# Review of literature

# 2.0 REVIEW OF LITERATURE

The review of literature pertaining to the study, "**A comparative study of the effect of biofertilizer, vermicompost and chemical fertilizer on the growth and yield of green chilli (Gundu variety)**" has been discussed under the following headings.

2.8 Chilli

2.8.1 Gundu type

## 2.1 Introduction

India is an agriculture and agro based industry dependent country (Reddy *et al.*, 2007). In the earlier years agriculture was practiced in a very simple way on natural resource and using less energy. However, modern agriculture took a new turn. No doubt, thus farm imparts resulted in an increase in crop-productivity many fold, at the same time removed the adverse effects on the environment and soil health. It is the need of the day to save our environment from pollution and sustaining crop production (Maurya *et al.*, 2006). Also, in order to feed the ever growing population, India has to increase the area of crop productivity (Chandra and Greep, 2005).

There is no doubt that, 'green revolution' during late 1960's in India, brought about a spectacular increase in agricultural production. In fact, during the era of 'green revolution' introduction of high yielding varieties of crops, extension of irrigated area and enhancing of cropping intensity increased the use of chemical fertilizers and pesticides in India and in turn, made the country self sufficient in food production (Prabhakara *et al.*, 2008).

## 2.2 Detoriation of soils

Soil although appears static and inert is in fact dynamic and versatile in nature beaming with biological activities and chemical reactions that goes on continuously unabated (Ramalakshmi *et al.*, 2008). The life can't be sustained if soil is exploited and used the way it is being inadequately cared. The four 'P's (i.e., population, poverty, pollution and production more than potential) are the main cause for bad soil health (Singh and De, 2007).

Going on withdrawing the fertility of soil by growing crop after crop without doing anything to rebuild it, the soil will become barren (Singhvi *et al.*, 2006). Continuous use of inorganic fertilizers and pesticides in large quantities and neglecting organics, biofertilizers and biocontrol of pests paved the way for detoriation of soil health and in turn ill effects on plants, human beings and animal's (Prabhakara *et al.*, 2008).

### 2.3 Impact of pesticides

Conventional farming demands excessive use of chemicals in the form of synthetic fertilizers and pesticides, confirming to the norms of green revolution. Farmers in general, specifically in developing countries resort to injudicious and excessive use of pesticides which is linked to the illiteracy and poverty of the rural farming community (Rathinam *et al.*, 2005).

Some chemical fertilizers in use contain toxic components such as heavy metals, inorganic and organic pollutants, and thus a long term application of these chemical fertilizers can possibly induce the accumulation of these components in soil, resulting in the worsening of soil ecological environment and making the heavy metals, nitrate and other harmful components in agricultural products including vegetables, grains and fruits seriously surpassed the standards (Li and Wu, 2008).

Pesticide toxicity in humans is responsible for acute poisonings as well as for long term health effects, including cancer and adverse effects on reproduction (Maroni *et al.*, 2006). Some organo chlorine pesticides suppress nitrogen-fixing bacteria from replenishing natural nitrogen fertilizer in soil, resulting in lower crop yields, stunted growth and an ever greater need for additives to boost production. This previously unrecognized effect stems from pesticides interfering with flavonoid signaling from leguminous plants such as alfalfa, peas and soybeans to soil bacteria that fix nitrogen (Dooley, 2007). The use of chemical fertilizers has been doubled during the last two decades (Kramany *et al.*, 2007).

### 2.4 Organic farming

Recently organic farming is practiced for sustainable agriculture production systems (Velmurugan *et al.*, 2007). Importance of organics is increasingly felt these days in sustainable crop production systems (Ganajaxi and Math, 2008). The goal of sustainable agriculture should be to maintain production at level necessary to meet the demands of the burgeoning population without degrading the environment (Yadav *et al.*, 2007).

For sustainable agriculture, it is imperative to utilize renewable inputs, which can maximize the ecological benefits and minimize the environmental hazards (Kumar and Singh, 2008).

Continuous use of chemical fertilizers, improved varieties cause several hazards to soil health by heavy with drawl of nutrients, nutrient imbalance and ultimately resulting in the reduction of crop yield (Thanunathan, *et al.*, 2002).

