

*Full Length Research Paper*

# Earthworm resources in the Gangetic Plain of Uttar Pradesh, India

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**Based on an extensive survey of Gangetic Plain of Uttar Pradesh during August - October 2008, the communication reports first-hand information on 11 taxa of earthworms belonging to 6 genera and 2 families that were commonly found in the study area. This constitutes 26.3% of total Indian earthworm fauna. Of these, 04 taxa are exotic with extra Indian origin. The information on their scientific names, family, distribution, locality and voucher specimen no(s), habitat, soil texture etc are given for each species enumerated in the text. The study contributes first-hand material on earthworm fauna of the study area, thus for neglecting and likely to add more native species to the existing ones which are very specific for vermicomposting process.**

**Key words:** Biodiversity, earthworm, agro-climatic zones, Gangetic plain, India.

## INTRODUCTION

Earthworms (folk names include dew-worm, rain worms, night crawler and angle worm) are important biological resources that have a tremendous potential in agro-ecosystems because they significantly affect soil physical structures and organic matter and nutrient dynamics, and promote plant growth (Lee, 1985; Lavelle et al., 1988). India is a diverse country harbouring a very high diversity of earthworms, mostly concentrated in Western Ghats and Eastern Himalayas both of which are recognized as biodiversity 'hot spots'. Although this area is only 2% of the world's land mass, it supports about 10.5% of the total known global earthworm diversity, estimated at 4000 species.

Indian earthworms fauna predominantly represented by native species, constitute about 89% of total earthworm diversity in the country (Julka and Paliwal, 2005). Forests in India have been cleared on a large scale primarily for agricultural practices, construction and other developmental activities. Changes in land use pattern have directly affected the composition and population structure of earthworm species in different agro-climatic regions of the country (Blanchart and Julka, 1997; Behera et al., 1999; Bhaduria et al., 2000). Native species are threatened because of rapid and extensive

destruction of their natural habitats.

## Review of literature and present work

During the last few decades, the earthworms of Indian subregion have been studied to some extent viz. Eastern Himalayas (Julka, 1975a, 1976a and 1977, 1981), Khasi and Garo hills (Julka, 1977), Orissa (Julka, 1976b, 1978), South India (Jamieson, 1977), Eastern Himalayas (Julka and Rao, 1982), Western Himalayas (Julka, 1979; Halder, 1980) and Andaman and Nicobar island (Julka and Halder, 1975a; Sotta and Halder, 1980). However, Gangetic Plain of Uttar Pradesh (U.P) has been more or less neglected as compared to other parts of the country. Further, earthworms have gained renewed scientific attention in India and abroad because of their wide application in the production of vermicompost, and as a source of animal protein for domesticated animals. However, out of 418 species of earthworms known from the country (Julka and Paliwal, 2005), only half a dozen are frequently used for vermiculture and vermicomposting. Therefore, there is an urgent need to undertake extensive survey of earthworms in such unexplored areas with a view to: (i) study their biodiversity; (ii) search for more native species which may come out very specific and could be used for vermicomposting; (iii) contribute material for preparation of earthworm inventory of the study area and (iv) suggest

