephelus* sp., a: dorso-ventral view, b: lateral view, c: polar capsule with extruded polar filament, bar = 10

Fig. 9: Toluidine blue stained section showing *M. mugilis* spores at different level of cutting, mature spore with two polar capsules (arrow head), bar = 10

Fig. 10 to 15: Transmission electron microscopy (TEM) for *M. mugilis* spores.

Fig. 10: TEM showing cross section in polar capsule (PC), cross section in helically arranged coils of membrane bound polar filament (F) and lipid droplet outside the spore (L). bar = 3

Fig. 11: TEM showing cross section in polar capsule (a) with complete coil of polar filament (F), longitudinal section in polar capsule (b) crossing six coils of polar filament, capsulogenic cell (CC) and sporogenic cell (SC) bar = 3

Fig. 12: TEM showing longitudinal section in polar capsule (PC), outer layer of polar capsule (OL), inner layer of polar capsule (IL), lipid inclusion (L), sporogenic cell nucleus (SN) and glycogen vacuole (GV), bar = 3

Fig. 13: TEM showing beginning of suture line (SL) of valvogenic cells, Section through apical portion of polar capsule (PC), two sporogenic cell nuclei (SN), narrow layer of valvogenic cell (arrow), spore valve (SV), capsulogenic cell (CC) and sporogenic cell (sporoplasm) (SC), bar = 3

Fig. 14: TEM showing section in polar capsule (PC), Lipid Inclusion (L), sporoplasmosomes (arrows) sporogenic cell (SC) and sporogenic cell nucleus (SN), bar = 3

Fig. 15: TEM showing uncutted cone shape of the apical portion of polar capsule (a), polar filament running internally (F), sporogenic cell nucleus (SN) and vacuole (V), bar = 3.

Fig. 13: TEM showing beginning of suture line (SL) of valvogenic cells, Section through apical portion of polar capsule (PC), two sporogenic cell nuclei (SN), narrow layer of valvogenic cell (arrow), spore valve (SV), capsulogenic cell (CC) and sporogenic cell (sporoplasm) (SC), bar = 3

Fig. 14: TEM showing section in polar capsule (PC), Lipid Inclusion (L), sporoplasmosomes (arrows) sporogenic cell (SC) and sporogenic cell nucleus (SN), bar = 3

Fig. 15: TEM showing uncutted cone shape of the apical portion of polar capsule (a), polar filament running internally (F), sporogenic cell nucleus (SN) and vacuole (V), bar = 3.

Table 1: Prevalence of the detected myxosporea in some marine fishes

Species	Host	Site	No. of Infected / No. of Examined	%
Myxobolus mugilis	*M. cephalus*	Gills	18/100	18
Myxobolus spinacurvatura	*M. cephalus*	Liver, mes.	18/100	18
Myxobolus spinacurvatura	*M. cephalus*	Brain	2/100	2
Total	*M. cephalus*	-	38/100	38
Myxobolus sp.	*Mugil* sp.	Cartilage	20/100	20
Myxobolus oreochrome sp.n.	*Tilapia zilli*	Operculum	8/80	10
Myxobolus labracis sp.n.	*Moron labrax*	Gills	2/40	5
Sphaerospora epinepheli	*Epinephelus*	Intes. Wall	1/50	2
Total			**69/370**	**18.64**

Table (2): Morphological criteria of the detected myxosporea of marine fishes.

Species	Host	Site	Spore		Polar capsules		Polar filament	Iodinophilous Vacuole
			Shape	Size	Shape	Size		
Myxobolus mugilis	*M. cephalus*	Gills	Sub-spherical	6-8 (d)	Ovoid	3-3.5 x2-2.5 2.5-3 x 1.8-2	40-47	Present
Myxobolus spinaeurvatura	*M. cephalus*	Liver,mes.&brain	Ovoid	9-11 x 11-13	Pear shape	3.5-4.5 x 2.5-3	30-32	Absent
Myxobolus sp.	*Mugil* sp.	Cartilage	Spherical	11-12 (d)	Fusiform	3-4 x 2-2.5		Present
Myxobolus oreochrome spn	*Tilapia zilli*	Operculum	Oval	17-19 x 9-10	Fusiform	4-5 x 2.5-3	25-27	Absent
Myxobolus labracis sp.n.	*Moron labrax*	Gills	Ovoid	11-12 x 9-10	Pear shape	5-6 x 3-4	15-20	Absent
Sphaerospora epinephali	*Epinephelus* sp.	Intestine Wall	Sub-spherical	11-12 x 10-11	Pyriform	6-7 x 4-5	30-35	Absent

All mensurements are in microns

Table (3): Morphological differences between previous detected *Myxobolus* spp. of *Tilapia* spp. and the present record.

