The very large amount of organic waste that are produced by intensive animal production cause major disposal problems and a considerable potential for pollution of surface and ground waters. The potential of using earthworms in the digestion of raw organic wastes has been well established, but very little is known about this use of earthworms in India.

Endogenic earthworms are the major components of soil faunal communities in natural ecosystems of the humid tropics. Incubation of soil with the endogenic earthworm species Millsonia anomala, Pontoscolex corenthurus have resulted in increased plant growth as compared to non-inoculated soils. The endogenic earthworm species Amynthas morrisi was chosen for the experiment because it was one of the most dominant earthworm species recorded in the cultivated soils at Kainchi in Kumaun Himalaya. This species is considered as a potential waste decomposer, but before it can be used in this way, data are required on: (1) growth and maturation rates of A. morrisi, (2) quantitative production of cocoons, (3) hatching success and the incubation time of cocoons in different substrates. These parameters have been studied for A. morrisi, in field soil and cow manure as the two substrates.

MATERIAL AND METHODS

Adults of A. morrisi, were collected from a cultivated land at Kainchi (29° 42' N and 79°51'E; altitude 1400m) about 17 km from Nainital and cultured in glass columns in the laboratory at 20-25°C. The worms were kept in soil with a moisture content of 25-30%. The soil used in the experiment was brought from the study site and water content was maintained at a uniform level by regular watering. The worms were fed with 5 g dry weight of cow manure every 15 days.

The cocoons were hatched separately in pots (15 cm diameter 20 cm deep) using cow manure without urine or straw, and field soil. The nutritive medium was prepared by air-drying, grinding and then sieving through a 2 mm sieve.

For the growth study newly hatched hatchlings were selected. The hatchlings were weighed individually after they had been rinsed in distilled water and gently dried on filter paper. Thirty hatchlings were placed in pots (100 cm² in surface area 15 cm deep) singly or in pairs of five (five groups of each) in the two substrate and covered with plastic mesh (1mm). 1 g dry wt. cow manure to the worms kept singly and 2 g dry wt. to the worms kept in pairs was added to each container on a regular basis. This was repeated every 15 days for 180 days to avoid any nutritional deficiency. The worms were weighed (with full guts) every 15 days.

At each weighing, the worms were examined to determine the extent of maturation as indicated by clitellum development. In order to determine the onset of cocoon production, the substrates were examined every day under a magnifying lens as soon as the clitellate worms were observed.

The cocoons were counted and weighed. Before weighing, the cocoons were washed lightly in distilled water and most of the debris and organic particles adhering to the sticky hull were removed with a fine brush. 20 cocoons were randomly
divided into two batches and incubated in petri dishes. Two media were used for incubation, fields soil and wet cotton with a moisture content of 25-30% at 20-25°C. The cocoons were observed every 24 h; hatchlings were removed daily, weighed and preserved in 10% ethanol.

The hatchlings success of the cocoons in the two media and over in the incubation periods was determined together with the number and weight of hatchlings per cocoon. The significance of difference between mean growth rates per worm in the substrates was estimated using regression coefficient.

**RESULTS AND DISCUSSION**

Growth rate and maturation: in field soil, the growth rate was slow in the first 30 days, 1.2 mg day$^{-1}$ for single worms and 0.73 mg day$^{-1}$ for worms kept in pairs, increasing to 3.0 mg day$^{-1}$ for single worms and 2.9 mg day$^{-1}$ for worms in pairs after 90 days. The mean growth rate per worm (Fresh weight) was 3.9 mg day$^{-1}$, and worms reached a mean weight of 770.4±6.9 mg when kept singly and 3.7 mg day$^{-1}$ reaching a mean weight of 716.2±1.5 mg kept in pairs after 180 days (Fig.-1a).