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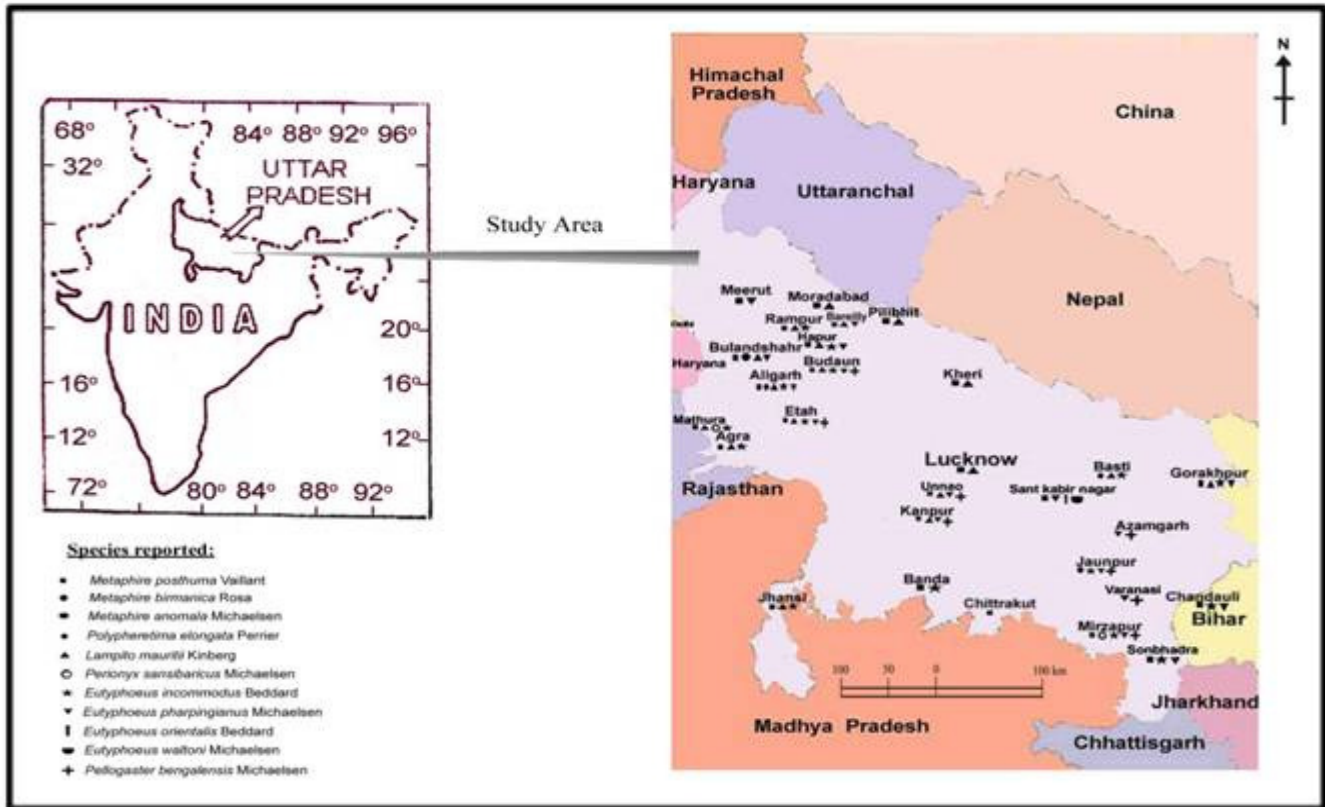


Figure 1. Study area: The Gangetic Plain of U. P., India.

measures for their conservation and protection, particularly, the species which are either threatened or on the verge of extinction. The present attempt, therefore, is to scientifically update investigation, identification and documentation of contemporary earthworm fauna of the study area.

### Study area

The Indo-Gangetic Alluvial Plains (IGP) are among the most extensive fluvial plains of the world and cover several states of the northern, central and eastern part of India. The IGP occupies total area of approximately 43.7 m hectare and represent eight agro-ecological regions (AER) and 14 agro-ecological sub regions. The area of the IGP is nearly 13% of the total geographical area of the country.

The Gangetic Plain of Uttar Pradesh from which data were derived is situated between 23°52' N latitudes and 77°3' and 84°39'E longitudes (Figure 1) and are highly fertile with alluvial soils having flat topography broken by numerous ponds, lakes and rivers slops. Climate of the area is tropical with wide variation because of dissimilarity in altitudes. The minimum and maximum temperature ranges from 01 to 47°C for the months of January and May respectively, with mean annual rainfall

120 - 160 cm. The area is bound in the west by the Indus river and on the south by the Vindhya mountain range. The vegetation is tropical dry and dry deciduous.

### METHODOLOGY

In the course of fieldwork, the authors visited different districts encompassing the various agro-climatic zones of the study area viz, South western semidry region, Western plain, Mid western, Mid region, Eastern region, Vidarv, North east, Tarai and Bundelkhand region of the study area during August - October 2008 (Table 1).

