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SECONDARY PRODUCTION AND ENERGETICS OF AN OCNERODRILID EARTHWORMS *OCNERODRILUS OCCIDENTALIS*, EISEN FROM TROPICAL AGROECOSYSTEM

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ABSTRACT

Earthworms play an important role in conversion and elaboration of primary production into subsequent flow and partitioning of fixed carbon between and within trophic levels of consumers by occupying key position in decomposer subsystem. Secondary production and energetics of an earthworm *Ocnerodrilus occidentalis* Eisen, have been studied in a tropical cropland agroecosystem at Ranchi, Jharkhand, India, having population density range between 75 ± 30.62 to 7600 ± 108.97 m^{-2}. The variation observed in biomass was from 30.01 ± 3.15 g dry wt. m^{-2} (in September) to 0.57 ± 0.33 g dry wt. m^{-2} (in June) with turnover value as 5.77 times yr^{-1}. Secondary production was investigated to be 302.10 kcal m^{-2} yr^{-1} while the respiratory and excretory energy losses were of the order of 900.04 Kcal m^{-2} yr^{-1} and 52.77 Kcal m^{-2} yr^{-1} respectively. Tissues growth efficiency was 25.13% for the worm.

KEY WORDS
People, Economy
Kosi Region
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INTRODUCTION

Ecological energetics concerns with the fixation of atmospheric carbon and its elaboration into organic compounds by primary producers, the subsequent flow and partitioning of fixed carbon between and within trophic levels of consumers and its eventual return to the atmosphere in the form of CO_2. One of the main concerns of International Biological Programme (IBP) was to quantify parameters in ecological energetics in order to clarify such relationships within ecosystems, to enable objective comparisons to be made between ecosystems and hopefully to provide a greater understanding of natural complexity via an assessment of its functional interplay (Luxton, 1975).

Earthworms dominate the soil faunal biomass in many tropical and temperate soils and make important contributions in the decomposition of material and vermicomposting (Satchell, 1967; Mishra *et al.*, 1984; Senapati *et al.,* 1982). Though reports are now available on population dynamics of different earthworms in grassland, compost pits, sewage sludge (Watanabe *et al.,* 1976; Hartenstein *et al.,* 1979; Sahu *et al.,* 1988), there is great paucity of knowledge on this aspect so far Indian scenario is concerned. No attempt has been made to understand the ecology of the worm *Ocnerodrilus occidentalis* dominant earthworm of Indian agro ecosystem. The present investigation was carried out in a tropical cropland agroecosystem to study the production and energetics of earthworm *O. occidentalis* (Eisen).

MATERIALS AND METHODS

Earthworms were collected from different agroecosystem sites in Ranchi, located between 21^0 58' N- 25^0 19' N latitude and 83^0 20' E - 88^0 4' E longitude and at a height of 629 m above mean sea level (MSL). The climate is broadly divided into three seasons: winter (October-February), summer (March-mid June) and rainy (mid June-September). Air temperature during the study period varied from a minimum of 5.6^{0}C (December 2000) to a maximum of 36^{0}C (May 2000). Relative humidity ranged from 25 to 93% and the total rainfall was 1423.3 mm out of which 72% fell during rainy season.

Earthworms were sampled and hand-sorted once a month from October 1999 to March 2001. Sampling was confined to first week of every month. During each sampling, 5 random samples from an area of 20 x 20 x 30 cm each were taken from the study site (Dash *et al.,* 1977). On the basis of length and clitellar development *O. occidentalis* worms were divided into 3 age classes: i) juvenile (< 2cm, non clitellate), ii) immature (≥ 2cm < 4cm, non clitellate) and iii) adult (≥4 cm, clitellate). The population of earthworm was expressed as number of individual per square metre. The lengths of live worms were measured after keeping the worms in ice-cold water for 30seconds (Mishra *et al.,* 1980).

Five replicates of freshly collected worms of each size groups were weighed separately after gut clearance and were kept in oven at 85^{0}C for 24 hrs to obtain dry weight. Gut clearance of worms was made by keeping them half immersed in distilled water (changed every 12 hrs) in glass petri dishes for about 36hrs. Dominance of earthworm species was determined on the basis of mean monthly Importance value (Sajise *et al.,* 1976).

