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Navsari Agricultural University

VALUE ADDED PRODUCTS FROM BANANA PSEUDOSTEM

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Disclaimer

The information presented herein is contribution of the consortium and NAU or ICAR shall not be responsible or liable for any discrepancy whatsoever.

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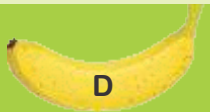


FOREWORD BY HON'BLE VICE CHANCELLOR

Dr. C. J. Dangaria
Vice Chancellor
Navsari Agricultural University
Navsari 396450 (Gujarat)

Banana is a common mans' fruit grown in about 7.0 lakh ha area of India. Apart from fruit, banana crop generate huge quantity of waste biomass in the form of pseudostem, leaves, suckers etc,. At present, this biomass is absolute waste in most of the states of India. Not only this, but farmers are spending about Rs. 15000 to 20000/ha for disposing off this waste from their fields. The present mode of disposing off pseudostem waste in nallas, borrow pits, road sides, burning etc; is causing environmental problems. In order to utilize this waste particularly pseudostem for developing different products, a project viz; "A Value Chain on Utilization of Banana Pseudostem for Fiber and Other Value Added Products" was sanctioned under NAIP (comp. II) in consortium mode by ICAR, New Delhi during 2008. Through concerted efforts of all the partners of this consortium, different products viz; fiber and non woven fabrics, handmade papers and boards, vermi-compost, enriched sap (NAUROJI Novel organic liquid fertilizer) and candy have been developed which are techno economically viable. The viability is substantiated by the fact that more than ten private parties have already signed MoU with NAU, Navsari for commercial production and marketing of organic liquid fertilizer prepared using banana pseudostem sap and central core candy. Simultaneously, processes for the products like non-woven fabrics, microcrystalline cellulose from fiber, sap as a mordant in textile dying, pseudostem Scutcher based vermi-compost as fish feed etc; have also been standardized during the project period.

Looking to the array of products developed using the waste pseudostem, not only farmers will get additional income, but industries like textile, paper, pharmaceutical, confectionary etc; will also have eco friendly alternative/supplementary raw material. In my opinion, the products developed and processes standardized for some of products under this project have vast potential i.e.; Wealth from the Waste. I would consider it as the path breaking research in the area of banana cultivation.

I put on record that commendable work has been done by the team of scientists of consortium which has been appreciated at state and national levels. I am happy that the work done under this project being brought out as a Book: 'Value Added Products from Banana Pseudostem' which will be of immense help to the entrepreneurs, researchers, policy makers, farmers and banana co-operatives. I congratulate the team of scientists involved in this project for doing such a wonderful work.

Place: Navsari
Date: 20/03/2016

Dr. C. J. Dangaria

FOREWORD BY DIRECTOR OF RESEARCH

Dr. A. N. Sabalpara
Director of Research and
Dean Faculty of PG Studies
Navsari Agricultural University
Navsari - 396450 (Gujarat)

Banana being poor man's fruit, it is grown in almost all the states of India. It covers about 7.0 lakh ha area. Apart from fruit yield, huge amount of waste biomass in the form of pseudostem, leaves, suckers etc., is generated. Disposal of such a huge biomass in unscientific way creates environmental problems. Not only this, but farmers have to spend about Rs. 15000 to 20000/ha for removing the waste biomass from their fields. In order to utilize this waste biomass in profitable way and resolve disposal problems, a project viz., "A Value Chain on Utilization of Banana Pseudostem for Fiber and Other Value Added Products" was sanctioned under NAIP (comp. II). During last seven years, commendable work has been done in this project which has attracted banana growers, entrepreneurs, policy makers and some industry peoples as well. Using pseudostem, products like fibre, fabrics, paper, organic liquid fertilizer, candy, vermi-compost, etc., have been developed. These products are capable of not only generating additional income for the farmers but can also provide alternative / supplemental eco-friendly natural raw material for some of the industries. Among the various products, I am very much hopeful for the 'NAUROJI Novel Organic Liquid Fertilizer'; which can be a excellent input in current trend of organic farming as well as for reduction in the use of agro-chemicals in the crop production. The work done by all the consortium partners during past seven years are summarized in this book along with some suggestions for future line of work in this area. I opined that this publication will act as a guide line for all the stakeholders. I congratulate the team of scientists who have contributed in developing technologies and also bringing out this publication. This book of 'Value Added Products from Banana Pseudostem' will be future outline for entrepreneurs as well as co-operative sectors.

Place: Navsari
Date: 20/03/2016

(A. N. Sabalpara)

PREFACE

Dr. V. P. Usadadia,
Research Scientist
Soil and Water Management Research Unit
Navsari Agricultural University,
Navsari – 386 450 (Gujarat)

Management of crop residues in eco-friendly and profitable way is one of the major issues in agriculture. Though, in some of the crops like sugarcane, wheat, rice etc, it has been achieved to some extent, yet lot is to be done on massive scale in India. Among various crops, banana is one such crop which generates huge quantity of fresh biomass and so far not much attention has been given towards its effective utilization. However, the residue of banana mainly consisting of pseudostem has tremendous potential to provide alternative/ supplementary raw material to industries like textile, paper, pharmaceutical, confectionary etc,. In view of this, Soil and Water Management Research Unit, N.A.U., Navsari have worked in consortium comprises of Central Institute for Research on Cotton Technology, ICAR, Mumbai, Manmade Textile Research Association, Surat and J. K. Mills Ltd., Songadh as the partners. The basic aim of this project was to develop different value added products using presently waste banana pseudostem as raw material.

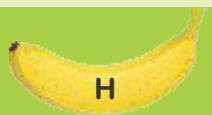
The value added products viz; fiber and non woven fabrics, handmade papers and boards, vermi-compost, enriched sap (NAUROJI Novel organic liquid fertilizer) and candy have been developed which are techno economically viable. The viability is substantiated by the fact that more and more private companies are eager to sign MoU with NAU, Navsari for commercial production and marketing of organic liquid fertilizer prepared using banana pseudostem sap. Simultaneously, processes for the products like microcrystalline cellulose from fiber, sap as a mordant in textile dying, pseudostem scutcher based vermicompost as fish feed etc; have also been standardized in the project. This has become possible due to highly dedicated efforts put in by the team of scientists from all the four partners and full moral boosting supports.

Though, this document is called as Book on 'Value Added Products from Banana Pseudostem' is published for the farmers, entrepreneur and policy maker for the beginning of the new phase of the value added products development using banana pseudostem as raw material on commercial scale. This book will be a bench mark document for taking up any new research and developmental projects on this aspect by anybody in future. I take this opportunity to express my deep sense of gratitude to all the scientists involved in this.

Place: Navsari

Date: 20/03/2016

(V. P. Usadadia)



CHAPTER 1
IMPROVED PACKAGE OF PRACTICES OF BANANA CULTIVATION

Introduction

Banana is having the largest production and maximum consumption amongst the fruits crop cultivated in India. It has great socio-economic significance, interwoven in the cultural heritage of the country. It is known as the 'common man's fruit. It is highly nutritive and very delicious. Banana is fourth important food crop in terms of gross value exceeded only by paddy, wheat and milk products and forms an important core for subsistence farmers. India is the largest producer of banana in the world. In India, banana crop is cultivated in 7.70 lakh hectare and has a share of 37% of the total fruit production. In Gujarat, banana crop is cultivated in 11 districts covering an area of about 62 thousand hectare. Gujarat ranks 5th among the states of India with an average productivity of 61 t/ha. The major banana growing districts are Surat, Valsad, Bharuch, Narmada, Vadodara, Kheda, Bhavnagar, Junagadh and Navsari. Number of factors influence banana production like climate, soil, variety, irrigation and fertilizer management *etc.* In view of higher productivity of banana as well as efficient use of water and fertilizer with drip irrigation, it is becoming popular among the farmers' of South Gujarat. In order to enhance the productivity of banana, further adoption of advance technology *viz.,* use of good quality planting materials, tissue culture plant, fertigation, mulching, sleeving and nutrient pouch feeding at distal end after denavelling *etc.,* along with drip irrigation are being advocated to the farmers by the university.

1) Climate

Banana is well-suited for cultivation from humid subtropical to semi-arid subtropics up to 2,000 m above mean sea-level with a temperature of 15°–35°C (average 27°c) and a rainfall of 2000 to 2500 mm/year. However, it requires assured irrigation facility. Mean temperature of 20°–30°C is optimum for its growth. Its growth declines with increase or decrease in mean temperature. If bunch emergence coincides with low temperature, it results in spadix emerging through pseudostem. Chilling temperature results in similar malformed bunches. Temperature above 36°–38° C causes scorching effect with increased transpiration. High temperature in combination with water stress cause reduction in growth. Apart from temperature and water, wind poses a major constraint in banana production. High wind results in uprooting and collapse of plants. Avoidance of bunching during the period of high wind velocity is advocated through adjustment in time of planting or develops shelter around banana field.

2) Soil

Banana can be grown in all type of soils having good drainage. Loamy and silty clay loam soils with good fertility status are best suited for banana cultivation. Though soil pH of 6.5–7.5 is optimum, banana can be grown in soils having a pH up to 8.5 with suitable amendments. Water stagnation in poorly-drained soils also leads to slow growth. The plants collapse in extreme cases. However, extremely clayey and sandy soils are not suited for banana cultivation.

3) Varieties

Throughout world, total 200 to 300 varieties are available. In India, about 60 varieties are available out of which only 12 varieties are under cultivation irrespective of area. In Gujarat, Grand Naine, Mahalaxmi and Basarai varieties are widely grown owing to high yield and wider market acceptability and high economic returns per unit area. Grand Naine is gaining popularity and is most preferred variety due to its tolerance to biotic stresses and good quality bunches. Bunches have well spaced hands with straight orientation of figures, bigger in size. Fruit develops attractive uniform yellow colour with better self life and quality than other cultivars. Presently, about 80 to 85 per cent area is covered under Grand Naine variety is in Gujarat.

Propagation

Propagation of banana is carried out by two methods, either using suckers/corms or tissue culture plants.

Sword-suckers with a well-developed rhizome, conical in shape with lanceolate leaves and actively growing central buds, weighing 500–750 g are generally used.

Propagation through shoot-tip culture is cost-effective for the production of disease-free plants. In-vitro propagated banana is becoming popular. Micro- propagation has been preferred over conventional propagation owing to its faster multiplication, uniformity in planting material and disease-free material from transmissible pests and diseases. In-vitro propagated plants are becoming a commercial reality.

4) Land preparation

After removal of all the debris of previous crop, the land should be prepared by ploughing and subsequently harrowing and planking for achieving leveled field. Use rotavator or harrow to break the clod and bring the soil to a fine tilt. In case of termite problem, mixing of 20 to 25 kg of Methyl Parathion powder at the time of land preparation is advised. For planting banana, a pit of either 30 cm x 30 cm x 30 cm at a spacing of 1.5 x 1.5 m^2 or 1.8 x 1.8 m^2 or 2.4 x 1.2 m^2 *etc.*, are dug out as per recommendation of respective area. The prepared pits are left exposed to solar radiation in order to kill harmful insects and are especially effective against soil borne diseases and aids aeration. The pits are to be refilled with topsoil mixed with 5 to 10 kg of FYM (well decomposed) or compost or 3 kg of vermicompost.

Time of planting:

Optimum time is 15th June to August. However, it can be planted round the year.

5) Planting materials:

Banana planting is done either by suckers or tissue culture plant.

Sucker management

Sucker should be selected from healthy banana plantation. Sufficient care should be taken for avoiding damage to the suckers while digging and transportation. Fresh sword suckers weighing approximately 500 to1000 g are commonly used as propagating material. In the event of unavailability of fresh suckers, use only up to 10 days old suckers for plantation. Otherwise, possible problems are late flowering, gap due to mortality, delays in maturity *etc.*, which ultimately leads to reduction in economical yield. Similarly due to the variation in age and size of sucker, the crop may not be uniform, harvesting is prolonged and management becomes difficult. For control of fungal diseases, sucker should dipped in solution of Aurofugine (10g/100 l water) or Captafol (200g/100 l water) or Carbendezin (100g/100 l water) for one and half hours prior to planting.

Tissue culture plantlets

Clonal propagation *i.e.*, tissue culture plantlets are recommended for planting. They are healthy, disease free, uniform and true to type. Properly hardened secondary seedlings are only recommended for planting. The ideal characters of tissue culture plant are, 15 to 20 cm height, 4 to 6 leaves, brown colour spot on leaves and virus free plant are used for plantation.

Advantages of tissue culture plantlets

- True to type of mother plant under good management.
- Pest and disease free seedlings.
- Uniform growth and higher yield.
- Early maturity of crop - maximum land use is possible in small land holding country like India.
- Round the year planting possible as seedlings are available throughout the year.
- Two ratoon crops are possible in a short duration which minimizes cost of cultivation.
- No staggered harvesting.
- 95% - 98% plants bear bunches.
- New varieties can be introduced and multiplied in a short duration.

6) Water management

Banana, a water loving plant requires a large quantity of water for higher productivity. Water requirement of banana has been worked out to be 1500 to 2000 mm per annum by giving 25 to 30 irrigations. Moreover, banana crop require irrigation at an interval of 10 to 12 during winter and 7 to 8 days in summer. Sufficient care should be taken so that the crop does not face water stress during any stage of crop growth otherwise there will be significant loss in yield. Therefore, under Indian condition banana production should be supported by an efficient irrigation system like drip irrigation. In drip system, water is supplied through laterals and discharges through emitters in the root zone.

Benefits of drip irrigation

- Save water, fertilizer, labour charges and electricity
- Application of fertilizer through drip (Fertigation) save 25 to 40 per cent of fertilizer
- Early harvest is possible with higher yield/unit area
- Possible to use of marginal quality water for irrigation purpose
- Increased crop production
- Improved quality of produce

Drip system details (on line)

- Lateral spacing : 1.5/1.8/2.4 m
- Dripper per plant : 2 Nos.
- Spacing between two dripper : 30 cm away on either side of stem
- Dripper discharge rate : 4 lph or 8 lph

Irrigation schedule: For example, 1.5 x 1.5 m^2 spacing the drip system is operated on alternate day for a period of 1.5 to 2.25 hrs during winter and 2.50 to 2.75 hrs during summer at a pressure of 1.2 kg/cm^2.

Note: The time application varies with the drip system design.

7) Manure and fertilizer

Banana being heavy feeder crop, it requires very large quantity of nutrients for growth and yield, accounting for 20–30% of the total cost of production. For obtaining higher yield of banana, timely application of recommended dose of fertilizer is a must (300:90:200 g NPK/plant). FYM should be applied @ 20 to 25 t/ha at the time of land preparation or in the case of pit planting, well decomposed FYM or compost should be applied @ 5 to 10 kg or vermicompost @3 kg /pit at the time planting.

Schedule of fertilizer application in banana under drip irrigation

Method of application	Days after planting	(g/plant)		
		Urea	SSP	MOP
Ring	00	-	-	-
	30	80	260	40
	60	80	260	40
Through fertigation	90	40	-	20
	105	40	-	20
	120	40	-	20
	135	40	-	20
	150	40	-	20
	165	40	-	20

Note:

- SSP: Single super phosphate, MOP: Muriate of Potash
- System should be flushed for few minutes.

8) Mulching

Mulching is the process or practice of covering the soil/ground to make more favourable conditions for plant growth, development and efficient crop production. Mulch technical term means 'covering of soil'. While natural mulches such as leaf, straw, dead leaves, leaf litter and crop residue have been used for centuries. During the last 60 years with the advent of synthetic materials has altered the methods and benefits of mulching. When compared to other mulches plastic mulches are completely impermeable to water; it therefore prevents direct evaporation of moisture from the soil and thus limits the water losses and soil erosion over the surface. In this manner, it plays a positive role in water conservation. The suppression of evaporation also has a supplementary effect; it restricts the rise of soluble salt of soil surface through capillary.

Different mulching materials:

Farmers can mulch with whatever organic matter is readily available and transportable. Common materials include straw (crop stems and stalks), dry grass clippings, sawdust, dry leaves, and other left-over crop residues for conserving moisture (reducing water evaporation), checking weed growth and moderating soil temperature. Alternative mulching materials include black plastic sheeting is also used. Now a days use of plastic mulch is much more popular among the farmers, especially banana and water melon growers.

Types of mulch material

1. Crop residue
2. Grasses
3. Plastic
4. Sand/gravels/soil

Plastic films for mulching

All the available organic mulching materials though beneficial, are found to have inerrant weaknesses of not easily available in large quantities. The plastic films, however are easily available, easy to handle, transport, and lay. This leads to the use of plastic films as mulch, which is the most preferable materials, even though it is costlier. A wide range of plastic films based on different types of polymers have all been evaluated for mulching at various place since 4 decades. Owing to its greater permeability to long wave radiation which can maintain the temperature around plants during the night times, polyethylene is preferred. Among the plastics, low density polyethylene (LDPE) and linear low density polyethylene (LLDPE) plastic films are commonly used for mulching. Today the vast majority of plastic mulch used is based on LLDPE owing to the

twin beneficial properties of down gauging and better puncture resistance. While down gauging leads to availability of thinner film at a lower cost, the puncture resistance and opacity check the weed growth under film. Thus, the non transparent black plastic films are recommended for use as mulch.

Benefits of Mulching

- Moderate temperature of soil: Mulch moderate fluctuations in soil temperature and protect the root zone from excessive heat or cold. Mulching protect the crop by reducing ill effect of low temperature during winter through maintaining micro climate temperature around root zone. Similarly, in summer, it maintains low temperature in root zone compared to unmulched conditions.
- Conserve soil moisture: Plastic film with its moisture barrier properties does not allow the soil moisture to escape from soil. Water that evaporates from the soil surface under mulch film, condenses on the inner surface of the film and falls back as droplets. Thus moisture is preserved for several days and increases the interval between two irrigations.
- Improves soil physical conditions: Mulching also prevents the soil from getting a hard crust. When raindrops hit bare soil in a heavy rainstorm, mulch is a protective cover for the soil, sheltering the soil from hard-hitting rain. Beside, it maintains aggregation of soil, which facilitates better soil moisture and air movement in soil. An experiment was conducted at PFDC, soil and water Management Research Unit, Navsari reveled that application of sugarcane trash @ 10 t/ha improved infiltration rate and water stable aggregate.

  When organics are used as mulch on the soil surface, it decays producing slimes and gums that help to form and stabilize soil structure. This process is mediated by soil microbes acting on organic matter for food. In this way, mulching can help loosen up heavy clay soils, making it easier for the farmer to work and for plant roots to push their way through.
- Control weeds: Use of organic mulch *viz.,* crop residue is reducing weeds to some extent. But, mulching with black plastic film does not allow the sunlight to pass through and thereby it arrests weed growth. This saves labour cost required for weeding. However, it is important to note that do not use transparent plastic films for mulching purpose under any circumstances as this enhances weed growth.
- Mitigate soil erosion: In dry region, where sandy soils are dominant are easily subjected to erosion. Similarly, during rainy season, water is also responsible for soil erosion. Mulch protects soil from high wind and rain by avoiding direct impact of the wind and water drops on soil.
- Improve soil fertility: Mulch around root zone of crop mimics the litter layer of a forest floor. The nutrients in the mulch are gradually released in plant available form. Mulching is cheaper than chemical fertilizers, and because it also improves soil structure, the nutrients will not be washed away or leached from the soil by heavy rain. Further, microbes decompose organic matter, it supplies nutrients demand by growing plants. The beauty of this natural nutrient cycle is that nutrients are released in harmony with the demand of the plants. When environmental

conditions are favorable for rapid plant growth, the same conditions favor a rapid release of nutrients from the organic matter. Beside, maintain aggregation of soil, which maintain soil moisture aeration it leads to improve/increase in carbon dioxide concentration in root zone. Further, reaction takes place between CO_2 and water to produce carbonic acid which reduces pH of soil ultimately increased availability of phosphorus and other micro nutrients. It also leads to crop to more vigorous, healthy growth and development.

- Increased crop production and save water: An experiment was conducted at Navsari show that application of sugarcane trash @ 10 t/ha increased banana crop yield by 13 per cent which saves about 32 per cent water as compared control (without mulch). In another experiment, lying of 50 micron black plastic mulch to cover 50 per cent area saves up to 30 to 40 per cent of water with 10 per cent of additional profit over control.
- Restrict the movement of salt from lower layer to upper layer: Mulching restrict the evaporation losses of water which result in reducing salt movement for lower to upper layer through upward capillary movement. This keeps soluble salt content in root zone within permissible limit.
- Induce early maturity: At Soil and Water Management Research Unit, Navsari an experiment with banana as a test crop found that use of black plastic films as mulch induce 30 to 40 days earlier maturity of crop and farmers' fetched higher market price. Contrary to this, use of sugarcane trash as mulch delays maturity of banana crop.

Disadvantages:

- After utilization of plastic mulch, it must removed and disposed off safely.
- Difficulty in application of fertilizer as top dressing.
- Plastic mulch is not advisable during rainy season and in areas where humidity is high.
- Reptile movement and rodent activities are experienced at some places.

Calculation of mulch films for laying area and durability

Particular	Approximate area covered (m^2)	Durability (month/season)
25 micron 1 kg plastic films	40	(3 to 4)/(1)
50 micron 1 kg plastic films	20	(5 to 8)/(2)
25 micron 1 kg plastic films	10	(16 to 24)/(4)

Selection of plastic mulch

Selection of plastic films is depends upon the seasons and crop in which it is being laid.

Kharif season	:	Perforated plastic mulch
Orchard and plantation	:	Thicker mulch (100 micron black plastic)
Soil solarisation	:	Transparent plastic (7 to 10 micron)
Agricultural crops	:	Black plastic (according to crop, ranging from 25 to 50 micron)

Point should be keep in mind when laying mulch

1. Mulch only conserves soil moisture and does not fulfill the total water requirement of particular crop.
2. Mulching area should preferably be equivalent to the canopy of the plant.
3. Clean the area to be covered by removing the stones, pebbles, weeds etc.
4. Round hole are to be made instead of square which minimize tearing of plastic.
5. Required length of film for one row of crop is taken and folded in middle.
6. Round holes are made at the center of the film using a punch or a bigger diameter pipe or scissor.
7. Small trench could be made around the periphery of the mulching area to facilitate anchoring of the mulch film.
8. One end of the mulch film (along width) is anchored in the soil and the film is unrolled along the length of the row of planting.
9. Cover the film to the entire bund and the end should be buried in the ground.
10. Cover the corners of the film with 10 to 15 cm of soil on all sides to keep the film in position.
11. The mulch material should be held tight without any crease and laid it on the bed. It should be place in such a way that it does not touch the plant stem.
12. Do not stretch the film very tightly. It should be loose enough to overcome the expansion and shrinkage conditions caused by temperature and the impacts of cultural operation.

Economics of plastic mulching

The cost economic of mulching is an important aspect. The durability of plastic mulch is equivalent to its thickness; hence, the cost of plastic per season is almost equal to its thickness. In a leveled field if mulching is to be done, then the film area required will be almost equal to that of field itself. However, generally, in horticultural crop like banana and papaya mulching is carried out in strips covering 50% of field area. A typical calculation has been given for working out cost economics of mulching (eg. 50 micron thickness, per season: 3-4 months period) in Banana crop.

Cost for 50 micron black plastic films use to cover 100 % area of field is:

Required quantity of plastic to cover 20 sqm area = 1 kg

So, requirement of plastic to cover 10,000 sqm (1 ha) area = 10000/20 =500 kg

Now the price of plastic mulch as per present market price is about Rs.126/kg

Hence, to cover an area of 10000sqm (1 ha) costing is

= 500 (kg) x 126 (Rs./kg)

= Rs. 63000/- per hectare

50 micron black plastic films are useful for two season, hence the cost per hectare is about Rs. 31500/ha. If farmers cover 100 per cent area through plastic, it's too costlier. But, when farmers adopt paired row planting and lay plastic mulch only on paired row, then the cost will be reduce to 50 % and its' about Rs. 15750/ha. When we see the benefits of mulching, it is found economical and profitable technique for horticultural crop.