#### Earthworm sampling

Earthworm for taxonomic studies was collected by digging and hand sorting method. Samples were taken from diverse ecological niches at 300 - 1000 m from study area.

#### Analysis of soil samples

Soil samples were analyzed for soil texture by international pipette method (Piper, 1966), moisture by oven drying method (Santhanam et al. 1989), pH by digital meter (Misra, 1968) and total organic matter by Walkley and Black's method (1934) and the data is presented in Table 2.

The methodology adopted for earthworm collection was based on Julka (1988). Collected worms were washed in fresh water and stored in test tubes in the field. Ethyl alcohol was gradually added

**Table 1.** Survey record of earthworms' biodiversity in Gangetic plain of U.P.

Date(s) of survey	Zone	Altitude	Collection no.	Districts covered
18.08.08 - 25.08.08	South-Western semidry region	554.2	D/01 to D/42	Aligarh, Agra, Etah, Mathura 4
21.08.08 - 03.09.08	Western plain	606.3	B/43 to B/57	Bulandshahar, Hapur, Meerut 3
03.09.08 - 04.09.08	Mid Western	514.5	E/58 to E72	Badaun, Bareilly, Moradabad 3
08.09.08 - 10.09.08	Mid region	227.0	C/73 to C/87	Kanpur, Lucknow, Unnao 3
09.09.08 - 12.09.08	Eastern region	265.6	H/88 to H102	Azamgarh, Jaunpur, Varanasi 3
10.09.08 - 19.09.08	Vidrav	269.2	I/103 to I/117	Chandauli, Mirzapur, Sonbhadra 3
18.09.08 - 21.09.08	North-East	238.3	G/18 to G/132	Basti, Gorakhpur, Santkabirnagar 3
14.10.08 - 16.10.08	Tarai	304.3	A/133 to A/147	Lakheempur kheri, Pilibhit, Rampur 3
16.10.08 - 18.10.08	Bundelkhand region	859.6	F/148 to F/162	Banda, Chitrakut, Jhansi 3

**Table 2.** Results of soil samples analysis.

S/no.	Collection sites	Results of soil analysis			
		Soil texture	Moisture (%)	Organic carbon content (%)	pH
1.	Aligarh	Loamy	25 - 30	4.01	6.94
2.	Agra	Sandy	20 - 25	4.01	7.34
3.	Azamgarh	Loamy	25 - 30	3.87	7.13
4.	Basti	Sandy	20 - 25	3.15	7.02
5.	Banda	Sandy	28 - 30	3.82	7.52
6.	Badaun	Clay	40 - 42	4.58	6.63
7.	Bareilly	Sandy loam	28 - 30	3.46	7.13
8.	Bulandshar	Sandy	25 - 28	1.54	6.76
9.	Chandauli	Loamy	28 - 30	1.55	7.73
10.	Chitrakoot	Loamy	28 - 30	1.93	7.12
11.	Etah	Sandy	20 - 25	3.14	7.18
12.	Gorakhpur	Clay	25 - 30	2.52	7.11
13.	Hapur	Loamy	25 - 30	6.68	6.80
14.	Jaunpur	Clay	25 - 30	3.49	7.13
15.	Jhansi	Sandy	28 - 30	1.76	7.31
16.	Kanpur	Sandy	24 - 30	3.82	7.52
17.	Lakhimpur	Clay	25 - 30	3.82	7.15
18.	Lucknow	Sandy	24 - 36	4.45	7.61
19.	Mathura	Sandy-Loam	28 - 30	1.54	6.76
20.	Meerut	Loamy	25 - 30	3.49	7.13
21.	Mirzapur	Clay	26 - 28	2.39	7.68
22.	Moradabad	Clay	24 - 26	4.20	7.29
23.	Pilibhit	Loamy	28 - 30	2.81	7.10
24.	Rampur	Loamy	28 - 30	3.90	6.69
25.	Santkabir nagar	Sandy	24 - 28	4.12	7.02
26.	Sonbhadra	Loamy	20 - 25	2.14	7.71
27.	Unnav	Sandy	24 - 28	6.72	8.0
28.	Varanasi	Loamy	24 - 26	3.49	7.13

to the test tube and then transferred to the dish containing a solution of 5% formalin for fixation and kept for a period 6 - 8 h, followed by their preservation in 70% ethyl alcohol or 5% formalin. All specimens were serially numbered and necessary field data were recorded.

