# Development of Innovative Procedures for Information Technology Articulated Agriculture

*PhD Thesis submitted to*

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*Doctor of Philosophy*

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*by*

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# Development of Innovative Procedures for Information Technology Articulated Agriculture

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# Certificate

Certified that the work presented in this thesis entitled **"Development of Innovative Procedures for Information Technology Articulated Agriculture"** is based on the authentic record of research carried out by Mr. Santosh Kumar M. B. under my guidance in the Department of Computer Applications, Cochin University of Science and Technology, Kochi- 682 022 and has not been included in any other thesis submitted for the award of any degree.

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# Certificate

Certified that the work presented in this thesis entitled **"Development of Innovative Procedures for Information Technology Articulated Agriculture"** submitted to Cochin University of Science and Technology by Mr. Santosh Kumar M. B. for the award of degree of Doctor of Philosophy under the Faculty of Technology contains all the relevant corrections and modifications suggested by the audience during the pre-synopsis seminar and recommended by the Doctoral Committee.

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# Declaration

I hereby declare that the work presented in this thesis entitled **"Development of Innovative Procedures for Information Technology Articulated Agriculture"** is based on the original research work carried out by me under the supervision and guidance of Dr. B. Kannan, Associate Professor and Head, Department of Computer Applications, Cochin University of Science and Technology, Kochi - 682 022 and has not been included in any other thesis submitted previously for the award of any degree.

Kochi– 682 022
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**Santosh Kumar M. B.**

*Dedicated to farmers……..*

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***Santosh Kumar M. B.***

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# Abbreviations/Notations/Nomenclature

| | | |
|---|---|---|
| Ack | : | Acknowledge |
| AE | : | Agriculture Expert |
| AKTM | : | Agriculture Knowledge Transfer Model |
| AKTS | : | Agriculture Knowledge Transfer System |
| ARS | : | Agriculture Recommender System |
| Ban-dis | : | Banana Disease |
| BP | : | Banana Plant |
| CPCRI | : | Central Plantation Crops Research Institute |
| CUSAT | : | Cochin University Of Science & Technology |
| DGR | : | Dial Gauge Reading |
| EF | : | Experienced Farmers |
| FEA | : | Finite Element Analysis |
| FOS | : | Factor of Safety |
| GUI | : | Graphical User Interface |
| HCI | : | Human Graphical Interface |
| IARI | : | Indian Agricultural Research Institute |
| ICAR | : | Indian Council of Agricultural Research |
| ICT | : | Information and Communication technology |
| IL | : | Initial Location |
| ISO | : | International Standard Organization |
| ISP | : | Internet Service Provider |
| IVDS | : | Integrated Vegetable Distribution System |
| KB | : | Knowledge Base |
| KBS | : | Knowledge Based Systems |
| KR | : | Knowledge retrieval |
| MDF | : | Medium Density Fiber board |
| MU | : | Multimedia |

| | | |
|---|---|---|
| NC | : | Not Commented |
| PATS | : | Portable Agriculture Towing System |
| PRR | : | Proving Ring Reading |
| PRS | : | Personal Recommender System |
| PSRT | : | Polymer Science & Rubber Technology |
| RS | : | Recommender System |
| SAG | : | Small Agriculture Groups |
| SPSS | : | Statistical Package for Social Sciences |
| SS | : | Stainless Steel |
| UI | : | User Interface |
| UTM | : | Universal Testing Machine |
| VFPCK | : | Vegetable and Fruit Promotion Council keralam |

# List of Patent and Publications

## Patent

[1] KUMAR Moorakkal Bhaskaran Santosh, BALAKRISHNAN Kannan, NEELAKANTAPILLAI Sunilkumar. “Portable Agricultural Network System PANS” I.N. Patent 5604IN001, 17 November 2017, (Patent filed).

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[2] M B Santosh Kumar, Renumol V G, B Kannan, "Design and Development of a Knowledge Based System for Diagnosing Diseases in Banana Plants", 1st International Conference on Latest Advances in Machine learning and DAta Science", Advances in Intelligent Systems and Computing, Springer, (Accepted).

[3] M B Santosh Kumar, B Kannan, “Smart Phone based System for Agriculture Product Procurement and Distribution”, International Journal of Computer Applications (Accepted).

[4] M B Santosh Kumar, B Kannan, “A Model Knowledge Based System for Exchanging Agricultural Knowledge - A Case Study”, International Journal of Control Theory and Applications, 9(10), 2016, pp. 1-11 © International Science Press.

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[1] M B Santosh Kumar, B Kannan, “Development of a Model Recommender System for Agriculture using Apriori Algorithm”, International Conference on Cognitive Informatics & Soft Computing (CISC-2017) held at Vignana Bharati Institute of Technology, Hyderabad during 20-21 Dec 2017.

[2] M B Santosh Kumar, Renumol V G, B Kannan, "Design and Development of a Knowledge Based System for Diagnosing Diseases in Banana Plants", 1st International Conference on Latest Advances in Machine learning and DAta Science", [LAMDA - 2017] at Department of Computer Science & Engineering, National Institute of Technology Goa, India during 25 - 27 Oct 2017.

[3] M B Santosh Kumar, B Kannan, “Smart Phone based System for Agriculture Product Procurement and Distribution”, 2nd International Conference on Cognitive Knowledge Engineering (2ndICKE-2016), BAMU Aurangabad, during 21-23 Dec 2016.

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## Technical Article

[1] M B Santosh Kumar, B Kannan, “Recommender System in Agriculture”, CSI-Communictaions. Vol. 41. Issue No. 6, Sept 2017.

# Chapter 1

# INTRODUCTION

Contents



Human brain can store several thousand folds of world's knowledge. It is probably the most complex and least understood part of the human body. It is continuously thinking in declarative and procedural way for problem solving, but still a mystery how brain works [1]. This new millennium brought us an opportunity to attack all such questions with the help of new knowledge, new tools and new resources. Development of systems that make use of knowledge, wisdom and intelligence is a step towards meeting this challenge. A significant amount of Gross National Product (GNP) is invested in transferring knowledge through education and training. The Knowledge-Based Systems (KBS), which are a step

towards an intelligent system, can be justified when a few individuals have the majority of the knowledge [2][3] and which can be transferred to another location.

## 1.1 Knowledge Based Systems

Knowledge-Based System (KBS) is one of the major family members of the AI group. These systems are capable of understanding the information under process and can take decision based on the residing information/knowledge in the system [4][5]. The KBS consists of a Knowledge Base and a search program called Inference Engine (IE). Ideally, the basic framework of a KBS rarely needs to be modified and, there should be an appropriate User Interface, which has the Natural Language Processing facility [6]. This system is based on the knowledge gained during the knowledge acquisition.

## 1.2 Knowledge acquisition, retrieval and transfer

Knowledge acquisition refers to the knowledge that can be obtained from external sources, like the expert farmers, agricultural experts, CPCRI and various other agricultural institutions. There are different sources of knowledge acquisition like the knowledge about the various diseases of BP acquired from the VFPCK manuals, websites, magazines etc. [7]. KM is about making the right knowledge available to the right people [8]. Traditional memory is associated with the individual's ability to acquire, retain, and retrieve knowledge. Memory therefore refers to the

collective ability to store and retrieve knowledge and information which can be intuitive, deliberate or controlled [9]. Moreover there should be clarity on what knowledge should be locked and what should be transferred [10].

## 1.3 Agricultural Knowledge

Achieving food security and environmental issues become greatest challenge of humankind. Further, natural resources are almost reaching its limit and hence there is a global call for optimum utilization and also conservation of natural resources. In this existing scenario, sustainable natural resources management heavily relies on sound sustainable agricultural practices. The sustainable agricultural practices dissemination, diffusion and adoption depend on agricultural knowledge information systems. To disseminate sustainable agricultural knowledge and technology, worldwide agricultural extension systems are undergoing a great transition. Efforts for reforming national extension systems are underway. At the same time, the agriculture knowledge infrastructure is evolving in a big way with the emergence of pluralistic extension providers and innovations to disseminate sustainable agricultural technologies to the farming community [11]. A research study was conducted in India to compare the extension objectives and nature of the farm technologies disseminated by the public extension, agri-business firms, agricultural consultancies and Non-Governmental Organisations (NGOs) indicated that a great majority of the farmers had favorable

perception towards the technologies transferred by the NGOs. Because, NGOs' extension personnel disseminated location and client specific, need based, locally feasible technologies with more emphasis on local wisdom and traditional knowledge blending with the low input modern farm technologies. The technological attributes wise perception of the clientele was also documented [12].

## 1.4 Farming systems in India

Farming Systems are strategically utilized, according to the locations where they are most suitable. The farming systems that significantly contribute to the Gross Domestic Product (GDP) of India are Subsistence farming, Organic farming and Industrial farming. India's agriculture has an extensive background which goes back to at least ten thousand years. Currently the country holds the second position in agricultural production in the world. India is the second biggest harvester of vegetables and fruit, representing 8.6% and 10.9% of overall production, respectively. The major fruit crops in India are mangoes, papayas, sapota and bananas [13]. The cropping systems are grouped into four major groups as coconut-based, rice-based, homestead-based and cassava-based [14].Homestead is a common agro-forestry system in India. Intercropping in coconut and oil palm plantations is also common. Farmers generally plant smaller trees such as coffee and banana underneath the palms [15]. Bananas and pine apple are the common fruit

crops in the homesteads. A number of cultivars of banana are widely cultivated in which Nendran being a very popular one [16].

The farming sector in Kerala currently facing a myriad of problems related to destruction of crops due to wind, flood and shortage of water etc [17]. The costs of production of the crops are high due to the lack of workers in the field. The crop considered for study was banana varieties namely Njali and Nendran. Moreover ICT initiatives like Akshaya [18] and KISSAN [19] are the important projects in the field of agriculture. Moreover this study is interdisciplinary, involving civil, mechanical, agricultural and IT with the motive to enhance the knowledge and the usability of knowledge based systems by the farmers to enhance their production and increase their profits.

## 1.5 Research Motivation

India is considered as the largest producer of banana in the world. Tamilnadu is the biggest producer of banana plants in India. Although Kerala stands 7th position in the cultivation of Banana plants, there are lots of farmers across the state that depends on banana plant cultivation. There exists large scope for export of varieties of banana from the country to different parts of the world.

The profit gained by the farmers once the banana bunches are sold is marginally low. The middle man/bidders take the major profit share once the banana bunches are sold. Again if there is any natural calamities like

heavy wind, earthquake, flood, Tsunami etc. there is a huge loss to the farming community. Thus there is a need for the Information Technology Articulated Agriculture System to protect banana plants. There is a wider scope for banana which is used as a staple food in Kerala and different parts of the country. Thus there is a need to develop IT articulated system for the production, protection and distribution of agriculture products.

## 1.6 Objectives of the study

Banana plants are being cultivated throughout the country. Wide range of various banana plants exists from north to south of Kerala. The cultivation practice differs from one district to another. The taste of the same variety of banana differs from one location to another. In this study two districts namely Ernakulam and Thrissur of Kerala state were considered. The major objectives of the study focused on four procedures namely,

1.6.1 Design and Development of a Model Portable Agricultural Network System (PANS)

1.6.2 Design and development of a model Knowledge Based System for Diagnosing Diseases in Banana Plants (Ban-Dis).

1.6.3 Design and development of a model Knowledge Based System for Exchanging Agricultural Knowledge (AKTS).

1.6.4 Design and development of a model Recommender System for Agriculture (ARS).

Therefore this thesis aims to explore these issues from the farmers' perspective and propose a better knowledge system based on the results of the study conducted.

## 1.7 Need and Significance of the study

Computers play a prominent role in Agriculture. When interacted closely with the farmers, it was found that the various knowledge, both traditional and non-traditional are becoming obsolete day by day and thus there is a need for a mechanism to store and retrieve them. Thus the idea of how technology can be used to enrich farmers and agriculture was conceptualized.

Archiving of traditional knowledge and how it can be transferred from one location to another and the idea of creating new knowledge with the help of existing knowledge was conceived. While discussing with the farmers, many major problems related to banana plants arose: for example the need for a mechanism to stabilize banana plants in the farm against such sudden failures due to wind, storm etc. How computer or technology can be integrated to agriculture for maintaining and transferring knowledge?, how the various diseases in banana plants can be identified and come up with remedial measures?. To counter such attacks, plans were initiated to develop a model agricultural recommender system that can inform the farmers about the buying behavior of the customers, online.

## 1.8 Research Approach

The study was conducted during the year 2013-2017 in Kerala state. The research design consists of mainly the plan, structure and various strategies to conduct the research [20]. This thesis is an investigation on the experimental aspects to find the physical and mechanical properties of banana plant. The modeling of the banana plants is done using Ansys software.

The present study was conducted in Kerala state in India. The state has an area of about 38,863 Square Kilometer, with a population of 33.387 million [21]. Kerala has high rate of literacy and excellent telecommunication networking reaching nearly all the towns and villages with world class IT professionals. It has initiated a lot of Information and Communication Technologies (ICT) in the field of Agriculture in Kerala [22].

### 1.8.1 Four Procedures used in this study

This research is multidisciplinary, hence four procedures were identify for the conduct of the study. The focus was on two varieties of banana namely "Njali" and "Nendran".

Procedure1: Portable Agricultural Network System PANS were designed after finding experimentally physical and mechanical properties of the banana plants. The samples of the banana plants (Njali/ Nendran) were collected from the above mentioned two districts and the

experiment was conducted in the civil engineering lab, Cochin University of Science and Technology (CUSAT). PANS was designed by considering the mechanical properties of the banana plant stem, soil and the materials used for tying the banana plant and to keep it intact The experiment was conducted by designing and developing the simulated version of the system using Ansys software.