In banana crop, Soil and Water Management Research Unit, Navsari Agricultural university, Navsari conducting demonstration on banana tissue culture plant, drip irrigation, fertigation and mulch as package at farmers' fileds with Cv. Grand Naine since seven years and found that with adoption of above said package, save 20 to 40 per cent fertilizer, 30 to 40 per cent water, 25 to 40 per cent more production and harvest the crop 40 days earlier then no mulching. On an average at farmers' fields, the banana production was recorded 80 and 110 t/ha depending upon the soil type. The experimental results and economics are given here.

The economics of banana cultivation is computed by considering the yield level recorded on research farm and farmers' fields.

Particulars	On research farm demonstration (1.5 m x 1.5 m)		Farmers' field demonstration (2.4 m x 1.2 m)	
	IP	CP	IP	CP
Annualized drip system cost (Rs./ha)	22000	3000	17600	3000
Annualized mulching cost (Rs./ha)	40000 (67 % area covered)	-	25000 (42 % area covered)	-
Cost of cultivation (Rs./ha)	160000	1870000	130000	140000
Total cost (Rs./ha)	222000	190000	172000	143000
Average yield (t/ha)	77	65	72	60
Income (Rs./ha)	462000	390000	432000	360000
Net income (Rs./ha)	240000	200000	259400	217000
Additional income (Rs./ha)	40000	-	42400	-

IP: improved practices CP: conventional practices

How to lay mulching

Plastic mulch in banana crop

10) Sleeving

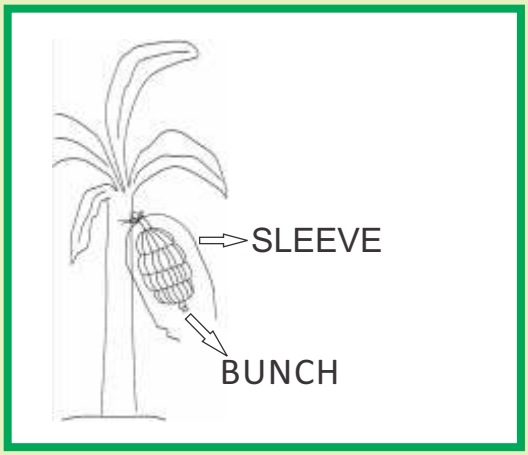
Sleeving technique involves a cylindrical plastic bag of 16-18 micron thickness having both ends open and is useful for protection of banana bunch from wind, rain, hail, dust, pest etc.

Importance of sleeving in banana

- Protect banana bunch from wind, rain, hail and other elements.
- Banana fruits gets better colour.
- Provide protection against pest and diseases thereby reduce the use of insecticides and fungicides.
- Improve the quality of banana fruit.
- Provide stable environment which results in healthy and earlier fruit.
- Useful to adjust maturity of banana fruit which enable the farmers' to fetch good market price.

How to use banana sleeves

1. The grower must check for flowering three time in month
2. Two weeks after flowering, when banana fruits begins to turn up, sleeve is placed on the bunch and is enclosed
3. Hold the sleeve loosely around the entire bunch of expanding fruits and is tied to the bunch at the upper end



Cost of Sleeving:

The cost economic of sleeving is an important aspect. Sleeving plastic durability is equivalent to its thickness; hence, the cost of sleeves per season is almost equal to its thickness. A typical calculation has been given for working out cost economics of sleeving materials (16-18 micron) is as per below:

Price of 1 kg sleeves = Rs. 108/kg
1 kg plastic (16-18 micron) materials covered an area of 50 sqm.
So, 1 sqm sleeving materials cost= Rs. 2.16/m^2
Generally, requirement of blue plastic sleeves to cover one bunch of banana crop is about 3 m^2
Hence, cost of sleeves for one bunch = 2.16 x 3 = Rs. 6.48/bunch

Sleeving on banana bunch (Control)

Treated

11) Nutrient Pouch

Nutrients play a significant role in improving yield of fruits as well as its quality. Providing appropriate quantities of nutrients in balanced proportion at right time is most essential for successful banana cultivation. Inspite of nutrient application through soil for banana plants with recommended quantity of major and micro nutrients in the form of mineral, organics and biological sources or by foliar application, the uptake and utilization of nutrients by banana plants is inadequate resulting in poor nourishment of the finger. This is more evident at the distal end fingers to the bunch which remain poorly developed owing to competition for nutrients of the top hands with those located at the lower end of the bunch. This reduces both the total weight as well as its overall appearance leading to a lower profitability. This has been a major constraint faced by the banana growers irrespective of the variety of banana grown.

To overcome this problem, there is need to develop a simple, easy and cost effective technology to address this problem, which enhances the size of the fingers in the entire bunch uniformly and especially those of the lower or the distal end of banana bunch.

1. This is achieved by de-navelling (removal of the male bud after complete fruit set) and post shooting direct feeding of nutrients through the excised distal stalk / rachis end of banana bunch.
2. De-navelling saves the unwanted mobilization of nutrients and energy to the redundant male bud and facilitates direct intake of nutrients by the young bunch.
3. This technique also helps in developing fruits in equal proportion, especially those of the lower or the distal end of banana bunch.
4. The removal of male bud can fetch additional income to the grower as a vegetable.

Composition of nutrient pouch

1. Fresh cow dung - 500 g/pouch
2. Ammonium sulphate - 20 g/pouch
3. Potassium sulphate - 10 g/pouch

How to prepare Nutrient Pouch

For this, slurry of the cow dung is prepared by dissolving 20 g of ammonium sulphate and 10 g of potassium sulphate in 100 ml of water and mixing it with 300 g of fresh cow dung. This slurry is placed in a plastic bag of 200 gauge (approximately 15cm L x 25 cm B size).

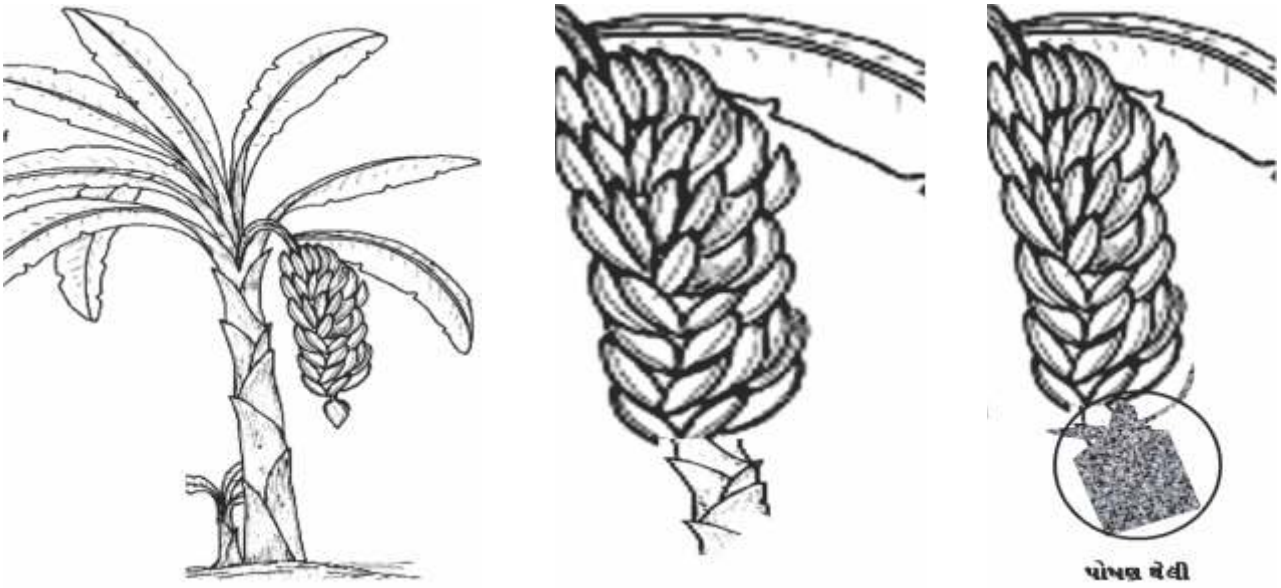
In case of organic cultivation of banana, this technology has also shown good results. Instead of using chemicals for blending with cow dung, the cow urine or Panchgavya may be used to prepare cow dung slurry. For preparation of one nutrient pouch required quantity of materials are as given:

1. 500 g fresh cow dung
2. 100 ml cow urine
3. 100 ml panchgavya

Use of nutrient pouch technique:

This technique is simple and easy.

1. De-navel the stalk/rachis of the distal/lower end of the banana bunch after the bunch formation completed when 7-8 petals (spathes) of the flower are shed, by cutting with a sharp knife at 60o angle keeping about 15 cm long rachis to receive the treatment.
2. Tying the filled nutrient pouch with strong thread such that about 8-10 cm of the distal end of the rachis is immersed in the slurry and the remaining 8-10 cm of the rachis is visible above the tied portion.



Points to be remembered:

- Use only sulphate of potash for blending with cow dung. Do not use muriate of potash which is commonly used fertilizer by the farmers.
- Use cow dung only for preparing the slurry. Use of dung of buffalo or bullock should be strictly avoided. Since 500 gm of cow dung contains about 5.5 g N, 3.5 g K and 1.6 g of S apart from several other minerals and bio-chemicals. These have beneficial effect on the development of the entire banana bunch especially the lower portion of banana fingers. It is also found that cow dung contains maximum antiseptic property due to numerous strains of Bacillus subtilis present compared to only a fewer strains in the dung of buffalo and bullock which therefore is less useful in this technology.
- Immerse at least 8 to10 cm of the denavelled distal end of the banana bunch in the plastic bag containing cow dung slurry while tying the bag to the stalk/rachis of the banana bunch.
- Do not remove the tied bags till harvest of banana bunch even though about 20% of the tied bags may dry and fall off on their own after 5-6 weeks without any reduction in the effectiveness of this technique.

Advantages of nutrient pouch:

1. This technology is very simple, easy to practice and must cost effective which protect the banana bunch from inadequate nutrition particularly at lower end of banana bunch.
2. Average increase in bunch weight by 22 to 25 per cent.
3. The expense for preparing nutrient pouch is only about Rs. 2 to 3 per bunch which result in increase in bunch weight by 3 to 4 kg.
4. The treated banana bunches fetches higher price in the market because of well developed finger size with uniform and excellent export quality.

Experiments conducted at IIHR, Bangalore in different villages with this treatment showed that, there was an average increase in bunch weight by 22 to 28 % in Robusta and Grand Naine banana varieties. The treated banana bunches fetched higher prices in the market because of enhanced size, uniform fruits and excellent quality.

With an adoption of improve package of practices for higher banana production, alongwith post harvest techniques like use of pseudostem for preparation of fiber, high quality paper, cloth, organics, liquid fertilizer, candy, pickles etc., farmer can make banana cultivation more profitable.

Nutrient pouch

After de-navelling (removal of the male bud after fruit set) nutrients pouch is fixed at distal stalk / rachis end of banana bunch.

CHAPTER 2
OVERVIEW OF BANANA PSEUDOSTEM

Introduction

Banana is one of the most important fruit crops grown in India. The area under banana has increased from 3.84 lakh ha during 1991-92 to 7.76 lakh ha during 2014-15, i.e., increase by 102 per cent. This was also true for productivity as it increased by 70 per cent where the average productivity during 2014-15 was 39 t/ha. Among the states, Maharashtra, Gujarat, Tamil Nadu, Andhra Pradesh, Karnataka and Kerala are the leading states in banana cultivation. The major cultivars grown in different states of India are belonging to Cavendish group.

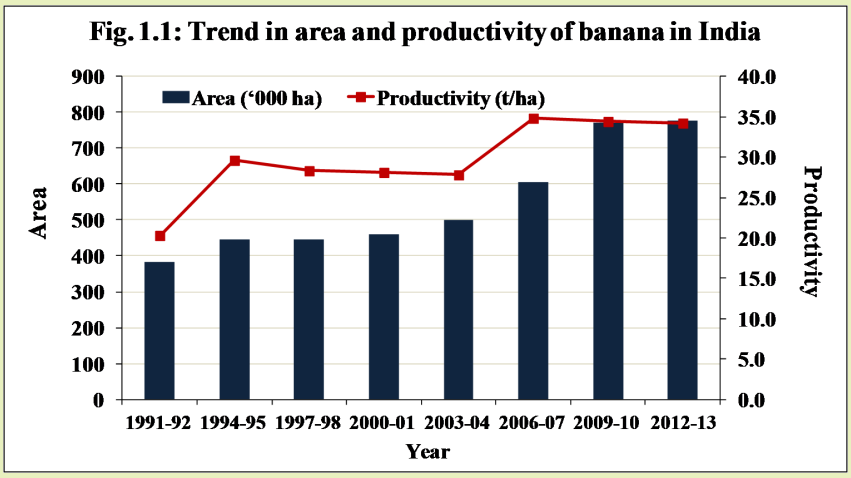


Fig. 1.1: Trend in area and productivity of banana in India

Considerable work has been done in the field of direct use and product development from banana fruits. However, not much attention has been focused on effective utilization of the huge waste biomass generated in the form of pseudostem, leaves, suckers etc. In India, presently this biomass is dumped on roadside or burnt or left in situ causing detrimental effect on environment. Though, the technologies for extraction of fibres and paper making from pseudostem are available, yet it has not been adopted by the industries mainly due to bulky nature leading to high transport cost. However, there exist a vast potential of extracting fibres from pseudostem. The quantity and quality of fibres show wide variability with cultivars. The finess of fibres ranges from 6.1 to 11.4 tex whereas its strength found in the range of 22.4 g/tex to 62.0 g/tex. The fibre extracted from banana pseudostem could not command proper market owing to its unassured supply and restricted use in cottage industries. There appears to be good scope for profitable use of this fibre in textile and paper industries on commercial scale. Not only this, but number of high value products such as handbags, non-woven felts, composites for car interiors etc., can also be developed from banana pseudostem. Therefore, it was thought to explore possibilities of utilization of fibre in textile and paper industries which was envisaged in this project. Similarly, the sap (liquid) generated while extracting fibres from pseudostem is rich source of K (~ 4% on dry weight basis) and can be recycled or enriched and use as liquid fertilizer. In addition, an attempt has also been made to develop edible products from the central core of pseudostem. In view of the above gaps, present project was submitted to PIU, NAIP, New Delhi for approval with the following major objectives. Once the processes are standardized, it would not only generate additional income for the farmers, but will also solve the disposal problem of pseudostem in an eco-friendly way.

Objectives:

- Standardize processes for extracting textile grade fibres from pseudostem and prepare home furnishings
- Standardize processes of pulp and paper making from pseudostem, fibres and scutching

waste both at hand made and industrial levels

- Develop value added edible products from central core
- Preparation and evaluation of enriched sap and scutching waste based vermicompost
- Develop linkage for marketing of pseudostem based products

Technical Profile

Objective	Work plan	Monitoring indicators	Expected output	Expected outcome
1) Standardize processes for extracting textile grade fibres from pseudostem and prepare home furnishings	**Woven fabric**			
	Procurement and installation of Raspador (Nos. 24)	Installation and commissioning of raspador m/c	24 raspador m/c installed and operationalized at farmers' fields & NAU	Fibre extracted : 100 t (NAU: 5 t and farmers: 95 t)
	Evaluating quality of fibre of different cultivars	Identified potential varieties for fibre	Fibre quality of 25 varieties evaluated & ultra structural studies conducted	Quality parameters based catalogue prepared
			Moisture content in fibre	Digital moisture meter standardized & it helps in maintaining fibre quality during storage
	Procurement and installation of yarn making machine	Yarn making unit	Yarn m/c procured and installed at CIRCOT & NAU and modification in yarn m/c which need further improvisation	Improved yarn quality suitable for weaving fabric on looms
	Preparation of yarn	Good quality yarn		
			Developing CIRCOT-Pheonix Charkha	10 modified m/c supplied to NE hilly region
	Weaving machinery modification for running of banana yarn	Modified machinery for running of banana yarn	Softening trials conducted for spinning of fibre to yarn	2.6 t of yarn prepared
	Weaving of fabrics on different types of looms	Fabrics	Weaving done on power looms, jute looms and handlooms	350 m of different quality fabrics prepared and tested. Using this febric different articles were prepared
	Analysis of gray fabrics for quality parameters	Finished fabrics	Quality parameters tested	Processes available for preparing different quality fabric

			Processes standardized for scouring bleaching, coating, chemical treatment, printing and pigment printing of fabric done	Printed, water repellent and fire resistant fabrics
	Coating and lamination	Value added apparel products	Process standardized for coating and lamination	Laminated fabric can be used for sofa/seat covers.
	Preparation of fabric products	Types of fabric products prepared	Trials conducted at laboratory and industrial level	Coat, apron, gloves, caps, shoe (*mojari*), vertical blinds *etc.*, prepared at laboratory scale. Utility bags and mats prepared at industrial and handlooms scale
	Non-woven fabric			
	Preparation of nonwoven fabric	Quantity of non-woven fabric prepared	Preparation of non-woven fabric at industrial scale (Gloster Jute mills) using banana fibre	3.1 tonnes of non-woven fabric prepared
	Preparation of products from non-woven fabric	Processes for preparing non-woven fabric products	Processes standardized for preparing carpets and composites	Processes available for preparing carpets, composites using non-woven fabric and can be used in automobiles and railway coaches. Carpets can also be used for home furnishing
	Other products			
	Preparation of Micro Crystalline Cellulose (MCC)	Process for extracting MCC from banana fibre	Process standardized at laboratory scale and quality is comparable with commercially available MCC	Processes available for extracting MCC from banana fibre
	Prepare handicrafts using banana fibre and yarn	Handy crafts prepared	Different articles like doll, wall hangings, key chain, mobile covers, decorative articles prepared Training given to SHG	Handy crafts preparation can generate employment in rural areas

2) Standardize processes of pulp and paper making from pseudostem, fibres and scutching waste both at industrial and handmade levels	**Industrial scale**			
	Preparation of pulp and paper making from fibres and scutching waste	Pulp from banana fibre and scutching waste	Process standardized for preparing pulp from banana fibre and scutcher	Process available for preparing pulp from banana fibre and scutching waste can be used for preparing kraft papers and boards
	Evaluation of bleached and unbleached pulp (physical strength, optical properties and fibre fractionation)	Quality parameters of bleached and unbleached pulp	Quality of bleached and unbleached pulp prepared from banana fibre and scutching waste evaluated	Banana fibre is good for preparing specialty grade papers *i.e.,* greaseproof, cheque & kraft papers
	Characterization of effluent generated during pulping and bleaching	Quality parameters of effluent	Quality parameters analyzed	Effluent generated is less hazardous as it requires less chemicals than other raw material
	Exploring possibility of paper making	Preparing quality papers from banana fibre	Processes standardized for preparing cheque and anti-grease papers and quality tested	Processes available for preparing cheque and grease proof papers from banana fibre
	Handmade scale			
	Procurement and installation of handmade paper unit at NAU, Navsari	Handmade paper making unit	Commissioned 100 kg/day HMPB processing plant at NAU, Navsari	Prepared different stationary articles like file covers (50000), box files (15000), binders (10000), writing pad (500), art paper, *etc.*, and marketed within the university
	Preparation of handmade paper and board	Handmade paper and board	Produced 30 t of papers and board of different qualities	
3) Develop value added edible products from central core	**3.1 Edible products**			
	Separation and cleaning of central core from pseudostem and preparation of recipes from central core	Edible products developed from central core & quality tested	Processes standardized for preparing candy, RTS and pickle. Pilot scale unit started at NAU	Processes available for preparing candy, RTS, Jam and pickle form central core. Candy is good source of K, Fe, digestible fibre and vitamins.

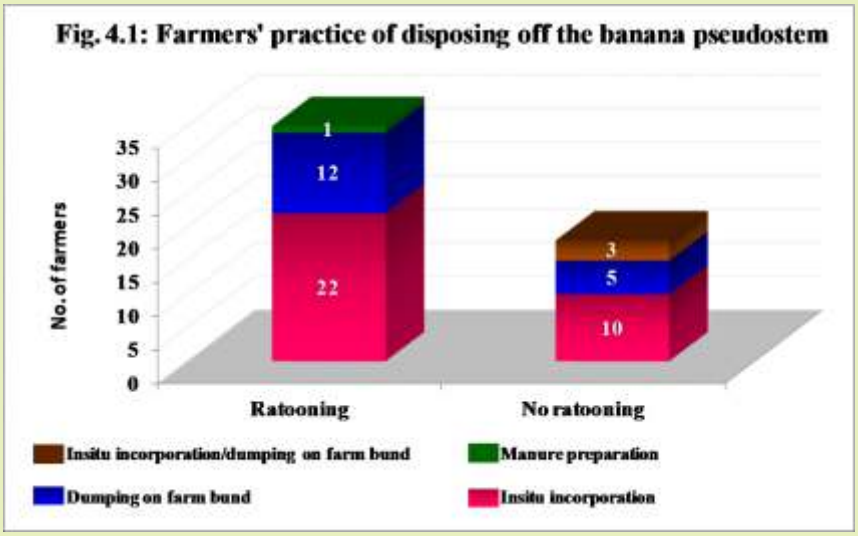
4) Preparation and evaluation of enriched sap and scutching waste based vermicompost	**4.1 Sap** ***a) Liquid fertilizer***			
	Explore possibility of use of sap as liquid fertilizer through field experiments.	Experimental results and yield data	Tested in different crops (sugarcane, banana, papaya, onion)	Found to improve crop yield, quality of produce & maintain soil fertility. It can also save 20% cost of fertilizers
	Enrichment of sap and testing different crops (NAUROJI Novel Organic Liquid Fertilizer)	Experimental results, yield data, validation and quantity produced	Process standardized for enrichment and tested in wheat, paddy, mango, banana, vegetable nurseries, leafy vegetables, garlic, okra, cluster bean, cowpea *etc.*	Produced about 100000 litres of Novel enriched sap (International patent filed in 4 countries). Increases yield and quality of produce.
	b) *Mordant* Development of process for using sap as mordant for textile dyeing	Dyed fabric	Process standardized at laboratory scale using natural dyes like *manjistha* and *annatto*	Good fastening properties observed. The sap seems to be a good natural mordant in textile dyeing industry
	4.2 Scutcher waste **a) *Vermicompost as manure***			
	Preparation of vermi-compost from scutching waste including sap	Quantity of vermicompost harvested	Process standardized for preparing scutching waste based vermicompost	70 % scutching waste and 30 % cow dung was found to ideal from nutrient point of view
	Comparative performance of scutching waste based vermicompost *vis-à-vis* FYM and biocompost	Experimental results and yield data	Evaluated in sugarcane, banana and papaya for 2 years and recommended to the farmers	Pseudostem based vermicompost is cheaper alternative than FYM or biocompost
	Large scale testing of liquid fertilizer (sap) and vermicompost in different crops on farmers' fields	No. of demonstrations and yield data	Demonstrated on 24 farmers' fields	Increase in yield by 10 to15 per cent.

	b) ***Vermicompost as fish feed*** Use of scutching waste based vermicompost as fish feed	Experimental results	Pelleted vermicompost tested as fish feed	Up to 30 % of routinely used cattle feed could be substituted by scutching waste based vermicompost which reduces the fish feed cost by 10 per cent
5) Develop linkage for marketing of pseudostem based products	Linkages for marketing of different products developed for banana pseudostem	No. of linkages established for marketing of products	MoU signed with 7 parties for commercial production and marketing of organic liquid fertilizer and candy.	Production and marketing of OLF at commercial level is initiated from 2014 all companies Gloster Mills, Kolkata is purchasing fibre from NAU for preparing different fabric products

Baseline Analysis of Banana Pseudostem:

With a view to know the practices being followed for disposing off the banana pseudostem by the banana growers of Gujarat, a systematic survey was conducted by SWMRU, NAU, Navsari as per the guidelines and prescribed format provided by NAIP, New Delhi. For this purpose, a standard questionnaire was designed and each respondent was interviewed personally. In all 53 farmers from 36 villages were interviewed (Fig. 4.1).