#### Field plots

The habitat preference was taken in the following plots located in 236, 286 sq. km of study area. South Western semi-dry region, Western plain, Mid-Western, Mid region, Eastern region, Vidrav,

Northeast, Tarai and Bundelkhand region.

- i. Grassland (ungrazed): Soil texture, silty clay loam (sand 33.0%; silt 37.5% and clay 29.5%), moisture 25 - 30%; temperature 25 to 30°C; pH 7.5 - 8.0; organic matter 5.05%.
- ii. Grassland (grazed): Soil texture, clay loam (sand 46.0%; silt 20.0% and clay 34.0%), moisture 20.25%; temperature, 22 - 25°C; pH 6.87 - 7.0; organic matter 1.89%.
- iii. Mixed forests: Soil texture, clay loam (clay 48%; sandy loam 40% and loam 12%), moisture 40 - 42%; temperature, 30 - 38°C; pH 7.0 - 7.2; organic matter 4.84%.
- iv. River Bank: Nearby vegetation comprises of mainly grasses and weeds. Soil texture, clay loam; temperature, 15 - 18°C; pH 8.0 - 8.2; organic matter 0.42%.
- v. Dung heap: Major physico-chemical characteristics of the dung heap is large amount of decomposed vegetable material; moisture 28 - 30%; temperature 25 - 30°C; pH 6.94 - 7.0; organic matter 4.63%.
- vi. Cultivated land: The terraced field with seasonally grown agriculture crops viz., pulses paddy and wheat and vegetables; manured periodically with chemical fertilizers and FYM; soil texture, sandy loam; pH 7.0-7.5; temperature 20 - 25°C and organic matter 2.35%.

Earthworms were identified with the help of monographs and other available literature on the subject (Stephenson, 1923; Gates; 1972, Julka, 1988) at the Vermiculture Research Station (VRS), D.S. College, Aligarh and later confirmed by experts at Zoological Survey of India, Kolkata. Voucher specimens of all specimens examined and reported in the present work are deposited in the Museum of VRS, for future reference and study.

### Systematic enumeration

Adverting shortly to the presentation of data, the earthworm species collected from the study area are arranged in alphabetical order. Each entry gives the information (in a format): Earthworm's scientific name, family, distribution, locality and voucher specimen number, date of collection, general habitat etc. It is important to know the species are native or exotic

- 1) *Eutyphoeus incommodus* Beddard  
Family: Octochaetidae  
Origin: Exotic  
Locality and collection no.s: *Rampur*: A/143, A/144; *Hapur*: B/48; *Aligarh*: D/01, D/05; *Etah*: D/09, D/10, D/11, D/12, D/13; *Mathura*: D/16, D/17; *Badaun*: E/63, E/64, E/65; *Jhansi*: F/149; *Banda*: F/153, F/154; *Basti*: G/118, G/119, G/122; *Gorakhpur*: G/129, G/130, G/132; *Jaunpur*: H/94, H/97; *Mirzapur*: I/103, I/104; *Sonbhadra*: I/108, I/111; *Chandoli*: I/116.  
Date(s) of collection: 18.08.08 to 17.10.08  
General habitat: Grassland (ungrazed), cultivated land (paddy crop).
- 2) *Eutyphoeus orientalis* Stephensen  
Family: Octochaetidae  
Origin: Native  
Locality and collection no: *Santkabirnagar* G/124.  
Date of collection: 19.09.08  
General habitat: Grassland (ungrazed)
- 3) *Eutyphoeus pharpius* Michaelsen  
Family: Octochaetidae  
Origin: Exotic  
Locality and collection no.s: *Bulandshahar*: B/46; *Hapur*: B/49, B/50, B/52; *Meerut*: B/53, B/56; *Kanpur*: C/75, C/77; *Unnav*: C/80; *Aligarh*: D/04; *Etah* D/14; *Badaun*: E/65, E/67; *Bareilly*: E/72;

*Gorakhpur*: G/128; *Santkabirnagar*: G/123, G/125; *Varanasi*: H/88, H/89, H/91; *Jaunpur*: H/95, H/96; *Azamgarh*: H/100; *Mirzapur*: I/107; *Sonbhadra*: I/110, I/112; *Chandoli*: I/114.  
Date(s) of collection: 18.08.08 to 20.09.08  
General habitat: Grassland (grazed and ungrazed) river bank, cultivated land (paddy and pulses), dung heap.

