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FIRST RECORD OF MONILIGASTRID EARTHWORMS FROM A SELECTED REGION OF THE GANGETIC PLAIN OF BIHAR, INDIA

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ABSTRACT
The paper deals with description of two species of Genus *Drawida* Michaelsen found in different locations of the Gangetic plain of Bihar. Though the genus is native yet only two species were found in this region during the collection. The two species dealt with are *Drawida calebi* Gates and *Drawida willsi* Michaelsen. The occurrence of these species in the Gangetic plain indicated the suitability of the edaphic profile of the region to the earthworm species. Both the species are endogeic in nature.

INTRODUCTION

Megadriles, according to Stephenson (1930) are mainly the 'true' terrestrial earthworm while the smaller, aquatic forms are termed as microdriles. The two groups are different in capillaries on their nephridia (Beddard, 1895) which is lacking in microdriles and also difference in some other features (Gates,1972). The family Moniligastridae Claus, 1880 comes under Megadriles along with Lumbricina or Haplotaxida (Easton, 1981).

Moniligastridae Claus, 1880 a single nominate family of the order Moniligastrida, Brinkhurst and Jamieson (1971) which is a large speciose group of terrestrial megadrile (Schmelz *et al.,* 2021). Order Moniligastrida, from phylogeny view point, has been considered as a sister group of the order Crassiclitellata (James and Davidson, 2012; Schmelz *et al.,* 2021; Misirlioglu *et al.,* 2023). It is advocated that the divergence of Moniligastridae–Crassiclitellata probably has taken place in Pangea in the Triassic period (Anderson *et al.,* 2017; Yuan *et al.,* 2019).

Moniligastridae is an Oriental family with wide distribution mainly due to the spread of genus *Drawida*, which is the most speciose and widespread among the moniligastrid genera (Gates, 1972; Jamieson, 1977). The genus *Drawida* is most widely distributed Oligochaete genera, both autochthonously and anthropochorously (Jamieson, 1977). Most of the species of this family are located in the tropical region (Shekhovstov *et al.,* 2022), while some are found in Asian subtropical and temperate zones also. It also occurs in South, Southeast and East Asia (Gates, 1972; Jamieson, 1977; Anderson *et al.,* 2017; Zhang *et al.,* 2020; Narayanan *et al.,* 2021, 2023). According to Jamieson (1977) species of the family occur in south east and eastern Asia, from South India to Manchuria, Korea, Japan, the Philippines, Borneo and Sumatra.

The discovery of *Moniligaster deshyaesi* in 1872 by Perrier is the beginning of study of this family. However, the term Moniligastridae was given by Claus in 1880. The species are rich and far and wide distributed genus *Drawida* described first by Michaelsen (1900) and there after Stephenson (1930) and Gates (1972). Important taxonomic contribution to this family has been made by many workers some important are Bourne (1886, 1894), Horst (1887, 1895, 1899), Rosa (1890, 1896, 1897), Beddard (1895), Michaelsen (1892, 1897,1907, 1910a, b, 1913, 1922, 1931, 1934), Cognetti (1911), Stephenson (1913, 1914, 1915, 1916, 1917, 1920, 1924a, 1925a, b, 1926), Rao (1921), Gates (1925, 1926, 1929, 1930a, b, 1931, 1933, 1934, 1935, 1938, 1940, 1943, 1945, 1962, 1969), Chen (1933, 1938, 1946), Kobayashi (1936, 1938, 1940, 1941a, b, c), Julka (1976, 1981), Jamieson (1977), Zhong (1986, 1992) and Wu and Sun (1996). In recent past notable contributors are Zhang *et al.,* (2006, 2021), Blakemore and Kupriyanova (2010), Blakemore (2013), Blakemore and Lee (2013), Blakemore *et al.,* (2014), Zhang and Sun (2014), Shen *et al.,* (2015, 2018), Hong (2022), Nguyen *et al.,* (2022). Similarly the Indian contributors of this field are Kale and Krishnamoorthy (1978), Julka and Senapati (1987), Bano and

Kale (1991), Singh (1997), Srivastava *et al.,* (2003, 2012, 2013), Sinha *et al.,* (2003, 2013), Sathianarayanan and Khan (2006), RajKhowa *et al.,* (2014), Parthasarthi *et al.,* (2015), Narayanan *et al.,* (2017), Ahmed and Chandra (2021), Tomar and Deshpande (2021) and Hasyagar *et al.,* (2022).

