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Novel treatment of selected post industrial textile waste into a sustainable product for agriculture

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Abstract

A statistical survey reports the fact that the total amount of willow dust generated, is about 80, 000 - 85, 000 tons per annum. [1] This willow waste is too short a fiber to be used for any textile application and is just disposed off as landfills. A better alternative for this waste was designed and thus the research aims in biomanaging this cotton textile waste by using three tier system of enzyme-earthworm-microbe interaction. Pretreatment and enzymatic treatment of the cotton textile waste enhanced good growth of earthworms with an additional benefit of reducing the toxicity of the wastes. The resultant vermicompost was a very good substitute for chemical fertilizer with a good source of carbon and appreciable amount of NPK. On addition of cellulose degraders, nitrogen fixers and phosphate stabilizers the compost can be converted into rich source of biofertiliser also. The efficacy of the prepared compost was analyzed using a pot culture study and the results were compared with control pot.

Key words: willow waste, decomposing, composting, biocompost, vermicomposting, textile recycling

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1. Introduction

In this era of green consumerism people's preference for organic products has introduced number of inventory practices for the development and effective utilisation of cotton textile and its byproducts. Perspective of age old days: the population was less, needs were few and resources were abundant. The generation of waste was such that it got naturally recycled, being mostly biodegradable. Conversely, after the advent of industrial revolution different types of wastes came into existence which are often both non-biodegradable and highly hazardous.

The total cotton fiber consumption in our country is estimated to be 26 lakh tons per year, of which approximately 2, 10, 000 tones of cotton dust (non-saleable waste) is produced during yarn manufacturing process. This willow waste is too short a fiber to be used for any textile application and is just disposed off as landfills, which if not

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degraded properly leads to infectious diseases and release of foul odour causing a hindrance to the ecosystem and people. Most of these wastes are disposed off by burning, which inturn increase carbon dioxide level in the atmosphere which adds on to the global warming. [2]

Comparative analysis shows that the cotton production has remained stagnated over the past few years wherein the main reason being loss due to pests. So in the process of increasing the productivity, more and more of synthetic formulations are used [3]**.** The latest set back in textiles is also the same abuse of chemicals in the form of fertilizers and pesticides, which have caused a downbeat on the health of animals, human and the general ecological balance. WHO report quoted that, every year 20,000 farmers die because of insecticides and their harmful effects. [4] Besides the fact that cotton is a fertilizer dependant crop, it has an undisclosed fact: that 65% of the chemicals used during cultivation enter into both directly and indirectly into our food chain, which is extremely agonizing.

Natural fertilisers, compost and soil amendment have enabled organic cotton to a viable enterprise comment [5]. Therefore the waste was recycled into a biocompost by the use of vermicomposting and enzyme technology which can be a very convincing effort to reduce and recycle waste. Vermicomposting, in its broadest sense is waste minimization. In addition to creating home for millions of microorganisms it plays a vital role in reducing the toxicity of the wastes. Undoubtedly, the manure castings excreted by worms, is an effective biofertiliser, which has a high content of readily available minerals for plant growth, which can be an enormous relief to the above discussed hitch.

Cultivation of organic methods has helped farmers to improve sustainable productivity. Thus a research was designed to make the selected textile waste into an eco-friendly product that can be gifted from the industry that pollutes the maximum (textiles), to the industry most pioneering and essential to mankind that is, agriculture, which might reduce the curse on the former industry. Unlike recycling textile waste into a textile product again, the composting and vermicomposting will open up newer vistas in textile recycling technology. This is a new beginning which will throw smiles on our poor hard toiled farmer, by reducing the dependence, on costly and hazardous chemicals and pesticides.

