सूक्ष्म,लघु और मध्यम उद्यम मंत्रालय, भारत सरकार
MINISTRY OF MICRO, SMALL & MEDIUM ENTERPRISES
GOVERNMENT OF INDIA

कयर बोर्ड
COIR BOARD

India International Coir Fair
IICF 2016

COIRPITH

WEALTH FROM WASTE

a reference

SAVE NATURE..USE COIR

Published on the occasion of the
India International Coir Fair 2016,
Coimbatore

COIR BOARD

सूक्ष्म,लघु और मध्यम उद्यम मंत्रालय, भारत सरकार
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India International Coir Fair
IICF
2016
JULY 15-18
CODISSIA TRADE FAIR COMPLEX
COIMBATORE

COIR PITH
WEALTH FROM WASTE
a reference

Save Nature,
Use Coir

Ministry of Micro, Small and Medium Enterprises, Government of India

MSME
MICRO, SMALL & MEDIUM ENTERPRISES

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India International Coir Fair 2016, Coimbatore

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India International Coir Fair 2016, Coimbatore

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कलराज मिश्र
KALRAJ MISHRA

सूक्ष्म, लघु और मध्यम उद्यम मंत्री
भारत सरकार
नई दिल्ली-110011
Minister
of
Micro, Small & Medium Enterprises
Government of India
New Delhi-110011

MESSAGE

I am happy to learn that the Coir Board, under the Ministry of MSME is organizing the 4th Edition of the **India International Coir Fair (IICF)** at CODISSIA Trade Fair Complex, Coimbatore from 15-18th July, 2016. Coir Board, during its existence spanning over six decades, has been extending dedicated services for the development of coir industry in our country. I am sure that the IICF 2016 would turn out to be an excellent opportunity to consolidate the gains so far and to equip the industry to face the challenges ahead. I hope that the compilations on coir products like Coir geotextile, coir pith, coir wood and coir floor furnishing material proposed to be released in this event would emerge as treasure of knowledge to information seekers on the industry and as a reference for posterity.

I wish IICF 2016 a grand success.

(KALRAJ MISHRA)

एम. वेंकैया नायडु
M. VENKAIAH NAIDU

शहरी विकास,
आवास और शहरी गरीबी उपशमन एवं
संसदीय कार्य मंत्री
भारत सरकार

MINISTER OF URBAN DEVELOPMENT, HOUSING & URBAN POVERTY ALLEVIATION AND PARLIAMENTARY AFFAIRS GOVERNMENT OF INDIA

28th June, 2016

MESSAGE

I am very happy to take note that the Coir Board, under the Ministry of Micro, Small and Medium Enterprises, is organizing the 4th edition of the India International Coir Fair (IICF) at CODISSIA Trade Fair Complex, Coimbatore from 15th to 18th July, 2016.

Coir industry in India holds its richest tradition and provides livelihood to lakhs of rural people across coconut producing regions. The industry produces wealth from waste and earns valuable foreign exchange to the exchequer. While lauding the Coir Board for its earnest commitment to promote coir industry, I convey my sincere appreciation to all those who are behind this endeavor.

I trust that the compilation on Coir Geotextiles, Coir pith, Coir Wood and Coir floor furnishing proposed to be released during this event would give complete information on application of these bio-degradable products.

I wish the IICF 2016 a grand success.

(M VENKAIAH NAIDU)

Office:- Room No. 104-C, Nirman Bhawan, New Delhi-110108; Phone: 011-23061166, 23061162, 23062089 (Fax)
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नितिन गडकरी
NITIN GADKARI

मंत्री
सड़क परिवहन, राजमार्ग
एवं पोत परिवहन
भारत सरकार
MINISTER OF ROAD TRANSPORT, HIGHWAYS AND SHIPPING
GOVERNMENT OF INDIA

MESSAGE

It gives me a great pleasure that the Coir Board, under the Ministry of MSME is organising the fourth edition of the India International Coir Fair at CODISSIA Trade Fair Complex, Coimbatore from 15th to 18th July, 2016.

Coir products, by virtue of its eco-friendly and bio-degradable qualities, have tremendous possibilities for applications to preserve environment and arrest global warming. The organization of these type of activities would lead to all round and sustainable growth of the sector.

I earnestly believe that the publications on Coir Geotextiles, Coir Pith, Coir Wood and coir floor furnishings, to be released coinciding with the event, would help for a detailed understanding on the product and its application.

I wish the IICF 2016 all success.

(Nitin Gadkari)

Date: 4th July, 2016
Place: New Delhi

Transport Bhawan, 1 Sansad Marg, New Delhi-110 001, Tel. : 23711252, 23710121 (O), 23719023 (F)
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सुरेश प्रभु
SURESH PRABHU

रेल मंत्री
भारत सरकार, नई दिल्ली
MINISTER OF RAILWAYS
GOVERNMENT OF INDIA
NEW DELHI

सत्यमेव जयते

3 0 JUN 2016

MESSAGE

I am happy to learn that the Coir Board is organizing the fourth edition of the India International Coir Fair at Coimbatore from 15th to 18th July, 2016.

As evident from the growing affinity world over and the steady increase in exports, Coir products have proven to be ideal for preserving the mother earth. I believe that the outcome from the event and the publications on various Coir products would be of immense prospects for the future.

I wish the event all success.

(Suresh Prabhu)

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राधा मोहन सिंह
RADHA MOHAN SINGH

कृषि एवं किसान कल्याण मंत्री
भारत सरकार
MINISTER OF AGRICULTURE
& FARMERS WELFARE
GOVERNMENT OF INDIA

सत्यमेव जयते

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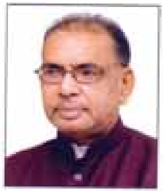

New Delhi
Dated: 30-6-2016

MESSAGE

I am extremely happy to note that the Coir Board, under the Ministry MSME is organizing the fourth edition of the India International Coir Fair at Coimbatore from 15th to 18th July 2016.

Being an agro based industry, the coir products have got a worldwide acceptance by virtue of its eco-friendly and bio-degradable qualities. Coir products, as I understand, have tremendous possibilities in soil conservation and agri-horti applications. I trust that organization of international events like the instant one are in the right direction to take the coir industry further forward. I have no doubt that the publications on Coir Geotextiles, Coir Pith, Coir Wood and Coir Floor Coverings, proposed to be brought out by Coir Board, would help much for a detailed understanding on the products and their applications.

WISHING THE VERY BEST FOR IICF 2016.

Radha Mohan Singh
RADHA MOHAN SINGH

Office : Room No. 120, Krishi Bhawan, New Delhi-110 001 Tel.: 23383370, 23782691 Fax : 23384129

गिरिराज सिंह
GIRIRAJ SINGH

D.O. No. 09 / MOS (MSME)/20.16.

राज्य मंत्री
सूक्ष्म, लघु और मध्यम उद्यम
भारत सरकार
नई दिल्ली - 110011
MINISTER OF STATE
FOR
MICRO, SMALL & MEDIUM ENTERPRISES
GOVERNMENT OF INDIA
NEW DELHI-110011

MESSAGE

I am very much delighted to note that the Coir Board under the Ministry of MSME is organizing yet another edition of the India International Coir Fair 2016 at CODISSIA Trade Fair Complex, Coimbatore from 15th to 18th July, 2016. Coir Board has been instrumental in developing and proliferating this industry in different parts of the country. I firmly believe that the fourth edition of this event is going to add another feather to the glittering cap of Coir Board.

I firmly believe that the events would bring in more tangible results to the industry for the longer run and the publication on Coir Geotextiles, Coir, pith, Coir wood and Coir floor furnishing proposed to be released in this context will be of much use to the trade.

WITH BEST WISHES FOR IICF 2016.

(GIRIRAJ SINGH)

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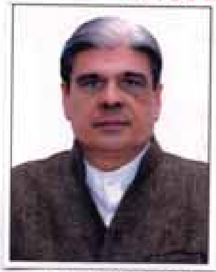
HARIBHAI P. CHAUDHARY
MINISTER OF STATE
GOVERNMENT OF INDIA

भारत सरकार
सूक्ष्म, लघु और मध्यम उद्यम मंत्रालय
उद्योग भवन, नई दिल्ली - 110011
GOVERNMENT OF INDIA
MINISTRY OF
MICRO, SMALL AND MEDIUM ENTERPRISES
UDYOG BHAWAN, NEW DELHI - 110011



MESSAGE

I am extremely happy to note that the Coir Board, under Ministry of MSME, Government of India is all set to organize the India International Coir Fair 2016 at Codissia Trade Fair Complex, Coimbatore from 15th to 18th July, 2016. I understand that the current edition of IICF is the fourth of its kind and organized in one of the major coir producing Statesin our Country.

Coir products, as known to everybody, has got a tremendous product range which can even address the current day issues on global warming etc. The efforts of Coir Board to release the compilation on products like Coir Geotextiles, Coir Pith, Coir Wood and Coir Floor Coverings during this event are definitely laudable.

I wish IICF 2016 the very best and congratulate all the stakeholders of Coir Industry for venturing into this important event.

New Delhi

Dated: 08.07.2016

Haribhai Chaudhary

(Haribhai P. Chaudhary)

कृष्ण कुमार जालान
सचिव
K. K. Jalan
Secretary

सत्यमेव जयते

msme

भारत सरकार
सूक्ष्म, लघु और मध्यम उद्यम मंत्रालय
उद्योग भवन, रफी मार्ग, नई दिल्ली-110 011
GOVERNMENT OF INDIA
MINISTRY OF MICRO, SMALL AND MEDIUM ENTERPRISES
UDYOG BHAWAN, RAFI MARG, NEW DELHI-110 011

MESSAGE

It is indeed a pleasure to note that the Coir Board under the Ministry of Micro, Small and Medium Enterprises, Government of India, is organising yet another edition of the India International Coir Fair at CODISSIA Trade Fair Complex, Coimbatore, Tamil Nadu.

Coir Industry, as I understand, has tremendous prospects to grow and develop in our country. I am confident that organisation of these type of event, followed by actual field level interventions would bring in incremental benefits to all the stake holders and sustainability to the coir sector for the longer run. I trust that compilations on products like Coir Geotextiles, Coir Pith, Coir Wood and Coir Floor Furnishings, proposed to be brought out during this event, would help to a greater deal in better understanding of the products and its varied end uses.

I wish IICF 2016 all success.

(K. K. Jalan)

New Delhi,
11th July 2016.

169, UDYOG BHAWAN, NEW DELHI-110 011, Tel. : +91-11-23062107 Fax : 2306 3045, E-mail: secretary-msme@nic.in; www.msme.gov.in

FOREWORD

The Indian coir industry is a traditional and export oriented one. This labour intensive industry plays a pivotal role in the socio- economic development of lakhs of rural population in our country. It provides employment to the economically weaker sections of the society, especially women, in rural areas spread over the coconut producing regions.

Coir Pith, once considered as a pollutant material thrown away by the coir fibre extraction mills, has emerged to be an excellent moisture retainer and soil conditioner and finds extensive applications in horticulture. The coir fibers are also extensively used in the manufacture of eco friendly agro based coco pots and basket liners. These applications of coir products, though nascent in our country, have been so fast in establishing its position in the global arena. Industry insiders, however continue to harp on to the view that the lack of awareness of the Coir Pith's potential in its home ground had compelled them to eye the markets abroad. Coir Pith as a media for plant growth has tremendous potential to replace peat moss and rock wool for use as an effective soil bed under green house conditions.

In this context, I gratefully acknowledge the support and guidance given by the Hon'ble Prime Minister of India, Hon'ble Minister of MSME and the Hon'ble Minister of State for MSME in our sincere efforts to promote this sector and in our endeavours for achieving further progress and prosperity of coir artisans. I hope this publication will be a complete reference document on Coir Pith for the future and help to a great extent in understanding the prospective end uses of the product. It can work as a catalyst in future to update the processes and techniques for the benefit of the coir industry.

The Technical Support Committee of IICF-2016 has taken painstaking efforts for bringing out this compilation by collecting information pertaining to Coconut Palm, Coir Pith and all other technical inputs and methods towards effective utilization of Coir Pith for diversified applications. I place it on record and appreciate the good efforts of the Technical Support Committee for providing such vital information about Coir Pith.

C.P. Radhakrishnan, Ex. M.P.
Chairman, Coir Board

DIRECTOR'S MESSAGE

The India International Coir Fair 2016 has been organized by Coir Board to demonstrate and disseminate to public the findings of research on coir conducted at Central Coir research Institute (CCRI) and Central Institute of Coir Technology (CICT) and through In –house / collaborative projects with reputed organizations in India. The theme for the IICF-2016 envisages sustainable development of the grass root workers in the Coir Industry and expands to overseas niche markets for coir/coir products through futuristic technologies. We are currently facing dramatic economic and market changes surrounding our business enterprises. In these circumstances, R&D becomes increasingly important in order to overcome this unprecedented transition stage and to succeed in expanding globally. The ability to predict market needs, select and focus on research themes, keep relevant divisions working together as a team, and operate with flexibility and speed is important.

Recently, much emphasis has been given worldwide to the use of biomass for different end uses due to fast depletion of fossil fuels. Coir pith a renewable biomass produced in abundance as a by-product in the coir industry which has immense potential for use as a source of biofuels besides being used as a plant growth medium. Through this book, an effort has been made to provide information about coir and its products. Grateful acknowledgements are due to Shri.C-P.Radhakrishnan, Chairman, Coir Board for his continued guidance and valuable support. I hope the information being delivered through this book will be helpful to entrepreneurs, researchers and for all in the coir industry.

Dr. Das Anita Ravindranath

Director, RDTE, CCRI

PREFACE

The India International Coir Fair (IICF) 2016, a mega event organized by the Coir Board will provide an opportunity to meet the challenges faced by the coir industry in 21st century, by highlighting the applications of eco friendly and renewable coir fibre/pith, a waste material extracted from the coconut fruit which is indeed a gift from nature for achieving a green environment.

The eco friendly innovative technologies developed at Central Coir Research Institute, Kalavoor have contributed a lot in providing value addition to coir pith for agri/horti applications. Through this book, an attempt has been made to provide an up-to-date guide about coir pith, which will be helpful for research students, entrepreneurs in agri/horti industry and also for users of coir pith and allied products.

Sincere thanks and appreciation to all members of the organizing committee of IICF 2016 and well wishers who have whole heartedly helped in compiling this publication. The blessings and guidance of Shri. C.P.Radhakrishnan, Hon'ble Chairman, Coir Board has been inspirational to complete the work on schedule and I place it on record my indebtness to him. Acknowledgement is also owing to Shri M.Kumararaja, Secretary, Coir Board, Dr. Das Anita Ravindranath, Director, RDTE and Shri. P.R. Ajithkumar, Director (Marketing) for their valuable support at every stage for the completion of this book.

It is worthy to mention and thank the combined effort, dedicated and painstaking secretarial assistance from Dr.Abesh Reghuvaran,Geena M.G.,Divya Patel, Sinjula C.S and Satheesh Kumar. R for satisfactory compilation of the data and publication of the document..

This publication is dedicated to the coir/agri/horti industry and I am sure that it will generate an enthusiasm among the scientific community in the country and abroad for development of new technologies/products in future.

Dr. S. Radhakrishnan
Senior Scintific officer (Microbiology), CCRI

CONTENTS

1. Introduction

Coir industry is one of the important cottage industries in India contributing significantly for creation of livelihood in major coconut growing states and Union territories i.e. Kerala, Tamil Nadu, Andhra Pradesh, Karnataka, Maharashtra, Goa, Orissa, Assam, Andaman & Nicobar, Lakshadweep and Pondicherry. Coir fibre is the raw material of the industry and during the extraction process coir pith is generated in large quantities as waste. In Kerala the coir industry exists since 1859 and coir fibre extraction was prevalent since then. Coir pith was dumped in the environment around the extraction units in the form of huge hillocks which occupies large land space making pollution problems. The export of coir fibre fetches a foreign exchange of over Rs. 200 crores per annum for India. It forms a major segment of village and small industries sector in terms of production and employment providing in rural areas to the economically weaker sections of the population. The coir sector provides employment to over five lakh households in Kerala alone, the majority being women engaged in the extraction and spinning of coir fibre to yarn.

Since the coir sector development contributes to the sustainable development agenda and also creation of environment friendly products, its application for domestic use and also in housing, building, agriculture and infrastructure development is significant. The world population is becoming more and more conscious about the need of preserving the nature and an increasing number of people are opting for environment friendly products. This is the opportune time to promote the case of coir to replace synthetic furnishings and certain wooden building materials. It is therefore extremely important that a major collective initiative has to be taken up to promote the cause of coir by identifying the thrust areas leading to a quantum jump in coir sector development. There is a need for better synergy in the coir activities by adopting to a two pronged strategy for the development of the coir industry in India. While in the state of Kerala, the strategy would be to sustain the existing workers and give them employment for more number of days and for other States, need to create additional employment opportunities to the coir workers by setting up of more units in the field of extraction of coir fibre, yarn and products. A wide range of coir and coir products are consumed in the country including the coir yarn, ropes, mats, mattings, rubberized coir products, mattresses, pillows, cushions, coir geo textiles, coir pith, rugs, carpets and curled coir.

1.1 Coconut Palm

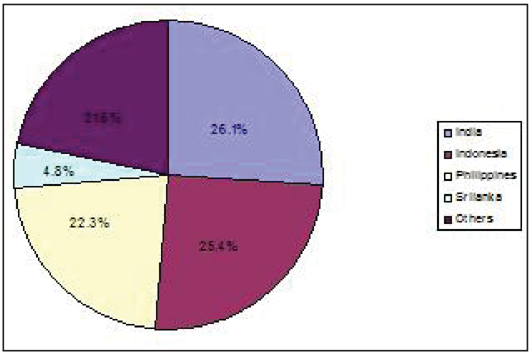
Coconut (*Cocos nucifera*) plays a significant role in the economy of India. Coconut popularly known as '*Lakshmi Phal'* is the symbol of prosperity linked with religious and social activities in India from Kashmir to Kanyakumari, irrespective of whether the palm is grown locally or not. The coconut is known to be a rich source of raw material for a variety

of products. Its nut is the most versatile of all, with its kernel of oil being widely used for edible purposes, manufacture of soaps, hair oil, cosmetics and other industrial products. The coconut husk is the raw material for the coir industry. The tender nut supplies coconut water, a popular thirst quencher of health and nutritive value.

1.2 Origin of Coconut

The origin of coconut palm is the subject of a great deal of controversy which once evoked the interest of a host of botanists. The first recorded history of coconut in the country dates back to Ramayana period. In the Valmiki Ramayana there are references of coconut in the Kishkindha Kanda and Aranya Kanda. The importance of coconut "*The tree of Heaven or Kalpavriksha*" can be appreciated when we consider its innumerable uses to mankind. The tree as well as its products have gone deep into our culture and have a record history of more than 4000 years.

1.3 Areas of Coconut Cultivation in World

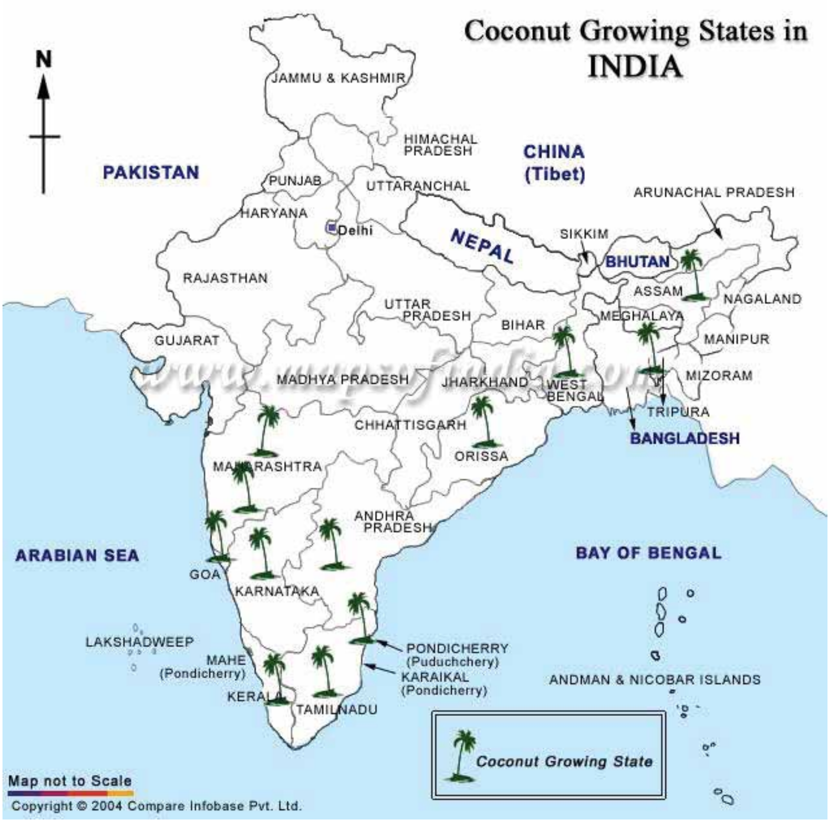


Although coconut palms grow throughout the tropical regions, the vast majority of the commercially produced coir comes from India and Sri Lanka. In recent years, India has attained the top position amongst the coconut producing countries ie. about 26.1%. Indonesia, Sri Lanka and Philippines are the other major countries. In India, coconut is primarily a food crop, which produces about one-fourth of the world's 53,598 million coconuts each year, and 15% of the husk fibers are actually recovered for use.

1.3.1 Coconut Growing States in India

Coconut cultivation and production of nuts is prevalent in the different states and union territories of India.

Coconut husk is a ubiquitous commodity. The most important commercial utilization of husk is for the manufacture of coir. The coconut is embedded in the husk which forms 35 to 65% of the weight of the whole fruit, when ripe .The seed of coconut is stripped off an



external leathery skin and a 2- 3 inches (5-8 cm) thick intermediate layer of fibrous pulp. The mesocarp is surrounded by a smooth outer skin, the exocarp . Fibers recovered from that pulp are called coir. The fibers range from sturdy bristles suitable for brush to filaments that can be spun into coarse, durable yarn. In India, which produces about one-fourth of the world's 55 billion coconuts each year, only 15% of the husk is actually used for recovery of coir fibers. The Coir Board is the registered proprietor of Alleppey Coir as per G.I.54 of the Registrar of Geographical Indication.