Fig. 4.1: Farmers' practice of disposing off the banana pseudostem



Farmers are either dumping it on field bunds (32%) or practicing in-situ incorporation (60 %). The cost of disposal of pseudostem is around Rs.15,000 to 20,000 per ha. Of all the varieties, Grand Naine is the most popular variety. The average yield of banana fruit ranges from 46 t/ha in rhizome to 70 t/ha in tissue culture planted crops with weighted average of 66 t/ha. At this productivity level, the net income realized under rhizome and tissue culture planting material is Rs. 49,800/ ha and Rs. 95,600 /ha, respectively. Though, net income is good, yet the B:C ratio is less than one

Table : Economics of banana cultivation with two different planting materials

Particulars	Planting material		Weighted average
	Rhizome	Tissue culture plants	
Yield (t/ha)*	46.00	70.00	66.00
Cost of cultivation (Rs/ha)	88,200.00	1,15,000.00	1,04,000.00
Gross income (Rs/ha)	1,38,000.00	2,10,000.00	1,99,000.00
Net income (Rs/ha)	49,800.00	95,600.00	88,600.00
B:C ratio	0.56	0.83	0.85

* Average yield was calculated considering 1.8 x 1.8 m spacing, 10% losses in tissue culture plants and 25% losses in rhizome

Though most of the farmers know about the utilization of banana pseudostem for vermicompost and fibre extraction, yet not a single respondent is practicing it. Of course, few respondents are preparing manure using banana pseudostem. After explaining the content of the project, reaction of the farmers was highly positive. After thorough understanding of the project, they put forth the following suggestions for realizing full benefits of the project by the farmers:

- Training for extraction of fibres from pseudostem and preparation of pseudostem based vermicompost
- Demonstrations of technologies on farmers' fields
- Subsidy on extraction machine
- Establish linkage for marketing of pseudostem based products

Regarding fibre extraction, manual and machine (developed by CIRCOT, Mumbai) both are followed especially in South and western states of India. However, they are at a small scale. Further, there is need to mechanize the existing fibre extraction machines through suitable modification to run it more efficiently and reduce labour requirement.

In case of quality of fibre, it is more comparable to jute fibre, rather than to other existing fibres. Some work on spinning fibre into yarn has been carried out jointly by CIRCOT, Mumbai and NIRJAFT, Kolkata on jute spinning machines. However, concerted efforts are needed to improve or modify the jute spinning machines to make it suitable for banana fibre. Handicrafts from banana fibre are being made in some states and have very good export potential which needs to be explored. Fabrics from banana fibre are being successfully made in countries like Japan and Indonesia, whereas in India it is still on a very small scale. The present survey shows that, banana fibre can be classified as medium quality fibre and may perform very well in combination with other fibres for making quality fabrics, handicrafts etc.

The work on use of banana fibre as raw material for extracting microcrystalline cellulose (MCC) and sap as mordant in taxtile dying industry is veery scanty.

In case of paper from banana waste/ fibre not much work has been done on a commercial scale. Processing technologies are available for preparing paper at hand made scale. Literature survey has indicated that composition of banana pseudostem is comparable with that of bagasse, which is an important raw material being used in paper industry. However, there is need to evaluate banana fibre for making different quality papers either sole or in combination with other raw materials used in paper industry. In addition to above uses, scutcher and sap obtained during fibre extraction can be used for preparing good quality manures.

Work on edible products with respect to central core from banana pseudostem is scanty. Of course, some products have been developed by NRC Banana, Trichy (Tamil Nadu).

CHAPTER 3
VALUE ADDITION OF BANANA PSEUDOSTEM

Fibre:

Objective: Standardize processes for extracting textile grade fibres from pseudostem and prepare home furnishings

Fibre extraction from banana pseudostem: From one hectare area of banana plantation, about 60 to 80 t fresh pseudostem as waste is available. For disposing these pseudostem, farmers spend around Rs. 15000 to 20000 per ha. The pseudostems are disposed-off on either field bunds and burnt on drying or in nallas or road side pits. Disposal of pseudostem in this way causes environmental problems. In present project, an attempt was made to use this pseudostem for fiber extraction and develop some value added products from it.

Extraction of fibre and their characterization

(A) Standardization of process for extraction of fibre from banana pseudostem

(i) Modification in raspador machine

For this purpose, initially two raspador machines were procured and based on the experiences gained; following modifications were done in consultation with CIRCOT, Mumbai.

- Additional pulley attachment for operating raspador on alternative energy source viz., power tiller, oil engine, kerosene engine.
- Attached bigger size wheel for ease in movement in field condition.

Subsequently, another 22 modified raspador machines were procured. Out of these, 20 machines were operationalized on farmers' fields along with necessary training to the farmers. The remaining 4 machines were commissioned on university farm for demonstrating to trainees, visitors etc.

Modified Raspador Machine

(ii) Development of cutter machine for splitting pseudostem

Simultaneously, for easy and speedy separation of sheaths from pseudostem, a cutter machine was developed by NAU, Navsari. Based on the systematic trial conducted on manual v/s mechanical sheath separation, it was concluded that use of cutter machine for sheath separation was cheaper (Rs.33.32 Rs/kg of

Banana pseudostem cutter machine

fibre) than manual sheath separation (42.36 Rs/kg of fibre). To facilitate speedy and cheaper sheath separation, 10 cutter machines were procured and distributed among the farmers who were extracting fibre using raspadore machines.

During the project period and till now, morethan 100 tonnes of dry fibre were extracted and subsequently used for product development.

It may be noted here that the fibres extracted even from farmers' fields could be directly used for preparation of yarn, woven fabric, non-woven fabric, high quality papers etc. This was possible inspite of small quantities of pithy matter present in the extracted fibres, as this was getting removed easily during processing for any of these final products.

(B) Preparation of catalogue for banana fibre based on their quality parameters

A comprehensive data has been lacking so far in order to have in depth study on banana fibre. An attempt has, therefore, been made to generate information related to quality of fibre of predominantly grown varieties for focusing their economic importance.

(i) Chemical composition of banana fibre:

In order to determine the chemical composition of banana pseudostem fibre, ten popular varieties were selected. The chemical properties viz., ash (TAPPI-T-211), hot water soluble (T2070M-81-1981), alcohol: benzene extractable matter (TAPPI T 204 Os – 76 -1976), lignin (T 222 Os-74-1974) and holo-cellulose (TAPPI T-9, M-54) were determined using TAPPI standards.

Table: Chemical composition of banana pseudostem fibres (dry weight basis)

Variety	Ash (%)	Hot water soluble (%)	Alcohol:Benzene (%)	Lignin (%)	Holocellulose (%)
Grand Naine	6.0	8.1	2.6	9.1	74.2
Ponchandan	4.7	4.8	1.3	11.7	77.5
Nendran	4.3	7.9	2.9	9.7	75.2
Paccakadali	5.2	8.3	3.1	9.8	73.6
Ladies Finger	3.7	7.9	2.4	10.0	75.9
Poovan	4.8	6.2	1.3	11.0	76.7
Adhar Velchi	3.1	10.4	2.0	8.8	75.7
Sugandhi	3.2	6.0	1.1	11.0	78.8
Sakar Chayna	4.4	9.3	1.9	8.9	75.5
Vannan	3.1	7.4	0.9	10.3	78.3

(ii) Tensile characteristic of banana fibre: For determining tensile parameters viz., fineness, tenacity and extension parameters, the pseudostem of 25 widely grown varieties of banana in India were collected from the AICRP on Banana, NAU, Gandevi (Gujarat).

The tensile parameter was tested using Tensile Testing Machine (Instron: model 400R) as per the method described in Indian Standard 234- 1973 an IS 235-1989. It is found that the linear

density of the banana fibre ranges 6.1 to 11.4 tex and strength ranges from 24.2 to 62 g/tex, whereas elongation ranges from 2.3 to 4.5 per cent. On the basis of data generated on quality parameters of banana fibres, grades have been framed.

Table: Range of fineness

SN	Range of Tex Value	Grades
1	Below 7	Extra Fine $(ExF)_f$
2	7 to 10	Fine $(F)_f$
3	10 to 14	Medium $(M)_f$
4	Above 14	Coarse $(C)_f$

Table: Grading of strength

SN	Range of Tenacity (g/tex)	Grades
1	Below 30	Weak $(W)_s$
2	30 to 40	Normal $(N)_s$
3	40 to 50	Strong $(S)_s$
4	Above 50	Extra Strong $(ExS)_s$

Table: Grading of extension

SN	Range of Extension	Grades
1	Below 2	Low $(L)_e$
2	2.1 to 3	Medium $(M)_e$
3	3.1 to 4	High $(H)_e$

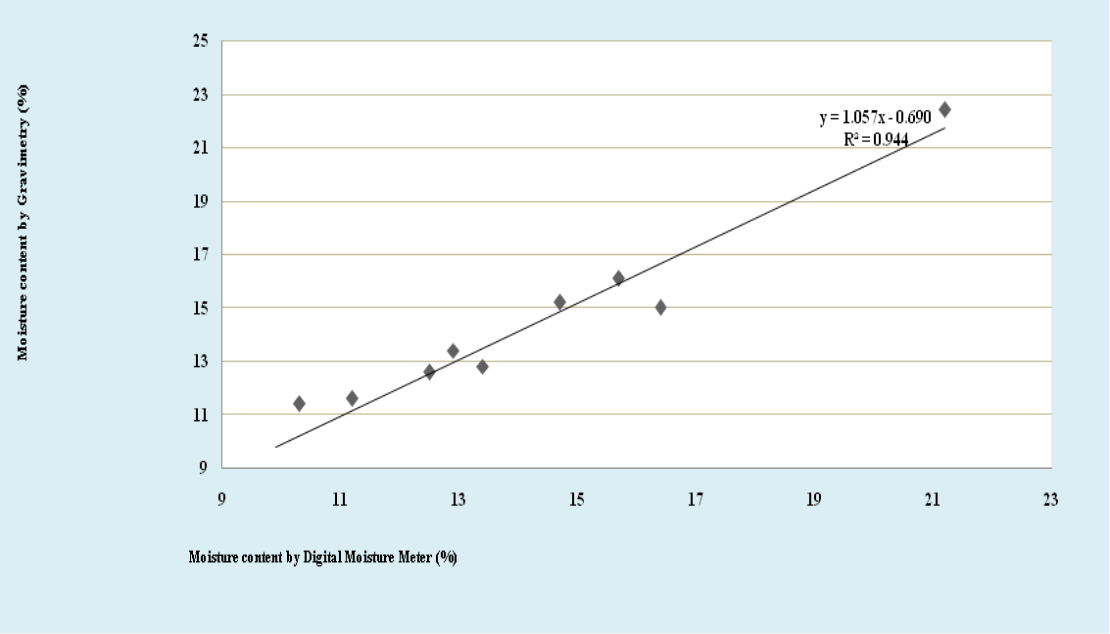
Considering the end use of products and processing requirements, the fibre were defined in four groups, i.e., Group I for the fabric preparation or spinning purpose, Group II for the handy craft, Group III for composite and non woven fabrics and Group IV for raw material for paper and pulp industry. This data base (catalogue) prepared by grading of fibres will help spinner to decide their process parameters in spinning. Breeders to know about which varieties are yielding good grade fibres and Research and Development workers to plan their research work.

(C) Moisture determination and ultra structural study of banana fibre

(i) Developing a method to measure moisture content in banana fibre

In the case of the natural fibre, the moisture content has significant influence on processing performance. The digital moisture meters are most popular electronic device for measuring the moisture content in natural fibre. For measuring the moisture content in banana fibre, specially designed moisture meters are not available. Therefore, a study was conducted to compare the moisture content in banana fibre determined by gravimetric and digital moisture meter generally used for jute fibre. Using the moisture content values obtained by both the methods, linear regression equation was developed.

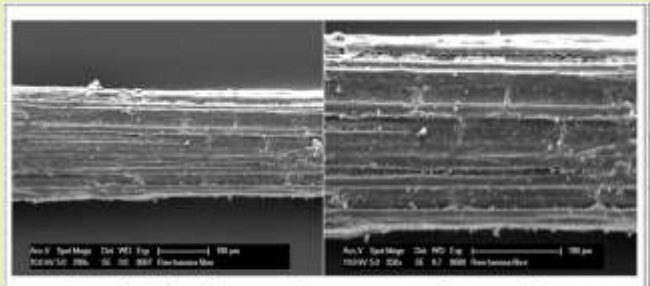
Fig. 2.1.1: Relationship between moisture content by digital moisture meter and gravimetric method



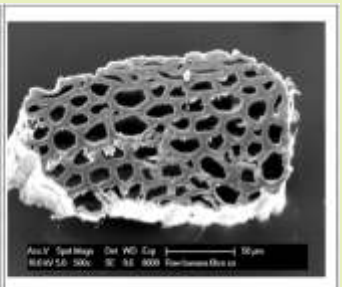
Using this equation, digital moisture meter can be calibrated and used for measuring the moisture content in banana fibre.

(ii) Ultra structural studies

The ultra structural studies were carried out using Scanning Electron Microscope. The fibre samples were mounted on a specimen stub and coated with gold in a sputter coater. The stubs containing the coated specimens were mounted on the specimen



Longitudinal views of banana pseudostem fibres



Cross sectional view of banana pseudostem fibres

stage of Phillips XL30 Scanning Electron Microscope. Fibre specimens were examined at an accelerating voltage of 10kV. Certain selected portions from the scans were recorded. SEM micrographs of longitudinal view show that the individual cells are packed together by lignin. Cross sectional view shows that the shape is to some extent circular. Embedded ultimate cells show wide distribution of size.

Product development using banana fibre

After standardizing the process for extracting fibre from banana pseudostem, an attempt was made to develop various products using fibre. Under this project, preparation of yarn using modified yarn making machine, Medalari Charkha and jute spinning system was done at laboratory and industrial scales. The yarn thus obtained was tested for its quality and woven fabrics of different quality were developed.

Preparation of yarn and its quality testing

(A) Conversion of banana fibre to yarn by different methods

(i) Modification in yarn making machine: The CIRCOT has designed and fabricated banana fibre processing assembly for converting banana fibre to yarn. This assembly is laboratory models spinning unit exclusively for spinning of banana fibre which comprises five machine viz., mechanical softening, staple cutting, carding, gill drawing and spinning machine. After optimizing machine parameters by conducting numbers of trials, the yarn was obtained and tested for its quality. Based on the observations during these trials, the modifications listed here are necessary for perfect functioning of machines.

I The change in gearing arrangement or motor to achieve desirable speeds of back roller, front roller and spindle of spinning machine so as to set the parameters like draft and twist for fine count of yarn
ii. Introducing compacting guide to reduce hairiness of yarn
iii. Introduction of proximity sensors, rpm indicator for correct display in control panel
iv. Coiler mechanism to be added for laying the coils of sliver in a can which will induce the compactness of sliver
v. The gear wheel of cutting machine has to change so as to cut the fibres of different staple length.
vi. In the sequence of this assembly one more machine i.e., fibre opener to be added for better removal of pithy matter from the sheath and individualization of the fibres. At present only carding machine is unable to solve the purpose.

The above listed design modifications were completed by CIRCOT in association with the fabricator, Trytex Machine Company, Coimbatore. Inclusion of fibre opener helped in the assembly cleaning the fibres as desired and spinning machine could able to run for longer time without any breakages in yarn.

After fine tuning of yarn making machines at CIRCOT, experimental trials were conducted with different softeners. For softening, fibres were treated with rice bran oil (RBO) and microbial consortium before processing. Yarn prepared by both the treatments were tested for quality parameters and results showed the best performance with rice bran oil as a softener.

Table: Tensile properties of banana fibre after softening

Samples/ Tensile properties	Fineness (tex)	Tenacity (g/tex)	Elongation %	TPI	Count (Ne)
Control	730	6.8	6.3	4.0	0.72
Sprayed with Rice Bran Oil	680	7.3	5.6	2.9	0.86
Sprayed with Microbial Consortium	913	3.2	7.8	4.4	0.65

(ii) Large scale trial of yarn preparation at Kolkata

Spinning of natural fibre always involves sequence of processes namely first cleaning the fibre, arranging fibre in a sliver form and then drafting and twisting. Each natural fibre spinning has their own sequence depending up on its fibre properties. An attempt was made to spin banana fibre to yarn using jute spinning system. The sequence followed was: Cutting (25 cm stable length) Piling (2 days) Softening (JBO emulsion-10%) Carding (breaker and finisher card Gill drawing (four drawing machine) Spinning.

The yarn test results revealed that banana fibre yarn is stronger than jute yarn with a quality ratio of 80%. However, it was observed that the yarns are having hairiness and more unevenness than jute yarn.

Subsequently, large scale trials were carried out at Gloster Jute Mills, Kolkata and in all 5 tones comprising of 100 per cent banana yarn, 90:10 per cent and 80:20 per cent Banana: Jute blended yarns were prepared.

Yarn trials at Kolkata

Yarn prepared at Kolkata

Table: Yarn test results

Data	Trial 1: (50 cm cut length, 2.0 TPI)	Trial 2: (25 cm cut length, , 3.0 TPI)
Yarn count (Actual)	16.36	18.57
MR%	17.55	18.86
Jute count (Converted)	15.87	17.81
Count cv	8.79	5.02
TPI	2.08	3.1
Twist cv	14.22	10.48
Strength (lb)	11.94	14.75
GRIST (LB) at 14%	15.87 (standard – 17)	17.81 (Standard – 17)
Strength cv	34.9	24.73
Quality ratio	73	79.44

(iii) Design and development of CIRCOT-Pheonix Charkha

Medlari charkha spinning unit is a foot operated self-winding spinning wheel with a bobbin to collect the spun yarn. The feeding to Medlari Charkha is done directly by hand without any feeding unit. Hence, it is also observed that, the fineness of yarn produced solely depend on the rate of feeding and this introduce a lot of non-uniformity in linear density and twist in the yarn produced. To synchronize feeding and twisting, a new drive mechanism has been designed and incorporated. The new design of the charkha, called CIRCOT-Phoenix Charkha. This is a pedal driven machine for spinning coarse long-staple fibres like banana pseudostem fibres at the cottage level. In CIRCOT-Phoenix Charkha the flyer and the bobbin are driven independently. The differential in the RPM decides the twist per inch (TPI) imparted to the yarn. The TPI of yarn produced can be altered by altering RPMs of the flyer and the bobbin by changing wheels in the drive mechanism. This charkha can produce relatively fine yarn with sufficient uniformity from natural fibres which are other wise difficult to spin. The fibres after extraction are cleaned and dried before use for spinning. Fineness of the yarn produced depends on the fineness of the fibre used, feeding rate and skill of the operator.

An Attachment to CIRCOT-Phoenix Charkha

Yarn prepared using CIRCOT-Phoenix Charkha

An attachment has also developed to CIRCOT-Phoenix Charkha which helps in feeding fibres, keeping twisted and non

twisted portions separate. A trial was under taken after fixing the attachment using banana pseudostem fibres. This yarn was evaluated for its tensile properties using Instron. These modifications enable spinning of long staple fibres like banana pseudostem on a peddle-driven machine that can be installed in any village household. Latest design of the CIRCOT-Phoenix Charkha can produce finer yarns of 2.9 counts with better uniformity and can be used for value added products at the village level.

(B) Testing quality parameters of banana fibre yarn

Yarns prepared on different spinning systems viz., Jute spinning system, CIRCOT-Pheonix Charkha and lab model spinning unit (Yarn Making Machines installed at CIRCOT) were tested and evaluated for quality with respect to tensile parameters and are presented in the table.

Table: Properties of yarn spin on different spinning systems

Spinning System	Breaking load (Kg)	Breaking extension (%)	Fineness (tex)	Tenacity (gm/tex)	Twist per inch	U%
Large Scale using Jute Spinning System	7.238	3.84	670	10.8	3.3	29.1
Lab Scale Using CIRCOT Developed Machines	4.964	5.6	680	7.3	2.9	40.6
Cottage Scale Using CIRCOT-Phoenix *Charkha*	2.188	2.7	166	14.6	3.1	23.5

Observations

- The yarn obtained on lab scale machines and on large scale machine are almost of same linear density.
- For the same linear density, yarn prepared on large scale machines shows 46% higher breaking load, when TPI is increase by 14%.
- The breaking extension of yarn at lab scale was showing higher extension among these methods. However, there was more variation observed in the extension value of lab scale system.
- Yarn on CIRCOT-Phoenix Charkha is reported for higher strength and fineness as compared to other methods.
- With the 9 tex fibres one can able to make a yarn of 670-680 tex in the lab as well as large scale spinning systems. But using CIRCOT-Phoenix Charkha, one can go up to highest level of 166 tex yarn which is hardly having 18-20 fibres to spun.
- Overall it is observed that banana fibre yarn is stronger than jute yarn with a quality ratio of 80%. However, it was found that the yarns are having hairiness and more unevenness than jute yarns.

Three different spinning systems discussed above differ widely in terms of technology used and scale of manufacturing. Large scale spinning of banana fibre using jute spinning is ideal for

large scale production of yarn at lower cost of production. However, such production system requires large quantity of raw materials for becoming economically viable. Moreover, such production system requires huge capital investments to set up. The laboratory level machines, on the other hand, are ideal for small scale production units where sufficient quantity of fibre can be sourced from the neighborhood itself. Laboratory scale machineries require comparatively less investment to set up and operate. The CIRCOT-Phoenix Charkha is least capital intensive and last in terms of production capacity. This peddle-driven device may be appropriate cottage level production of yarns in the villages.

(C) Preparation of woven fabrics using banana yarn

(i) Banana fabric processing (laboratory trials): On trial basis, MANTRA had prepared four types of blended fabrics with banana fibre yarn as weft and cotton as warp. Banana fabrics were tested for physical parameters, the results are shown in table. Among these in two fabric samples, banana fibre yarn was covered with polyester and the other with viscose. Weaving type also changed one fabric sample as 3/1 twill, while rest were of 4 end satin. Using above banana yarn and keeping 100 per cent cotton in warp following different banana union fabrics were woven on a conventional loom. The quality parameters of these fabrics are given in table.

Table: Physical parameters of different quality fabrics prepared using banana fibre yarn

Sample No.	Warp	Weft	Reed	Pick (Set)	R/S	Remark	Type of weave
1	2/24 s 100% cotton	Banana fibre yarn	36 S (72/1)	15	50.00”	--	3/1 Twill
2	2/24 s 100% cotton	Banana fibre yarn	36 S (72/1)	17	50.00”	Singed yarn	4 end Satin
3	2/24 s 100% cotton	Banana fibre yarn covered with polyester	36 S (72/1)	17	50.00”	Covering of 80 den. polyester roto yarn	4 end Satin
4	2/24 s 100% cotton	Banana fibre yarn	36 S (72/1)	17	50.00”		4 end Satin
5	2/24 s 100% cotton	Banana fibre yarn covered with viscose	36 S (72/1)	17	50.00”	Covering of 120 den. viscose roto yarn	4 end Satin

Table : Quality parameters of different fabrics

Parameters	Sample no.									
	1		2		3		4		5	
Fabric direction	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
Load at break (Kg)	34.8	186.7	43.2	134.3	24.3	114.6	51.36	189.1	48.86	197.1
Actual ends/inch	36		37		37		36		36	
Actual picks/inch	18		20		18		18		18	
GSM	503.5		447.4		515.7		568.3		566.23	

(ii) Banana fabric processing (industrial trial): About 250 m of fabric in three lots were processed on industrial scale in local process house.

- Grey fabric was given gas singeing with m/c speed of 70 m /min. and slit width of 2" blue flame. Scouring and bleaching was done in an open jigger machine. This was followed by enzymatic desizing at 70°C for 2 hrs. Peroxide bleaching was given at 90°C for 4 hrs.
- Reactive dyeing was carried out by Pad – Batch method of reactive dyeing. Chemical finishing was given on stenter with softener and resin. This was followed by mechanical finishing in the form of calendaring and sanforizing.

