Waste includes all items that people intend to get rid of, no longer have any use for or have already discarded because of their hazardous properties. Types of waste include Municipal waste, Industrial waste, Mining waste, Electronic waste, Agricultural waste, etc.

Solid waste refers to any refuse, garbage, sludge from water supply treatment plants, wastewater treatment plants and other discarded materials which include solid, semi-solid, liquid or gases discharged from community activities as well as from commercial, agricultural, industrial and mining operations. There is an indiscriminate disposal of solid wastes generated by domestic, commercial and industrial activities. In Indian urban areas, wastes of all kinds and piles of garbage are littered everywhere. The rural areas have also not been spared from the menace of mounting garbage and associated hazards. With the expanding population coupled with wasteful consumerism and general ignorance regarding cleanliness, the symptoms of stress on the environment and living conditions are clearly evident in rural as well as urban areas of India.

Disposal of municipal solid waste is generally done through open dumping or land filling which further leads to more landfill gases emissions and organic load on the ground water. Most of the Indian cities have shortage of land for dumping of wastes as most of the land-filling sites have been already over used. So there is an obvious need to reuse or recycle the urban waste. The technologies for recovery of energy and nutrients from such wastes can play a major role in eliminating the solid waste problems. Technologies that have been developed to manage solid wastes include biomethanation, sanitary land fill gas, pelletisation, pyrolysis/ gasification, composting and vermicomposting.

Agricultural waste is organic waste which includes farmyard manures, crop residues, animal excreta in the form of slurries and silage effluent and inorganic waste including pesticides, plastic, waste oils, scrap machinery, fencing and veterinary medicines. Large amounts of organic materials are in the form of farm waste, city waste, sewage sludge, poultry litter and agro-industrial wastes (Lal 2005). Agricultural waste is the waste produced through various farming activities such as crop cultivation, weeds, horticulture, dairy farming, market gardens, grazing land and nursery plots.
Wastes, residues and refuse from agriculture and food industry constitute a significant proportion of agricultural productivity worldwide. Proper management of agricultural waste can contribute in a consequential way to farm operations. A healthy environment can be maintained for farm animals by waste management which can further reduce the need for commercial fertilizers and can provide nutrients needed for crop production. If the agricultural waste is not managed properly, it can lead to a number of potential environmental impacts, the most harmful being run-off of nutrients to the surface waters which leads to over enrichment of the water bodies. If the waste reaches the surface waters, leaking and improper storage of this waste can also raise a critical threat to the environment. Various types and sources of organic wastes are utilized in agriculture but most of these materials remain unutilized and become potential sources of air, land and water pollution. Soil fertility deterioration through loss of organic matter and nutrients, environmental pollution, erosion and salinity are the negative outcomes of modern agricultural practices.

Traditionally in India, the integration of livestock and crops; and use of manure as fertilizer were the basis of farming systems. During the green revolution period, use of chemical fertilizers helped in boosting food productivity at the cost of environment and society. Although it has increased the quantity of food dramatically, yet it has also led to deteriorated soil fertility and nutritional quality of food over the years. Use of chemical fertilizers kills beneficial soil organisms which help in restoring the natural fertility. The biological resistance of the crops is also impaired which makes them more susceptible to pests and diseases. There is an increase in the level of inorganic nitrogen content in groundwater and in the human food due to excessive use of nitrogenous fertilizer (urea) leading to severe consequences on the human health.

India is an agrarian economy where majority of the land is used for farming and various crops are cultivated in different regions of the country. Depending on the crops grown, their productivity and cropping intensity, generation of crop residues and their use varies in different regions. According to Indian Agricultural Research Institute report (2012), 500 million tonnes of crop residues are generated annually whereas according to Pathak 2004, 523 Mt crop residues were produced in India annually, out of which 127 Mt was surplus. The crop residues are used for
composting, thatching homes, as animal feed and as industrial and domestic fuel but to clear the left-over straw after harvest a large part of unused crop residues are burnt in the fields. The main reason for burning the crop residues is the high cost of residue removal from the field and non availability of labour. Burning of crop residues leads to environmental pollution which further leads to production of greenhouse gases namely methane, carbon dioxide and nitrous oxide causing global warming and loss of plant nutrients like N, P, K and S. It also lowers the biological activity and destroys the structure of soil.