As an alternate, this organic farming accentuates shift from high volume production system to high value production system. For achieving this, management practices that conserve soil health, efficient nutrient supply systems that rely on organics instead of chemicals and integrated pest management play vital role (Kalidasu *et al.*, 2008).

Organic manures not only increase the yield but also improve physical, chemical and biological properties of soil which in turn improve fertility, productivity and water holding capacity of soil. Nowadays many commercial organizations have brought some readymade organic fertilizers into the market. These are enriched with bio-inoculants and micronutrients (Kalalbandi *et al.*, 2007).

### 2.4.1 Key characteristics of organic farming

- Protecting the long term fertility of soil by maintaining organic matter levels, fostering soil biological activity and careful mechanical intervention.
- Providing crop nutrients indirectly by using relatively insoluble nutrient sources which are made available to the plant by the action of soil microorganisms.

- Nitrogen self-sufficiency through the use of legumes and biological nitrogen fixation, as well as effective recycling of organic materials including crop residues and livestock wastes.
- Weed, disease and pest control relying primarily on crop rotations, natural predators, diversity, organic manuring, resistant varieties and limited thermal, biological and chemical intervention (Prabhakara *et al.*, 2008).

Application of organic and inorganic combination is very effective in realization of high yield and high responses to added nutrients (Sarkar *et al.*, 1997). An integrated approach is considered as the need of the hour. The incorporation of the bulky organic manures such as vermicompost, FYM plays important role in plant nutrition especially nitrogen (Ilhe *et al.*, 2007).

It is also true that high yield of vegetable cannot be realized only with the use of organic and biological origin products. Therefore a judicious combination strategy of using chemical fertilizers, organic manures and biofertilizers may be helpful in increasing vegetable productivity. Such efforts will be effective not only in sustaining productivity and soil health but also in supplementing a part of chemical fertilizers requirement of the crops (Upadhyay *et al.*, 2007).

The combined and/or sole application of organic amendments and biofertilizers increase the yield and also influence quality attributes in several vegetables, besides considerable saving of inorganic fertilizers (Worthington, 2001; Bahadur *et al.*, 2004).

Thus the coincident application of organic manures and biofertilizers is frequently recommended firstly for improving biological, physical and chemical properties of soil and secondary to get high and clean agricultural yield products free from undesirable high doses of heavy metals and other pollutants (Kramany *et al.*, 2007).

### 2.4.2 Changes in soil properties induced by organic matter

Combined application of biofertilizer and organic matter

- Application of soil particles → Soil-porosity → Water and air permeability → Root development activity → Crop quality and growth
- Activites of microbes (Organic matter is the energy and nutrient for microbial activity and growth)
- Ion exchange capacity → Cumulative soil fertility → Buffering capacity and water holding capacity → Growth stimulative substances

(Chandrasekaran *et al.*, 2005).

### 2.5 Biofertilizers

Biofertilizers are commonly called as microbial inoculants which are capable of mobilizing important nutritional elements in the soil from non-usable to usable form by the crop plants through their biological processes. For the last one-decade, biofertilizers are used extensively as an ecofriendly approach to minimize the use of chemical fertilizers, improve soil fertility status and for enhancement of crop production by their biological activity in the rhizospheres (Rao *et al.*, 2007).

They are 100% natural organic nutrients that can be easily applied with water over plantation or at any age. They are the most advanced technology necessary to support developing organic agriculture, sustainable agriculture, green agriculture, and non pollution agriculture. Addition of biofertilizers not only helps to proliferate beneficial microbes in soil but also provide residual effect for subsequent crops and helps in recycling and decomposition of organic matter. They can increase the output, improve the physical, chemical, and biological properties of the soil and is responsible for better agriculture environment. Today, it has been widely used with excellent results in all kinds of crops (Kumar *et al*., 2006).

Need to adopt biofertilizers as a partial substitute to chemical fertilizers is because they result in

- Reduction in level of residues
- Helps in maintaining environmental health by reducing the level of pollution
- Optimum utilization and conservation of natural resources
- Saves fossil fuel energy, otherwise required to fix molecular nitrogen
- Improves the physical and chemical properties of soil
- Increases the agricultural products (Fotadar *et al*., 2008).