Procedure 2: Later a knowledge based system for diagnosing the various agricultural diseases by identifying the symptoms and suitable remedial measures were designed and developed into a mobile app 'Ban-Dis', which can be downloaded by any farmers and run it on any android mobile. Thus the farmers will get an idea about what all steps to be taken (remedy) to protect the banana plant from various diseases by using the knowledge based system. The knowledge acquired from the agricultural experts (AE) and the expert farmers (EF) were stored in a knowledge base. If the knowledge has to be used by any farmers, they have to just key in the symptoms of the disease then the system will pop up the name of the disease followed by various remedial measures.

Procedure 3: The knowledge acquired from one geographical location to protect the banana plant can be adapted to another location by abstracting the knowledge from the source and making the necessary changes to adopt into the new location.

Procedure 4: A smartphone based agricultural product distribution system was designed and implemented. The agricultural product

cultivated from the two districts (Ernakulam and Thrissur) were brought directly from the farm without any middleman. A website named 'GoOrganic' (http://nss.cusat.ac.in/goorganic/home.php) was designed and the customers were given a username and password through which they can place the order. Also a mobile app 'GoOrganic' (http://nss.cusat.ac.in/goorganic/app.php) was developed that can be freely downloaded. A model recommender system was designed and developed to investigate the buying behavior of the customers. The buying behavior of 350 customers was analyzed and predictions were made accordingly. The recommender system was designed and implemented to make a recommendation for the various items that the customer will purchase every month. An apriori algorithm was used for the designing of the Recommender System (RS). Thus farmers can streamline the production for the subsequent year without any wastage, which results in increase in profits.

Most of the primary data was collected from the expert farmers, experts in the field of agriculture, through face to face interview, question and answer sessions and discussions. A questionnaire was designed, pre-tested and data was collected from two districts namely Ernakulam and Thrissur of Kerala state. Pre-appointment was fixed with the farmers, officials and various experts in the field of agriculture.

After a sample survey, the questionnaire was re-organized and the final survey was conducted. The secondary data was collected by referring journals, textbooks, magazines and various other online resources. Testing and validation of the information collected was done and the knowledge based system was designed.

## 1.9 Organization of the thesis

Rest of the thesis is organized as follows

**Chapter 2:**

**Experimental investigation to explore the mechanical properties of certain common varieties of banana plant stems**

Experimental investigation is done to determine Poison's ratio, Young's Modulus of Elasticity for Nendran and Njali banana plant stems. Compressive strength and flexure strength of the banana stem were also determined.

**Chapter 3:**

**Design and Implementation of a model Portable Agricultural Network System (PANS)**

A model portable agricultural network system was designed and developed using Ansys software. This network system protects the banana plant or any flexi trees from uprooting or breakage due to wind.

**Chapter 4:**

**The design and development of a model Knowledge Base System for Diagnosing Diseases in Banana Plants**

Farmers find difficulties to identify and treat various diseases in banana plants. As it demands wide spectrum of knowledge, a technology assisted knowledge base was designed and developed to help the farmers to early diagnose the disease by using inter-rater reliability Cohen Kappa.

**Chapter 5:**

**A Model Knowledge Base System for Exchanging Agricultural Knowledge**

It is highly essential to preserve traditional knowledge for protecting BP which are being followed by farmers for decades in different geographical locations. This chapter focuses on abstracting the agricultural knowledge from one location and adapting it in another location.

**Chapter 6:**

**A Model Smart Phone Based Agricultural Product Distribution System**

In this chapter, investigation on the strategies required for efficient and effective means of distribution of agriculture products through Information and Communication Technology (ICT).

**Chapter 7:**

**Design and Development of a model Recommender System for Agriculture (ARS)**

The focus of the study is given to both content based system and collaborative filtering. The experiment results obtained from a website and a mobile application are used in the development of the Recommender System (RS). The farmers will get a prediction and recommendations for the products to be cultivated in the subsequent year.

**Chapter 8:**

**Conclusion**

This chapter presents the conclusions of the various studies done. It summarizes what has been presented and reported in chapter 2 to 7 followed by explaining major findings of the research study and various contributions made. The limitations of the study suggesting future scope of research is also presented. The thesis also includes an extensive list of references and appendices at the end.

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# Procedure I

## Experimental Investigation to Explore Mechanical Properties of Certain Common Varieties of Banana Plant Stems

*Santosh Kumar M B, Sunilkumar N, Kannan B, Purushothaman K. T., "Experimental Investigation to Explore Mechanical Properties of Certain Common Varieties of Banana Plant Stems", Journal of Materials Science, Springer, (Communicated).*

## Design and Implementation of a Model Portable Agricultural Network System (PANS)

*Kumar Moorakkal Bhaskaran Santosh, Balakrishnan Kannan, Neelakantapillai Sunilkumar. "Portable Agricultural Network System PANS" I.N. Patent 5604IN001, 17 November 2017, (Patent filed).*

Chapter 2

# EXPERIMENTAL INVESTIGATION TO EXPLORE MECHANICAL PROPERTIES OF CERTAIN COMMON VARIETIES OF BANANA PLANT STEMS

Contents



## 2.1 Introduction

In India about 1.5 million acres of land is occupied with banana plantation [1]. There is lot of destruction of banana plants in small as well as large farms due to wind and other climatic conditions. Most of the banana farms along the long costal belt in Kerala face problem of uprooting of banana plants due to windy and stormy conditions. The maximum wind speed ranged from 2 $m/s$ to 6.4 $m/s$ during the period from December 28$^{th}$ 2015 to July 4$^{th}$ 2016 in Eranakulam district of Kerala state (*courtesy*: Department of Atmospheric Science, Cochin

University of Science and Technology). Banana plants of height three to four meters are standing like slender cantilever columns and are subjected to stability issues added with bending owing to severe lateral wind pressure in these areas.

Mechanical properties of interest of stems of banana plants are hard to find in the literature. Determinations of mechanical properties of *Nendran* and N*jali* type banana plants which are made available from farms in Kochi, Kerala, India are attempted. Young's modulus of elasticity (E), Poisson's ratio (ν), Compressive strength ($\sigma_u$) and Flexural strength ($\sigma_f$) are the properties which are determined through conducting compression and flexural tests on specimens of banana plant stems of both the varieties. The experimental investigations showed variations in the properties owing to anisotropic behavior of the specimens. However, as an initial phase of investigation, isotropy is induced to the specimens and the properties were arrived at through central point load flexural test and direct compression test. The results are: $E = 4$ to $25\ N/mm^2$, $\nu = 0.02$ to $0.056$, $\sigma_u = 0.25$ to $0.46\ N/mm^2$, and $\sigma_f = 0.58$ to $0.87\ N/mm^2$. The study is motivated from an attempt to stabilize banana plants from a possible instability when subjected to wind loads, fruit-bunch load or poor soil conditions.

Motivated by stabilizing banana plants against such sudden (or gradual) failures, a tying grid system is planned to be developed for

which the failure pattern of such plants are to be studied, in detail to find the mechanical properties of banana plants stem. The methodologies adopted for determination of mechanical properties and their limitations are detailed in the sections to follow.

## 2.2 Literature Review

Some of the research publications regarding mechanical properties of banana plants stem and their fibres, as available from literature are reviewed and are summarized, below:

The physical and mechanical properties of medium density fibreboard (MDF) made from banana plant (Musa Sapientum) and usage of banana plant as a raw material for the manufacturing of MDF was revealed by Mamunur, *et al.* [2]. Akgul in his paper proposed that agricultural residues which are renewable, widespread and plentiful, can be used in the industrial environment [3]. Just like other fibres, banana fibres also showed high specific strength which helps in making light weight composites [4]. Xie, *et al.* indicated that density influences the modulus of elasticity which increases with increase in density [5],[6]. The stress strain curve for banana fibre is normally characterised by an initial stress-strain curve and slope of which can be considered as the initial modulus as given by Kulkarni, *et al.* [7]. The breaking strength and breaking strain increases with the decrease in test length as mentioned by Kulkarni, *et al.*[8]. There occurs a property change when a

banana plant stem is pulled in tension and both its crystalline and non-crystalline parts undergo deformation. The decrease in strength with length may be due to the fact that the probability of deflection and weakling increase with length of fibres which is seen in many polymeric materials [9]. The timing of lodging of the banana plants as determined by the season, dry or wet has an influence on the mechanical properties of plantain pseudo stem with reference to Ghana [10]. The bending and flexural tests conducted normally confirms to international standard organisation (ISO: 178) [11]. Mechanical properties of banana fibre cement composites were investigated physically and mechanically [12]. The results of the impact strength test showed that pseudo stem banana fibre improved the impact strength properties of virgin epoxy material by approximately 40% that leads to higher toughness properties of materials [13].

Natural fibres from plants are beginning to find their way into commercial applications such as automotive industries, household applications, etc. [14]. The measurement of maximum bending strain and torsional shear strain of banana stems under combined loading were also discussed [15]. In 1990, lot of destruction occurred as timber was blown down in Germany during storms [16]. In 2008, wind and ice storm slashed large areas of forest across China with around 20.86 million hectares of forest and plantation getting damaged [17]. There existed some hidden risks to large urban, ancient and rare trees because

of wind and rain which would also have damaged land property and injured people [18].

The mechanical stability of a tree under static loading assumed that a tree would break once the stress acting on its stem exceeded critical value of modulus of rupture for green timber and it is widely discussed in many studies [19][20][21][22]. There is no scientific testing to measure torsional shear strain of stem of a tree. According to literature there were several methods to measure the stem deformation [23][24]. The various physical and mechanical properties of different types of fibres were also observed [25].

Thus from the literature survey it is found that the physical and mechanical properties of banana plant will vary from place to place and also depend on the climatic conditions of the location.

## 2.3 Significance of the work

Banana plant farmers are facing severe problems of uprooting and breakage of their fully grown plants due to climatic (wind or other) effects. They find it difficult to safeguard their plants from such natural forces owing to their ignorance as to how and where failure could get started. In order to predict failure pattern of banana plants through a Finite Element Analysis (FEA), the mechanical properties of the plants are essential. Isotropic behavior is assumed for the banana plants and the Young's modulus of elasticity, Poisson's ratio, compressive strength and

flexural strength of the material of stems of banana plants were determined.

The fully grown banana plants (having an age of 12 months), both *Nendran* and *Njali* after removing the fruit-bunch were collected from two farms in Kochi, India were considered as samples for the study. The samples were collected during monsoon season in the state of Kerala. The cut samples were brought to the strength of materials laboratory (civil lab of CUSAT) to be tested within 24 hours of cutting.

## 2.4 Methodology

The methodology adopted to determine the mechanical properties of banana plants stem are as follows: To determine the Poisson's ratio and Young's modulus of elasticity of the material of stems of *Nendran* and *Njali* banana plants, compression test was conducted in the strength of materials lab. The Universal Testing Machine (UTM), a Proving ring with a load dial, Longitudinal Compressometer and Lateral Extensometers were employed as essential equipment to conduct the test. The UTM was employed to apply necessary compressive load to the specimens through the proving ring and the measurement of load is effected through the load dial in the latter. The specimens were cut in the shape of cylinders, nearly resembling concrete cylindrical specimens which are used to determine Young's modulus and Poisson's ratio of concrete. The Longitudinal compressometer and Lateral extensometers are used to

measure shortening and lateral extension of stems of banana plant specimens. The surface of banana plant stems is slippery and easy to pierce through and hence it was difficult to place the sharp jaws of the Lateral extensometer. To safeguard against this, proper packing with aluminum plates was provided between the jaws and the specimens (Fig.2.1). Some of the specimens of the banana plants, especially *Njali* type, were too small in diameter than that of the lateral extensometer. Sufficient packing materials (aluminum sandwiched with thick wood) were used to make sure that the screws of the frame of lateral extensometer were in midway of their run. Extreme care is exercised not to slip or tilt the lateral extensometer from the specimens during testing.

(a) Specimen, extensometers and load dial of the UTM

(b) The Lateral and Longitudinal extensometers

**Fig. 2.1:** Lateral extensometer is fitted to stem of a banana plant specimen with aluminum packings, the longitudinal extensometer is also seen

The compressive strength and Poisson's ratio of banana plant specimens are calculated, as follows:

$$\sigma_u = \frac{P_u}{A}$$

Where, $\sigma_u$ is the compressive strength in $N/mm^2$, $P_u$ is the ultimate load in compression and $A$ is the area of cross-section of the specimen.

$$\nu = -\frac{\varepsilon_{lat}}{\varepsilon_{lon}}$$

Where, $\nu$ is the Poisson's ratio, $\varepsilon_{lat}$ is the lateral strain and $\varepsilon_{lon}$ is the longitudinal strain in the banana plant specimen.

The flexure test is conducted in the UTM with the flexure attachment and a dial gauge to measure deflection and a proving ring and associated dial gauge to measure load. The test is conducted to determine flexural strength of the banana plant and Young's modulus in flexure. Specimens are kept in the flexure attachment as simply supported beams and a central point load is applied with the proving ring and UTM. Deflection at the centre span is measured with a dial gauge of least count 0.01 mm (Fig.2.2).

**Fig. 2.2:** Flexure test set-up of a banana specimen in the UTM, the proving ring, its dial and the dial gauge to measure deflection are also seen

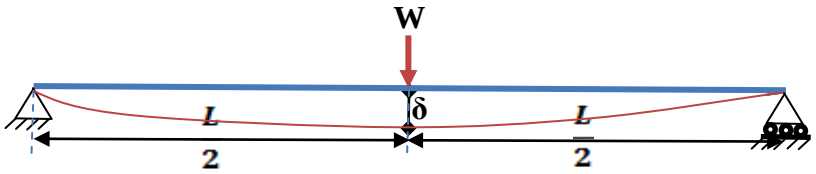


**Fig. 2.3:** Loading diagram for flexure test of banana plant (as a simply supported beam)

The schematic loading diagram of a banana plant specimen is shown in Fig.2.3. The supports are: a hinge on the left and a roller on the right, the load being applied at the centre and the deflection ($\delta$) is measured at the centre, itself. A typical deflected shape of the specimen is shown as a curve, below the beam. The span ($L$) of the banana plant specimens is set as 700 mm in the UTM. The perimeters of the two ends of the plant were measured and the diameters of the respective ends were calculated. The average diameter is used for determination of second

moment of area of cross section ($I$). The deflection ($\delta$ ) at the centre of a simply supported span subjected to centre point load ($W$) is given by:

$$\delta = \frac{WL^3}{48EI}$$

Where, $E$ is the Young's modulus of elasticity of the material of the banana plant specimen. Sufficient data of load-deflection (W-$\delta$) would enable a straight line fit to be plotted between them and the slope of the same $\left(\frac{W}{\delta}\right)$ could be employed to determine $E$, as follows:

$$E = \frac{L^3}{48I}\left(\frac{W}{\delta}\right) \text{where,} \qquad I = \frac{\pi d^4}{64}$$

Where, $d$ is the average diameter of the specimen.

