Res. Bulletin 1/2013

Vermicomposting for Efficient Crop Residue Recycling, Soil Health Improvement and Imparting Climate Resilience

Experiences from Rainfed Tribal Regions

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February 2013

Citation :

Srinivasarao, Ch, Venkateswarlu, B., Veeraiah, R., Rammohan, S., Vijay S. Jakkula, Sreenath Dixit, Rammohan, R.V., and Shivarudrappa, B. 2013. Vermicomposting for Efficient Crop Residue Recycling, Soil Health Improvement and Imparting Climate Resilience : Experiences from Rainfed Tribal Regions. Central Research Institute for Dryland Agriculture, Hyderabad. Andhra Pradesh. 40 p.

Copies 1500

Published by

The Director
Central Research Institute for Dryland Agriculture
Santoshnagar, Hyderabad - 500 059
Ph : 040-24530177 Fax : 040-24531802
website : http://www.crida.in
E-mail : director@crida.in

Printed at :
Sree Ramana Process Pvt. Ltd. Ph : 040-27811750

PREFACE

The importance of biomass-both crop residue and from other sources such as weed-is felt more acutely in the current context where there is severe dearth of biomass for soil incorporation. Efficient use of biomass by converting it as a useful source of soil nutrients is necessary to manage soil health and fertility in all eco systems and particularly in rainfed regions. However, there is growing concern that the current practices of crop residue and weed biomass management are either unscientific or inadequate considering the need of nutrient recycling. Ideally the entire residue after the crop is harvested must go back to the soil to replenish the lost nutrients. But the competing demand for crop residue as a source of livestock feed often comes in the way and even the farm yard manure prepared out of livestock dung does not get recycled efficiently. In this context, vermicomposting which not only encourages efficient recycling of biomass but also generates income and employment for the rural poor is being promoted as a prudent option.

Vermicomposting has been in practice sporadically for over two decades now. It's time that vermicomposting takes the center stage as far as crop residue management and soil fertility enhancement is concerned. Over these years, many research institutes and NGOs have worked out several feasible options for vermicompost production. These vary from small backyard units to large scale production units combining biogas and energy production. This bulletin documents the hands-on experience of setting up and running different models of vermicompost production. It can be used as a handy manual for students and particularly useful for the practitioners and the field functionaries of development departments, KVKs and NGOs that are involved in training and capacity building activities. We hope this publication will enthuse many to take to vermicomposting and wish that this will go a long way in reducing the carbon footprints of agriculture by diverting the crop residues to vermicomposting which otherwise would be burnt.

- Authors

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Introduction

India has only 2.3% of the world's geographical area but supports 17% of its population. Out of the estimated 141 m ha net cultivated land in India, 80 m ha is rainfed which produces 40% of the food grains in the country. Rainfed regions are characterized by low and erratic rainfall, high temperature, degraded soils with low available water content and multi-nutrient deficiencies which are critical productivity constraints causing low crop yields in these regions. Various forms of soil degradation accounting for 120.72 m ha, of which 73.3 m ha is affected by water erosion, 12.4 m ha by wind erosion, 6.64 m ha by salinity and alkalinity and 5.7 m ha by soil acidity. Land degradation, poor soil quality are major threats to our food and environmental security and the extent of degradation is more pronounced in rainfed regions, with larger soil erosion, loss of fertile soil, organic matter, nutrients and beneficial microbes. Falling yield trends in various crop production systems in India is a serious concern. The growth rates of food production have declined from 2.93 during 1996-2010 as compared to 0.93 during 1986-97. Oilseeds and pulse crops are showing low yields particularly in rainfed regions, thus many of the oil seeds and pulses are being imported to meet the requirement of growing population of the country.

Low biomass production per unit area is a prominent feature of rainfed farming. Soil health deterioration is one of the important causes for falling productivity levels and factor productivity of farm inputs (Srinivasarao et al. 2011). The indicators for soil health can be physical, chemical and biological. The physical indicators are soil texture and structure; aggregate stability; compaction, crusting; water holding capacity; rate of water infiltration and percolation; drainage and soil aeration. The chemical indicators are electrical conductivity (EC); pH; cation exchange capacity (CEC); soil organic carbon (SOC); soil fertility etc. The potential value of microbial biomass, soil microflora, root pathogens, biodiversity, soil microfauna, soil arthropods, soil macrofauna, soil enzymes, and plants are considered as biological indicators of soil health. Biological indicators reflect the organisms that form the soil food web, that are responsible for decomposition of organic matter and nutrient cycling (Srinivasarao et al. 2012c).

Low soil organic matter in rainfed regions

Most soils in rainfed-dryland areas have very low organic matter content (Fig.1), and particularly so in soils that receive less than 500 mm annual rainfall. Optimum soil organic matter (SOM) is however important to sustain reasonable crop productivity in stressed environments. The level of SOM is primarily a function of climate and soil management. While cultivation of grain crops without organic inputs lowers SOM, fallowing in cultivated soils reduces it further (Srinivasarao et al. 2012a). Regular addition of locally available organic resources like crop residues, green manures, green leaf manures, cover crops, vermicomposting and tank silt improve soil organic matter in dry ecosystems. For example, groundnut shell (GNS) was tested as organic amendment in light textured red soils of Anantapur, A.P. With regular additions of

4 t/ha GNS annually, soil health parameters like organic carbon, microbial biomass carbon, particulate organic carbon etc. were improved besides N, P, K, Ca, Mg, S, Zn, Fe, Cu, B status, and the available water content of soils (Srinivasarao et al. 2012b). Organic matter levels have declined sharply in intensively cropped regions, leading to stagnant yields of major food crops in India. Organic carbon improves the biological activity in the soil, helps retain soil moisture longer and reduces the leaching of plant nutrients besides imparting drought tolerance during dry spells.

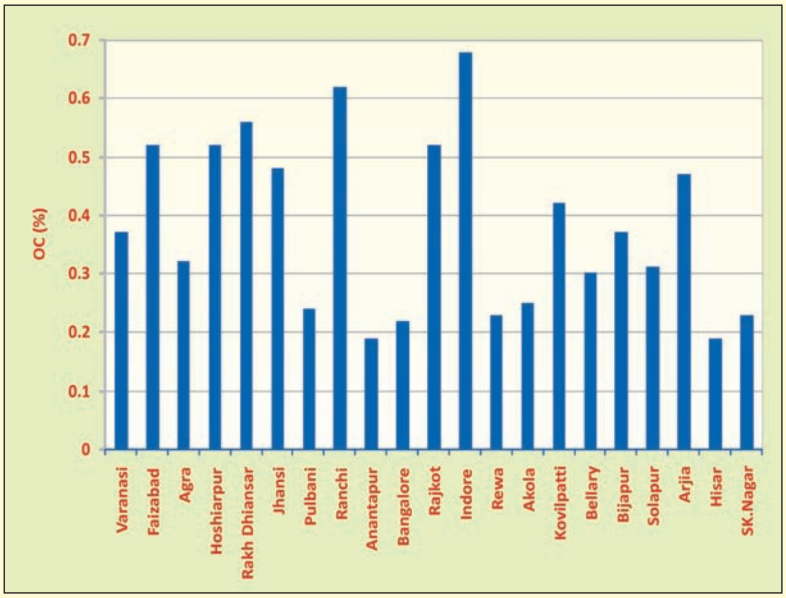

Figure 1 : Soil organic carbon levels in rainfed production systems across India (Source: Srinivasarao et al., 2009).