Printing of banana fabric: Banana x Cotton fabric with satin weave and banana yarn facing on one side was printed with reactive and vat dyes after pretreatment as mentioned above. The printed fabric was dried and steamed in rapid ager at 102°C in saturated steam followed by washing and soaping. The fabric was finished to impart softness. The fabric processing conditions under industrial were established. Apparel made out of dyed fabric like 'Jawahar coat' was appreciated by all. The printed fabric can be used as curtain and sofa cover material.

Finishing of banana fabric (water repellent finish): Banana fabric was finished with hydrophobic chemical by pad-dry-cure method. The fabric was tested for water repellency by spray rating method. It showed good water repellence with rating 4 (rating 1 means poor and 5 means very good). Further, water repellency was achieved by eco-friendly chemical and process. The dyed/printed water repellent banana fabric can be used for different applications like home furnishing fabric, table mat, etc., where water repellency is important property. The product made can be claimed as 'green' product.

Coating of banana fabric: Banana fabric was coated with various coating chemicals to impart functionality which can then be used as technical textile material.

PVC coating: PVC coating was applied by knife over air technique with paper release method. Coating was done with paste containing PVC powder, DOP (Dioctyl phthalate) as plasticizer, epoxy resin, $CaCO_3$, stabilizer and pigment. The speed of the machine kept at 2 m/min. The

temperature set at 150ºC. PVC coated banana fabric can be used as artificial leather.

Acrylic coating: Acrylic coating was applied to banana fabric to make it hard. This acrylic coated banana fabric can be used for window blinds like vertical blind, roman blind, etc. Coating recipe for banana fabric vertical blind is given in table.

Table: Coating amount used for banana fabric vertical blind

Chemical	Amount
Pidicryl VB	4 kg
Pidicryl 361 M	150
Ammo. Chloride	50
Water	200
Pidicryl 260 A	150
Liq. Ammonia	25

Technique: Knife in air
Curing temp.: 150 – 160°C; Speed: 3 m/ min.
Two Coats on both sides of the fabric
Above recipe can be changed to produce different effects according to end use.

Banana fabric can be coated with various chemicals to have technical textile fabric with different end uses. To produce artificial leather instead of PVC alternate chemicals like Polyurethane (PU) and acrylics can be used to provide eco-friendly nature. The acrylic coated banana fabric was excellent in properties and looks. The coating was done using aqueous base chemicals (free from hazardous solvents) hence coating process was environment friendly.
Develop woven end products: In order to develop various woven end products, fabrics having following specifications were prepared initially at Kolkata in consultation with CIRCOT.

a. Warp : Jute yarn of 20 pounds
b. Weft : Banana yarn of 17 pounds
c. Ends/dm : 42
d. Picks/dm : 44
e. Loom speed : 142 rpm (0.3 metre/minute)
f. Fabric width 0.55 metre
g. Weave plain
h. 60% banana and 40% jute (weft 100% banana and warp 100% jute)
i. Bag size – 17" x 14"

The fabric prepared was bleached using hydrogen peroxide. The bleached fabric was then used to make hand bags of size 17 inches x 14 inches. Around 500 m of fabric was prepared and

then these fabrics used for making hand bags (1000). The hand bags were printed with floral designs apart from printing of NAIP, ICAR, NAU and CIRCOT logos.

(D) Preparation of non-woven fabrics using banana fibre and product development

(Ipreparation of non-woven fabric: Initial trials were conducted at CICT, Bangalore for preparation of non-woven felts from banana fibres. The prepared non-woven felt evaluated for its strength parameters and it was found that it has a good strength. Hence, large scale trials were conducted at Gloster Jute Mills, Kolkata for preparation of non-woven felts. About 3.1 t of banana fibres was converted into non-woven fabric by needle punching method. Fabrics with linear density of 450, 700 and 900 gram/sq m (GSM) were prepared with 2 levels of thickness for each GSM. Mechanical properties of the fabrics are presented in table.

Non-woven fabric trial at Gloster Jute mills Kolkata

Table: Mechanical properties of non-woven felt prepared at Gloster Jute Mills

GSM of nonwoven felt	Thickness (mm)	Bursting Strength (kg/cm^2)	Weight/ m^2 (gm)	Strength (gm)		Elongation (%)		Tearing Strength (gm)
				Draw Direction	^ Direction	Draw Direction	^ Direction	
450	3.8	20.4	558	3460	1465	15.1	20.9	4063
700	5.3	24.5	817	4761	3050	22.3	25.9	8568
900	5.9	22.6	910	4146	3347	23.9	26.8	3150

Some exploratory work on use of these fabrics as geo-textiles has shown that these fabrics have more life underground vis-à-vis similar jute fabrics, i.e., degradation of these fabrics is at a slower rate as compared to that of jute. This is an advantage over jute fabrics particularly for agro/geo-textile applications where bio-degradation of fabrics should be at a slower rate.

(ii) Product developed from non woven fabrics

A banana fibre needle punch non woven fabric was supplied by NAU to MANTRA in three different GSM i.e. 500, 700 and 100. These fabrics were finished or coated with different chemicals to produce non woven fabric which can be used as floor covering material. The coated non woven fabric was tested for different properties.

Table : Properties of coated nonwoven fabric

SN	Test	Result
1	GSM before coating	500
2	GSM after coating	653
3	Abrasion cycle before coating	422
4	Abrasion cycle after PU coating	5575

Banana needle punch nonwoven fabric can be coated or laminated to produce floor covering mat, carpet, etc., by coating or finishing it with different chemicals like acrylics, PU and others. The required property like abrasion resistance was obtained to a very good level of above 5000 cycles. By careful selection, a product can be made having eco-friendly nature. Simultaneously, preparation of resin reinforced banana non-woven fabric composite was also attempted by MANTRA.

Polyester resin: Banana nonwoven felt 30 x 30 cm (two layers) was put in a match mould and polyester resin with chain initiator and accelerator was poured over it. The material was pressed with hydraulic press with high pressure of 300 kg/cm2. The assembly was kept for 24 hours under pressure and a square tile was taken out. It was further kept in open air for two days to dry up. The sheet was cut in round shapes.

Acrylic resin: Banana nonwoven felt 30 x 30 cm was immersed in 25 per cent solution of acrylic resin Acrodur 3550 (BASF) was padded by passing through mangle with 40 psi (3 bar) pressure and subsequently heated at 120ºC. The semi processed sheet was kept in a mould and hydrolytic pressure of 150 bars. The compressed sheet was heated to a temperature of 200 °C for 1 minute. Three sheets of different thickness were prepared and it was tested for properties as shown table.

Table: Properties of acrylic treated sheets

Properties	Sheet 1	Sheet 2	Sheet 3
Thickness mm	1.27	1.43	2.30
Density g/cc	0.69	0.73	0.73
Impact strength ISO 179-1 kJ/m^2	2	3	3
Bending E - module W4 14125 N / mm^2	1815	3481	1536
flexural strength N / mm^2	23	34	35

Fiber reinforced composites using banana fiber and polyester resin was made which can be used as substitute for wood. The material obtained was cut in round shape easily. The polyester resin used does not contain formaldehyde.

The composite made using acrylic resin was light in weight with density around 0.7. This means that it can be used for automobile applications where strength is secondary criteria and light weight is advantageous. The composite can be easily given shape during manufacturing

An attempt at CIRCOT was also made to prepare a composite from banana non woven felt at CIRCOT Electric press machines without using any binder. The non woven fabric of 450 GSM was compressed with different combination of mechanical parameters and 8 types of sheets were prepared and tested for its strength properties. On the basis of the findings of this trial, another experiment was conducted for preparation of banana fibre composite using Acrodur DS 3515 as a binder at BASF Chemical Ltd., Mumbai. For the purpose, a non-woven felt of 500 GSM was used which was prepared at Gloster Jute Mills, Kolkata. The proportion of raw material to binder was

75:25 and binder density of 450 g/l. Foulard parameters were maintained as pressure of 3 bars, speed of 1.5m/min and gap of o mm. The pressing parameters were 200 C temperature and 150 bar pressure. The two semi-finished products are compressed in the longitudinal direction of a planar plate. The prepared semi-finished composite sheets were tested for various parameters and are presented in table.

Table: Properties of composite sheets

Parameters	Unit	Sample	
		1	2
Plate Thickness	(mm)	1.43	1.39
Density	(g/cm^3)	0.72	0.85
Water Absorption after 2 hr	(%)	43 (8)	26 (4)
Water Absorption after 24 hr	(%)	66 (7)	47 (1)
Swelling after 2 hr	(%)	19 (2)	14 (2)
Swelling after 24 hr	(%)	22 (2)	18 (2)
Impact ISO 179-1/1fU	(kJ/m^2)	3 (0)	4 (1)
Bending E-module W2 14125	(N/mm^2)	3481 (245)	3360 (171)
Flexural Strength	(N/mm^2)	37 (1)	33 (1)
fmax	(N)	18	20

(Figures in parenthesis are Standard Deviation values)

Observations:

- The surface density of the mat varies greatly, which set the density at pressing difficult.
- The impact value reported as 4 kJ/m^2 which is low and it is mainly due to the great brittleness of non-woven felt.
- The modulus of elasticity is also at a low level.
- The water absorption is with 47% in the target area.

Acrodur® DS 3515 (Acrylic copolymer binder) as a binder & non-woven felt of 500 GSM

Conclusion: It can be concluded that in combination of banana with any binder, state-of-the-art lightweight composites can be achieved–using conventional machinery. With increasing emphasis on fuel efficiency, natural fibre such as banana based composites would enjoy wider applications in automobiles and railway coaches. In fact, the market segments such as railway coaches and buses for public transport system in India have vast potential, which is yet to be tapped to a good extent.

(E) Preparation of handicrafts using fibre

Apart from woven and non woven fabrics and their products, direct use of fibre for preparing handy craft item was also attempted by NAU, Navsari and CIRCOT, Mumbai. At Navsari, the fibres was supplied to NGO viz. Manav Kalyan Trust, Navsari for preparing wall hangings, bags, doll, idols, keychain, mobile phone cover, mat for dining table etc. items. Such attempt was made by CIRCOT, Mumbai by using fibre as well as yarn.

Handicrafts items from banana fibre

Conclusion:

Based on the variety of handy craft items which can be prepared by the NGOs using fibre and yarn, this has great potential in tribal as well as rural areas. This will generate huge employment opportunity in rural area. In introducing this activity on large scale in tribal and rural areas, there is need to get support from KVICs or NGOs etc., for marketing the products prepared from fibre/yarn.

(F) Preparation of microcrystalline cellulose (MCC) using banana fibre

An effort was made to standardize a bio-chemical route for preparing MCC from banana fibre and to compare the physical and chemical characteristics of the product obtained with that MCC available in the market. The bio-chemical route requires less chemical and energy with lower investment than the conventional process for preparing MCC. In other words, bio-chemical route is environmentally safe. The MCC extracted by adopting bio-chemical route was tested for different properties Details of process for preparing MCC using banana fibre is given in.

Table: Properties of MCC extracted from banana fibre and commercial available

SN	Property	MCC prepared from Banana Fibres	Commercial MCC (Avicel®)
1.	**Moisture content (%)**	5.3	5.0 ± 0.5
2.	**Ash content (%)**	0.07	0.06 ± 0.005
3.	**Cellulose content (%)**	99.0	100
4.	**Starch**	Nil	Nil
5.	**pH value**	6.4	7
6.	**Solubility**		
	a. Distilled water	Partially Soluble	Partially Soluble
	b. 1% NaOH	Partially Soluble	Partially Soluble
	c. 1% HCl	Insoluble	Insoluble
	d. Petroleum ether	Completely Insoluble	Completely Insoluble
	e. Acetone	Completely Insoluble	Completely Insoluble
	f. Ground nut oil	Completely Insoluble	Completely Insoluble
7.	**Degree of polymerization**	267	157
8.	**Molecular weight**	43254	25434
9.	**Particle size in µm**	30-60 at 800 X	20-100 at 800 X
10.	**Degree of compressibility (%)**	24.9	11.0
11.	**X-ray crystallinity**	72.1	82.1

Interpretation: The moisture content of banana fibre MCC is 5.3 per cent which is in close agreement with 5 per cent that of commercial MCC. According to U.S. Pharmacopeia (USP) 1980, the possible effect of moisture is expected to be negligible for the moisture content below 10 per cent. The ash content of cellulose powder from banana fibre was 0.07 per cent which is in close agreement with ash content (0.06%) of commercial sample and according to U.S. Pharmacopeia 1980, ash content should not be more than 0.1 per cent. The starch content in cellulose powder prepared from banana fibre is nil which is in close confirmation with the specification given for MCC in U.S.P. The cellulose content in MCC prepared from banana fibres is 99.0 per cent which is in close agreement with that of commercial MCC product. According to U.S. Pharmacopoeia cellulose content should not be less than 97 per cent. Hence this product stands well in agreement with U.S.P. specifications. The particle size of the prepared MCC is in narrow range of 30 µm whereas commercial MCC is having 80 µm. It can be observed from the SEM micrographs that banana MCC surface is plain without any serrations. Prepared cellulose powder as well as commercial MCC is having similar characteristics for solubility in water, dilute alkali, dilute acid, organic solvent and groundnut oil which is as per standards of Pharmacopoeia of India. The pH value of prepared MCC is in close confirmation with commercial material. Particle size depends upon the extent of degradation of cellulose molecule. The cellulose powder prepared from banana fibres having lower molecular degradation than commercial MCC.

The powder X-ray diffraction spectra of both the cellulose samples showed typical of Cellulose I structure with diffraction peaks of the 2 angles at 15°, 16.5° and 22.6°. The sharp peak of 22.6° indicates higher crystallinity. Percentage crystallinity of cellulose powder prepared from banana fibres is 72.1 per cent where as for commercial MCC is 82.1 per cent. The Crystallinity Index gives a quantitative measure of the crystallinity in powders which can be related to the strength and stiffness of fibres. High crystallinity indicates an ordered compact molecular structure, which translates to dense particles, whereas lower crystallinity implies a more disordered structure, resulting in a more amorphous powder. The cellulose powder prepared from banana fibres is found to have 13.9 per cent more compressibility than commercial MCC.

Conclusion: Banana fibre is rich in cellulose and thus can be a potential raw material for the preparation of microcrystalline cellulose. The MCC prepared from banana fibres compared favourably with Avicel (commercial brand of microcrystalline cellulose) in most of the physical and spectroscopic properties. The results also confirm that one can use a bio-chemical route for preparation of MCC. Bio-chemical route is highly environmentally safe and minimizes the use of chemicals.

In the industry MCC is prepared from wood. MCC yield from wood is about 30 to 35 per cent. In comparison MCC yield from banana fibres is about 50 per cent. During the project period only laboratory scale MCC production from banana fibre could be undertaken. Hence, it is very difficult to give cost economics for preparation of MCC exclusively from banana fibres on large scale. However, it is envisaged that the present plants producing MCC from wood pulp as raw material can also use banana fibre for its production. Higher yield of MCC from banana fibres is expected to increase the profit margin.

Summary: Banana fibre extraction and product development

After incorporating essential modifications i.e., providing additional pulley for using alternative energy source and bigger size wheels for easy mobility in field in raspador machines, about 100 tones of dry fibre from banana pseudostem were extracted by active involvement of the banana growers. With the output of 25 to 30 kg dry fibre / day/machine by employing 5 to 6 laborers, it is economically viable by considering selling price of dry fibre at Rs.100/kg. Though, fibre extraction is economically viable, yet there is need to reduce cost of fibre for its wider applicability.

With respect to product development, woven as well as non woven fabrics were prepared. In woven fabrics, quality of yarn obtained has two problems i.e., protruded fibre and coarseness with poor linearity. In spite of these problems, about 350 m woven fabric was prepared using handlooms weaving method. This fabric was processed and varieties of products (bags, coat, curtain, mats etc) were developed on small scale.

To overcome the problems of poor quality of yarn, non woven fabric (~3 tones) was prepared by employing needle punching technique. The product viz., coated with resins and composite developed from non woven fabric are potential candidates for use in automobile and railway coaches as these products have advantage of lighter in weight than currently used material.

For obtaining good quality yarn, peddle operated modified CIRCOT-Phoenix Medalari Charkha has been designed and the quality of yarn prepared using charkha was much better than yarn prepared on jute spinning system. Apart from improvement in yarn quality, it can generate good employment in tribal and rural areas especially for women empowerment. Along with preparing banana fibre yarn using charkha, tribal women can also prepare handicrafts using banana fibre and earn their livelihood. Both these jobs can be performed perfectly by tribal women who are by birth artisans. Ultimately, popularization of these activities in tribal area may minimize migration.

Apart from the above techno-economically viable technologies, the processes for preparing micro crystalline cellulose (MCC) using indigenously available raw material like banana fibre and use of sap as mordant (natural adhesive) in textile dyeing have been standardized at laboratory scale. Large scale trials are yet to be done after which it is possible to compute the economic viability of the technology. The properties of MCC prepared by using banana fibre are comparable with the MCC (pharmaceutical grade) available in the market.

Objective: Standardize processes of pulp and paper making from pseudostem, fibres and scutching waste both at hand made and industrial levels

Optimization of pulping conditions for banana fibre and scutcher

(A) Use of banana fibre and scutcher waste as raw material for pulping

(i) Fibre: In order to find out the economic viability of using pseudostem fibre, scutcher and whole pseudostem as raw materials in paper and pulp industries, in present project series of trials were conducted at J.K. Paper Mills Ltd., Songadh (Gujarat). These trials were conducted for optimizing the pulping, cooking time, chemical doses, temperature, bath ratio and bleaching parameters using fibre, whole pseudostem and scutcher as raw material. The detail results are appended in.
Based on results of the trials, following inferences were emerged.

- Ideal bath ratio for Kraft pulping using banana fibre was found to be 1:5 with 71.0 per cent unbleached pulp yield (unscreened) and 13.4 Kappa No.
- Optimum cooking chemical dose for banana fibre appears to be 16 per cent with 55.35 per cent unbleached pulp yield (unscreened) and 11.6 target Kappa No.
- Because of higher dilution, chemical recovery is not economical. To overcome this problem, continuous digester with plug screw feeder arrangement is suggested.
- For banana fibre, soaking time of 60 minutes was found better in view of low Kappa No. and higher twaddle of black liquor obtained.
- Optimum cooking temperature for banana fibre was found to be 165oC due to low Kappa No. and cooking time of 60 minutes with better unbleached pulp yield was found to be ideal.
- Subsequently, the normal pulping conditions maintained for different raw material by paper mills vis-a- vis the optimized pulping conditions arrived for banana fibre were compared.

Table: Standard pulping conditions of different raw materials

Particulars	Unit	Bamboo	Eucalyptus	Subabul + Bark	Bagasse	Banana fibre	Remarks
Active Alkali as Na_2O	%	16-18	18.4	17	12.5-13	15 -16	Active alkali requirement is higher than bagasse
Time to temp. (85-165°C)	Hrs.	3	3	3	--	2	Time requirement is less
Time at Temp.(165°C)	Hrs.	2	2	2	1.5	1.0	Time requirement is less
Kappa No.	No.	19	20	16.8	12 ± 1	12 + 1	Less than other raw materials
Screened unbleached pulp yield	%	49.3	48.9	49.4	48.5	56 -57	Yield is better than bagasse.
Reject	%	0.5	0.7	1.5	1.5	3.5 + 0.5	Rejects are higher
Total Yield	%	49.8	49.7	50.9	50	59.5 – 61.0	Yield is better than bagasse
Bleached Pulp Yield	%	41.4	45.3	43.5	45	53 + 0.25	Yield is better than bagasse

The results clearly indicate that screened pulp yield from fibre was found to be comparatively higher (60%) as compared to other raw material used in paper industry. Further, for maintaining the same Kappa No. of 12±1, the active alkali requirement for banana fibre seems to be higher (15%) only as compared to sugarcane bagasse. Similarly, bleaching conditions were also optimized. The results appended suggest that banana fibre are easily bleachable and has good bleaching response with CEpHD bleaching sequence, bleached pulp brightness achieved was 88% ISO.

(ii) Scutcher: As like fibre, scutcher waste obtained during fibre extraction was also tested as raw material for pulping. Based on the results, it is concluded that scutcher waste require higher cooking chemicals (22%) and also have high Kappa No. of 20.8, that too with very low unbleached pulp yield (24.4%). It is, therefore, concluded that scutcher waste is not fit for paper making.

(B) Testing quality parameters of pulp and paper

After optimizing pulping and bleaching parameters using fibre and scutcher waste as raw material, physical parameters of bleached and unbleached pulp and papers were tested.

(i)pulp: Physical strength properties and fibre classification results and fibre dimensions of the bleached pulp produced from banana pseudo stem are given in the tables.

Table : Physical properties of pulp tested at J K Paper Ltd, Unit: CPM

Particulars	Unit	Unbleached Pulp	Bleached Pulp
Freeness of pulp	°SR	40	40
GSM	g/cm^2	60	60
Bulk	Cc/g	1.29	1.22
Breaking Length	M	6978	4931
Burst Factor	(kg/cm^2)	88	79
Tear Factor	$(mN.m^2/g)$	86	86
Double Folds	No.	3080	1389
Strength Index		2975	2776

Interpretation: The unbleached and bleached pulp physical properties are more or less comparable in terms of bulk and tear factor, however burst factor is 88 and 80, respectively. Breaking length in unbleached and bleached pulp is 6678 and 5931 m, and double fold 2580 and 1389, respectively. The overall strength index is 2956 and 2764 in case of unbleached and bleached pulps. These properties indicate that the pulp quality is adequate for specialty grades of paper i.e., greaseproof, cheque and currency paper etc.

Table: Classification of banana pseudostem fibre pulp

Particulars	Unit	Unbleached Pulp	Bleached Pulp
+ 20	%	70.8	72.2
- 20 +50	%	16.8	17.6
- 50 + 65	%	2.8	2.9
- 65 + 125	%	0.68	0.65
- 125	%	8.9	6.6

Interpretations:

- Plus 20 fraction of banana pulp is very high at 70 to 72 per cent which indicates the presence of long fibre pulp.
- This type of pulp is bound to give good folding endurance (double folds) indicating its suitability for the production of packaging papers and boards.
- It is also suitable for the production of papers which needs to be preserved for long times like Bond paper etc., where rag pulp is normally used to some extent.
- It is most suitable for the production of currency paper as it has good folding endurance and good strength properties in view of the very high long fibre fraction

Testing of pulp quality by external agencies

The results of the paper quality tested by PAPRI, Rayagada (Orissa) is given in tables.

Table: Fibre dimensions (Tested at PAPRI –Rayagada, Orissa)

Particulars	Unit	Bamboo	*Subabul* with bark	Soft wood	Banana fibre
Fibre Length	mm	1.8 -2	0.95	2.45	1.44
Fibre Diameter	micron	15	15.4	20.2	18.9

Interpretation: The results showed that fibre length and fibre diameter is 1.44 mm and 18.9 micron, respectively, for bleached banana pulp. The fibre length is better than subabul (hardwood pulp) and inferior than softwood pulp. The fibre length shows good paper making properties potential.

(ii) Paper: Un-bleached and bleached paper samples prepared at JK Paper were sent for testing to CIRCOT Mumbai. The results are given in table.

Table: Mechanical properties of paper samples

Paper type	G.S.M (g/m^2)	Brightness (%)	Opacity %	Burst factor (kg/cm^2)	Breaking length (m)	Double fold (No.)
Bleached	60	73.8	77.5	55.0	3210	840
Un-bleached	60	----	80.8	63.3	6020	1972

Interpretation: The brightness of bleached paper is 73.8 per cent i.e., low. However the pulp brightness can be produced to level of 87-88 per cent brightness. The paper can be made of high brightness with banana pseudostem fibre pulp. The strength properties of hand sheets in terms of double fold and bursting factor are good and showing good paper making potential.

Hand sheet (Bleached & unbleached pulp)

(iii) Physical properties of scutcher waste pulp

The results of physical strength properties of the pulp obtained from scutching waste are given in table.