- 4) *Eutyphoeus waltoni* Michaelsen  
Family: Octochaetidae  
Origin: Native  
Locality and collection no: *Santkabirnagar* G/127.  
Date of collection: 19.09.08  
General habitat: River bank
- 5) *Lampito mauritii* Kinberg  
Family: Megascolecidae  
Origin: Native  
Locality and collection no.s: *Pilibhit*: A/135; *Lakhimpurkheri*: A/138, A/140, A/142; *Bulandshahar*: B/43, B/44, B/45, B/46, B/51; *Kanpur*: C/74; *Unnav*: C/78, C/79, C/81; *Lucknow*: C/183; *Aligarh*: D/02, D/03, D/21, D/23, D/24, D/38, D/39, D/42; *Agra*: D/33, D/34, D/36, D/37; *Etah*: D/07, D/08; *Mathura*: D/20, D/21, D/23, D/24; *Moradabad*: E/58, E/59, E/61; *Badaun*: E/67; *Bareilly*: E/68, E/70; *Basti*: G/120; *Jhansi*: F/148, F/151; *Gorakhpur*: G/130.  
Date(s) of collection: 18.08.08 to 16.10.08  
General habitat: Garden land (ungrazed), cultivated land (paddy crop) and river bank.
- 6) *Metaphire anomala* Michaelsen  
Family: Megascolecidae  
Origin: Native  
Locality and collection no: *Bulandshahr* B/43.  
Date of collection: 21.08.08  
General habitat: Cultivated land

- 7) *Metaphire birmanica* Rosa  
Family: Megascolecidae  
Origin: Native  
Locality and collection no: *Jaunpur*: H/96.  
Date of Collection: 11.09.08  
General habitat: River bank
- 8) *Metaphire posthuma* Vaillant  
Family: Megascolecidae  
Origin: Native  
Locality and collection no.s: *Pilibhit*: A/133, A/134, A/136; *Kheri*: A/138, A/139; *Rampur*: A/143, A/144, A/146; *Bulandshahr*: B/44, B/45, B/46, B/47; *Hapur*: B/49; *Meerut*: B/54, B/55, B/56, B/57; *Kanpur*: C/73, C/74, C/75, C/76; *Unnav*: C/78, C/79, C/80, C/81, C/82; *Lucknow*: C/83, C/85, C/86, C/87; *Aligarh*: D/01, D/03, D/04, D/23, D/25, D/26, D/27, D/29, D/38, D/39, D/40, D/41; *Agra*: D/30, D/31, D/32, D/34, D/36, D/37; *Etah*: D/06, D/08, D/11, D/12, D/13, D/15; *Mathura*: D/16, D/17, D/19; *Moradabad*: E/59, E/61; *Badaun*: E/64, E/66, E/67; *Jhansi*: F/149, F/150, F/152; *Banda*: F/153, F/154, F/155, F/156; *Chitrakut*: F/155, F/159, F/160, F/161, F/162; *Basti*: G/120, G/121, G/122; *Santkabirnagar*: G/126, G/127; *Gorakhpur*: G/128, G/130, G/131, G/132; *Mirzapur*: I/104, I/106; *Sonbhadra*: I/108, I/109, I/110, I/112; *Chandoli*: I/113, I/115, I/117.  
Date(s) of collection: 18.08.08 to 18.10.08  
General Habitat: Garden (ungrazed), cultivated land, river bank.