Reports are available on the use of biofertilizer in many crop plants in increasing crop yield and nutrient uptake (Yasari *et al*., 2007). Biofertilizers have been reported to be beneficial in augmenting the yield of legumes, and are likely to play a vital role in imposing soil fertility (Wankhde *et al*., 2001). Navala *et al*., (2004) reported a higher uptake of N, P and micronutrients by inoculating *Azospirillum* in onion. Likewise positive effects of inoculation with *Azotobacter* and *Azospirillium* on wheat and mustard (Gupta *et al*., 2006) have already been reported.

Yasari *et al*., (2007) reported that *Penicillum bilaji* increased the vegetative growth, P uptake and grain yield of canola either with or without phosphate fertilizer under phosphorus responsive conditions, most likely by solubilising unavailable soil phosphorus.

### 2.5.1 Benefits of biofertilizers

- Increases crop yield by 20 -30%
- Replaces chemical nitrogen and phosphorus by 25-50%
- Stimulates plant growth
- Activates soil biologically
- Resolves natural fertility, drought and some soil borne diseases.

### 2.5.2 Advantages of biofertilizers

- Cost effective
- Supplement to fertilizers
- Ecofriendly
- Reduces the costs towards fertilizers use, especially regarding nitrogen and phosphorus.

### 2.5.3 Availability of biofertilizers

**For nitrogen**

- ✓ *Rhizobium* for legume crops
- ✓ *Azotobacter* (*Azospirillum* for nonlegume crops)
- ✓ *Acetobacter* for sugarcane only
- ✓ Blue Green Algae (BGA) and *Azolla* for paddy

**For phosphorus**

- ✓ Phosphotika for all crops to be applied with *Rhizobium*, *Azotobacter*, *Azospirillum* and *Acetobacter*.

**For enriched compost**

- ✓ Cellulolytic fungal culture
- ✓ Phosphotika and *Azotobacter* culture (Chandrasekaran *et al.*, 2005).

### 2.5.4 *Azospirillum*

The genus *Azospirillum* was first studied by Dobereiner for nitrogen fixation capacity and occurrence in the rhizosphere, forming different kinds of association with non-leguminous plants. *Azospirillum* species are nitrogen-fixing rhizobacteria with the potential to increase the yield of economically important cereals and grasses in different climatic regions. Members of the genus *Azospirillum* are pleomorphic, gram-negative, aerobic, chemoorganotrophs and under free-living conditions, fix nitrogen at low oxygen tension in a medium devoid of ammonia (Fischer *et al.*, 2003).

The beneficial effects of plant growth are not only nitrogen fixed in the rhizosphere, but are also related to the ability of these bacteria to reduce nitrate, solubilise phosphates, synthesize antibiotics and growth-promoting substances, including phytohormones and siderophores. The positive effects of bacterial inoculation are mainly attributed to improved root development and subsequent increase in the rate of water and mineral uptake (Steenhoudt and Vanderleyden, 2000). Apart from direct agricultural application, *Azospirillum* is an excellent model for plant-associative bacteria in general (Bashan and Holgin, 1997).

#### 2.5.4.1 Effect of *Azospirillum* inoculation on plants

Inoculation of plants with *Azospirillum* can result in a significant change in various plant growth parameters, which may or may not affect crop yield. Plant responses to *Azospirillum* inoculation in cereals and non cereal species were reported; increases in total plant dry weight, in the amount of nitrogen in shoots and grains, and in total number of tillers, fertile tillers and ears, earlier heading and flowering time, increased number of spikes and grains per spike, increased grain weight, greater plant height and leaf size and higher germination rates. In addition, a marked inoculation effect on development of the root system such as on root length and volume has frequently been observed (Bashan and Levanony, 2000).

