Chapter 4

DISCUSSION
Earthworms population fluctuation reality to depth the observations recorded from January to December of the years 2007-2008 and 2008-2009 showed that during active season (July to Sept.) the majority of earthworms stayed between 10.2 to 21.5 cm depth (Table 2 and 3). In the months of Oct., Nov, and December majority of the animals rested at depths between 28.6 to 57.7 cm. In January they moved down to depths of 77.5 to 85.7 cm. The population of earthworms recorded in the area of sampling was 320000 earthworms per hectare during July 2007 and 300000 earthworms per hectare during July 2008. The population started declining after August every year till the end of January of the next year (Table 3). During the inactive season, the earthworms showed downward movement. The movement appeared to be an attempt on the part of animals to stay in the soil zone having optimum moisture and temperature conducive to their species. Observations of the present study demonstrates that all species of earthworms occurred in semi arid region were widely dispersed which might depend on organic matter content or C/N ratio of the soils. Kale and Krishnamoorthy (1981) reported that the density of earthworms is dependent on carbon and nitrogen content and also on the humic and fulvic acid content of soils. Similar observation has been made by Satchell (1967), Ruz Jerez et al (1988) and Nainawat (1997). Quality, quantity and placement of organic matter is a main determinant of earthworm abundance and activity in agricultural soils (Edwards, 1983 and Lofs-Holmin, 1983) as are disturbances of the soil.
by tillage, cultivation and the use of pesticides (Doran and Werner, 1990).

Werner (1994) indicated that tillage disrupts earthworm populations and in general, the greater the intensity and frequency of soil disturbance, the lower the numbers of biomass of earthworms. Cultivation lowers soil organic matter levels, destroys soil horizonation, removes the cover of vegetation, kills earthworms, and causes soil to dry more rapidly. Earthworm populations are usually much less abundant in cropped fields relative to pasture or undisturbed lands. Similar observations were made by Haukka (1988), Mackay and Kladivko (1985), Dash and Patra, 1977, Edwards (1980), Gerard and Hay (1979) and Barnes and Ellis (1979). Zicsi (1969) observed that earthworms are dependent on moderate soil moisture content, and cultivation tends to have a negative effect on earthworms by decreasing soil moisture. Earthworm population is usually significantly depressed in cropped fields in relation to pastures or undisturbed lands. Lumbricids in a South African soil were decreased by cultivation to about one-third of original levels (Reinecke and Visser, 1980). Soil compaction caused by agricultural traffic can also decrease earthworm populations (Bostrom, 1986).

A study in Denmark found that 200 T/ha of manure was optimal for increased earthworm abundance and biomass (Andersen, 1980). The Rothamsted experiment station plots in England which
received manure for 118 years also had increased earthworm abundance, and inorganic fertilizers in this case caused decreases in earthworm population (Edwards and Lofty, 1974). Heavy applications of inorganic fertilizers may cause immediate reductions in earthworm abundance (Edwards, 1983).

Werner and Danial (1990) reported that organic mulches enhance earthworm habitat by moderating microclimate and supplying a food source. In corn plots in Pennsylvania, earthworms were most abundant in the fall in treatments that were not ploughed before winter and where corn residues had been chopped and left as a mulch, regardless of whether the plots were organically or conventionally managed. Kumawat (1996) also opines that during inactive season the earthworms showed the downwards movement. This movement appeared to be an attempt on the part of earthworms to stay in the soil zone having optimum moisture and temperature conditions.

**Effect of different soils and their combinations on the biomass of earthworms**

As earthworms tunnel through the soil, they ingest the soil and digest any organic matter in it. Organic matter is dragged in to their burrows and is broken down. Although they are the most numerous in the top 6 inches, they also work in the sub soil, bringing mineral rich soil from below to the surface. This adds to the supply of nutrients
available to the plants. Each day they produce nitrogen, phosphorus, potassium and many micronutrients in a form that all plants can use. Not only do they produce this fertilizer but spread it thoroughly within the top 12 inches of soil. They may also incorporate it as far down as 6 ft. A soil that is well managed, rich in humus may easily support 25 worms per cubic ft., which translates into at least 175 lbs. of fertilizer per year for the same 200 sq ft garden.