In the perspective of soil quality, of all the chemical properties, soil organic matter content is the most important one as it regulates most of the soil processes. Though literature is enormous on soil health degradation, its direct link with falling productivity levels of food crops is still a central point for discussion. The amount of residual organic C left in the soil after the crop is mainly the function of the amount of root and shoot biomass left in the field after the harvest of the crops. However, in field conditions no root residue is going into soil system because of smooth farm operations. In nature's soil laboratory there are a number of organisms (micro and macro) that have the ability to convert organic waste into valuable resources containing plant nutrients and organic matter, which are critical for maintaining soil productivity and soil health. Most of the rainfed districts that are in very low or low productivity range, offer immense opportunities for raising agricultural production in the country to meet the ever increasing food demand of the rising Indian population, through recycling of farm wastes, and farm-based by products in the form of direct addition of residues, mulching, composting etc.

Crop residue availability

Soils under rainfed production systems show depletion in soil organic carbon due to complete removal of crop residue or burning it for want of clean cultivation in the field and lack of addition of organic matter from external sources. Paddy straw which has high lignin content and hence not a preferred livestock feed is burnt after the crop is harvested by a combiner. Though farmers realize the importance of crop residue and its recycling, decomposition of these hardy stalks is a problem either for direct addition of residues or composting. CRIDA has introduced chaff cutters to make such crop residues into small pieces before adding to the soil. However, labor availability and cost have become constraints in adopting this technology. Annually about 100 million t of crop residue is available from 80 million ha of rainfed regions, but its effective utilization for soil health maintenance lacks direction. Leaving crop residue on the surface is another important component of conservation agriculture (CA). However, CA practices need more refinement to be able, to be adapted, in rainfed regions of the country.

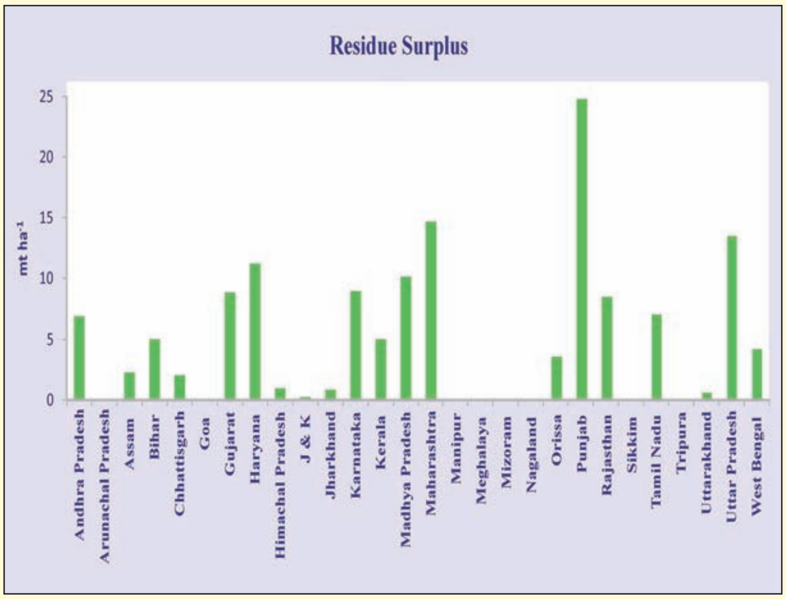

Figure 2 : Surplus of farm crop residue in various states of India (Source: IARI, 2012).

In dryland farming, crop residues can be converted into compost of better quality than farmyard manure (FYM), and its use, along with fertilizers, can help sustain or even improve yield. Crop residues must be considered a natural and valuable resource and not a waste (Srinivasarao et al., 2011). The increased use of fertilizers alone, often in an unbalanced manner has resulted in deteriorating soil health and multiple nutrient deficiencies in various areas of the high potential rainfed regions. Therefore, efficient crop residue management can play a vital role in refurbishing soil productivity as well as in increasing the fertilizer use efficiency (FUE). Residue management needs a great deal of attention by farmers because of its diverse and positive effects on soil physical, chemical and biological properties. Organic wastes are generated regularly at farm as well as house-hold levels. Disposal of such residues is difficult and could become a serious problem if the residues are burnt or not disposed of properly. Besides agricultural wastes, large quantities of domestic wastes (700 million t yr^{-1}) are generated in cities and rural areas. Most of these organic residues are wasted by burning or used as land fillings. These residues contain valuable plant nutrients and through proper treatment of residues, these nutrients can be effectively used as organic manure for increasing the agricultural productivity besides having environmental benefits. In India, among different crops, cereals generally generate 352 mt residue, followed by fibers (66 mt), oil seeds (29 mt), pulses (13 mt) and sugarcane (12 mt). Generation of cereal residues is highest in Uttar Pradesh (53 mt), followed by Punjab (44 mt) and West Bengal (33 mt). Maharashtra contributes the maximum to the generation of residues of pulses (3 mt), while residues from fiber crops is dominant in Andhra Pradesh, mainly from cotton (14 mt). Gujarat and Rajasthan generate about 6 mt each of residues from oilseed crops. The surplus crop residue (which is defined as total crop residue minus fodder used) varies from state to state (Fig. 2) with Punjab showing the highest surplus (24.83 mt yr^{-1}) of farm crop residues followed by Maharashtra (14.67) and Uttar Pradesh (13.53) (IARI, 2012).

Burning of crop residue in fields

Farmers use residues either for their own needs or sell to other landless households or intermediaries, who in turn sell the residues to industries. The surplus residues are typically burned by farmers in the field or used to meet household energy needs. Some of the reasons for intentional burning include clearing of fields, fertility enhancement in the form of ash addition, and pest and pasture management. As the time gap between rice harvesting and wheat sowing in northwest India is 7-15 days, farmers resort to burning the rice stalk in the field in order to clear the field within a short period of time. In states like Punjab and Haryana where rice residues are not used as cattle feed, large scale rice straw burning takes place. It is also perceived by farmers that burning kills harmful pathogens. Residue burning in fact increases the short-term availability of some nutrients (Ca and K) and reduces soil acidity, but

Figure 3 : Cotton, maize and combined harvested rice straw burned in Nalgonda, Kurnool and Srikakulam districts of Andhra Pradesh (Source: Srinivasarao, 2012)

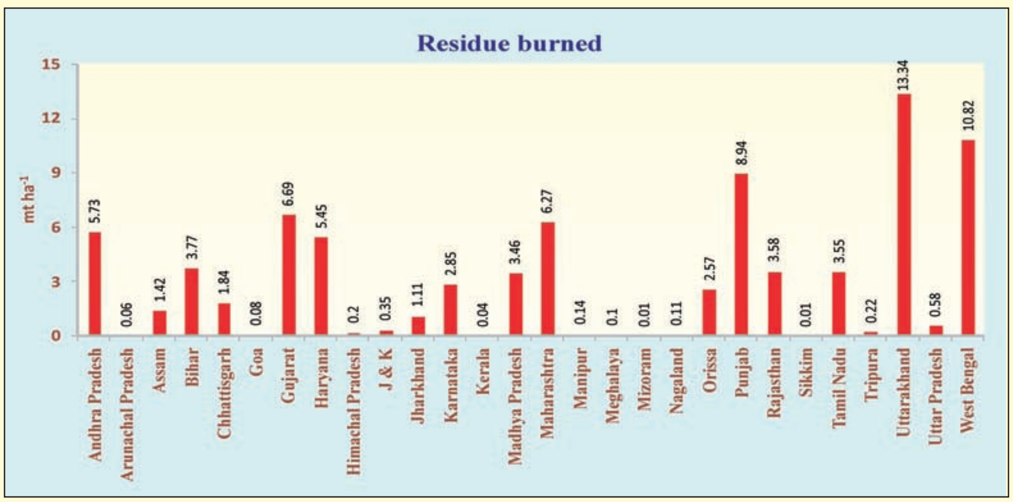

Figure 4 : Amount of residue burned in different states of India (Source: IARI, 2012).

leads to loss of other nutrients (e.g. N and S), organic matter and damages microflora in top soil. For example, in Nalgonda district of Andhra Pradesh, a 100 house-hold village (Nandyalagudem) about 1000 t of cotton, 400 t of pigeonpea is burned annually. Many dryland crop residues are burned regularly, particularly hardy crops like cotton, pigeonpea, castor, chilli, maize etc (Fig. 3). The amount of residue burnt varies from state to state (Fig.4), with Uttarakhand showing the highest value (13.34 mt yr^{-1}), followed by West Bengal (10.82 mt yr^{-1}) and Punjab (8.94 mt yr^{-1}).