Section of Coconut

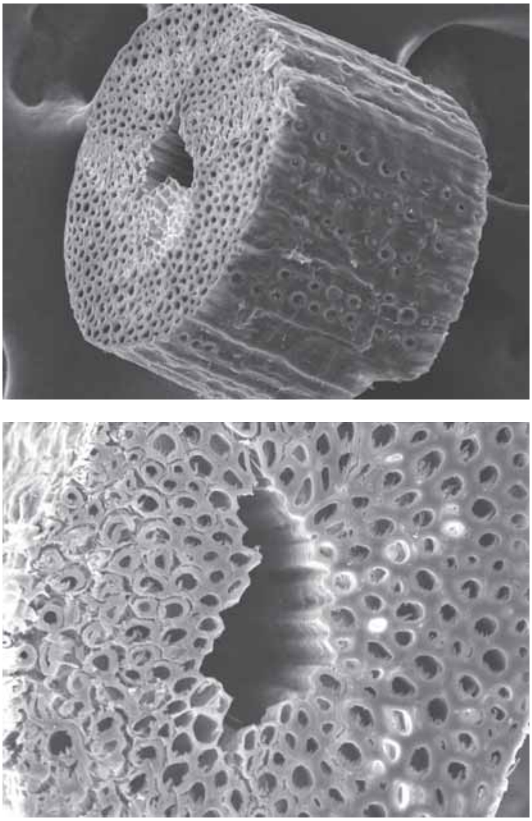
The most popular uses for coir are door mats, agricultural twine and geo textiles (blankets that are laid on bare soil to control erosion and promote the growth of protective ground covers) because of its durability, eventual biodegradability, ability to hold water and hairy texture. The very strong global markets for coir fibre products and the increasing utility of coir fibre in new products – such as mattress, geo textiles and products for the automotive industry – means that coir fibre processing is an abundant activity in coir producing nations; the largest of which are India and Sri Lanka.

1.3.2 Kerala and Coir Industry

Kerala, the largest area under coconut cultivation, is situated in the south western part of Indian Peninsula, with a total land area of 38,863 sq.km. The name 'Kera' denotes coconut and Kerala means the land of coconut. Coir industry enjoys the status as the largest cottage industry in Kerala, giving employment to over a million people of which, 80 per cent of the work force is women.In India, particularly in Kerala, coir fibre is extracted from coconut husk on a commercial scale by the natural retting process.

2. Coir Fibre

Coir is a 100% organic naturally occurring fiber derived from a renewable resource of coconut husk. Coir fibers resemble the wood fibers in terms of physical properties and chemical composition. Naturally resistant to rot, moulds and moisture, it is not treated with any chemicals during its spinning process for converting it into yarn .Hard and the strongest among all natural fibers, it can be spun and woven into different types of mattings and mats.



SEM Structure of coir fibre

Coir fibers are categorized in two ways. One distinction is based on whether they are recovered from ripe or immature coconut husks. The husks of fully ripened coconuts yield brown coir. Strong and highly resistant to abrasion, its method of processing also protects it from the damaging ultraviolet component of sunlight. Dark brown in color, it is used primarily in brushes, floor mats and upholstery padding. On the other hand, white coir comes from the husks of coconuts harvested shortly before they ripen. Actually light brown or white in color, this fiber is softer and less strong than brown coir. It is usually spun into yarn, which may be woven into mats or twisted into twine or rope.

The other method of categorization is based on fiber length. Both brown and white coir consist of fibers ranging in length from 4-12 inches (10-30 cm). The fibres of at least 8 inch (20 cm) long are called bristle fiber. Shorter fibers which are also finer in texture are called mattress fiber. A 10 oz (300 g) coconut husk yields about 3 oz (80 g) of fiber, one-third of which is bristle fiber.

The only natural fiber resistant to salt water, coir is used to make nets for shellfish harvesting and ropes for marine applications. Highly resistant to abrasion, coir fibers are used to make durable floor mats and brushes. Strong and nearly impervious to the weather, coir twine is the material that hops' growers in the United States prefer for tying their vines to supports.

2.1. Coir Fibre Extraction

The traditional method of coir fiber extraction from the coconut husk is retting, a laborious and time consuming process and often results in the pollution of the environment. However, this natural retting process yields fiber, which is strong and has a golden colour. This is due to the leaching out of deleterious matter by the constant tidal action. Defibering of husk is carried out traditionally by soaking in backwaters, which require 10-12 months. Novel development using biotechnological approach with selected strains of microbial cultures *viz.,* 'Coirret' developed by Central Coir Research Institute (Coir Board) has reduced the period of retting from 11 months to 3 months.

The traditional coir industry in the state of Kerala is facing an acute crisis of fibre shortage. For some time, it has been depending on the green husk fibre, the major part of which is brought from the neighbouring states. The industry feels that there is an untapped stock of husks in the rural areas from where collection of husk is difficult and on-site defibering

Traditional extraction of coir fiber

is not possible. Therefore the coir fibre can be extracted through MFEM (Mobile Fibre Extraction Machine) developed by the Coir Board that could be taken to the remote villages so that unutilized husks from such areas could be tapped and fibre could be made available to the coir industry.

Mobile Fibre Extration Machine (MFEM)

The time required for the extraction of fibre by MFEM is only for a few seconds and the problem of polluting backwaters can be eliminated by the new technology. However despite the advantage of yielding coir fibre in a short span of time, the greatest disadvantage of the mechanically extracted fibre is its inconsistent colour and harsh texture. Obviously environmental pollution and occupational health hazard from traditional husk retting for coir extraction have been a serious concern not only to general public but also to labours involved in the retting work.

2.2 Quality Improvement of Coir Fibre

A successful cleaner, faster and eco friendly technology of bleaching and softening of coir using **"Biochem"** has been developed by Coir Board through its Central Coir Research Institute and is being popularized among coir entrepreneurs. Biochem is a consortium of phenol degrading bacteria grown in softer media (Tamarind extract & Auxisoftener) and the treatment of coir fibre with selected strains of bacterial cultures in Biochem solution yielded a fibre exhibiting a higher degree of light fastness and a softer feel which is advantageous. The advanced technology of **"Biochem"** treatment for quality improvement of machine extracted coir fibre is carried out in open areas on a tarpaulin sheet. It is a zero effluent process and cost effective.

Biochem Solution

3. Coir Pith

Once harvested the whole coconut is separated into kernel and husk, where the kernel is used either directly as food or processed further into food products or oil. The coconut shell itself is also an economically important commodity when converted to carbon and activated carbon for use in water and air filtration systems. The husk goes to fibre mills where the coir fibre is extracted. In the process of extraction of coir fiber from husk generally about one third of it is obtained as fiber and two third of it is obtained as coir waste. Coir pith is a by-product of the coir fibre processing industry.

In the husk, coconut fibers are seen tightly packed along with non-fibrous, fluffy and light weight corky material known as coir pith or coir dust, which constitutes about 50-70 percent of the husk. The spongy material that binds the coir fiber in the husk is the coir pith or coir pith. The composition and properties of coir pith vary depending on maturity of coconut, method of extraction and disposal, period between extraction and use and environmental factors. Wide variations in C: N ratio of coir pith from 58:1 to 112:1 has been reported. Retted husk yield coir pith with less nutrients than that obtained by mechanical processing of unretted husk. Coir pith obtained from fully mature nuts has higher amounts of lignin and cellulose and lesser amount of water soluble salts compared to younger nuts.

For many years coir pith was considered as a waste product of the extraction process and was dumped outside of coir fibre mills, generating large environmental pollution issues of its own. It is only over the last 20 years or so that the coir pith, has been utilized. In the early years the coir pith was generally of a variable quality and unfit for use by the horticultural sector. Today with an economic value almost equal to fibre for high quality pith that has all changed.

When husk of 10000 coconuts are utilized for coir extraction, 1.6 ton of coir pith is obtained as a byproduct. If all the coconut husks available in India are processed, it is estimated that about 2.25 million tons of coir pith could be obtained annually. But in reality, all the available coconut husks are not diverted for coir extraction and it has been reported that only 10 lakh tons of coir pith is produced in India annually. Because of high fertilizer prices and environmental concerns associated with its use, recent years have witnessed growing interest in utilizing coir pith for organic farming in a more productive way in agri-horticulture.

Coir pith has got many enviable characteristics, making it a highly potential resource if used after proper composting. Coir pith has very high moisture retention capacity of 600-800 per cent and can be as high as 1100 per cent of dry weight. It has high potassium content and low bulk density (0.18g/cc) and particle density (0.8g/cc). High CEC, which

Raw coir pith

Coir pith hillock

varies from 20-30 meq/100 g, enables it to retain large amounts of nutrients and the absorption complex has high contents of exchangeable K, Na, Ca and Mg. All these characteristics make it ideal for use as a mulch and soil amendment, especially for dry and sandy areas with low water retention. The processed coir pith resembles peat and has got many characteristics as that of sphagnum peat, the most common potting media used in horticulture and hence it is commercially known as coco peat. With the development of commercial horticulture and reduction in the availability of sphagnum peat, coco peat has become internationally recognized as an ideal soil amendment and component of soilless container media for horticultural plants. Coco peat finds use in propagation methods, hardening of tissue and embryo cultured plants, hydroponic system of plant cultivation, cultivation of glass house plants, soil conditioning, lawn making etc.

Despite many advantages and availability in large quantities, coir pith is not fully utilized for productive purposes and every year large amounts of coir pith accumulate nearby coir processing units, causing severe disposal problems, fire hazards and ground water contamination due to the release of phenolics compounds. Because of high C: N ratio (112: 1) and content high lignin under natural conditions its degradation and mineralization rates are very slow, preventing its direct use as an organic manure. The application of raw coir pith with wide C: N ratio can result in immobilization of plant nutrients. In addition, polyphenols and phenolics acids can be phytotoxic and inhibit plant growth. Many farmers who

Whole coconut showing the white coconut meat, dark surrounding shell and the outer husk. The husk is made up of fibrous material and the pith is the corky material that can be seen amongst the fibers.

apply fresh coir pith often complain that plants develop toxic yellowing symptoms. The inhibitory effect can be eliminated by using biodegraded coir pith. Coir pith can be made suitable for use in agri- horticulture after composting process using microorganisms capable of degrading lignin and polyphenols and bringing down C: N ratio. Coir pith having a C: N ratio 24:1 or less could be used as a good source of organic matter for agricultural use.

Sri Lanka is the leading processor and exporter of coir pith into a form suitable for horticultural applications and India has the potential to become the major source of this valuable organic resource for internal use and for exports.

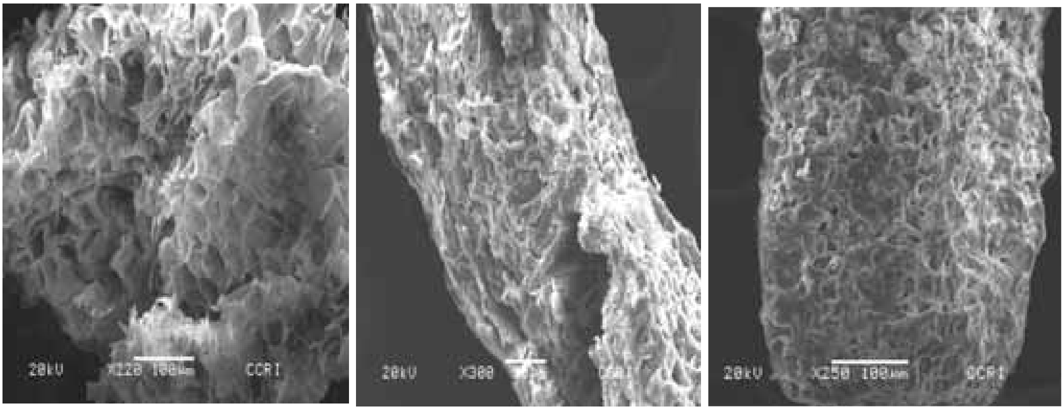
Coir pith or dust is a biomass residue that decomposes very slowly due to its lignocellulosic nature. It is one of the largest agro wastes in tropical countries. Hillocks of coir pith accumulate in the vicinities of coir fibre extraction units. The coir pith is traditionally disposed by burning which results in environmental problems, including carbon deposits and air pollution. During the rainy season, the tannins and phenols are leached out into the soil and irrigation canals, thereby making agricultural land unproductive. Moreover, the water pollution caused by such leaching is harmful to the aquatic and soil biological life. Therefore, alternate ways to dispose of coir pith such as composting, is of critical importance in these areas.

Physically, coir pith is a very light and compressible material. It is highly hygroscopic and has good water holding properties. With a structure similar to peat it can be used as a 100% peat free material to grow many plants such as houseplants and conifers and is widely used in soft-fruit production and other horticultural crops. It is also mixed with other materials as peat diluents, especially wood fibre and green compost. It is used in horticulture as a soil conditioner, surface mulch/rooting medium and desiccant.

It is processed into many different products for the horticultural sectors. It can be compressed (6:1) into varying size blocks (600g – 5kg) to enable the export of large volumes of pith for formulation by growing media manufacturers overseas. It can also be processed and compressed (4:1) into grow bags for direct use by large-scale growers who benefit from a product that lasts 1-2 years longer than a traditional peat based grow bag. These products are made to a high specification where the physical and chemical properties have been carefully managed to produce a finished product for a very demanding growing situation. Coir pith has an ability to be compressed into a wide range of added value products such as seed cells, propagation modules all the way up to bagged coir pith blocks that when hydrated fill a specific volume for home growing.

It has been reported that treatment under hydraulic pressure resulted in rupturing of the cell structure and lumen of coir pith which was not regained after soaking in water. Application of high pressure during compressing was observed to decrease the lumen of coir pith and cells became more compact. Overall evaluation reveals that the lumen of raw coir pith (loose form) was observed to lie in a size ranging from 85 -126 μm where as size of coir pith treated under hydraulic pressure ranged from 15-32.8 μm. Treatment of coir pith under pressure was resulted in a decrease in size range on an average level of 5.6% from the untreated control

Processing of coir pith blocks

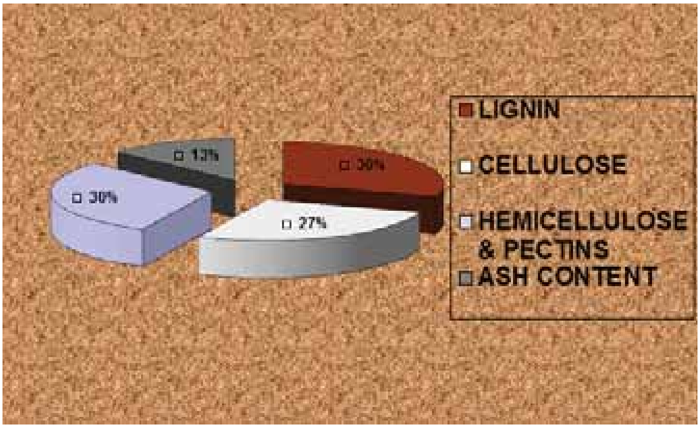


SEM structure of coir pith (a) loose form (b) block -1:8 kg (c) block -1:10 kg

3.1. Composition of Coir Pith

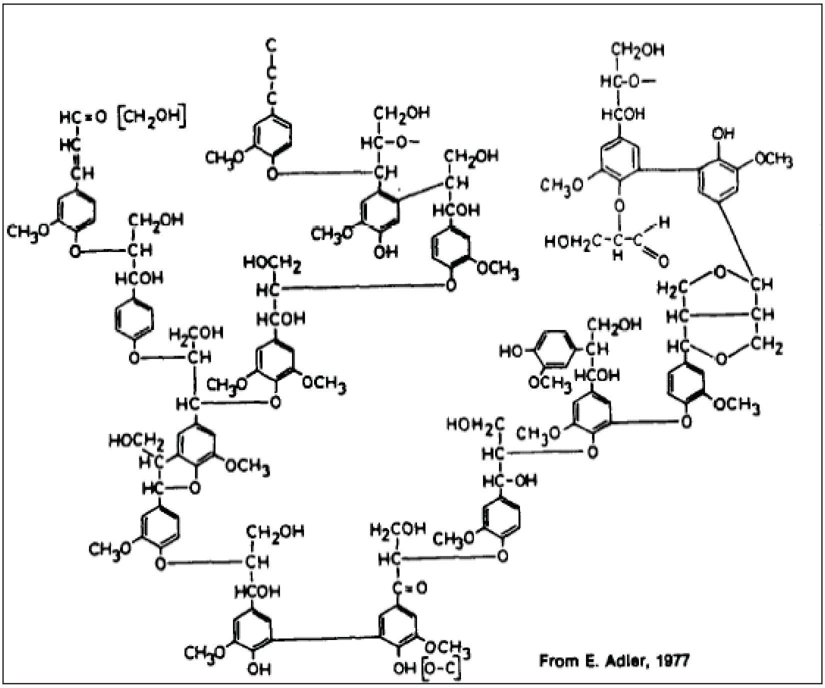
Coir waste has a high lignin (30-31%) and cellulose (26.8%) content. Its carbon nitrogen ratio is around 112:1. Lignin is a complex amorphous polymer of phenyl propane which surrounds the cellulose in cell walls and is relatively inert to hydrolysis. Because of the high lignin content left to it, coir waste takes decades to decompose.

Coir pith has a calorific value of 3975 kcal per kg close to 4200 kcal per kg of coal and hence it can be used as fuel briquette and also in pig iron manufacture, tobacco flue-curing, gas absorbent cotton etc.



3.1.1 Structure of coir pith

Lignin and cellulose work together to provide a structural function in plants analogous to that of epoxy resin and glass fibres in a fibre glass boat. The fibrous components, cellulose or glass fibres, are the primary load bearing elements while the matrix, lignin or epoxy resin, provides stiffness and rigidity. Thus trees (lignin content between 20% and 30% of



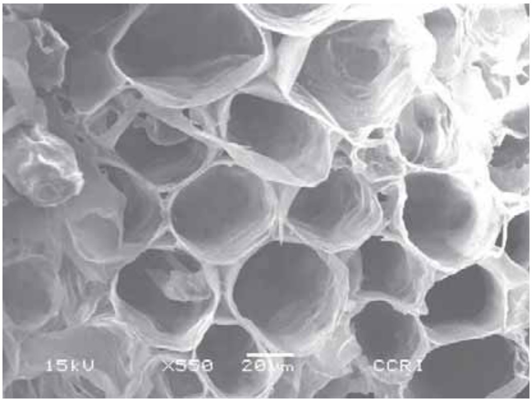
Structure of Lignin

dry weight) grow much taller than grasses (lignin content below 20%) before they bend under their own weight. An additional complexity of lignin is that there are many possible bonding patterns between individual units. Thus our knowledge of lignin chemical structure is less precise than our knowledge of other natural and synthetic polymers. Figure below shows a representative lignin fragment containing the most important bonding patterns.

Beyond the structural function, lignin plays several other important biological roles in plants. Because it is much less hydrophilic than cellulose and hemicellulose, it prevents the absorption of water by these polysaccharides in plant cell walls and allows the efficient transport of water in the vascular tissues. Lignin also forms an effective barrier against attack by insects and fungi.

3.2. Properties of Coir Pith

Coir pith is a recalcitrant agro-residue containing high amount of lignin and cellulose resisting decomposition by microorganisms under natural conditions. The recalcitrant nature of coir pith is due to the presence of lignin. It contains 8-12% soluble tannin like phenolics. Coir pith has high water holding capacity of 8 times of its weight. It has fixed carbon, low sulphur, fats and ash. Nutrient content of coir pith varies with place, method of retting, rate of decomposition and storage method.



Scanning Electron Microscope of raw coir pith

The major properties of coir pith are:

- High water holding capacity, i.e., 6-8 times than its weight.
- Excellent moisture retention even after drying.
- Slow degradation due to high lignocellulosic bonding.
- High porosity, stores and releases nutrients over extended periods of time.
- Greater physical resiliency that withstands compression better.
- Excellent aeration / oxygenation providing enhanced root penetration.
- Acceptable Electrical Conductivity (EC), pH and Cation Exchange Capacity (CEC).
- 100% degradable, organic and a renewable resource.
- Contains natural substances beneficial for plant growth.

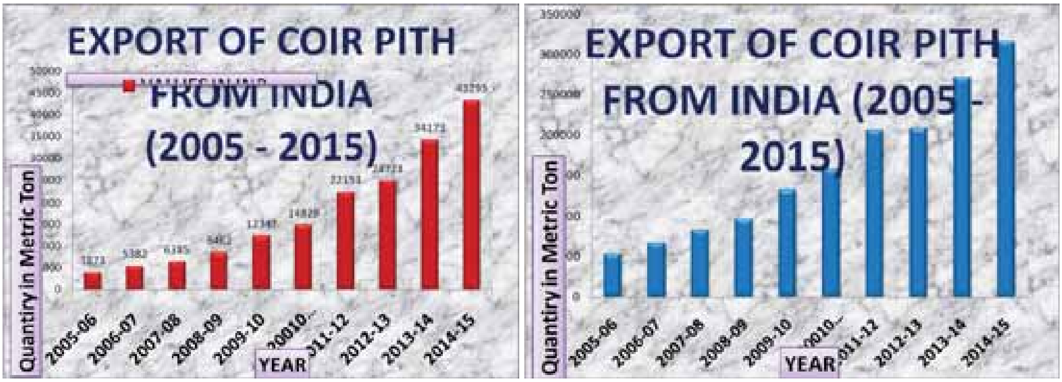
Chemical composition and physical properties of coir pith

Sl No	Constituents	Unretted coir pith	Retted coir pith
1	Lignin (%)	30.0	28.5
2.	Cellulose (%)	26.40	25.80
3	Organic Carbon (%)	29.5	29.0
4	Nitrogen (%)	0.24	0.26
5.	Phosphorous (%)	0.01	0.01
6.	Potassium (%)	0.71	0.76
7.	C:N ratio	123:1	112:1
8.	Calcium (%)	0.40	0.47
9	Magnesium (%)	0.36	0.41
10	Copper (ppm)	3.10	4.20
11	Iron (ppm)	0.07	0.08
12	Manganese(ppm)	12.50	17.00
13	Zinc(ppm)	7.50	9.80
14	Moisture (%)	20-30	60-80
15	pH	5.4-5.8	5.6-6
16	EC (millimhos/cm)	0.6-1.2	0.3-0.6
17	Salinity (ppt)	1	2-4
18	CEC (Meq / 100 g of sample)	15-20	20-30

3.3. Export Potential of Coir Pith

Coir pith offers good scope for export if processed for use as soil conditioner. The most recent realization that there is shortage in development of peat moss and that the indiscriminate exploitation of bogs is very harmful to the environment has opened an opportunity for coconut husk in the growing market demand for gardening supplies. Coir pith is gaining popularity as a plant growth medium in U.K and elsewhere in Europe as an excellent natural alternative to other soil conditioners. The fibrous nature of coir pith makes it capable of breaking even the heaviest of clay soils, allowing free drainage. Because of its sponge like structure, coir pith helps to retain water, oxygen and prevent loosening of vital nutrients.

Coir pith could also be effectively marketed due to its consistent size, absence of glass, plastic, metals and objectionable odour. Some processes have been reported in the prior art for use of coir pith in horticulture, oil absorption, bio-pesticides, soil conditioners and as fertilizers. The industry though nascent in our country has managed to establish its position on the global arena. Industry insiders, however lament that the lack of awareness of the



Export of coir pith

coir pith's potential in its home ground had compelled them to eye the markets abroad. This eco-friendly material is said to be replacing peat moss (dug from the swampy area) and rock wool (used as cultivation medium in the developed countries) as an effective soil bed under green house conditions.