2. Materials and methods

2.1. Selection of Waste:

Many types of waste like willow fly, raising fly, flat strip, dirty oily cotton, comber noil are produced during the processing of textiles. These are lifted by traders and get Rs 7/-to Rs 32/ per kg depending on the quality of waste. **[**2**]** But certain other types of waste like the willow waste/micro dust find no end use and are just disposed in the landfill. Due to lack of landfill sites and its related problems, we need to reduce our landfill waste drastically [6]. Reports say that the solid waste of industries should be biocomposted before applying to soil in order to achieve biological transformation of organic matter to avoid potential risks of pathogens [1]. The waste from the ginning

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factories are rich in minerals, tricarboxyalic acids, proteins and thus good quality compost can be prepared from it [7]. Considering these facts willow waste was selected for the study.

2.2. Collection, Pre-treatment and Processing of Waste:

The investigator visited nearby OESM (Open End spinning mills) and collected the willow waste in clean bags. The collected waste was loosened and checked for any metal particles and later transferred into a wide plastic bin.

Natural cellulosic fibers are known to be biodegradable, ecofriendly and don't harm the natural ecological balance of the environment [8]. A very note worthy program, to reduce the amount of waste as landfill was done by a company named Sampson (Sampson County, 55 Agriculture Pl, Clinton, NC 28328) which implemented vermicomposting program that transforms high grade compost, from food, paper and cotton fiber waste [9]. Considering these facts, the willow waste was subjected to vermicomposting program.

The result of case studies suggests that cellulase can be used in the treatment of wastes from cotton industry. The three tier system of enzyme-earthworm-microbe interaction with a pretreatment and enzymatic treatment of waste material proves to enhance good growth of earthworms. The resultant product with addition of cellulose degraders, nitrogen fixers and phosphate stabilizers can be converted into rich source of biofertilisers [10]. Taking this into consideration, the investigator subjected the collected waste to enzymatic treatment.

2.3. Treatment with selected enzymes

2.3.1. Selection of Enzymes:

Cotton fibers are basically made up of flexible cellulose [11] and the biodegradation of which can be facilitated by enzyme known as "cellulase" that can be produced by microorganisms like bacteria or fungi. Generally cellulosic material is biodegradable with species like *trichoderma viride, aspergillus sp.* and the *cochlea helix pomatia* as they have the ability to decompose cotton fiber. [Source: National Cotton Council and Cotton Inc. (United States) [13][14] Hence the researcher selected the enzymes cellulase and amylase for the study. The enzymes were extracted from the sources namely *trichoderma species* and *Aspergillus niger* respectively in the Bio-textile laboratory, Avinashilingam university for women, Coimbatore.

2.3.2. Selection of Source for Enzyme Extraction:

Cellulase can be obtained from cellulose substrate. [15] The dung of chewing animals is rich in cellulose enzymes. Apart from the fact that it is eco-friendly, naturally available and low cost enzyme**.** Also cellulase originating from trichoderma sp. fungus can also degrade cotton cellulose efficiently [16]. Amylase can be obtained from bacillus source [17] can act on cellulose and decreases its strength [10**]**

Taking into consideration these facts cow dung was selected as the source for extraction of enzymes.

2.3.3. Isolation and Screening of Selected Enzymes:

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Fungi was isolated from the cow dung by using serial dilution technique, sample suspension was prepared by mixing one gram of cow dung in 4ml of sterile distilled water and serially diluted up to 10^{-7} dilution, Aliquots from 10^{-4} dilution for fungi was used. Rose Bengal gram agar applying eight petri dishes were taken and sterilized in hot air oven at 110^{0} C for 10 mins. In this 0.1 ml of sample suspension was pour plated. Two hundred of Rose Bengal gram agar solution was taken in a conical flask and sterilized in the autoclave for 30 mins after 30 mins. The conical flask was taken out and 25ml of agar solution was poured to each sterilized petri plates. These plates were incubated at room temperature 25 to 2 degree° C for seven days. After incubation the fungal colonies were identified visually

After incubation the colonies were identified visually and selected enzymes were extracted. Since the enzymes were used only for decomposing they were used in their crude form of nature. The extracted enzymes were stored in the fridge to be added alone with decomposing source.