Strategies to improve soil health

Any amount of rise in biomass production improves root biomass proportionately, a major component of which goes back into the soil. Soil organic carbon (SOC) enhancement through crop residue recycling, inclusion of legumes in the cropping sequence or as intercrops, green manure crops, green leaf manuring, tank silt addition, farm yard manure, biofertilizers, composting/vermicomposting along with fertilizers and integrated nutrient management (INM) are some of the important options to improve soil health and crop productivity in rainfed dryland areas (Srinivasarao et al. 2011a).

Composting of agricultural waste is an important method in which organic waste such as food, leaves, and paper is turned into a material that is useful to the environment. Micro-organisms and bacteria break down the waste to form a paste-like substance. The resulting material is rich in nutrients and oxygen. Composting is becoming an effective way to increase organic matter of the soil. In addition to increasing organic matter of the soil, amending with composts also increases soil microbial populations (Pera et al., 1983; Perucci, 1990), which leads to an improvement of the soil quality. The suppressive activity of compost towards plant pathogens has been well documented with the majority of success shown in container systems (Hoitink and Fahy, 1986). Popular uses include residential and commercial gardening, landscaping, and agriculture. Composting comes in many different forms. The type of composting depends on the space available, the length of time required for composting and the amount of effort you are willing to put forth. Composting allows you to take advantage of nature's recycling program to create usable gardening soil. There are three types of composting anaerobic, aerobic and vermicomposting.

What is Vermicompost?

Vermicompost is nothing but the excreta of earthworms, which is rich in humus and nutrients. Vermicompost is greatly humified through the fragmentation of the parent organic materials by earthworm colonization by microorganisms (Edwards and Neuhauser, 1988; Edwards, 1998). It is a non-thermophilic process by which organic materials are converted by earthworms and microorganisms into rich soil amendments with greatly increased microbial activity and nutrient availability. Earthworms have been on the earth for over 20 million years. They are nature's way of recycling organic nutrients from dead tissues back to living organisms. Many have recognized the value of these worms. Ancient civilizations, including Greek and Egyptian valued the role earthworms played in soil. The Egyptian Pharaoh, Cleopatra said, "Earthworms are sacred." She recognized the important role the worms played in fertilizing the Nile Valley croplands after annual floods. Charles Darwin was intrigued by the worms and studied them for 39 years, referring to an earthworm, Darwin said, "It may be doubted whether there are many other animals in the world which have played so important a part in the history of the world." The earthworm is a natural resource of fertility and life.

The process of preparing valuable manure from all kinds of organic residues with the help of earthworms is called "vermicomposting" and this manure is called vermicompost. Vermicomposting is an effective way to increase organic matter of the soil and in doing so increases the productivity as well. Among their superior chemical attributes, Edwards and Burrows (1988) reported that vermicomposts, especially those from animal waste sources, usually contained more mineral elements than commercial plant growth media, and many of these elements were changed to forms that could be readily taken up by the plants, such as nitrates, exchangeable phosphorus, and soluble potassium, calcium, magnesium etc.

Process of vermicomposting

The earthworm-processed organic wastes, often referred to as vermicomposts, are finely divided peat-like materials with high porosity, aeration, drainage, and water holding capacity (Edwards and Burrows, 1988). Earthworms consume and fragment the organic wastes into finer particles by passing them through a grinding gizzard and derive their nourishment from microorganisms that grow upon them. After digestion, the undigested material moves through the alimentary canal of the earthworm, a thin layer of oil is deposited on the castings. This layer erodes over a period of 2 months. So although the plant nutrients are immediately available, they are slowly released to last longer. The process in the alimentary canal of the earthworm transforms organic waste to natural fertilizer. The chemical changes that organic wastes undergo include deodorizing and neutralizing. This means that the pH of the castings is 7 (neutral) and the castings are odorless. The worm castings are very important to the fertility of the soil. Castings contain 5 times the available nitrogen, 7 times the available potash, and 1½ times more calcium than found in good topsoil. The worm castings also contain bacteria, so the process is continued in the soil, and microbiological activity is promoted. Ample research has demonstrated that earthworm castings have excellent aeration, porosity, structure, drainage, and moisture-holding capacity. The content of the earthworm castings, along with the natural tillage by the worms burrowing action, enhances the permeability of water in the soil. Worm castings can hold close to nine times their weight in water. "Vermiconversion", or using earthworms to convert waste into soil additives, has been done on a relatively small scale for some time. The worm castings contain higher percentage (nearly two fold) of both macro and micronutrients than the garden compost (Table 1).

Table 1. Nutrient composition of vermicompost and compost

Nutrient element	Vermicompost (%)	Compost (%)
Organic carbon	10-14	12
Nitrogen	0.51–1.6	0.8
Phosphorus	0.19-1.02	0.4
Potassium	0.15-0.73	0.5
Calcium	1.18-7.61	2.2
Magnesium	0.093-0.568	0.5
Sodium	0.06–0.16	< 0.01
Zinc	0.0042–0.011	0.0012
Copper	0.0026–0.0048	0.0017
Iron	0.2050–1.3313	1.1690
Manganese	0.0105–0.2038	0.0414

Source: *Based on vermicompost analysis in Kadapa, Nalgonda, Anantapur etc clusters.
Source: (Srinivasarao et al. 2011)

Earthworms for composting

Of the 4,400 identified earthworm species, specific species of litter-dwelling earthworms are required for the process of vermicomposting, classified as *epigeic* earthworms, they tend to be more pigmented than the other species that create burrows and live in soil (Fig. 5). *Eudrilus eugeniae* is a species of earthworm native to tropical West Africa and now widespread in warm regions, both wild and under vermiculture, also called the African night crawler. *Eisenia foetida* worms are used for vermicomposting. They are native to Europe, but have been introduced (both intentionally and unintentionally) to every other continent except Antarctica. *Eisenia foetida* is commonly used for cow dung vermicomposting in many parts of India. *Perionyx excavatus* is a commercially produced earthworm. They are also known as "blues" or "Indian blues". They belong to the *Perionyx* genus. Their origins may be the Himalayan Mountains. This species is particularly good for vermicomposting in tropical and subtropical regions. Limiting factors for vermicomposting include insufficient water supply, extremely cold weather

Figure 5 : Various types of earthworms used for vermicomposting in India (Source: TNAU Agric-Portal).

conditions, poor quality of feedstock's, high salinity in feedstock's, poor management of worm beds, and lack of suitable species and ready supply of earthworms to begin and continue the task. Although composting earthworms may multiply rapidly when the key process variables are present and at optimum levels, it takes time for a small number of earthworms to multiply. Some have claimed that earthworms may double their biomass every 90 days or thereabouts. However, abundant anecdotal evidence confirms that earthworms are capable of multiplying rapidly, where conditions are optimal.

Why vermicomposting?

Vermicompost is an important source of organic manure. It has the following useful attribution

- helpful in recycling any organic wastes into a useful biofertilizer and leaves no chance of environmental pollution.
- a eco-friendly, non-toxic product, consumes low energy input while processing.
- a preferred balanced nutrient source.
- Improves physical, chemical and biological properties of soil without any residual toxicity.
- Reduces the incidences of pests and diseases in crop production.
- Improves quality of agricultural produce.