Table: Physical strength properties of paper prepared using scutcher waste pulp

Particulars	Values			
Chemical charge as NaOH (%)	16	18	20	22
Tear factor	51.2	53.3	49.2	50.0
Burst factor	19	17	17	14
Breaking length (meter)	4064	3981	3210	2532
Double fold (nos.)	20	17	14	10

Interpretation: This scutcher waste pulp physical strength properties are low as compared to banana pseudostem fibre. The breaking length, double fold, burst factor is 1/3 as compared to pseudostem fibre. Tear factor is about half as compared to banana pseudo stem fibre. This type of pulp may be utilized only in low grade paper.

Exploring possibility for preparing speciality papers

Banana pseudostem fibre being costlier raw material than conventionally used raw material, it was thought to prepare speciality paper viz., cheque book and grease proof using banana fibre.

(A) Cheque (MICR) paper from banana fibre pulp: Cheque paper (MICR- Magnetic Ink Character Recognition) is one of the valuable papers in Indian paper market. It is utilized by banks to generate payment. It is prepared by adding special chemicals using special pulp. Pulp used in manufacturing of cheque paper is prepared from some special softwood pulp. This pulp is with higher strength properties and brightness. The pulp prepared from banana pseudostem fibre for making cheque paper was tested for its physical properties.

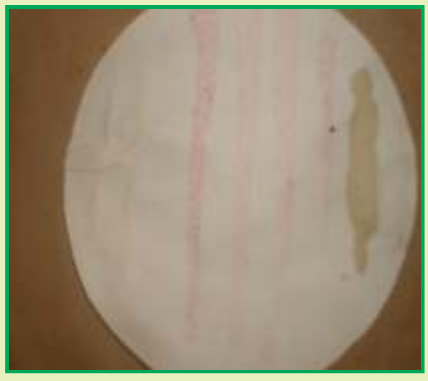
Table: Comparison of physical properties of pulp prepared from banana fibre to that of other standard pulp used for making cheque papers

Particulars	Unit	C70+I30	C70+B30	MICR paper standard parameters	Banana fibre pulp
Caliper (Thickness)	Micron	110	119	110±10	112
Burst Factor	Mullen	25	32	-	64
Tear Factor	Eim	78	82	78	124
Breaking length	Metre	3216	4628	-	5040
Double Fold	MIT	35	142	-	1332

C – CPM pulp, I – Imported pulp and B – Banana fibre pulp

Wax Pix test

Sensitization test before Sizing



Sensitization test after Sizing

Interpretation: The physical strength properties of bleached pulp are very good in terms of tear factor, burst factor, breaking length and overall strength index is 2764. These properties indicate that the pulp quality is adequate for making cheque paper (MICR) is one of the valuable papers in Indian paper market.

(B) Grease proof paper: Grease proof paper is one of the valuable papers in Indian paper market. Grease proof paper is that impermeable to oil or grease and normally used in cooking or food packaging. Normally grease proof papers is produced by refining the pulp stock for paper making to a very high degree refining and thus create a sheet with very high bursting strength and low porosity, which is the requirement for grease proof paper. The test results of the exploratory trials on lab scale for grease proof paper prepared from banana fibre are given in table.

Table: Greaseproof paper from unbleached banana fibre pulp

Freeness ° SR	Beating time (min)	Tear factor	Burst factor	Breaking length (Meters)	Double folds	Blister test	Oil transduction period (min)
80	60 min	130	>100	8786	Very High	Very Good	Over 1800
90	90 min	130	>100	8736	Very High	Very Good	Over 1800

Interpretation: The grease proof paper produced using banana fibre is showing good bursting strength as well as high oil absorbency time. These properties indicate good potential for making grease proof paper from banana pseudostem fibre.

Characterization of effluent generated during pulping and bleaching

The effluents generated during processing of banana fibre and hardwoods were characterized. As at each step of pulping and bleaching, effluent is generated, stage wise characterization of effluent was also done and the results are reported in table.

Table: Stage wise characterization of banana fibre effluent

Particulars	Unit	Chlorination	Extraction	Hypochlorite	Chlorine dioxide
pH		5.2	10.3	6.6	3.4
TSS	mg/l	60	69	43	41
TDS	mg/l	1720	845	1241	1840
BOD	mg/l	156	760	184	74
COD	mg/l	666.4	2136	700.6	281.9
Colour	Pt-Co Unit	10	60	1.7	1.7
Conductivity	µ mhos/cm	2600	1288	1890	2720

Interpretation: The value of pH, TSS, TDS, BOD, COD, colour and conductivity reported in table clearly prove that the effluents generated are not hazardous in nature due to less use of bleaching chemicals.

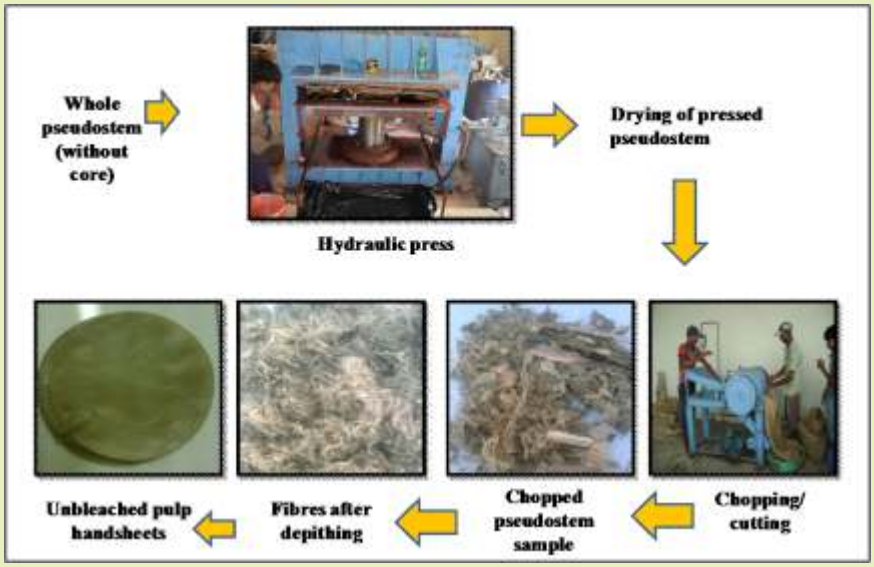
Unbleached paper sheet prepared from mechanically depithed fresh pseudostem

Use of whole fresh banana pseudostem for paper making

For resolving the problem of high cost of banana fibre, at JK Paper Mills Ltd., Songadh an attempt was made to use whole fresh pseudostem for preparing paper vis-à-vis banana fibre. The results of trials conducted at JK Paper Mill Ltd. reported that the fibre obtained by depithing of whole fresh pseudostem are having good pulpable and pulp properties which are comparable with the fibre extracted by raspador. This was further substantiated by the bleaching results. Bleaching results of whole pseudostem fibre extracted with the help of raspador machine and mechanical wet depithing process are given in table.

Table: Properties of bleached fibre extracted using raspador m/c and depithing process

Particulars	Unit	Banana pseudostem fibre	Depithed whole banana pseudostem pulp
Screened pulp kappa No.	no.	15±2	15.2
Bleaching sequence	--	CEpHD	CEpD
Cl_2 as gas	%	2.5	1.3
Cl_2 as Hypo	%	1.5	0
Caustic (NaOH)	%	1.5	1.8
H_2O_2 (as 100% basis)	%	0.75	1.0
ClO_2	%	0.7	0.5
Bleached yield	%	50± 2	49.5
Brightness	% ISO	89.5	86.5
Viscosity	cps	7.0	16.2
PC No.	no.	1.0	1.5



Depithing and pulping process using fresh banana pseudostem

Conclusions: From the overall results, it is concluded that banana pseudostem fibre can be a potential source of raw material in pulp and paper industry. This will not only resolve waste disposal problem of banana pseudostem, but farmers can realize additional income from this waste. Further, if not alternative, use of banana fibre as supplemental raw material in paper and pulp industry will reduce the tree cuttings activity. Banana pseudostem fibre gives higher pulp yield and brightness with less chemical consumption. This extracted fibre pulp seems suitable as a mix for preparing special grades of paper i.e., parchment, greaseproof, cheque and currency paper. However, the cost economics seems to be an area of concerned for its commercial use by paper industries. Fibre extraction cost from pseudostem is high due to manpower intensive which increases the pulp manufacturing cost. Further, efforts are required to reduce the cost of fibre from banana pseudostem through complete mechanization of the extraction process. Another option for cost reduction of fibre is to use fresh whole pseudostem for pulping. However, there is need to optimize the depithing parameters for fresh whole pseudostem.


Sheet preparing m/c at NAU, Navsari

Preparation of handmade papers and boards using fibre and their quality testing

Under NAIP, one handmade paper and board unit has been established at NAU, Navsari (capacity: 100 kg/day). In this unit, variety of paper and board (6 t) have been prepared using banana fibre, scutcher, cotton rags, waste paper and paddy straw in varying proportion. The quality parameters of these papers were tested at CIRCOT, Mumbai.

Mechanical properties of paper samples

Sample	G.S.M. (g/m^2)	Burst factor (kg/cm^2)	Tear factor ($mN.m^2/g$)	Breaking length (m)	Double fold (nos.)
Whole pseudostem tissue paper	14.0	28.6	699.9	3158	49
Banana fibre tissue paper	26.0	51.9	470.8	6259	845
Whole pseudostem paper sheet	74.4	30.9	219.3	4450	3220
Banana fibre paper sheet	86.3	44.0	198.4	5676	5440

The quality of paper prepared both at handmade as well as at laboratory scale was quite satisfactory when blended with banana fibre. It had excellent burst factor and folding properties.

Mechanical properties of paper samples

Raw materials used	G.S.M. (G/m^2)	Burst factor (kg/cm^2)	Breaking length (m)	Double fold (nos.)
Banana fibre (Yellow)	145	31.72	4140	5000
Banana fibre (Thick- White)	309	38.83	3117	3000
Banana fibre:Cotton rags (50:50) (Thick)	513	25.34	2321	1300
Banana fibre:Cotton rags (50:50) (Thin)	146	36.99	2604	300
Banana fibre + Cotton + Paddy straw (33.3: 33.3: 33.3)	335	19.10	2334	115
Banana fibre + Cotton Rags (colour)	335	20.90	1786	320

Summary of paper related work

Banana pseudostem fibre and scutcher waste were tried as a raw material for making pulp and quality papers. The processes have been optimized for preparing good quality pulp and high value paper like grease proof, cheque book etc., using fibre as raw material.

Though, from quality and pollution point of view, fibre is much better raw material than other material used for paper making, yet its high cost is major problem in making large scale use of fibre in paper industry. This problem needs to be addressed by using fibre as blending in certain proportion and/or by using whole fresh pseudostem for pulping by employing depithing technique. Of course, further research and development is required on this aspect.

However, fibre is an excellent raw material for preparing handmade paper and board at small scale/cottage industry level. This was found profitable even with 100 kg paper/day capacity handmade paper and board unit commissioned at NAU, Navsari

Scutcher Waste:
Standardization of process for preparing scutching waster based vermicompost and its use as organic manure

As organic manure

(A) Process standardization: While extracting fibre from banana pseudostem with raspador machine, fibre and scutcher + sap are obtained simultaneously. In general, from 1 ha banana plantation, about 40 to 50 tonnes fresh scutcher + sap is generated. On an average, one unit of five raspador machine can generate about 12 to 15 tonnes scutcher waste per day. The scutcher + sap generated during fibre extraction can be used either for preparing vermi-compost or for extracting sap. For standardizing the proportion of dung and scutcher waste to be used for preparing vermi-compost one trial was conducted. The results of the trial revealed that 70:30 scutcher: dung is good proportion in comparison to the 50:50 of other waste: dung used in preparing general vermicompost. Advantage of this ratio is that, it requires 20 per cent less dung which is in short supply.

(B) Study comparative performance of vermicompost vis-a-vis FYM and biocompost

(i) Title: Evaluation of pseudostem based vermi-compost vis-à-vis FYM and bio-compost in banana and sugarcane.

Methodology: Integrated use of FYM or biocompost with inorganic fertilizers is recommended for the crops like banana, sugarcane etc., so as to achieve the sustain productivity and maintain the soil health. However, these organics are not liberally available for application to these crops. In this project, it was envisaged to develop enriched vermicompost from pseudostem which can be a viable alternative of either FYM or biocompost. Accordingly, the field experiments were conducted during the year 2008-09 and 2009-10 evaluating the performance of different organics using banana and sugarcane as test crops. The experimental details are given here.

Banana		Sugarcane	
T_1 - FYM @ 5 kg/plant + RDF		T_1 - FYM @ 20 t/ha + RDF	
T_2 – Biocompost @ 3 kg/plant + RDF		T_2 – Biocompost @ 15 t/ha + RDF	
T_3 – Vermicompost @ 1.5 kg/ plant + RDF		T_3 - Vermicompost @ 5 t/ha + RDF	
T_4 – Vermicompost @ 3.0 kg/ plant + RDF		T_4 – Vermicompost @ 10 t/ha + RDF	
T_5 – Vermicompost @ 5.0 kg/ plant + RDF		T_5 – Vermicompost @ 15 t/ha + RDF	
T_6 - Only RDF (No organics)		T_6 - Only RDF (No organics)	
Other details			
RDF (NPK)	300 : 90 : 200 g/plant	RDF (NPK)	250: 125: 125 kg/ha
Design	Randomized Block Design	Design	Randomized Block Design
Replications	4	Replications	4

Crop yield: The pooled results related to fruit yield of banana and cane yield are depicted in figs.

Banana: The fruit yield of banana was affected significantly due to different manurial treatments. Among the treatments, T4 recorded conspicuously higher fruit yield of banana (71 t/ha) as compared to T6. However, it was at par with treatments T1, T3 and T5. The result of present study implies that banana pseudostem based vermi-compost is an economically viable alternative for the routinely used FYM and bio-compost (press mud based). Not only this, but the quantity of pseudostem based vermicompost required is only 3 kg/plant as against 5 kg/plant of FYM. This could be due to narrow C: N ratio of pseudostem based vermi-compost than FYM and bio-compost.

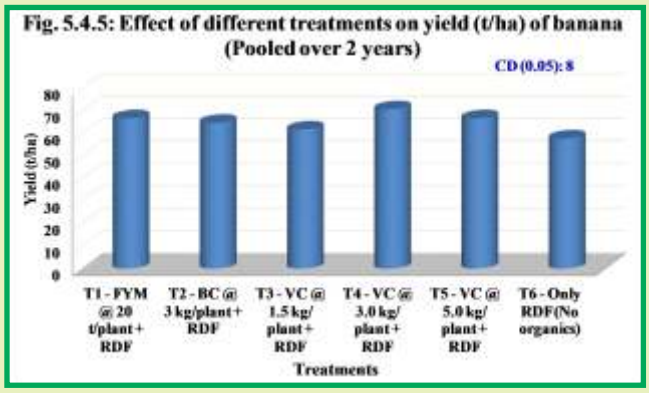
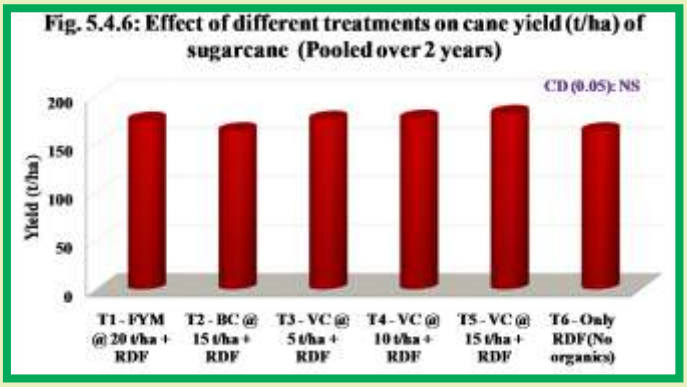


Fig. 5.4.5: Effect of different treatments on yield (t/ha) of banana (Pooled over 2 years)

Sugarcane: The cane yield recorded was not affected significantly by the treatments of different organics + RDF. However, numerically higher value of cane yield were recorded with T5 (181

t/ha), T4 (176 t/ha), T3 (175 t/ha) and T1¬ (174 t/ha) as compared to T2 (163 t/ha) and T6 (163 t/ha). These results clearly indicate that pseudostem based vermi-compost is comparable with FYM or bio-compost being used by the farmers.

Apart from increase in yield in banana and sugarcane, addition of organics viz. FYM, bio-compost and pseudostem based vermi-compost also maintains the soil fertility in terms of organic C, available P and K.



Conclusions: Based on the yield and economics, it is concluded that use of banana pseudostem based vermi-compost is techno-economically viable alternative for FYM or biocompost in heavy feeder crops like banana, sugarcane etc.

(ii) Experimental title: Evaluation of sources of organics in presence and absence of sap on yield of papaya under organic farming system

Methodology: Apart from use of scutcher based vermi-compost alone, it was attempted to study the effect of combined application of vermicompost and sap on yield of papaya on Certified Organic Farm during 2009-10 and 2010-11. In all eight treatments were evaluated in FRBD with three replications.

Results: The pooled results of fruit yield of papaya reported in table revealed that only main effects of Organics (O) and Sap (S) were significant. Among the organics, application of bio-compost, vermi-compost and castor cake in equal proportion recorded significantly higher yield of papaya in comparison to remaining treatments. Similarly, between two sap level, S1 (64.13 t/ha) recorded significantly more fruit yield than S0 (57.65 t/ha). From economics point of view, O4 and S2 showed superiority over other treatments.

Table: Effect of different treatments on papaya yield and income

Treatments	Fruit yield (t/ha)	Net income (Rs lakh/ha)	
		Normal price	Premium price
O_1= BC:CC (50:50)	52.3	1.33	3.94
O_2= BC:VC (50:50)	57.5	0.96	3.84
O_3= BC:VC:CC (50:25:25)	65.0	1.55	4.80
O_4= BC:VC:CC (33.3: 33.3: 33.3)	68.8	1.62	5.06
CD @ 5%	**2.7**	-	-
S_0= No sap	57.6	1.20	4.08
S_1= sap @8 l/plant	64.1	1.27	4.48
CD @ 5%	**2.0**	-	-

Conclusion: Based on the results of two years, it is concluded that pseudostem scutcher based vermi-compost is a good alternative source of organics in organic farming and it can reduce the cost of organics also through supplementation for castor cake. Similarly, sap application was found to be more remunerative than no sap application.

(C) Validation on farmers' fields: In view of encouraging effect of banana pseudostem scutcher based vermi-compost, in all 10 demonstrations were arranged on farmers' fields for validating the results of field experiment. The increase in yields of the crops viz., sugarcane, banana and papaya were 14-35, 7-19 and 8-14 per cent, respectively. The overall average increase in the yields of the crops due to use of scutching waste based vermicompost was 15.8 per cent over control i.e., farmers practice. This clearly validates the results of field experiment on farmers' fields in different crops.

As a fish feed

The banana pseudostem based vermicompost was also tested as a fish feed. Most of the farmers use cattle feed in fish culture in ponds, where the cost of this feed is high. In light of this, an experiment was planned to study the feasibility of using banana pseudostem based vermicompost as a fish feed by partially substituting the cattle feed. Before feeding, the vermicompost was pelleted on using a pelleting machine and dried in shade. The cattle feed was partially substituted by 10, 20 and 30 per cent by pelleted vermicompost. The results indicated that substitution of cattle feed up to 30 per cent with vermicompost not only reduced the cost of feed by 10 per cent but also increased body weight of fish.

Summary of scutching waste based vermicompost

The scutcher waste which is another by-product obtained during fibre extraction from pseudostem using raspador machine is easily degradable and found highly suitable for preparing good quality vermicompost. The main advantage of using scutcher is it requires less dung (30%) as against the 50 per cent in other crop residues used for preparing vermicompost. It was tested in banana, sugarcane and papaya and found that it is comparable with the routinely used organics like FYM, biocompost (sugar industry press mud based) etc. This is good alternative source of organic manure for the farmers which they can prepare on their on farms.

Further, scutcher based vemicomspost was pelleted and tested it as a fish feed. Substitution of cattle feed up to 30 per cent with vermicompost reduced the cost of feed by 10% and increased body weight of fish.

Sap:

Objective: Preparation and evaluation of enriched sap (Organic Liquid Fertilizer) and scutching waste based vermicompost

Banana pseudostem sap is obtained as a by-product during extraction of fibre. It is a rich source of plant nutrients like K, Fe and plant growth regulators. Hence, experiments were

conducted to use the sap directly as a liquid fertilizer initially in different crops through soil and foliar application. In response to its positive effect in enhancing the yields of the crops, enrichment process was standardized and tested in different crops at NAU, Navsari.


Screw press m/c for extracting sap from scutcher

Use of sap as a liquid fertilizer (without enrichment)

(A) Separation of sap from banana pseudostem scutcher: From the scutcher + sap collected in tray placed bellow raspador machine during fibre extraction, sap can be separated either by squeezing the scutcher manually or by using screw press developed by NAU, Navsari. Use of screw press is more efficient in sap separation from scutcher than manual squeezing. On an average, from one hectare banana plantation around 12000 to 15000 litres sap is obtained. In other words, one unit of five raspador machines can generate about 4000 to 5000 litres sap per day.

(B) Study on variation in composition of sap: For assessing the field wise variation in composition of sap in all 110 samples were analysed for plant nutrient and biochemcial parameters.

Table: Nutritional and biochemical composition of banana pseudostem sap (on fresh weight basis)

Parameter	Unit	Content (range)	Mean
N	%		0.015
P		0.002 – 0.007	0.0028
K		0.154 – 0.234	0.208
S		Trace – 0.004	0.002
Ca		0.004 – 0.020	0.014
Mg		0.014 – 0.101	0.048
Fe	ppm	2.57 – 38.17	10.72
Mn		2.66 – 19.34	9.78
Zn		Trace – 1.79	1.07
Cu		Trace – 4.30	0.98
Total soluble sugars	(mg/ml)	0.356 - 4.881	1.877
Total phenols		2.750 - 25.19	13.803
Total amino acids	(mg/ml)	0.022 - 0.232	0.129
Urease activity	(U/ml/min)	1.450 - 10.14	4.676
Cytokinin (mg/l)	(mg/l)	44.5	
Gibberellic acid	(mg/l)	13.7	

The range and mean values reported in table revealed that variation in the composition of sap vary with the element which is higher in N, Cu and biochemical parameters. Based on the mean value K, Fe, Zn and Mn are higher as compared to rest of the elements. Among the biochemical

parameters, phenol content recorded higher value in comparison to rest of the parameters. The sap also contains plant growth regulators in appreciable quantity.

(C) Response of different crops to application of sap: Considering the nutrient rich composition of sap it is suitable for direct use as liquid fertilizer. The work done during project period on this aspect is described here.

(i) Experiment title: Evaluation of banana pseudostem sap as a liquid fertilizer through drip in banana and sugarcane.

Methodology: An experiment was conducted at SWMRU farm, NAU, Navsari consecutively for two years (2008-09 and 2009-10) using banana (cv. Grand Naine) and sugarcane (cv. CoN. 5071) as test crops. In all following 9 treatment combinations were tested in FRBD with three replications in both the crops.

Banana		Sugarcane		Banana		Sugarcane	
Sap application (l/plant)		Sap application (l/ha)		RDF (%)		RDF (%)	
S_1	2	S_1	5000	F_1	60	F_1	60
S_2	3	S_2	10000	F_2	80	F_2	80
S_3	4	S_3	15000	F_3	100	F_3	100
Note: Sap was applied in 10 equal splits through drip in both the crops				*RDF 300: 90: 200 g NPK/plant*		*RDF 250: 125: 125 kg NPK/ha*	

Crop yields:

Banana: The two years pooled results showed that application of RDF @ 80 per cent along with sap @ 3 l/plant in 10 equal splits recorded significantly higher yield (70 t/ha) as compared to application of RDF alone. This could be attributed to the nutritional composition of sap along with plant growth regulators applied along with 80 per cent RDF to crop. This implies that 20 per cent RDF cost in banana can be saved that too with higher fruit yield. This treatment was also found more remunerative by recording B: C ratio of 2.0.