- 9) *Pellogaster bengaleusir* Michaelsen  
Family: Octochaetidae  
Origin: Exotic  
Locality and collection no. s: *Kanpur*: C/73, C/74; *Unnav*: C/82; *Etah*: D/14; *Badaun*: E/65; *Varanasi*: H/88, H/90, H/91, H/92; *Jaunpur*: H/93, H/95; *Azamgarh*: H/98, H/94, H/100, H/101, H/102; *Mirzapur*: I/106.

**Table 3.** Contributions made by different workers on earthworm survey in Gangetic plain of Uttar Pradesh, India from 1907 to 2009.

Species	Beddard	Michaelsen	Stephenson	Perrier	Vaillant	Rosa	Gates	Julka	Tripathi	Bisht	Joshi and Swati	Present study
<i>E. incommodus</i>	+(1907)							+(1993)			+(2009)	+(2009)
<i>E. orientalis</i>	+(1883)	+(1907)	+(1914)					+(1993)			+(2009)	+
<i>E. Pharpingianus</i>		+(1910)						+(1993)		+(2003)		+
<i>E. waltoni</i>		+(1907)						+(1993)			+(2009)	+
<i>L. mauritii</i>			+(1913)									+
<i>M. anomala</i>		+(1907)	+(1923)				+(1925)	+(1995)				+
<i>M. biramnica</i>						+(1888)	+(1972)					+
<i>M. posthuma</i>	+(1912)			+(1872)	+(1888)			+(1988)	+(2003)	+(2003)		+
<i>P. sansibaricus</i>		+(1891)						+(1988)	+(2008)			+
<i>P. bingalensis</i>		+(1910)						+(1988)				+
<i>P. elongata</i>	+(1890)			+(1872)			+(1926)	+(1988)				+

Date(s) of collection: 20.08.08 to 10.09.08

General habitat: Grassland (ungrazed), cultivated land (paddy crop), river bank.

10) *Perionyx sansibaricus* Michaelsen

Family: Megascolecidae

Origin: Native

Locality and collection no.s: Mathura: D/20; Mirzapur: I/107.

Date(s) of collection: 20.08.08 to 10.09.08

General habitat: Grassland (ungrazed), cultivated land

11) *Polypheretima elongata* Kinberg

Family: Megascolecidae

Origin: Exotic

Locality and collection no: Aligarh D/04.

Date of collection: 18.08.08

General habitat: Grazed grassland

## RESULTS AND DISCUSSION

Of the 236 field samples of earthworms collected and identified from certain districts of Uttar Pradesh (Figure 1), encompassing various agro-climatic zones of the Gangetic Plain of India, the

present study has brought to light 11 species including 04 exotic with extra Indian origins. It has been observed that *Metaphire posthuma* Vaillant is predominant species with wide distribution within the study area.

In recent years, the diversity of Indian earthworms has been mainly studied by Julka (1988). He described the family Octochaetidae in the publication '*Fauna of India*' providing illustrated descriptions of 154 taxa including 6 new genera and 16 species. The knowledge on the earthworm fauna of India has also been enriched by Julka and Senapati (1987), Senapati et al. (1990), Julka and Paliwal (1994) and Paliwal and Julka (2005). However, a close review of literature on the study of earthworms in U.P. indicates that the first report appeared in 1912. Subsequently, many workers contributed to the study until 1988. Thereafter, the taxonomical studies in the region have been more or less neglected between 1989 and 2009 except for few fragmentary reports (Table 3). Present work, therefore, is a humble attempt in this direction and contributes to update our contemporary knowledge on the biodiversity

of earthworms' resources in the study area.

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## REFERENCES

- Beddard FE (1883). Notes on some earthworms from India. Ann. Mag. Nat. Hist. 12: 231-224 (Ser. 5).
- Behera B, Giri S, Dash NC, Senapati BK (1999). Earthworm bio-indicators of forest land use pattern. Indian Forester, 124(3): 273-281.
- Bhadauria T, Ramakrishnan PS, Srivastava KN (2000). Diversity and distribution of endemic and exotic earthworms in natural and regeneration ecosystems in the central Himalaya, India. Soil Biol. Biochem. 32: 2045-2054.
- Bisht R, Pandey H, Bharti D, Kaushal BR (2003). Population dynamics of earthworms (Oligochaeta) in cultivated soils of Central Himalayan tarai region. Trop. Ecol. 44(2): 229-234.
- Blanchart E, Julka JM (1997). Influences of forest disturbance on earthworm communities in Western Ghat, South India. Soil Biol, Biochem. 29: 303-306.