Materials required for preparation of vermicompost

Key materials required for composting are any types of biodegradable wastes such as crop residues, weed biomass, vegetable waste, leaf litter, house-hold waste, hotel refuse, and waste from agro-industries, cow dung, biogas slurry, and biodegradable portion of urban and rural wastes. And the five essential commodities are a hospitable living environment, usually called "bedding"; a food source; adequate moisture; adequate aeration and protection from temperature extremes, and are discussed below:

i. Bedding material/organic residue

Bedding is any material that provides the worms with a relatively stable habitat. Some of the commonly used bedding materials are peat moss, corn silage, hay, straw, paper mill sludge, sawdust, shrub trimmings, shredded plant stalks, corn stalks and corn cobs. By shredding plant biomass such as cotton, pigeonpea stalks and weed into small pieces gives impetus for production of good quality vermicompost. Bedding materials should have high moisture absorbance as the worms breathe through their skins and therefore must have a moist environment in which to live. Although the worms do consume their bedding as it breaks down, it is very important that this be a slow process. High protein/nitrogen levels in bedding material can result in rapid degradation and its associated heating, creating inhospitable, often fatal, conditions. Another material in this category is paper-mill sludge, which has the high absorbency and small particle size, which so well complements the high C: N ratios and good bulking properties of straw, bark, shipped brush or wood shavings. If available, shredded paper or cardboard makes excellent bedding, particularly when combined with typical on-farm organic resources such as straw and hay. Vermiculture bed or worm bed (3 cm) can be prepared by placing saw dust or husk or coir waste or sugarcane trash in the bottom of tub / container. A layer of fine sand (3 cm) should be spread over the culture bed followed by a layer of garden soil (3 cm). All layers must be moistened with water. This will give impetus for production of good quality vermicompost and allows usage of all kinds of biomass such as cotton and pigeonpea stalks, weed biomass etc.

ii. Housing or shed facility

Vermicompost can be produced in any place with shade, high humidity and cool surrounding. The waste heaped for vermicompost production should be covered with moist gunny bags. Vermicompost can be prepared on the floor in a heap; in pits (up to 1 m depth); in an enclosure with a wall (1m height) constructed with soil and rocks or brick material or cement; and in cement rings. Some low cost farm waste boundary (pigeonpea stock) structures are also useful for vermicomposting, but quality of compost is poor. Sheltered culturing of worms is recommended to protect the worms from excessive sunlight and rain. All the entrepreneurs have set up their units in vacant cowsheds, poultry sheds, basements and back yards. Cement tanks were constructed. These were separated in half by a dividing wall. Another set of tanks were also constructed for preliminary decomposition. A cement tub may be constructed to a height of 2½ feet and a breadth of 3 feet. The length may be fixed to any level depending upon the size of the room. The bottom of the tub is made to slope like structure to drain the excess water from vermicompost unit, which is called as vermin wash (Figure 6). A small sump is necessary to collect the drain water. In another option over the hand floor, hollow blocks / bricks may be arranged in compartment to a height of one feet, breadth of 3 feet and length

Figure 6 : Containers for vermicompost production models used in 8 districts of Andhra Pradesh

to a desired level to have quick harvest. In this method, moisture assessment will be very easy. No excess water will be drained. Vermicompost can also be prepared in wooden boxes, plastic buckets or in any containers with a drain hole at the bottom, as illustrated in Figure 6.

iii. Worm food

Compost worms are big eaters. Under ideal conditions, they are able to consume in excess of their body weight each day, although the general rule-of-thumb is ½ of their body weight per day. They will eat almost anything organic (that is, of plant or animal origin), but they definitely prefer some foods to others. Manures are the most commonly used worm feedstock, with dairy and beef manures generally considered the best natural food for *Eisenia foetida*. The former, being more often available in large quantities, is the feed most often used. Cattle manure provides good nutrition, whereas the poultry manure has a high N content resulting in good nutrition and a high-value product. Sheep and goat manure, fresh food scraps and sea weed are also excellent sources of nutrition.

iv. Cowdung/biogas slurry

Cattle dung, farm wastes, crop residues, vegetable market waste, flower market waste, agro industrial waste, fruit market waste, sheep dropping, biogas slurry, husks and corn shells and all other bio degradable waste are suitable for vermicompost production. The cattle dung should be dried in open sunlight before used for vermicompost production. All other waste should be predigested with cow dung for twenty days before placing in vermibed for composting. The predigested waste material should be mud with 30% cattle dung either by weight or volume. The mixed waste is placed into the tub / container up to brim. Over this material, the selected earthworm is placed uniformly. For one-meter length, one-meter breadth and 0.5-meter height, 1 kg of worm (1000 Nos.) is required. There is no necessity that earthworm should be put inside the waste. Earthworm will move inside on its own.

Traditionally cow dung has been used as a fertilizer; today dung is collected and used to produce biogas. This gas is rich in methane and is used in rural areas of India and elsewhere to provide a renewable and stable source of energy. Vermicompost can be made from the slurry of bio-gas plants. The vermicompost made from the bio-gas plant slurry is highly concentrated in bacteria. The biogas slurry aged aerobically for 15 days enhances vermicomposting process.

v. Watering the vermibed

Daily watering may not be required for vermibed. However, depending on the ambient temperature and humidity, frequency of watering needs to be adjusted. But 60% moisture should be maintained throughout the period. If necessity arises, water should be sprinkled over the bed rather than pouring the water. Watering should be stopped before the harvest of vermicompost.

Earthworm multiplication

The bedding and feeding materials are mixed, watered and allowed to ferment for about two to three weeks in the cement rings or sheds (Fig. 7). During this period the material is overturned 3 or 4 times to bring down the temperature and to assist in uniform decomposition. When the material becomes quite soft, it is transferred to the culture containers and worms ranging from a few days to a few weeks old are introduced into them. A container of 1mx1mx0.3m, holds about 30-40 kgs of the bedding and feeding materials. In such a container, 1000 - 1500 worms are required for processing the materials. The material should have 60 per cent moisture, a pH of 6.3 to 7.5, and a temperature range of 20 to 30^{o}C. The earthworms live in the deeper layers of the material. They actively feed and deposit granular castings on the surface of the material. The worms should be allowed to feed on the material until it is converted into a highly granular mass. The earthworms take 7 weeks to reach adulthood. From the 8th week onwards they deposit cocoons. One mature worm can produce two cocoons per week. Each cocoon produces 3-7 young after an incubation period of 5-10 days depending on the species of worms, quality of feed and general conditions. The resulting increase is about 1200-1500 worms per year from initial 100-200 worms. The population doubles in about a month's time.

Figure 7 : Vermicompost preparation at household level (cement ring) and community level (sheds)

The procedure for preparation of vermicompost is similar for all the methods. For example, the preparation in cement rings is described below step by step.

- Cover the bottom of a cement ring with a polythene sheet.
- Spread a layer (15-20 cm thick) of organic waste material on the sheet.
- Sprinkle rock phosphate on this layer for enrichment depending upon need.
- Prepare cow dung slurry.
- Sprinkle the slurry as a layer.
- Fill the ring completely with the material in layers.
- Paste the top portion of the ring with cow dung or soil.
- Allow the material to decompose for 20 days.
- After 20 days release selected earthworms through the cracks.
- Cover the ring with wire mesh or gunny bags to prevent birds from picking the earthworms.
- Sprinkle water at 3-day intervals to maintain adequate moisture and body temperature of the earthworms.

- Check compost after about 2 months. Vermicompost is ready in 2-2½ months. It is black and light, and has no smell.
- When the compost is ready, remove from the ring and heap as a cone.
- Leave the heap undisturbed for 2 to 3 hours to allow the earthworms to move down the heap slowly.
- Separate the upper portion of the heap.
- Sieve the lower portion of the heap to separate the earthworms which can be used again for preparation of vermicompost.
- Pack the compost in bags and store these in a cool place.