Species	Spore		Polar capsules		Polar filament	Host	Site	Locality
	Shape	Size	Shape	Size				
Myxobolus tilapiae Abolarin (1974)	-	15 x 9	Equal	2.7x 2.2	25.5	*Tilapia* sp.	Gill	Nigeria
Myxobolus sp. Imam *et al.*, (1987)	Broad oval	14 x 9.7	Equal convergent	4.2 x 2.2	48-63	*Tilapia* sp.	Eye	Egypt (Giza)
M. acrularis Abu El-Wafa (1988)	Oval	9.6 x 8.5	Equal oval	5.6 x 3.4	-	*Tilapia* sp.	Eye	Egypt (Behera)
Myxobolus sp-1 Abdel Ghaffar *et al.* (1995)	Ovoid	16.2-18.9 x 10.8-12.6	Ovoid	3.6-6.3 x 2.6-3.6		*O. niloticus O. aureus*	Gill, mouth & operculum	Egypt (Giza)
Myxobolus sp. (Present record)	Oval	17-19x 10-11	Pear shape	4-5x 2.5-3	25-27	*Tilapia zilli*	Operculum	Egypt Manzala

Table 4: Morphological difference between previous detected *Myxobolus* spp. of mugilidae and the present record.

Species	Spore size	Host	Site	Locality
Myxobolus mugilis Negm El-Din *et al.*, (1999)	7.4 x 7.3	*Mugil cephalus*	Gills	Egy
Myxobolus microspora Narasimhamurti *et al.*, (1980)	4.8-5.2	*Mugil cephalus*	Gills	Indi
Myxobolus intestinalis Narasimhamurti (1970)	12.5-13.5 x 8.6-9.5	*Mugil waigensis*	Gut epithelium	Indi
Myxobolus lairdi Narasimhamurti and Kalavati (1979)	4.6-5.2 x 9-9.5	*Liza macrolepis*	Gut epithelium	Indi
Myxobolus Sp. Present record	11-13 x 10-11	*Mugil cephalus*	Liver and mesenteries	Egy

All measurements are in microns

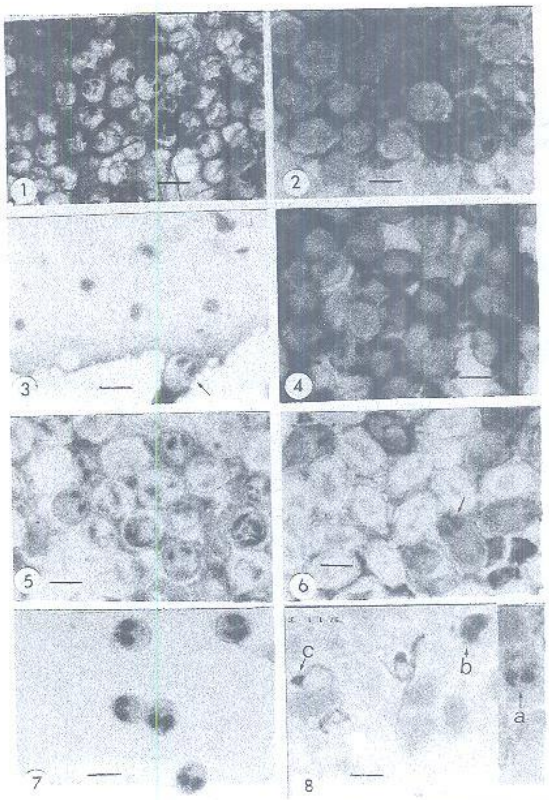

Fig. (1): *Myxobolus mugilis* spores from gill filaments of *M. cephalus*. Spore with unequal polar capsules (arrowhead), bar = 10 µm.
Fig. (2): *Myxobolus spinacurvatura* spores from liver of *M. cephalus*, bar = 10 µm.
Fig. (3): *M. spinacurvatura* spores from brain of *M. cephalus*, bar = 10 µm.
Fig. (4): *M. spinacurvatura* spores from mesenteries of *M. cephalus*, bar = 10 µm.
Fig. (5): *Myxobolus* sp. spores from cartilage of the head of imported *Mugil* sp., bar = 10 µm.
Fig. (6): *Myxobolus oreochrome* sp. n. spores from the internal surface of the operculum of *T. zilli*, mature spore with two polar capsules (arrow), bar = 10 µm.
Fig. (7): *Myxobolus labracis* sp. n. spores from the gill filaments of *Moron labrax*, bar = 10 µm.
Fig. (8): *Sphaerospora epinephcli* spores from intestinal wall of *Epinephelus* sp., a: dorso-ventral view, b: lateral view, c: polar capsule with extruded polar filament, bar = 10 µm.