Secondary production is defined as the amount of tissue substance produced (change in body weight Δb) and reproduction (Δg) over a period of time (say one year) irrespective of whether it has survived to the end of that period or not (Cragg, 1961; Macfadyen, 1967). Production can be written as $P = \Delta B + E$, where ΔB represents the change in biomass (growth + reproduction) and E stands for elimination (loss) i.e., the biomass of individuals that have died or been killed. Changes in number of worms show loss or gain of weight (Golley, 1961). Growth and mortality were calculated from the gain and loss of number and biomass of earthworms (Dash *et al.,* 1977). Since cocoon production by worm was not examined, the secondary production has been calculated taking growth and the loss of tissue due to mortality into consideration. Biomass turnover value was calculated from the ratio of secondary production to average biomass (Senapati *et al.,* 1981).

Oxygen consumption measurements are generally a better index of heat liberation than the measurements of CO_2 output (Petrusewicz *et al.,* 1970). Consumption of oxygen was measured taking different age groups of worm by Winkler's method (Welch, 1948) in a temperature controlled water bath (30 ± 1^0) and the laboratory data and the average total oxygen consumption of earthworms was extrapolated to field conditions taking general lumbricid Q_{10} as 2 (Gromodaska, 1962).

Estimation of excretion of ammonia and urea of different age groups of worms were made in the laboratory condition at 30 ± 1^{0}C. The worms of different age groups were kept in water medium in half submerged condition and the rate of excretion (g rejecta/g dry tissue /h) of ammonia and urea was determined by indophenol and diacetyl monoxime methods respectively (Kaplan, 1965). The laboratory data on the average ammonia and urea excretion of earthworms was extrapolated to field conditions in the same way as oxygen consumption.

Calorific conversion of different materials were calculated by utilising standard values (Golley, 1961) for earthworm tissue, ammonia (Barfield *et al.,* 1972) urea (Satchell, 1971) and oxygen (Engelman, 1961).

RESULTS AND DISCUSSION

Four species of earthworms *Glyphidrilus tuberosus* Stephenson, *O. occidentalis* Eisen, *Lampito mauritii* Kinberg and *Drawida willsi* Michaelsen were found in the study site. Of these, *O. occidentalis was* dominant both in number and biomass (> 90%) in the study sites.

The total population density as well as density of different age groups of *O. occidentalis* at the study sites has been

Table 1: Total density (No m^{-2} month^{-1}± SEM, n=5) and density of different age groups of *O. occidentalis*

Months	Juvenile wormsJ	Immature wormsIM	Mature wormsM	Totaldensity
Oct. 99	1330 ±225.97	2680±242.64	1225±186.24	5235±167.33
Nov. 99	110±57.55	740±114.02	235±106.95	1085±202.02
Dec. 99	50±39.52	325±65.19	50±46.77	425±123.24
Jan. 00	45±20.91	385±65.19	115±45.41	545±110.96
Feb. 00	150±77.05	350±82.92	125±53.03	625±157.12
Mar. 00	245±57.01	1015±84.04	535±57.55	1795±161.43
Apr. 00	50±30.61	800±88.38	95±27.39	945±105.18
May 00	-	330±59.69	150±75.00	480±89.09
Jun. 00	-	75±30.62	-	75±30.62
Jul. 00	1100±113.19	3000±276.69	700±86.60	4800±179.41
Aug. 00	3000±140.31	3660±85.88	940±179.06	7600±108.97
Sep. 00	2160±271.91	3705±480.03	1550±346.86	7415±596.23
Oct.00	1330±150.7	2700±322.37	1395±163.13	5425±267.51
Nov.00	175±93.54	750±128.69	200±68.47	1125±155.12
Dec.00	35±28.5	265±76.24	75±46.77	375±131.10
Jan.01	50±39.53	375±88.39	100±39.53	525±128.70
Feb.01	80±64.71	460±80.23	85±60.21	625±146.84
Mar.01	325±98.43	1200±221.50	625±174.10	2150±232.51

Table 2: Total biomass (g dry wt m^{-2} month^{-1}± SEM, n=5) and biomass of different age groups of *O. occidentalis*