### 2.5.5 Phosphorus Solubilizing Bacteria

Studies demonstrate that plants play an active role in modifying the soil environment for better uptake of minerals by the plants (Nakamaru *et al.*, 2000; Sas *et al.*, 2001). Roots can induce rhizosphere pH changes, resulting from the root release of $H^+$ or $OH^-/HCO_3$, organic acid exudation, redox potential and root exudates (Hinsinger, 2001). The pH changes might alter the availability of some inorganic nutrients. Acidification in the root zone can increase soil inorganic phosphorus uptake by plants such as maize, alfalfa, wheat, rape, soybean and rye grass (Nakamaru *et al.*, 2000).

The availability of phosphorus for plant uptake is also determined by the amount of bioactivity in the soil. Phosphate solubilising microorganisms (PSM), acting in unison with plant roots, are responsible for solubilising phosphate minerals (Leyval and Joner, 2001). In natural soil systems, PSM consists of a broad class of bacteria and fungi that interact in the soil, especially in the extreme microenvironments found around plant roots, called the rhizosphere (Waisel *et al.*, 1996). While most PSM obtain a great deal of their energy needs from plant root exudates, some drive their nutrient needs directly from the rock minerals, thus temporally converting a portion of phosphorus into an available form (Taalab and Badr, 2007).

### 2.5.6 *Azophos*

A composite biofertilizer inoculum containing both *Azospirillum* and Phosphobacteria has been named as *Azophos*. The main advantage of this single biofertilizer containing both nitrogen fixer and phosphorus solubiliser is less expensive, easy to use and also better efficiency of both the organisms in mixed culture. Studying their compatibility it has been standardized that at 50:50 level of mixing both *Azospirillum* and Phosphobacteria was better in both pot culture and field condition for rice. Survival test showed that *Azospirillum* and Phosphobacteria survived in the *Azophos* packets for 3 months with maximum population of $10^5$ cells $g^{-1}$ of inoculum. The field trials in kuruvai season in rice confirmed that *Azophos* inoculation recorded the yield difference which was statistically significant. There was considerable reduction in use of biofertilizers and input cost for biofertilizer purchase as well as labour used for application for large areas. Also the efficiency of *Azospirillum* and Phosphobacteria is increased when both are mixed and packed together (Premalatha *et al.*, 2005).

## 2.6. Inorganic fertilizers

Almost every soil contains enough lime, magnesia, sulphur, iron, silicon, chlorine and sodium for the growth of a full crop but nitrogen, phosphorus and potash are often present but in small quantity and become exhausted by the removal of farm produce (Mamoria and Tripathi, 2003). The bioregulation of growth and yield by extremely supplied chemicals are effective in several crops to balance the source sink rate for increasing the yield (Lone *et al.*, 2005).

Nitrogen, phosphorus and potash are regulated as the most important fertilizer elements, since one or more of which often controls or limits the yield of crops (Gustafson, 2003). Effect of NPK is of paramount importance, nitrogen stimulates vegetative growth, and phosphorus helps in early establishment of crop and formation of fibrous and strong root system and thereby helping absorption of nutrients from soil and contributing towards rapid growth in seedling (Gunjikar *et al.*, 1999). The supply of N, P and K with biofertilizers at crucial stages of crop growth prove efficient increase in crop yield and nutritive value (Ghodpage and Datke, 2005).

### 2.6.1 Nitrogen fertilizers

One of the major essential elements for growth of plants is nitrogen. Nitrogen is required in large quantities for plants to grow, since it is the basic constituent of proteins and nucleic acids. Nitrogen is provided in the form of synthetic chemical fertilizer urea (Chandrasekar *et al.*, 2005). Urea based nitrogen fertilizers are less acidifying than the ammonium based fertilizers. It is estimated that approximately 43,102 and 131 kg of lime ($CaCO_3$) is required to overcome the acidity produced by the application of 25kg N $ha^{-1}$ as urea, diammonium phosphate and ammonium sulphate (Dahama, 2003).

Nitrogen influences the crop growth in many ways e.g., it encourages the development of foliage, imparts green color to leaves; in case of cereals, it tends to produce lump ness in seeds and succulence or tenderness in the plant. If it is lowered it causes delay in maturity, decreases the resistance to diseases and it may weaken the stems and cause lodging in cereals (Mamoria and Tripathi, 2003). It is largely used in the synthesis of proteins, so when nitrogen supply is adequate, proteins are formed which help in increasing the plant height (Panchabhai *et al.*, 2005).