The family is represented by five genera namely *Moniligaster* Perrier 1872; *Desmogaster* Rosa 1890; *Drawida* Michaelsen 1900; *Eupolygaster* Michaelsen 1900, and *Hastirogaster* Gates 1930 (Gates, 1972; Jamieson, 1977; Blakemore, 2012; Misirlioglu *et al.,* 2023). Aladesida and Owa (2015), however, added a new fifth genus *Imekodrilus* to Moniligastridae which has been invalidated by Csuzdi *et al.,* (2020). Of these the genus *Drawida* is the species-rich (147 species) genus, while the family includes 204 species (Misirlioglu *et al.,* 2023).

The family Moniligastridae according to Jamieson (1977) is of special interest due to of great size, retention of primitive features like the large-yolked eggs and single layered clitellum which is typical of aquatic oligochaetes and some more like these. The family is considered as the primitive family. Three theories namely the contraction theory (Stephenson, 1922, 1930), the sex-reversal theory (Gates, 1962) and the haplotaxidan theory (Jamieson, 1977) have been put forward to explain its origin.

Many workers have studied the earthworms of this family from different parts of India (Kale and Krishnamoorthy, 1978; Julka and Senapati, 1987; Singh, 1997; Srivastava *et al.,* 2003, 2012, 2013; Sinha *et al.,* 2003, 2013; Narayanan *et al.,* 2017; Ahmed and Chandra, 2021; Tomar and Deshpande, 2021; Hasyagar *et al.,* 2022) but the Gangetic Plain of Bihar remains untouched. No systematic account is available except Srivastava *et al.,* (2021, 2022) from this region which deals with Octochaetidae and Megascolecidae. The communication is the first record of species belonging to Moniligastridae from the Gangetic plain of Bihar.

MATERIALS AND METHODS

Earthworm samples were collected using the monolith method and manually sorted once a month from a 25 × 25 cm area in the morning, in accordance with Sinha and Srivastava (2001). The collected worms were sorted and divided into three age groups according to clitellar development and length. Earthworms were preserved in 70% ethanol with adding a little quantity of glycerine in it. Apart from examining the earthworms, a few physico-chemical profile that affect the earthworm population were also analysed and recorded in the soil samples. A soil thermometer and a portable digital pH meter were used to measure the temperature and pH at the site of sampling. The oven drying method was followed to determine the moisture content while Walkley and Black (1934) was adopted in estimating the total organic matter (TOM) and organic carbon (OC) content.

RESULTS

Table 1 embodies the physical and chemical characteristics of the soils at the sampling sites which indicate that the soils at sampling sites are alkaline and with moderate to low levels of organic carbon and total organic matter. The moisture content of the soil, where earthworms were found, was recorded always at least 25%. The soil type was sandy loam.

Two species belonging to family Moniligastridae have been identified.

SYSTEMATIC ACCOUNT

Order Moniligastrida belongs to class Oligochaeta of Phylum Annelida.

Order **MONILIGASTRIDA**

Diagnosis- Intraseptal testes and male funnels in paired dorsal testis sacs, male pores at or close to the intersegmental furrow immediately posterior to the testis sac.

Family **MONILIGASTRIDAE**

Diagnosis- Absence of dorsal pores. Segments 10/11 or 11/12 or 12/13 bears male pores. Anterior spermathecal pores as compared to male pores. Oesophageal gizzards posterior to the ovarian segment. Band-shaped ovaries, large and yolky ova. Holonephric.

Distribution- South Eastern Asia which includes South India, Korea, Japan, Borneo, Sumatra and Philippines.