2.4. Decomposing of wastes:

Decomposition refers to reduction of living organism into simpler forms of matter [18] in which various environmental factors like moisture, temperature, presence or absence of oxygen play a prominent role. [19]

2.4.1. Selection of Decomposing Source:

Cow dung is the digested residue of herbivorous matter which is acted upon by symbiotic bacteria residing within the animal's rumen. [20] Case studies reveal the potentiality of cow dung in the decomposition of disposable diapers and sewage sludge [21][22]**.** Also, fly ash waste mixed with cow dung and vermicomposted using Eudrilus eugeniae for 60 days, in different combinations showed that, 1:3 of fly waste and cow dung was found to be the best [23] On viewing the above detail, cow dung was selected as decomposing source to act with the collected waste.

2.4.2. Collection and Mixing of Cow dung:

The investigator visited the nearby cattle farm early in the morning and collected cow dung and mixed with equal proportion of willow waste. Fifteen ml of the extracted cellulase and amylase enzymes were added to the mixture to ensure a composition for earthworm feeding. The process was repeated twice for a period of ten days and the material was overturned. The material was sprinkled with water and overturned every day. (Plate 1)

2.4.3. Preparation and addition of EM Solution:

Effective microorganisms (EM technology) is a scientific method of improving soil quality and plant growth using a mixture of microorganisms consisting mainly of lactic acid bacteria, purple bacteria and yeasts which co-exist for the benefit of whichever environment they are introduced. The application of effective microorganism in waste management is remarkable and was prepared in the following procedure.

Powdered jaggery (75 gms) was dissolved in warm water and poured in a glass bottle of one liter capacity having a glass cap to cover airtight. The stock solution required for the preparation of EM was collected from the Department of Extension Education, Avinashilingam University for Women, Coimbatore. The stock solution was

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poured into the bottle. The remaining portion was filled with warm water. The bottle was kept away from direct sunlight (dark place) for a period of seven to ten days. The pressure built up was released by unscrewing the cap of the container once a day.

After a week, the solution colour changed from brown to light orange and also white mould on the top accompanied with a sweet sour smell. The solution was then ready to be used in the study [Catalogue National Environment Awareness Campaign (NEAC)]

Many factors determine the rate of decomposing of cotton. There are samples of cotton that remain for more than 10,000 years, but however under favorable conditions, cotton can decompose within a period of two weeks [24]. Considering this, the investigator thoroughly mixed the cotton waste with 15ml of the prepared Effective Microorganism solution.

2.5. Actual Decomposing:

The collected willow waste was mixed with of cow dung, fifteen ml of cellulose, amylase and effective microorganism solution were all added. (Plate 1) Water was sprinkled once in two days and the mixture was turned thoroughly to maintain the pH and moisture. After 20 days the waste was found to have completely decomposed after which the earthworms were introduced. Care was taken to maintain the pH and moisture. When the mixture turned into light brown, with good smell the willow waste vermicompost was ready. This waste was taken dried in shade and stored for pot culture study.

Plate 1
Collection and processing of willow waste

Collection of willow waste

Mixing of willow waste with cow dung slurry

Addition of Effective microorganisms

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Mixing of wastes for decomposing

Periodic turning and watering of willow waste

Introduction of worms

2.6. Vermicomposting

A major portion of solid waste (more than 60%) is decomposable which can be used for vermicomposting [25]. The potential of earthworms have been proved in decomposing waste. Where the breakdown of organic waste can be made as profit, producing useful material and also reduce pollution [26**]**

2.6.1. Selection and Introduction of Species

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More than 3000 species of earthworms are found in nature among them only 5-6 are used in agriculture [27]. Globally, *Eudrillus eugeniae* is popular for vermicomposting in subtropical and tropical countries [28] and thus the investigator selected the African earthworms, namely *Eudrillus eugeniae* (sp.), which is of engenous type and surface feeders in nature. One kilogram of earthworms Rs 250/- consisting of around 1000 worms were purchased from H5 Organics, Thudiyalur, Coimbatore. Small scale vermicomposting can be managed in plastic buckets, wooden or earthworm pots, cement tanks and metal brins having holes for proper variation. Considering the suggestion the waste decomposing was done in a plastic bucket.