Bouche (1977) classified earthworm species into three morpho-ecological groupings. Epigeic species live in organic horizons and ingest large amounts of undecomposed litter. These species produce ephemeral burrows in to the mineral soil for diapause periods only. They are relatively exposed to climatic fluctuations and predator pressures, and tend to be small with rapid generation times. Endogeic species forage below the surface, ingest large quantities of soil with a preference towards organic rich soil, and build continuously ramifying burrows that are mostly horizontal. These species are apparently not of major importance in litter incorporation and decomposition since they feed on subsurface material. The anecics build vertical burrows that penetrate the soil deeply. These species are detrivores and come to the surface to feed on partially decomposed litter, manure and other organic matter. Anecics have profound effects on organic matter decomposition, nutrient cycling and soil formation.
A study in Denmark found that 200 T/ha of manure was optimal for increased earthworm abundance and biomass (Andersen, 1980). *L. terrestris, A. longa* and *A. caliginosa* were increased by manure, while *A. rosea* and *A. chlorotica* were not influenced. The Rothamsted experiment station plots in England which received manure for 118 years also had increased earthworm abundance, and inorganic fertilizers in this case caused decrease in earthworm populations (Edwards and Lofty, 1974). Heavy applications of inorganic fertilizers may cause immediate reductions in earthworm abundance (Edwards, 1983).

Kale and Krishnamoorthy (1981) observed that the density of earthworms is dependent on carbon and nitrogen content and also on humic and fulvic acid content of soils. Nainawat (1997) observed that all the species recorded from study area are widely dispersed with respect to carbon and nitrogen content of the soil. Kumawat (1996) reported that earthworms prefer clay + FYM (1:1) combination followed by sand + clay + FYM (1:1:1) and well rotten FYM for their rapid growth and development. Soils having good organic matter, humus and moisture favour rapid growth of the earthworms.

**Effect of the soil of different pH levels on the biomass of earthworms**

Earthworms add calcium carbonate, a compound that helps moderate soil pH. Another effect on the environment is that the casts
are always more neutral (close to pH 7) then the surrounding soil. This helps neutralize the acids or alkali that may be present in the soil thereby optimizing the pH for the root development of majority of cultivated plants. Slocum (1999) observed that the earthworm, *Eisenia foetida* is the best suited for general vermicomposting. It tolerates the widest range of temperatures, moisture and pH levels of the epigeic species, tolerates handling well and remediates a wide range of organic materials. It will tolerate an environment with between pH 2 and 9, and prefers pH 5.0-5.7.

Hamblen (1995) stated that redworms have a role when the pH becomes acidic and bacteria slow down their activity. It is found that redworms grow fastest and eat fastest when the pH is around 5. redworms consume the acidic food and produce alkaline excretions, thus shifting the pH to neutral, which is more suitable for bacteria. Walter (1996) analysed earthworm castings, or earthworm manure, shows that the soil that comes out of the back end of an earthworm is closer to a neutral pH (7) than what goes in the front end, regardless of whether the existing soil is above or below pH 7. This is achieved by the action of the worm's calciferous gland and the buffering action of carbonic acid.

Stewart *et al.* (1988) reported that abundant earthworm activity is observed in soil pH of between 5.5 and 7.5, organic matter content between 4 and 12%. Acharya (1999) reported that highly acidic
(having pH below 3.5) and alkaline (having pH above 9.2) soils show adverse effect on the growth and development of worms. The pH range of 5 to 7.4 is much suited for the rapid growth of worms.

**Mass rearing of earthworms or vermicomposting technology**

The emphasis upon breeding or raising quantities of earthworms for re-sale is called vermiculture (vermin comes Latin and means “worm”). For many years vermiculture has been practiced to produce baitworms for fishermen, but raising composting worms for the purpose of turning garbage into gold has become a relatively recent phenomenon. Since some earthworms multiply incredibly quickly (doubling within a couple months), opportunities to build a growing operation in a relatively short time are possible.

Bhawalkar (1994) described vermiculture as the process of converting our organic waste into valuable fertilizer by treating it with deep burrowing earthworms. This process takes place directly on the soil, not in a bin, there is less material handling and thus ideally it could be conducted on an agricultural soil in conjunction with growing crops. He identified the burrowing earthworms, *Pheretima elongata*, as the most effective organic waste converter. White and Frankel (1994) stated that vermiculture biotechnology or ecotechnology is used for vermicomposting in the field itself in crop fields and orchards for composting farm wastes, crop residues left after the harvesting and uprooted weeds competing with crops in the
fields. In this technology burrowing earthworm, *Pheretima elongata*, was employed being most effective waste converter.

White (1993, 1994 and 1995) described that the burrowing species, *Pheretima elongata*, appropriately called an earthworm, is used productively in India for waste land reclamation as these worms are great cultivators and processors of the soil. They are especially suitable for large scale waste processing and can be used in the treatment of diverse solid and liquid wastes. Her further stated that several experiments in India have proven that vermiculture can contribute significantly to crop yields and quality. In the Pune district grape production increased 50 per cent at a vineyard in which earthworms (*Pheretima elongata*) were introduced. In Maharashtra state the introduction of vermiculure helped to stabilize pH and increase potash content of the soil. In Auroville, South India, wheat production doubled while pasture production quadrupled. In addition, due to savings on input costs, dramatic increase in profit was experienced.