- Gates GE (1972). Burmese earthworms. An introduction to the systematic and biology of megadrile Oligochaeta with special references to Southeast Asia. *Trans. Am. Phol. Soil*, 62(7): 1-326.
- Halder KR (1980). Annelida. In: Fauna of Nanda Devi Biosphere Reserve; Fauna of Conservation Areas 9. Zoological Survey of India, Calcutta pp. 31-34.
- Jamieson BGM (1977). Preliminary description of Indian earthworms (Megascolecidae: Oligochaeta) from the Palni Hills. *Bull. Mus. Nat. His. Nat. Paris (ser) Zool.* 313(450): 477-502.
- Joshi N, Swati A (2009). Diversity and distribution of earthworms in a subtropical forest ecosystem in Uttarakhand. India. *The Natural Hist. J. chulalongkorn Univ.* 9(1):21-25, April.
- Julka JM (1988). The fauna of India and the adjacent countries. Megascolecidae: Octochaetidae (Earthworms) Haplotaxida, Lumbricina: Megascolecidae: Octochaetidae xiv, Zoological Survey of India, Calcutta pp. 400.
- Julka JM (1975a). Notes on the earthworms fauna of Darjeeling district with descriptions of two new species Miti. *Zool. Mus. Berlin* 52(1): 19-27.
- Julka JM (1975b). Abnormal variations in *Perionyx millardi* Stephenson (Megascolecidae: Oligochaeta) Newsletter. *Zool. Surv. India*, 1(2): 26-27.
- Julka JM (1976a). Studies on the earthworms collected during the Daphabum expedition in Arunachal Pradesh. India. *Rec. Zool. Surv. India* 69: 229-239.
- Julka JM (1976b). Studies on the earthworms fauna of Orissa (India). Moniligastridae and Ocnerodrilidae. *Mitt. Zool. Mus. Berlin.* 52: 32-329.
- Julka JM (1977). Contribution to the knowledge of the earthworm fauna (Oligochaeta: Annelida) of Meghalaya. Newsletter. *Zool. Surv. India*, 3(6): 398-400.
- Julka JM (1978). Studies on the earthworm fauna of Orissa (India) 2. Megascolecidae, Octochaetidae and Microchetidae. *Mitt. Zool. Mus. Berlin* 54: 185-1970.
- Julka JM (1979). First record of *Lumbricus castaneus* Savigny from India (Limbricidae: Oligochaeta). *J. Bombay Nat. Hist. Soc.*, 76(1):191-192.
- Julka JM (1981). Taxonomic studies on the earthworms collected during the susbansiri expedition in Arunachal Pradesh, India. *Rec. Zool. Surv. India* 26:1-37.
- Julka JM (1982). Earthworm fauna of the Andaman and Nicobar Islands, India. *Rec. Zool. Surv. India*, 80:127-155.
- Julka JM (1983). A new genus of earthworm (Octochaetidae :Oligochaeta) from South India. *Geobios.* 2:48-50.
- Julka JM, Senapati BK (1987). Records of the Zoological Survey of India. Miscellaneous Publication. Occ. Pap. 92 Grafic Printall, Calcutta, India pp. 1-105.
- Julka JM, Rao BR (1982). A new earthworm *Mallehulla indica* gen. et. sp. nov. (Oligochaeta: Octochaetidae) from Karnataka, India. *J. Soil Biol. Ecol.* 2(2): 67-72.
- Julka JM, Halder KR (1975a). Record of *Pheretima malaca* Gates (Oligochaeta: Megascolecidae) from Andaman Islands. Newsletter. *Zool. Surv. India* (4): 65-66.
- Julka JM, Halder KR (1975b). On the occurrence of giant earthworm *Perionyx macentoshi* Beddard (Oligochaeta: Megascolecidae) in Bhutan and Arunachal Pradesh (India). *Proc. Zool. Soc. Calcutta* 28: 15-17.