2.6.2. Collection and storage of Prepared Biocompost

The earthworms perforated and loosened the willow waste compost resulting in an infinite numbers of lumps of worm casts. (Plate 2) Composting process can be marked as complete by the earthworms when the waste mixture turns into light brown or dark brown [29]. This change was seen in the bedding at the end of 14days. The composted waste was separated and collected in a wooden bin. (Plate 2) The vermibed is taken care of to maintain the pH, temperature and moisture. So it is periodically sprinkled with water. The finished compost was kept away from direct heat and sunlight as recommended [30]

Plate 2

Collection and storage of vermicompost

Checking of the vermicompost

(Loose brown particles with good smell)

Periodical Collection of vermicompost

(Top layer)

Storage of vermicompost

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Sieving of vermicompost

Ready for use

2.7. Analyzing the efficacy of the prepared vermicompost In order to study the effectiveness of the prepared vermicompost pot culture study was selected.

2.7.1. Pot Culture Study

Pot culture experiments can be conducted to ascertain the enrichment in soil quality, growth response of selected plant species. Pot culture is the simplest form of hydroponics (growing plant with nutrients and not soil). It involves use of an inert medium such as greenmix in a plastic pot in place of soil**.**[31]

Plate 3
Pot Culture Study

Cotton Seeds | Marigold Seeds | Soaked Green Gram | Lady's Finger Seeds

Collection of Soil | Preparation of pots (sun drying) | Labeling of pots | Mixing of red soil and river sand

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Mixing Of Soils Filling Of Pots Sowing of Seeds

2.7.2. Selection of Plants

The major problem in growing cotton is use of chemical fertilisers and pesticides. In order to solve this problem the investigator wanted to evaluate the efficacy of prepared vermicompost to grow cotton plant. Marigold, lady's finger and green gram dhal are commonly used for pot culture study because of their short life span and ability to grow and flower quickly. Hence four plants namely cotton, marigold, lady's finger plant and green gram dhal were selected for study. (Plate 3)

2.7.3. Selection and Purchase of Seeds

The cotton seed was selected based on lifespan and fiber qualities as the duration of the study was short. In MCU 13 variety, the fiber had many superior qualities. The staple length was 30.3mm, fiber strength was 23.0 g/Tex, fineness 4.2 and spinability as 35% producing 50s count fabrics. [32]. The fiber is very common in southern regions of Tamil Nadu with a lifespan of 150 days. Hence, MCU 13 variety was selected and purchased from the Central Institute for Research on Cotton Technology, Coimbatore. The seeds for the other three plants were purchased from Tamil Nadu Agriculture University, Coimbatore.

2.7.4. Purchase and Preparation of Pots

The investigator purchased a total of eight medium sized earthen pots of dimension 10" x 8" to grow and compare the plants. Four pots for the control sample and four pots to grow plants using the willow waste vermicompost. The purchased pots were cleaned with an emery paper and washed in a large tank of cold water.

The pots were immersed in the tank for 24 hours and later dried in sun. The pots were labeled in white enamel paint as per the nomenclature followed in the study. (Plate 3)

2.7.5. Preparation of Soil

The ideal garden soil should be deep, loose, fertile, well-drained with plenty of organic matter and also free of weeds and diseases. The usage of red soil is highly recommended since it dries slowly after a rain and the spaces

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between the soil particles are small and thus water moves through them slowly. Sandy soil, on the other hand, has many spaces and dry out quickly.