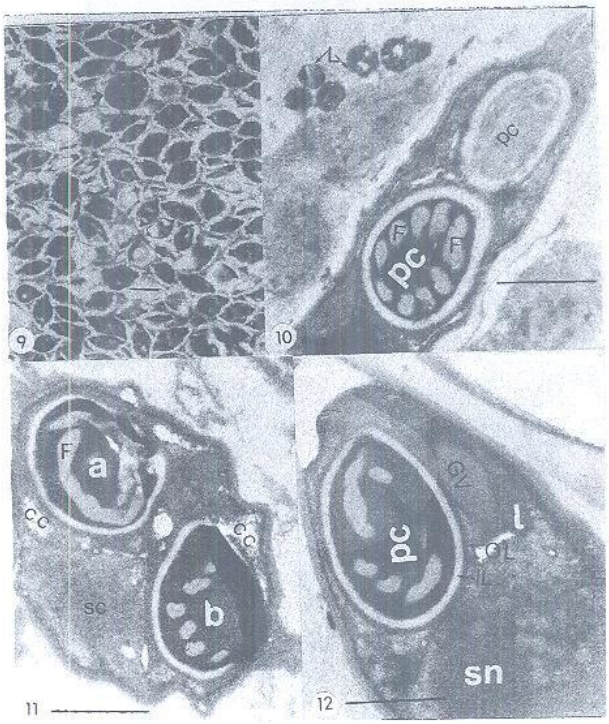

Fig. (9): Toluidine blue stained section showing *M. mugilis* spores at different level of cutting, mature spore with two polar capsules (arrow head), bar = 10 µm.

Fig. (10 to 15): Transmission electron microscopy (TEM) for *M. mugilis* spores.

Fig. (10): TEM showing cross section in polar capsule (PC), cross section in helically arranged coils of membrane bound polar filament (F) and lipid droplet outside the spore (L). bar = 3 µm.

Fig. (11): TEM showing cross section in polar capsule (a) with complete coil of polar filament (F), longitudinal section in polar capsule (b) crossing six coils of polar filament, capsulogenic cell (CC) and sporogenic cell (SC) bar = 3 µm.

Fig. (12): TEM showing longitudinal section in polar capsule (PC), outer layer of polar capsule (OL), inner layer of polar capsule (IL), lipid inclusion (L), sporogenic cell nucleus (SN) and glycogen vacuole (GV), bar = 3 µm.

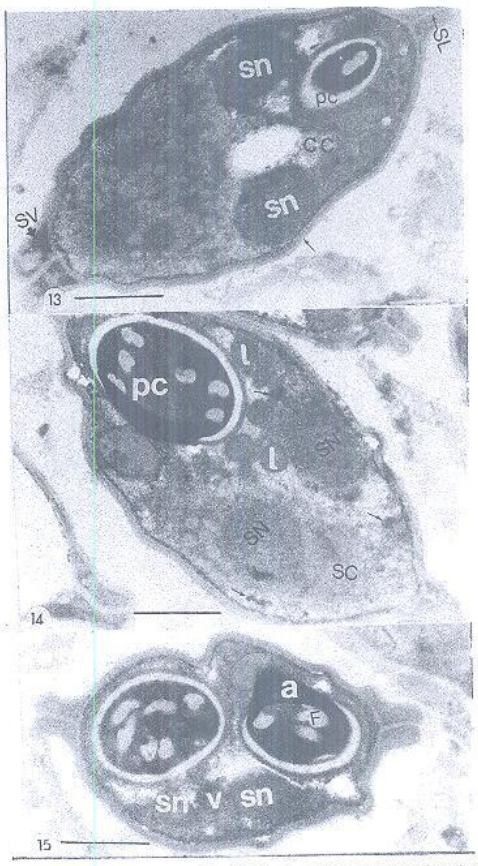

Fig. (13): TEM showing beginning of suture line (SL) of valvogenic cells, Section through apical portion of polar capsule (PC), two sporogenic cell nuclei (SN), narrow layer of valvogenic cell (arrow), spore valve (SV), capsulogenic cell (CC) and sporogenic cell (sporoplasm) (SC), bar = 3 µm.

Fig. (14): TEM showing section in polar capsule (PC), Lipid Inclusion (L), sporoplasmosomes (arrows) sporogenic cell (SC) and sporogenic cell nucleus (SN), bar = 3 µm.

Fig. (15): TEM showing uncutted cone shape of the apical portion of polar capsule (a), polar filament running internally (F), sporogenic cell nucleus (SN) and vacuole (V), bar = 3 µm.