Harvesting of vermicompost

The harvesting of vermicompost involves the manual separation of worms from the castings. For this purpose, the contents of the containers are dumped on the ground in the form of a mound and allowed to stand for a few hours. Most of the worms move to the bottom of the mound to avoid light. The worms collect at the bottom in the form of a ball. At this stage, the vermicompost is removed to get the worms. The worms are collected for new culture beds. The vermicompost collected is dried, passed through a 3 mm sieve to recover the cocoons, young worms, and unconsumed organic material (Fig. 8). The cocoons and young worms are used for seeding the new culture beds. The vermicompost recovered is rich in macro-nutrients, microbes such as *actinomycetes* and nitrogen fixers, and is used as manure. In the tub method of composting; the castings formed on the top layer are collected periodically. The collection may be carried out once in a week. By hand, the casting will be scooped out and put in a shady place as heap like structure. The harvesting of casting should be limited up to earthworm presence on top layer. This periodical harvesting is necessary for free flow and to retain the compost quality. Otherwise the finished compost gets compacted when watering is done. In small bed type of vermicomposting method, periodical harvesting is not required. Since the height of the waste material heaped is around 1 foot, the produced vermicompost will be harvested after the process is over.

Separation of earthworm

After the vermicompost production, the earthworm present in the tub/small bed may be harvested by trapping method. In the vermibed, before harvesting the compost, small, fresh cow dung ball is made and inserted inside the bed in five or six places. After 24 hours, the cow dung ball is removed. All the worms will be adhered into the ball. Putting the cow dung ball in a bucket of water will separate this adhered worm. The collected worms will be used for next batch of composting. Worm harvesting is usually carried out in order to sell the worms, rather than to start new worm beds. Expanding the operation (new beds) can be accomplished by splitting the beds that is, removing a portion of the bed to start a new one and replacing the material with new bedding and feed. When worms are sold, however, they are usually separated, weighed, and then transported in a relatively sterile medium, such as peat moss. To accomplish this, the worms must first be separated from the bedding and vermicompost. There are three basic categories of methods used by growers to harvest worms: manual, migration, and mechanical. Each of these is described in more detail in the sections that follow.

Figure 8 : Mechanical (left) and manual (right) separation of earthworms

Manual separation is used by hobbyists and smaller-scale growers, particularly those who sell worms to the home vermicomposting or bait market. In essence, manual harvesting involves hand-sorting, or picking the worms directly from the compost by hand. This process can be facilitated by taking advantage of the fact that worms avoid light. If material containing worms is dumped in a pile on a flat surface with a light above, the worms will quickly dive below the surface. The harvester can then remove a layer of compost, stopping when worms become visible again. This process is repeated several times until there is nothing left on the table except a huddled mass of worms under a thin covering of compost. These worms can then be quickly scooped into a container, weighed, and prepared for delivery. There are several minor variations and/or enhancements on this method, such as using a container instead of a flat surface, or making several piles at once, so that the person harvesting can move from one to another, returning to the first one in time to remove the next layer of compost. They are all labour-intensive, however, and only make sense if the operation is small and the value of the worms is high. Earth worms have a large number of predators, including: birds, fowl, rodents, frogs, toads, snakes, ants, leeches, and flat worms such as *bipalium*. To avoid attacks of these predators vermiculture should be practiced in protected places.

Storing and packing of vermicompost

The harvested vermicompost should be stored in dark and cool place. Sunlight should not fall over the composted material. It will lead to loss of moisture and nutrient content. It is advocated that the harvested composted material is openly stored rather than packed in over sac. Packing can be done at the time of selling. If it is stored in open place, periodical sprinkling of water may be done to maintain moisture level and also to maintain beneficial microbial population. If the necessity comes to store the material, laminated sac is used for packing.

This will minimize the moisture evaporation loss. Vermicompost can be stored for one year without loss of its quality, if the moisture is maintained at 40 per cent level. The various steps involved in the preparation of vermicompost are as follows (Fig. 9).

Steps in Vermicomposting

Collection of wastes and processing including shredding and separation of non-degradable material.

↓

Preparation of earthworm bed. A concrete base is required to put the waste for vermicompost preparation. Loose soil will allow the worms to go into soil and also while watering; all the dissolvable nutrients go into the soil along with water.

↓

Collection of earthworm after vermicompost collection. Sieving the composted material to separate fully composted material. The partially composted material will be again put into vermicompost bed.

↓

Storing the vermicompost in proper place to maintain moisture and allow the beneficial microorganisms to grow.

Figure 9 : The various steps in the preparation of vermicompost

Nutrient value of vermicompost

In general, a great proportion of the crop nutrient input during cultivation returned in the form of the plant residues. Estimation showed that 30-35 % of applied N and P and 70-80 % for K remained in the crop residues of food crops. Such nutrient rich crop residues must be 'prepared' before they are used as a fertilizer, and earthworms are suitable candidates for the same (Suthar, 2007). Suthar (2006) demonstrated that during the vermicomposting of some crop residues mixed with cattle dung, resulted in an increase in total N (91–144%), available P (63–105%), and exchangeable K (45–90%) content of it. Therefore, ready vermicompost relatively contains more exchangeable plant nutrient in available form than those by other plant growth media. Present results support above hypothesis that worm casts can act as a best plant growth media when conjugated with some amount of NPK fertilizer. The nutrients content in vermicompost vary depending on the waste materials that are being used for compost preparation. If the waste materials are heterogeneous one, there will be wide range of nutrients available in the compost. If the waste materials are homogenous one, there will be only certain nutrients available. Studies by (Aira et al. 2002; Suthar, 2008) have revealed that vermicompost may be a potential source of nutrients for field crops if applied in suitable ratios with synthetic fertilizers. Also, vermicompost may contain some plant growth-stimulating substances. The plant-hormone-like is extensively reported in worm-processed materials possibly due to higher microbial populations (Krishnamoorthy and Vajranabhaiah, 1986; Tomati et al., 1987; Mascolo et al., 1999). Also, Suthar et al. (2005) reported a hormone like effect of earthworm body fluid on seedling growth of some legumes. The earlier workers have reported a positive effect of vermicompost application on growth and productivity of cereals and legumes, ornamental, flowering plants and vegetables, etc.

Influence of vermicompost on soil properties and crop growth

Limited studies on vermicompost indicate that it increases macropore space ranging from 50 to 500 µm, resulting in improved air-water relationship in the soil which favorably affects plant growth (Marinari et al. 2000). The application of organic matter including vermicompost favorably affects soil pH, microbial population and soil enzyme activities (Maheswarappa et al. 1999). It also reduces the proportion of water-soluble chemical species, which cause possible environmental contamination (Mitchell and Edwards 1997). By establishing vermiculture units entrepreneurs can recycle their own resources and create an effective fertilizer in the process. The extra worms that are produced can be used as feed for poultry and fish. The advantages of this technology in improving physical, chemical and biological properties of soil are listed below:

Physical properties

- It improves soil structure, texture, aeration etc. and prevents soil erosion.
- Improvement of the water holding capacity in sandy soils that reduces intermittent drought impacts on crop growth.
- Improvement in the percolation property of clay soils (from the compost's granular nature).

Chemical properties

- Improvement of soil pH (acts as a buffering agent).
- Provides available forms of nutrients.
- Increase of oxidizable carbon levels, improving the base-exchange capacity of the soil.
- It enhances the decomposition of organic matter in soil.
- It prevents nutrient losses and increases the use efficiency of chemical fertilizers.

Microbiological properties

- Vermicompost is rich in beneficial micro flora such as N- fixers, P- solubilizers, cellulose decomposing micro-flora etc in addition to improving soil environment.
- Vermicompost contains earthworm cocoons and increases the population and activity of earthworm in the soil.