3.4. Environmental Impact due to Coir Pith Hillocks

Coir pith degrades very slowly and it remains in the soil for a very long periods of time, but eventually damage or reduced to harmless levels by natural process. Coir pith is recalcitrant and accumulates in the environment forming hillocks posing environmental pollution in the areas close to coir fiber extracting units. As a result of its fluffy nature, its transportation will not be cost effective. Coir fiber extraction units contribute considerably to the problems of environmental pollution, both land and water pollution.

The high quantum of its production in the defibering units and the difficulties experienced in its disposal have tended to create a major problem of pollution of large areas of land and water in coir fiber extraction units. During monsoon rains leaching of tannins and salts from the hillocks of coir pith leads to ground water pollution and may be magnified up the food chain to levels that are harmful for wild life and possibly for humans because most of these pollutants are extremely difficult to remove by waste treatment methods. Therefore biodegradation of coir pith is essential to control the pollution caused by accumulation. Coir pith, even though is a problematic waste; it is a potential wealth and can be converted into valuable organic manure by microbial degradation.

The defibering units are facing great difficulties in the disposal of coir pith. Very often coir pith is heaped as mounds on way side. Large quantities of coir pith thus stored causes contamination of ground water due to the percolation of leachates containing residual phenol from these dumps especially during rainy season. It also offers an ideal breeding base for rodents and insect pests. Coir pith is easily blown by wind due to its light weight thereby creating air pollution. In comparison to saw dust, rice husk and groundnut shell, coir pith is found to have a higher heat value (3975 kcal/kg) which is close to that of coal. Unfortunately, high levels of carbon dioxide and smoke are released from coir pith due to its poor combustion properties while burning.

After the coir fibre is extracted from the husk the pith can be collected and processed to enter the supply chain for the production of horticultural grade material. The process for the production of coir pith for horticultural grade material follows a number of steps depending on the requirement of the end user and customer.

It is firstly matured for up to 6 months which serves to reduce the salt content, to change the pH from acidic to neutral, to reduce the content of tannins and phenols in the pith and to achieve a more favorable carbon to nitrogen ratio. The pith is then initially sieved to remove physical contaminants and remaining coir fibre.

This is followed by washing with water to further reduce the salt content. An additional stage could be buffering at this point if required by the end user. The pith can be buffered using the same process as washing, except that calcium nitrate is mixed with the water, followed by a further washing step. Buffering displaces sodium and balances the naturally occurring potassium. It prevents unwanted lock out of calcium and magnesium and avoids sodium toxicity issues.

In terms of impacts, coir pith processing requires extensive washing with water to reduce the salt concentration. The run-off from these processes will contain high levels of sodium and potassium. Some researchers report that biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrates, nitrites, ammonia, calcium and magnesium were present in high amounts, as were bacteria, fungi and algae in the wastewater from the coir industry. CCRI (Coir Board) had developed a simple cost effective technology for treatment of effluents.

Leachate from accumulated coir pith washing.

3.5. Diversified Uses of Coir Pith

Commercial utilization of coir pith depends on its physical / chemical properties to a great extent. The use of coir pith @ 10-15 tons per hectare improves soil physico-chemical properties and productivity of many crops. The use of coir pith has also been proved to be good as a soil ameliorant for reclaiming saline alkaline soil. Coir pith is generally used in reclamation of low lying areas and mulching of soil. It is an excellent surface mulch in all kinds of soil, which absorbs water slightly more than six to eight times its weight and releases it comparatively slowly. There have been a number of investigations on the suitability of coir pith in the production of building materials such as boards, insulating materials, expansion joint filters,gaskets, dyes, light weight porous brick for export purpose etc. Other areas of application being investigated include development of good quality light weight polymers and composites from pith, chemical degradation of coir pith to yield monomers like phenol and furfurals and pith as a substrate for biogas generation.

In certain parts of India, coir pith finds its application in making bricks and particle-boards. A combination of cow dung and coir pith at 4:1 ratio increases the biogas production. Coir pith forms a good bedding material in poultry shed. The coir pith bed enriched with poultry litter is directly used as manure for crops such as sorghum, groundnut and sunflower. Removal of fluoride from drinking water is also affected by the application of activated carbon prepared by carbonization of coir pith. Charcoal made from coir pith is also employed in selected industries to absorb toxic metals (cadmium, arsenic, nickel, copper and lead), harmful dyes (rhodamine B, acid violet and cargo red) and chosen pesticides (paraquet).

Application fields of coir pith

- Mulching effect to preserve the moisture and soil conditioning
- Organic manure (Compost)
- Briquetted fuel for chulas and furnaces, bricks and roofing sheetsfor building purposes etc.
- Production of particle board.
- Activated carbon
- Textile industries
- Erosion control
- Bio-gas production
- Mushroom cultivation
- Potting mixture for seedling growth
- Extracting lignosulphonates
- Wetting agent

- Dispersing agent
- Adhesion compounds in pesticides, fertilizers

3.5.A. Agri / Horti Uses

The abundance of coir pith, the problem of its disposal and the environmental hazards have forced to investigate the use of coir pith to various industrial , energy and agricultural applications not only in India but in other coir producing countries also . One of the remarkable properties of coir pith is its very high moisture absorbent capacity. For centuries farmers and horticulturalists in coconut producing countries have been using coconut husk in to the soil as a moisture conservation measure. The orchards in Indonesia and Philippines, sea walls in St.Vincent etc, are a few examples. Coir pith is now accepted as soil conditioner in many countries abroad for plant growing. The characteristic of coir pith indicates stability of the material for conditioning of farm soil for retention of moisture for mulching and as a receptacle slow release of added nutrients to the crop.

The growing public rejection of peat and peat based product in western countries like UK as a result of the realization that indiscriminate exploitation of bogs was very harmful to the environment has opened up an opportunity for coir pith being utilized as an alternative to moss and sedge peat. According to a report, at current rate of extraction lowland peat reserves in UK will be depleted in less than 10 years. A greater threat to peat mining industry is pressure from the consumers and the government conscious of the environment costs of exploiting peat bogs which have taken many thousands of years to develop.

The coir pith has the following qualities which recommend its use as peat substitute:

- Water holding capacity equal to sphagnum peat
- Good drainage similar to sphagnum peat
- Absence of weed and pathogens
- Physically resilient capable of withstanding the compression associated with baling better than peat
- Natural renewable recourse
- Slow to decompose more slowly than peat
- Acceptable pH, EC and CEC.
- Excellent wettability superior to peat.

3,5.A.1. Growing Media

Application of coir pith in soil helps in improving the structure and other physical and chemical properties of the soil. Coir pith improves the physical properties such as bulk density, pore space, infiltration rate and hydraulic conductivity of even the heaviest clay soils and allows free drainage when coir pith is incorporated as an ameliorant. Because of its sponge like structure, coir pith helps to retain water and improve aeration in root zone.

With a structure similar to peat it can be used as a 100% peat free material to grow many plants such as houseplants and conifers and is widely used in soft-fruit production and other horticultural crops. It is also mixed with other materials as peat diluents, especially wood fibre and green compost. It is used in horticulture as a soil conditioner, surface mulch/rooting medium and desiccant.

Coir pith grow bags are manufactured by blending coir pith with adequate quantity of short Coir fibre. This is then compressed and packed loosely in a UV stabilized black and white polythene bag. At the user end suitable holes are to be cut for planting as well as for drainage. Coir pith grow bags enable to enjoy delicious crop such as tomatoes, strawberries and cucumbers. The bags are ready to use as planting containers. Simply transplant plants into the coir pith grow bags during the planting season.

Specifications

- Weight 350 g +/- 30g
- Size 100 x 18 x 13 cm
- Compression ratio 5:1
- Moisture content less than 20%
- Electrical Conductivity less than 0.65 millimhos/cm

Selection of Coir Pith to Manufacture Coco peat

Physical Parameters

The coir pith should not be more than two years old and should not be decomposed. It should be golden brown in colour with good ‘cushion’ nature. It should absorb water quickly. It should be free from other contamination, sand and other foreign materials. It should be stored in a clean environment. There should not be any water-soaking pit around the pith heaps. Above all, it should be free from weeds and seeds.

Chemical Parameters

The coir pith extracted from the husk soaked with good water alone should be collected. The coir pith from the hard water process is not useful for the purpose. The electrical conductivity should be below 0.5ms/cm. The K, Na, Cl, Ca and Mg contents are well within the limit when EC below 0.5. The pH value should be 5.4 to 6.0.

Grow bags filled with coir pith for plant cultivaton

3.5.A.2 As Amendment

Coir pith can be used as amendment as it has got higher water holding capacity ranging from 475% to 800% by weight. Coir pith buried between rows of coconut palms increased moisture availability. Incorporation of coir pith will improve soil structure and chemical composition. In saline and sodic soils, coir waste application reduced the salt encrustations and improved the soil by conserving moisture

Utilization of coir pith as amendment in crop cultivation

Growth of population, increasing urbanization, rising standards of living due to technological innovations have contributed to an increase in the quantity and variety of solid wastes generated by industrial, mining, domestic and agricultural activities.

3.5.A.3 Coir Pith Blocks and Discs

Coir pith block is specially designed for commercial nurseries and greenhouses. This soil conditioner is suitable for all types of garden plants, lawns, flowers, orchids and vegetables in pots or on the ground

Coir Pith Block Specifications

Available Sizes- 5 kg and 650 gm

Parameters	5 kg Block	650 gm Block
Weight	5 kg +/- 0.3 kg	650gm +/- 30gm
Size	30 x 30 x 13 cm	20 x 10 x 5 cm
Compression ratio	5:1	8:1
Moisture content	< 20%	< 20%
Electrical Conductivity	< 0.5 millimhos/cm	< 0.5 millimhos/cm
Expanded Volume	13 to 14 L/kg	8 to 9 L/kg

Coir pith disc specifications

- Disc & coin Sizes - 20 mm to 100 mm diameter
- Product Weight – 5 gms to 120 gms
- Tonnage Capacity - 200 tons
- Power – 15 kw / 20 hp

3.5.A.4. As a substitute to Peat Moss

Sphagnum is a genus of approximately 120 species of mosses, commonly known as **peat moss**. Accumulations of *Sphagnum* can store water, since both living and dead plants can hold large quantities of water inside their cells; plants may hold 16–26 times as much water as their dry weight, depending on the species. The empty cells help retain water in drier conditions. Hence, as sphagnum moss grows, it can slowly spread into drier conditions, forming larger mires, both raised bogs and blanket bogs. These peat accumulations then provide habitat for a wide array of peat land plants, including sedges and ericaceous shrubs, as well as orchids and carnivorous plants. *Sphagnum* and the peat formed from it do not decay readily because of the phenolic compounds embedded in the moss's cell walls. In addition, bogs, like all wetlands, develop anaerobic soil conditions, which produce slower anaerobic decay rather than aerobic microbial action. Peat moss can also acidify its surroundings by taking up cations, such as calcium and magnesium, and releasing hydrogen ions. Under the right conditions, peat can accumulate to a depth of many meters. Different species of Sphagnum have different tolerance limits for flooding and pH, so any one peat land may have a number of different Sphagnum species.

Sphagnum peat moss has been used for centuries in Europe, Canada and Australia for mainly horticultural purposes and energy. Exploitation of peat moss for horticultural purposes in New Zealand, Ireland and the Baltic countries has been facing stiff opposition from the environmentalists, as it has resulted in destruction of wetland in these countries.

Advantages of Coir pith over Sphagnum peat

COIR PITH	SPHAGNUM PEAT
Requires lesser amount of lime due to high pH	Requires large amount of lime to maintain pH for growing plants
Quick and easy rewetting after drying	Becomes hydrophobic once dried
Requires short time for irrigation to replace loss of water and drainage from pot, saving fertilizer due to non leaching of nutrients	Requires longer time for irrigation due to hydrophobicity resulting in leaching of nutrients
High capillary wetting property	Comparatively low capillarity
Distributes moisture evenly in pot mix	Distributes moisture evenly in pot mix
Able to provide aeration in base of mix	Under influence of gravity water collects in bottom to fill pore spaces and reduce availability of air to roots
Very resilient and exceptional physical stability when wet or dried	Collapses when wet retarding availability of air and water to plant roots, shrinks when dried allowing to run water between roots and pot wall increasing the time to rewetting

3.5.A.5. As an Organic Fertilizer

The concept of food for all in Green Revolution resulted in degradation of natural soil fertility due to the continuous use of chemical fertilizers. Chemical fertilizers were used as a temporary measure, as a part of soil nutrient management and it does not take care of the soil organic matter. Maintenance of soil organic matter, therefore assumes greater importance especially in tropics and subtropics. The main constraint in maintaining level of organic matter in soil is non-availability of the requisite quantity of organic manures.\

Environmental protection through the development of clean technologies and bioremediation of effluents and environmental pollutants is one of the main areas of biotechnology. Bioremediation of effluents and waste can be achieved through biodegradation and mineralization. It results in the conversion of waste in to useful materials as in the case of composting. Composting is the bioconversion of waste into a hygienic soil conditioner and fertilizer. Restoration and maintenance of soil humus conserves the resources and represents one of the most essential and beneficial ecological process. To compost, one needs to bring the congenial materials together to achieve ideal conditions of C: N ratio, pH and moisture content. Coir industry leads to the accumulation of coir pith hillocks and coconut husk leachate. Both cause environmental pollution of land as well as water.

During monsoon, leaching of tannins and its salts from the hillocks of coir pith leads to ground water pollution. It can get magnified up the food chain to levels that are harmful for wild life and possibly for humans as most of these pollutants are extremely difficult to be removed by waste treatment methods. Therefore biodegradation of coir pith is essential to control the pollution caused by its accumulation.

In modern times, there is an increasing force for organic waste recycling in agriculture. In such situations, coir pith, which is still an untapped source, could be used and conversion of this waste into manure will also result in fruitful disposal of the solid waste, which could otherwise cause problems of environmental pollution.

The composting is an exothermic biological oxidation process of different organic substances occurs in the presence of air and certain microbes. The organic matters through stabilization attain its maturity and deodorized into a humic substance rich product. It can be used as an effective soil conditioner and is also easy to store and distribute. It is a non- self-degrading material and remains in the soil for years together. The smoke emitted during its burning last continuously for a long time polluting the environment and creating disposal problems. Coir pith has got many enviable characteristics making it a highly potential resource if used after proper composting. Recently coir pith as a money spinner is used as a moisture retaining source in rain fed agriculture areas. Due to the high water holding capacity coir dust is used as mulch for agro crops. An effective way to partially solve the growing concern of solid waste management is the composted manure. Monitoring the microbial succession for the effective management of the composting processes is essential as microbes play an important role in biodegradation process

3.5.A.5.1. Biological Treatments for Enhancing Rate of Composting of Coir Pith

Coir pith can be made more amenable for microbial attack and subsequent decomposition by various chemical and biological treatment methods. The C: N ratio can be reduced by adding nitrogen fertilizers or nitrogen rich organic materials such as legume biomass; oil cakes etc. Lignin can be degraded by favoring the buildup of native lignin degrading microorganisms or by the artificial introductions of starter cultures of efficient lignin degrading microorganisms.

Treatment with lime is yet another approach to enhance the process of decomposition of coir pith. This is based on the fact that liming can enhance humification process in plant residues by enhancing microbial population and activity and by weakening lignin structure. It can also improve humus quality by changing the ratio of humic to fulvic acids. Liming has also been shown to decrease the amount of bitumen’s and humins, thus enhancing the humification process. Lime treatment has been shown to make coir pith more suits for growth of lignolytic fungi, which subsequently ensures faster degradation of lignin and humification of coir pith. Pretreatment with lime at 5kg/ton of coir pith is sufficient to enhance the degradation of lignin.

As a nutrient source, coir pith has not much value. But, it can be made rich by addition of specific nutrients and cultures of beneficial microbes capable of enhancing the availability of nutrients. These enrichment techniques would make coir pith compost better equipped to influence plant growth and soil quality much efficiently. Coir pith can also be composted and enriched with phosphates using rock phosphate. Enrichment of coir pith compost with rock phosphates results in more labile fractions of phosphorous in the resultant compost. In addition, use of rock phosphate at 2kg per ton of coir pith during composting resulted in greater percentage of carbon loss.

Coir pith compost can also be enriched with super phosphates, biogas slurry and cow dung slurry. This treatment increase nutrient content and enhances the composting rates. It can also be enriched with nitrogen from organic sources such as green manures, weeds etc and their use at 100kg per ton of coir pith has been found to be beneficial. Composting can also be done along with coffee husk. In addition to increasing nitrogen content of the final compost, amendment with organic additives in coir pith during composting results in more labile and aliphatic humic acids. Being less aromatic and labile, these fractions form more labile chelated complexes with micronutrients. Hence, with organic amendments, more availability of micronutrients in coir pith compost has been observed.

Coir pith compost can be fortified with micronutrients. The trace metals can be added to coir pith at the beginning of the compost process. The trace metals get chelated with natural ligands like humic acid and fulvic acids synthesized during decomposition of coir pith. Zinc can be chelated by mixing zinc sulphate at 4kg per 750kg raw coir pith and allowing the mixture to undergo composting. Manganese is yet another micronutrients, which can be enriched in coir pith compost. Coir pith can also be enriched with cultures of beneficial microorganisms such as Trichoderma, Azotobacter and phosphate solubilizers, so that the compost could save as a biofertilizer and biopesticide.

3.5.A.5.1 (a) Biodegradation of Lignin

The enzymology and molecular biology of lignin degradation was well studied by Cullen and Kersten (2004). They described that lignin is a formidable substrate formed through oxidation and free radical coupling of phenyl alcohol precursors . In contrast to hydrolysable bonds between subunits of other wood polymers (eg: cellulose and hemicelluloses), lignin degradation requires oxidative attack on the carbon – carbon and ether inter unit bonds. The lignin polymer encrusts cellulose micro fibrils, particularly within the secondary walls. No microbes, including white rot fungi, are known to capable of utilizing lignin as a sole carbon or energy source. Lignins are complex plant materials characterized by abezol ring structure with empirical formula, $C_{42}H_{32}O_6$ (OH) (OCH_3) It has a unit molecular weight of about 800 and is usually associated with harder tissues in plants, including fibres. Lignin prevents the permeation of water, nutrients and metabolites into the internal structure . Among the cellulolytic substances of pith, the hemicellulose contains chains of branched hetero polysaccharides of pentoses and hexoses that are easily amenable to bacterial attack. An excellent review of the decomposition of lignin by wood rotting fungi was presented by Higuchi (1980). All lignin degrading microorganisms excrete enzymes such as phenol oxidases in to the substrate. The phenol oxidases produced by lignin degrading fungi is identical with laccase. The lignin is more readily attacked by fungi than cellulose.

Most of the research concerning biodegradation of lignin has been centered on some fungi only such as *Phanerochaete chrysosporium*, *Streptomyces viridosporus, Pleurotus eryngii, Trametes trogii, Fusarium proliferatum.* Wood-rotting Basidiomycetes fungi that cause white rot in wood are the most efficient lignin degraders in nature and they are perhaps nature's major agent for recycling carbon of lignified tissues. No other microorganisms have been described to mineralize the lignified tissues as efficiently. The role of bacteria in lignin biodegradation is still a matter of conjecture. Some workers have demonstrated that either mixed or pure culture of bacteria can grow on lignin as a carbon source. *Pseudomonas* spp. was claimed by Kawamori *et al.* (1987) to degrade plant lignin. In most of the studies, the lignin degrading enzymes was produced at higher levels in cultures containing lignocelluloses. The white rot fungi occur naturally as degraders of lignin in fallen trees and ground litter and because of lignin is a mixed polymeric compound; these organisms have evolved a wide range of nonspecific enzymatic oxidative systems.

3.5.A.5.1 (b) Ligninolytic Enzymes

The major enzymes involved in lignin biodegradation by fungi are two extracellullar heme containing peroxidases *viz.*, lignin peroxidase and manganese peroxidases (Kirk and Farrell, 1987). The main difference between LiP and MnP is the nature of substrate that is oxidized. LiP is capable of oxidizing non phenolic or phenolic lignin structure directly to yield aryl cation radicals and phenoxy radicals respectively. White rot fungi have necessary enzymatic system to remove lignocelluloses and are the best organisms for the removal of colour from the effluent (Balsare and Prasad, 1988). *Phanerochaete chrysosporium*, a white rot fungus has been extensively studied as a model for fungal lignin peroxidases and manganese peroxidases (Hiroak and Wu Feng, 1996; Masud and Anantharaman, 2008). An H_2O_2 generating systems have been identified to date as the major components of lignin degrading enzyme system of this organism (Trivedi, 2003). Veratryl alcohol (3, 4-dimethoxybenzyl alcohol) is synthesized *de novo* from L-phenylalanine by *P. chrysosporium* and the formation coincides with lignolytic activity. This aromatic compound is a substrate for ligninase, which catalyses its oxidation to veratrylaldehyde (Tien and Kirk, 1984).

Extra cellular peroxidases and oxidases are thought to play an important role in the initial depolymerisation of lignin and small molecular weight fragments are subsequently metabolized intra cellularly ultimately to water and carbon dioxide. White rot fungi have been convincingly shown to efficiently mineralize lignin (Eriksson *et al*., 1990). Enzyme intermediates in the catalytic cycle of lignin peroxidase are analogous to other peroxidases; steady state and transient state kinetics have been studied in detail (Tien and Kirk, 1984). Usually MnP is not able to oxidize or depolymerise the more recalcitrant non phenolic lignin structures that make up about 90% of the lignin in wood. It seems primary attack on lignin requires low molecular weight agents, because LiP and their enzymes are too large to penetrate lignocelluloses (Call and Mucke, 1996). Because of these discrepancies, it has been proposed that there are mechanisms that enable MnP to cleave non phenolic lignin structures *via* the action of small mediators such as lipid radicals.

3.5.A.5.1 (c) Biodegradation of cellulose

Cellulose is a polysaccharide which forms the major constituent of coir pith. Because of its specific physical structure and its resistance to most enzymes and chemical reagents, it presents distinct problems as retards decomposition in soils and in composts. Cellulose is resistant to soil inhabiting microorganisms. The mechanism of the breakdown of cellulose by microorganisms depends entirely upon the nature of the organism and the conditions of decomposition. The aerobic bacteria and fungi break down cellulose completely, producing only CO_2, some slimy material, certain pigments and considerable amount of microbial cell substances (Mathur, 1982). Ghosh *et al*. (2007) reported that cellulosic compounds present in the coir pith (26.4%) support the initial growth of the fungus.