Fodder prices have increased in recent years due to burning of crop residues and scarcity of fodder. Therefore there is a need to manage the crop residues appropriately. Recent research efforts have led to development of more resource-efficient agriculture-based crop management technologies than the conventional practices. Crop residue management is a very important mitigation technology wherein vermicompost, biomass etc. can be processed under aerobic conditions to reduce greenhouse gas emissions.

Conservation agriculture (CA) is very helpful in managing the residues in a profitable and productive way. By adopting conservation agriculture technologies the crop residues can be utilized for increasing crop productivity, minimizing pollution, improving soil health and sustainability of agriculture. Burning of crop residues must be stopped and utilized properly in improving soil health and minimizing environmental pollution. For ensuring country’s food security and sustainable agriculture, crop residues should be either partly or entirely used for conservation agriculture. Crop residues of wheat, sorghum, maize, mustard and other crops can be managed properly rather than burning them. Crop residues especially from Brassica and pulses contain organic as well as inorganic matter and offer good possibilities for recovery of energy in its organic fraction for gainful utilization through adoption of suitable processing and treatment technologies.

In the present study straw of Brassica juncea was used as the agricultural waste to be converted into vermicompost. Brassica juncea is the botanical name of Indian mustard or raya. Mustard leaves, seeds and stems are edible. According to Grover et al., 2002, Yadav et al., 2004 and Alam et al., 2007 the plant appears in
some form in African, Indian, Chinese, Japanese and Soul food cuisine. *Raya* is used in diseases like anorexia, abdominal pain, tumors and wounds (Ouyang *et al.*, 2002). Indian mustard is cultivated on 5.86 million ha area in India and predominantly in Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh, Gujarat and West Bengal (DES 2010). About 45.5% of total area and 48.6% of the total production (6.41 Mt) of oilseed Brassicas in the country is contributed by Rajasthan alone (Premi *et al.*, 2012). Mustard straw has poor fodder and fuel value so it is usually burnt to clear the fields but if it is incorporated into the soil it can improve the soil health and fertility enormously.

A proper technology is needed to incorporate the crop residues in soil. A technology that would help to maintain soil productivity and meet essential plant nutrients through organic resources and their implementation in a balanced way to provide humified materials. Composting is a safe and non-polluting method for disposing off and recycling of organic waste by converting them to organic fertilizers. These are the main resources used for building soil fertility. Composting is more economical and environment friendly and so it provides an effective and environment friendly procedure of organic waste disposal (Millner *et al.*, 1998). It is a natural process in which the organic matter is decomposed by microorganisms under controlled conditions.

Organic farming helps to produce food of good quality by using eco-friendly technologies, and such practices exclude use of chemical fertilizers, pesticides and weedicides etc. Leguminous plants and microbial inoculations are used for nitrogen fixation; crop rotation, organic manures and wastes (*viz.*, Vermiculture and Vermicompost) and biological control methods for pests, diseases and weeds are used in this system. Indiscriminate rather injudicious use of pesticides and weedicides lead to environmental degradation, killing of beneficial non targets organisms, like earthworms which are essential for maintaining ecological balance. To have an efficient, eco-friendly sustainable agriculture, there is need of cutting down usage of chemicals, especially insecticides and weedicides in agriculture. Organic farming systems can provide food safety and farm security with the help of nutrients of biological origin such as compost. Municipal solid waste (MSW) is being generated in large amount every day all over the world and the compost prepared from
biodegradation of organics of MSW contains nitrogen (N), phosphorus (P) and potassium (K) in sufficient quantity and is a good source of other macro and micronutrients required for plant growth. There are a number of beneficial soil microbes in the compost which help in fertility improvement, regeneration of soil and protecting it from degradation and also promote growth in plants (De Brito Alvarez et al., 1995; Weltzien 1989). It also protects the plants from pests and diseases (Hoitink and Fahy1986; Scheuerell and Mahaffee 2002).