Red and sandy soils were thus mixed and used to substitute for a rich loam by adding organic matter. (Plate 3) Increasing the organic matter content of a red soil improves the internal drainage. Adding organic matter to a sandy soil increases its water-holding capacity and thus improves its fertility. [33] Based upon the studies the ratio of soil was mixed in the following proportion:

Control pot	Red soil: river sand soil	1:1
Pot with willow waste vermin compost	Red soil: river sand soil: vermicompost	1:1:3

2.7.6. Growing of Plants

The prepared soil was filled and the seeds were sown. Care was taken to maintain the growth of the plants by proper watering and maintenance. The growth of the plants was recorded every day and factors like germination, growth, root length, flowering ratio and vegetable growth were regularly recorded. (Plate 4)

2.8. Evaluation

Plate 4

Periodic supplementation, watering and checking the shoot length

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2.8. Evaluation

Wikipedia defines evaluation as the systematic determination of merit, worth, and significance. It is used to characterize and appraise subjects of interest. Hence the prepared vermicompost evolved from the willow waste were tested.

2.8.1. Evaluating the prepared vermicompost

The presence of macro and micronutrients greatly affects the efficiency. The level of pH helps in maintaining the salinity and alkalinity of the soil. The Electrical conductivity is important in improving plant nutrient absorption and organic carbon for improving the soil texture [34]. About 78.6 % of nitrogen is found in atmosphere, soil microorganism's plays a great role in fixing this atmospheric nitrogen into the soil. This fixation is done by nitrogen fixing bacteria. This is found in the intestine of cow and its products of cow like the cow dung, etc. [35] Since the research includes cow dung, the nitrogen content of the willow waste vermicompost was evaluated.

The organic carbon content and fertility status of NPK is higher in vermicompost. [36] The worm casts ingested soil often have high content of soil organic carbon and nutrient than surroundings soil [37] also nitrogen is found in urine of the earthworms gets mixed with the soil and hence found in casts also. The nitrogen in earthworms casts is completely assimilated by plants thus provides significant source and available nutrient for plant growth [38]. The worm casts were rich in water soluble phosphorous [39] and inorganic nitrogen and phosphates.

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Therefore, factors like pH, electrical conductivity, nitrogen, phosphorous, potassium, organic carbon, copper, zinc, iron and manganese were evaluated for the prepared vermicompost.

2.8.2. Evaluation of growth

The plants grown using the vermicompost made from willow waste had very good growth rate compared to the control pot. (Plate 5) The harvested plants were washed in running water and individual plants were recorded for the growth and development. The parameters like width (W) and length (L) of all leaves of the cotton plants were measured using a simple ruler. In addition plant height, root and shoot length were measured [40] and recorded for all the three types of plants.

Plate 5

Growth of plants at the end of the study

From the top to bottom (row wise)

Row of control pot

Row of willow waste vermicompost plants

From left to right (column wise)

Cotton MCU 13 variety

Lady's finger

Marigold

Green gram dhal

2.8.2.1. Evaluation of Germination Index and Height

A seed starts to grow from the time it begins to germinate. When the seed starts to germinate the main root comes first and then the skin starts to split and later leaves appear [41] For high productivity, the adequate stand of crop plants largely depend on seed germinability and seeding vigor under a wider range of climatic conditions [42] This process requires a large amount of energy, [43] therefore the investigator noted the days when germination started in order to see if the plants were healthy. The height of the plants was noted for a period of 60 days.

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Plate 6
Evaluation of the growth index of plants
Evaluating the growth index of plants grown using willow waste vermicompost

2.8.2.2. Root and Shoot Length of Plants

Roots allow a plant to absorb water and nutrients from the surrounding soil and a healthy root system is the key to healthy plant. The root: shoot ratio is one measure to assess the overall health of the plants. [44]

Thus the investigator recorded the root and shoot length of all the plants after 60 days. (Plate 6)