3.5.A.5.1 (d) Biodegradation of phenols

Phenols are the most important class of synthetic industrial chemicals and often present in the industrial effluents. Phenols are known to inactivate enzymes and inhibit pectinase and since coir pith has high percentage of polyphenolic compounds in the form of lignin, tannins etc., they have been stated as potential inhibiting / inactivating agents (Nazareth, 1986). The vast majority of phenols have been classified as toxicity priority pollutants and some of them are even known to be suspected carcinogens (Kayhanian, 1995). Many bacteria and fungi have the ability to degrade phenolic constituents. This property is of considerable significance to the distribution and characteristics of phenol utilizing microbes in coconut husk retting. Basidiomycete fungus has the ability to degrade lignin and is capable of detoxifying phenolic compounds by producing bio-polymerizing enzymes. It degrades the phenolic group, and causes an oxidative shortening of side chain. Some enzymes such as laccase and phenol oxidases are also involved in the process of lignin degradation (Amlatha *et al*., 1987).

Many species of Pleurotus can be utilized for coir pith degradation, as the genus is well known for its lignin degradation capacity. The oyster mushroom, Pleurotus sajor caju and P.platypus are used for complete degradation of coir pith. It was found that P.sajor caju elaborated more cellulose and lactase and mediated a reduction of 82.92% of lignin. Inoculation with P.platypus resulted in 58.6% reduction in cellulose and 78% reduction in lignin after 35 days of inoculums and the C: N ratio was maximum with this(18:1) as against the composted coir pith(104:1).

The services of earthworm can also be utilized for composting coir pith and a local strain of Eudrilus spp. has been found to be highly useful for this purpose. A technology for large scale vermicomposting of coir pith has been standardized at CPCRI, Kasarod using this local earthworm. Other epigenic or compost worms such as Perionyx excavate and Eudrilus eugeniae have also been utilized for vermicomposting of coir pith.

3.5.A.6 Coir Pith Organic Manure (C-POM)

Coir Board in collaboration with the Tamil Nadu Agricultural University has developed the technology for converting coir pith into valuable organic manure. **PITHPLUS**, a spawn of edible mushroom *Pleurotus sajor caju* speeds up the decomposition process and leads to 42% reduction in volume of coir pith. The mushroom belongs to the fungal group Basidiomycetes capable to detoxifying phenolics and producing bio polymersing enzymes. Cellulosic compounds present in coir pith support the initial growth of this fungus and act as co-substances for lignin degradation. The degradation of coir pith by PITHPLUS is marked by the increased evolution of carbon dioxide.

Application of coir pith manure improves the physical and chemical properties of the soil and enhances the yield of crops. The fungal culture - *Pleurotus sajor caju* is maintained in PDA slants, storing under refrigeration at 15°C. The microbe is mass cultured on sterilized media consisting of sorghum mixed with 0.2% calcium carbonate as carbon source in polythene bags. Fully grown packets of mushrooms after 15 days of incubation were used for carrying out the composting of coir pith.

(a) Pleurotus sajor caju - Culture on PDA (b) Fruiting body in natural condition

PITHPLUS

3.5.A.6 .1. Composting of Coir pith

6.	**PITH PLUS**
5.	COIR PITH
4.	UREA
3.	COIR PITH
2.	**PITH PLUS**
1.	COIR PITH

Sandwiching process of composting of coir pith with Pithplus and urea

Coir pith when inoculated with a proprietary bio-formulation, such as PITHPLUS, and enriched with urea shows a definite reduction in lignin and cellulose contents with an increase in total nitrogen and other nutrient elements after a period of 30 days. PITHPLUS is derived from *Pleurotus sajor caju,* which is a fast growing, edible oyster mushroom, originally found in India and grows naturally on a succulent plant (*Euphorbia royleans*) in the foothills of the Himalayas.

3.5.A.6.1 (a). Method of Composting of Coir Pith (Conventional process)

According to this process the pith is composted in a multilayered structure, where the different pith layers are interspersed with PITHPLUS mushroom and urea. A schematic diagram of such a multilayered structure is shown in figure. The first layer of pith is covered with a layer of PITHPLUS. The layer of PITHPLUS provides the necessary cellular organisms to biodegrade the coir pith. The first layer of coir pith is overlaid by second layer of coir pith followed by urea. Urea provides the necessary nutrient media to proliferate the growth of PITHPLUS that leads to the degradation of coir pith. The urea layer is finally topped off by a layer of pith and PITHPLUS respectively. The process is continued until the height of the heap reaches a maximum of 1.5 meters. The moisture in the heap maintained at 200% by sprinkling water at frequent intervals for 30 days. The mass of coir pith is gradually converted in to organic manure which is dark coloured and enriched with Nitrogen, Phosphorous and Potassium (NPK) and micronutrients.

Method of composting

- Spread uniformly 100 kg coir pith in an area 5M x 3M
- Apply one packet of Pithplus (400gm) uniformly over it
- Cover with100 kg coir pith and apply 1 kg urea uniformly over it.
- Spread 100 kg coir pith again
- Repeat the sandwiching process
- Moisten the heap by sprinkling 25 buckets (approx) of water daily.
- Allow the heap to decompose for 30 days
- 200 % Moisture
- 1 Ton Coir Pith + 2kg Pithplus + 5 kg Urea -----------------------> C-POM

  30 days

The organic manure thus obtained is richer in nitrogen, phosphorus and potassium. The method described above, although effective in composting coir pith, suffers from two limitations. First, it takes over a month for composting when the heaps are larger in dimensions. Second, the height of the coir pith heap that this process can compost has to be less than 1 metre, which results in a large area of land usage for composting, for a given heap of coir pith. Both of these limitations originate because of the absence of a proper aeration system in the heap of the coir pith. The process described above relies on natural aeration, which can be limiting, especially when multilayered heap structures are designed. The lack of proper flow of air also results in longer composting times.

The correct moisture is crucial. When there is too little, the biological reactions slow down and when there is too much, the space between the particles becomes clogged with water, preventing the movement of air through the heap. As a rough guide, the material should be as damp as a squeezed out sponge. In tropical conditions, the materials will dry out more quickly than in temperature climates except, of course, in the rainy season. To ensure the moisture content at all times, the mixture should be wetted initially and again when necessary during the composting process.

Air must be supplied to all parts of the heap so that oxygen can get to the microorganisms and flush out the CO_2 produced. When the heap begins the composting process the material becomes slightly acidic, as the simple organic acids are the first to break down. It then turns slightly alkaline as proteins are attacked and ammonia released. But, if the materials are carefully mixed and moisture content and aeration regulated, it won't be necessary to change the acidity of pH during composting.

Heat very soon develops as the more materials break down in the composting process. This is normally enough to raise the central core of the heap to a temperature of 60°C. To reduce heat losses as much as possible, the heap should be covered with coconut palm leaves thatching mounted at an angle at least 15 cm above the top of heap or can also be spread on top of it and draped over the sides to prevent heat loss and drying out. This type of cover insulates while allowing air to pass through. This enables the high temperature zone to move out toward the edges of the heap. It will provide some form of overhead protection against heavy rain or drying sun. It should be easy to remove to allow work on the heap when necessary.

3.5.A.6.1 (b). Modification of Existing Composting Process

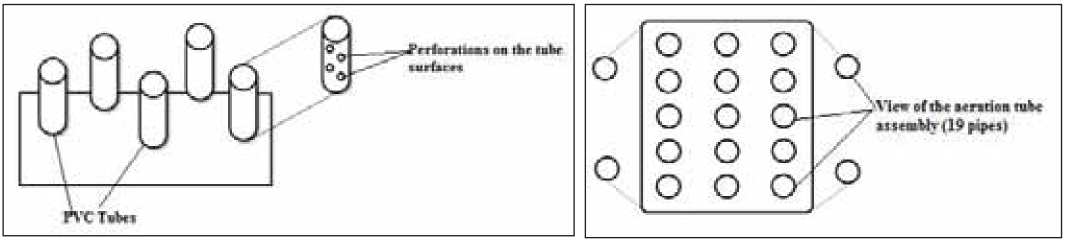
In order to compost larger quantities of coir pith (100 MT or more) would be difficult if we use the conventional method. This can be attributed to the decrease in efficiency of biodegradation due to the lack of aeration for the release of carbon dioxide produced. The dissipation of heat generated during composting process would also be slower, resulting in rise in the temperature within the bulk of the composting heap. This in turn would destroy the microbial population responsible for the biodegradation and thereby slowing down the process. The composting process would therefore be considerably arrested and would restart only after natural cooling of the composting heap.

Provision of perforated PVC pipes

In order to enable bulk composting of coir pith hillocks (more than 100 MT) aeration of carbon dioxide was provided using a simple aerator assembly. Perforated 4 inch PVC pipes of length 5 meter were inserted inside the composting heap at a distance of 1.5 m between two pipes over an area of 10 m x 6 m for composting of coir pith hillock.

The new design system provides aeration within the coir pith hillock that enables the inflow of an increased quantity of oxygen for the biodegradation activity of the lignolytic microorganisms. The system comprises 19 numbers of 5 m perforated PVC pipes. The pipes used for the composting was of diameter of 100 mm(4 “) and embedded in the heap equally spaced from each other over an area of 10 m x 6 m arranged near the hillock. The perforated pipes are light weight and resistant to corrosion. The pipes are placed vertically with the support of clay bricks and extended 1 meter above the heap. Each PVC pipe has a large number of perforations, all over its curved surface, to allow the uninterrupted free inflow of air and as an outlet for the carbon dioxide and dissipation of the heat generated during composting through convection. These pipes are connected to vertically placed pipes through T/elbow joints. About 25 cm of the vertical pipes are protruding above the top surface of the multi-layered heap of coir pith. The ends of pipes protruding outside the heap are covered with plastic fabric wire mesh cap to work as air vent and to prevent over flooding due to rains which may cause leaching out of urea and other soluble beneficial materials from the heap through the laid down pipes protruding outside the pit.

The schematic arrangement of PVC pipes over an area of 10 x 6 m is illustrated in figure below.



Schematic diagram of aerator tube assembly

The laying of coir pith with the inoculums and the supplements were in accordance with the procedure as described earlier. The hillock was trenched and coir pith was lifted, transported and spread over the marked area (10 m x 6 m dia) in between the pipes by using a JCB and compost hillock was created using coir pith, PITHPLUS and urea. The JCB


Demonstration of PVC aerator tube assembly

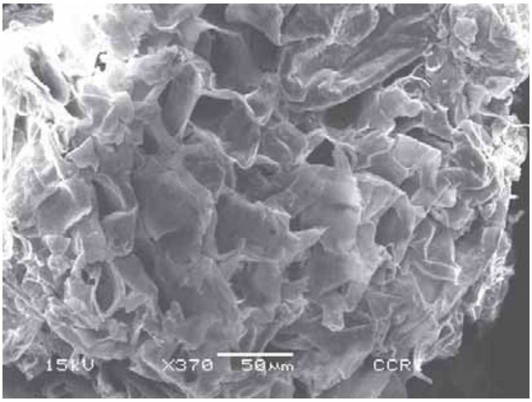
could lift and spread approximately 100 kg of coir pith in one rotation on the interspaces of the pipes positioned over the marked area. The inoculums was supplemented with calcium carbonate and cattle manure to the extent of 0.05% of the weight of the initial coir pith (12.5 kg each) The heap after laying took the shape of a trapezoid with a vertical height of 4 m at the centre of pith dumped above the ground level. The heap was watered daily from the surfaces at regular intervals to ensure that the surfaces remained moist. The composting of pith could be completed in 21 days. The composted coir pith obtained is 100 % organic manure which turns into a black mass with reduced C: N ratio of 112:1 to 20:1 and volume ratio from 100 to 58. The pH increases from 5.5 to 6.8 and the electrical conductivity decreases from 0.98 millimhos/cm to 0.25 millimohs/cm. Composted coir pith organic manure obtained does not contain or carry weeds and undesirable pathogens

Pilot demonstration on coir pith hillock composting (250 tons) at Chirayinkeezhu in Thiruvananthapuram

Properties of C-POM

- Excellent medium for plant growth.
- High moisture retention
- Improves physical and biological condition of soil.
- Reduces frequency of irrigation.
- Enhances strong and healthy root system.

- Contains natural enzymes and plant nutrients.
- Stimulates the production of phytohormones.



SEM view of C-POM

Significance of Organic manure

Sunlight, air, water and nutrients are the basic requirements for healthy plant growth. However, a good growth medium is a vital link essential for the proper utilization of nutrient and water. The global agro-industry has been facing a serious crisis due to the steady build up of biological resistance to chemical pesticides and chemical fertilizers. Improper use of chemical fertilizers in soil leads to altering the physical and chemical properties of soil and pollutes the biosphere. Coir pith compost developed from coir pith is a good organic manure and soil conditioner applicable to agricultural crops.

Requirement of Coir Pith Organic Manure (C-POM)

Nutrient Status

Nitrogen (%)	1.26 %
Phosphorous (%)	0.06%
Potassium	1.20%
Lignin	4.8%
Cellulose	10.20%
Organic Carbon	24.4%
C:N Ratio	19.1%
Calcium	0.60%
Magnesium	0.58%
Copper (ppm)	6.20
Iron (ppm)	0.90
Manganese (ppm)	25.00
Zinc (ppm)	15.80

Technical Specification

Moisture	30- 40%
pH	6.6-6.9
Electrical Conductivity (EC)	.< 0.25 Millimhos/cm
Salinity	0-1 ppt
Cation Exchange Capacity (CEC)	40-60 meq/100 gm
Porosity	65-70%

Dosage (per annum) for application of C-POM on different crops

Coconut	12 kg / Palm	Rose	0.75 kg / Plant
Plantain	5 kg / Plant	Anthurium	500 gm / Plant
Black pepper	5 kg / standard	Orchid	250 gm / Plant
Areca nut	12 kg / Palm	Zennia	250 gm / Plant
Cardamom	5 kg / clump	Jasmine	300 gm / Plant
Coffee	5 kg / Plant	Sunflower	600 gm / Plant
Tea	0.5 kg / Plant	Ixora	300 gm / Plant
Rubber	2 kg / Plant	Chrysanthemum	300 gm / Plant
Paddy	150 kg /Acre	Oscimum	300 gm / Plant
Tapioca	2 kg / Plant	Tomato	0.3 kg / Plant
Betel	2 kg / Plant	Legume	0.3 kg / Plant
Cocoa	2 kg / Plant	Snake guard	0.5 kg / Plant
Vanilla	1 kg / Plant	Yam	0.5 kg / Plant
Mango	6 kg / Tree	Colocasia	0.5 kg / Plant
Pineapple	1 kg / Plant	Turmeric	0.1 kg / Plant
Grapes	1 kg / Plant	Ginger	0.1 kg / Plant
Chikku (Sappotta)	3 kg / Plant	Cabbage	0.3 kg / Plant
Carrot	0.1 kg / Plant	Chilly	0.3 Kg / Plant
Beetroot	0.1 kg / Plant	Lady finger	0.3 kg / Plant

3.5.A.6.1 (c). Composting of Coir Pith Substituting Urea with Natural Supplements

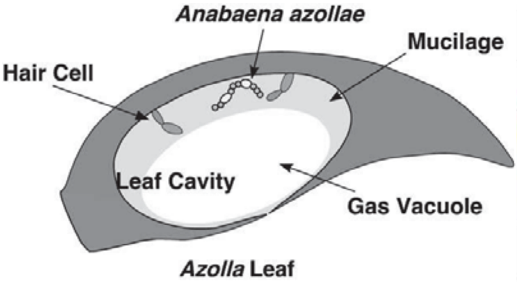
The existing process of coir pith composting is efficient in terms of lignin degradation. It involves the supplementation of urea, an inorganic nitrogen source which can result in the formation of excess ammonia and may immobilize other soil nutrients. Thus, it can generate a negative impact on soil fertility. A new technology was developed for the conversion of coir pith into environmental friendly bioorganic manure without using urea. Studies were conducted on composting of coir pith using PITHPLUS in combination with various biological nitrogen sources as supplements in different proportions. Biochemical analysis showed reasonable variations in physico-chemical properties of coir pith during composting.

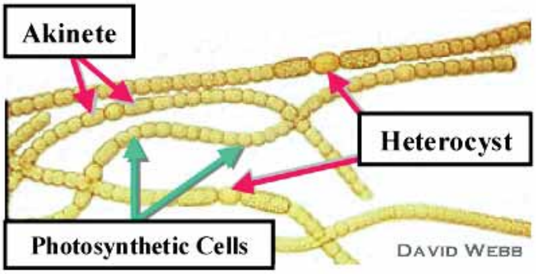
3.5.A.6.1 (c).1 Azolla –Soya hulls combination

Overall assessment of these parameters reveal that coir pith supplemented with natural nitrogen sources - Azolla and Soya hulls in 2:1 ratio inoculated with *P. sajor caju* shown a reduction in lignocellulosic content and enhancement in NPK status.

a, **Azolla pinnata**

Azolla is a small aquatic floating fern, which contains an endo-symbiotic microbial community living in the dorsal lobe cavity of the leaves and this association was capable of nitrogen fixation. The presence of nitrogen fixing filamentous cyanobacteria, anabaena, in these cavities makes Azolla-Anabaena symbiotic association that provides sufficient amount of nitrogen in to the field. In many countries this has been extensively used as green manure for long term soil fertility.





b. Soya hulls

Soybean seed coats, or hulls, represent about 8 to 10% of the weight of soybean grain. The major constituents of soya hulls, on a dry weight basis are cellulose -14 to 25 g/100g, hemicellulose -14 to 20, pectin -10 to 12, protein -9 to 12, uronic acid -7 to 11, ash -4 to 5, lignin-3 to 4 g/100g. This is used as a primary dietary ingredient in cattle feed.

Table. The Nutrient status of the coir pith degraded with *Pleurotus sajor caju* supplemented with Azolla and Soya hulls (2:1)

Parameter	Values		
	Raw coir pith	Coir pith degraded with P. sajor caju supplemented with Urea	Coir pith degraded with P. sajor caju supplemented with Azolla and Soya hulls in 2:1 ratio
Nitrogen	0.26	1.26	1.18
Phosphorous	0.01	0.06	0.056
Potassium	0.78	1.20	1.17
Lignin	30	4.8	5.8
Organic Carbon	29	24.9	25.0

Partial substitution studies of carbon and nitrogen with vegetative sources have resulted in the vigorous growth of the mushroom and this led to the enhancement of nitrogen, phosphorous, potassium and decreased lignin content in biodegraded pith. Addition of Azolla and Soya hulls (2:1) is found to be efficient in lignin degradation.

3.5.A.6.1 (c).2 Azolla –Fish waste combination (2:1)

Parameter	Values
Nitrogen (%)	1.258
Phosphorous (%)	0.16
Potassium (%)	1.19
C:N Ratio	19:1

3.5.A.6.1 (c).3 Nitrogen fixing bacteria -Azotobacter vinelandi.

The use of nitrogen fixing bacteria is a good alternative for urea for composting of coir pith. The microflora consumes the coir pith as substrate and fix the nitrogen from atmosphere. Instead of the individual action of *Pleurotus*, the combined action of fungus with bacteria influences the coir pith degradation with an enrichment in NPK

Composting Medim	Lignin (%)	Nitrogen (%)	Phosphorous (%)	Potassium (%)
Coir pith + *P.sajor caju* +*Azotobacter vinelandii*	19	1.19	0.055	1.16

3.5.A.6.1 (c). 4 Cyano bacteria

Modern agriculture and food systems, including organic agriculture are undergoing a technological and structural modernization and are faced with a growing globalization.

Organic agriculture can be seen as pioneering efforts to create sustainable development based on other principles than mainstream agriculture. In order to make agriculture sustainable, it is necessary to implement a balanced and responsible use of organic agriculture. The principles of organic farming also outline the similar concepts where the soil health and biodiversity is built up to sustain the plant growth in longer term. Biofertilizers have important roles to play in improving the nutrient supplies and their availability to crop production through sustainable way. They are also less expensive, highly biodegradable, non pollutants to both aquatic and terrestrial ecosystem help small and large scale farmers. Cyanobacteria have the ability to degrade the coir pith and convert into cyanopith and cyanospray fertilizers. This work is undertaken to cultivate user land by introducing coir pith based cyanobacterial biofertilizer technology.

Cyanobacteria also known as blue-green algae, blue-green bacteria or cyanophyta belong to phylum of bacteria that obtain their energy through photosynthesis.It need simple nutrient supply for their growth and multiplication. The use of Cyanopith and cyanospray have the benefits include easy availability, the inoculums get immobilized, increase the potential of the inoculums, eliminate bacterial contamination because of its high lignin content and increase the shelf life of the inoculums.

3.5.A.7 As a Base for Preparation of COCOLAWN ™

COCOLAWN is a lush green instant lawn of grass has been developed by CCRI based on coir products viz coir geotextiles, coir fibre, coir pith and (C-POM) Coir Pith Organic Manure. The lawn is encased in a composite comprising a single layer of coir fibre embedded in coir netting or coir geotextiles. A layer of coir pith is placed on the fibre Grass slips are planted on the coir pith bed so made and Coir Pith Organic Manure [CPOM] is sprinkled thereon to form a thin layer. Grass of choice can be grown to prepare the lawn. It is easy to shift the material from one place to another and it can be rolled for transportation.

At present about 20,000 sq. meters of grass turfs are being imported everyday only in UAE, removal of weeds involves huge expenditure. Further, cutting these grass turfs creates scars on the earth’s surface, elsewhere, due to removal of top layer of fertile soil. Grass turfs require frequent watering and are difficult to transport due to heaviness. The grass turfs also suffer from limited sustainability. Therefore, there is requirement of a readymade lawn which is free from weeds, eco-friendly [that could be produced without removing the top fertile soil], light weight and which can release absorbed water in a sustained way for its longest survival. Recent developments in improvement of technology by using heap composting of coir pith and comparative study of the physico-chemical properties of composted coir pith and peat moss has put coir pith in the forefront in the field of soil less medium of plant growth. The development of a readymade lawn using the coir fiber and pith together to prepare a mat in conjunction with the natural grass that can be rolled, cut or shaped in any form to suit the contour or place to be installed. The lawn is easy to handle and can be transported easily because of its light weight. Coir based lawn can be used in restoration of riparian land to establish quick vegetation which will decrease soil erosion and support silt, sediment and nutrient deposits that are important for enhancement of biodiversity.

"Coir bhoovastra, coir needled felt, raw coir pith, Coir Pith Organic Manure (CPOM) and grass are used to make the lawn. The synthetic lawns are very costly. The disposal of synthetic material is harmful to nature. This readymade lawn can be applied on any arid surface, even on a concrete floor.

3.5.A.7.1. Preparation of COCOLAWN Tm

The following materials are used for making a readymade lawn of natural grass comprising:

- A layer of (Coir bhoovastra) netting material made of coir
- A single or plurality of non woven layers (Coir Needled felt) layer / Coir fibre
- A raw coir pith layer on non-woven layer.
- A layer of fertilizer viz. coir pith organic manure (C-POM) and natural grass on the coir pith layer.