The specimen is further subjected to its ultimate load ($W_{max}$ ) and the flexural strength is calculated employing the simple bending equation, $\frac{M}{I} = \frac{\sigma}{y}$, (where $M$ is the maximum bending moment at the centre of the specimen and $y$ is the distance from neutral axis to the fibre where axial stress $\sigma$ is calculated) as:

$$\sigma = \frac{W_{max}\, L}{4I}\left(\frac{d}{2}\right)$$

The maximum bending moment at the centre of the specimen is given as:

$$M_{max} = \frac{W_{max}\, L}{4}$$

## 2.5 Details of experiments and results

The banana plant stem was cut from the farm at about 20 cm above ground level and then shaped as per requirements of the compression and flexure tests, afresh. The edges of stems of the plants were cut perpendicular to their length. The specimens for both the tests were transported to the strength of materials laboratory, immediately.

Specimens for the compression test were prepared by cutting the trunk of the banana plants to 200 mm to 300 mm length, as described in detail in the next section using a hack-saw blade and smoothened with the help of a chisel. The lengths of the specimens were set as 700 mm for the Flexure test. The perimeter at both the ends and actual length of the specimens after planning their edges (perpendicular with the length) were measured to an accuracy of 1 mm with a steel tape. The methodology of determination of the parameters has already been described in the above section. The details of actual conduct of the experiments and the results there upon are of interest in this section.

### 2.5.1 Compression test

The load is either directly applied to the specimen from the compression jaw of the UTM or through a proving ring whose constant is $\frac{25000\ N}{902}$. The dial gauges used to determine the longitudinal shortening and lateral extension have least count of 0.01 mm and 0.002 mm, respectively. Table 2.1 gives the geometrical dimensions of the samples

of banana plants (*Njali* and *Nendran* varieties) used in the test. Diameters of the specimens are calculated from their perimeters of cross-sections. Typical observation tables for *Njali* and *Nendran* samples are given as Tables 2.2 and 2.3.

**Table 2.1:** Geometric data of *Njali* and *Nendran* samples for Compression Test

| Type of banana plant | Specimen number | Perimeter of cross-section, $\pi d$ ($mm$) | Diameter of specimen, $d$ (mm) | Length of specimen, $L$ (mm) |
|---|---|---|---|---|
| *Njali* | 1 | 430 | 136.9 | 300 |
| | 2 | 505 | 160.8 | 250 |
| | 3 | 465 | 148.0 | 245 |
| | 4 | 500 | 159.2 | 245 |
| *Nendran* | 1 | 460 | 146.4 | 300 |
| | 2 | 360 | 114.6 | 200 |
| | 3 | 340 | 108.2 | 200 |
| | 4 | 340 | 108.2 | 200 |

**Table 2.2:** Observations made during compression test of a typical *Njali* banana specimen (*Njali* – 3) in Table 2.1 and calculation of quantities; $d = 148.0\ mm, L = 245\ mm$

| Load, $P$ ($N$) | Lateral extension (divisions) | Longitudinal shortening (divisions) | Change in diameter, $\Delta d$ ($mm$) | Change in Length, $\Delta L$ ($mm$) | Lateral (extensional) strain($\varepsilon_{lat}$) | Longitudinal (shortening) strain($\varepsilon_{lon}$) | Poisson's ratio ($\nu$) | Compressive stres ($\sigma_c$)$\left(N/mm^2\right)$ |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |
| 1000 | 5 | 35 | 0.01 | 0.35 | $6.76 \times 10^{-5}$ | -0.0014286 | 0.047 | 0.058 |
| 2000 | 14 | 155 | 0.028 | 1.55 | 0.000189 | -0.0063265 | 0.029 | 0.116 |
| 3000 | 22 | 197 | 0.044 | 1.97 | 0.000297 | -0.0080408 | 0.037 | 0.174 |
| 4000 | 30 | 237 | 0.060 | 2.37 | 0.000405 | -0.0096735 | 0.042 | 0.232 |
| 5000 | 38 | 282 | 0.076 | 2.82 | 0.000513 | -0.0115102 | 0.045 | 0.290 |
| 6000 | 51 | 350 | 0.102 | 3.50 | 0.000689 | -0.0142857 | 0.048 | 0.349 |
| 7000 | 81 | 450 | 0.162 | 4.50 | 0.001094 | -0.0183673 | 0.059 | 0.407 |
| 8000 | 81 | 620 | 0.162 | 6.20 | 0.001094 | -0.0253061 | 0.043 | 0.465 |

**Table 2.3:** Observations made during compression test of a typical *Nendran* banana specimen (*Nendran* – 3) in Table 2.1 and calculation of quantities; $d = 108.2\ mm, L = 200\ mm$

| PRR (divisions) | Load, $P = PRR \times \frac{25000}{902}(N)$ | Lateral extension (divisions) | Longitudinal shortening (divisions) | Change in diameter, $\Delta d$ (mm) | Change in Length, $\Delta L$ (mm) | Lateral (extensional) strain ($\varepsilon_{lat}$) | Longitudinal (shortening) strain ($\varepsilon_{lon}$) | Poisson's ratio (v) | Compressive stress ($\sigma_c$)$(N/mm^2)$ |
|---|---|---|---|---|---|---|---|---|---|
| 4 | 11.1 | 0 | 15 | 0 | 0.15 | 0 | -0.00075 | 0 | 0.000201 |
| 9 | 24.9 | 8 | 43 | 0.016 | 0.43 | 0.000148 | -0.00215 | 0.069 | 0.000452 |
| 18 | 49.9 | 8 | 80 | 0.016 | 0.80 | 0.000148 | -0.004 | 0.04 | 0.000904 |
| 27 | 74.8 | 20 | 118 | 0.040 | 1.18 | 0.00037 | -0.0059 | 0.06 | 0.001356 |
| 36 | 99.8 | 31 | 155 | 0.062 | 1.55 | 0.000573 | -0.00775 | 0.07 | 0.001809 |
| 45 | 124.7 | 35 | 190 | 0.070 | 1.90 | 0.000647 | -0.0095 | 0.07 | 0.002261 |
| 54 | 149.7 | 42 | 243 | 0.084 | 2.43 | 0.000776 | -0.01215 | 0.06 | 0.002713 |
| 60 | 166.3 | 66 | 325 | 0.132 | 3.25 | 0.00122 | -0.01625 | 0.07 | 0.003014 |

$\text{PRR} = \text{Proving Ring Reading}$

$\Delta d = Lateral\ extension\ (divisions) \times 0.002\ mm$

$\Delta L = Longitudinal\ contraction\ (divisions) \times 0.01\ mm$

$$\varepsilon_{lat} = \frac{\Delta d}{d}, \varepsilon_{lon} = \frac{\Delta L}{L}$$

$$\nu = -\frac{\varepsilon_{lat}}{\varepsilon_{lon}}, \sigma_c = \frac{Pu}{A}$$

Where, $A$ is the area of cross-section of the specimen. Young's modulus, $E$ is the slope of the initial straight line portion of the $\sigma_c$Vs $\varepsilon_{lon}$ graph. A straight line fit of the initial portion of the graph is considered to calculate $E$ in this experiment. $\sigma_c$Vs $\varepsilon_{lon}$ Graphs of the specimens are generated through spreadsheets and are given as Fig. 2.4 and 2.5.

### 2.5.1.1 Result of Compression Test

The result of compression tests are compiled, in Table 2.4.

**Table 2.4**: Result of Compression Test on *Njali* and *Nendran* specimens

| Type of banana plant | | Young's Modulus, $E$ | Poisson's ratio(v) | Ultimate Load, $P_u$ $(N)$ | Compressive Strength, $\sigma_u(N/mm^2)$ |
|---|---|---|---|---|---|
| *Njali* | 1 | 25.10 | 0.083 | 6153.0 | 0.418 |
| | 2 | 23.64 | 0.043 | 8600.0 | 0.424 |
| | 3 | 29.57 | 0.044 | 9800.0 | 0.570 |
| | 4 | 21.61 | 0.0001 | 9200.0 | 0.462 |
| *Nendran* | 1 | 14.95 | 0.008 | 5654.0 | 0.336 |
| | 2 | 0.415 | 0.008 | 2716.2 | 0.263 |
| | 3 | 0.228 | 0.056 | 1718.4 | 0.187 |
| | 4 | 0.149 | 0.008 | 1884.7 | 0.205 |

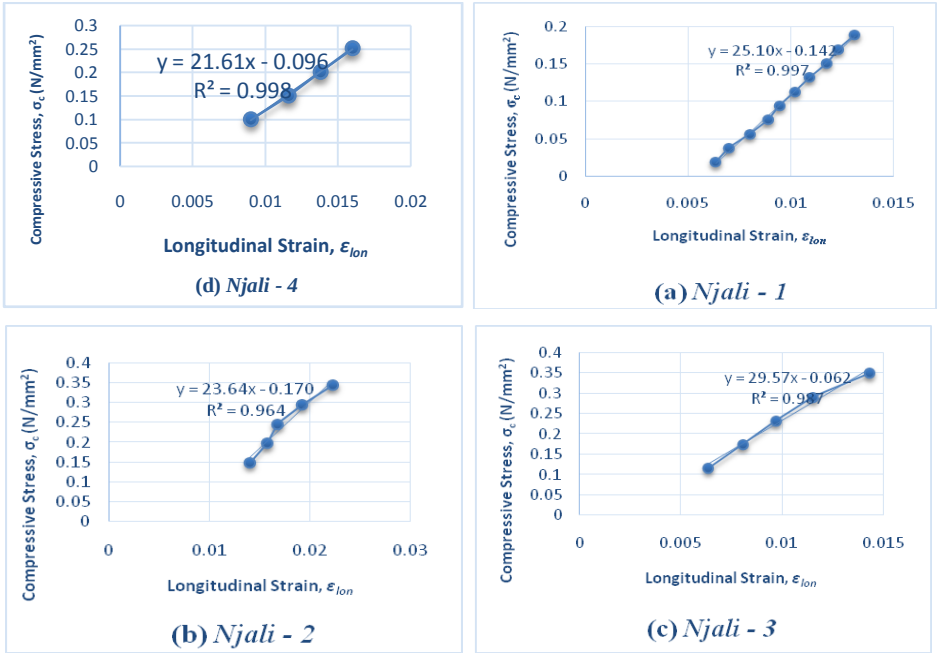


**Fig. 2.4:** $\sigma_c$Vs $\varepsilon_{lon}$ graphs for *Njali* specimens in compression test

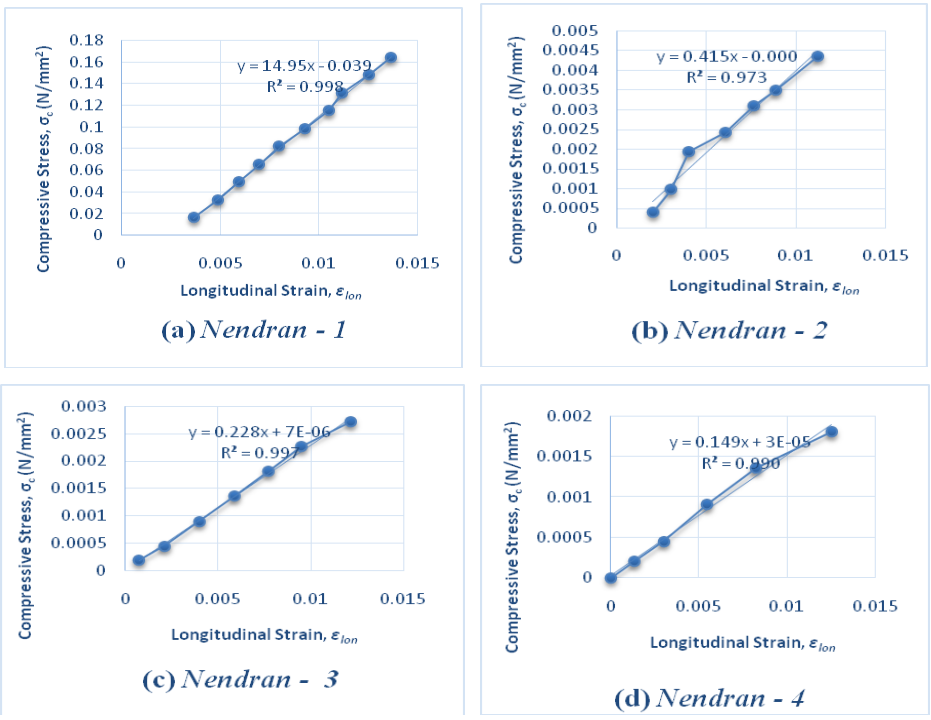


**Fig. 2.5:** $\sigma_c$ Vs $\varepsilon_{lon}$ graphs for *Nendran* specimens in compression test.

The specimens for compression test are collected from the same field and at the same time. It may be observed from Table 1 that diameters of *Njali* specimens are more than that of *Nendran* specimens (2, 3 and 4). Noting the buckling failure of longer *Nendran* specimens, the lengths of the specimens 2, 3 and 4 were reduced to 200 mm so as to bring down their slenderness ratios. Crushing failure was observed in all the samples. Sample observation and calculation tables for one specimen each from the *Njali* and *Nendran* varieties (Tables 2.2 and 2.3) show load (either directly observed from the load dial of the UTM or calculated from the

Proving Ring Reading – PRR), Longitudinal and Lateral extensometer readings, calculation of quantities like changes in diameter and length, lateral and longitudinal strains (the negative sign in longitudinal strain is owing to shortening of specimens), Poisson's ratios and compressive stresses corresponding to load applied. The plots of $\sigma_c$ Vs $\varepsilon_{lon}$ for the specimens (Figs. 4 and 5) revealed that near straight line behavior could be assumed for all specimens and Young's modulus could be calculated as the slope of the straight line fit of such curves, as shown alongside the plots. Finally, the results are compiled in Table 4 which shows that the Young's modulus of *Njali* specimens do not vary much whereas that of the *Nendran* specimens do so as well as depict very low values. The Poisson's ratios for *Nendran* samples are observed to be lower than those of the *Njali* ones. The ultimate load for each sample in compression is divided by its area of cross-section to arrive at an estimate of compressive strength and is given as the last column in Table 4. It is clear that the *Njali* samples possessed more compressive strength than the *Nendran* ones.