After composting, raw organic materials like animal wastes, municipal wastes, industrial wastes, food garbage and crop residues act like resources of nutrients which are more suitable for application to the soil. Compost acts as a rich source of organic matter. Organic matter in the soil helps in sustaining soil fertility and consequently in sustainable agricultural production. Compost is a source of plant nutrients and assists in improving the biological and physico-chemical properties of the soil. As a result the soil becomes more tolerant to stresses like diseases, toxicity and drought. There is an improved uptake of nutrients by the plants and soil possesses an active nutrient cycling due to strong microbial activity. Composting helps in conserving natural resources and enhances the cycling of non-renewable resources. It is an excellent option for energy conservation because a lot of energy is utilized in fertilizer sector. Biologically this process converts the organic waste material into stable humus like substances, which may be stored and applied without any environmental impacts (Gallardo-Larva and Nogales 1987). Organic manures and compost are important in sustaining farming by providing rich N-supply to the plant (Korsaeth et al., 2002). Compost is considered as a valuable soil amendment. Use of compost helps in increasing healthy plant production and also assists in reducing the application of chemical fertilizers and conserving natural resources. Compost improves the physical properties of the soil and reduces the soil bulk density. It also directly improves the structure of the soil by loosening heavy soils with organic matter. Water requirement and irrigation can be reduced as compost improves water-holding capacity of the soil as it binds the organic matter to water and improves the movement and absorption of water in the soil.

Large amount of organic wastes is produced throughout the world, which creates environmental problems, so vermicomposting has been considered as a way of
converting some of these wastes into useful compost for plants and soil while decreasing their negative environmental impacts. Vermicomposting is a process in which biological degradation of organic wastes takes place in controlled conditions, by the action of earthworms. Maximum productivity can be attained by maintenance of aerobic condition with optimum moisture and temperature (Edward 1998). The most favourable worm for vermicomposting is *Eisenia foetida* which is prevalent in India (Neuhauser *et al.* 1980, Elvira *et al.*, 1997, 1998). Vermicomposting improves the physical properties of waste (Ghatnekar *et al.*, 1998). The process comprises digestion of farm waste by earthworms and turning it into vermicompost which is different from other composts due to the presence of worms like earthworms, white worms, red wigglers, etc.

Earthworms constitute a large part of the biomass (living bodies) inhabiting soil. In some situations, these may constitute 80% of the biomass. Zoologically, these have segmented body, therefore are classified under Phylum *Annelida* and Class *Oligochaeta*. Grossly, earthworms are tubular wriggling creatures with worm like appearance. Hence for these, usage of word worm of ‘vermi’ (latin) have come into popular usage. However, technically, earthworms considerably differ from other worms. The number of earthworm species existing worldwide is over 4000 and so far, Indian earthworm fauna is reported to comprise 418 species referable to 67 genera and 10 families (Kale 1991). However, these have many distinctly advanced features that add to their adaptabilities for life in soil. *Eisenia foetida* is a common earthworm which is also known as red wiggler, brandling worm or dung worm. It helps in decaying organic matter and thrives in compost, rotting vegetation and manure. *Eisenia foetida* originated in Europe is now found in every other continent except Antarctica.

With criteria of ‘adaptability’, two types of earthworms are found, namely, peregrine species and endemic species. Former ones are highly adaptive and are widely distributed. Such species are numerous exotic species like *Eisenia foetida*, the sewage worm and *Eudrilus eugeniae*, the African Night Crawler which have got established with introduction by man in countries other than their natural homes. Such species are called Peregrine. Epegeic species [species that live above the mineral soil surface (Lee 1985)] of earthworm have more capability of decomposing waste than
anecics [species that live in burrows in mineral soil layers and play a major role in burying surface litter (Lee 1985)] and endogeics [species that lives in mineral soil horizons feeding on soil more or less enriched with organic matter (Lee 1985)] which is mainly due to the humus consuming surface dwelling nature of the epigeics. The commonly used epigeic species are *E. eugeniae*, *Eisenia foetida* and *Perionyx excavatus* Perrier (Hartenstein *et al.*, 1979; Graff 1974; Haimi and Huhta 1986; Kale *et al.* 1982; Reinecke and Venter 1987). Earthworms are very reactive to hydrogen ion concentration and thus soil pH sometimes becomes a limiting factor in their number, distribution and species that live in a particular soil.