Months	Juvenile wormsJ	Immature wormsIM	Mature wormsM	Totalbiomass
Oct. 99	1.3±0.21	11.64 ± 2.09	6.49±0.87	19.26±1.86
Nov. 99	0.10 ±0.04	4.66±0.25	1.26±0.63	6.02±0.69
Dec. 99	0.04±0.03	1.98±0.22	0.34±0.28	2.36±0.40
Jan. 00	0.04±0.03	2.24±0.20	0.79±0.36	3.07±0.52
Feb. 00	0.14±0.07	2.35±0.73	0.85±0.38	3.34±1.02
Mar. 00	0.22±0.06	8.00±0.51	2.77±0.27	10.99±0.66
Apr. 00	0.05±0.03	6.65±0.55	0.53±0.37	7.23±0.84
May 00	-	1.95±0.54	0.89±0.46	2.84±0.64
Jun. 00	-	0.57±0.33	-	0.57±0.33
Jul. 00	1.02±0.15	16.89±0.73	3.51±0.28	21.42±0.96
Aug. 00	2.61±0.24	20.57±1.68	5.51±1.05	28.69±1.08
Sep. 00	1.79±0.28	20.10±2.26	8.12±1.70	30.01±3.15
Oct.00	1.12±0.16	12.74±1.68	7.8±0.60	21.66±1.25
Nov.00	0.15±0.09	4.11±1.03	1.36±0.49	5.62±0.72
Dec.00	0.03±0.02	1.4±0.43	0.47±0.34	1.9±0.69
Jan.01	0.04±0.03	2.07±0.51	0.66±0.26	2.77±0.61
Feb.01	0.07±0.06	2.44±0.51	0.61±0.42	3.12±0.75
Mar.01	0.29±0.1	6.15±0.98	4.28±0.87	10.72±1.14

presented in Table 1 as mean ± SEM (n=5). The average monthly worm density during the study period was 2292 m^{-2}. The worm density was maximum (7600 ± 108.97 m^{-2}) in August 2000 whereas, a minimum of 75 ± 30.62 m^{-2} was observed in June 2000. The total worms density was constituted by 5.29 – 39.47% of juveniles, 48.16 – 100% of immature and 10.05 – 31.25% of adults during October 1999 to March 2001 (Table 1).

Table 3: The total biomass, secondary production and biomass turnover value of *O. occidentalis*

Months	Total biomass (g dry weight m^{-2})	Sec. production ΔB	E
Oct. 1999	19.26 ± 1.86	-	-
Nov. 1999	6.02 ± 0.69	-	13.24
Dec. 1999	2.36 ± 0.40	-	3.66
Jan. 2000	3.07 ± 0.52	0.71	-
Feb. 2000	3.34 ± 1.02	0.27	-
Mar. 2000	10.99 ± 0.66	7.65	-
Apr. 2000	7.23 ± 0.84	-	3.76
May 2000	2.84 ±0.64	-	4.39
Jun. 2000	0.57 ±0.33	-	2.27
Jul. 2000	21.42 ± 0.96	20.85	-
Aug. 2000	28.69 ±1.08	7.27	-
Sep. 2000	30.01 ± 3.15	1.32	-

Total biomass (g dry wt. m^{-2}) and biomass of different age groups of *O.occidentalis* has been shown in Table 2. The total biomass ranged between 0.57 ± 0.33 to 30.01 ± 3.15 g dry wt. m^{-2} with a monthly average of 10.09. The total worm biomass consisted of 0.69 – 9.10% by juveniles, 57.37 - 100% by immatures and 7.33 - 39.92% by mature worms (Table 2).

Table 5: Energetic utilization of earthworm's components of *Ocnerodrilus occidentalis*

S. No.	Parameter	Amount
1.	Biomass(i) Average biomass (B)	11.32 g dry wt. m^{-2}
2.	Secondary production Annual secondary production	302.10 Kcal m^{-2}yr^{-1}
(a)	Tissue production (TP)	38.07 g dry wt. m^{-}
(b)	Tissue lost due to production (P)	^{2}27.32 g dry wt. m^{-2}
3.	Annual respiratory metabolism (R)	900.04 Kcal m^{-2}yr^{-1}
4.	Annual excretory metabolism (AU)	52.77 Kcal m^{-2}yr^{-1}
5.	Annual assimilation (A) =(SP+R)	1202.14 Kcal m^{-2}yr^{-1}
6.	Energy utilization (EU)	
(i)	Annual energy utilization	1254.91 Kcal m^{-2} yr^{-1}
(ii)	Percentage contribution to energy utilization	24.07 %
	(a) Secondary production	71.72 %
	(b) Respiration	4.21%
	(c) Excretion	
7.	Biomass turnover (P/B)	5.77 times yr^{-1}
8.	Production efficiency or tissue growth efficiency (SP/A x 100)	25.13 %