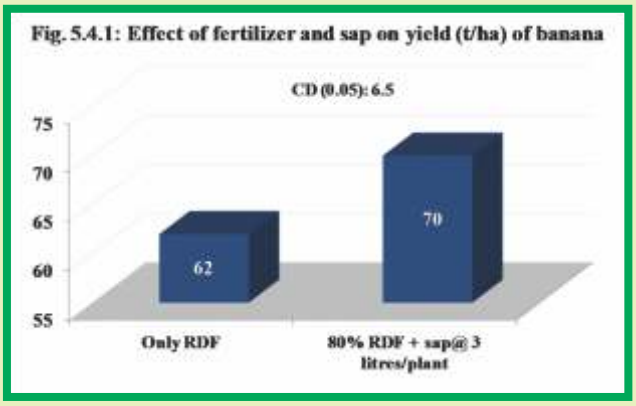


Fig. 5.4.1: Effect of fertilizer and sap on yield (t/ha) of banana

Sugarcane: In the case of sugarcane, the effect of different treatments was not significant on cane yield. This clearly suggests that application of sap @5000 l/ha in 10 equal splits + only 60% RDF (low input treatment) is good enough for getting relatively higher cane yield. Here, 40 % cost of RDF can be saved without significant reduction in cane yield.

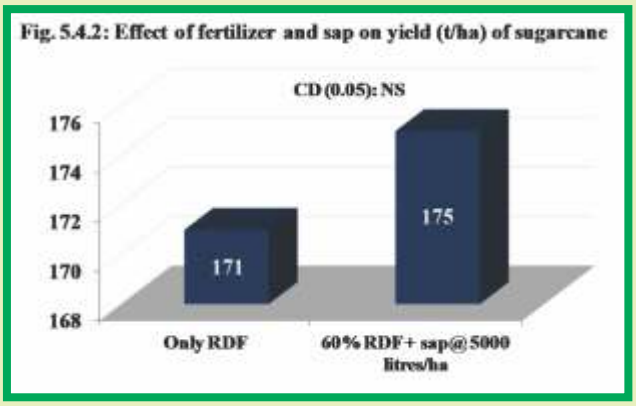


Fig. 5.4.2: Effect of fertilizer and sap on yield (t/ha) of sugarcane

(ii) Experiment title: Effect of sap application on yield of different crops

In addition to NAIP trials, 3 additional experiments were also conducted with onion, garlic and leafy vegetable crops. The magnitude of increase in yield was ranging from 67 per cent in onion to 4 per cent in leafy vegetable. Further, in the case of onion 20 per cent saving in recommended fertilizer dose and that on organic farm 50 per cent saving of castor cake in garlic was also observed. These treatments are also more remunerative than control.

Table: Effect of sap application on yield of different crops

Test crop	Yield		% increase over control	Method of application	Remark
	Control	Treatment			
Onion (Field)	28.75 t/ha	47.9 t/ha	67	Through drip @1500 l/ha in 5 equal splits	20% saving of fertilizer
Garlic (Field)	4.58 t/ha	6.54 t/ha	43	Through drip @2000 l/ha in 5 equal splits	50% saving of castor cake
Leafy vegetable (Amaranths& Spinach) (Poly house)	537 kg/100 sq m	559 kg/100 sq m	4	Drenching @2000 l/ha	-

Develop process for enrichment of sap and study responses by different crops

(A) Development of process for preparing enriched sap

(NAUROJI Novel Organic liquid fertilizer)

Enriched sap of banana pseudostem

Process: The banana pseudostem sap is collected by squeezing scutcher waste either manually or by press obtained during the process of fibre extraction. The sap obtained is to be filtered using muslin cloth for removing the suspended material. Mixing of different organic inputs and sap has to be done in sequential manner (Patent, PCTIB2012053268, 1609/ MUM/2011).
The whole mixture is then filled in bio-digester and incubated under anaerobic condition. The mixture is to be stirred periodically. After specified period the supernatant is to be collected, filtered and stored in air tight container.

(B) Composition of enriched sap: In order to know the variation in composition of sap during anaerobic decomposition, periodical samples were collected and analyzed for major and micronutrients content by adopting standard analytical procedures. The results indicated no variation in content except N, P, Fe and Mn which tended to increase with the time of incubation. Similarly, after completion of incubation, ready for use enriched sap (OLF: organic liquid fertilizer) was analyzed for nutrient, biochemical and microbial parameters. Based on the

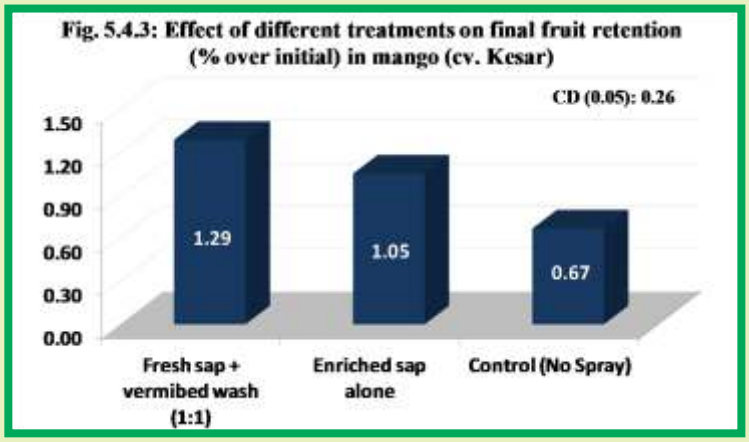
composition of enriched sap, it can be used as spray solution in different crops. It contains not only essential plant nutrient but also plant growth regulators viz. cytokinin and GA3 as well as some beneficial organisms.

Table: Composition of enriched sap ready to use

Chemical			Biochemical		
Parameters	**Unit**	**Mean**	**Parameters**	**Unit**	**Content**
N	%	0.062	Total phenol	mg/100 ml	48.0 – 49.1
P		0.018	Urease activity	U/ml/min	63 – 81
K		0.180	Gibberellic Acid	mg/l	110.2 – 205.0
Ca		0.031	Cytokinin	mg/l	137.8 – 244.3
Mg		0.092	**Microbe**	**Unit**	**Population**
S		0.010	Total viable count	(CFU/ml)	1065×10^3
Mn	ppm	5.73	PSB		1025×10^2
Cu		0.40	Rhizobium		285×10^2
Zn		2.92	Azotobacter		460×10^2
Fe		109.3	Fungal count		1200

(C) Response of different crops to application of OLF

(i) Experiment title: Effect of pseudostem sap and vermi bed wash on fruit setting in mango (cv. Kesar)



Methodology: As enriched sap contents GA_3 and cytokinin, it was thought to study the effect of its spraying on fruit retention in mango. A field experiment was conducted for two years (2009-10 and 2010-11) with seven treatments In all four sprays were done i.e., at flower initiation, 15 days after first spray and rest two subsequently at 10 days interval. All the solutions were sprayed @ 5 per cent (v/v).

Results: The pooled results related to per cent retention of mango fruits were affected significantly due to different spray solutions Among the treatments, treatments receiving four sprays of enriched sap alone (1.054 %), sap + vermi-wash in 1:1 ratio (1.291 %) were significantly more than control (0.67 %). It means depending on availability and economics, farmers can use enriched sap or sap + vermi-wash for increasing the fruit retention in mango.

Conclusion: Spraying of sap + vermi-wash or enriched sap four times can increase the fruit retention and ultimately the fruit yield considerably. This was also validated on farmers' fields through large scale demonstrations.

(ii) Experiment title: Evaluation of sap based products on vigour of vegetable nursery.

Methodology: An experiment was conducted in polyhouse for two seasons during 2009. The vegetable crops tested in the experiments were brinjal (cv., Surati Ravaiya) and chillies (cv. Suryarekha) with seven different treatments in RBD with 4 replications under poly house condition. In all the treatments, concentration of spray solution was 1 % (v/v). Such five sprays were applied at an interval of 4 days starting from two fully open leaves stage.

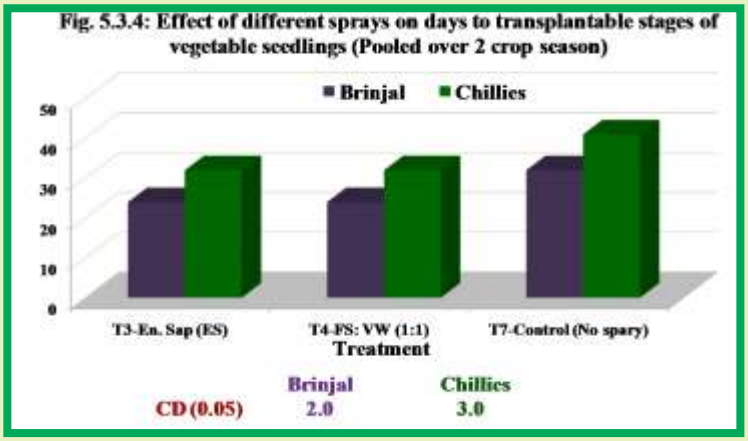


Fig. 5.3.4: Effect of different sprays on days to transplantable stages of vegetable seedlings (Pooled over 2 crop season)

Results: The two seasons pooled results clearly indicated that four sprays of either enriched sap or sap + vermi-wash (1:1) improved the vigour of brinjal and chillies seedlings and there by the seedlings are attaining transplantable stage 8 to 9 days earlier as compared to control (Fig. 2.4.4).

Conclusion: Spraying enriched sap or sap + vermi-wash could save about 8 days time of the nurserymen. This reduces the cost of seedling production as well as facilitates timely transplanting of the crops.

(iii) Experiment title: Effect of application of enriched sap (OLF) on yield of different crops

The enriched sap was also tested in field experiment other than NAIP trials. The enriched sap being costlier than sap, it was tested as a foliar spray in different crops. The results revealed that an increase in pod yield of summer vegetable crops viz., okra, cluster bean and cowpea was 31, 30 and 20 per cent, respectively. In case of banana, an increase in fruit yield was 23 per cent and that in cereals the increase was around 11 per cent. The wheat and paddy crops were grown on certified organic farm. It means that the enriched sap can be used in organic farming system also. This has special significance in organic farming, as this nutrient solution being suitable for organic farming which is very scanty in the market.

Table: Effect of application of enriched sap (Organic Liquid Fertilizer) on yield of different crops

Crops	Type of experiment (Design)	Total no. of treatment	Season / year	Yield (t/ha)		Method of application	% increase over control
				Control	Treatment		
Okra (S)	Field (RBD)	5	1	1.34	1.76	4 foliar sprays @ 1 or 2 % (v/v)	31
Cluster bean (S)	Field (RBD)	5	1	1.59	2.07		30
Cowpea (S)	Field (RBD)	5	1	1.39	1.67		20
Banana	Field (CRD)	21	3	81	100	Cone feeding @120 ml/plant in 3 splits	23
Wheat	Organic farm Field (RBD)	13	2	2.15	2.42	3 foliar sprays @1% (v/v)	13
Paddy	Organic farm field (RBD)	13	2	3.73	4.05		9

Use of sap as a mordant in textile dyeing

Apart from use of sap directly or after enrichment as a organic liquid fertilizer, it was also tested for its use as a mordant in textile dyeing. The process for this was tested on laboratory scale at CIRCOT, Mumbai. Sap was applied to cotton fabric by padding in a padding mangle to 80% wet pick up air dried and treated with 10% alum solution in alkaline condition. Mordanted samples were dyed with manjisth (20% owf) and annatto (7.5% owf). Colour parameters and fastner properties are presented in tables 2.4.5 and 2.4.6, respectively. The natural dyes like manjistha and bixa were tested for its fastening properties using fresh banana pseudostem sap. The test results indicated very good fastening with manjistha dye along sap.

Table: Colour parameters of dyed cotton fabric

SN	Dye Used	K/S at max	max (nm)	L	a	B	c	H
1.	Manjistha	2.33	500	58.30	27.95	13.24	30.92	25.35
2.	Annatto	4.34	470	69.73	29.36	52.25	59.94	60.66

Table: Fastness properties of dyed cotton fabric

Dyed Used	Fastness to Light	Fastness to Washing	
		Colour Change	Staining Cotton/Wool
Manjistha	2-3	4-5	4-5 / 5
Annatto	2	3-4	3-4 / 5

Interpretation: Colour obtained was darker and uniform. Wash fastness was found to be very good for manjistha and satisfactory for annatto but light fastness needs improvement.

Summary of pseudostem sap and its uses

Organic liquid fertilizer:

The liquid portion sap obtained along with scutcher during fibre extraction from pseudostem by raspador machine is good source of plant nutrient along with growth promoting substances like cytokine, GA_3, etc. If used as liquid fertilizer either through drip system or drenching in crops like banana, sugarcane, papaya, onion, leafy vegetable, it can save 20 to 40 per cent dose of fertilizer with yield advantage of 10-15 per cent. This can be directly adopted by the farmers themselves.

Apart from direct use of sap as liquid fertilizer, an enrichment process was developed (patented) for preparing Novel Organic Liquid Fertilizer (OLF) suitable for foliar and soil application. It was tested in mango, banana, wheat and paddy crops. Application of 3 – 4 sprays of OLF @ 1 to 2 % (v/v), could increase the yield by 12 to 15 per cent across the crops. The OLF has been prepared using only organic inputs and hence suitable for use in organic farming system as liquid formulation. Looking to the techno-economic viability, five parties have signed MoU with NAU for OLF production and marketing on commercial scale.

Sap as a mordant in textile dyeing:

Use of sap as mordant has twine advantages i.e., improves colour fastness and being natural product it is not hazardous to the environment.

Central Core:

Objective: Develop value added edible products from central core

Standardize of process for preparing candy and testing its quality parameters

Process: Central core is inner most tender portion of the pseudostem which is edible. It is a by-product obtained from banana pseudostem during the process of fibre extraction. About 10 to 12 tonnes of central core can be obtained from one hectare banana plantation. Since no such product made from banana pseudostem central core is existing in the market, NAU has standardized processes for developing various edible products from it.

Quality parameters: After processing of central core into candy it becomes delicious and palatable which is prefered by people and especially children. The product was tested at CFTRI, Mysore and SICART, Anand for its quality. It is found to contain digestible fibres, Iron, Vitamins B_3 and B_5 in appreciable amount.

Table: Quality parameters of candy prepared from central core

Parameters	Unit	Content	Parameters	Unit	Content
Protein	%	4.1	K	%	0.20
Carbohydrates	mg/100 g	46.8	Na	%	0.42
Calorific value	k.cals/100 g	390	Ca	%	1.37
Total sugars	%	85.4	Mg	%	2.22
Total Dietary fibre	%	3.95	Fe	mg/kg	643
Vitamin (Pantothenic acid B_5)	(mg/100g)	86.4	Vitamin (Niacin B_3)	(mg/100g)	34.1

It is a potential product for commercialization by the food and cottage industry. It has opened doors for institutional suppliers like Govt's mid day meal scheme and nutrition improvement programs of UNDP and WHO. If adopted by SHGs, Mahila Mandals etc., it will uplift rural women and boost women empowerment ultimately leading gender mainstreaming. Hence, this business can be a very profitable and lucrative. Patent has been filed at National level (1624/MUM/2011) as "A novel process for manufacturing banana candy from banana pseudostem".

Standardize process for preparing Ready to Serve Drink

The soft drinks are prepared from sugar syrup left out during candy preparation as well as directly from central core sap. The drinks prepared are fortified with flavours for which standardization has been done by NAU. Large quantity of sugar syrup generated during processing of banana central core candy is generally considered as waste material. The left out syrup, with 70o brix was flavored either artificially or naturally to improve its overall acceptability. The concentrated syrup is heated to 85ºC for 25 min followed by immediate cooling to room temperature. The prepared RTS drink is filled into pre-sterilized glass bottles and then hermitically sealed by crown corking machine. The bottles can be stored at ambient temperature for 6 month.

RTS from sap of central core

Conclusion: Based on the quality as well as sensory parameters, banana pseudostem central core can be processed into delicious candy and RTS which are good sources of potassium, iron and digestible fibres. As central core is tasteless, it can be flavored using any artificial as well as natural flavor and can have good economical value to small and medium scale entrepreneurs. The central core seems to cheaper alternative raw material for confectionary industry.

Summary of edible products developed from central core

The central core of banana pseudostem is a edible portion. The process for preparing candy using central core has been standardized. The candy so obtained in rich source of K, Fe and content vitamins B_3 and B_5 in appreciable quantity. A pilot scale production is being done at NAU and it was found to be profitable. This technology was also grouped under "ready for commercialization category" by national committee of NAIP. The syrup (70% brix) obtained as by product during candy preparation can be used for preparing RTS drink in various flavours. This technology is also most suitable for cottage or small scale industry. Here the cost of raw material i.e., central core is negligible.

Innovations

In the project proposal, six innovations were proposed. However, during the project period, additional three innovations pertinent to the objectives of the project were also attempted. The status of all the innovations is mentioned here.

SN	Innovations	Brief information about innovations	Remarks
(A)	**Proposed innovations**		
1.	Garments from banana fibre	Using the yarn obtained from jute spinning system, garments like apron, coat, cap, curtains *etc*., were prepared and quality parameters were tested.	Laboratory scale
2.	Nanotechnology for improving fibre quality	Banana fibre being the strongest among the natural fibres and hence, it was not attempted.	--
3.	Mircrocrystalline cellulose (MCC) from banana fibre	The processes *viz*., chemical and biological routes were standardized. The quality of MCC was found comparable with that of commercially available pharmaceutical grade MCC in the market.	Laboratory scale
4.	Sap as a mordant in textile dyeing	Process for use of sap as a mordant was standardized and the results are encouraging. Sap can be used as a natural mordant in textile dyeing.	Laboratory scale
5.	Edible products from central core	The processes for preparing candy and RTS have been standardized. The candy is nutritionally rich and central core is cheaper material.	Pilot scale production unit at NAU, Navsari

6.	Sap as a liquid fertilizer	Tested in heavy feeder crops like banana, sugarcane, papaya, onion *etc.* Application of sap through drip or drenching can save up to 20 per cent cost of the RDF with add ed yield and quality advantages.	Tested on farmers' fields

(B)	**Additional innovations**		
1.	Enrichment of sap for preparing Organic Liquid Fertilizer (NAUROJI Novel Organic Liquid Fertilizer)	Developed process for enrichment of sap and tested in differen t crops. Foliar application of OLF could increase crop yield by 12 to 15 per cent. It can be used in organic farming also.	Five parties have signed MoU for production and marketing at commercial scale. Patented in four countries other than India.
2.	Non-woven fabric using banana fibre	Using needle punching technique, non -woven fabrics of different GSM were prepared in an industrial trial. Some end users products were prepapred. This has advantages over the non -woven fabrics prepared using other fibres.	Ready for commercialization
3.	Medalari *charkha*	CIRCOT- Phoenix *Charkha* for spinning banana fibres into good quality yarn has been developed.	This is a very good technology capable of generating employment in tribal and rural areas. 10 units supplied to NE Hilly Region Research Complex, ICAR, Barapani (Meghalaya)

Process/ Product/Technology Developed

S. No.	(Process/Product/Technology Developed	Adoption/ Validation/ Commercialization, *etc.*	Responsible Partner
1.	**Fibre**		
1.1	Standardized process for efficient fibre extraction through development of pseudostem cutter and suitable modification in raspador m/c.	Adopted by morethan 100 farmers. Extracted about 100 tonnes of dry fibre (5 t at NAU)	NAU, Navsari & CIRCOT, Mumbai

1.2	Process for preparing yarn and woven and non-woven fabric/ products using banana fibre	Processed and prepared 350 meters of woven fabric and 3.1 tonnes of non-woven fabric at industrial scale (Jute mills, Kolkata). Processes standardized for preparing different quality fabrics.	CIRCOT, Mumbai, MANTRA, Surat and NAU, Navsari
1.3	Process standardized for preparing quality papers from banana fibre	Pulping and bleaching process standardized for making grease proof and cheque papers from banana fibre.	JK Paper, Songadh
	Handmade paper and board	From handmade paper and board various stationary items were prepared and marketed within the university.	NAU, Navsari and CIRCOT, Mumbai
2.	**Scutcher**		
2.1.	Preparation of scutching waste based vermicompost from one acre unit	About 1000 tonnes of vermicompost harvested 70% scutching waste and 30% cow dung was found to be ideal from nutrient point of view.	NAU, Navsari
	Quality tested and evaluated as manure as compared to other organics (FYM & Biocompost).	Evaluated in sugarcane, banana and papaya for 2 years and recommended to the farmers. Demonstrated on 12 farmers' fields as well.	
2.2	Pelleted vermicompost also tested as fish feed.	Substitution of cattle feed up to 30 per cent with vermicompost reduced the cost of feed by 10% and increased body weight of fish.	
3.	**Sap**		
3.1.	Process developed for preparing organic liquid fertilizer from banana pseudostem sap	Tested in different crops (sugarcane, banana, papaya, onion, wheat, paddy, vegetable nurseries and mango for fruit setting) and found to improve yield (10 to 15 %) and quality of produce. Demonstrated on 12 farmers' fields through drip and 107 as spray in mango for fruit retention. Produced about 50000 litres of enriched sap. International patent filed in 5 countries MoU signed with five parties.	NAU, Navsari
4.	**Central core**		
4.1	Processes standardized for prepapring edible products like candy and RTS from central core	Candy has been tested in reputed testing centres (CFTRI, Mysore and SICART, Anand) for its quality. It found to contain vitamins (B_3 and B_5) along with good amount of Fe. The product has shown good level of acceptability which are being sold by the University during mega events like *Krishi Mahotsav* and farmers day organized by GoG and the University. These products are also marketed by banana cooperatives.	NAU, Navsari

Patents (Filed/Granted)

S. No.	Title of Patent	Inventor(s) (Name & Address)	Filed/Published/Granted (No./Date)	Responsible Partner
1.	A Novel Process for Manufacturing Banana Candy from Banana Pseudostem.	Dr. C. S. Desai, Parag Pandit, K. K. Patel, Dr. S.K. Desai, Dr. B. N. Kolambe, Dr. R. G. Patil, NAU, Navsari	Filed 1624/MUM/2011 1st June 2011	NAU, Navsari
2.	A Novel Organic Fertilizer of Banana Pseudostem.	Dr. B. N. Kolambe, K. K. Patel, S. L. Pawar, Dr. J. M. Patel, Dr. D. R. Prajapati, Dr.C.S. Desai, H.B. Vaidya, Dr. R. G. Patil NAU, Navsari	Filed at International level PCT/IB2012/ 053268 28th June 2012 Country specific patents filed in Philippines, Brazil, Indonesia & Mexico	NAU, Navsari
3.	A Novel Machine for Extracting Fibre from Banana Pseudostem Sheaths' has been filed.	Dr. R. P. Nachane Er. N. G. Savani Dr. R. G. Patil Dr. B. N. Kolambe NAU, Navsari & CIRCOT, Mumbai	Filed 1590/MUM/2011 30th May 2011	NAU, Navsari & CIRCOT, Mumbai
4.	Multi Sheath Feeder to Raspador Fibre Extractor	Dr. R. P. Nachane CIRCOT, Mumbai	Filed 901/MUM/2010	CIRCOT, Mumbai
5.	An Attachment to *Medhlari Charkha*	Dr. R. P. Nachane, CIRCOT, Mumbai Dr. J. M. Patel, NAU, Navsari	Filed 1371/MUM/2008	CIRCOT, Mumbai
6.	Pedal Driven Banana Fibre Spinning System	Dr. R. P. Nachane Mr. Vivekanandan, CIRCOT ,Mumbai	Filed 1554/MUM/2012	CIRCOT, Mumbai
7.	Banana Pseudostem Fibre Drawing Machine	Dr. R. P. Nachane, Dr. N. Shanmugam, CIRCOT, Mumbai	Filed 3464/MUM/2012	CIRCOT, Mumbai
8.	Banana Pseudostem Fibre Carding Machine	Dr. R. P. Nachane, Dr. N. Shanmugam, CIRCOT, Mumbai	Filed 3465/MUM/2012	CIRCOT, Mumbai
9.	Banana Pseudostem Fibre Ring Spinning Machine	Dr. R. P. Nachane, Dr. N. Shanmugam, CIRCOT, Mumbai	Filed 3467/MUM/2012	CIRCOT, Mumbai