One kg earthworm can use up one kg organic material per day. They secrete castings (vermicompost) that are rich in useful microorganisms (fungi, protozoa, bacteria and actinomycetes), Ca, Mg, K, N, enzymes, hormones and vitamins and certain micronutrients required for plant growth. (Lee 1985; Bansal and Kapoor 2000).

Efforts have been made in recent years to use of earthworms in waste management, reprocessing of nutrients and developing vermicomposting systems at commercial scale which raise the types and number of microbes in the soil by creating conditions under which these creatures can thrive and multiply. Consequently earthworms are also known as “Ecosystem engineers”. Role of earthworms in recycling of decomposable wastes for use in agriculture and forestry has been extensively studied. Charles Darwin and various scientists have depicted earthworms as good benefactors of agriculture and soil (Satchell 1983). Earthworms help in cleaning the dead organic matter by feeding on it. As conventional composting, earthworms help in stabilizing biodegradable organic matter such as vegetable waste, animal waste and municipal sludge. The worms ingest solids while maintaining the aerobic conditions in the mixture and a portion of the organic matter is converted into respiration products and to worm biomass and the remaining partially stabilized matter is expelled as castings which is the discrete material. Scientific rearing of earthworm, their nutrition, reproduction and conservation come under vermiculture.

Vermicomposting differs from composting because earthworms and microorganisms which are active in a temperature range 50–90 degrees Fahrenheit are utilized in vermicomposting which is a mesophilic process whereas composting is a
thermophilic process. Vermicomposting is comparatively faster than composting as the material passes through the gut of earthworm and a significant transformation takes place and the resulting earthworm castings are abundant in plant growth regulators and microbial activity.

The potential benefits of vermicomposting of agricultural waste include production of a value added product and pollution control. Vermicomposting is the method which recycles the crop residues and significantly raises the N, P and K concentration in compost (Jambhekar 1992). There is an improvement in the quality of vermicomposts with respect to yield, C/N ratio, nutrient content and humus fractions when vermicomposting of mustard (*Brassica juncea*) residue was done with pretreatments of immersion in water, nutrients (low grade rock phosphate and urea) supplementation, microbial (*Bacillus* sp., *Cellulomonas fimii* and *Trichoderma viride*) inoculation and their integrated use with fresh cow dung/slurry (Shilpkar et al., 2011).

It is now well known that there is an urgent need to maintain environmental and agricultural sustainability without reducing productivity but by cutting down inputs that are adversely affecting these. Therefore, there is a need to appreciate needs of integrating various systems viz. integrated plant nutrient systems (IPNS), various related systems covering recycling, production, protection, conservation and integrated vermiculture and composting systems. Vermicomposting has been considered as a cost-effective and rapid technique for the efficient management of the organic solid wastes (Logsdon 1994). But increasing human population and its needs or demands for food and other amenities cannot be overlooked as all these are interlinked. To these earthworms provide various levels of solutions. Several research studies have demonstrated the capability of some earthworm species to consume a wide range of organic wastes such as sewage sludge, animal dung, crop residues and industrial refuse (Chan and Griffiths 1988).

This research aims to develop a state-of-art-technology using earthworm composting to manage the crop residues and convert them into a useful product for better growth and quality of crops. The research thus has economic environmental and social relevance.
OBJECTIVES

➢ To assess the potential of the earthworm species (*Eisenia fetida*) to transform agricultural waste into useful compost.
➢ To evaluate the physicochemical parameters of the crop residue collected.
➢ To evaluate the physicochemical parameters of the vermicompost produced.
➢ To manage the crop residues and convert them into a useful product for better growth and quality of crops.
➢ To assess the value addition in vermicompost after its production from crop residue.