Plant growth

- Encouragement of plant root growth system.
- Early and profuse plant flowering.
- Improvement in the size and girth of plant stems.
- Provides excellent effect on overall plant growth, encourages the growth of new shoots / leaves and improves the quality and shelf life of the produce.

Benefits

Farmers

- Enhancement of soil productivity
- Increase in yields with less irrigation
- Less risk of crop loss during intermittent dry spells
- Vermi wash for plant protection
- Crop produce has better taste, luster, keeping quality

Industry

- Cost-effective pollution abatement technology

Environment

- More groundwater recharge and lesser depletion of groundwater
- Reduces soil salinization and lesser soil erosion
- Less pollution as chemicals need not be purchased and used

National Economy

- Lesser imports of agrochemicals, saving valuable foreign exchange
- Boost to rural economy
- More export of agricultural produce with lower pesticide residues
- Less expenditure on water supply and pollution control
- Lesser wasteland formation

Figure 10 : Benefits of vermicompost in terms of farm productivity and environmental safety

Other benefits

- Recycling of organic wastes.
- Production of energy rich resources.
- Reduction of environmental pollution.
- Creation of a substitute protein in poultry and fish feed.
- Vermicompost is free flowing, easy to apply, handle and store and does not have bad odour.
- Vermicompost is free from pathogens, toxic elements, weed seeds etc.
- Vermicompost minimizes the incidence of pest and diseases.
- It contains valuable vitamins, enzymes and hormones like auxins, gibberellins etc
- Provision of job opportunities for women and self help groups (SHG).

Vermicomposting: On-farm experiences from rainfed tribal regions

In India, vermicomposting technology is getting increased attention during the last 2-3 decades. A number of agro-industrial organic wastes discarded as unusable, which contain essential nutrients can be exploited to improve the physical, chemical and biological properties of soil. In 1991-92, Department of Science and Technology, Government of India, promoted the adoption of vermicompost technology in 13 states in India. Under National Agricultural Innovative project (NAIP-Component III) on "Sustainable Rural Livelihoods through Enhanced Farming Systems Productivity and Efficient Support Systems in Rainfed Areas" vermicomposting was implemented as one of the soil health improvement strategies in several villages in eight backward districts of Andhra Pradesh. The soils of these villages were degraded, low in biological activity with multi-nutrient deficiencies and as a result productivity of various crops was low. It was therefore necessary to promote composting of farm waste with available crop residue and cow dung. Various forms of vermicompost units (individual, larger-community based, biogas linked-community vermicomposting units) were established in these villages.

Depending upon the number of participating farmers, number of animals and crop residue available in the village and infrastructure, various models of vermicomposting were promoted. Training programmes were conducted at NAIP clusters (Adilabad, Nalgonda, Kadapa, Anantapur, Warangal, Rangareddy, Mahboobnagar and Khammam districts of Andhra Pradesh) to train members of women self-help groups (SHGs) about technical aspects of breeding earthworms, managing and collection of organic wastes, application of vermicompost for various crops, book keeping and marketing. Community based vermicomposting units were established with self help groups in Pampanur cluster (Anantapur district) by using renovated shed; biogas linked vermicomposting unit was established in Nalgonda district, first ever in Andhra Pradesh; in Kadapa district large scale community vermicomposting unit was established with SHGs; and in Khammam district, individual house hold vermicomposting units were encouraged.

Community biogas cum Vermicompost unit at Dupahad cluster, Nalgonda

In order to promote effective recycling of valuable waste into a potential source of alternative energy, vermicomposting was encouraged at the community level. Backyard vermi compost units were promoted for individual households where common interest groups for vermicomposting units were not available. In order to address the scalability issues, the project encouraged large scale vermicomposting through farmer groups and women self help groups in Dupahad cluster (Nalgonda). Large sheds were erected for taking up vermicomposting

Figure 12 : Community biogas unit at Dupahad cluster (Nalgonda)

activities. Groups of youth were trained to prepare vermicompost by using decomposable biomass and dung. The farming community was encouraged to cart semi/undecomposed material from their backyards to the community vermicompost units. These farmers would get fully decomposed vermicompost in return to the raw material supplied by them. In addition to this, a large biogas unit was installed at the community vermicomposting unit.

This biogas unit uses dung slurry for biogas production and passes on the same for vermicomposting unit. The biogas unit has been connected to a generator (15 kva) which can produce and supply electricity to about 100 houses. These add-on features ensure the viability of vermicompost unit besides contributing to clean manure and energy production. This innovation has a high degree of scalability besides having implication in the climate change scenario. The biogas plant was constructed as per the approved designs for 85 cum capacity (Flouting drum type/KVIC Model) according to standards and designs approved by Ministry of New and Renewable Energy (MNRE), Govt of India. Manure management is an integral part of a biogas power generation system for arriving at an economically feasible operation level. Figures 12-16 illustrate the stages from feeding biogas unit to vermicompost formation. It starts with household collection of cowdung and mixing in a tub with water and then feeding the sauce into biogas tank. From the tank, biogas slurry is released through an outlet and is passed through a series of cement tanks to reduce its moisture content. The fine slurry is collected and poured into vermibed, where composting takes place.

Figure 13 : Biogas slurry conversion into semi-dry

Figure 14 : Adding semi-dry biogas slurry into vermibed

Figure 15 : Community vermicomposting and vermibeds at Dupahad cluster (Nalgonda)

Figure 16 : Final produce vermicompost and separated worms after harvesting

Biogas for empowerment of rural women

This programme also aims at providing cooking fuel and organic manure especially to rural households through community biogas plants. Biogas is generated using dung. The dung requirement is met form the cattle mostly available in rural areas.

Figure 17 : Beneficiary women's group of community biogas plant and household cooking gas connection in Dupahad clustor, Nalgonda Dist.

This scheme has the following advantages:

a) Reduction in the consumption of conventional energy sources such as kerosene, firewood, cow-dung cakes and LPG.

b) Encouraging people in villages to use dung for generation of gas and slurry from bio-gas plant as a source of vermicompost.

c) Providing the rural women clean source of cooking fuel thereby discouraging use of firewood, dung cakes.

d) Successful continuation after project period under Banjara Society.

Community vermicomposting cum calf rearing centre and enterprise, Pampanur (Anantapur district)

A community vermicomposting initiative was taken up at Kadapa cluster under NAIP, by the anchoring agency Aakruthi involving SHG women. An exposure visit to Kadapa cluster was made in August 2008 for educating SHG women of Pampanur cluster on vermicomposting. The exposure visit helped in boosting the confidence of the women to take up a collective enterprise of vermicomposting. After identifying an old abandoned building, 9 member women group sought permission for using an abandoned building of DRDA. CRIDA and BIRD-AP project staff facilitated this process. With NAIP support the building was repaired and 9 units of vermicompost were set up under one roof. First batch of compost was produced in February 2009 (21 q). Later the production capacity was increased by setting up more units by using stone slabs available in the building. Another group of women was encouraged to take up calf rearing in the remaining space. A manger was constructed for rearing calves within the building. Initially nine crossbred calves procured through revolving fund loan, later on 8 more calves were procured. The dung from calves is used for vermicomposting. Azolla units were also established and managed by the women for fodder supplementation. The uniqueness of this intervention lies in:

- Utilization of abandoned infrastructure (public & private)
- Wholly managed by women group
- Commercially viable unit
- Linking calf rearing to provide backward linkage besides optimally using the space
- Collective intervention
- Good post-project sustainability

Figure 18 : Different steps in community based vermicomposting in Pampanur cluster of Anantapur District, A.P.

Figure 19 : Enterprise of vermicomposting in Pampanur cluster of Anantapur District, A.P.