### 2.5.2 Flexure test

The central point load applied on simply supported banana plant specimens enforces flexure or bending. The theory of simple bending which is applicable to the cross-section where bending moment is a maximum is employed, here to calculate flexural strength and Young's modulus of elasticity. The material of the banana plant is assumed to be isotropic and linearly elastic up to certain load for the purpose of

determination of these parameters. The span (length between supports) of specimens is set as 700 mm in the bending attachment in the UTM. Load is applied to the centre of specimens through a proving ring which is attached to the upper jaw of the UTM as shown in Fig.2.2. Realizing that the loading platform of the proving ring would punch the banana specimens and cause shear failure before actual flexure failure, wooden pieces with square cross-sections $(5\ cm \times 5\ cm)$ which were a little longer than the diameters of specimens were employed to transfer load from the proving ring to the specimens. This could be justified from the fact that the flexural strength of wood pieces used are much more than that of the banana specimens. The dial of the proving ring shows load as divisions which could be converted to *Newton* by multiplying them with $\frac{25000}{902}$.

Geometrical dimensions of specimens are available in Table 2.5, sample observation tables are given as Tables 2.6 and 2.7 and the result of flexure test, generated via. Spreadsheets, in Fig. 2.6 and Table 2.8.

**Table 2.5:** Geometric data of *Njali* and *Nendran* samples for Flexure Test

| **Type of banana plant** | **Specimen number** | **Mean Perimeter of cross-section, $\pi d$ (*mm*)** | **Mean Diameter of specimen, $d$ (*mm*)** | **Length of specimen, $L$ (*mm*)** | **Second moment of area of cross-section, $I = \frac{\pi d^4}{64} (mm^4)$** |
|---|---|---|---|---|---|
| *Njali* | 1 | 418.5 | 133.2 | 700 | $1.545 \times 10^7$ |
| | 2 | 385.0 | 122.5 | 700 | $1.105 \times 10^7$ |
| | 3 | 482.5 | 153.6 | 700 | $2.732 \times 10^7$ |
| *Nendran* | 1 | 395.0 | 125.7 | 700 | $1.225 \times 10^7$ |
| | 2 | 403.0 | 128.4 | 700 | $1.334 \times 10^7$ |
| | 3 | 390.0 | 124.1 | 700 | $1.164 \times 10^7$ |

**Table 2.6:** Observations made during Flexure test of a typical *Njali* banana specimen (*Njali* – 3) and calculation of quantities; $d = 153.6\ mm$, $L = 700\ mm$

| Proving Ring Reading, PRR (divisions) | Load, $W = PRR \times \frac{25000}{902}$ $(N)$ | Dial Gauge Reading, DGR (divisions) | Deflection, $\delta = DGR \times 0.01$ $(mm)$ |
|---|---|---|---|
| 2 | 55.4 | 90 | 0.90 |
| 4 | 110.9 | 156 | 1.56 |
| 6 | 166.3 | 230 | 2.30 |
| 8 | 221.7 | 293 | 2.93 |
| 10 | 277.2 | 358 | 3.58 |
| 15 | 415.7 | 520 | 5.20 |
| 25 | 692.9 | 600 | 6.00 |
| 30 | 831.5 | 997 | 9.97 |
| 35 | 970.1 | 1006 | 10.06 |
| 40 | 1108.6 | 1300 | 13.00 |
| 45 | 1247.2 | 1570 | 15.70 |
| 50 | 1385.8 | 1810 | 18.10 |
| 60 | 1663.0 | 2030 | 20.30 |

**Table 2.7**: Observations made during Flexure test of a typical *Nendran* banana specimen (*Nendran* – 2) and calculation of quantities; $d = 128.4\ mm$, $L = 700\ mm$

| Proving Ring Reading, PRR (divisions) | Load, $W = PRR \times \frac{25000}{902}$ $(N)$ | Dial Gauge Reading, DGR (divisions) | Deflection, $\delta = DGR \times 0.01$ $(mm)$ |
|---|---|---|---|
| 2 | 55.4 | 70 | 0.70 |
| 4 | 110.9 | 149 | 1.49 |
| 6 | 166.3 | 230 | 2.30 |
| 8 | 221.7 | 328 | 3.28 |
| 10 | 277.2 | 450 | 4.50 |
| 12 | 332.6 | 558 | 5.58 |
| 14 | 388.0 | 710 | 7.10 |
| 16 | 443.5 | 865 | 8.65 |
| 18 | 498.9 | 1022 | 10.22 |
| 20 | 554.3 | 1315 | 13.15 |
| 22 | 609.8 | 1595 | 15.95 |
| 23 | 637.5 | 2150 | 21.50 |

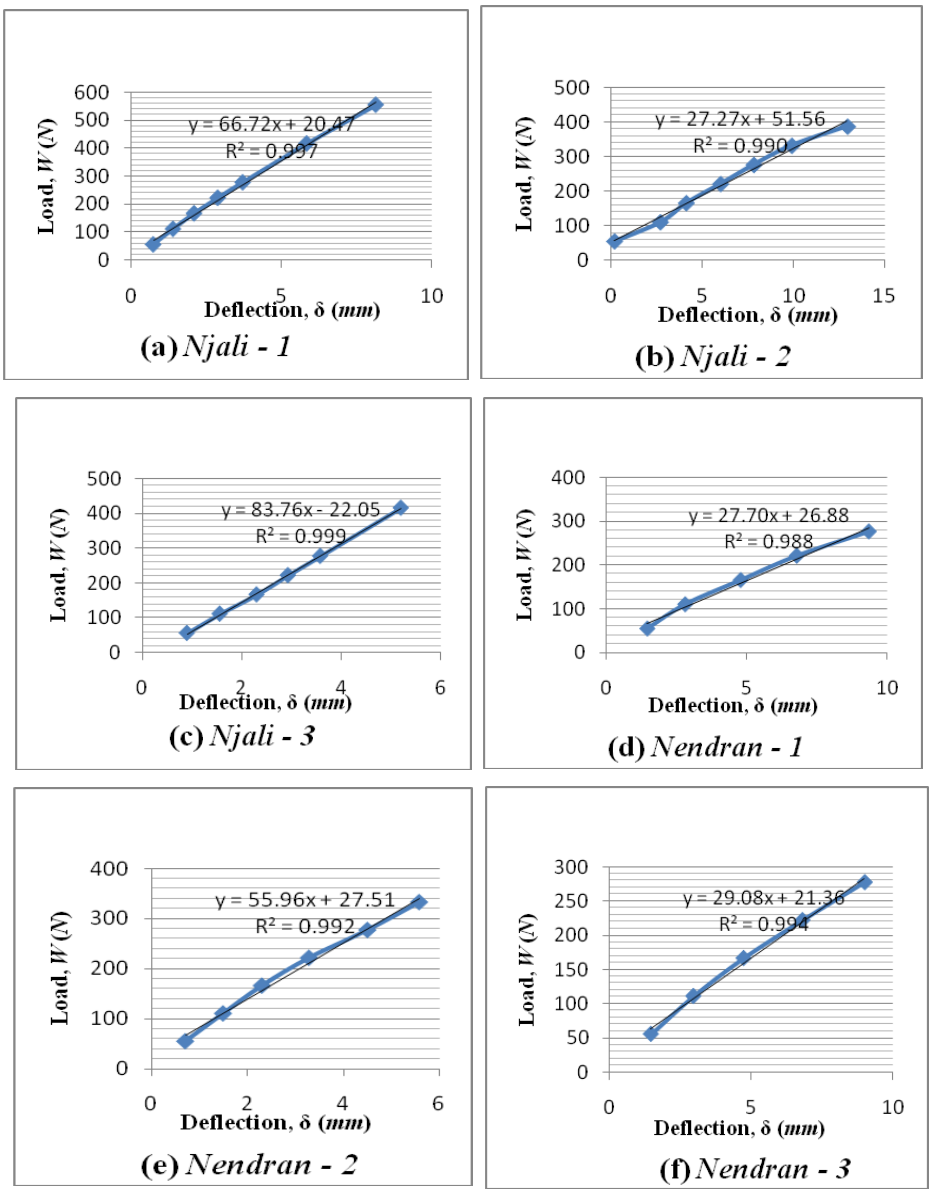


**Fig. 2.6:** *W* Vs *δ* graphs for *Njali* and *Nendran* specimens in Flexure Test.

### 2.5.2.1 Result of Flexure test

**Table 2.8**: Result of Flexure Test on *Njali* and *Nendran* specimens

| Type of banana plant | Specimen number | Slope of the $W$ Vs $\delta$ graph, $\frac{W}{\delta}(N/mm)$ | Young's Modulus, $E = \frac{L^3}{48I}\left(\frac{W}{\delta}\right)(N/mm^2)$ | Maximum load in flexure, $W_{max}$ (N) | Flexural Strength, $\sigma_f = \frac{W_{max}L}{4I}\left(\frac{d}{2}\right)(N/mm^2)$ |
|---|---|---|---|---|---|
| *Njali* | 1 | 66.72 | **30.86** | 1219.5 | **0.920** |
| | 2 | 27.27 | **17.63** | 609.8 | **0.591** |
| | 3 | 83.76 | **21.91** | 2217.3 | **1.091** |
| *Nendran* | 1 | 27.70 | **16.16** | 582.0 | **0.522** |
| | 2 | 55.96 | **29.98** | 803.8 | **0.677** |
| | 3 | 29.08 | **17.85** | 582.0 | **0.543** |

It has been observed from Table 5 that the mean diameters of the *Njali* and *Nendran* specimens which are used in the flexure test do not vary much (average mean diameter for *Njali* is 136 *mm* and that for *Nendran* is 126 *mm*). The mean diameter is calculated as the average of the diameters at the ends of each specimen. The second moment of areas of each specimen is calculated and added as the last column in Table 2.5. Sample proving ring readings and dial gauge readings for typical *Njali* and *Nendran* specimens are given in Tables 6 and 7. The load ($W$) and deflection ($\delta$) are calculated in the same Table and $W$ Vs $\delta$ graphs are given as Fig. 2.6. The initial portions of the $W$ Vs $\delta$ graphs (as available in Fig. 2.6) reveal that they depict near straight line behavior. The slopes

$\left(\frac{W}{\delta}\right)$ from straight line fits of the curves are employed to calculate the Young's modulus of elasticity ($E$) of the material of the banana plants stems. The flexural strengths $(\sigma_f)$ of the specimens are obtained from the maximum load in flexure ($W_{max}$) and geometric properties, as shown in Table 8. The average Young's modulus of elasticity for *Njali* samples is 23.47 $N/mm^2$ and that for *Nendran* samples is 21.33 $N/mm^2$ and the average flexural strengths for *Njali* and *Nendran* specimens are 0.867 $N/mm^2$ and 0.581 $N/mm^2$, respectively. It is evident that better material properties and strengths are exhibited by the *Njali* variety of banana plant than *Nendran* ones in flexure test, also.

## 2.6 Conclusion and Future work

Mechanical properties of certain varieties, namely *Njali* and *Nendran* which are most commonly available in Kerala were determined in this work. Isotropic and homogenous properties are assumed for the samples. Young's modulus of elasticity, Poisson's ratio, Compressive strength and Flexural strength are determined through conducting compression and flexure tests. The samples are collected from two different farms near Kochi, India and the tests revealed that the mechanical properties had variations depending upon the way of application of loads and varieties of banana plants. The Poisson's ratio of the samples which are tested in this work is very close to 0.05 and the average Young's modulus of elasticity, close to $25N/mm^2$.

Similarly sample of different varieties of BP can be collected and its mechanical properties with reference to different geographical locations can be found out.

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# Chapter 3

# DESIGN AND IMPLEMENTATION OF A MODEL PORTABLE AGRICULTURAL NETWORK SYSTEM (PANS)

Contents



## 3.1 Introduction

The flexi plants falling under the category of a perennial herb such as banana plants usually have pseudo stems. Many such plants, particularly in the age group of two months to eight months are prone to damage due

to the heavy wind or storm, and as such the breaking of banana plants due to high magnitude wind persists as a major concern for farmers. Additionally, the holding of these flexi plants is often neglected which also leads to their uprooting or excessive bending leading to breakage. This is a major problem in the field of agriculture and as a result the pain taken by the farmers and the agriculturists goes waste.

The failure of banana plants is mainly attributed to their weak mechanical properties. Some of the common modes of failure includes: (i) Direct breakage at different sections (ii) Breakages at the locations of flaws or cracks (iii) Overturning or uprooting of the entire plant due to the presence of loose soil (iv) uprooting from soil owing to fruit bunch load and wind forces (v) breakage of stem in flexure and buckling and (vi) animal or human intervention. Banana plants may assume slightly lean orientation with respect to the vertical when banana bunches grow on them and any discontinuity in the form of cuts or cracks in the tapering stem of a banana plant or loose soil also cause failure of the plant in flexure (at the location of the cut) and uprooting, respectively.