Non woven layers provide thickness to the lawn and allows grass roots to get entangled in the non woven material. The layer of coir pith gives a support base, coir pith layer can be treated with other nutrients such as mushroom seeds and urea etc. and allowed to mature

Cocolawn

till the weight is substantially reduced as lignin is consumed by fungi or mushroom seeds. After making the coir bed using ‘coir bhoovastra’ and pith, the grass is planted on it. The lawn will become ready for use within one month. Readymade lawn can be made in the form of rolled like blankets which can be laid on any surface.

Cocolawn (Under-view)

The coir netting can also be usefully laid to adjust any contour with proper hugging due to its rugged is an open weave mesh structure to support the lawn and ensures complete drainage of excess water and heavy construction. It has the property of minimum swelling (up to maximum 5%) even on absorption of 200% moisture. The open weave of the supporting fabric also helps in supporting the roots of the planted grass slips, which form a mat by entangling with the coir fiber and yarn. The coir netting can therefore be laid on any arid surface or even concrete floor to act as a support material as the surface only forms a support for the blanket without contributing to the sustenance of grass.

The netting also helps to drain the excess water accumulated during irrigation. Coir non woven [needled] felt has been used as a semi-permeable membrane to retain the coir pith with C-POM, and to give support to the readymade lawn. It helps in creating a microclimate which boosts plant development. The non-woven layers impart thickness or bulk properties to the lawn. Another function of the non-woven layers is to allow the grass roots to form a bush and get positively entangled in the non-woven material .A layer of coir pith is provided on the non-woven layer, which adds to the bulk properties of the lawn. Further, such a layer of coir pith forms a support/ bed for grass. Coir pith has been used as a moisture retaining agent for the roots of grass due to its cylindrically opened foam cell like structure to provide an inexpensive and environment friendly matrix for diffusion controlled moisture release. Retention of as much as 800% of moisture on its weight supports the grass slips even during drought by providing adequate moisture which is released slowly creating the ideal conditions for the growth of plants. Because of the moisture retention capacity sprinkling of water can be minimized reducing cost and saving water.

Grass is planted on the top most layer of Coir Pith Organic Manure, C-POM . Initially, C-POM is required to sustain the grass by providing nutrients like Nitrogen, Phosphorus and Potassium and other micronutrients essential for the growth of grass. However, as the bed and the non-woven layers are biodegradable in nature, nutrients are released

subsequently and absorbed for the further growth and sustenance of grass. The ingredients of coir based readymade lawn are mechanically bound together with the grass. Undesirable plastic net need not be used. It completely shelters the underlying bare surface from weather erosion while grass develops, to provide long-term protection. It is recommended on sites where seeds are prone to be washed out, excessive deprivation (bird colonies), seed application is impractical or where competitive weed growth is a problem. C-POM has been utilized as a source of soil less, pesticide free, nutritional medium for healthy growth of natural grass in an environment friendly manner. The harmful effects of excessive use of chemical fertilizers to the environment are well known. Replacement of soil makes the product much lighter in weight which helps in transportation and installation. When laid on a bare surface, the lawn protects the surface against erosion by rain, run-off and wind, which in due course of time allows vegetation to establish in a natural way. Coir based lawn can be used for restoration of riparian and wetlands besides channel outlets.

3.5.A.7.2 Advantages over other Known Alternatives

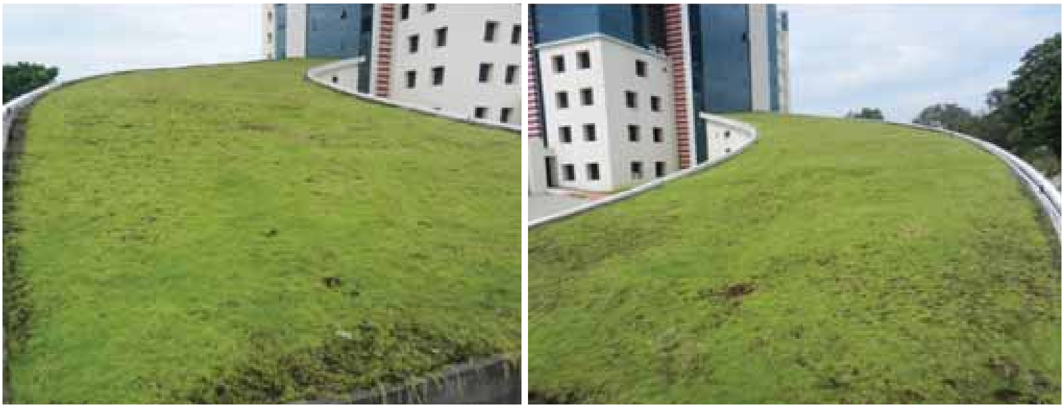
Coir based lawns are devoid of pesticides, weeds which are normally associated with grass turfs. Further, the composted coir pith provides long term sustainability by slowly releasing the nutrients unlike grass turfs. The coir based lawn is lighter in weight and therefore, easy to handle in comparison to the grass turfs. Synthetic lawns are usually treated with ultraviolet radiation resistant chemicals to extend their durability. The disposal of such synthetic lawns becomes a problem. Artificial turf tends to be much hotter than natural grass when exposed to the Sun. The abrasions caused by artificial turf have been linked to a higher incidence of infections. Sometimes artificial turf requires infill such as silicon sand and/or granulated rubber made from recycled car tyres. This material carries heavy metals which can leach into the water table. Periodic disinfection is required as pathogens are not broken down by natural processes in the same manner as for the coir based natural grass lawn. Recent studies suggest certain microbial life is less active.

Coir materials do not require such treatment as the presence of large amount of surface lignin nullifies the effect of UV light. Being a biodegradable material, its disposal does not pose any ecological problem. Coir materials are fully decomposed over a period of 5 years into humus providing sustained nutrition to the growing grass; meanwhile, the lawn is also established completely. Unlike synthetics the readymade lawn does not pose any ingestion risk to wild life. The subtle fawn color of the coir materials blends well with the surrounding ground and does not require any disguise of top dressing. With a high tensile strength, variable open area and being completely biodegradable, coir netting has been found to be effective and dependable erosion control material.Global fever [warming] is causing major concern worldwide. Different techniques are being adopted to cool the earth by cutting green house gas emissions such as pumping CO_2 down below the earth's surface etc.

It is estimated that a tarred roof in summer reaches a scalding temperature of 60°C. If such roofs are covered with the readymade lawn based on coir, it will bring down the temperature substantially. Therefore, the best way to cool the earth is to cover it with coir based lawn as and where possible. The coir based natural grass lawn can be used on the roof of a house or balcony of an apartment for growing vegetables and flowers. Such vegetables/flowers require limited quantity of water for sustaining because of high water retention capacity of coir pith. The roof/balcony gardens perform the dual function of growing vegetables/flowers by organic farming methods besides cooling the houses/ apartments. This system also ensures abundant supply of oxygen in the surrounding area.

3.5.A.7.3. Maintenance

Proper mowing practices are especially important for an organic lawn to give grass a competitive edge over weeds and to avoid disease. Organic lawns are generally mowed higher than conventional lawns. Longer grass shades the soil, helps prevent weed seed germination, keeps the soil cooler, and reduces water loss.



Demonstration of Cocolawn at University of Kerala Health Science, Thrissur

3.5.A.7.4 Fertigation

The application of fertilizer ensures adequate soil fertility and contributes to satisfactory plant growth. Many substances used as organic fertilizers also add organic matter to the soil. The three major nutrients plants need are nitrogen (N), phosphorus (P), and potassium (K). Nitrogen is needed for vegetative growth and good green colour. It is used up quickly by growing plants and must be replaced regularly. Phosphorus is important for good root development and many growth processes. Potassium is essential for physiological functions, disease resistance, and winter hardiness.

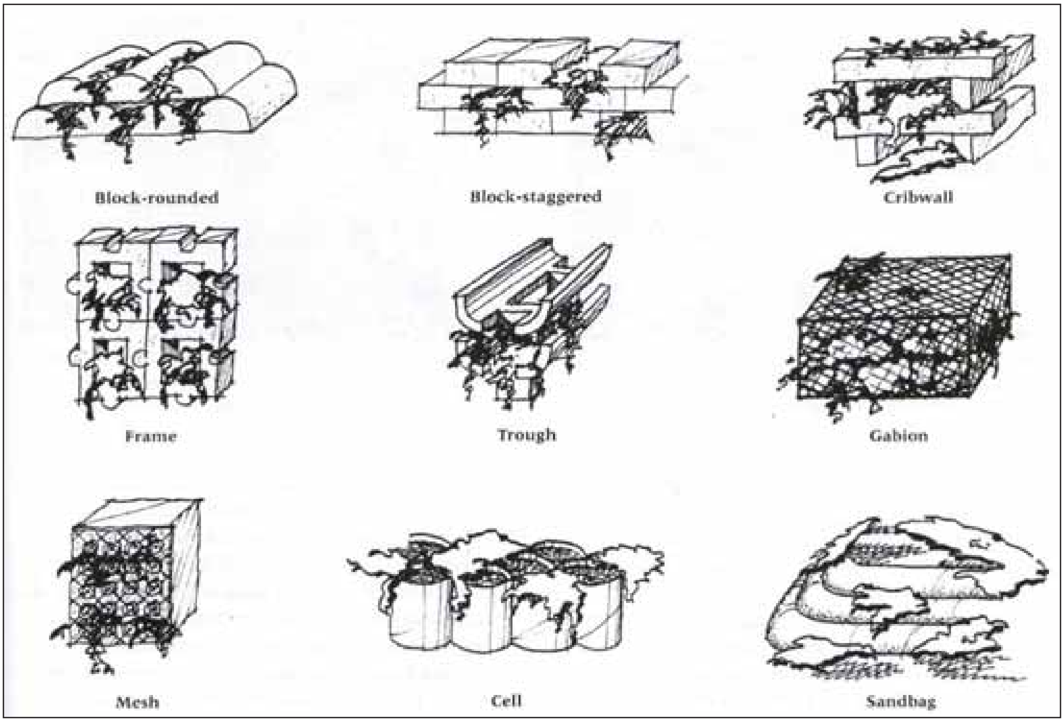
3.5.A.7.5 Applications of COCOLAWN Tm

- The lawn can be used to cover golf and tennis courts, hockey and football grounds and as a roof cover for multi-storey buildings and has vast potential in tourist resort, hotels and as cycle path or footpath.
- The lawn protects the moisture condition in nature. The coir pith absorbs a lot of moisture which supports the grass saplings during the drought season by providing adequate moisture which is released slowly creating the ideal microclimate.
- The open weave of the supporting fabric ensures complete drainage of excess water and helps supporting of roots of the planted grass and it completely shelters the underlying bare surface from weather erosion while grass develops, to provide long term.

3.5.A.8 As a Base for Home / Vertical / Roof Garden

Green Wall or Vertical Garden is the term that used to refer to all form of vegetated wall surfaces. Green walls are not only spectacularly beautiful, but also helpful in enlivening the ambiance. It can absorb heated gas in the air, lower both indoor and outdoor temperature, providing a healthier indoor air quality as well as a more beautiful space. They hold or slow rainwater, providing food and shelter for wildlife. Some plants are able to grow on walls by taking root in the substance of the wall itself belonging to the small herbaceous species such as ivy-leaved toadflax, wallflower and plants such as mosses, lichens and grasses. But other species are naturally adapted to climbing up and over obstacles such as rock faces, trees and shrubs. Some kind of support structure is usually essential for these to grow successfully on walls and buildings. Green walls can be constructed with many systems that include the following structural concepts.

The use of Vertical garden using C-POM will be advantageous to the beneficiaries especially nursery industry to increase yield, uniform & better quality crops, reduction in



Structural concepts of vertical garden

labour cost, reduction in fertilizer cost, low water requirement, less chances of disease attack, thus reduction in disease control cost and less area to get maximum yield and benefits.

Agriculture intensification and diversification would lead to increased cropping intensity,

Demonstration of Vertical Garden at CCRI productivity through better health and nutritional management and sustainable use of land and water resources.

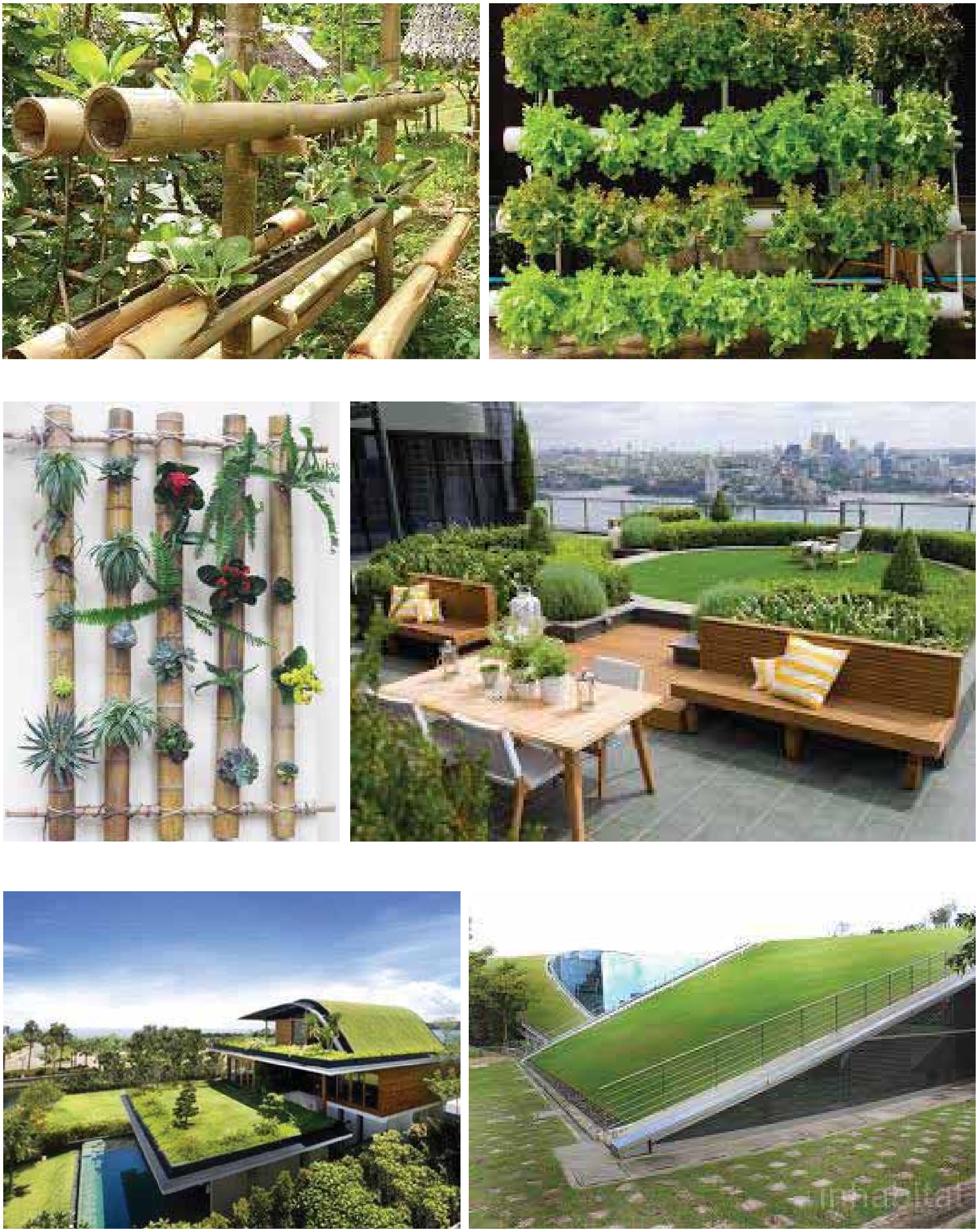
Laying Methodology for Roof Lawns:

Plant Species Used for the vertical garden at CCRI

1	Aglaonema	Aglaonema sp. Red
2	Dieffenbachia	Dieffenbachia sp.
3	Philodendron	Philodendron golden erubescens
4	Scindapsus-Golden-Pothos	Epipremnum aureus
5	Dracaena marginata 'Colorama	Dracaena marginata

Before After

Bridge in France with Vertical Garden



Roof gadening

Parameters	Values
Weight	5-8 Kgs/ Sft
Layer Height	Wet: 100 mm - 150 mm Dry: 65 mm – 75 mm
Roof Pitch	1-5˚
Vegetation Form	Mexican Sod Lawn, Ground Covers & selected grasses
Water Consumption	500 ml/ SFT
Watering Frequency	Once every 2 days
Run-Off Discharge	Slow Release
Modulus of Rupture (Min)	16 N/mm²


Terrace garden also a gardening practice which were getting tremendous attentions in urban areas like flats and multi floored villas

- A thin water proof/ Root Barrier Sheet is laid on the waterproofed roof surface.
- The NG Mat is then laid on top of the above root barrier sheet.
- NR Mat – Manufactured by a combination of NG Mat and the NSAP substrate in a tile form consolidated with Scrim.
- Finally the Mexican Sod Lawn is laid on top and the system is then watered
- The compressed Super absorbent natural polymer present in the NR Mat expands 5 times to its normal size and retains water and helps the roots to set.

3.5.A.9 Potting Media

3.5.A.9 (a) As Soil Substitute

Mostly the coir pith from India and Sri Lanka are briquettes or compressed into bale or block form. It is done only for loading convenience and to reduce freight cost. The importers reprocesses the compressed pith by wetting into loose forms and grade according to particle size and mixed in different ratios according to the

farmers requirements, either for floriculture or horticulture. They also mix fertilizers and micronutrients with it depending on the crop to grow in the pot. It is then transferred to the pot-filling machine where different sizes of pots are filled with these mixed material automatically.

3.5.A.9 (b). Coir baskets

These are moulded rubberised coir fibre baskets made from sheets of coir fibre, which are mainly available in spherical shape. Used as liners to wire baskets after filled with coir pith or husk chips as growing medium for climbers and hanging plants in agri-horti-floricultures. They are also available in “U” shape and conical shapes. They are used in roof gardens.

The wall thickness varies from 10 mm to 15 mm. The diameter of ¼ sphere shape is usually of 16 inch, the diameter of ½ sphere shape ranges from 10 inch to 20 inch, “U” shape from 10 inch to 12 inch and conical shape from 9 inch to 20 inch.

3.5 B Industrial Applications

3.5. B.1. For Active Carbon for SiC (Silicon Carbide)

Several investigators reported the industrial uses of coir pith as bio fertilizers, particle boards, briquetted fuel, light weight ferro cement beams etc. The dry untreated or treated pith can be subjected to controlled carbonization, followed by the granulation to obtain charcoal pellets with at least 75% fixed carbon (bulk density around 0.8 -1.0 gm/cc). This charcoal pellets when mixed with desired quantity of quartz for synthesis of SiC.

Carbonization Process

Carbonization process is heating the lignocellulosic material without the contact of air to drive out the volatile matter to form carbon. The process involves thermal decomposition of coir pith together with distillation. Coir pith can be carbonized by prolonged heating to a final temperature of 400 ^{0}c in a properly designed carboniser

3.5. B.2. As a Source of Power Alcohol

It is estimated that about 100 million tons per year of carbon is fixed by photosynthesis using solar energy. Cellulose of all kinds of plant material in general and coconut pith in particular has a high potential to meet food, chemical and energy requirement.

Bio conversion of cellulose to glucose and/or ethanol is a long range solution to our resource crunch. While conversion of cellulose of lignocellulosic to sugars through hydrolysis is possible by acid and enzymes and the second stage conversion of sugar to power alcohol is carried out by biosynthetic process called fermentation. The acid hydrolysis generates total carbohydrates from coir pith.

3.5. B.3. Production of Cellulase

Lignin present in the coir pith was observed to interfere with hydrolysis by irreversibly binding the hydrolytic enzymes, thereby blocking access to cellulose. Pretreatment of coir pith increases the crystallinity and surface area of cellulose thus removing lignin and thereby enhancing its enzymatic degradation reactivity and its transformation. Cellulose is commonly degraded by an enzyme called cellulase. Several studies have been carried out to produce cellulolytic enzymes from bio-waste using degradation process by using microorganisms including fungi such as *Trichoderma, Penicillium* and *Aspergillus* spp.

The commercial use of *Cellulases* is dependent on the high titer and good enzymatic activity, low production cost and feasible mass production. *Cellulases* are inducible enzymes and their synthesis is strongly repressed by soluble sugars. *Cellulases* are imperative enzymes not only for their potent applications in different sectors, like industries of food processing, animal feed production, pulp and paper production, detergent and textile, but also for the significant role in the bioconversion of agricultural wastes into sugar and bio ethanol. The cellulase enzyme derived from a thermophilic anaerobe Clostridium thermocellum has been reported to be resistant towards end product inhibition and repression. The control of pH and temperature are critical for the production and release of cellulases.

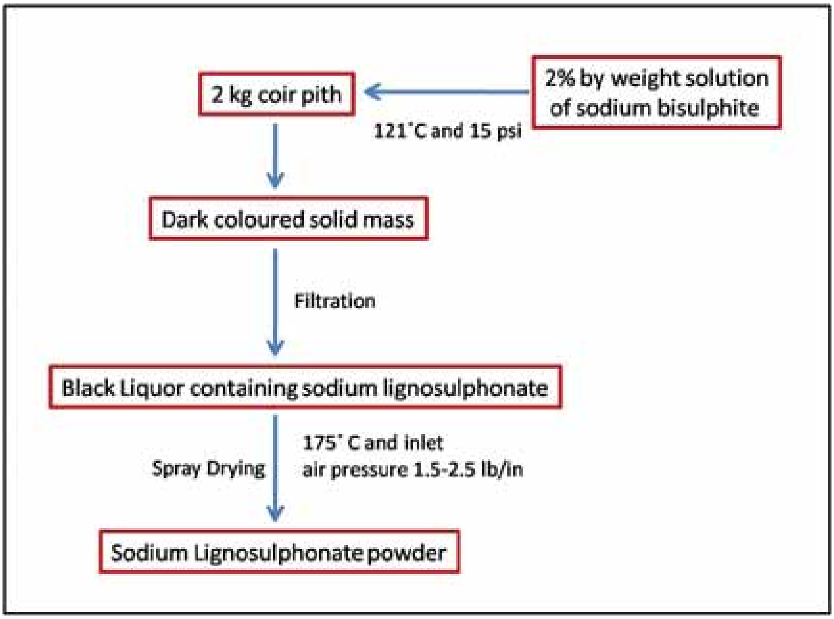
3.5. B.4. Extraction of Sodium Lignosulphonate

Sodium lignosulphonate (lignosulphonic acid) is used in the food industry, as a de-foaming agent for paper production and in adhesives for items that come in contact with food. It has antimicrobial and preservative properties, and is used as an ingredient in animal feeds and used for construction, ceramics, mineral powder, chemical industry, textile industry (leather), metallurgical and petroleum industry, fire-retardant materials, rubber vulcanization and organic polymerization. In addition to this, Sodium lignosulphonate can be used for an expander formulation in battery paste compositions. The expander formulation incorporates effective or elevated concentrations of sodium lignosulphonate to lessen or minimize the accumulation of lead sulfate on the surface of the negative plate during high rate of battery operation. This also helps to increase the electrochemical efficiency, reserve capacity, cold cranking performance and life cycle of lead-acid batteries.