2.8.2.3. Leaf Area Index of Plants

Leaf area measurement is useful for small plant populations [45]. Leaf area index (LAI) is simulated using a fairly simple function based on the heat unit index and on parameters that describe the shape of the LAI curve [46]. Compost supplemented plants generally have greater leaf areas that in turn facilitate increased photosynthesis and thus better growth. The leaf area was measured to evaluate the efficacy of prepared biocompost in cotton plant. (Plate 7)

Plate 7
Greater leaf area index in cotton plant

3. Results and discussion:

The findings of the research work were as follows

3.1 Parameters of prepared Willow waste vermicompost is listed below

Table 1

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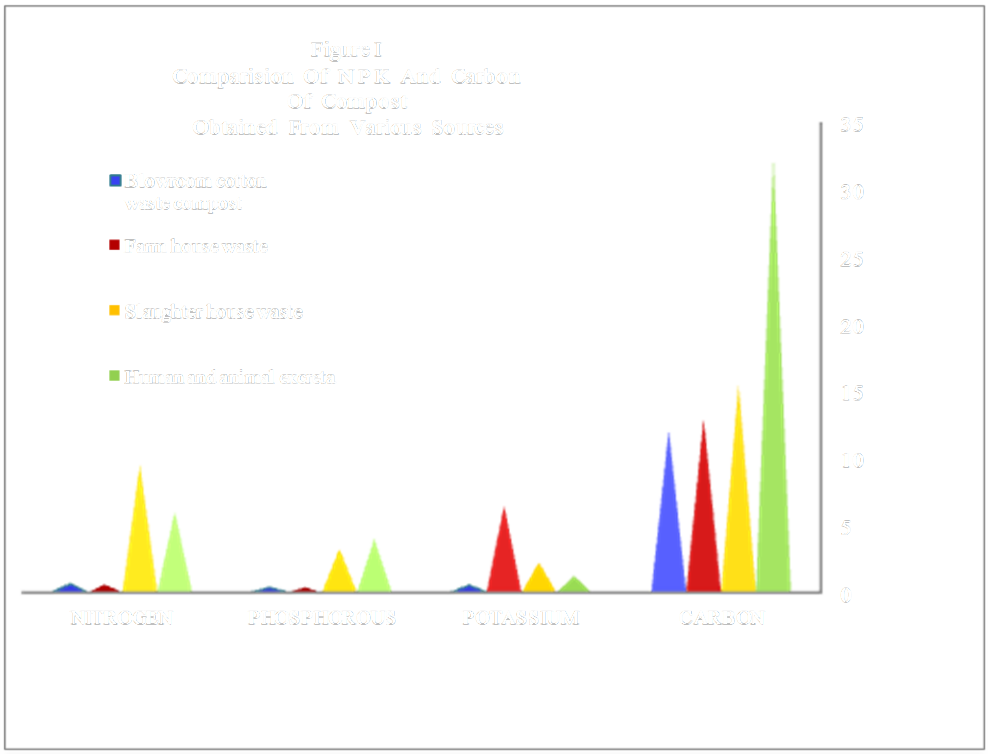
NUTRIENTS IN THE PREPARED COMPOST

S. No	Parameters	Values
1.	pH	7.20
2.	Electrical conductivity EC (dS/m)	1.85
3.	Total nitrogen (%)	0.62
4.	Total phosphorous (%)	0.35
5.	Total potassium (%)	0.52
6.	Organic carbon (%)	12.1
7.	Copper (mg/kg)	180
8.	Zinc (mg/kg)	210
9.	Iron (mg/kg)	35
10.	Manganese (mg/kg)	12

3.2 Comparison of the Prepared vermicompost with compost obtained from other sources:



The results of the vermicompost obtained from other sources namely farmyard waste, slaughter waste,