Commercially viable group enterprise – Vermi hatchery cum composting unit, Kadapa

In Kadapa, larger vermicompost units were developed, as it was felt that commercially viable unit will be more sustainable. Initially awareness was created among SHGs about the possibility of establishing commercially viable vermi hatchery unit. The group was encouraged to come out with a proposal regarding infrastructure and working capital. Women came out with a unique plan. They suggested utilizing the existing infrastructure (abandoned poultry shed) either on lease basis or partnership basis. The shed owner agreed to lease out the shed to the women's group. The women's group, that had undergone training on vermicompost making, started operating the unit successfully (Fig. 20). This helped in creation of wage employment in addition to making organic matter accessible to the vegetable farmers of the village.

Figure 20 : Vermi hatchery unit Kadapa district and vermi-wash collection

Mobile vermicomposting units - Mahboobnagar

Mobile vermicomposting units were set up in Mahboobnagar district. The size of these units was 3 m in length, 1.2 m in width and 0.5 m in height. HDPE material was used to fabricate these units, and depending upon the resources available organic wastes were collected from individual households and used as filling material. The production duration was 45 days. The cost for establishing a single unit was Rs. 1500 besides Rs. 500 for worms; Rs. 1050 for labour (7 man-day @ 150), and Rs. 500 towards other expenditure. Total production was of the order of 1030 kg. and currently vermicompost is sold at Rs. 4.50.

Figure 21 : Small-scale vermicompost models in Mahboobnagar district

Warangal

Several trainings were conducted in Jaffergudam cluster, Warangal district on the preparation of vermicomposting. Some house-hold units were initiated at the selected villages. Vermicompost thus generated, was used in vegetable cultivation and few farmers used in cotton during the years when DAP was readily unavailable at the village level.

Household level vermicomposting

Individual household level vermicomposting units were promoted in Khammam district. Farmers used cement tanks for vermicompost preparation (Fig.22).

Figure 22 : Household level vermicomposting units at Tummalacheruve cluster in Khammam Dist.

The biogas plants of 1 cu m capacity were introduced in collaboration with NEDCAP in the tribal households. In all, 97 plants were promoted and presently all the 97 are in use. Slurry from bio-gas plants is used by individual households for vermicomposting. To begin with, six households have started vermicomposting in this district.

Application of vermicompost to crops

Vermicompost can be used for all crops such as agricultural, horticultural, ornamental, and vegetable etc. But generally, vermicompost is recommended for high value vegetables and fruit crops. Application need to be done around root zone in the opened ring and covered by the soil.

- **For general use in agriculture:** 3-4 t ha^{-1}. For agricultural crops, apply vermicompost by placement beside crop row when the seedlings are 12-15 cm is height.
- **For fruit trees:** 5-10 kg per tree around the base of the tree, cover with soil and water regularly
- **For vegetables:** 3-4 t ha^{-1} around the base of the plant, cover with soil and water regularly
- **For flowers:** 500-750 kg ha^{-1} around the base of the plant, cover with soil and water regularly

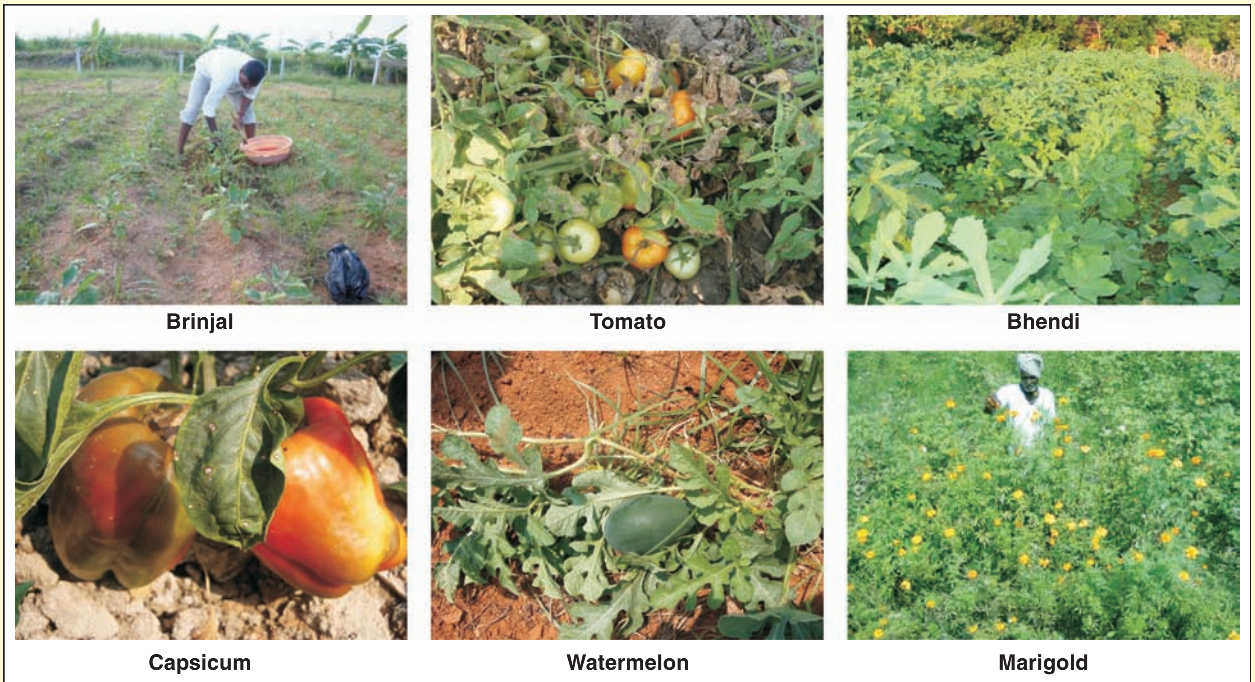

Figure 23 : Vegetable and fruit crops raised by applying vermicompost

Impact on crop productivity and income

Self help groups of women were encouraged to take up vermicomposting as income generation activity and make the vermicompost available for different agricultural crops within the cluster. This was successfully done in Anantapur, Kadapa and Nalgonda clusters. The availability of organic resources within the cluster is playing a major role in improving soil health and crop productivity. Figure 23 & 24 illustrates field application of vermicompost to various vegetable crops.

Figure 23 : Field demonstrations of vermicompost impacts on vegetable productivity

Figure 24 : Field demonstrations of vermicompost impacts on vegetable, fruit and flower crops

Addition of vermicompost along with INM including vermicompost + chemical fertilizers increased the size of watermelon in Dupahad cluster of Nalgonda district, as illustrated in Fig. 25. Watermelon produced was sold in local supermarkets and corporate supermarkets. This particular intervention of market linkages works on backward integration strategy. The profit through this intervention is around 95% more than that obtained in the local market and around 100% more than that comes from leasing the crop to vendors.

Figure 25 : Impacts of vermicompost application on fruit size, colour and productivity of watermelon in Dupahad cluster, Nalgonda Dist.

Impact on farm income

Although farmers in specific localities have similar social backgrounds and possess similar natural resources, there are often surprisingly drastic differences in their economic status. In the dry tropical regions of India, livelihood opportunities are often closely linked to soil fertility conditions. Vermicomposting is a suitable manure source for improving the soil fertility and also to enrich soil with nutrients, at the same time it enhances livelihood opportunities by increasing farmer's income. In all of the clusters marketing of compost initially is being done within the cluster, i.e. procurement of vermicompost by vegetable and fruit farmers of the cluster. In one of the clusters (Kadapa), economics of the vermicompost unit was as follows: total production done - 70000 kg; total income on sale - Rs.230000. This intervention generated an employment of approximately 800 days. Each member got profit of Rs. 9800 (Rs.7000 as wage +Rs.2800 as profit). In Ananthapur cluster, three rounds of composting produced 3 tons of compost that was sold by the women groups @ Rs 5/kg. In Nalgonda cluster over 10 tons of vermicompost has been produced from inception.