Boggess and Frankel (1997) reported that vermiculture ecotechnology uses soil-based earthworms like night crawlers (burrowing worms), which always remain in their soil environment. Most agricultural soils the world around contain the same European species, *Lumbricus terrestris*, introduced by European settlers. These species are experts at turning decomposing organics in to microbially-
active humus. Acharaya and Sharma (1997) reported that in Indian conditions the earthworm species *Lampito mauritii* and *Pheretima elongata* are the most useful and effective in vermiculture and soil processing.

Acharaya (1999) described that vermiculture is practiced in India for the purpose of decomposition of farm and animal waste. Integrated vermiculture is a system which besides production of high quality compost, by way of symbiosis, combines vegetable production also. Earthworms, in turn, add nutrients to vegetable plants besides better aeration and improved water absorption, integrated vermiculture, thus, enhances profitability of such a venture of compost and vegetable production. Kumawat (1996) conducted extensive survey of the semi-arid region of Rajasthan and found that three earthworm species, *Lampito mauritii*, *Metaphire posthuma* and *Pheretima elongata* are the potential species of this region, actively engaged in soil processing.

**Vermicomposting biotechnology**

Vermicomposting is the process of using earthworms to transform organic matter to compost or humus, a chemically and biologically rich component of healthy soil. Earthworms ingest microorganisms (fungi, protozoa, algae, nematodes, bacteria), organic matter and excrete their casts or castings that contain a wealth of soil nutrients. Large vermicomposting operations around the world use
certain species of earthworms to convert tons of organic waste into vermicompost (another term for earthworm castings), and sell this valuable product to nurseries, garden centers, landscapers, organic farmers, green house growers, and others interested in growing healthy, nutritious, and disease resistant plants. Analysis of earthworm castings reveals that they are richer in plant nutrients than the soil, about three times more calcium and several times more nitrogen, phosphorus and potassium. Slocum (1999) reported that the earthworm, *Eisenia foetida* is found to be the best suited for general vermicomposting. It tolerates the widest range of temperature, moisture and pH levels of the epigeic species, tolerates handling well and remedies a wide range of organic materials.

Shweta *et al*, (2001) tested the efficiency of red worms, *Eisenia foetida* and reported that the vermicompost from different sources of organic wastes took variable periods of time and the nutrient contents also showed variation. Parker (1995) conducted experiment to study the effect of vermicompost and top soil on the growth of plants. He concluded that vermicompost is the better choice for growing plants. Ismail (1997) reported that vermiwash is sprayed on plants as a nutrient foliar spray. It has proved very effective on vegetable plants like okra, tomato, beans, eggplant, lawans, golf courses and orchids. Bhawalkar (1994) described that vermicompost is a mixture of worm castings high in beneficial bacteria that also contains cocoons which will hatch more earthworms. He further stated that it is a rich
substance that can be used to bring less productive soils to a high level of potential productivity. When this mixture applied to the soil, increases earthworm and bacteria populations which, in turn, increases the ability to the soil to assimilate organic material. Singh and Rai (1997) reported that African giantworm, *Eudrilus eugeniae* and redworm, *Eisenia foetida* are very efficient in vermicomposting.

Sauvage (1994) described that vermicompost contains high levels of trace elements to support plant growth and provides a better aggregate structure and water-holding capacity than regular compost. Acharya (1999) analysed vermicompost produced by, redworm, *Eisenia foetida* and found that nutrient content of vermicompost is 2.5 percent N$_2$, 2.9 percent P$_2$O$_5$ and 1.4 percent K$_2$O in contrast to locally produced FYM with 0.5 percent N$_2$, 0.25 percent P$_2$O$_5$ and 0.5 percent K$_2$O. Barley (1961) analysed the earthworm castings and reported that they are richer in plant nutrients than the soil, having about three times more calcium and several times more nitrogen, phosphorus and potassium. Inamdar (1997) analysed the N: P: K of the original soil sample, a soil sample from the bottom of the vermipits after 3 months and the vermicompost produced in the pits. She reported that N: P: K content of these samples to be as follows—

<table>
<thead>
<tr>
<th>Samples taken</th>
<th>N%</th>
<th>P%</th>
<th>K%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic soil</td>
<td>0.40</td>
<td>0.26</td>
<td>0.003</td>
</tr>
<tr>
<td>Soil sample from the bottom of vermicompost</td>
<td>0.13</td>
<td>0.32</td>
<td>0.19</td>
</tr>
<tr>
<td>Vermicompost</td>
<td>1.40</td>
<td>0.67</td>
<td>0.37</td>
</tr>
</tbody>
</table>