Status on Environmental and Social Safeguard Framework

Environmental			Social		
Positive benefits	**Negative benefits**	**Mitigation measures for -ve effects**	**Positive benefits**	**Negative benefits**	**Mitigation measures for -ve effects**
NAU - Navsari					
Utilization of pseudostem for fibre **(+ 4)**	--	--	Employment generation in rural areas **(+ 4)** Disposal of pseudostem in eco-friendly way	--	--
Partial substitution in chemical fertilizer by using scutching waste based vermicompost and sap as liquid fertilizer **(+ 4)**	--	--	Alternative organic source and improves soil health **(+4)** Organic product Increases crop yield	--	--
Partial substitution of cattle feed with vermicompost as a fish feed **(+ 4)**	--	--	It can reduce the cost of fish feed without any decline in fish production **(+ 4)**	--	--
Use of central core for edible product **(+ 4)**	--	--	Candy prepared tested in referral labs and has found to contain minerals and vitamins (B_3 & B_5) **(+ 4)**	--	--
Handmade paper and board **(NAU)**	Generation of effluent **(-2)**	Use of effluent treatment plant	Recycling of paper waste and scutcher and farm waste (crop) for paper making Employment generation **(+3)**	--	--
Quality paper at industrial scale **(JK Paper)** Alternative raw material can be blended or used as such for preparing quality grade papers (anti grease, Magnetic Ink Character Recognition (MICR) paper **(+2)**	Generation of effluent **(-2)**	Has well established modern effluent treatment plant. Further, effluent characterization studies have shown that compared to presently used raw materials like wood, bagasse *etc.*) in paper industry, pulp of banana fibre requires less chemicals and cooking temperature.	--	--	--

CIRCOT, Mumbai					
--	Generation of dust while making yarn from fibres on large scale **(-2)**	Workers will be provided with protective mask	Employment generation as large scale yarn will be produced from fibres **(+2)**	--	--
Eco-friendly mordant for natural dyes (Obj.: Sap as mordant) **(+4)**	--	--	Eco-friendly mordant for natural dyes **(+2)**	--	--
--	Renewable raw material (Obj.: Microcrystalline cellulose from fibres) **-(2)**	The BOD and COD levels are very low and ETP will take care Only laboratory scale study was conducted	Renewable raw material **(+2)**	--	--

Constraints, if any and Remedial Measures Taken

A) During project implementation period

SN	Constraints	Remedial measures
1.	Electric power supply available at farmers' fields for irrigation purpose and cannot be used for running raspador machine.	- On request by University and farmers, Gujarat Electricity Board permitted on case by case basis - We made additional attachment to raspador machine to make it suitable to operate on power tiller or oil engine
2.	Obtained poor quality yarn prepared on jute spinning system from banana fibre	- Special yarn machines fabricated for spinning banana fibre. - Prepared non-woven fabric on industrial scale, where yarn preparation is not required - Developed CIRCOT-Phoenix modified *medhlari charkha* for spinning banana fibre to good quality yarn.
3.	High transport cost as jute spnning mills are available in Kolkata (WB)	- There is need to establish pilot scale unit for spinning and weaving of banana fibre in the areas where banana is cultivated on large scale.
4.	Excess availability of pseudostem during peak period of banana harvesting	- Pseudostem can be retained on fields for a period of 30-40 days if leaves are not removed after harvesting of bunch.

B) After project period

SN	Constraints	Remedial measures
1.	Lack of assured market demand for small quantity, but sporadic/ occasional demand in bulk quantity is there for banana fibre	- Encouraging cluster based approach for fibre extraction so as to obtain fibres in bulk quantity. Here Banana Cooperatives / small entrepreneurs will act as a facilitator between industry and banana growers
2.	Labour shortage for fibre extraction work during peak periods of agricultural operations	- There is need to increase mechanization in fibre extraction through involving experts from Univ./ ICARinstitute/ hiring professionals.
3.	High cost of fibre	- Suggesting business model comprising fibre extraction, vermicompost preparation and use of sap as liquid fertilizer which has potential to reduce cost of fibre. - We are encouraging the parties who have signed MoU for production and marketing of Organic Liquid Fertilizer on commercial scale to sell fibre @ Rs.50/kg instead of Rs.100/kg fibre. - Selling fibre at lower rate will create huge market demand in paper industry, handicraft unit, non-woven industry *etc.*

Possible Future Line of Work

Fibre extraction

At present about 25 to 30 kg of dry fibre can be extracted on one raspador machine per day in a shift of 8 hours. Considering the labour cost, asset value, overheads (electricity, water) etc., cost of extraction of fibres on farmers' fields is approximately Rs.60/ kg. It means if fibres are to be sold in the market with some profit margin, cost of dry fibre per kg cannot be less than Rs.70. Since the fibre is similar to jute fibres and can be used to produce items which are normally produced using jute fibres, it is expected that cost of banana pseudostem fibres should be comparable to that of jute fibres. The present cost of jute fibres is about Rs.30 to 35 per kg. In view of this constraint if fibre extraction from banana pseudostem has to become commercial venture, cost of production has to be considerably reduced. This may be possible by modification of raspador to get more fibre output keeping all the requirements for extraction same, such as labour, cost of electricity etc. Two attempts tried under the project viz., multisheath feeder for raspador and direct sheath feeding appears promising but requires more research in that direction.

Yarn quality improvement

Under the project yarn was prepared using two different approaches, one was yarn spinning on newly developed CIRCOT Phoenix charkha and the second was using spinning assembly developed at CIRCOT.

First approach is peddle operated and requires feeding of fibres by hand. It has been possible to spin finner and more uniform yarn of reduced hairiness. However, the quality of this yarn and quantity produced depends mainly on the expertise developed by the artisan who is spinning yarn on this charkha. It is expected that more and more person start using it and develop expertise which can then be passed on to as many interested persons as possible.

In the other attempt to produce yarn on industrial scale, machineries have been developed consisting of treatment for softening, staple cutting, carding, gill drawing and spinning. Carding machine has been further modified with increasing the number of pins for improving fibre separation and removal of nonfibrous materials. Sliver prepapred is also introduced with a small twist to hold fibres together. Spinning assembly has been further modified to control speed of feeder rollers, draw ratio and twist introduced. This has resulted in improvement in the production of yarn on yarn making assembly. At present yarn of 1's cotton count can be produced. But it is envisaged that after adjusting the spinning parameters one will be able to get yarn of up to 4's cotton count. However, many more trials are required to be conducted varying different parameters in the assembly lines to optimize spinning conditions for better quality yarn. One of the important requirements in machine spinning of these fibres is process of softening of fibres to make them more pliable for spinning. During the project work it was observed that use of rice bran oil (RBO) as softener gave better results as compared to that of Jute Batch Oil (JBO). Also piling fibres after softening treatment for 72 hours seemed to be better than that for 48 hours. But many more softening agents can be tried to get better results. Different staple lengths of fibres can also be studied for optimization. Once good quality yarn is produced weaving it into fabric is easily possible on handlooms. Depending on the quality of yarn it may be even possible to use it on powerlooms for high productivity.

In the initial stages of the project fibre extraction was considered as the main activity. To enthuse farmers to extract fibres from banana pseudostem they were promised that all the fibres extracted by them would be purchased by the project. To work out cost of extraction of fibres, the entire cost of extraction was considered for recovery from sale of fibres only. But during extraction other byproducts of value are also available such as scutcher waste, sap and central core. Each of these can be utilized for preparation of value added products. For e.g., scutcher waste can be used for preparation of vermicompost. Sap can be used as it is, as liquid fertilizer or can be converted into enriched sap using the technology developed. It can be sold as Novel Organic Liquid Fertilizer of high value. If income from these products is also considered, the cost of fibres can be brought on par with that of jute fibres.

Replacement of imported pulp with banana fibre pulp for cheque paper making

As had been mentioned under item (Exploring possibility of preparing speciality papers) in the book, quality of cheque paper (MICR) from banana fibre pulp was found to be much better than that prepared using imported pulp. Here for comparison both imported and banana fibre pulp was used to the same proportion with respect to CPM pulp. At this level (30%) of use of banana fibre pulp the cost of cheque paper will be higher as compared to that being produced using imported pulp, but it may be noted that there is scope to reduce percentage of banana fibre pulp may be to 20 per cent or even 10 per cent and still get the paper qualities comparable to the normally produced cheque paper. This optimization of use of banana fibre pulp will be able to reduce the cost of cheque paper to the present level or even less.

NAU, Navsari

1. Adoption of cluster based approach for fibre extraction and holistic way i.e., prepare more number of products rather than concentrating on one product only.
2. Increase the fibre output efficiency of existing raspador machines, for reducing the cost of extracting fibre.
3. Creating awareness among different stakeholders' through trainings and workshop.

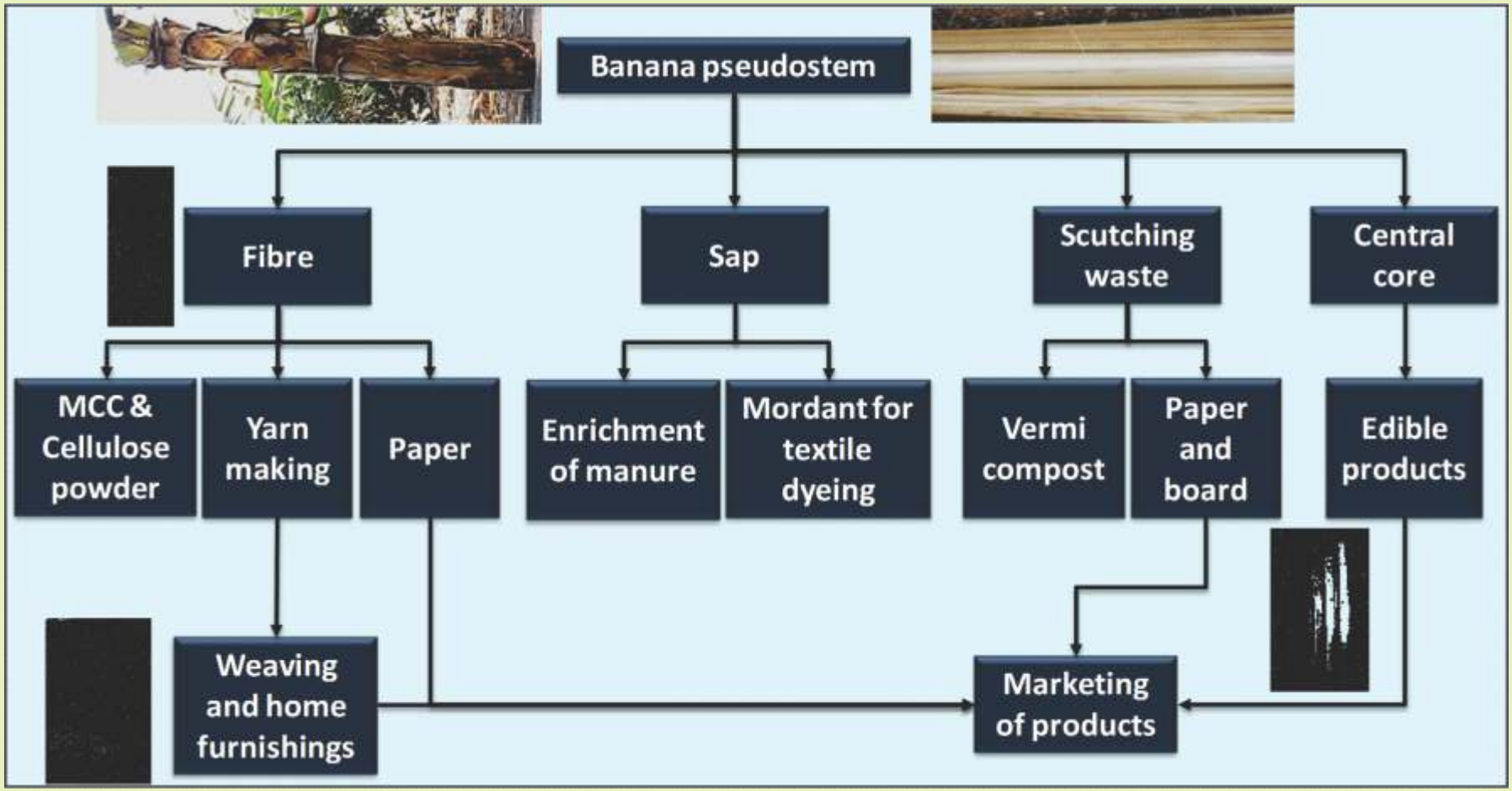
CIRCOT, Mumbai

1. Preparation of Composites and development of its products
2. Use of yarn Knotters and development of hi-value shirtings
3. Study the efficacy of banana MCC in pharmaceutical industry
4. Preparation of finer count yarn in banana spinning machinery
5. Development of Automatic feeder for CIRCOT-Pheonix Charkha

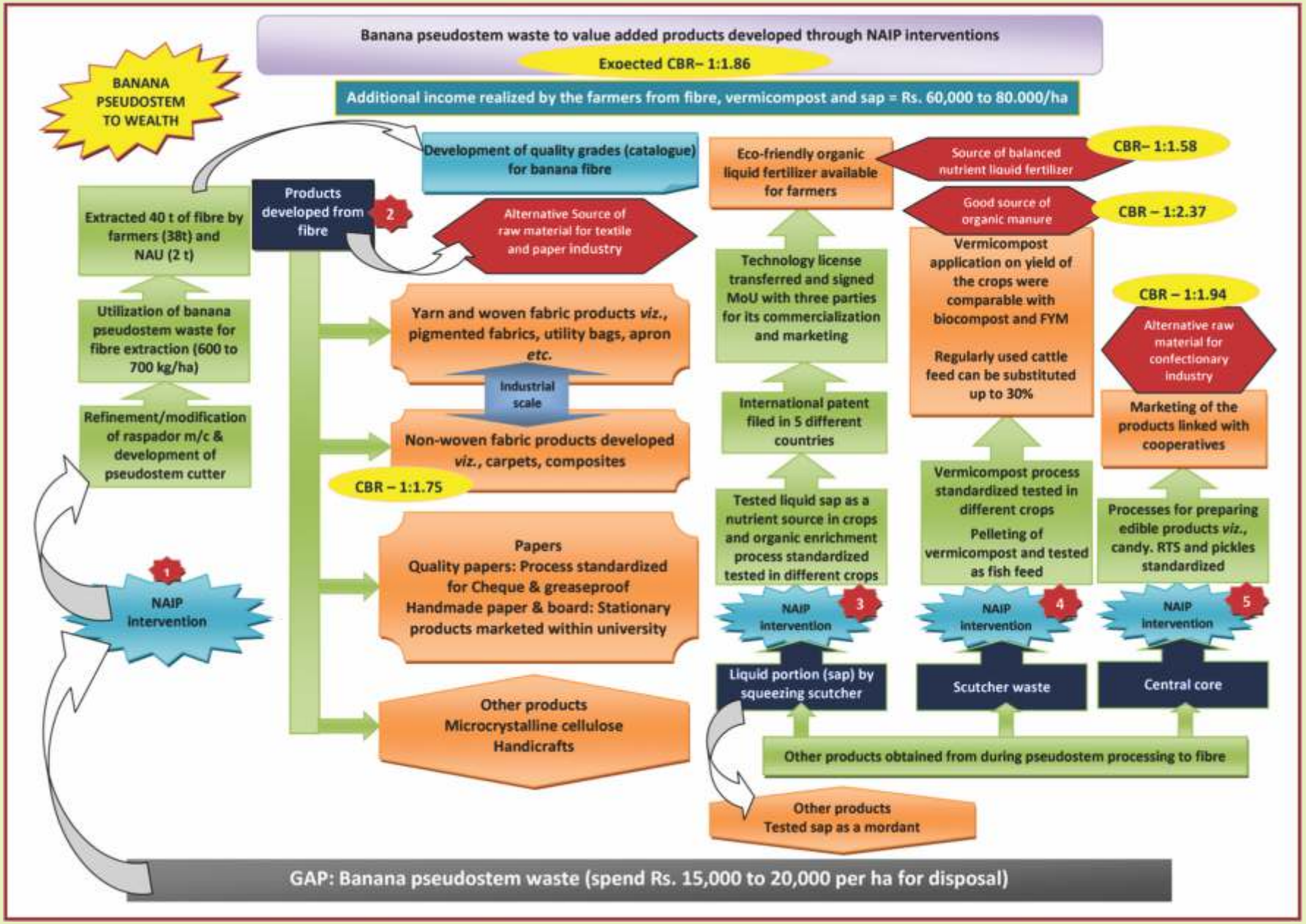
Value chain analysis

Based on the baseline survey, it can be stated that before the start of the project there was no value chain existing as far as utilization of banana pseudostem is concerned. A very small quantity of fibre was being extracted and is even now extracted by hand scrapping mostly in southern part of the country. This may not be even more than 10 tonnes per annum. All these fibre is used for preparation of handicrafts mostly for the foreign tourist market. Proposed value chain at the beginning of the project is as given below.

Proposed value chain flow chart



Flow chart of the value chain after NAIP interventions



CHAPTER 4
BUSINESS MODELS

In India, about 7.76 lakh ha area is under banana crop with the total fruit production of 26.5 million MT contributing 14.7 per cent of global production (Anon., 2013-14). In India, the area under banana is increasing steadily because of higher return as compared to other crops. Apart from fruit, banana crop also generate huge quantity of biomass in the form of pseudostem, leaves, suckers etc. At present, this biomass particularly pseudostem is absolute waste in most of the states of India. Not only this, but for disposing pseudostem presently farmers are spending about Rs. 15,000 to 20,000/ha. Disposal of pseudostem in a routine ways i.e., dumping on field bunds and burning, disposing in nalla/ natural drains etc., causes environmental problems. In order to develop different products from the banana pseudostem a World Bank funded project entitled, "A Value Chain on Utilization of Banana Pseudostem for Fibre and Other Value Added Products" was sanctioned by NAIP (ICAR) under Component 2 in a consortium mode with Navsari Agricultural University, Navsari as lead centre and Central Institute of Research on Cotton Technology, ICAR (CIRCOT, Mumbai), Manmade Textile Research Association (MANTRA, Surat) and JK Paper Ltd. (Songadh).

As envisaged in the project, the products viz., woven and non-woven fabrics, handmade papers, high value papers, handicrafts and microcrystalline cellulose (pharmaceutical grade) using banana fibre, enriched sap (organic liquid fertilizer – patented), mordant from sap, vermicompost, handmade paper from scutcher and edible products (candy, RTS, pickles) from central core were developed and/or processes standardized. Out of these products, three technologies i.e., (1) Extraction of fibre from banana pseudostem and preparation of non-woven fabrics; (2) Preparation of organic liquid fertilizer from sap and (3) Preparation of candy from central core of banana pseudostem were identified as the technologies ready for commercialization. In present publication, an attempt has been made to analyze the pre and post project scenarios with the help of result framework and business models prepared for the technologies ready for commercialization are described briefly.

Analysis

Sustainability 	- Assured market demand and supply of fibre	- Management of scutcher waste in eco-friendly way and availability of good quality organic manure	- Banana pseudostem sap waste converted into Organic liquid fertilizer which are available for the farmers'	- Suitable for small and medium scale entrepreneurs - Disposal problem solve
Impact 	- Farmers can realize an additional income of Rs. 25,000 to 30,000/ha through fibre extraction - Use of pseudostem in eco-friendly way	- Farmers' can prepare and sale/use them self - Alternative organic manure available for crops production - Improvement soil health (saves 20% chemical fertilizer)	- Increase in yield 10-15 per cent - Three parties sign MoU for production and marketing on commercial scale	- Cheaper and ample available raw material for confectionery industries
Outcome 	- Availability of natural raw material for textile/paper/pharmaceutical industries/ handicrafts	- Waste utilization in profitable way - Alternative source for organic manures (FYM & Bio-compost) - Good supplement for fish feed	- Saving in chemical fertilizer requirement - Enrichment technology patented and ready for commercialization - Sap can be use as mordent	- Process for candy and RTS standardize - Contain Fe and vitamin B_3/B_5 - RTS from left-out syrup obtained during candy preparation
Intervention 	- Extraction of fibre using modified raspador m/c - Developing different products from fibre	- Preparing good quality vermicompost - Vermicompost as fish feed	- Use as liquid fertilizer (as such or after enrichment) - Use as natural dye in textile dying	- Process standardization for preparing edible products
Reasons 	- Dumping and burning of pseudostem on field bunds, *nallas* and road side causing environmental problems - Spending Rs.15000 to 20000/ha for disposal or cleaning their field	- Scutcher- 30-35 t/ha	- Sap- 15000-20000 l/ha	- Central core- 8-10 t/ha
Issues	- Banana pseudostem is absolute waste	Disposal of scutching waste + sap and central core obtained during pseudostem processing		

Some statistics:

- Pseudostem availability – 60 to 80 tonnes/ ha
- Area under banana cultivation – 8 lakh ha
- Total pseudostem availability in the country – 64 million tonnes
- Fibre availability – 6.4 lakh tonnes (0.64 million tonnes)
- Sap availability – 14 million tonnes, i.e., 14 billion litres
- Scutcher waste – 21 million tonnes
- Central core – 7 million tonnes

It may be noted that value of the raw material viz., fibre (Rs.30/kg), sap (Rs.1/litre), scutcher waste (Rs.0.50/kg) and central core (Rs.1/kg) will be approximately Rs. 5150 crorers. With value addition this may become manifold. For extraction alone, one unit of five raspadors requires at least 30 persons. The unit can produce about 30 tonnes of fibres per annum. For utilization of the entire pseudostem available, 20000 such units will be required, that too, in rural areas where banana cultivation takes place. Thus, employment generation will be approximately six lakh persons or in man days it will be 120 million man days (6*10^5*200 with the assumption that units will be working for 200 days in a year). In the conversion of fibres to fabric and end products, sap to enriched sap, scutcher waste to vermicompost, central core to edible products, etc., there will be additional employment generation. It means value of raw material generated per manday will be Rs.425. After paying labour charges and other overheads even to the tune of Rs.350 per manday an entrepreneur will be able to earn Rs.75 per person employed per day. An entrepreneur establishing one unit of 5 raspadors will therefore be able to earn Rs.2250 per day. Even if the unit works for 25 days in a month his total earnings per month will Rs. 56250.

The three technologies recognized by ICAR which are ready for commercialization.