Presently, unscientific methods (mostly by trial and error) are used to tie and support the plants, which may either lead to increased material usage and cost or insufficient and improper support via tying and using unscientific designs. Thus, there exists a need for a solution to overcome at least one of the aforementioned deficiencies.

## 3.2 Literature Review

The tying system used in the field differs from location to location. To prevent the stem damage, support is provided by using standard coir ropes or any tying material for each plant during the bunch sprouting time. Banana-plant fibre is strong, soft, and coarse, and a technique developed for processing the fibre on standard jute machinery after stapling it to 20 cm is reported. In some trials, the fibre was blended with jute and mesta. A disadvantage was that the yarn was hairy, but hessian and sacking fabrics woven with banana-fibre yarn as weft or warp and with jute yarn in the other direction complied with standard specifications and looked brighter and dyed better than corresponding all-jute fabrics [1].

The Banana cultivation is one of the major agricultural productions in many countries. In India the North Indian States are much concentrating to the Banana cultivation. The higher cost benefit ratio depends on favorable seasonal and climatic conditions; the farmers are practically facing a most serious threat in banana cultivation. The damage of banana is not due to bad stem but due to the harmful wind.

To prevent the stem damage is by providing support using standard poles and coir ropes for each plant during the bunch sprouting time as the usual practice. These poles are costly and cannot be used for more than one or two seasons due to the mites attack and natural decaying. So, the farmers need to spend the money for the poles for each

plant under this method. The cost availability is varying according to place. It is obvious that the not genuine stem protection requires more than 70% of cultivation cost. In this simple method, every plant is provided with the galvanized iron (GI) rings at maximum possible height during the bunch sprouting. Every installed ring is then connected to the nearest four rings firmly using plastic ropes [2].

The simulation is working system based on a working model, existing system or else. The simulation is like a system, sometimes a source of some confusion due to the lack of an accepted terminology. Simulate means to duplicate the essence of a system or activity without actually attaining reality itself.

Using models to design alternative cropping systems is of growing interest but most of the research work has been concentrated on annual crops and most often in temperate climate. A specific model called SIMBA was built to assess environmental risks under a large range of cropping techniques and to help design more sustainable cropping systems. SIMBA simulates banana cropping systems at field level over several cropping cycles [3]. It includes sub-models that simulate soil structure, water balance, root nematode populations, yield, and economic outputs with a sound balance between representing the major phenomena well and keeping the model simple to reduce the parameterization costs in a large range of conditions.

Simulations lead to trends in rotation-based cropping systems characterized by systems that can be considered as intensive for profit evaluation, and combinations of frequent replanting, low nematicide application, no ploughing, and low fertilization level, for environmental evaluation. Simulations performed to optimize the replanting decision rule showed that relatively frequent replanting is good for profit while low frequency re-plantations (over four banana cycles) give a better environmental evaluation.

Intensive agriculture has led to major environmental issues that affect global sustainability. It is now essential to design new cropping systems to address the needs of farmers, the authorities, and the society, while preserving the environment simultaneously. Several strategies are being explored to solve these problems, including new field practices or new spatio-temporal arrangements of practices.

Ansys software can be used for analyzing the various mechanical performance of banana and various other materials. Finite element analysis of banana plant and other materials were conducted and found that various materials can be used for tying the banana plant and protecting it from uprooting [4].

## 3.3 Portable Agricultural Network System (PANS)

The current system refers to a reusable network assembly for holding banana plants or any such set of flexi-trees, but not exclusively to a

portable network system for holding a set of banana plants or other trees within a specific field or agricultural land. The figure for the PATS is depicted in the fig.3.1.below.

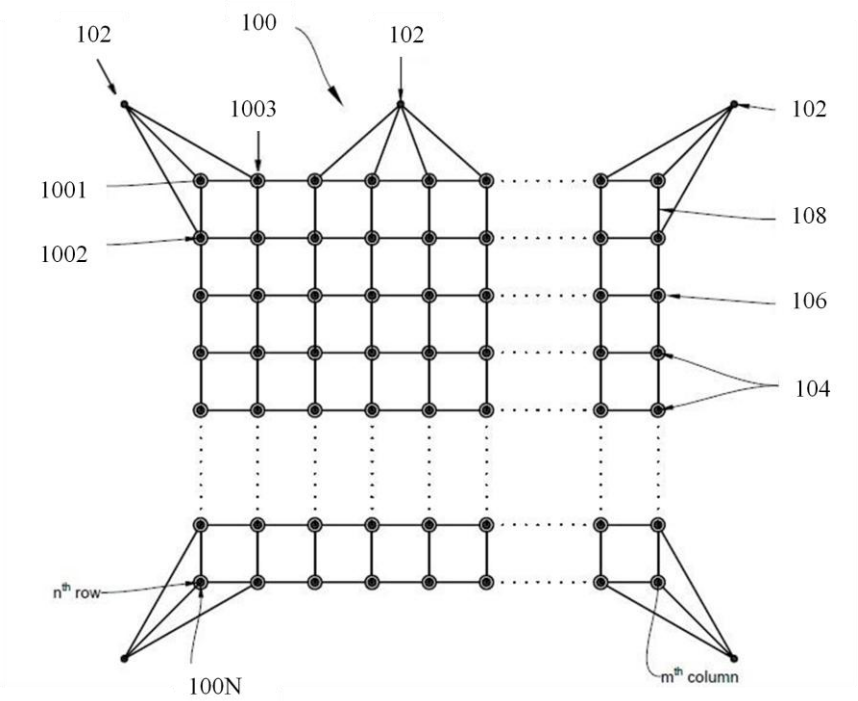


**Fig. 3.1:** Pictorial representation of PANS

Figure 3.1 illustrates an exemplary Portable Agriculture Network System (PANS) (100). The PANS (100) comprises of at least of a Primary Support or Steel Pole (101) as shown in Figure.3.1, a plurality of flexi plants (103) where each of the plurality of flexi plants (103) may include at least one connecting member (104), and at least one string (105) connecting the plurality of flexi plants (103) with the primary

support (101) or with each other (103). The flexi plants (103) may include, for example, banana trees, palm trees, etc. In a particular area of agricultural land, considering $n \times m$ matrix of banana plants or similar trees (all rows are similar); plants at the end of the rows are supported by primary support (101) and intermediate banana plants or flexi trees are connected to each other by strings.

Further, the connecting member (104) provided on each of the plurality of flexi trees may be flexible or adjustable. The connecting member, also referred to as a flexible connecting member (104), may be made up of, but not limited to, waste materials such as bunch of fibres cut from banana plants, banana fibre rope, coir rope, used cycle or car tubes, used conveyer belt, canvas material etc. The flexible connecting member (104) has a capability of adjusting itself anywhere on the banana plant (103) and tying is possible from any point on its circumference. The flexible connecting member (104) is adjustable depending on the size of the plant (diameter) and height of the plant (length). By way of an example, the flexible connecting member (104) may be applied and fastened to the flexi plants (103) when the flexiplants (103) are of 1.5 m height or more in the upper middle portion and adjusted as the plants grow.

### 3.3.1 Anchorage System (AS)

Figure 3.2 illustrates an Anchorage System (AS) (200) used in the PANS (100). The AS (200) rigidly supports the primary support (102)

and prevents from being torn during high speed winds. The primary support (102) may include at least one steel hook (202) providing as a connection means on the primary support (102) and to which the string (108) may be connectable to in a tying relationship to the primary support (102). The tension in the steel hooks (202) can be adjusted as per requirement. The steel hook (202) may include hooks or nails attached to the primary support (102). The steel hooks (202) on the primary support (102) may act as the starting point for the tying of the strings (108). The strings (108) can then tag the flexible connecting member (106) which is in looping around the banana plant or flexi-tree. The flexible connecting member (106) does not tear or rupture the structure of the plant, because the latter is adjustable depending on increase in diameter of the plant.

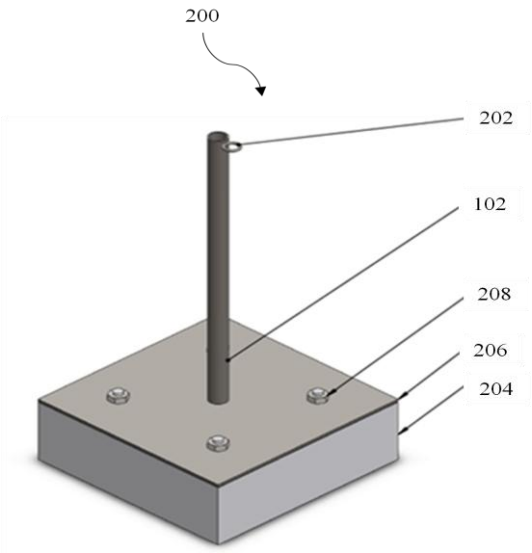


**Fig. 3.2:** Pictorial representation of Anchorage system (AS)

The primary support or steel pole (102) may be further supported from its base on the ground by the anchorage system (200).The anchorage system (200) consists of an RCC (204) (Reinforced Cement Concrete) foundation of dimensions $45\,cm \times 45\,cm \times 15\,cm$ and a steel plate (206) of 6mm thickness embedded on the top. The steel pole is of external diameter 38mm, hollow cross-section and length, 90cm of which, 15cm (half feet, 1/24 part of height of banana plant) projects on top of the earth surface. There is a steel hook (202) provided on the steel pole above the earth surface. The RCC slab (204) of 45 cm×45 cm×15 cm size is cast with foundation bolts (208) of 20 mm diameter placed at four locations. This RCC slab (204) is buried in the ground to a depth of 75 cm. A steel hook, on which the banana rope is tied, is welded on the steel pole at its top. The primary support (102) with steel plate and steel hook is placed over the RCC slab and is fixed to it using nuts. Washers are placed on the foundation bolts to increase the bearing area.

Each of the flexible connecting members (106) may be connected with the steel hook (202) by using strings (108). The strings (108) may include but not limited to, nylon-6, tangy strings, steel wire, banana fibre ropes, etc. and can be looped from the primary support (102) to the flexi plants (104) in any direction. By way of an example, the banana plant (104) is connected in a loop via the strings (108) to the primary support (102). Whenever a solid support like wall, tree, pole etc. are available, they all can replace the provision of a primary support as described,

above. All the banana plants or flexi trees in the rows and columns are interconnected as shown in Figure 3.1.

The first row of the banana plant (104) is supported from two sources, i.e., from the primary support (102) and an immediate next row of the banana plants (104) to provide strong support against heavy wind or storms. By way of an example, $n \times m(n \text{ rows} \times m \text{ columns})$ matrix arrangement of banana plants (104) may be considered, as illustrated in Figure.3.1. To illustrate further, an interior banana plant or flexi tree is supported by its adjacent four banana plants or flexi trees through ties, a banana plant on an edge (but not at the corner) of the rows or columns in the field is supported by primary support on one side and adjacent three banana plants with ties and a banana plant in a corner is supported by ties to two primary supports and to two adjacent banana plants or flexi trees.

By way of an example, the primary support (102), as illustrated in Figure 3.2, can be positioned at a distance but not limited to 3 to 5 feet from the banana plants (104) in order to provide natural movement of the banana plants (104).

PANS (100) have many advantages over other systems available. As shown in the Figure 3.1, the corner banana plants/flexi trees need only three ties to hold the plant in position. Another advantage is that four banana plants/flexi trees require only one Primary support in the

edges of the farm. The elements of the PANS (100) and the various arrangements as disclosed above can withstand hot and rainy seasons. Moreover, it is expected that the same materials are portable and can be reused.

The methodology adopted was a simulation of the banana plant (for example, the banana plant 103, disclosed above) subjected to wind and fruit bunch loading. A model of the banana plant was created; support and loading conditions were imposed and analyzed using the Finite Element Method (FEM) based solver. The required physical and mechanical properties of the banana plant were obtained by experimental investigations and through direct field visits to the plantations.

The simulation study on banana plants was carried out using ANSYS software. The analysis was conducted with two cases: Analysis without tie for the banana plants or flexi trees and Analysis with tie for banana plants or flexi trees.

## 3.4 Analysis without tie for banana plants or flexi trees

The mode of failure of the banana plant under wind and fruit bunch loading was investigated. It is quite obvious that the presence of a crack can make the plant vulnerable to failure. Thus, the study was conducted for banana plants without cracks and with initial flaws or cracks. The material properties of banana plants vary from top to

bottom. In order to incorporate this, the geometry of a typical banana plant was divided into a number of parts with each part assigned certain mechanical properties.

Thus, the following cases were investigated: Banana Plant without initial cracks, Banana Plant with initial cracks – Crack placed at the middle of the banana plant, Position of the crack varied from middle to the top of the banana plant and Cracks with variable sizes on the banana plant.

### 3.4.1 Modelling of Banana Plant

The average height of a sample banana plant is found to be 3.75 m and its diameter varies from 36.4 cm at the bottom to 24.3 cm at the top. The banana plant was modelled as a frustum of a cone, with the above mentioned dimensions [5]. The soil was modelled as a cube of size, 1 $m^3$ and the bottom part of the banana plant was inserted into this soil model, to a depth of 45 cm. The whole modelling was done in 'designmodeller' in Ansys.

The experimental investigations on the mechanical properties of banana plants indicated a significant variation along the length of plants. For example, the Young's modulus varied from 4 to 25 $N/mm^2$, from the top to bottom of a plant. So, in order to incorporate this anisotropic material behaviour, the model was divided into three parts and each part was assigned different material properties as shown in figure 3.3.