Now-a-days, sodium lignosulphonate is importing from the foreign countries to meet the requirements in its applications in industries.The chemical extraction of sodium lignosulphonate from coir pith is a much cheaper source.

3.5. B.4. 1. Extraction of Sodium Lignosulphonate

2 kg of coir pith was digested with 2% solution of sodium bisulfate at 121^{0}C and 15 psi for a period of 3 hrs. The resulting product is a dark colored solid mass which upon filtration produces black liquor solution of sodium lignosulphonate. The pH of this black liquor was then brought to alkaline by adding NaOH and spray dried at a temperature of 175^{0}C and inlet air pressure of 1.5-2.5 lb/inch^2 to get sodium lignosulphonate in powder form.



Schematic diagram showing production of sodium lignosulphonate

3.5. B.4. 2. Uses of Sodium Lignosulphonate

1. Expander in Lead acid batteries.
2. Mud thinner in oil well drilling fluids.
3. Binder in roads to increase its load carrying capacity.
4. Binder in animal feed preparations.
5. Dispersant in cement manufacture, concrete admixtures and boiling water.
6. Stabilize emulsions making them highly resistant to breaking.

SEM view of C-POM

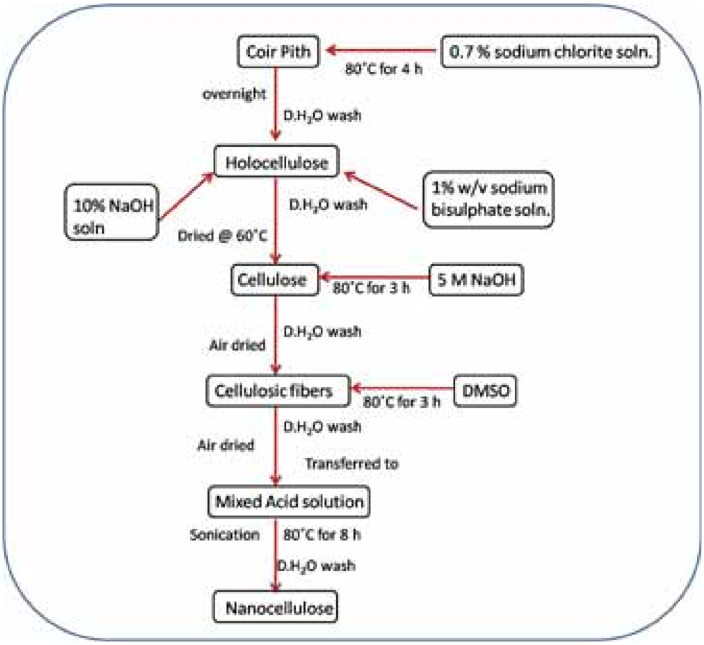
3.5. B.5. Nanocellulose from Coir Pith

The ability to manipulate physical, chemical and biological properties of nanoparticles opens up a whole lot of possibilities in rationally designing these nanoparticles for use in drug delivery, as image contrast agents, in tissue engineering and for diagnostic purposes. The unusual physicochemical properties of nanoparticles are attributes of their small size, large surface area to volume ratio, chemical composition, shape etc.

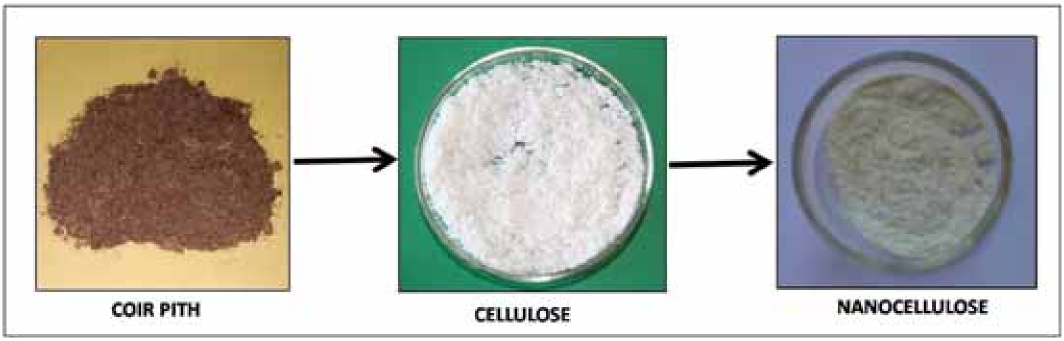
Cellulose is providing a very versatile material and can be used in a wide variety of biomedical applications, from topical wound dressing to the durable scaffolds required for tissue engineering as it is both durable and biocompatible. Its impact on man is evidenced that natural cellulose based materials have found extensive use in the areas of cosmetic and biomedical industry for preparing deep moisturizing packs, surgical equipments, artificial ligaments, hip joints, dental bridges, artificial heart valves etc.

The promising performance of cellulose nanofibres and their abundance encourages the utilization of coconut husk which acts as the main source of cellulose. Unique properties such as biodegradability, low density, availability, low pricing and easily adjustable surface properties of the nature's wonder provide potential opportunities to develop new materials based on cellulosic fibre.

Cellulose was extracted from coir pith and the extracted cellulose was converted to nanocellulose.



Flow Diagram for Nanocellulose Production from Coir Pith



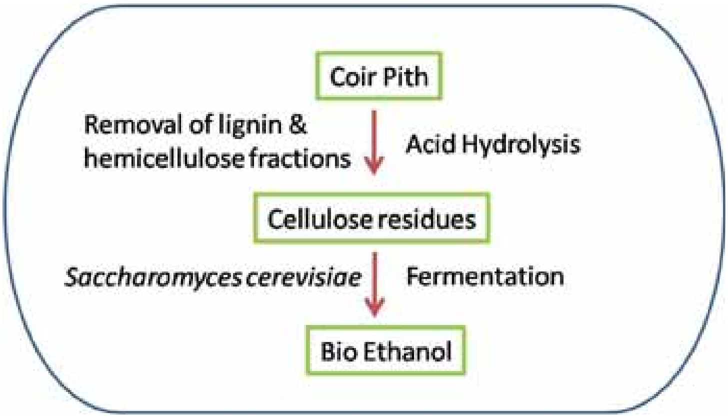
Conversion of coir pith to nanocellulose

3.5. B.6. Production of Bio ethanol

Bio ethanol is an alternative fuel to gasoline that is made from renewable resources. There are three kinds of resources: sugar base (sugar cane, molasses, sugar bit, etc), starch base (corn, cassava, sago, etc), and cellulose base (wood, rice musk, grass, etc).

The energy crisis is one of the most serious problems facing the sustainability of human civilization. Lignocellulosic biomass, which comprises mainly cellulose, hemicellulose and lignin has been considered as a second-generation feedstock for bio-ethanol production. The lignocelluloses may prove to be one of the most useful alternatives to renewable energy sources.

Coconut husk has high proportions of well defined polymeric structures of cellulose, hemi cellulose and lignin content of 28, 38 and 32.8 % respectively. Efforts have already been made to create value from these components as a precursor for the preparation of fibers that can be incorporated in cementitious matrices and as potential adsorbents in waste water purification.



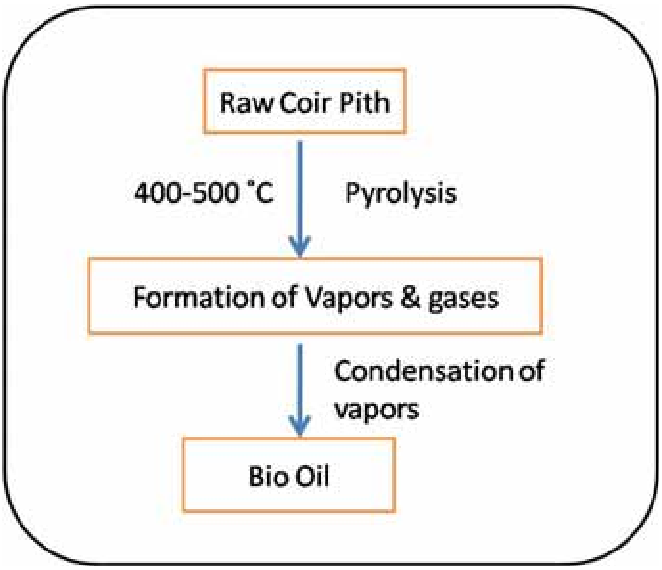
Flow Diagram of Bioethanol Production

Sugar base bio ethanol is the simplest process. Sugar source can be directly fermented by yeast to produce ethanol.

Cellulose base bio ethanol is the most complex and difficult technology since it is quite hard to crack cellulose into more simple molecules like carbohydrate or starch. Cellulose is treated with strong acid to produce simple starch molecule. This process also produces some by product like carbon, carbon dioxide, volatile matter, etc. Simple starch molecule is then seeded to liquefaction and fermentation process to produce ethanol. Even though it is most difficult, cellulose base ethanol is a solution to produce cheap environment friendly fuel since its can convert cellulose from wood waste, farm waste, etc to ethanol.

3.5. B.7. Production of Bio Oil

Zero net emission of CO_2 can be achieved because CO_2 released from biomass will be recycled into the plants by photosynthesis quantitatively. The energy crisis and fuel tension made biomass fast pyrolysis liquefaction a more important area of research and development Bio-oil from biomass fast pyrolysis is mainly produced from biomass residues in the absence of air at atmospheric pressure, a low temperature (450–550^{0}C), high heating rate (103–104 K/s) and short gas residence time to crack into short chain molecules and be cooled to liquid rapidly. Fast pyrolysis, an effective biomass conversion with high liquid yield, as much as 70–80% and a high ratio of fuel to feed, is regarded as one of the reasonable and promising technologies to compete with and eventually replace non-renewable fossil fuel resources.



Flow Diagram of Bio Oil Production from Coir Pith

3.5. B.8. Preparation of Particle Board

Particle boards of size 250 mm×250 mm and up to 12 mm thick with 0·9 g/cm^{3}density were made using coir pith of 0·45, 0·80, 1·20 and 2·10 mm particle size with phenol formaldehyde and urea formaldehyde resins. The proportion of resin, curing temperature and curing time determine the quality of the boards. The high strength boards were made from the larger particle size of the coir pith keeping the proportion of resin, curing temperature and curing time of 16·7%, 138°C and 26 min respectively for phenol formaldehyde resin. The proportion of resin, curing temperature and curing time of 20·4%, 139°C and 17 min respectively were optimum for the urea formaldehyde resin.

3.5. B.9. As an Insulator

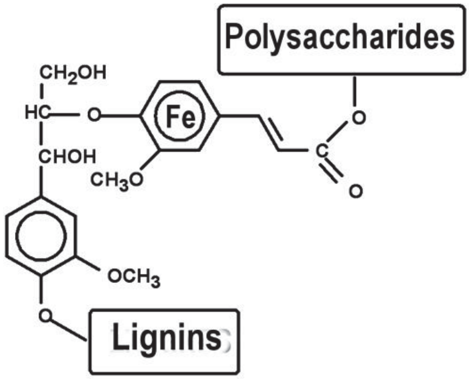
The gasification characteristics of coir pith are studied in a circulating fluidized bed gasifier using air as the gasifying medium. The effect of temperature, Equivalence Ratio (ER), Oxygen/Carbon ratio (O/C) on gas yield, gas composition, gas heating value, carbon conversion, cold gas and overall thermal efficiency was studied. The ERs employed in the study are 0.18, 0.21, 0.24 and 0.31. It has been found that temperature has an influence on the cracking reactions, as indicated by the increased yield of hydrogen. The maximum yield of hydrogen is obtained at a temperature of 1028.6 °C and as the Equivalence Ratio (ER) increased, the hydrogen yield decreased. The gas yield also increased with increase in temperature and ER. Also it has been observed that the gas heating value increases with increase in temperature and decrease in ER. Carbon conversion is found to increase with increase in temperature and increase in ER. It is found that the increase in temperature favours both the cold gas thermal and overall thermal efficiencies.

3.5. B.10. Production of Vanillin

Microbial or enzymatic processes to produce vanillin have used any of the following precursors; lignin, Curcumin, Siam benzoin resin, phenolic stilbenes, isoeuginol, eugenol. Most attention was given to the biotransformation of ferulic acid and eugenol, as they are readily available precursors. Ferulic acid, which is a phenolic acid, has been considered to be the most attractive precursor for microbial formation of vanillin.

Lignin recovery and Vanillin production upholds the sustainable concepts of waste management and product development of coir pith. The present study aimed at finding out coir pith as a cheap and suitable substrate for extraction of biovanillin with the adoption of biotechnological approach and it was found that biovanillin could be extracted from coir pith. Coir pith was initially subjected to alkaline hydrolysis which resulted in the formation of ferulic acid and the same was used as a substrate for biotransformation by *Aspergillus niger* to vanillic acid which underwent fermentation by *Phanerochaete chrysosporium* to vanillin. Vanillic acid was detected to be on the third day of incubation and optimum vanillin production was observed to be 0.5090 gm/100 gm of coir pith. However, Ferulic acid is a valuable product developed from coir pith which can be used as a means of carbon sequestration and shall be suitable for pharmaceutical applications.

Ferulic acid links with various carbohydrate like mono, di saccharides, polysaccharide, lignin and insoluble carbohydrate biopolymer of cell wall to create a cross linking between each other . The cross linking seems to inspire the extensibility, plasticity, accessibility and digestibility of cell wall. Ferulic acid is known to be a strong antioxidant and has several potential applications; especially for food, health, cosmetic and pharmaceutical industries. Moreover, ferulic acid seems to be used as a feed stock for biovanillin production by selected fungus. The vanillin, which has intensely sweet aroma, has gained high attraction in related industries. It has wide applications in foods and beverages industries. It is used as a fragrance ingredient in perfumes and in pharmaceutical area.



Structure of ferulic acid linked to lignin and cellulose

The production of Vanillin from coir pith is cost effective in comparison with the synthetic vanillin. The study also gives value addition to coir pith as a precursor for Vanillin production for industrial applications.

3.5. B.11. Production Activated Carbon

Activated carbon is a non-graphite form of carbon which could be produced from any carbonaceous material such as coal, lignite, wood, paddy husk, coir pith, coconut shell, etc. Due to its highly porous structure and fixed carbon content, it has been tried as a raw material for the production of activated carbon (AC). Several studies reported that carbonized coir pith was effective for the treatment of dyeing industry's wastewater and the removal of As, Cu, Cr, Hg, Ni and organics, including pesticides from aqueous solution. Activated carbon manufactured from coconut shell is considered superior to those obtained from other sources mainly because of small macro pores structure which renders it more effective for the adsorption of gas/vapour and for the removal of colour and odour of compounds. Two commonly used processes for the manufacture of activated carbon are,

- Steam activation
- Chemical activation

Steam activation process is chosen to produce good quality activated carbon from coconut shell. The activated carbon is extensively used in the refining and bleaching of vegetable oils and chemical solutions, water purification, recovery of solvents and other vapours, recovery of gold, in gas masks for protection against toxic gases, in filters for providing adequate protection against war gases/nuclear fall outs, etc.

The ACs from coir pith is mainly divided into three,

- Granular Activated Carbon (GAC)
- Powdered Activated Carbon(PAC)
- Extruded Activated Carbon (EAC)

3.5. B.11.1 Steam Activation

Firstly the coconut shell is converted into shell charcoal by carbonization process which is usually carried out in mud-pits, brick kilns or metallic portable kilns. The coconut shell charcoal is activated by reaction with steam at a temperature of 900°C -1100°C under controlled atmosphere in a rotary kiln. The reaction between steam and charcoal takes place at the internal surface area, creating more sites for adsorption. The temperature factor, in the process of activation is very important. Below 900°C the reaction becomes too slow and is very uneconomical. Above 1100°C the reaction becomes diffusion controlled and therefore takes place on the outer surface of the charcoal resulting in loss of charcoal.

3.5. B.11. 2 Chemical Activation

Activated carbons (ACs) can be prepared by chemical activation also. Chemicals include,

- Acids
- Bases
- Salts

For the production of chemically activated carbon, the coir pith was put in the small porcelain crucible with lid and burned in the furnace with temperature range of 500 C for 2 hours. Then activated with sulphuric acid and distilled water to balance the pH value.

Zinc chloride activated carbon from coir pith has shown excellent adsorption capacity in removal of organic refractory effluents from aquatic wastes. Similarly ACs obtained from coir pith can remove pollutants like dichlorophenols, many organic compounds such as chlorinated and non-chlorinated solvents, gasoline, pesticides and tri halomethanes (THM). It is effective in removing chlorine and moderately effective in removing some heavy metals.

3.5. B.12. Coir Pith Polyester Composites

Composite articles can be manufactured from polyester and coir fibre/pith. The composites so produced have high strength, water resistance, durability and transparency. Thermoset polyesters are formed from linear, unsaturated thermoplastic polyesters that are cross linked by curing with MEKP (methyl ethyl ketone peroxide) in the presence of cobalt naphthenate as catalyst. When the peroxide is mixed with the resin, it decomposes to generate free radicals, which initiate the curing reaction.

Coir reinforcement

The coir reinforcement used are either coir bit fibres or coir pith. The reinforcement should be dried properly before composite manufacturing. The presence of moisture in the material leads to the formation of pinholes in the products. The materials are sieved and properly dried before the moulding. 20-25% coir can be incorporated as the reinforcement

Mould releasing agent.

Releasing agents are used for the easy release of the product from the mould. If the releasing agents are not applied the product will stick on to the mould. The common releasing agents used in this kind of application are PVA, soap solution, oils, polishing wax etc. Polishing wax is found to be the most suitable release agent in the production of coir poly ester moulding.

Moulds

The moulds can be of fibre glass, plaster of Paris, glass or metal moulds. Glass moulds give glossy finish to the product. But handling of the mould is too difficult and the life is very short. Metal moulds are costly and handling is difficult. Plaster of Paris moulds are cheaper, but the life of the mould is very short. Among the available mould materials fibre glass moulds are cost effective for the production of coir pith poly ester mouldings. Hundreds of products can be produced from one mould. The finish of the product depends upon the finish of the mould. Single piece moulds are used for one side finished products. Multiple piece moulds are required for three dimensional products.

Method

Steps involved in the production of coir poly ester mouldings are.

1. Apply suitable release agent to the mould.
2. Weigh the required quantity of resin in to a container
3. Mix the cross linking initiator and catalyst to the resin with continuous stirring.
4. Mix the required quantity of coir reinforcement to the resin with constant stirring
5. Pour the mixture in to the prepared mould.
6. Allow the material to set
7. Eject the product from the mould


Coir Polyester Moulded Products

The cross linking reaction is an exothermic reaction. As the reaction proceeds the viscosity of the mix increases and starts setting. The product can be ejected within 15-20 min of reaction and the product is allowed to set completely. On completion of the reaction the temperature lowers to room temperature.

Pigments can be incorporated in to the resin for obtaining coloured products. The pigments should be compatible with the poly ester resin. Painting can also be done to the product for getting attractive designs and ornamentation of the product. Multiple coloured products can be produced depending on the design of the mould.

The composites so produced have high strength, water resistance, durability and transparency. The production process does not require external pressure, temperature or heavy equipments. No skilled labour is required for the production. The process could advantageous to women entrepreneurs without a huge investment.

3.5. B.13. Binder less Coir Wood

The coir fibre and pith has high lignin and phenolic content. The lignin present in the coir fibre and pith act as a thermosetting binder resin. Using the intrinsic resin properties of lignin, high quality particle boards can be made by the compression moulding process without the addition of chemicals and binders. The largely unutilized biomass resource can be transferred into a valuable feedstock for the production of wood substitute products. The thermal behavior of the original (chemically unmodified) lignin in the coir fibre/pith at temperatures above 140 °C where it melts and shows thermosetting properties has been exploited successfully for application as intrinsic resin in board production [Dam et. al. (2004)]. Based on this concept high strength and high density boards were produced without addition of chemical binders.

The binderless board produced from coir is 100% eco friendly as there are no harmful emissions, no chemical treatment required for the production and there are no byproducts during the production process of the boards. The boards so produced can be utilized for the application as acoustic absorbing panels, since coir fibre and pith contains large number of voids in it.

Drying of the materials

The raw materials needs to be dried before hot pressing so as to remove the moisture present in the materials. The presence of moisture in the material creates air entrapments in the board and may affect the strength of the boards. The materials are dried in a standard hot air oven maintained at a temperature of 100˚C for 1-2 hours depending upon the moisture present in the material.

Sieving

The coir bit fibres and coir pith material is sieved in a standard IS 100 mesh sieve to remove the foreign materials present and to ensure a uniform particle size distribution. The boards produced from particles of less than 5mm size have high strength compared to the board produced from bigger size particles.

Hot pressing

The coir bit fibres and pith were compressed in a hydraulic press at elevated temperature and pressure at compression ratio of 1:15 ie. the material fills in the mould at a height of 15cm and compressed to a thickness of 1cm. In the case of matting boards the compression ratio is comparatively less and 2-4 pieces of the matting cut in to the required size and placed in the mould and compressed. The boards are compressed for the required time of 20-30min depending up on the thickness of the product. The boards are allowed to cool under pressure for another 30min and ejected from the mould. The flow chart below explains the different stages in the production of binderless boards from coir pith

1. Husk

2. Defibering process

3. Coir pith

Effect of Moisture

The presence of moisture in the coir pith/fibre creates air entrapments in the produced boards and may lead to deterioration in the strength of the boards. The raw material should be dried to a moisture level of less than 10% before hot pressing.

Effect of Temperature

The thermal behaviour of the original (chemically unmodified) lignin in the plant tissues shows thermosetting properties as it melts at temperatures above 140 °C.. At lower temperatures proper setting of the board has not taken place and at higher temperatures charring of the board observed and 150°C is the optimum temperature for satisfactory flow and setting of the lignin to produced good boards.

Effect of pressure and cooling under pressure

At low pressures, the flow of lignin doesn't take place and the produced boards shown moisture absorption and loss in strength on exposure to the atmosphere. The produced boards were allowed to cool under the applied pressure for half an hour. After the required cooling period, boards are ejected from the mould. Bending of the boards may occur if it is not cooled under the applied pressure inside the mould.

Machining

The binderless boards produced from coir fibre and pith was able to undergo conventional machining operations such as sawing, cutting using high speed cutter and drilling operations.