Genus ***Drawida*** Michaelsen

Diagnosis- Lumbricine setae. Paired male pores, at or near 10/11, paired female pore, at or immediately posterior to 11/12, paired spermathecal pores on or near to 7/8. Septa all present from 4/5, 5/6-9/10 muscular. Oesophagus with one or more gizzards in *xii-xxvii*, Absence of supra-intestinal glands and intestinal caeca. Paired capsular prostates, in *x*. Holonephridia in *iii* and posteriad segments.

Distribution. India, Sri Lanka, Nepal, Burma, Malay Peninsula, Thailand, China, Korea, Japan, Philippine Islands, Borneo, Sumatra and Java.

Drawida calebi Gates (Plate- 1a, Fig-1)

1945. *Drawida calebi* Gates, *Proc. Indian Acad. Sci.,* **21**(B): 211 (Type locality: Jubbalpore, Madhya Pradesh, India); Julka, 1976, *Mitt. Zool. Mus. Berlin*, **52** (2): 322.

Diagnosis. Length 32-83 mm, diameter 2-4.5 mm, 115-170 segments. Paired male pores with transverse slits at mid *bc*. Paired spermathecal pores median to *c* lines. Small genital markings, pre or postsetal, usually single and median and widely paired in *bc*, on *vii-xiii*; sometimes widely paired in *ab* on *xii* and closely paired in *aa* on *vii-x,* one of the paired markings sometimes absent or doubled or tripled. Single series of Nephridiopores close to *d* lines.

Gizzards 2-4, in *xii-xvii,* intestine begins in *xxvi* (±1). Short vas deferens, in a small column of loops in *ix*, almost straight in *x*, entering the antero-median aspect of the prostate directly. Muscular and spheroidal prostates, sessile, with an internal ventral portion protrusible as a shortly tubular penis. Spermathecal atrium conical, in *viii*, smaller than prostate. Genital marking glands spheroidal to shortly oval, concealed beneath longitudinal muscles.

Distribution- India: Bihar (S1, S3, S4, S5, S6, S8, S9), Jharkhand, Madhya Pradesh, Karnataka, Orissa, Chhatisgarh, Tamil Nadu, Uttar Pradesh.

Habitat- Geophagous in habit and generally found in grasslands, upland crop fields, lawns, pastures and compost

Table 1. Sampling centres with their latitude and longitudes and some edaphic characteristics.

District	Sampling sites	Latitude	Longitude	pH (M±SD)	Moisture content (M±SD)	OM (M±SD)	OC (M±SD)
Vaishali	Minapur (S1)	25.74°N	85.199°E	7.7±0.61	28.5±2.28	7.9±0.063	4.6±0.036
	Goraul (S2)	25.93°N	85.33°E	7.6±0.6	27.2±2.17	6.7±0.053	3.9±0.031
Saran	Dighwara S3)	25.74°N	85.01°E	7.2±0.57	27.4±2.19	7.4±0.059	4.3±0.034
	Sobarna (S4)	25.728°N	84.929°E	7.6±0.6	25.4±2.03	8.1±0.064	4.7±0.037
	Ekma (S5)	25.96°N	84.53°E	7.1±0.56	27.4±2.19	6.7±0.053	3.9±0.031
	Sonepur (S6)	25.69°N	85.178°E	7.6±0.6	28.6±2.28	6.2±0.049	3.6±0.028
Muzaffarpur	Sakra (S7)	25.97°N	85.56°E	8.1±0.64	24.6±1.96	7.7±0.062	4.5±0.036
	Dholi (S8)	25.99°N	85.59°E	7.7±0.61	25.4±2.03	6.8±0.055	4.0±0.032
	Minapur (S9)	26.34°N	85.60°E	7.8±0.62	26.8±2.14	7.2±0.057	4.2±0.033

pH in units , moisture in %, TOM and OC in mg g^{-1} soil.

pits at a depth below 10 cm of soil.