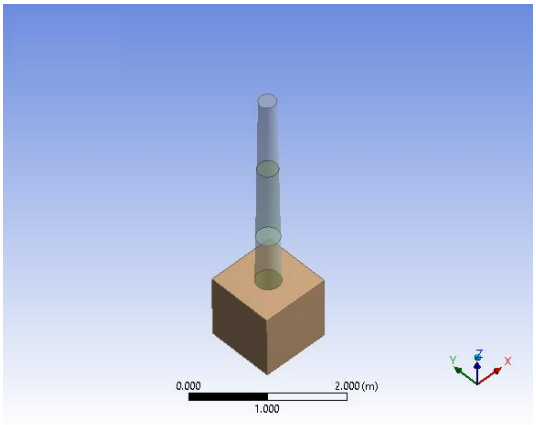


**Fig. 3.3:** Model of the banana plant with supporting soil - Isometric view

### 3.4.2 Modelling the Cracks on Banana Plant

It was evident from the field visits to the plantations that the presence of cracks was highly detrimental and such banana plants were vulnerable to rupture. These cracks are initiated due to many reasons such as by birds or insects, by fatigue due to frequent change in wind directions (micro cracks, which eventually grow in size), etc. The cracks vary in size and shape.

On the banana plant model, a crack was modelled. The width and length of the crack is such that the included angles are $20^{o}$ and $90^{o}$ respectively and the depth of the crack is 3 cm (Figure.3.4).

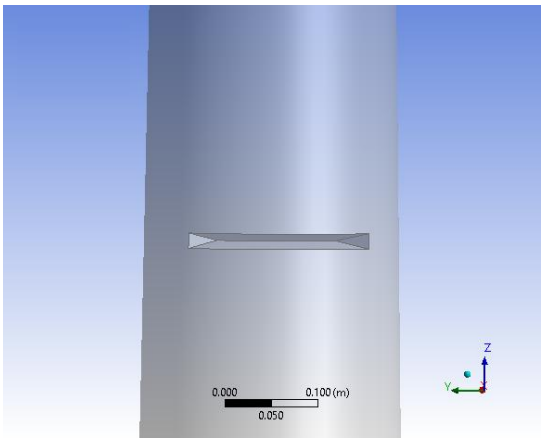


**Fig. 3.4:** Model of a typical crack or flaw in a banana plant

The effect of cracks on the failure of banana plant was studied by placing them at different locations on the plant, varying the distance from the base.

## 3.5 Material Properties

Material Properties were obtained from experimental investigations as stated earlier. The mechanical properties of banana plants, varies significantly along the length of plants. For the model which was divided into 3 parts, the Young's modulus was given as 25 $N/mm^2$, 10 $N/mm^2$ and 4 $N/mm^2$ for the lower, middle and upper parts, respectively. The flexural strength of the *Nendran* variant was obtained as 0.58 MPa, whereas that for the *Njali* was 1 MPa. The density of the banana plant is found to be 0.04 $g/cm^3$ and the Poisson's ratio is 0.05.

For the supporting soil, the density, Young's Modulus and Poisson's ratio are 2 g/cm$^3$, 50 MPa and 0.3, respectively.

The properties are summarised in Table 3.1.

**Table 3.1:** Material Properties of Banana Plant and soil

| Sl. No. | Material | Density, ρ (g/cm$^3$) | Young's Modulus, E (MPa) | Poisson's Ratio, μ | Tensile strength, $\sigma_{max}$ (MPa) |
|---|---|---|---|---|---|
| 1 | Banana plant | 0.04 | 4 to 25 | 0.05 | 0.58 |
| 2 | Soil | 2 | 50 | 0.3 | - |

## 3.6 Meshing

The banana plant part of the geometry was meshed using hexahedral mesh whereas the soil part was meshed using tetrahedral mesh (Figure.3.5). The total numbers of elements used were 48380.

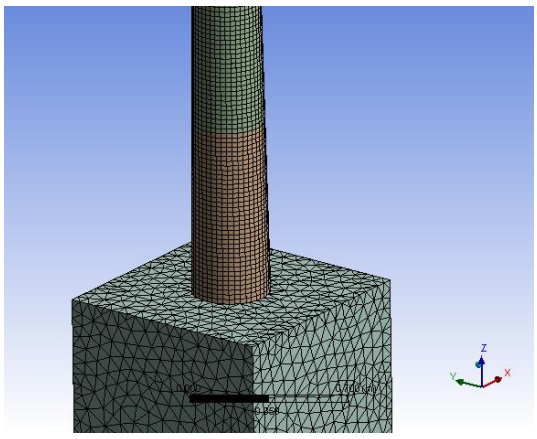

**Fig. 3.5:** Meshed model of the Banana Plant and supporting soil - a Closer view

## 3.7 Boundary Conditions

The various loads and supports on the model were specified based on data obtained from field visits and subsequent investigations. The following are the boundary conditions imposed for analysis.

### 3.7.1 Wind Load

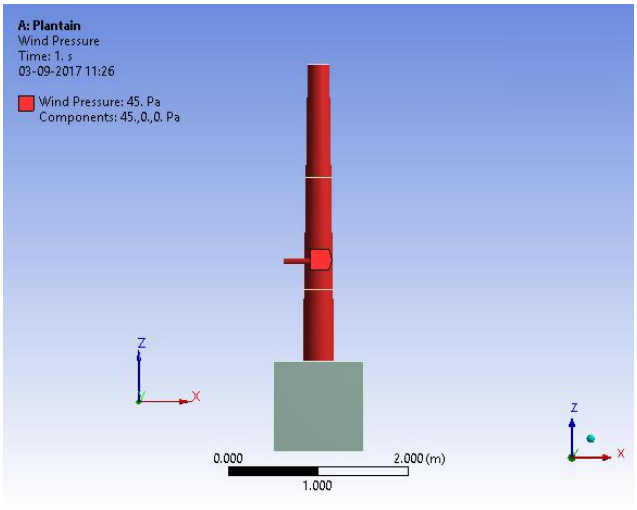


**Fig. 3.6:** Wind Load

The wind pressure is given by the equation,

$$P = \frac{1}{2}\rho_{air} V^2 x ShearFactor$$

Where, $\rho_{air}$ is the density of the air, and V is the wind velocity.

The density of air is evaluated as follows.

$$\rho_{air} = \frac{P_{atm}}{RT}$$

Where, $P_{atm}$ is the atmospheric pressure equal to 101325 Pa, R is the characteristic gas constant equal to 287 J/kg K and T is the temperature in Kelvin (Assumed as 303 K or $30^{o}$ C)

$$\rho_{air} = \frac{101325}{287\ x\ 303}$$

$$\rho_{air} = 1.165 \frac{kg}{m^3}$$

Therefore, assuming a shear factor of 1, the wind pressure corresponding to a velocity of 8.8 m/s, is given by,

$$P = \frac{1}{2} x\ 1.165\ x8.8^2 x\ 1$$

$$P = 45\ Pa$$

Thus, the wind load corresponding to a wind velocity of 8.8 m/s is found to be equivalent to a pressure of 45 Pa. This pressure is evenly distributed over the entire curved surface of the banana plant and is directed along the direction of the wind, i.e. along X-axis as in Figure 3.6.

### 3.7.2 Fruit Bunch Load

Fruit Bunch load was given as a remote force acting at the topmost surface of the banana plant, at an offset distance of 0.5m from the banana plant axis and directed at $10^{o}$ with respect to the vertical (Figure.3.7).Bunch weight is 147.15 N and Bunch Angle=$10^{o}$.

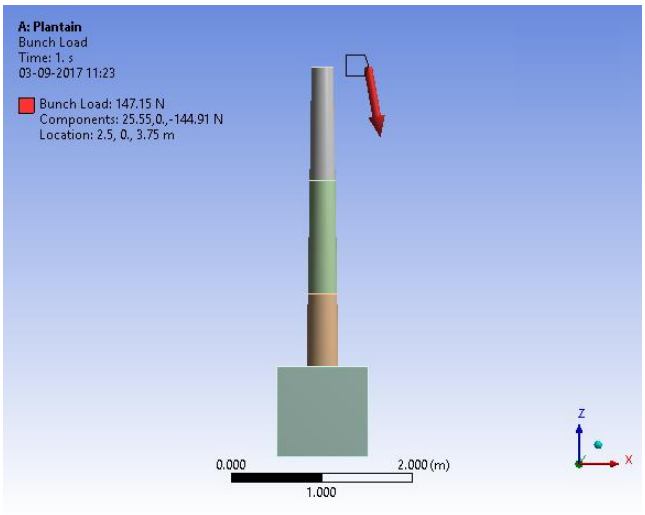


**Fig. 3.7:** Fruit Bunch Load

### 3.7.3 Wind load on the Leaves

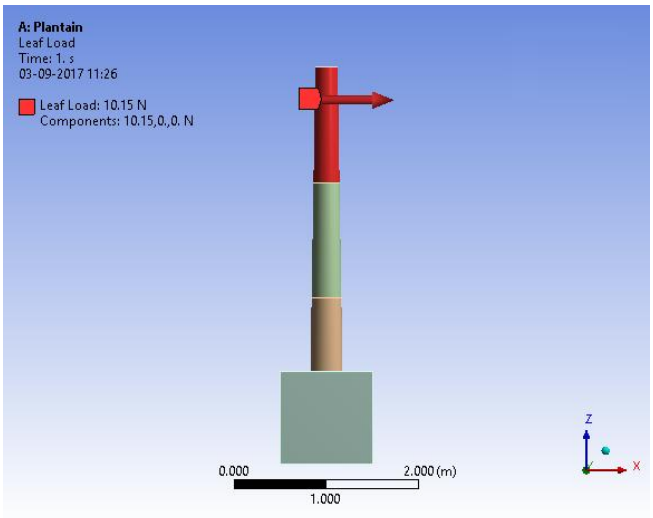


**Fig. 3.8:** Wind load on the Leaves

The wind load on leaves was modelled as the wind pressure contained in the whole area of leaves. Fair and accurate results can be obtained if the wind load on the leaves are evaluated and applied on the upper part of the banana plant. Calculation of Wind load on the Leaves is exercised, as follows:

The surface area of the leaves where measured from a banana plant sample and was obtained as 0.2256 $m^2$. Pressure corresponding to a wind velocity of 8.8 m/s = 45 Pa.

Hence, the drag force = Pressure × Area = 45 ×0.2256=10.15 N.

This force was applied uniformly over the top portion of the banana plant (Figure. 3.8).

### 3.7.4 Gravity

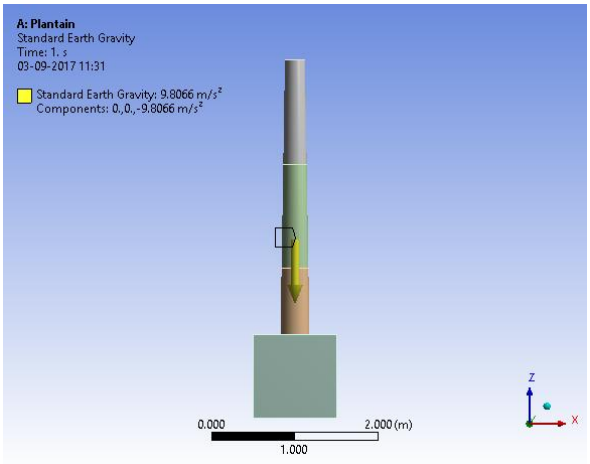


**Fig. 3.9:** Gravity enabled in the vertically downward direction

The software considers the weight of the banana plant, only if gravity is enabled. Here, the gravity was directed, vertically downward, obviously, i.e. along the -Z Axis (Figure.3.9).

### 3.7.5 Support

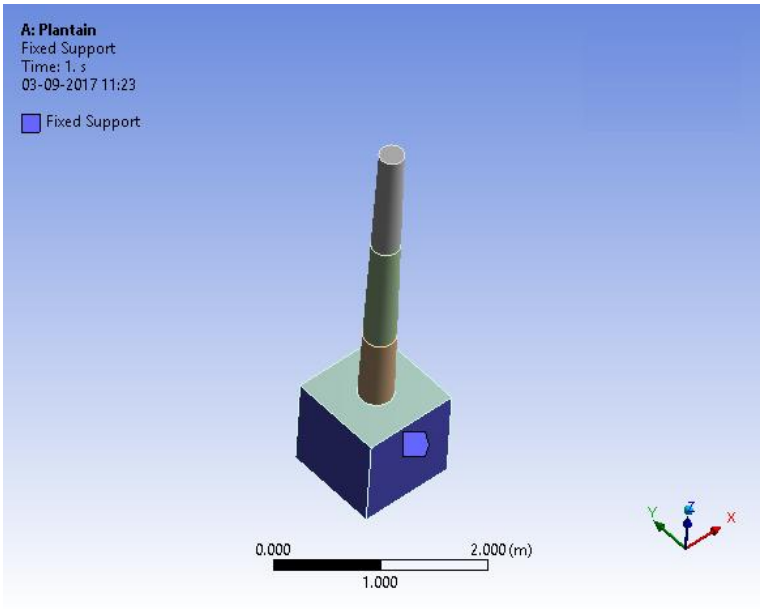


**Fig. 3.10:** Banana Plant with soil supported at its base

The base of the banana plant was needed to be fixed for analysis. Instead of fixing the base itself, the bottom and side surfaces of the soil were fixed (Figure.3.10). This will enable proper interaction between the base of the banana plant and the soil.

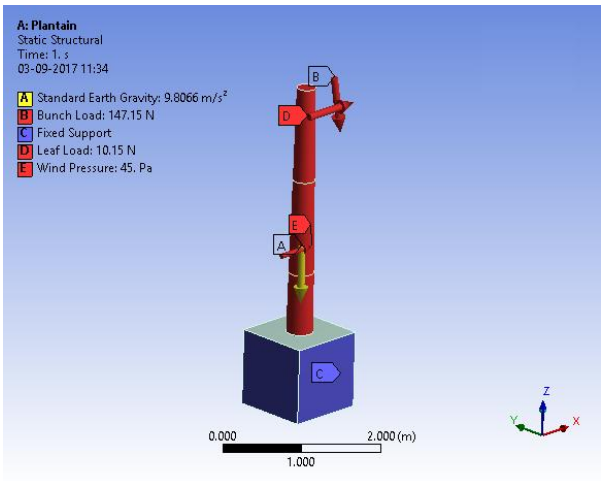


**Fig. 3.11:** Model with force and displacement boundary conditions - Isometric view

The model with force and displacement boundary conditions is shown in the Figure.3.11. It can be seen that the model acts as a typical cantilever beam.