In cow manure, the growth rate during the first month was 1.3 mg day$^{-1}$ for single worms and 0.46 mg day$^{-1}$ for worms kept in pairs and increased to 2.9 mg day$^{-1}$ for single worms and 2.98 mg day$^{-1}$ for worms in pairs after 90 days. The mean growth rate was 7.74 mg day$^{-1}$, and worms reached a mean weight of 1482.8±28.5 mg singly and 5.92 mg day$^{-1}$ reaching a mean weight of 1095.0±7.9 mg when kept in pairs after 180 days (Fig.-1b). The worms showed decline in weight after attaining maximum biomass and finally died.

The first indication of clitellum development appeared on 50th day after hatching both in single and in pairs in soil and 100% worms being clitellate by the 59th day (Table-1). In cow manure clitellum development was observed on 48th day in single worms and on 46th day in paired worms and 100% worms being clitellate between 55-63 days. Significant correlations were observed between age of worms and percentage of clitellate worms ($r = 0.98; P < 0.01$ raised singly and $r = 0.967; P < 0.01$ raised in pairs) in field soil; and ($r = 0.992; P < 0.01$ raised single and $r = 0.962; P < 0.01$ raised in pairs) in cow manure (Table-2).

Our results indicate that cow manure supports faster earthworm growth than field soil. The study also showed that when *A. morrisi* was raised in pairs, it grew more slowly and reached a lower final body weight. Our study agrees with the result of *Eisenia andreii* and *Octolasion tyrtaeum* which had slower growth rates when grown under crowded condition. Growth rates in the present study are lower compared to other species: 8.02 mg worm$^{-1}$ day$^{-1}$ for *Lumbricus rubellus* fed on cow manure$^{15}$; 14.1 mg worm$^{-1}$ day$^{-1}$ fed on horse manure and 21.3 mg worm$^{-1}$ day$^{-1}$ fed on paper sludge for *Dendrobaena vendetta*; 9.0 to 18 mg worm$^{-1}$ day$^{-1}$ fed on cattle manure for *Apporectodea longa* and *Lumbricus terrestris*; 13.36 to 21.4 mg worm$^{-1}$ day$^{-1}$ fed on different food substrates for *Pontoscolex corethrurus*.$^{20}$

Maturation rate of *A. morrisi* recorded in the present study (48 to 59 days) fall in the range of reported studies$^{17, 18, 21}$.

**Cocoon production:** Mating does not seem to be prerequisite for cocoon production in *A. morrisi* as worms kept singly in the two food substrates produced cocoons which hatched successfully. The cocoons of *A. morrisi* have an oval shape. There are two sticky fibrous spines at both ends of the cocoon to which organic particles can adhere. The cocoons are soft and brown in colour directly after their formation harden rapidly.

The hatchlings emerge through a round aperture usually at the broader end of the cocoons. The hatchlings retreat back into their cocoons when disturbed at the time of emergence. The mean length of the cocoons was 3.43±0.1 mm (ranges 2.4-4.0 mm; n= 30) and the diameter 2.48±0.88 mm (range 1.6-3.5 mm; n= 30). *A. morrisi* started cocoon production after 60 days and continued till 180 days in both substrates. The cocoon production ranged from 0.34 to 0.67 cocoons worm$^{-1}$ day$^{-1}$ in two substrates.

The number of cocoons produced is uncorrelated with the mass of the parent adult ($r = 0.282; P<<0.05; n=9$ raised single) but positively correlated ($r = 0.959; P<0.01; n=9$ raised in pairs) in field soil (Fig.-2a); ($r = 0.759; P<0.05; n=9$ in single and $r=0.822; P<0.01; n=9$ raised in pairs) in cow manure (Fig.-2b).