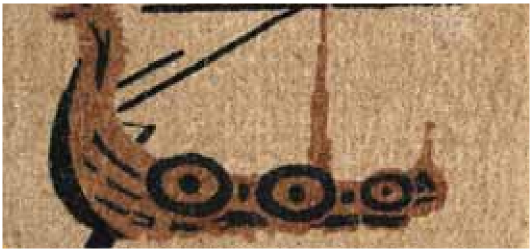
3.5. B.14. As a Carrier Material

The shelf life of Biofertilizer formulation is significant that depends on the quality of the carrier in preserving the inoculants for a long time. An ideal carrier material should be posses the following:

- Highly absorptive and easily processable
- Non toxic to micro organism
- Available in adequate amounts and also inexpensive
- Increase in shelf life of inoculums
- Easy to sterilize
- Provide good adhesion to seeds
- Have a good buffering capacity
- Allow easy germination during field application

A large number of carrier materials such as peat, straw, husk, peanuts, hulls, corncobs, lignite, rice husk, soil, coir pith have been tried for bacterial inoculants. A colaborative study with FACT Cochin has established the potential use of C-POM as a career for biofertilizers.

3.5. B.15. Extraction of natural dyes out of coir pith



Weigh 15 kg raw coir pith. Mix with 300gm caustic soda uniformly. Add equal quantity (15 kg) of water. Cook at 80°c for 30 minutes. Squeeze the hot cooked coir pith through cotton cloth. Collect the liquor in a stainless steel vessel. Repeat the process till the liquor collected is sufficient to dye 1 kg coir yarn with a material to liquor ratio of 1:15. Neutralize with concentrated hydrochloric acid. Add oxalic acid @ 10% on the weight of the coir yarn to be dyed in the liquor extracted from cooked coir pith. Stir well. Heat to 50°c. Enter the weighed quantity of coir yarn into the bath. Maintain the temperature at 80°c for 1 hour. Keep the bath overnight at room temperature. Take the coir yarn from the bath. Wash with cold water. Dry at room temperature.

3.5. B.16. Expansion Joint Filler

The process developed for making expansion joint filler using coir pith with cashew nut shell liquid resin and other additives finds application in all such construction jobs where joints in slabs, beams, shelves, prefabricated components etc. are to be filled up.

4.Value addition of Tender Coconut Husks

Tender coconuts are consumed largely in the summer season for their cooling properties and as a natural drink.The green tender coconut is highly required in different industries like as cosmetic, food & beverage etc. Coconut water is good for jaundice, urinary stones, pimples, measles, prickly heat, heat boils, sun burn, itching, diabetes and cancer. Green tender coconuts are excellent food source and good for health because its own sweet scent, delicious taste and enrich in nutritional value and it can mixes easily with blood.

Chemical Constituents of Tender Coconut Husks

Sl.No.	Parameter	Content
1	Total Carbon. %	45.63
2	Nitrogen,%	0.191
3	Phosphorous,%	0.039
4	Potassium,%	0.149
5	Ash,%	3.35

4.1 Composting of Tender Coconut Husks

- It is an environmentally sound and economically advantageous way to utilize waste for soil organic amendment
- Involves complete or partial degradation of variety of chemical compounds by consortium of microorganisms
- Various constituent elements especially carbon, nitrogen, sulphur, phosphorus are liberated in mineralized forms during composting
- Would lead to the reduction in volume of waste generated
- Supplying nutrients (N, P, K) and moisture to plants
- Help to hold water
- Can be used as a natural soil conditioner

Composting of tender coconut husk

4.2. Production of Pulp and Paper

The waste husk of green / dry tender coconuts is chopped in to uniform size and made in to powder form which contains fibre, pith and outer skin .It is then pulped after mixing with the waste paper by organo-solv treatment using an organic solvent in presence of mineral acid catalyst .This pulp from tender coconut husk is an excellent wood substitute in making paper.

4.2.1 Important features of the paper making machine for coir :

- A3 size paper of medium quality can be produced
- Production of 100 no A3 size paper in 8 hours
- Papers can be used for making garden articles, carry bags, file folders, invitation letters for using blotting paper purpose
- Production capacity of the equipment is to produce 48kg. of pulp/ 8 hrs.
- Machine cost is Rs. 5 lakhs
- Man power required is two
- Power consumption : single phase, 4 HP motor
- Women workers can easily operate the unit
- Paper can be cut into required size by paper cutting tool
- Paper in different variety of colours can be produced by adding dyes
- Pulp can be produced from used paper and cotton waste , Jute/pine apple fiber with 40 % of coir fibre / pith
- Plant and machinery is indigenously available and no foreign exchange is required.
- The units require small quantity of locally available fibrous raw materials for paper manufacture.
- The employment potential is about 20 times that of modern mill in large sector for equivalent production.

5. COIR PITH TESTING LABORATORYAT CCRI

(Recognized by Australian Quarantine Inspection Service)

CCRI is facilitating the export of coir products viz, Coir pith, Coir pith Organic Manure, Coir geo textiles, Coir logs, coconut husk chips etc by issuing Phytosanitary Certification on the sample intended to export.

The RHP Foundation examines, evaluates and directs itself towards maintaining quality standards and the inspection of peat products, raw materials, peat substrate such as coir products, perlite, pummice stone etc. It also awards the special RHP quality mark. The coir products with the RHP hallmark will be tested at two stages

When supplying the material to processors or end users, the quality will be determined. Processed material refers to fertilizing of coir products with a calcium or magnesium fertilizer with the aim to repress the potassium and sodium from the cation complex of the coir and fertilized materials, to reach the desired level of pH, EC, main and trace elements of the coir. The independent RHP quality mark is issued under licence to firm which fulfill all the requirements of the certification scheme. The requirements set for all quality mark do not only relate to the product itself, but also to the production, transport and handling of the product. The quality mark is monitored by an independent certification organization that test both processes and products for compliance with specific requirements. This scheme applies to coir products that is used as substrates or processed in substrates in the agricultural sector and the hobby sector. The scheme contains general requirements and requirements for coir products. The scheme applies from the site where a chemical treatment is done.

5.1 Fermentation Laboratory

Fermentation Laboratory is for carrying out microbiological studies on coir fibre/ coir pith as per RHP standards. The laboratory extend the facility for testing samples of consignments of coir pith intended for export to Australia, Germany, Malaysia, Philippines, The Netherlands and UK from coir entrepreneurs

5.2. Pilot Scale Laboratory (PSL)

Pilot Scale Laboratory was set up for the production of PITHPLUS for composting of Coir pith and Biochem for quality improvement of mechanically extracted fibre. The laboratory became functional at CCRI in November 1994 by launching the sales of PITHPLUS & Biochem (Coirret). The facilities of the PSL has been extended to coir entrepreneurs all over India

5.3. Quality Control Laboratory

Quality Control Laboratory extends for testing physical/ chemical properties of coir fibre/ coir pith as per International Standards for different parameters viz. pH, Electrical Conductivity, Salinity/ Bulk density, Cation Exchange Capacity, Moisture, Lignin, C: N ratio etc.

The Microbiology department of CCRI has facilities for testing the parameters such as Phytosanitary test (Plant Quarantine Certificate),pH, Electrical Conductivity (EC), Sand content, Salinity, Fibre content, Cation Exchange Capacity (CEC), Expansion volume, Bulk density, Pore space volume, Ash content, Water holding capacity, Sulphur, Moisture, Nitrogen (N), Phosphorous (P), Potassium (K), Organic Carbon, Organic matter, Lignin, Cellulose, Hemicellulose, Pectin, Sodium, Calcium, Magnesium, Copper, Iron, Manganese, C: N Ratio, Tannin, Chloride, Zinc, SEM Analysis, HPLC Analysis, GCMS Analysis, TGA/ DSC Analysis, ICP Analysis, Particle size analysis against request.

6. International Bodies for Quality Certification of Coir pith as a potting medium for hoticulture

6.1 AQIS AUSTRALIAN QUARANTINE AND INSPECTION SERVICE
DEPARTMENT OF AGRICULTURE, FISHERIES AND FORESTRY

Commodity: Coir peat - including bales, blocks, bricks, briquettes, compressed or non-compressed

Botanical name: *Cocos nucifera*

Country: **All countries**

End use: **Fertiliser**

Date printed: **Aug 26 2008**

- *The information here covers AQIS quarantine requirements only and is current on the date of transmission but may change without notice. AQIS makes no warranties or representations with respect to the accuracy or completeness of that information and will bear no liability with respect to that information. Importers must satisfy quarantine concerns and comply with quarantine conditions applicable at the time of entry. The Commonwealth through AQIS is not liable for any costs arising from or associated with decisions of importers to import based on conditions presented here which are not current at the time of importation. It is the importer's responsibility to verify the accuracy and completeness of the information at the time of importation.*

Quality Standards for Horticultural Coir for Use as a Growing Media

- 1. Each consignment must conform to the following microbial standards.
- 2. Consignments that have been tested overseas must be accompanied by a certificate of analysis from an acceptable government testing laboratory (see table below).
- Provisional Microbiological Analysis
- Salmonella - absent in 25 grams.
- E. coli - five samples must be tested and the result of each sample must be listed on the microbiological analysis certificate.

- Three samples - must contain less than 100 bacteria per gram Two samples - can contain 100-1000 bacteria per gram No samples - can contain more than 1000 bacteria per gram
- Table of AQIS approved overseas laboratories (correct at the time of printing the conditions) Country

  INDIA
- Central Coir Research Institute, Coir Board, Ministry of MSME is an AQIS approved overseas laboratory for quality certification of coir pith

6.2. RHP; knowledge and quality mark for substrates

In The Netherlands the RHP foundation is responsible for the certification of substrates for consumer and horticulture. If you buy RHP certified substrates, the complete process from base material to production and storage is guaranteed. There are two main RHP labels, one for consumers and one for horticulture. Companies, who bear the RHP-Horticulture, have to be verified by a certification institute (CI). This CI is therefore accredited by the Accreditation Board. ECAS is the only CI with accreditation for the RHP quality mark. The requirements of the products are such that it complies with the demands and/or questions from the professional grower.

Substrates and substrate components that carry the RHP quality mark Horticulture satisfy the highest chemical and physical requirements, are low in weeds and free of pathogenic germs, this all to guarantee a safe and reliable application at the grower. The RHP quality mark guaranties quality, stability and crop safety.

RHP since 1963, the European knowledge center for soil and substrate (growing media) for professional horticulture and the consumer . If you are a breeder and has listed the quality of your final product high in ‘t valued, you are at the right place RHP. Also, if you want to be a gardener and are guaranteed of good quality and clean potting soil, you’re at the right with RHP.

Also for the professional arborist and landscaper offers RHP stable substrates and soil improvement materials to guarantee optimal soil.

Chemical aspects

RHP Horticulture provides insight into the chemical properties of substrates. The property of a substrate is closely related to the nature of the use and of the plants which grow in. Refers to lettuce plants, bedding plants and orchids; Each plant has its own wish list. The acidity is important, but also the (trace) elements.The RHP quality mark makes demands on the materials and the composition of additives (eg. Fertilizers) added to the substrate.

RHP puts high demands on the composition and quality of fertilizers. Some examples:

- The composition of basic potting soil fertilizer was developed based on scientific research and practical experience. This has led to the current composition including a necessary and safe level trace elements.
- Specification of pH, EC and assessment NPK. Soil samples from the field and substrate businesses will be analyzed at accredited laboratories RHP. Then the data is evaluated in the database RHP, called Minerva.
- The RHP product must not be outside the legal regulations, as applicable in the country of production and processing.
- Controlled release fertilizers (release pattern specifying ‘ early - mid - late).

Physical properties

RHP actively developing new parameters to assure you that RHP certified substrates give guarantee for the basis of an optimal cultivation. Nothing can be left to chance! There is a number of internationally established methods to analyze physical (and chemical) properties. However, there is a need for an understanding of a wider range of properties.

New parameters RHP develops, for example:

- The -biologische- stability Capture
- Water absorption and WOK method (WOK = water absorption characteristic), it determines how quickly record a dry substrate water.
- Specification on air content.
- RHP develops handles in order to better align the soil oppotsituatie.

Phytosanitary requirements

substrates and materials that carry the RHP Horticulture quality mark must comply with many requirements. The products must be clean and pure, so that there is no risk for use in cultivation. It starts with the raw materials. If they are pure, they must remain pure in the whole production process with the substrate supplier.

A RHP product should include to meet the following requirements:

- The use of peat in areas where no agricultural activities have taken place (no potential contamination).Preventing contamination and mixing during production combined with strict logistics management.
- The occurrence of weeds that could pose problems in cultivation and / or in a country (eg tropical origin, invasive alien species).
- No organisms that pose a risk to cultivation (for example, plant parasitic nematodes).

7. Coir pith- Technical specifications

1. SCOPE

1.1 This standard prescribes the various requirements of coir pith extracted from coconut husk either by mechanical means or retting.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 COIR PITH

The coir pith is light weight, elastic, granular material having uniform, cylindrically opened cells, with foam likes structure. Due to its porosity, it also gives buoyancy to the coconut fruit during its transport in water while falling from the tree. The coir fibre is embedded in the matrix of coir pith and during the extraction of coir fibres nearly double the quantity of coir pith is obtained. Besides being rich in lignin, the coir pith has also a very high water holding capacity up to 800 %

Coir pith is lignocellulosic in nature, brown coloured, lightweight corky dust; particle size varies from 100-300 microns. It has a porous structure. The pores are responsible for allowing good aeration around the roots of plants and retain water content in the pores for rewetting when dry. Coir pith has readily available nutrients like nitrogen, phosphorus and potassium suitable for plant growth. The organic matter content of soil/substrate is an indicator to its fertility and nutrient availability and coir pith has a higher organic matter content as compared to peat moss. Chemical analysis reveals that coir pith contains three major constituents-cellulose, hemi cellulose and lignin.

It is a high volume, low value product and therefore, the transportation cost will be high.

Most of the available coir pith also contains salts, which are harmful to young nursery plants (high electrical conductivity). It is also extremely difficult to dry under normal conditions.

3. REFERENCES

The following Indian Standards indicated in table1contain provision which formed basis for formulating this standard.

4. REQUIREMENTS

4.1 Texture **-** The material shall be clean and free from adulterants such as sand, metallic pieces, weeds and seeds.

4.2 Colour and Odour **-** The colour of the coir pith shall be golden brown and have no foul odour.

4.3 The characteristics such as pH , Electrical Conductivity, Cation Exchange Capacity, Nitrogen, Phosphorus, Potassium, Copper, Organic carbon, Carbon-Nitrogen Ratio, Lignin, Total organic matter, Moisture content and Ash content shall be tested as per Annex A to H

4.3 The coir pith shall comply with the requirements given in Table 1 when tested according to the methods prescribed in Column 4 of Table 1.

TABLE 1 REQUIREMENTS OF COIR PITH

Sl. No.	Characteristics tested	Value	Method of Test
(1)	(2)	(3)	(4)
	pH	5.4 – 6.0	IS 2711
	Electrical Conductivity, (mm/cm)	0.50 – 1.20	IS 14767 : 2000
	Cation Exchange - Capacity (meq/100 gm percent)	20 - 40	
	Nitrogen, percent (Min.)	0.10	IS 6092 (Part 2/Sec 2): 2004
	Phosphorus, percent (Min.)	0.01	IS: 5305-1969
	Potassium, percent (Min.)	0.50	Testing methods for fertilizers
	Copper, percent (Min.)	1.5	
	Organic Carbon, percent (Min.)	110:1	
	Carbon-Nitrogen ratio (Min.)	110:1	
	Lignin, percent	30 - 35	
	Total Organic Matter, percent (Min.)	75	
	Moisture, percent	15-20	IS 15340: 2003
	Ash Content, percent	1.0 - 1.5	IS 199:1989

5. CORRECTED INVOICE MASS

The corrected invoice mass of the lot shall be taken to be equal to the mass determined by adding 60% to its oven dry mass.

5.1 The oven-dry mass of each bag shall be calculated from its net mass and the moisture content of the lot, the latter being determined as per prescribed in Annex B.

NOTE – Oven-dry mass = $W_1 - \frac{W_1 R}{100}$

where

W_1 = net mass of the bale in the standard atmosphere; and

R = moisture content, percent.

6. PACKING

The material shall be packed as agreed to between the buyer and the seller

7. MARKING

7.1 Each bag shall be marked indicating clearly with the following information attached to it

a) Name and type of the material;

b) Name of the manufacturer containing

i) Nitrogen

ii) Phosphorous

iii) Potassium

iv) Organic carbon

v) C: N ratio

vi) Gross and net weight in kg

vii) Date of packing; and

viii) Any other information as required by the buyer or by the law in force.

7.1.1 BIS Certification Marking

The bags shall be marked with the BIS Certification Mark, if required.

7.1.2 The use of the Standard Mark is governed by the provisions of Bureau of Indian

Standard

Act, 1986 and the Rules and Regulations made there under. The details of conditions under which the licence for the use of the Standard Mark may be granted to manufacturers by the Bureau of Indian Standards.

8. SAMPLING AND CRITERIA FOR CONFORMITY

8.1 Sampling

8.1.1 Lot – Quantity of pith bags of the same type, colour, dimensions, size and shape manufactured under similar conditions and delivered to a buyer against one dispatch note shall constitute a lot.

8.1.2 The conformity of a lot to the requirements of the standard shall be determined on the basis of the tests carried out on the bags selected from it.

8.1.3 Unless otherwise agreed to between the buyer and the the seller, the number of bags to be selected from the lot shall be in accordance with Table 2.

TABLE 2 Size of gross sample and number of test specimen for each test

No. of bags in Lot (N)	No. of bags in Sample (n)
Upto 50	2
51 to 100	3
101 and above	5

8.1.3.1 The bags shall be selected at random. In order to ensure randomness of selection all the bags in the lot may be serially numbered as 1, 2, 3 …... and so on and every r^{th} bag maybe selected until the requisite number is obtained, r being the integral part of N/n where N is the lot size and n is the sample size.

8.2 CRITERIA FOR CONFORMITY - The lot shall be considered conforming to the requirements of this standard if the following conditions are satisfied:

The averages of all the values for all required parameters are in accordance with the applicable value of the relevant grade.

9 REQUIREMENTS FOR ECO MARK

9.1 GENERAL REQUIREMENT

9.1.1 Coir pith shall meet the requirements specified in this Indian Standard.

9.1.2 The manufacturer shall produce to BIS environmental consent clearance from State pollution control board, as per the provisions of Water (Prevention and Control of Pollution) Act 1974 and Air (Prevention and Control of Pollution) Act 1981 and Water (Prevention and Control of Pollution) Cess Act 1977, along with the authorization and rules made as under the Bureau of Indian Standards (See IS 15651) while applying for the ECOMARK.

9.1.3 The product or product packaging may display in brief the criteria based on which the product has been labeled Environment Friendly.

ANNEX A

[Table 1, Sl No. (i)]

METHOD FOR DETERMINATION OF pH

A-1 PRINCIPLE

The aqueous extract of the coir pith is prepared and then the pH is determined using direct reading pH meter.

A-2 TEST SPECIMEN

Draw at least two test specimens each weighing about 10 g from the test sample.

A-3 CONDITIONING OF TEST SPECIMEN

Prior to the test, the test specimens shall be conditioned for 24 h to attain moisture equilibrium in a standard atmosphere at 65 ± 2 percent relative humidity and 27± 2 ˚C temperature (see IS 6359).

A-4 PREPARATION OF AQUEOUS EXTRACT

A- 4. I Procedure

Weigh the test specimen and transfer it to a clean, chemically resistant glass flask, fitted with ground glass joint for reflux condenser. Add distilled water (see IS 1070) weighing 50 times the mass of the coir pith taken for the test to the flask. Fit the flask to the reflux condenser and heat the contents of the flask to boil. Continue boiling for 1 h. Remove the flask and close while the liquid is still boiling gently using a clean ground glass stopper. Cool to room temperature. Squeeze the soaked coir pith for sufficient quantity of aqueous extract required.

A-5 DETERMINATION OF pH VALUE

Transfer a portion of the aqueous extract to the electrode of pH metre (IS 2711) and determine the PH.

ANNEX B

[Table 1, Sl No. (12)]

METHOD FOR DETERMINATION OF MOISTURE CONTENT IN COIR PITH

B-1 TEST SPECIMEN

B-1.1 For the purpose of this test, test specimens each weighing about 10g shall be drawn from the test sample as in 8.1.3.1

B-2 APPARATUS

B-2.0 Petri Dish, Hot air oven, desiccators, weighing balance

B-2.0.1 Conditioning oven-with forced ventilation, provided with positive valve control and capable of maintaining a temperature of 100 ˚C to 110˚C.

B-2.0.2 Weighing balance of either of analytical type or electronic type capable of weighing 500 g with an accuracy of 0.5 g.

B-3PROCEDURE

B -3. 1 The test specimen is weighed correct to the nearest 0.5 g. Place the test specimen in the conditioning oven and dry for 1 h and cool in a desiccator and weigh to the nearest 0.5 g. Dry for another 15 min and weigh to the nearest 0.5 g, provided the loss in mass in drying of the test specimen as disclosed by the first and second weighing, does not exceed 0.25 percent of the first mass, take the second mass to be the dry mass of the test specimen. If the loss exceeds 0.25 percent weigh the test specimens at 15 min intervals till the loss between two successive weighing is 0.25 percent or less.

B-4 CALCULATION

B-4.1 Calculate the percentage of moisture content by the following formula:

$$\text{Moisture content, percent by mass} = \frac{m_1 - m_2}{m_1} \times 100$$

Where

m_1 = Mass of the original test specimen, and

m_2= Mass of the oven dried test specimen.

B-4.2 Repeat the test with the remaining pith specimens. The average of all the values thus obtained shall be deemed to be the moisture content.

ANNEX C

[Table 1, Sl No. (11 &13)]

ESTIMATION OF ASH CONTENT, TOTAL ORGANIC MATTER AND ORGANIC CARBON

C-1 TEST SPECIMEN

C-1.1 For the purpose of this test, test specimens each weighing about 10g shall be drawn from the test sample as in 8.1.3.1

C-2. APPARATUS

C-2.1 Silica or Porcelain Crucible of about 50g capacity.

C-2.2 Muffle Furnace capable of being heated to 750°C.

C-2.3 Drying Oven, controlled at 105±3°C.

C-2.4 Weighing Bottle of suitable size and shape to contain the crucible.

C-2.5 Desiccator (Vacuum Type), containing an-hydrous calcium chloride.

C-3 PROCEDURE

C-3.1 Weigh to the nearest mg about 5 gm of coir pith and heat in an open, tared, weighing bottle at 105± 3^{0}C overnight (see Note 2). Place the stopper in the bottle and after cooling in a desiccator, determine the mass of the bottle and its contents. Transfer the pith to the crucible which has previously been ignited, cooled in desiccator and its mass accurately determined in the weighing bottle. Burn the pith cautiously at the front of the open furnace, taking care to avoid draughts and when the material has reached the glowing stage, move the crucible towards the rear of the furnace, close the front door, and complete ashing at about 750°C (see Note 3). Transfer the dish after it has been allowed to cool in the desiccator, to the weighing bottle and finally determine its mass (see Note 3).