## 3.8 Failure Criterion

The *Nendran* variant of banana plant is found to have a tensile strength of 0.58 MPa. The Factor of Safety (FOS) for this case can be taken as 2.5 due to the following reasons: The anisotropic material behaviour on the outset and in particular the mechanical properties varying with age, availability of nutrients from soil and change of seasons and moreover, the unforeseen flaws which would have occurred in banana plants owing to fatigue, initial cracks, etc. The failure of banana plants is expected hence, if it develops a flexural stress of 0.23 MPa or more.

## 3.9 System configuration and software details

| | | |
|---|---|---|
| Processor | : | Intel Core i7 |
| Memory | : | 16 GB |
| Software Used | : | Ansys |
| Time for Simulation | : | 53.719 s [For the case, without cracks] |

## 3.10 Analysis and Results

The structural analysis was carried out in the 'static structural' module of ANSYS. Initially, the analysis was carried out by varying the wind speed and it was found that the minimum wind speed at which failure occurs is 8.8 m/s. Also, the deflection contours of the plant indicate chances of overturning of the plant.

### 3.10.1 Banana Plant without Cracks

#### 3.10.1.1 Stress at the base of the banana Plant

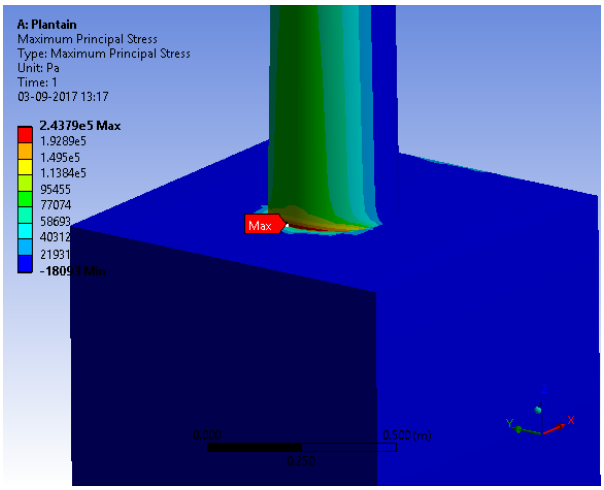


**Fig. 3.12:** Flexural Stress contours- Closer view

The flexural stress is maximum at the base and it decreases towards the top (Figure.3.12) which is typical cantilever behaviour, as expected. The maximum flexural stress is 0.24MPa, developed at the outer periphery of the base. This is sufficient for failure as per the failure criterion.

### 3.10.1.2 Deflection at the top of the Banana Plant

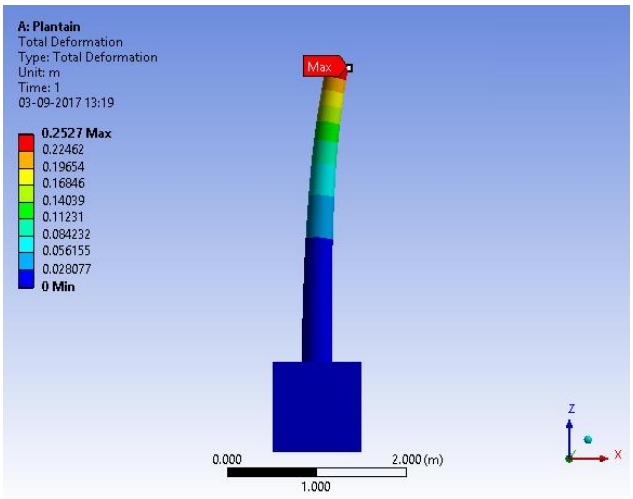


**Fig. 3.13:** Deflection contour

The maximum deflection obtained is 25.3 cm, which occurs at the top end of the plant (Figure.3.13).The design of the tie system will be aimed at minimizing the flexural stress in plants below the permissible limit and deflection close to zero.

### 3.10.2 Banana Plant with Crack

The most vulnerable place for failure in the banana plant is the region around a crack, in accordance with the findings from the field. So,

the effect of initial cracks due to flaws on the failure of the banana plant was studied by placing a wedge-shaped crack at two-third distance from the base of the plant (2.5 m). The following results were obtained.

### 3.10.2.1 Stress variation at the crack

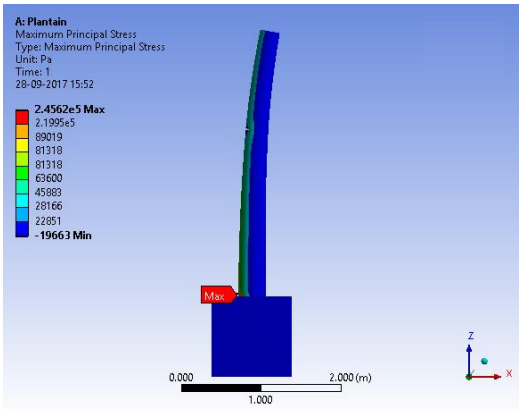


**Fig. 3.14:** (a) Flexural stress variation with crack

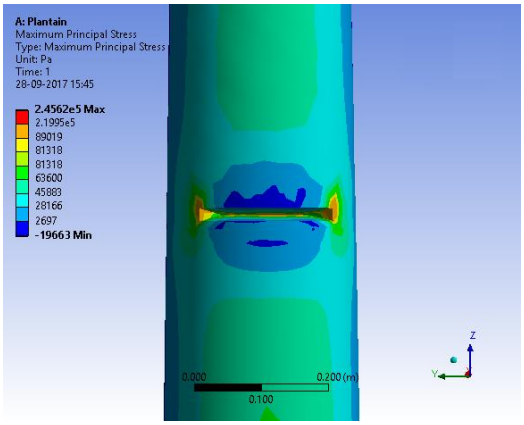


**Fig. 3.14:** (b) Stress variation close to crack

In this case also, the maximum flexural stress occurred at the base of the plant and is 0.25 MPa (Figure. 3.14 (a)). Close to the crack tip, the flexural stress is obtained as 0.110 MPa (Figure. 3.14 (b)). Even though this is slightly lower than the failure stress, the cracks can be fatal in case of wind blowing at a higher velocity.

### 3.10.2.2 Deflection of the banana plant with crack

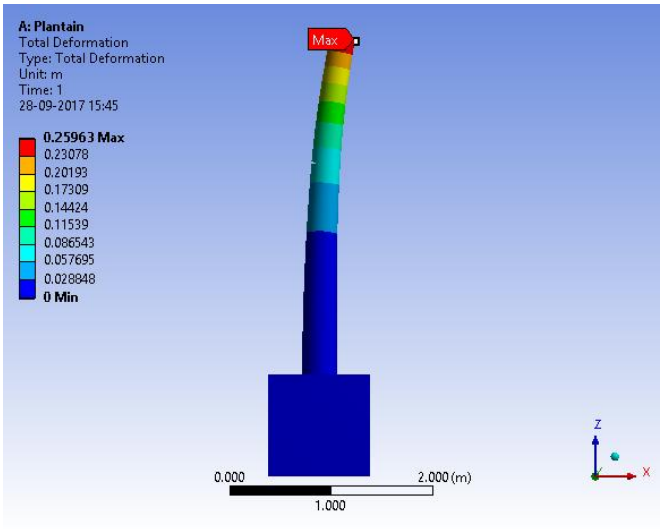


**Fig. 3.15:** Deflection contour

The deflection increases slightly to a value of 26 cm (Figure.3.15) due to the introduction of a crack.

### 3.10.3 Banana Plant with occurrence of crack between top to two-third of its length from bottom

The effect of the position of the crack on the banana plant was also studied. A parametric analysis was carried out with the position of the

crack, taken as the input parameter and the resulting maximum flexural stress at the crack tip obtained as the output.

**Table 3.2:** Variation of maximum flexural stress with respect to the position of the crack

| Sl. No. | Height from the Base (m) | Maximum flexural stress in the crack tip (MPa) | Maximum deflection of the banana plant (cm) |
|---|---|---|---|
| 1 | 2.50 | 0.110 | 26.0 |
| 2 | 2.75 | 0.103 | 25.8 |
| 3 | 3.00 | 0.097 | 25.6 |
| 4 | 3.25 | 0.088 | 25.5 |
| 5 | 3.50 | 0.091 | 25.3 |

The variation of maximum flexural stress with respect to the position of the crack from the base is given in Table 3.2. Considering anisotropic behaviour of the banana plant also into account, it can be concluded that the chances of failure are very high, with the presence of cracks.

### 3.10.4 Banana Plant with different size of the crack

As mentioned in the modelling section, a crack was included; with the width and length of the crack such that the included angles along the width and length are $20^o$ and $90^o$, respectively. The depth of the crack is 3 cm. The length of the crack was varied by varying the included angle of the crack and the corresponding stresses were determined. In all the

cases, the crack was placed at 2.5 m (two third distances) from the base. These results are summarised in the table 3.3.

**Table 3.3:** Variation of maximum flexural stress with respect to the length of the crack

| Sl. No. | Included Angle of the crack ($^o$) | Maximum flexural stress in the Crack tip (MPa) | Maximum Deflection of the banana Plant (cm) |
|---|---|---|---|
| 1 | 30 | 0.099 | 25.4 |
| 2 | 60 | 0.128 | 25.7 |
| 3 | 90 | 0.109 | 26.0 |
| 4 | 120 | 0.128 | 26.2 |
| 5 | 150 | 0.140 | 26.4 |
| 6 | 180 | 0.140 | 26.5 |

## 3.11 Analysis with Tie for banana plants or flexi trees

### 3.11.1 Geometry and Boundary Conditions

The geometry and boundary conditions were maintained the same as before, except for the following: a tie band was modelled as a line body (with rectangular cross section of width 30mm and thickness 3 mm) around the banana plant at a height of 3 m from the base. (Figure. 3.16a) and the maximum load which the tie can withstand (safe load) was applied in this tie band at an angle of $60^o$ (convenient angle of tying in the field) with the horizontal (Figure. 3.16b).

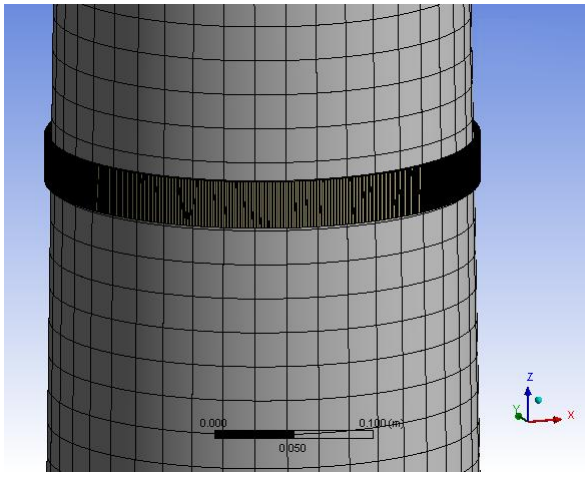


**Fig. 3.16:** (a) Model with the tie band

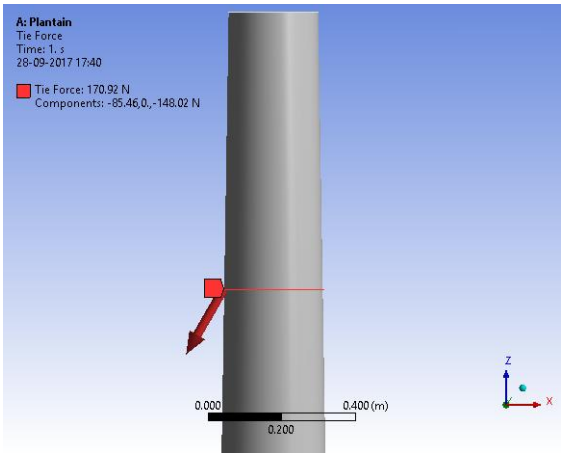


**Fig. 3.16:** (b) Model with the tie force

### 3.11.2 Geometric and mechanical properties of ties (banana rope)

The material (banana rope) intended to use for tying is specially made from banana plants, themselves with a diameter of 6 mm. Three different exposures of ties were considered for analysis, as follows: Dry (with natural moisture content), Wet (fully saturated) and Salty. The testing was carried out on banana ties for these three cases and the following data was obtained for designing the towing of banana plant.

**Table 3.4:** Mechanical properties of tie

| Sl. No. | Material | Tensile strength, $\sigma_{max}$(MPa) | Ultimate load at failure(N) | Safe Load (FOS=2) (N) |
|---|---|---|---|---|
| 1 | Tie (Dry) | 12.09 | 341.83 | 170.92 |
| 2 | Tie (Wet) | 9.0779 | 256.63 | 128.32 |
| 3 | Tie (Salty) | 9.28 | 262.42 | 131.21 |

## 3.12 Results

### 3.12.1 Banana plant with tie and without cracks

When a dry tie of diameter 6 mm was connected with a tie band to a banana plant, the maximum flexural stress in the banana plant is obtained at the base and is found to be 0.098 MPa, which is much lower than the cases without using a tie (Figure 3.17). Thus, the use of dry tie with tie band would drastically reduce the flexural stress in the banana plants and this in turn would result in stability of plants.

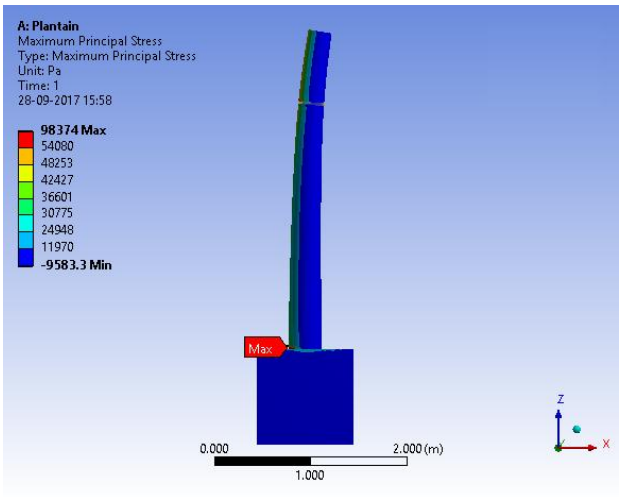


**Fig. 3.17:** Flexural stress contour in the banana plant with dry tie

Moreover, the maximum deflection is reduced to 15.8 cm, compared to 25.3cm in the case without using a tie (Figure.3.18).