Worm biomass is positively correlated with cocoon mass: ($r=0.605; P<0.05; n=9$ raised single) and: ($r=0.572; P<0.05; n=9$ raised in pairs) in field soil (Fig.-3a); and ($r =0.901; P<0.01; n=9$ raised single) and ($r=0.676; P<0.05; n=9$ raised in pairs).
GROWTH AND REPRODUCTION OF THE EARTHWORM AMYNTHAS MORRISI

Fig.-1a. Growth rate of *Amynthas morrisi* raised singly and in pairs in field soil

Fig.-1b. Growth rate of *Amynthas morrisi* raised singly and in pairs in cow manure

Fig.-2a. Relationship between worm biomass and number of cocoons produced by *Amynthas morrisi* raised single and in pairs in field soil
Fig.-2b. Relationship between worm biomass and number of cocoons produced by *Amynthas morrisi* raised single and in pairs in cow manure

![Graph showing the relationship between worm biomass and number of cocoons produced by *Amynthas morrisi* raised single and in pairs in cow manure.](image)

Singly (r=0.759; P<0.05)  In pairs (r=0.822; P<0.01)

Fig.-3a. Relationship between worm biomass and mass of cocoons produced by *Amynthas morrisi* raised singly and in pairs in field soil

![Graph showing the relationship between worm biomass and mass of cocoons produced by *Amynthas morrisi* raised singly and in pairs in field soil.](image)

Singly (r=0.605; P<0.05)  In pairs (r=0.572; P<0.05)

Fig.-3b. Relationship between worm biomass and mass of cocoons produced by *Amynthas morrisi* raised singly and in pairs in cow manure

![Graph showing the relationship between worm biomass and mass of cocoons produced by *Amynthas morrisi* raised singly and in pairs in cow manure.](image)

Singly (r=0.901; P<0.01)  In pairs (r=0.676; P<0.05)
GROWTH AND REPRODUCTION OF THE EARTHWORM AMYNTHAS MORRISI

Fig.-4a. Relationship between mass of cocoons and mass of hatchlings of Amynthas morrisi raised singly and in pairs in field soil

Fig.-4b. Relationship between mass of cocoons and mass of hatchlings of Amynthas morrisi raised singly and in pairs in cow manure

Cocoon mass and the mass of hatchlings was positively correlated (r=0.972; P<0.01; n=9 raised single) and (r=0.988; P<0.01; n=9 raised in pairs) in field soil (Fig.-4a); and (r=0.952; P<0.01; n=9 raised single) and (r=0.972; P<0.01; n=9 raised in pairs) in cow manure (Fig.-4b).

Cocoon production rate of A. morrisi recorded in the present study (0.34 to 0.67 cocoons worm$^{-1}$ day$^{-1}$) are much lower than those reported for other earthworm species$^{17, 18, 22}$ but higher than for Pontoscolex corethrurus$^{20}$; Metaphire posthuma$^{23}$; and Apporectodea trapezoides$^{24}$.

Hatching success of cocoons and fecundity: The hatching success was 100% in field soil and moist cotton. The incubation period of cocoons hatched in field soil was 26.0±0.81 days and 27.0±0.7 days in moist cotton. In the present study with 20 cocoons of A. morrisi a mean of 1.45±0.17 hatchlings emerged per cocoon which is very similar to other reports of 1 to 1.21 hatchling for Pontoscolex corethrurus$^{20}$; 1-4 hatchling...
Table 1. Maturation (clitellum development) of *Amynthas morrisi* reared in laboratory in field soil.

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<th>Age of worms (days)</th>
<th>Clitellate worms</th>
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<td>Singly (n=5)</td>
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Correlation between age of worms (days) and % maturation

\[ r = 0.980; \quad P < 0.01; \quad n = 9 \]

\[ r = 0.967; \quad P < 0.01; \quad n = 10 \]

Table 2. Maturation (clitellum development) of *Amynthas morrisi* reared in laboratory in cow manure.

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Correlation between age of worms (days) and % maturation

\[ (r = 0.992 \quad P < 0.01; \quad n = 8) \]

\[ (r = 0.962 \quad P < 0.01; \quad n = 10) \]

It can be calculated that *A. morrisi* could be of a great advantage under certain conditions as it could produce without mating and a higher growth rate when reared in cow manure.

REFERENCES

29: 394.