Nitrogen fertilizers promotes the growth and increases the biomass of plants, this is due to the fact that nitrogen has a positive action on the growth of vegetable plants (Muthumanickam and Balakrishnamurthy, 1999).

### 2.6.2 Phosphorus fertilizers

Phosphorus (P) is essential macronutrient for plant growth and function (Tsvetkova and Georgiev, 2003). It is mainly required for root development, tillering, metabolic processes, nodulation, flowering and fruiting, thereby increase rapidly vigorous growth of plants and finally helps in seed formation. Besides helping the early maturity, phosphorus acts as a store house of energy (ATP) by plants (Gosave *et al.*, 2008).

The phosphorus content of the soil is very low (0.5% (w/w)) and its availability is still low in India (0.01% of total phosphorus) due to poor solubility and fixation. Only about 10-20% of the phosphate fertilizer added to any crop is used and the remaining gets fixed as insoluble $Ca_3 (PO_4)_2$ in calcareous and alkaline soils and as $FePO_4$ and $AlPO_4$ in acidic soils (Ramalakshmi and Raj, 2008). Phosphorus fixation tends to be more pronounced in clays if they are predominant with CaO and $CaCO_3$. The availability and uptake of phosphorus is greatly influenced by soil properties and degree of soluble forms of phosphorus in fertilizers. Nitro phosphate contains water and citrate soluble forms of phosphorus. The different grades of nitro phosphate (15:15:15, 20:20:0) popularly known as sulphala contain any differential water soluble phosphorus were used (Dange *et al.*, 2007).

Of total soil P, only 1% to 5% is in a soluble, plant available form. Phosphorus deficiency is considered to be one of the main biophysical constraints to food production. This deficiency is a result of low inherent phosphorus fertility due to weathering, in combination with intensive nutrient-extracting agricultural practices (Sanchez *et al.*, 1997). Additionally phosphate diffusion to plant roots may be too low to meet the need of the crop if soils have low phosphorus solubility and a high phosphorus fixation capacity (Hoberg *et al.*, 2005).

The use of conventional phosphorus fertilizers is highly limited in developing regions due to cost (Sagoe *et al.*, 1998) and is prohibited for use by organic farmers. As a result, locally available sources of phosphate rock (PR) are increasingly recognized as potential phosphorus fertilizers (Goenadi *et al.*, 2000).

### 2.6.3 Potassium fertilizers

Potassium is one of the three major essential nutrient elements required by plants. Unlike nitrogen, phosphorus, potassium does not form bonds with carbon or oxygen, so it never becomes a part of protein and other organic compounds. Although potassium is not a constituent of any plant structures or compounds, it is involved in nearly all processes needed to sustain the plant life. Potassium in cell sap is involved in enzyme activation, photosynthesis, transport of sugars, protein and starch synthesis. Since it is involved in many metabolic pathways that affect crop quality, it is often called as 'the quality element' (Hoeft *et al.*, 2000).

Distribution of potassium in soils is dependent on its fixation and release. Potassium is initially soluble and exchangeable but has become entrapped in non exchangeable form in the lattice of mineral crystal such as vermiculite and weathered mica is called potassium fixation (Sparks, 2001). Application of potash, phosphorus, individually and in combination has found to influence growth and metabolic transport which lead to proper vegetative growth and ultimately increased flower yield in many herbaceous ornamental plants (Deshpande *et al.*, 2005).

## 2.7 Vermitechnology

In India about 320 million tonnes of agricultural waste are generated annually (Suthar *et al.*, 2005). The biological treatment of these wastes appears to be most cost effective and carry a less negative environmental impact (Coker, 2006; Paraskeva and Diamadopoulos, 2006). A possible way to utilize this waste is by vermicomposting biotechnology (Benifez *et al.*, 1999; Mills, 2006). It enables the utilization/recycling of organic wastes for which no proper disposal mechanisms are available, or that the conventional techniques such as incineration may be hazardous (Preetha *et al.*, 2005).