Table 4: Total oxygen consumption, Ammonia and Urea excretion of *O. occidentalis*

Months	Earthworm Biomass g dry wt m^{-2}	Oxygen consumption g m^{-2}	Ammonia excretion g m^{-2}	Urea excretion g m^{-2}
Oct. 99	19.26±1.86	37.66±1.32	0.945±0.189	1.572±0.387
Nov. 99	6.02±0.69	10.60±0.53	0.226±0.010	0.469±0.201
Dec. 99	2.36±0.40	4.61±0.51	0.071±0.031	0.172±0.051
Jan. 00	3.07±0.52	6.33±0.66	0.110±0.042	0.191±0.063
Feb. 00	3.34±1.02	5.73±0.31	0.096±0.022	0.236±0.091
Mar. 00	10.99±0.66	20.44±1.04	0.370±0.096	0.837±0.076
Apr. 00	7.23±0.84	15.16±0.97	0.155±0.076	0.675±0.032
May 00	2.84±0.64	5.60±0.55	0.057±0.023	0.248±0.041
Jun. 00	0.57±0.33	1.14±0.31	0.017±0.009	0.066±0.013
Jul. 00	21.42±0.96	48.41±1.81	0.843±0.221	1.859±0.325
Aug. 00	28.69±1.08	53.54±2.74	1.309±0.342	2.274±0.576
Sep. 00	30.01±3.15	58.64±2.25	1.651±0.289	3.033±0.431
Total	135.8	267.50	5.85	11.632

Table 6: Population density (No m^{-2}) and biomass (g fresh weight m^{-2}) of earthworms in various world agro ecosystems

Habitat	Location	Extraction Method	Population density	Biomass	References
Savana					
Tropical Savannas	Ivory Coast	H & WS	230	49	Lavelle (1974)
Low laying wet Savana	Lamto (Ivory coast), Africa	H	180-340	39.57	Lavelle (1977)
Shrub Savana	Lamto (Ivory coast), Africa	H	400	-	Lavelle (1978)
Organic waste deposit sites					
Pasture receiving Kitchen waste	Jyoti Vihar, Orissa, India	H & WS	0 - 8038	0-66.2	Sahu *et al.,* (1986)
Dung deposit site	Sambalpur, Orissa, India	H & WS	0-12617	0-51.4	Sahu *et al.,* (1988)
Straw thatched roof drain site	Ladukhai, Orissa, India	H	800	-	Julka *et al.,* (1987)
Garbage Site	Ranchi, Jharkhand, India	H	375-10050	58.25 – 1647.08	Sinha *et al.,* (2001)
Grasslands					
Sown Pasture	New Zealand	H	208 – 775	60-241	Sears *et al.,* (1953)
			740– 1235	146-303	Waters (1955)
			690-2020	305 (Mean)	McColl *et al.,* (1978)
Old Pasture	Wales	H	646	149	Reynoldson (1966)
Pasture (lowland protected)	Berhampur, Orissa, India	H	64-800	6-60	Dash *et al.,* (1977)
Cropland agroecosystem	Ranchi, Jharkhand, India	H	75-7600	0.57-3.15*	Present study

H = Hand sorting, WS = Wet sieving *Dry weight

The net increase in earthworm tissue over one year was 38.07 g dry wt. m^{-2} and the elimination figured to be 27.32 g dry wt. m^{-2}. The total production amounted to 65.39 g dry wt. m^{-2} yr^{-1}.The calorific value of secondary production was 302.10 kcal m^{-2} yr^{-1}. Population biomass turnover value was 5.77 times yr^{-1} (Table3).

As shown in table 4 the total earthworm biomass (135.8 g dry wt. m^{-2} yr^{-1}) consumed 267.5 g oxygen m^{-2} yr^{-1} which was equivalent to 900.04 Kcal m^{-2} yr^{-1}. Ammonia and Urea excretion by *O.occidentalis* have been presented in Table 4. By calorific conversion, it has been estimated that about 23.69 Kcal m^{-2} yr^{-1} and 29.08 Kcal m^{-2} yr^{-1} were utilized for urea and ammonia excretion respectively. The total value for excretory loss came to be 52.77 Kcal m^{-2} yr^{-1}.