Biology - The population of the species in forest ecosystem has been recorded as maximum 32 m^{-2} by Mishra and Dash, (1984) while in an upland pasture it is 131 m^{-2} (Senapati and Dash, 1981). It has been estimated that this species makes up roughly 21% and 29% of all worms in grassland and forest ecosystems, respectively. The cocoons are round and also are distinctively decorated. The cocoons are 4.3 mm in diameter, 4.56 mm in length, and 0.94 mm in diameter to length when measured (Senapati *et al.,* 1979).

After three to eight weeks of incubation, the live weight of the cocoon was found to be 15.17 mg. A single worm typically hatches from each cocoon. A grazed upland pasture has been found to have a higher death rate as well as a higher reproductive rate (3-5 cocoons per adult/year), in contrast to a protected upland pasture (Senapati, 1980). After hatching, the maturation time appears to be 18-20 months thereafter they undergo hibernation for 4-6 months. When soil temperature rises beyond 30°C and soil moisture falls below 10g%, *Drawida calebi* undergoes diapause. This species leaves behind midden which is globular pellet-shaped on the soil subsurface.

Economic importance. Presence of digestive enzymes such urease, amylase, cellulase, protease, and invertase have been reported in the gut of the species by Mishra and Dash (1980). The presence of cellulase-breaking enzymes in their stomachs raises the possibility that this species is important for the biodegradation of garbage. This is why these worms are frequently found in compost pits. Further due to its preference for fungus feeding (Dash *et al.,* 1979) the species occurs at garbage site and appear to be important to the decomposer subsystem.

Drawida willsi Michaelsen (Plate- 1b)

1907. *Drawida willsi*, Michaelsen, *Mitt. Naturh. Mus. Hamb.,***24**: 145 (Type locality: Hyderabad, Andhra Pradesh, India); 1909. *Drawida willsi*, Michaelsen, *Mem. Ind. Mus.,* **i**: 143; Stephenson, 1923, *Fauna Br. India, Oligochaeta*: 161-162; Gates, 1945, *Proc. Indian Acad Sci.,***21(B)**: 214.

Diagnosis. Length 55-60 mm with 155-160 segments and diameter 2.5 mm. Prostomium is prolobatic. Clitellum annular (*x-xiii*). Setae *aa* equals *bc*. Male pores are paired and minute at or near *b* lines, with each pore located on the ventral end of the circular to oval porophore's slightly depressed or conically protuberant core portion. Paired spermathecal holes, tiny at *ab*. Paired genital marks, round, smaller than male porophores,

Plate 1a: *Drawida calebi*

Plate 1b: *Drawida willsi*

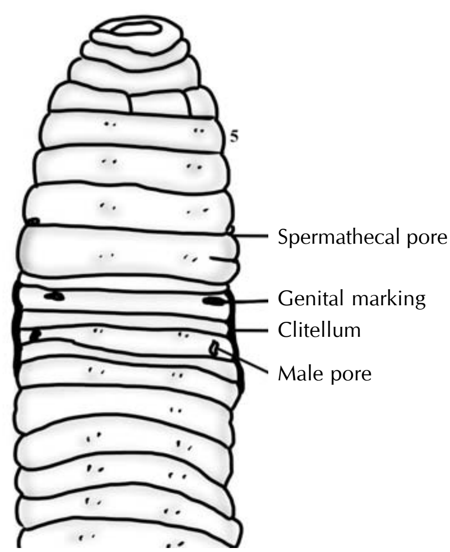

Figure 1: *Drawida calebi* Gates, external ventral view

with tiny central pores, on 9/10 or close to *b* lines; one of the paired markings is occasionally absent.

Gizzards 2-4, *xii-xvi*; intestinal origin in *xxi*, occasionally in *xxii* or *xxiii*. The vas deferens is fairly short, with many loops on the anterior and posterior faces of septum 9/10 that enter the prostate directly. Prostates glandular and erect; capsule digitiform. Paired spermathecae, in *viii*: atrium digitiform, in *vii*, as long as or slightly longer than the prostate, emerging from the internal end of the spermathecal duct. Genital marking glands are digitiform, occasionally or somewhat protruding into the coelomic cavity, and smaller than the prostate.