- Fibre extraction using raspador machine and preparation of non-woven fabric
- Preparation of organic liquid fertilizer from banana pseudostem sap
- Preparation of candy from central core of banana pseudostem

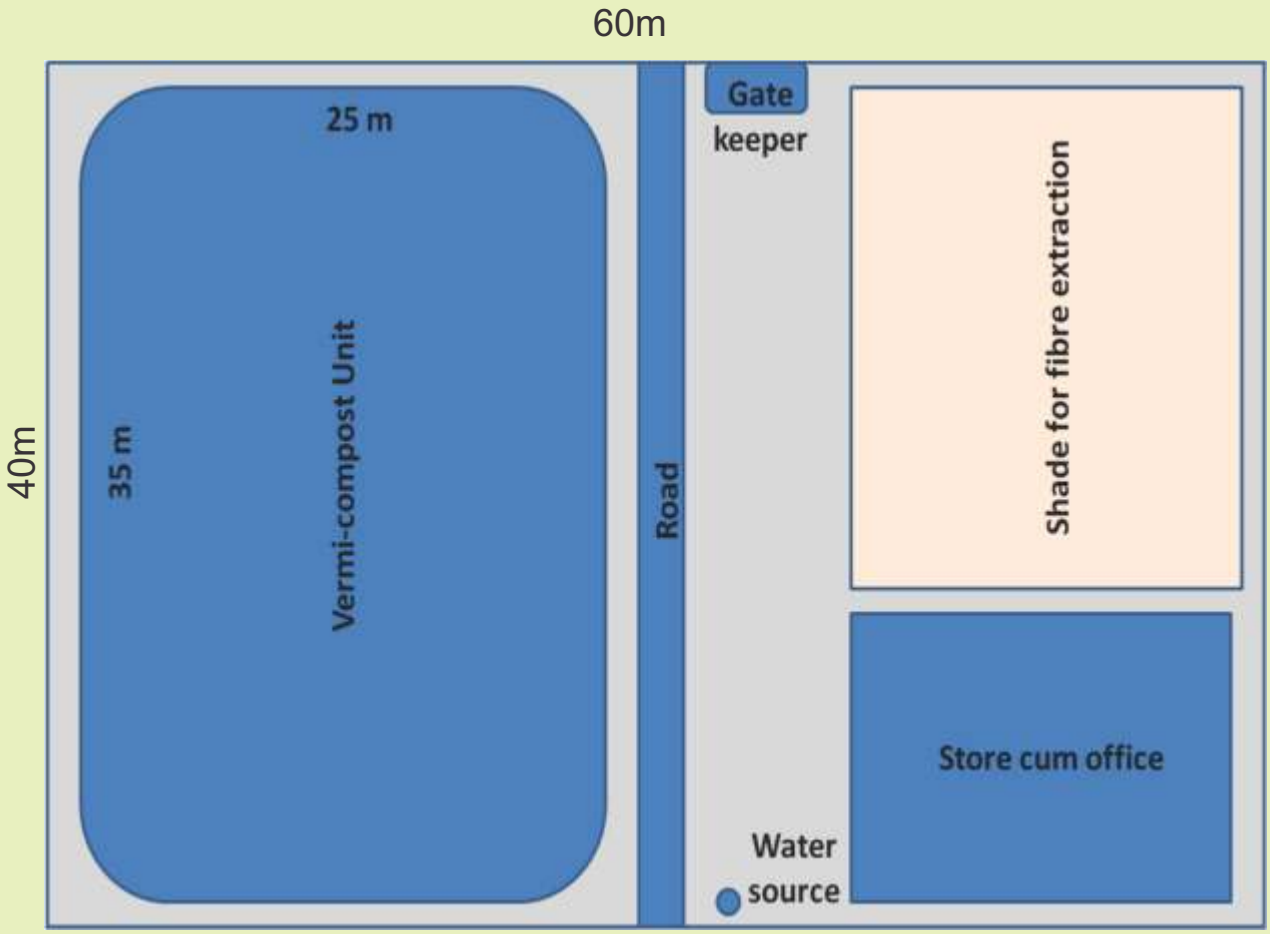
To establish and operationalized a unit on a commercial scale, business models for the three technologies are described here in detail

I Fibre extraction using raspador machine and preparation of non-woven fabric

Establishment of banana processing unit: For establishing Banana Pseudostem Processing Unit (BPPU), identify banana growing cluster of about 40 to 50 ha area. Wherever possible, the site for BPPU should be either at the centre of cluster or within the cluster area so that the lead should not

be more than 10 km. For an ideal BPPU, one should have to select around 0.3 to 0.4 ha area (Fig. 1) with three phase power connection facility. If power connection is not available, then alternative energy sources viz., power-tiller, oil engine and Honda engine (Fig. 2) may be used for extracting fibre from banana pseudostem.

Fig. 1: Layout of the BPPU



Engine operated raspador

Power-tiller operated raspador

Diesel engine operated raspador

Methodology

After establishment of BPPU, the next step is collection of pseudostem and its processing. While extracting fibre from pseudostem using raspador machine four components viz., fibre, scutcher, sap and central core are simultaneously obtained. The details of processing banana pseudostem are given here.

Fibre extraction and its uses

Step 1: Collection of banana pseudostem

After harvest of banana bunch at appropriate stage, the stem needs to be cut manually at least 6" as above the ground level. Similarly, remove the leaves at the base of lowest or oldest leaf petiole or 12" from the apical point. In either case, after cutting pseudostem, it should be transported to BPPU by using tractor with hydraulic trolley.

Normally, banana pseudostem processing should be done immediately after harvest of bunch. However, if excess pseudostems are available, then pseudostem can be kept standing in the field up to 8-10 days after removing the top leaves or 15-20 days without removal of the leaves. This period may vary with the season i.e., fewer days during summer and more during winter or monsoon seasons. Further, after cutting the pseudostem, it can safely be used up to 2-3 days, so as to avoid the deterioration in pseudostem.

Step 2: Processing of banana pseudostem

Splitting of pseudostem: Banana pseudostems are to be splitted into two halves for separating sheaths from it. The splitting can be achieved either manually using knife (Koyta) or mechanically by using

Pseudostem Cutter machine developed by NAU, Navsari under NAIP (comp II). The mechanical splitting is cheaper, faster and more efficient than manual splitting. One pseudostem cutter machine is good enough to provide sheaths for 4 - 5 raspador machines.

Splitting of pseudostem using cutter machine and separation of sheath

Preparation of sheaths for fibre extraction:

Once the pseudostem is splitted in to two halves, the sheaths are separated easily. After peeling out each sheath from pseudostem, it should be cut at the both ends so as to remove dry or rotten part. Similarly, remove the thin portion longitudinally present on either side of sheath with knife (Koyta). This ensures cleaner fibre output than non removal of thinner portion.

The prepared sheaths should be stacked properly on the table behind raspador to enable extraction of fibre more efficiently.

Step 3 Fibre extraction using raspador machine:

After preparation of sheaths, the fibre extraction is done by using raspador machine developed by CIRCOT, Mumbai and subsequently modified during NAIP period. The licensed manufacturer for raspador machine is Mac Well Engineering Works, Mumbai. The prepared sheath is to be fed in between two rollers of raspador machine by holding one end sheath firmly. The sheath is fed and pulled back to get clean fibres. The fibre should be rinsed in the water thoroughly and air dried. The dried fibre should be collected and bundles are to be prepared. The dried fibres are stored in dry room (damp free). From one hectare banana plantation approximately 600-800 kg dry fibre are obtained.

Fibre extraction, rinsing, drying and storing the dried fibres in bundles

Potential commercial uses of fibre:

- Raw material for textile industry for preparing yarn and fabrics (woven and non woven)
- Handmade and high quality paper
- Microcrystalline cellulose (MCC- pharmaceutical grade)
- Handicraft, ropes etc.

Non-woven fabrics

Trials were conducted at industrial level at Gloster Mills, Kolkata for preparing yarn and non-woven fabrics where jute fibres are used currently. The non-woven fabrics of different GSM were prepared successfully. The non-woven fabric was tested and used for preparing various products on a laboratory scale. The potential commercial uses identified for non-woven fabric are

- acoustic /Sound Absorption,
- insulator in automobiles,
- wall paneling,
- carpeting,
- technical textile industries

The advantages of fibre extraction and non-woven fabric preparation are:

- Use of banana pseudostem (presently waste) in eco-friendly way
- Additional monetary benefit to the farmers
- Employment generation in rural and urban areas
- Alternative natural fibre for different industries
- Alternative material for organic manures (from scutcher and sap)
- The details of the cost economics of fibre extraction covering 40 ha of banana plantation using one unit consisting of five raspador machines

Total no. of pseudostems available	:	3400/ha
Extractable fibre	:	200 g /pseudostem
Area covered by one unit comprising of five raspador machines	:	40 ha
Total no. of pseudostems available	:	3400 x 40=136000
Fiber extracted from 40 ha	:	27200 kg
Realizable revenue	:	Rs. 29.1 lakhs

Raw materials obtained during fibre extraction and their cost details

Component	Rate (Rs./kg)	Quantity (t)	Amount (Rs. in lakhs)
Fibre	50.00	27	13.5
Scutching waste	0.60	1600	9.6
Sap	1.00	600	6.0
Total			**29.1**

Cost details of fibre extraction

Fixed cost	Cost (Rs. lakh)	Man power	Nos.	Cost/ month (Rs. lakh)	Cost/ 6 months (Rs. lakh)	Variable costs (Rs. lakh)	Per month (Rs. lakh)	For 6 months (Rs. lakh)
Raspador M/c (5)	5.00	Manager	1	0.10	0.60	Fuel (eng.)	0.25	1.50
Cutting m/c (1)	0.50	Driver	1	0.05	0.30	Fuel (trac.)	0.18	1.08
Diesel M/c (1)	0.75	Labour	25	0.90	5.40	...	1.13	6.80
Tractor tailor (1)	8.00							
Civil work	5.00							
Total	**19.25**				**6.30**			**9.38**

*Note: Above calculations are based on 180 working days

Total cost for first year= Rs.19.25+6.3+9.38= 34.93 lakhs

Cost details for transportation and processing of fibre to non-woven fabric

Recovery	:	80% of 27.2 t
Processing and transport cost	:	Rs. 50 per kg
Selling price	:	Rs. 150 per kg
Revenue	:	Rs. 32.64 lakhs (21.76 t nonwoven fabrics)

(a) Year wise cost and returns for fibre extraction (Rs. lakhs)

Particulars	Year				
	1st	2nd	3rd	4th	5th
Cost	34.93	18.25*	20.07	22.08	24.29
Revenue	29.10	32.01	35.21	38.73	42.61
Profit	-5.83	7.93	15.14	16.65	18.32
B:C	0.83	1.75	1.75	1.75	1.75

* Variable cost = 9.38 + manpower = 6.30 + interest on fixed cost (12%) + M & R =2% of fixed cost

(b) Year wise cost and returns for fibre extraction + non-woven fabric (Rs. lakhs)

Particulars	Year				
	1st	2nd	3rd	4th	5th
Cost	48.53*	31.85	35.04	38.54	42.39
Revenue	48.24$	53.06	58.37	64.21	70.63
Profit	-0.29	20.92	23.34	25.67	28.24
B:C	0.99	1.67	1.67	1.67	1.67

** Fibre extraction (Rs. 34.93 lakh) + Processing & Transport (Rs. 13.60 lakh)*
$ Revenue from nonwoven (32.64 lakhs) + Sap (6.0 lakhs) + Scutcher (9.6 lakhs)

The cost-economics have been worked out as per the experimental trials conducted during the project period on needle punching machines at Kolkata. The cost for transportation of fibre to the industry will vary as per the distance and transportation facilities available. The cost economics are calculated are tentative and will vary as per demand by the industry and supply of fibre by the banana growers.

ii) Preparation of Organic Liquid Fertilizer (OLF) from banana pseudostem sap

Banana pseudostem sap is obtained as a byproduct during extraction of fibre. It is a rich source of plant nutrients and growth regulators. This can be enriched with organic inputs through anaerobic incubation.

The details of facilities required and processes followed for extraction of sap are given described here.

Establishment of sap enrichment Unit:

For establishing unit of enrichment of sap (1 lakh litres capacity per year) following facilities are required.

1. **Land requirement:** 200 m2
2. **Shed:** Suitable infrastructure may be constructed as per the local condition
3. **Specification of bio digester:** For preparing 1 lakh litres enriched sap, two biodigesters each of 5000 litres capacity are required. Using two biodigester each of 5000 litres capacity and 10 batches per year one can produce about 1 lakh litres of enriched sap (Organic liquid fertilizer)
4. **Filter unit:** After enrichment, the sap is required to be filtered using filter press machine
5. **Bottling plant:** The filtered sap is to be bottled suitably (PET bottle of different capacity) and sealed in appropriate packing. The bottle needs to be labeled appropriately.
6. **Packaging for transport and marketing:** The labeled and sealed bottles are to be packed in cartoon boxes for easy transport to marketing outlet.

Separation of sap from scutcher: From the scutcher with sap collected in tray placed below raspador machine during fibre extraction, sap can be separated either by squeezing the scutcher manually or by using screw press developed by NAU, Navsari. Use of screw press is more efficient in sap separation from scutcher than manual squeezing. On an average, from one hectare banana plantation around 12000 to 15000 litres sap is obtained. In other words, one unit of five raspador machines generates about 4000 to 5000 litres sap per day.

Filtration and storage of sap: The sap obtained during fibre extraction should be filtered using muslin cloth. The filtered sap can be stored in plastic tank.

Uses of Sap

- Can be injected directly through drip system in any crop.
- Can be used in all crops
- Reduces the use of chemical fertilizers
- Suitable for use in organic farming system also

A patented technology available of organic liquid fertilizer from banana pseudostem sap. For commercial production and marketing of OLF, will have to get license from NAU, Navsari

Cost economics for OLF covering 40 ha area

- Sap available: 6 l/pseudostem
- Number of pseudostem : 3400/ha
- Area covered with one unit of five raspador machines : 40 ha
- Number of pseudostem available : 136000 (3400*40)
- Total sap available: 8,16,000 litres
- With 10,000 litres capacity / month x 12 months : 1.20 lakhs litres
- Recovery of enriched sap @ 80% : 96000 litres
- Revenue realizable : 96,000 litres *120 : Rs. 115.20 lakhs
- Cost and profit statement: Total Project cost (first yr)=40+75.8+4.46=120.26 lakhs

Digester for enrichment of sap

NAVROJI Novel Organic Liquid Fertilizer

Cost breakup for organic liquid fertilizer unit of 10000 liters capacity per month

Fixed cost	Rs. in lakhs	Variable cost	Rs. in lakhs	Manpower	Rs. in lakhs
Land and building	10	Sap @ Rs. 5/l (1.2 lakh l)	06.0	Manager @ Rs. 20000 per month	2.40
Digester	10	Additives @ Rs. 25 per liter	30.0	Skilled labours (2) @ Rs. 3600 per month	0.86
Bottling plant	15	Labeling, packaging @ Rs.15 per liter	14.4	Supervisor @ Rs. 10000 per month	1.20
Storage Tank	05	Marketing and advertising	4.0		
		Transport	2		
		Trade margin	19.2		
		Misc. (Electricity *etc.*)	0.2		
Total fixed costs	40	Total variable cost	75.8	Total (manpower)	4.46
Total project cost (first yr)					**120.26**

(a) Year wise cost and returns for organic liquid fertilizer (Rs. lakhs)

Particulars	Year				
	1st	2nd	3rd	4th	5th
Cost	120.26	85.86*	94.45	103.89	114.28
Revenue	115.20	126.72	139.39	153.33	168.66
Profit	-5.06	40.86	44.95	49.44	54.38
B:C	0.96	1.48	1.48	1.48	1.48

* Variable cost = 75.8 + manpower = 4.46 + interest on fixed cost (12%) + M & R =2% of fixed cost

iii) Candy from central core of banana pseudostem

Central Core

Central core is a by-product obtained from banana pseudostem during the process of fibre extraction. From one hectare banana plantation about 12,000 to 15,000 kg central core is obtained. It is rich in digestible fibres, iron, vitamins B3 and B5. Further, it is colour and tasteless edible part which can be blended with any fruit pulp. After processing of central core into candy it becomes delicious and palatable and liked by people and children especially. This is unique product for the consumers as well as for processor. At present no such product made from banana pseudostem central core exists in market. Hence this business can be a very profitable and lucrative.

Basic requirements/ inputs to start business with technology

- banana plantation
- cabinet drier
- packaging and storage facilities

Process: The standardized process for preparing candy using central core is given here in flow chart.

Composition: After preparing candy, it was sent to CFTRI, Mysore and SICART, Anand laboratories for nutritional analysis and value are given below.

Nutritional content of candy prepared form central core

Parameters	Unit	Content	Parameters	Unit	Content
Protein	%	4.1	Total Dietary fibre	%	3.95
Carbohydrates	mg/100 g	46.8	Vitamin (Pantothenic acid B_5)	(mg/100g)	86.4
Calorific value	k.cals/100 g	390	Vitamin (Niacin B_3)	(mg/100g)	34.1
Total sugars	%	85.4	Fe	mg/kg	643

The major advantage of central core candy is it contains vitamins B3 and B5 in addition to appreciable quantity of Fe.

NAVROJI Central Core Candy

Scope: The central core is cheaper raw material for confectionary industry. It being colourless and tasteless can be blended with any fruit with improvement in nutritional quality as added advantage. Still there is scope of improvement in the quality as well as product diversification.

Application and use of the technology

- Banana pseudostem central core can be used for preparing candy
- Suitable for SHGs, Mahila Mandals etc.
- Creation of employment opportunities in rural areas

Cost breakup for 10000 kg/year candy and 2500 litres RTS processing capacity

Fixed cost	Rs. in lakhs	Variable cost	Rs. in lakhs	Manpower	Rs. in lakhs
Land and building	15.00	Electricity bill	1.10	Skilled @ Rs. 6000 per month	0.72
Cabinet drier	20.00	Central core	0.40	Unskilled labours (5)@ Rs. 625 per day	2.25
Utensils, *etc*.	03.00	Sugar	08.00		
		Packaging	10.00		
		Misc.	02.00		
Total fixed costs	**38.00**	**Total variable cost**	**21.50**	**Total (manpower)**	**2.97**
	Total project cost (first yr)				**62.47**

Business potential including cost and profit projections
(1000 kg/year candy and 2500 litres RTS processing capacity)

Yearwise cost and returns for candy and RTS (Rs. Lakhs)

Particulars	Year				
	1	2	3	4	5
Cost	62.47	24.47	26.92	29.61	32.57
Revenue	47.50	47.50	52.25	57.48	63.22
Profit	-14.97	8.06	33.39	27.87	30.65
B:C	0.76	1.94	1.94	1.94	1.94
Note: Selling price: Rs. 450/kg candy and Rs. 100/litre RTS					

CHAPTER 5
USE OF NAUROJI NOVEL ORGANIC LIQUID FERTILIZER IN DIFFERENT CROPS

Organic Farming:

Trend of organic farming is increasing day by day and it's most urgent need to human being. Navsari Agricultural University is also working on organic farming concept and regularly updating package of practices of different crops through organic inputs. Reduction in the use of chemical fertilizer as well as different agro chemicals as pesticides/fungicide without significant effect on production and quality of commodities is a main object of scientists. There are so many well-known harmful effects of such agro chemicals on environment, ecology as well as on human. Not only these, but such chemicals are also affecting soil fertility and health.

NAUROJI Novel Organic Liquid Fertilizer:

Novel is made from the banana pseudostem. About 12000 liter of fresh sap is available in the 1 ha of banana cultivation. This fresh sap is rich in the Potassium and Iron, so it can be directly use as a fertilizer or foliar spray in all the crops. There where most urgent need to add other nutrients in this fresh sap, so scientist of NAU have taken different treatments to add other nutrients and hormones in fresh sap. After the exercise of five long years, they have get successful combination to enrich the fresh sap and named this innovative product as NAUROJI Novel Organic Liquid Fertilizer. Novel contains all the nutrients viz. Nitrogen, Phosphorus, Potassium, Zink, Iron, Boron, Mn, Mg, Ca, S, Cu etc. Not onlt these, but it also contains plant growth hormones like Gibbrelic acid and Cytokines. Novel also contains bacteria which can improve soil health. Novel can be useful in different stages of plant growth e.g. vegetative development, Flowering, Fruit setting, Fruit development etc. Looking to such innovative benefits of Novel, it gets international patent also. For the benefit of the farmers of India and to make available such Novel product, Navsari Agricultural University has done MoU for commercial scale production and Marketing of Novel with different private companies. Currently, it is available in the commercial market with different brand names e.g. Dr.Unitech. Profit, Nutrimon, Organic Power, Tapti etc. NAU is also selling Novel with brand name of 'NAUROJI'. All above brand packaging contain NAU symbol on it. Novel can be use in different crops in different stages by various methods like fertigation, drenching, foliar spray, injection, cone feeding etc.

Farmers are advised to use Novel as per the suggestion by NAU. Scientists have taken different crops for the experiments and from the results of these experiments, regular advices is

released for better results on specific crops as under. Farmers are also advised to follow the common suggestion to use Novel as under.

Care to be taken for using Novel:

- Do not mix any pesticides or fungicides in it
- Do not mix any sticker or spreader in it
- For the better results, use university recommendations
- Store it in shade and don't expose to direct sun light
- Use it as early as possible after purchase
- Don't use it in afternoon hours
- Shake well before use
- minimum gap of a week should be maintain between use of Novel and other agro chemicals

Mango:

Novel can be use through fertigation or by drenching in young graft of mango up to 5-6 year. Application should be done twice in a year, which will be helpful in the vegetative growth as well as to maintain health of the grafts. It is also advised to remove the floral inflorescence on the graft up to 3 year of plantation.

For the commercial aged mango grafts (about above 6 year), three splits are recommended as below. 1% solution is recommended for all the splits (100 ml Novel per 10 liter water)

- First spray will be done at the 10-15 % flowering stage, which can be helpful for boosting flowering. Spray should be only done on the outer periphery of tree.
- Second spray should be done at the pea stage, which will be helpful for the fruit setting as well as reduce the dropping of mango. It also attracts the pollinators.
- Third spray will be done at the marble stage, which reduce the dropping as well as increase the fruit size and reduce the maturity timing.

Chiku:

1% Novel should be spray immediately after monsoon followed by second spray after one month. In the south Gujarat condition it is normally in first week of September and first week of October. It increases the fruit size as well as reduces the maturity period. Farmers are getting higher price of chiku during winter only, so these two sprays can be very helpful to meet winter period.

Banana:

Banana growing farmers are advice to use novel through fertigation in three equal splits. First split of 4 liter per hector should be done after one month of planting followed by two equal splits up to three months. This can be helpful in vegetative growth of banana as well as reduce up to 10-15 % of chemical fertilizers. During the winter, when growth of banana become stunted, farmers are advice to do cone feeding of 20 ml of Novel per plant which can be useful for better vegetative growth of banana plants and reduce the maturity period. Bunch yield can be increase by spraying 1% Novel on the fruit bunch after one month of bunch emergence.

Vegetable crops:

Vegetable nurseries should be sprayed by 0.5% Novel after 1 week of seed germination. it will boost the vegetative growth and make seedling healthy. it also reduce the transplanting time so, early transplanting can be possible.

For all the vegetables, it is recommended to apply Novel in soil application during initial vegetative stage. 4 liter of Novel per hector should be applied through fertigation or by drenching at every 15 days. After flowering and fruit setting stage start, 1% Novel should be sprayed at every 15 day interval on the crop. It will helps in fruit setting, continuous flowering and early maturity of vegetables. Results revealed that, 15 % yield can be increase by using Novel with about 15-20 % saving of chemical fertilizers.

Crops like Onion, Garlic and other tuber crops, 1% Novel should be sprayed at 20 days interval. Novel can also be helpful for seed treatment in most of the crops. For seed treatment, 1% Novel solution should be prepared and dipping should be done for about 10-15 minutes.

For the leafy vegetables, 0.5 % Novel should be sprayed at 7 days interval. It will be helpful for the better growth and yield.

Flower Crops:

For any flower crops, during the vegetative phase Novel should be applied through fertigation or drenching. 4 liter of Novel can be use for the 1 hector at 15 days interval. After starting of flowering, 1% spray of Novel should be done at 15 days interval on the crops.

Sugarcane:

Three equal split of Novel is recommended for the sugarcane. 4 liter of Novel per hector should be applied through fertigation or by drenching will increase the yield and decrease the use of

chemical fertilizer. First split will be done after one month of showing followed by two more equal split at one month interval. It is not advised to spray Novel on sugarcane.

Paddy:

Foliar spray of 0.5% Novel is recommended for the nursery of paddy after 1 week of germination. It make seedling healthy and reduce the transplanting stage time. Three equal split of 1% Novel is advised to farmers after 15 days of transplanting, at tillering stage and at milking stage. It increases the crop yield as well as earlier the harvesting time.

Cotton:

During the vegetative phase 4 liter of Novel should be applied in the soil through fertigation or through irrigation water or by drenching. 1% Novel also should be sprayed at flowering initiation stage and flower opening stage. It increases the crop yield as well as reduces the maturity period.

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