Vermicomposting is a process that involves the oxidation and stabilization of organic wastes through the joint action of earthworms and microorganisms, thereby turning wastes into a valuable soil amendment called vermicompost. Among the sources of organic manures, vermicompost has a special place because of the presence of readily available plant nutrients, growth enhancing substances, and number of beneficial microorganisms like nitrogen fixing, phosphorus solubilising and cellulose decomposing organisms (Sultan, 1997). This technique has been widely used to process many different types of residues, including organic and industrial wastes (Atiyeh *et al*., 2002).

This process is faster than composting; because the material passes through the earthworm gut, a significant but not yet fully understood transformation takes place, whereby the resulting earthworm castings (worm manure) are rich in microbial activity and plant growth regulators and fortified with pest repellence attributes as well. In short, earthworms, through a type of biological alchemy, are capable of transforming garbage into 'gold' (http://www.daniet.org/livelihoods/default.htm).

In vermicompost, compared to conventional compost, accelerated bio-oxidation of organic matter is achieved mostly by high density earthworm populations (Dominguez *et al*., 1997; Subler *et al*., 1998). Vermicomposts are typically finely divided peat-like materials with high porosity, aeration, drainage and water holding capacity. There is an increasing interest in the potential use of vermicomposts as plant growth media and soil amendments (Chamani *et al*., 2008). Thus the vermiculture provides for the use of earthworms as natural bioreactors for cost-effective and environmentally sound waste management (Aalok *et al*., 2008).

Vermicomposting facilities have already entered domestic and industrial marketing in countries like Canada, USA, Italy and Japan. Vermicomposting was started in Ontario (Canada) in 1970 and is now processing about 75 tonnes refuse per week. American Earthworm Company (AEC) began a farm in 1978-1979 with about 500 tonnes capacity per month. There are about 3000 other vermicomposting plants in Japan with 5-50 tonnes capacity per month. It has also started in Italy and in Philippines. It is now time for India to think about vermitechnology commercially (Palaniappan *et al*., 2005).

Vermitechnology comprises three main processes:

- Vermiculture - rearing of earthworms
- Vermicomposting - biodegradation of waste biomass in earthwormic way
- Vermiconvertion - mass maintenance of sustainability waste lands through earthworms.

Utilizable products and benefits of vermitechnology are waste biomass management, animal protein production, and organic pollution abatement, waste land conservation, land reclamation, production of worm worked manure, soil fertility and enhancement in plant production.

### 2.7.1 Vermiculture

Nature has created and differentiated earthworms into epigeic, anecic, and endogeic species based on definite ecological and trophic functions in the respective soils. Of the three ecological varieties, the epigeics in particular and the anecic in general, have largely been harnessed for use in vermicomposting process.

Epigeics like *Eisenia foetida* and *Eudrilus euginiae* have been used in converting organic wastes (agro waste and domestic refuse) into vermicompost. Though these surface dwellers are capable of working hard on the little layer and can convert all the organic waste into manure they are of no significant value in modifying the structure of the soil. The anecies however are capable of both organic waste consumption as well as in modifying the structure of the soil. Such burrowing species that are widely used in soil management like the earthworms, *Lampito mauritii* also effectively create a drilosphere apart from helping in compost production (Aalok *et al.*, 2008).

Worm, worked soils are conspicuously different from soil devoid of earthworms. Importantly, the tunnel formed by the worm's aid in the passage of water, which also washes the nutrients from the drilosphere to the roots that extend quite rapidly along these channels. This principle is also applied in the preparation of vermiwash (Ismail, 1997).

### 2.7.2 Characteristics of vermicompost

Vermicompost, a product of a non-thermophilic biodegradation of organic material through interactions between earthworms and microorganisms, is a peat like material with high porosity, aeration, drainage, water holding capacity and microbial activity, (Atiyeh *et al.,* 2000a). It contains most nutrients in plant available forms such as nitrates, phosphates, exchangeable calcium, soluble potassium etc (Edward, 1998) and has large particular surface area that provides many micro sites for microbial activity and for the strong retention of nutrients. The plant growth regulators and other plant growth influencing materials i.e. auxin, cytokinins, humic substances etc., produced by microorganisms have been reported from vermicompost (Atiyeh *et al.,* 2000b).