The assimilation value has been calculated to be 1202.14 Kcal m^{-2} yr^{-1}, which includes secondary production, respiratory and excretory energy. The total earthworm energy utilization was 1254.91 Kcal m^{-2} yr^{-1}. The tissue growth efficiency was 25.13% (Table 5).

DISCUSSION

Population size of earthworms varies greatly and maximum density generally occurs in base rich grassland and minimum in acid soil (Petersen, 1982). The earthworm densities in different world sites, largely depends on types of sampling methods, climate and soil types. The *O. occidentalis* population in the present study was very high (7600 ± 108.97 m^{-2}) in comparison to the previously reported values (Table 6). Presence of high population density may be attributed to the rainfall that occurred throughout the period of investigation with fairly moderate temperature range.

Information on the structure of earthworm population is very few. In the present investigation, the juveniles and immatures occupied a large proportion of earthworm population throughout the year, which is in conformity with the earlier reports (Evans *et al.,* 1948; Satchell, 1967; Lavelle, 1978; Dash *et al.,* 1977; Mishra *et al.,* 1984).

The biomass of *O. occidentalis* here is comparable with previous findings (Sears *et al.,* 1953; Reynoldson, 1966) for pasture ecosystem .The values are more than those for tropical pastures (Dash *et al.,* 1977). One of the reasons for high biomass during the present study is the presence of higher population density throughout the study period.

Secondary production values of very few species of earthworm have been reported from different agro-ecosystem of the world (Lakhani *et al.,* 1970; Satchell, 1971; Nowak, 1975; Dash *et al.,* 1977; Senapati *et al.,* 1981; Sahu *et al.,* 1986). The earthworm production in terms of kcal m^{-2} yr^{-1} obtained in the present investigation (302.10) is much higher than the previous reports. The higher values of production for tropical agro-ecosystem of the present study and previous studies indicate that earthworms of the tropical climate are more productive in comparison to those of the temperate climate.

Biomass turnover values of earthworms are not available for many world sites (Petersen, 1982). The biomass turnover value in the present investigation was 5.77 times yr^{-1} which lies in the range of 1.2 to 7 times yr^{-1} (Lavelle, 1974; Dash *et al.,* 1977; Senapati *et al.,* 1981) for tropical agro-ecosystem. In temperate agro-ecosystems, however, the turnover values range from 0.5 - 1.3 times yr^{-1} (Lakhani *et* *al.,* 1970; Nowak, 1975). The higher turnover values obtained for the study area at Ranchi indicate rapid replacement in tropical in comparison to temperate habitats.

Earthworm respiration is affected by temperature, body size, diurnal rhythms, activity and the soil characteristics (Phillipson *et al.,* 1976). Smaller species with a greater surface area for gaseous diffusion respire more in terms of oxygen uptake per g body tissue. Earthworms in tropical areas respire faster than those in temperate regions because of high temperature. In the present investigation the respiratory energy loss of 900.04 Kcal m^{-2} yr^{-1} was found to be much more than earlier reported (Satchell, 1971; Mishra *et al.,* 1984; Mishra *et al.,* 1997).

The excretory products in earthworms include mucus-protein which can account for about half of the total nitrogen lost each day and the end products of metabolism i.e. a fluid urine comprising a mixture of ammonia, urea and free amino acids (Laverack, 1963; Edwards *et al.,* 1972). In the present study the mucus-protein content and amino acid content could not be evaluated and thus the excretory energy loss and energy utilization values for *O. occidentalis* is expected to be much more than evaluated. The reported excretory loss of 52.77 Kcal m^{-2} yr^{-1} is much more than previous report from Indian grassland (Mishra *et al.,* 1997) who reported the loss to be 2.42 Kcal m^{-2} yr^{-1} for *Lampito mauritii* population.

The production efficiency (Standen, 1973) is similar to tissue growth efficiency (Odum, 1959). The production efficiency in the present study was 25.13%. A production efficiency of 34% for oligochaete population in temperate climate has been reported (Satchell, 1967). In tropical grassland a production efficiency of 26% and 35% has been recorded in a grazed and ungrazed plot respectively (Senapati *et al.,* 1981). Growth efficiency usually ranges from 14-40% in invertebrates (Hughes, 1970). The growth efficiency appears to be species specific affair influenced by climo edaphic characteristics.

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