NOTES

1. The mass of material used is governed by the anticipated ash, for example, for grey cottons, a 5 g specimen is generally used; for a well-scoured or bleached cotton material, a 10 g specimen is needed to give an amount of ash that can be determined with reasonable accuracy.

2. For many purposes, the initial drying of the specimen may be neglected and an average figure assumed for the moisture content of the fibre.

3. Certain metals can be lost under these conditions of heating. Mercury is least readily and zinc is lost above 450°C. Temperatures in excess of general ashing temperature may occur locally in large specimens and the general ashing temperature in such cases may have to be considerably reduced to avoid loss of certain metals Lead is also lost under the specified conditions of heating unless sulphate ion is present.

4 .Considerable losses in ash may occur due to draught. It is particularly necessary to exercise caution in opening the desiccator in which the ash has been cooled since a partial vacuum is created during cooling. The safest procedure is to press a piece of filter paper against the outlet whilst cautiously opening the tap.

5. Silica and porcelain crucibles become etched during heating and cooling cycles over a prolonged period and it is recommended that crucibles should be renewed fairly frequently.

C-3.1 Similarly repeats the test with at least one more test specimen.

C-4 CALCULATION

C-4.1 Ash content in percent by weight (C) = $\frac{A}{B} \times 100$

C-4.2 Total organic matter in percent by weight= 100.00- C

Where,

A = mass in gram of the residue (ash)

B = oven-dry mass (calculated) in g of the test specimen.

C= Ash content (%)

C-4.3organic carbon (%) = $\frac{\text{Total organic matter}}{1.724}$

ANNEX D

[Table 1, Sl No. (2)]

ESTIMATION OF ELECTRICAL CONDUCTIVITY

D-1 APPARATUS

Conductivity meter (with temperature compensation system), sieve (2-4 mm), flask (250 ml), funnel (outer diameter = 75mm), beaker (100 ml), analytical balance, filter paper.

D-2 REAGENTS

Potassium chloride (AR grade), distilled water.

D-3 PROCEDURE

Pass fresh sample of coir pith through a 2-4mm sieve. Take 20 g of the sample and add 100 ml of distilled water in the ratio of 1:5. Stir at regular intervals for 1 hour. Calibrate the conductivity meter by using 0.01 M potassium chloride solution. Measure the conductivity of the unfiltered coir pith suspension.

D-4 CALCULATION

Express the results as millimho/cm or dSm^{-1} at 25^0C specifying the dilution of the organic fertilizer suspension viz, 1:5 organic fertilizer suspensions.

ANNEX E

[Table 1, Sl No. (4)]

ESTIMATION OF TOTAL NITROGEN

Estimation of total nitrogen can be done by IS 6092 (Part 2/Sec 2): 2004

APPARATUS

For Digestion-Use Kjeldahl flasks of hard, moderately thick well annealed glass with total capacity of about 800ml. Conduct digestion over a heating device adjusted to bring 250ml of water at 25°C to a rolling boil in about 5min.

For Distillation-Use 800 ml Kjeldahl flasks fitted with rubber stoppers through which passes the lower end of an efficient scrubber bulk or trap to prevent mechanical carry over of sodium hydroxide solution during distillation. Connect the upper end of the bulb tube to the condenser tube by rubber tubing. Trap the outlet of the condenser in such a way as to ensure complete absorption of ammonia distilled over into the acid in the receiver of Erlenmeyer flask, 250 or 300 ml capacity.

REAGENTS

Boric acid solution, 4% (40g/L)-Dissolve 40g of boric acid (H_3BO_3) in water and dilute to 1 litre.

Mercuric oxide Tablets (HgO).

Mixed indicator- Dissolve 200mg methyl red in 100 ml alchohol. Dissolve 200 mg methyene blue in 100 ml alchohol. Mix in a ratio of 1 part methylene blue in 100 ml alcohol. Mix in a ratio of 1 part methyl red to 2 parts methylene blue.

Potassium sulfate (K_2SO_4).

Potassium sulfide solution (40g/L)-Dissolve 40 g of potassium sulfide in water and dilute to 1 litre.

Sodium hydroxide solution (450 g/L)- Dissolve 450 g nitrate free Sodium hydroxide (NaOH) in water and dilute to 1litre. The specific gravity of the solution should be 1.36 or greater.

Standard Sulfuric acid (0.1 to 0.3 N)-Dissolve 3.0 to 9.0 ml concentrated sulfuric acid in water and dilute to 1litre

Preparation of Sample

Air dry the sample in accordance with Annex B. Record the percentage of moisture removed by air drying.

PROCEDURE

The nitrogen is converted into ammonium salts by destructive digestion of the sample with a hot, catalyzed mixture of concentrated sulfuric acid and potassium sulfate. These salts are subsequently decomposed in a hot alkaline solution from which the ammonia is recovered by distillation and finally determined by acidimetric titration. Nitrogen content is important as it is one of the primary plant food elements necessary for plant growth. Nitrogen is present in coir pith as organic nitrogen and therefore does not release nitrogen to plants as quickly as chemical fertilizers. However, nitrogen from coir pith continues to be released for several years as the organic matter decomposes.

Mix thoroughly the air dried, grounded sample and weigh to the nearest 1 mg the equivalent of 10.0 g of test specimen on the as received basis. Determine the grams air dried sample equivalent to 10.0 g of as received sample as follows:

Equivalent sample weight, g = 10.0 X percent moisture removed)/100 place the weighed sample in the digestion flask; add 0.7 g of HgO, 15 g of powdered K_2SO_4, and 35 ml of K_2SO_4. Placed the flask in an inclined position and heat gradually. Then boil briskly until the solution clears. Continue the boiling for an additional 30 min, Cool, add about 300ml water, cool below 25°C, add 25ml of K_2S solution and mix to precipitate the mercury. Add a pinch of zinc to prevent bumping, tilt the flask, and add a layer of NaOH solution sufficient to make the contents strongly alkaline. Do not agitate the mixture. Immediately connect the flask to digestion bulb or condenser. The tip of the condenser immersed in the H_3BO_3 solution (this need not be measured) in the receiver and then rotate the flask to mix the contents thoroughly. Heat until the ammonia has distilled (at least 150 ml of the distillate). Titrate with standard acid using mixed indicator to violet end point.

CALCULATION

Calculate the percentage nitrogen as follows:

Nitrogen (as received), % = (AxB)x0.14 where:

A = milliliters of 0.1 “N to 0.3 N K_2SO_4 required for titration of the solution, and

B = normality of the H_2SO_4

REPORT

Report to the nearest 0.1% the nitrogen content of the as received sample.

ANNEX F

[*Table* 1, *Sl No.* (9)]

CALCULATION OF C: N RATIO

F-1 The C: N ratio is calculated using total organic carbon, percent by mass of total dry mass determined at C-5 and total nitrogen (as N), percent by mass of total dry mass determined at annex E

F-2 CALCULATION

C: N ratio = A:B

where A= Total Organic Carbon, percent by mass of total dry mass determined at C-5; and

B= Total nitrogen (as N), percent by mass of total dry mass determined at annex E

ANNEX G

[*Table* 1, *Sl No.* (5)]

ESTIMATION OF PHOSPHOROUS

Estimation of phosphorus can do by IS: 5305-196

METHOD A - AMMONIUM PHOSPHOMOLYBDATE METHOD

G-0 Outline of the Method - The solution of the sample is treated at about 45°C with a large excess of ammonium molybdate solution in the presence of nitric acid. The precipitated ammonium phosphomolybdate is suitably washed with dilute potassium nitrate solution, dissolved in an excess of standard sodium hydroxide and the solution of sodium hydroxide is titrated with standard hydrochloric acid. The phosphorus is calculated from the volume of sodium hydroxide solution that was required to react with the ammonium phosphomolybdate.

G-1Reagents

G-1.1 Phenolphthalein indicator-See Table 1 of IS: 2263-1962#

G-1.2 Dilute Nitric acid- 10 percent (v/v) and 40 percent (v/v),

G-1.3 Ammonium nitrate - 10 percent (w/v).

G-1.4 Standard Sodium hydroxide solution - Carbonate-free, 0.1 N (see IS: 2316-1968s).

G-1.5 Standard Hydrochloric acid- 0.1 N (see IS: 2316-1968s).

#Methods of preparation of indicator solution for volumetric analysis.

G-1.6 Ammonia - sp gr O-90.

G-1.7 Potassium nitrate solution - 1 percent (w/v).

G-1.8 Ammonium molybdate solution - Add solution A (G-1.8.1) slowly and with constant stirring to solution B (G-1.8.2) kept cool in a cold water bath. Add 10 ml of ammonium phosphate solution (one gram per litre) and keep the solution at least for 24 hours. Filter the solution through Whatman filter paper No. 1 before use.

G-1.8.1 Solution A - Dissolve 100 g of molybdic acid (MoO_3 85 percent) or 118 g of ammonium molybdate in a mixture of 145 ml of concentrated ammonium hydroxide and 270 ml of water. Cool the solution.

G-1.8.2 Solution B -Add 490 ml of concentrated nitric acid to 1150 ml of water and cool.

G-2 Procedure -Take in an Erlenmeyer flask a clear solution of the material, prepared as prescribed in the relevant material specification containing 5 to 10 mg of phosphorus present as orthophosphate in about 100 ml of the solution. Add

10 ml of 10 percent nitric acid and 10 ml of 10 percent ammonium nitrate. Dilute to about 200 ml and heat to 45°C. Add ammonium molybdate reagent in small quantities with stirring to precipitate all phosphate present. After the precipitate formed on addition of the reagent has settled, test for completion of precipitation and then add further 10 ml of reagent (generally 20 to 30 ml will be sufficient), Stopper the flask, shake vigorously for 5 to 10 minutes and allow to stand for 30 minutes. Filter through a Whatman No. 40 filter paper. Wash the flask and the precipitate a few times with 1 : 50 nitric acid and then with 1 percent potassium nitrate solution until a portion of the filtrate does not decolourise 1 ml of water containing 1 drop of 0.1 N sodium hydroxide and 1 drop of phenolphthalein. Transfer the paper and precipitate in the original flask. Add a slight excess of 0.1 N carbonate free sodium hydroxide (say 50 ml). Disintegrate the filter paper by means of a glass rod.

Stopper the flask and shake, if all the precipitate does not dissolve, a further quantity of standard alkali solution shall be added. Dilute to approximately 150 ml, add 5 drops of phenolphthalein indicator, and titrate with standard 0.1 N hydrochloric acid until the pink colour is completely discharged.

G-2.1 Carry out a blank determination using all reagents but without the sample in the same manner and simultaneously.

G-3 Calculation

$$\text{Phosphates (as P), percent by weight} = \frac{0.134\,9 \times (V_1 - V_2)\,N}{W}$$

$$\text{Phosphates (as } P_2O_5\text{)} = \frac{0.308\,8 \times (V_1 - V_2)\,N}{W}$$

where

V1= Volume in ml of 0.1 N hydrochloric acid consumed for the blank determination,

V2 = Volume in ml of 0.1 N hvdrochloric acid consumed by the excess sodium hydroxide solution,

N= Normality of standard hydrochloric acid, and

W = Weight in g of the material contained in the solution taken for the precipitation.

METHOD B - QUINOLINE PHOSPHOMOLYBDATE METHOD

G.0 Outline of the Method- This method involves the formation of phosphomolybdic acid in a solution free from ammonium salts, followed by its precipitation as the salt of quinoline. Finally the quinoline phosphomlybdate is titrated with sodium hydroxide.

G.0.1 General -This method has some advantages over the ammonium phosphomolybdate method, namely, the precipitate is less soluble than ammonium phosphomolybdate, of constant composition, free from absorbed or occluded impurities and free from cations which interfere in the subsequent titration of the precipitate.

The method is applicable in the presence of calcium, magnesium, iron, aluminium, alkali salts, citric acid and citrates. Chromium present up to 18 times the phosphorus content and titanium up to 3.5 times has no effect on the method. The vanadium shall not exceed one fifth of the phosphorus content. Nitric acid may be substituted for hydrochloric acid. Sulphuric and hydrofluoric acids are deleterious, but the effect of hydrofluoric acid may be avoided by the addition of boric acid. The interference of soluble silicates is avoided by the addition of citric acid with which molybdic acid forms a complex of such stability that its reaction with silicic acid is prevented, whereas the reaction with phosphoric acid proceeds normally. The interference of ammonia is avoided in the same manner.

G.1 Reagents

G.1.1 Quinoline Hydrochloride Solution - Add 20 mi of purified quinoline to 500 ml of hot distilled water acidified with 25 ml of concentrated hydrochloric acid conforming to IS : 265-1962*. Cool and dilute to one litre.

G.1.1.1 The quinoline used shall be purified and distilled as follows:

Dissolve the technical grade quinoline in concentrated hydrochloric acid and add excess zinc chloride solution. This precipitates quinoline as a complex $[(C_9H_7N)_2.ZnCl_4]$and in well-defined crystals. Separate and wash the crystals with cold dilute hydrochloric acid. Regenerate the pure quinoline by sodium hydroxide solution. Dry and distil to yield pure and distilled quinoline.

*Specification for hydrochloric acid (revised)

G.1.2 Citro-molybdateReagent - prepared as follows:

a) Dissolve 150 g of sodium molybdate ($Na_2MoO_4.2H_2O$) in 400 ml of water.

b) Dissolve 250 g of citric acid in 250 to 300 ml of water and 280 ml of concentrated hydrochloric acid (conforming to IS ; 2651962*). Pour with stirring solution (a) to solution (b), cool and filter through a filter pad. A slight greenish colour is obtained on mixing which may deepen when exposed to sunlight. Add in drops, a 0.5 percent (w/v) solution of potassium bromate to discharge the colour. Store the solution in coloured, air-tight, stoppered glass bottles in the dark.

G.1.3 Mixed indicator solution-Mix 3 volumes of alcoholic phenol-phenolphthalein solution and 1 volume of alcoholic thymol blue solution (see Table 3 of IS: 2263-1962*)

G.1.4 Standard Sodium hydroxide solutions- carbonate free, 0.5 N and O-1 N (see IS: 2316-1968**).

G.1.5 Standard Hydrochloric acids - 0.5 N and 0.1.N (see IS: 2316-1968#).

G.1Dilute Hydrochloric acid - 10 percent, dilute 100 ml of hydrochloric acid (conforming to IS: 265-1962**) to 1 litre with water.

G-2 Procedure -Take in a 250-ml conical flask an aliquot of the clear solution of the material, prepared as prescribed in the relevant material specification containing about 50 mg of phosphorus pentoxide (30 mg of P) present as orthophosphate in about 100 ml (see Note 1). Add 50 ml of citro-molybdate reagent and bring to boil. Add 5 drops of quinoline hydrochloride solution, stirring during the addition. Again heat to boiling and add quinoline hydrochloride solution drop by drop with constant stirring until 2 ml have been added. To the gently boiling solution add the quinoline hydrochloride solution few milliiitres at a time with constant stirring until a total of 60 ml has been added. In this manner, a coarsely crystalline precipitate is produced. Allow to stand on the hot-plate for 15 minutes and then cool to room temperature. Filter through a filter paper employing suction and wash the flask, precipitate and filter with cold water until they are free from acid. Transfer the filter pad and the precipitate to the original flask and rinse the funnel with water into the flask. If necessary, wipe the funnel with a small piece of damp filter paper to ensure complete removal of the precipitate and place the paper in the flask. Dilute to about 100 ml with water. Stopper the flask and shake it vigorously until the pulp and the precipitate are completely disintegrated. Remove the stopper and wash it with water, returning the washings to the flask. From 2 burette add 50 ml of 0.5 N standard sodium hydroxide solutions, shaking the flask during the addition. Shake vigorously until all the precipitate dissolves (see Note 2). Add 1 ml of mixed indicator solution and titrate the excess of sodium hydroxide solution with 0.5 N hydrochioric acid until the indicator changes from violet to green-blue and then very sharply to yellow.

G-2.1 Carry out a blank determination using all reagents, without the sample and using exactly 0.1 N standard sodium hydroxide solution and 0.1 N standard hydrochloric acid instead of 0.5 N acid and 0.5 N alkali.

**Specification for hydrochloric acid (revised).

*Methods of preparation of indicator solution for volumetric analysis.

#Methods of preparation of standard solutions for calorimetric

and volumetric analysis (revised).

NOTE 1 ---The volume should not exceed 100 ml, as any reduction in the concentration of hydrochloric acid may lead to the formation of a cream coloured precipitate of the wrong composition. To avoid such contamination in the presence of sulphate, a higher concentration of hydrochloric acid is necessary.

NOTE 2 - Examine the disintegrated paper pulp carefully for specks of undissolved precipitate which sometimes dissolve excess of sodium hydroxide with difficulty.

$$\text{Phosphates (as P), percent by weight} = \frac{0.05965\left[V_1 - V_2 - \frac{(V_3 - V_4)}{5}\right]}{W}$$

$$\text{Phosphates (as } P_2O_5\text{), percent by weight} = \frac{0.1366\left[V_1 - V_2 - \frac{(V_3 - V_4)}{5}\right]}{W}$$

V_1 = Volume in ml of 0.5 N sodium hydroxide solution used with the sample

V_2 - Volume in ml of 0.5 N hydrochloric acid used with the sample,

V_3 = Volume in ml of 0.1 N sodium hydroxide used jn the blank,

V_4= Volume in ml of 0.1 N hydrochloric acid used in the blank, and

W = Weight in g of the material contained in the solution taken for the precipitation.

ANNEX H

[*Table* 1, *Sl No.* (x), *Col* 4]

ESTIMATION OF POTASSIUM

(Flame photometry method)

H-1 APPARATUS

Porcelain crucible, weighing balance, muffle furnace, flame photometer

H-2 REAGENT AND STANDARD CURVE

a) Potassium chloride standard solution: Make a stock solution of 1000 ppm K by dissolving 1.909 g. of AR grade potassium chloride (dried at 60oC for 1 h) in distilled water 1; and diluting up to 1 litre. Prepare 100 ppm standard by diluting 100 ml of 1000 ppm stock solution to 1 litre with extracting solution.

b) Standard curve: Pipette 0, 5, 10,15 and 20 ml of 100 ppm solution into 100 ml volumetric flasks and make up the volume upto the mark. The solution contains 0, 5,10, 15 & 20 ppm potassium respectively.

H-3 PROCEDURE

Take 5g sample in a porcelain crucible and ignite the material to ash at 650-700 ^{0}C in a muffle furnace.

Cool it and dissolve in 5 ml concentrated hydrochloric acid, transfer in a 250 ml beaker with several washing of distilled water and heat it. Again transfer it to a 100 ml volumetric flask and make up the volume. Filter the solution and dilute the filtrate with distilled water so that the concentration of potassium in the working solution remains in the range of 0 to 20 ppm, if required. Determine potassium by flame photometer using the potassium filter after necessary setting and calibration of the instrument. Read similarly the different concentration of potassium of the standard solution in flame photometer and prepare the standard curve by plotting the reading against the different concentration of the potassium.

H-4 CALCULATION

$$\text{Potassium (K) \% by weight} = \%K_2O = \frac{\text{ppm } K_2O \text{ in sample solution} \times 20}{\text{Volume of aliquot}}$$

Note

A suitable aliquot to contain 16ppm K2O based on the guaranteed analysis of the compound fertiliser may be calculated as follows:

$$\text{Aliquot volume in ml} = \frac{20 \times 16}{\text{Guaranteed } K_2O \text{ content}}$$

Lignin

Lignin in the coir pith is estimated by Klason method (Stephen and Carlton, 1992). Approximately one gram of coir pith is weighed out in triplicate in tarred weighing bottles and dried at 105^{0}C for one hour. The material is weighed thrice till a constant weight (A) is obtained. The material is then carefully transferred to a clean filter paper and roll to pack the contents. The three packed samples are transferred into the reflux unit of the soxhlet extraction apparatus for the first extraction with ethanol: benzene (2:1 v/v) for 4 h. The samples are then allowed to dry and the contents transfer to a 400 ml beaker and reflux in 200 ml distilled water for 4 h.

The cooled samples are then transfer into a 100 ml beaker to which 3 ml of 72% sulphuric acid is add carefully with the help of a glass road. Another 22 ml of 72% H_2SO_4 is add to make the total volume to 25 ml. The sample is then carefully macerate to form a fine paste and keep it covered at room temperature for 2 h. The sample is then dilute with distilled water (575 ml) in a one liter beaker and heat on a water bath for 4 h. After cooling the sample was filtered carefully through a clean tarred G-4 sintered Gooch crucible. The residue is wash till free of acid, dried at 105^{0}C and weigh till constant reading obtained (B). The net weight is recorded and the % of lignin is calculated as per the formula

% Lignin = B/A x 100

Total organic matter

The total organic matter in coir pith is determined by oven dry method using muffle furnace (Gupta, 2001). The coir pith sample is sieved and packed in a crucible filling ¾ of its volume. Determine the mass and place the crucible with coir pith in a hood (600^{0}C), gently increase the temperature till the material has been oxidized to black color. It is ignite for 2-3 hours removed from the furnace and place in a desiccator for cooling, and further analysis.

Cellulose

Cellulose content in coir pith is estimated by following the method as described by Sadasivam and Manickam (1997). 3ml of acetic/nitric reagent is added to 1 g of the coir pith sample in a test tube and mixed using a vortex mixer. The tube was placed on a water bath at 100^{0}C for 5 minutes, cooled and centrifuged the contents for 15-20 minutes. The supernatant is discarded, washed the residue with distilled water, added 10 ml of 67% H_2SO_4 and allowed it to stand for 1 hr. 1ml of the above solution is diluted to 100 ml. To 1ml of this diluted solution, 10 ml of anthrone reagent was added and mixed well, heated the tubes in boil water bath for 10 minutes. This is cooled and measured the color at 630 nm. A blank is set with anthrone reagent and distilled water.

Phenol

The phenol content in coir pith is extracted in ether and analyzed using High Performance Liquid Chromatography (HPLC- Model Shimadzu LC 8 A) as described by Lenore *et al.* (1989) (Fig. 9.1). The analysis is done using HPLC (Shimadzu 10 *vp*) equipped with an PDA detector (Shimadzu SPD-MA *vp*). C-18 column (Luna 5u C18 (2) 100 A, Phenomenex) of 250 X 4.6 mm dimension and 5µm particle size is used for the analysis. A mixture of acetonitrile and water (8:2) at a flow rate of 1 ml min^{-1} is used Binary Gradient as the mobile phase for the analysis. The separation is done at ambient temperature. The standards and samples are delivered *via* a 20 µl injection loop using a 25 µl capacity Hamilton micro liter syringe. A run time of 10 minutes was given for each run. Shimadzu Class – VP software (Chromatography Data System) on PC is used for integration and computation of signals. 20 µl of standards and samples are injected.

8. Patents Granted On Coir Pith Technology

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