The humic materials extracted from vermicomposts have been reported to produce auxin-like cell growth and nitrate metabolism of carrots (Muscolo *et al*., 1999). However humic substances can occur naturally in mature animal manure, sewage sludge or paper-mill sludge but their amount and rates of production are increased dramatically by vermicomposting.

The nutrient status of vermicompost produced with different organic waste is, organic carbon 9.15 to 17.98%, total nitrogen 0.5 to 1.5%, available phosphorus 0.1 to 0.3%, available potassium 0.15%, calcium and magnesium 22.70 to 70 mg $100g^{-1}$, copper 2 to 9.3 ppm, zinc 5.7 to 11.5 ppm and available sulphur 128 to 548 ppm (Sharma *et al*., 2005).

### 2.7.3 Vermicasts

The vermicasts have been reported with a higher base exchange capacity and are rich in total organic matter, phosphorus, potassium and calcium with a reduced electrical conductivity, large increase in oxidation potential and significant reductions in water - soluble chemicals which constitute possible environment contaminants.

Humic acid like components (HAL) were isolated by conventional procedures from various organic wastes including animal manures, a municipal solid refuse and a sewage sludge that were composed for 2-3 months with the earthworms *E. fetida* or *Lumbricus rubellus* by Sharma *et al.*, (2005). Vermicomposts HAL containing appreciable amounts of Fe and Cu in inner sphere complexes of definite chemical and geometrical forms, similar to those found in humic acid (HA) from soil and other sources, can be considered adequate analogues of soil HA with respect to their metal complexion properties and behavior.

Vermicompost is rich in microbial diversity, population, and activity (Subler, 1998) and vermicasts contains enzymes such as proteases, amylases, lipase, cellulose and chitinase which continue to disintegrate organic matter even after they have been ejected. The chemical analysis of casts shows 2 times the available magnesium, 5 times the available nitrogen, 7 times the available phosphorus and 11 times the available potassium compared to the surrounding soil. The vermicompost is considered an excellent product since it is homogeneous, has reduced level of contaminants and tends to hold more nutrients over a longer period without affecting the environment (Ndegwa and Thompson, 2001).

### 2.7.4 Vermiwash

Advances in vermiculture technology have recently lead to novel products like vermiwash. This product has not only caught the attention of commercial vermiculturists but also the farmers. Farmers in their own way have started collecting vermiwash for foliar application. For preparation of vermiwash, 1 kg of adult earthworms devoid of casts (approximately numbering 1,000 - 1,200 worms) are released into a trough containing 500ml of lukewarm distilled water (37°C - 40°C) and agitated for 2 minutes. Earthworms are then taken out and again washed in another 500ml at room temperature (+30°C) and released back into the tanks. The agitation in luke warm water makes the earthworms to release sufficient quantities of mucus and body fluids. Transferring into ordinary water is to wash the mucus sticking still on to their body surface and this also helps the earthworms to revive from the shock (Singh, 2007).

### 2.7.5 Vermicompost as ideal biofertilizers

An earthworm takes in biodegradable wastes as feed and produces vermicasting, is the ideal biofertilizer for the soil.

- Vermicastings have immobilized enzymes like protease, lipase, amylase, cellulose, lichenase and chitinase which keep on their function of biodegradation of macromolecules of the agricultural residues in the soil so that further microbial attack is speeded up.
- Vermicastings are rich in vitamins, antibiotics and growth hormones.
- Vermicastings are free from pathogens.
- Vermicastings have immobilized micro flora which function in the soil, thus ensuring continuous production of vermicastings in the soil itself.
- Give structural stability to the soil.
- Absorb moisture from air.
- N, P, K and other micronutrients are more than normal manure (Kumar, 2005).

### 2.7.6 Benefits of vermicomposts

They serve as "nature's plowman" and form nature's gift to produce good humus, which is the most precious material to fulfill the nutritional needs of crops. The utilization of vermicompost results in several benefits to farmers, industries, environment and overall national economy.

**To farmers**

- ✓ Less reliance on purchased inputs of nutrients leading to lower cost of production.
- ✓ Increased soil productivity through improved soil quality.
- ✓ Better quality and quantity of crops.
- ✓ For landless people provides additional source of income generation.