- Julka JM, Paliwal R (2005). Distribution of earthworms in different agro-climatic region of India. In : Ramakrishnan PS, Saxena KG, Swift MJ, Raoks Maikhuri RK (eds) Soil biodiversity, ecological processes and land scape. Oxford and ABH Publications Co. Pvt. Ltd., New Delhi pp. 3-13.
- Julka JM, Paliwal R (1994). On a new species of *Plutellus* Perrier (Acanthodrilidae: Oligochaeta) from Northwest Himalayas, India, Indian. Res. Bull. Punjab Univ. 44: 217-220.
- Julka JM, Paliwal R (2005). Distribution of earthworms in different agro-climatic region of India. In : Ramakrishnan PS, Saxena KG, Swift MJ, Raoks, Maikhuri RK (eds) Soil biodiversity, ecological processes and land scape. Oxford and ABH Publications Co. Pvt. Ltd., New Delhi pp. 3-13.
- Julka JM, Giri S, Panigrahi PK, Senapati BK (1977). *Parryodrilus lavellei* gen. nov. and sp. nov. (Octochaetidae: Oligochaeta) from Western Ghats. South India. *Eur. J. Soil Biol.*, 33: 141-144.
- Lavelle P, Barois L, Blanchart E, Brown GG, Brussaard L, Decaens T, Fragosco J, Jimenez K, Kajondo MA, Martinez AG, Moreno Poshanasi, Senapati B, Villenane C (1988). Earthworms as a resource in tropical agroecosystems, *Natural Resources* 34: 26-41.
- Lee KE (1985). Earthworms - their ecology and relationship with soil and land use. Academic press, Sydney.
- Michaelsen W (1907). Neue Oligochatenvon vrder Indien, Ceylon, Birma und den Andaman-inseln. *Jb. hamb. Wiss. Anst.* 24: 143-188.
- Michaelsen W (1910). Die Oligochaten fauna der vorde indisch-ceylonischen region. *Abh. Geb. Naturw, Hamburg* 19(5): 1-108.
- Misra R (1968). Ecology work book. Oxford and IBH publishing company, Calcutta, India.
- Paliwal R, Julka JM (2005). Checklist of earthworms of Western Himalaya, India. *Zoos Print J.* 20(9): 1972-1976.
- Perrier E (1872). Recherches Pour servir a l' histoire des lombriciens terrestres. *Nouv. Archs. Mus. Hist. Nat, Paris* 8: 5-198.
- Piper CS (1966). Soil and Plant Analysis. Hans Publishers, Bombay p. 368.
- Rosa D (1888). Viaggio di Leonardo fea in Birmanica e regioni vicine. V. Perichetidi Annali Mus. Civ. Stor. Nat. Giacomo Doria 6: 155-167.
- Santhanam R, Velaycitham P, Jegatheesam (1989). A manual of Fresh water Ecology. Daya Publishing House, Delhi p. 134.
- Senapati BK, Julka JM, Dash MC (1990). On a new species of *Lenogoster* Gates (Octochaetidae: Oligochaeta) from India. *Rev. Ecol. Biol. Soil* 27: 467-470.
- Sotta JD, Halder KR (1980). Some earthworms from Western Himalayas. *Rec. Zool. Surv. India* 76: 195-205.
- Stephenson J (1923). Oligochaeta. The Fauna of British India, including Ceylon and Burma, Taylor and Francis, Ltd. London.
- Tripathi G, Bhardwaj P (2003). Biodiversity of earthworm resources of arid environment. *J. Enviorn. Biol.* 26(1): 61-71.
- Vaillant L (1888). Note Sur-anatomie de deux especes de perichaeta et essai de classification des Annelides lombriciens. *Annls Sci. Nat. (Ser.5)* 10: 225-256.
- Walkley A, Black IA (1934). Determination of Organic carbon in Soil. *Soil Science* 37: 29-31.