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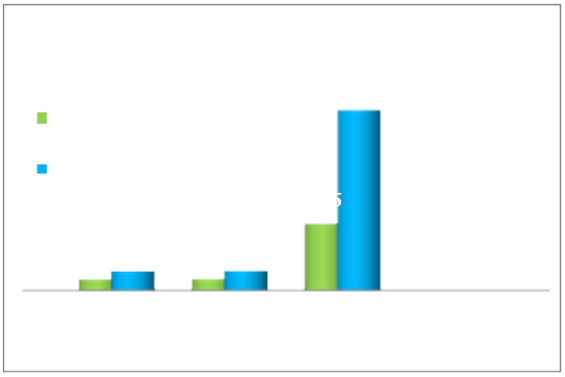
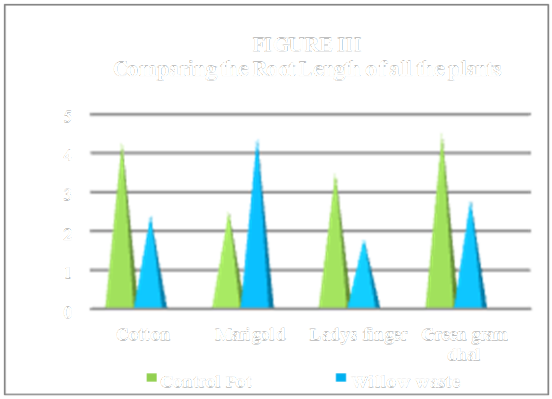
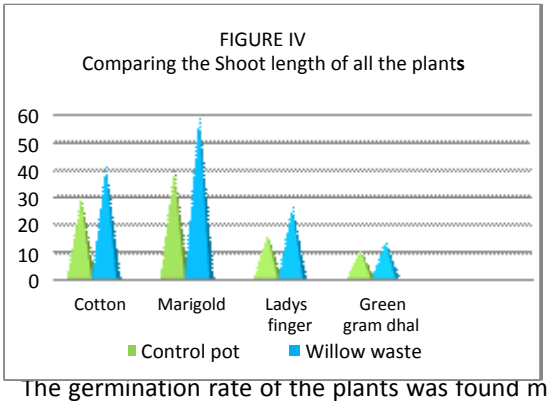
human and animal excreta was compared for the nitrogen, phosphorous, potassium and carbon. The results portray that vermicompost made from the willow waste is a very good source of carbon with appreciable amount of NPK values

3.3 Leaf Area Index of the Cotton Plant:



3.4 Root and Shoot Length of the plants:





The germination rate of the plants was found maximum of 90% in plants grown using the willow waste vermicompost. After 18 days, the maximum 16 germinated plant was recorded from the willow waste vermicompost sample and minimum 5 in Control pot

3.6 Growth Rate of Plants

On viewing the total mean growth, the maximum and minimum growth was observed as 60cms in marigold with willow waste vermicompost and minimum 15cms in green gram dhal grown with willow waste vermicompost.

3.7 Yield of the Grown Plants

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On evaluating, the marigold plant grown with willow waste vermicompost had 12 flowers and 3 buds compared to 5 flowers 1 bud in the control pot. The yield in lady's finger was 14vegetables in willow waste vermicompost plants and minimum 1 vegetable in control pot. The observation on the yield of pods was found to be 11 in willow waste vermicompost green gram dhal and minimum 2 in control pot.

4. Conclusions:

The finding of the study in the selected cotton textile waste namely willow waste can be completely decomposed into vermicompost. When supplemented to the plants with short life span they had a remarkable difference on the overall growth of the plants viz., root length, shoot length, leaf area index.

Rapport for ecofriendliness is alarming in all vistas, at a greater pace and the awareness about textile recycling is gaining increased importance in recent times. Many researches are being designed to innovate new concept and technologies, but not many focus on the used up and wastes discarded in the landfills. Adding on to the fact, a survey report denotes that, India is expected to grow around 3-5% in the area of disposals, that inturn is going to add on to the landfill pollution. This process of recycling, transforms the disposal waste into a valuable product for agriculture, in an ecofriendly way, at an economically viable basics. Now, let every individual and institution, think and act as a responsible trustee, of Earth.

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