Figure 26 : Processing and packing of vermicompost for sale

Environmental impacts : Towards climate resilience

Compared with other waste related sectors such as municipal composting or recycling, vermicomposting has the potential to have a high environmental impact. Vermicomposting helps in the conservation of the environment. The organic content of earthworm droppings encourages the passage of air and water through soil. So soil ends up being a better environment for the critters of the soil food web and for plants. It likewise ends up being less likely to compact and erode. So the resources within the soil are put to best use instead of becoming inaccessible through compaction or erosion. Paper and paperboard products account for 34% of the total, food scraps and yard trimmings make up 25%, and wood waste is 0.06% (by weight). Instead of disposing of these materials in landfills, they can be recycled, composted, or vermicomposted. In India and Australia worms studied have shown to remove heavy metals from soil, which they termed vermiremediation. The accelerated humification of organic waste with less cost is the need of the hour and vermicomposting technology using earthworm is the solution for the current urban organic waste. The converted urban waste through vermicompost technology results in good humus, which is highly valued material fulfilling the major nutritional need of plants. The use of vermicompost reduces N application rate of fertilizers, in this way the vermicompost technology will reduce the harmful side effects to environment by the application of huge amounts of chemical fertilizer to agricultural field thereby reducing N_2O emission, a potential GHG. Organic matter in soil could effectively increase the activity of metals in soil and improve metal mobility and distribution in soil. The application of natural fertilizer (compost and vermicompost) in soils has helped in increase in metal mobility through the formation of soluble metalorganic complexes (Yang et al., 2005). Leachate from vermicomposting operations is often regarded as beneficial in the sense that when collected it can be used a liquid fertilizer, often called "worm tea". While this is true, the leachate also has the potential to pollute when not collected and used positively. Previous studies using earthworm reactors to help treat dilute sewage found that while such reactors achieved good results, the resulting leachate was still polluting in terms of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and nitrate concentration.

Vermicomposting in the light of current fertilizer price escalation

Green revolution in India witnessed phenomenal increase in fertilizer consumption to meet the food needs of the country. To increase food production it was a necessity to use more amounts of chemical fertilizers. High N fertilizer use and less N use efficiency results in increased cost of cultivation. The present hike in the price of chemical fertilizers has compelled the Indian farmers to resort to imbalanced nutrition of crops and thus reduction in crop yields. Gradually, because of secondary problem of green revolution such as soil health degradation, salinity, falling productivity, the need for development of alternative strategies to supply the nutrient needs of crops was necessary to reduce cost of cultivation on chemical fertilizers and their damaging effects on soil. Vermicomposting is one such strategy followed by farmer's to reduce the use of chemical fertilizers. Recently, the price of DAP-50 kg bag has increased from Rs. 487/- to Rs. 955/- within the last one and half year. An increase of nearly 100%, similar is the case with most of the chemical fertilizers. Due to the hike in DAP prices, and lack of fertilizer availability in the villages, farmers in some of the clusters purchased vermicompost at 15 rupees/kg instead of 5 rupees/kg., common price. Similarly, MOP-K fertilizer price also increased 4 folds from Rs. 7/kg K to Rs. 28/kg K during last year. Thus, due to the fertilizer price escalation in the recent past, farmers look for alternative sources of nutrients such as crop residues and vermicomposting. Therefore effective crop residue recycling and promotion of vermicomposting at household level as well as community level is need of the hour.

Government policies and subsidy facilities

In India, government agencies are giving considerable subsidies for building vermicompost pits and structures. The intervention of vermicompost subsidy component has encouraged the farmer to meet the expenditures of different over heads and certain unforeseen expenses. In India, subsidies are mainly provided by the national government and channeled through state agriculture departments; the technique is well-tested, having already been used for the synthetic fertilizer. Indeed, subsidies have been provided for, setting up biofertilizer and vermicomposting units under NPOF and for setting up export schemes under NPOP. Additional subsidies could be provided for setting up organic input production units for composting. Various states in India have different subsidy patterns. In Andhra Pradesh the government was granting Rs. 15,000 subsidy on each vermicompost unit and there was no restriction on the number of such units. The government would purchase the vermicompost and hence there is no marketing problem.

Conclusion

Vermicomposting technology is known throughout the world, albeit in limited areas. It may be considered a widely spread, though not necessarily popular technology. As a process for handling organic residues, it represents an alternative approach in waste management, in as much as the material is neither land filled nor burned but is considered a resource that may be recycled. In this sense, vermicomposting is compatible with sound environmental principles that value conservation of resources and sustainable practices. Vermicompost is a valuable input for sustainable agriculture and wasteland development in India. There are many successful farmers' experiences of using vermicompost from different climatic zones of the country. There will be lot of demand for vermicompost in future for developing cultivable land subjected to some form of degradation. Vermicomposting is akin to composting in that similar feedstock's i.e. organic residuals are used. A two-part program, consisting of both composting and vermicomposting, may be useful when introducing the concept of adding organic material for agricultural and horticultural production. Composting is, by far, the simpler of the two processes and involves fewer risks. Where soil is severely lacking organic matter, the addition of compost alone would pay huge dividends. Once composting has been implemented in a new situation, vermicomposting may be introduced later on as a secondary process, offering a better product but requiring better management as well. Both systems utilize microbial activity to break down organic matter in a moist, aerobic environment. In areas where creation of low or semi-skilled jobs is considered advantageous, vermicomposting may supply an opportunity for employment. Where accumulation of food waste, paper, cardboard, agriculture waste, manures, and biosolids is problematical, composting and vermicomposting offer potential to turn waste material into a valuable soil amendment. Vermicompost, a more valuable commodity, is best used sparingly such as in container media, greenhouse application, establishing new plants such as rootstock in vineyards, and wherever it can be directed in close proximity to plants.

Way forward

Awareness about the usefulness of vermicompost is critical for its promotion. Therefore, government agencies and NGOs are popularizing INM in agriculture using vermicompost by organizing awareness campaigns in rural and urban areas. Some of the agricultural universities have started schemes on vermicomposting, such as vermicompost production scheme implemented to conduct demonstration and training to farmers. Mass rearing and maintaining of worm cultures and tapping of organic wastes for their maintenance has a good scope for developing it as a cottage industry. Organic waste recycling through vermicomposting in rural areas can create an asset at the farm level which can act as a source of nutrient self sufficiency. Unlike large scale industries which occupy prime land close to the urban centers, vermicomposting units can be built at the farm level or at the back yards of rural households as it requires minimal space. The cost of setting up vermicompost units can be borne by rural infrastructural fund or from grants from the government, as it has the potential to create employment at the rural areas while supporting the nutrient security efforts. Vermicompost production encourages local and decentralized nutrient production and recycling systems which are economical and eco friendly.

Acknowledgements

Authors are thankful to all the consortium partners, Co-PIs of the project, CCMT members of 8 NAIP clusters, project staff in 8 districts and participating farmers in the project.

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Annexure

Schemes of government, banks etc

- NWDPRA (River Valley Project).
  {*www.karunadu.gov.in/watershedsite/nwdpra_proj.htm*}

- NABARD (Capital Investment Subsidy Scheme for Commercial Production Units of Organic Inputs under "National Project on Organic Farming).
  {*www.nabard.org/pdf/Circular-NPOF.pdf*}

- Integrated scheme (the Khadi and Village Industries Board (KVIB) and the Non-Conventional Energy Development Corporation of Andhra Pradesh (NEDCAP).
  {*http://planningcommission.nic.in/reports/peoreport/peoevalu/peo_npbd.pdf*}

- CMSA (Community Managed Sustainable Agriculture)
  {*www.rd.ap.gov.in/NPM/NPM_presnt.pdf*}

- DBT (Agro-ecological conservation using Integrated Approach)
  {*www.kvk.pravara.com/horti/dbtbio.htm*}

- Agriclinics and agribusiness centers
  {*www.agriclinics.net/*}

Vermi hatcheries

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