Distribution. India: Bihar (S1, S2, S4, S5, S7, S8, S9), Uttar Pradesh, Jharkhand, Orissa, Madhya Pradesh, Andhra Pradesh.

Material examined. 5 aclitellate, 8 clitellate specimens

Habitat. *Drawida willsi* inhabits soils with high organic matter content (>10g%). It is abundant in crop fields, compost pits and drains; pH ranging from slight acidic to alkaline soils (6.8-7.5).

Biology. The species feeds on plants. The maximum population densities have been recorded to be 32 m^{-2} in an upland protected pasture, 250 m^{-2} in a low-lying crop field, and 500 m^{-2} in a compost pit (Senapati,1980). Srivastava *et al.,* (2012, 2013) reported maximum population density of 2115 ± 189.87 m^{-2} whereas biomass of the worm was 29.55 ± 3.15 g dry weight m^{-2}. Live cocoons measure 3.2 mm in length and 2.9 mm in breadth. The cocoons are circular (diameter: length = 0.9) with pale to reddish brown incolour, weighing about 6 mg. The incubation period recorded for the species is 14-18 days at a soil temperature of 25°C and a moisture content of 16 g%. From each cocoon two baby worms emerges but sporadically three; however, emergence of four worms from a single cocoon has also been reported (Dash and Senapati, 1980).

Cocoons are laid all year round when soil is fully wet in rainfed locations. In environments that receive just rainwater, where growth is impeded by quiescence, maturity is reached in approximately 18 to 20 months. In the dry summer months, it develops diapause coils. Under laboratory circumstances, an estimated 5–6 kg of dry cast output can be produced annually for every gram of dry weight of worms. The casts are left as globular pellets on the soil's surface. It is anticipated that the rate of cast production is approximately ten times higher than that of *Lampito mauritii*. For the development of worm casts, soil moisture levels between 15 and 22 g% are ideal.

Economic importance. According to Dash (1999), the intestines of the animal included protease, urease, cellulase, and invertase. According to findings made in laboratories, this species promotes the breakdown of straw and green manure in culture.

DISCUSSION

Two species belonging to genus *Drawida* Michaelsen, namely *Drawida calebi* and *Drawida willsi* were found during the study. Both the species are native. The occurance and distribution of earthworms in different habitat are diverse (Guild, 1952; Satchell, 1955; Svendsen, 1957; Singh *et al.,*2016). The population of earthworms also varies considerably in different habitats according to the prevailing abiotic conditions of the soil (Evans and Guild, 1947). The environmental variables such as temperature, pH, moisture content and soil texture are said to have considerable impact on population dynamics. The earthworm biodiversity, its presence or absence and the dispersal pattern of earthworm species have been reported to be influenced by a range of biotic and abiotic factors, including soil properties, above ground vegetational cover, vegetation type, land use pattern and various management practices, local or regional climate condition as well as human pressure (Bhadauria and Ramakrishnan, 1989; Singh *et al.,* 2016; Soro *et al.,* 2019). Quite a good number of species belonging to this genus have been reported from different parts of the country while only two have been collected during the present study.

The reports show that different earthworm species have different habitat (Scullion and Malik, 2000). So far the distribution of earthworm species within ecosystems is concerned it is not homogenous, rather one species is present in one habitat and absent from others (Tripathi and Bhardwaj, 2004; Soro *et al.,* 2019). The dispersal of species is also influenced by prevailing and altering physico-chemical properties of the soil. The distribution of earthworms is to a great extent dependent on the environmental variables as temperature, moisture, pH, and soil texture (Fokam *et al.,* 2016). The demographic makeup and composition of earthworm groups are subservient to factors like land use patter, the above ground vegetation, type of vegetation, use of insecticides or pesticides, type of agro-climatic zone etc. Recent researches indicate that contrary to popular view that than burrowing and movement in drilosphere is due to ingesting POM-rich soil; the primary mechanism for soil bioturbation by burrowing earthworms relies on their ability to penetrate and deform the wet soil matrix using their flexible hydroskeleton and not simply ingestion (Ruiz *et al.,* 2015, 2021).

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