**To industries**

- ✓ Cost-effective pollution abatement technology.

**To environment**

- ✓ Wastes create no pollution, as they become valuable raw materials for enhancing soil fertility.

**To national economy**

- ✓ Boost to rural economy
- ✓ Savings in purchased inputs
- ✓ Less waste land formation (Nagavallemma *et al*., 2004)

**2.8 Chilli**

*Capsicum annuum L.* is one of the most important cash crops grown extensively under a wide range of agro climatic conditions in India and other parts of the world (Shankar *et al*., 2008). It is believed to be the nature of tropical South America (Shetty *et al*., 2007). No country in the world has so much area and production of chilli as much as India. India possesses many varieties of chilli with different quality factors (Jyothi *et al*., 2008).

Chilli (*Capsicum annuum L.*) also known as bell pepper or sweet pepper or hot pepper, belongs to the family Solanaceae is one of the important spice cum vegetable crops. It is an integral part of Indian diet and used at all time in every Indian home (Vitkar *et al*., 2007). They are used in green and dry form in all culinary preparations of Indians equally by rich and poor. Chilli is natures wonder with two important qualities. They are biting pungency attributed capsaicin and captivating red color due to the pigment capsanthin (Singegol *et al.,* 2007). The pungent form of chilli earns an alternative export value in the foreign market (Maheswari and Haripriya, 2008).

Chilli is used for the extraction of vitamin C, oleoresin and colouring matter. Besides, it is used as herbal medicine for maladies ranging from itch and pains to constipation (Singegol *et al.,* 2007). Capsicum comprises L-asparginase, which is an anticancer enzyme and used in the treatment of acute lymphatic leukemia in children.

India is the leading producer of chilli in the world having production of 10.18 lakh tonnes of dry chilli with an area of 9.15 lakh hectares and also exports chillies up to 12.39 per cent of its total production over 90 countries (Peter and Nybe, 2002). There is an immense possibility for export of dry chilly and its derivatives especially that have low pungency and high color (Mathew *et al.*, 2000).

Growing of capsicum under green/polyhouses has been reported to give high productivity of good quality produce in developed countries (Shetty *et al.*, 2008). The main constraints for low productivity or inferior fruits quality in chillies are due to ravages caused by insect pest irrespective of seasons and geographical locations (Shankar *et al.*, 2008).

### 2.8.1 Gundu type

It is local gundu type from Nambiyur of Tirupur district in Tamil Nadu [CA (P) 63]. The crop duration is 210 days and yield 200 kg of dry pods per hectare. The stem is angular, semi dwarf and less spreading. The fruits are long, thick and bright red in color. Seed content is high (60%). The capsaicin content of dry pod is 0.56%. It is suitable for harvest both as green pods and red ripe pods. The green pod yield is about 11t $ha^{-1}$ (Bose and Kahir, 2002).

### Medicinal values of chilli

- The capsaicin content of chillies has vitamin C and A containing *β*-carotenoids, which are powerful antioxidants. These antioxidants destroy the free radicals.
- Chillies act as detoxifiers as they remove waste products from our body and increases nutrient supply to the tissues.
- They stimulate the release of endorphin, a natural pain killer.
- As an antibiotic they bring fresh blood to the site of infection. The WBC's and leucocytes present in the fresh blood fights viruses.
- Vitamin – C, *β* carotene and folic acid found in chilli reduces the risk of colon cancer. Chilies such as red pepper have carotenoid lycopene, which prevents cancer.

- Vitamin $B_6$ and folic acid of chilli reduces high homocysteine level, that has been shown to cause damage to blood vessels and are associated with a greatly increased risk of heart attack and stroke. It also converts homocysteine into other molecules, which is beneficial to lower cholesterol level.
- They give relief from natural congestion by increasing the metabolism. It also dilates airway of lungs, which reduces asthma and wheezing. It relieves chronic congestion in people who are heavy drinkers.
- The vitamin A present in chilli reduces inflammation of lungs and emphysema caused due to cigarette smoking (http://www.spiceskerala.com/usesofchilly.htm).

Being a major spice, the emphasis now lies on improving the quality apart from increasing the productivity.