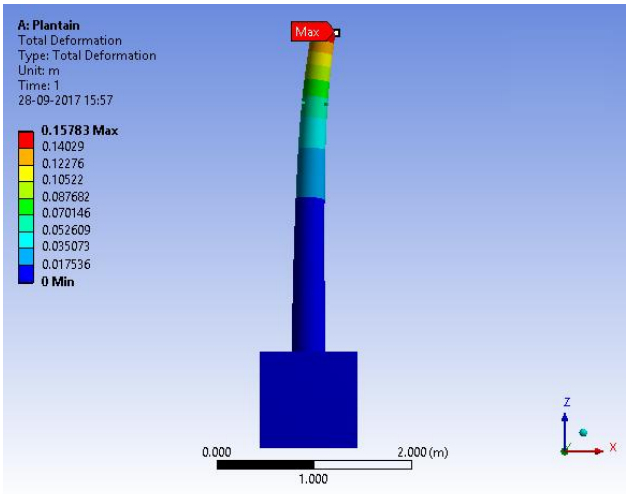


**Fig. 3.18:** Deflection in the banana plant with dry tie

The other two cases, i.e., wet (fully saturated) and salty tie were also analysed and the results are summarised in table 3.5. A factor of safety of 2 is applied, uniformly.

**Table 3.5:** Flexural stresses for different exposure of ties

| Sl No. | Case | Maximum flexural stress, MPa | Maximum deflection, cm |
|---|---|---|---|
| 1 | Dry (FOS=2) | 0.098 | 15.8 |
| 2 | Wet (FOS=2) | 0.135 | 18.1 |
| 3 | Salty (FOS=2) | 0.132 | 18.0 |

## 3.13 Banana Plant with Tie and with crack

In the banana plant with a tie, the effect of the position of the crack on the banana plant was studied. Here also, a parametric analysis was carried out with the position of the crack, taken as the input parameter and the resulting maximum flexural stress at the crack tip obtained as the output.

**Table 3.6:** Variation of maximum flexural stress with respect to the position of the crack

| Sl. No. | Height from the Base (m) | Maximum flexural stress in the Crack tip (MPa) | Maximum Deflection of the banana Plant (cm) |
|---|---|---|---|
| 1 | 2.50 | 0.087 | 16.2 |
| 2 | 2.75 | 0.092 | 16.2 |
| 3 | 3.00 | 0.384 | 5.4 |
| 4 | 3.25 | 0.095 | 16.0 |
| 5 | 3.50 | 0.089 | 15.9 |

If the tie is attached to the banana plant away from a possible flaw, the maximum flexural stress is well within the safe limit. However, accidentally, if the flaw occurs very close to the knot, there is a chance of failure of the banana plant.

## 3.14 Variation of position of the Tie

The position of the tie was varied along the vertical distance for the dry exposure case.

**Table 3.7:** Variation of flexural stress with respect to the position of the tie

| Sl. No. | Position from base (m) | Max flexural stress (MPa) | Maximum deflection (cm) |
|---|---|---|---|
| 1 | 2.5 | 0.125 | 19.9 |
| 2 | 2.75 | 0.112 | 18.1 |
| 3 | 3 | 0.098 | 15.8 |
| 4 | 3.25 | 0.085 | 13.1 |
| 5 | 3.5 | 0.072 | 10.1 |

Both the maximum flexural stress and the deflection decrease as the vertical distance, at which the knot is made, increases.

It is expected that the *Njali* variant is stronger than the *Nendran* variant and its flexural strength is of the range 0.75 to 1MPa. Analysis was carried out with these values and it is found that the *Njali* variant with a flexural strength of 0.75 MPa fails with a wind velocity of 10.5 m/s and that with strength of 1MPa fails when the wind velocity is 13.06 m/s. The results are summarised in Table 3.9.

**Table 3.8:** Velocity at which failure occurs in the Njali variant

| Sl. No. | Flexural Strength (MPa) | Failure Stress (FOS=2.5) | Wind velocity at failure (m/s) |
|---|---|---|---|
| 1 | 0.75 | 0.3 | 10.5 |
| 2 | 1 | 0.4 | 13.06 |

It is also verified that the towing system that has been developed would be able to withstand this load for the *Njali* variant banana plants.

## 3.15 Tie Force

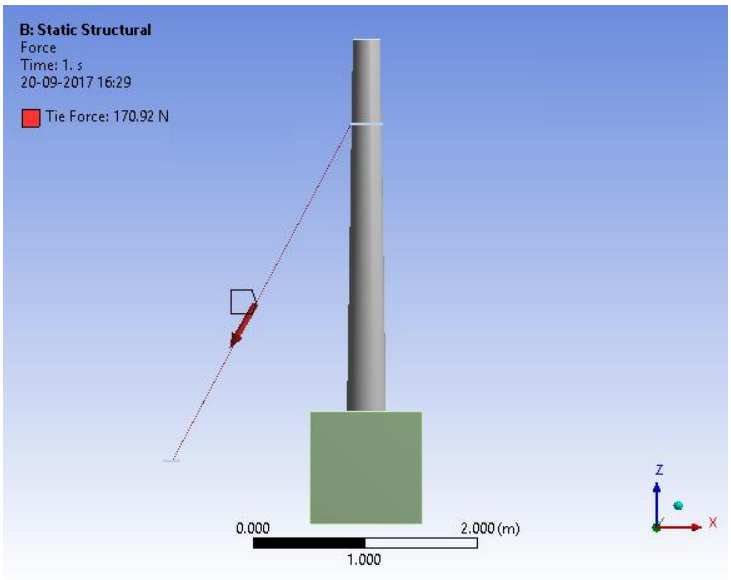


**Fig. 3.19**: A single tie on a banana plant, the safe load is shown

From the analysis, it is clear that the stress developed in the banana plant, when it is tied, is much lower than the stress at failure. Thus, the banana plant will be able to withstand high magnitude wind loads, if it is

tied properly around its periphery (Figure.3.19), with a tie force of 170.92 N.

## 3.16 Design of banana rope for a network of banana plants in a row

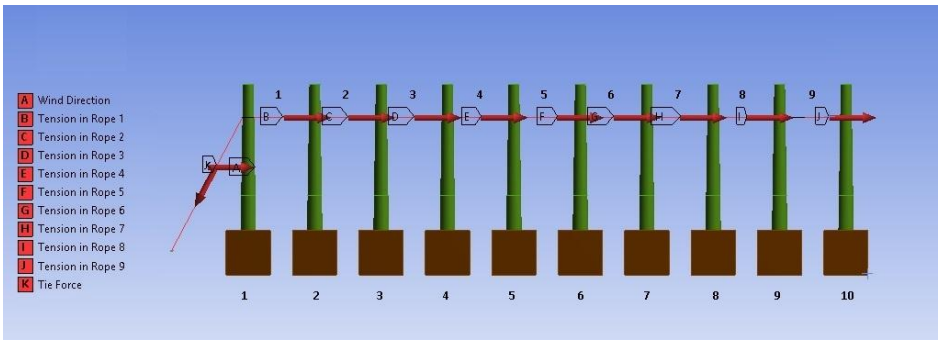


**Fig. 3.20:** Network of 10 banana plants in a row

Consider a network of 10 banana plants in a row. The banana plants are tied to each other using horizontal ropes as shown in Figure.3.20. This tie network is finally anchored to the ground by an inclined rope, with an angle of inclination of $60^{o}$ with the horizontal. Let the banana plants be numbered, 1 to 10 and the horizontal ropes be numbered, 1 to 9 from left to right.

From the analysis done on a single banana plant in the earlier Sections, it is found that, when wind of magnitude 8.8 m/s blows over the plant, failure occurs. It is seen that, at this wind velocity, the banana plant develops a flexural stress of 0.24 MPa (which is approximately

equal to the failure stress). With the application of a small force in the direction opposite to that of the wind, the stress developed in the banana plant can be reduced to less than the failure stress (0.23 MPa). This can be achieved by using a tie.

The tension in the horizontal rope 9 will be equal to the sum of horizontal components of forces acting on the banana plant 10. This includes the wind load, fruit bunch load and the wind load on the leaf.

With reference to Section 2.1.4, the wind pressure of 45 Pa is acting on the banana plant. The surface area of the banana plant is obtained as 3.068 $m^2$.

Therefore, Force = Pressure × Area
= 45 × 3.068
= 138.06 N.

The fruit bunch load is equal to 147.15 N which is acting at an angle $10^o$ with the vertical. The horizontal component of this force is equal to 147.15 × sin (10) = 25.55 N. Also the wind load on the leaves is equal to 10.15 N, acting in the horizontal direction.

Thus the sum of horizontal components of these forces is equal to 138.06 + 25.55 + 10.15 = 173.76 N. This force will be acting on the banana plant 10 and the rope 9 should be able to withstand this tensile force.

Again the tension developed in the rope adjacent to rope 9 (i.e. rope 8) will be equal to 173.76 + 173.76 = 347.52 N. The tension on each rope can be calculated in this manner. Thus the total horizontal force acting on banana plant 1 will be equal to 173.76 x 10 = 1737.6 N.

The banana plant on the extreme left (banana plant 1) will be subjected to a load of 1737.6 N, horizontally. So the rope tied to the ground should be designed to withstand this force.

The failure stress, $\sigma_{max}$, for the banana rope (Dry type) was obtained as 12.09 MPa.

Considering a factor of safety, FOS=2, the permissible stress is given as,

$$\sigma_{per} = \frac{12.09}{2} = 6.045\ MPa.$$

$$\text{But, } \sigma_{max} = \frac{F}{A}$$

$$F = \frac{1737.6}{\cos 60} = 3475.2\ N$$

So, the area of cross section of the rope, $A = \dfrac{F}{\sigma_{max}}$

$$= \frac{3475.2}{6.045}$$

$$= 574.9 \text{ mm}^2$$

Therefore, the diameter of the rope, d = 27 mm

Thus, banana rope of 27 mm diameter is enough to successfully tie the network of 10 plants in a row. It may be noted that the ultimate tensile stress in banana rope is calculated with a 6 mm diameter rope in the laboratory and a factor of safety of 2 was applied during design. When banana ropes would be manufactured with good workmanship, ropes of better tensile strength could be produced and the factor of safety may be reduced to 1.5.

The outcome of this Section is a sample design of banana fibre rope for tying banana plants. The diameter of banana fibre ropes, as obtained above is to support 10 banana plants when a wind velocity of 8.8 m/s blows and the horizontal pull offered by all the plants are borne by the tie at the end (connected to the primary support). Diameter required for banana fibre ties can thus be found out with the knowledge of the permissible tensile stress in the material through result of tension test and all possible forces acting on the plants. Hence, the diameter of the tie member is set as a variable in this disclosure and it would be optimised through structural design, depending upon the exposure conditions and wind velocity in the plantations and the availability of the tie material.

## 3.17 Stress concentration developed in the region around tie band while using Nylon-6 rope

The purpose of this Section is to compare the tying system found in other systems. Consider the case of a single banana plant, tied to the

ground at $60^{o}$ inclination. The main aim of this tie is to prevent deflection of the plant and to restrict the stress developed to safe limits. The tensile force on the tie increases with increase in the load on the banana plant. A parametric study on a single banana plant with wind load of 8.8 m/s was carried out, with tie force as the input parameter and the resulting deflection as the output. The results suggest that if the tie develops a force of 410 N, the deflection ceases.

Nylon-6 is having a young's modulus of 2.63 GPa*(Lab experiment, Polymer science & Rubber Technology department, Cochin University of Science & Technology)* and can be considered inextensible. When using Nylon-6 of diameter 6 mm, as the material for tie band that is wrapped around the banana plant, and the application of tie force of 410 N, the stress developed in the region around the band is obtained as 0.5 MPa (Figure.3.21). This happens with the presence of a small but possible crack in the region (generated due to the non-expandable nature of the nylon tie band). It may be noted that the failure stress of banana plant is 0.23 MPa. Thus the use of Nylon-6 increases stress and concentration of stress near flaws, especially in the region around the tie and this eventually would lead to shear or bending failure of the banana plant.

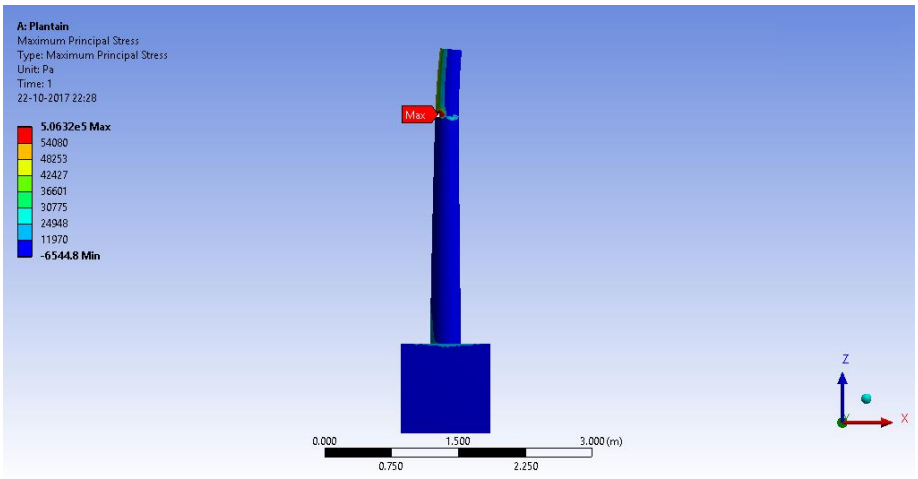


**Fig. 3.21:** Flexural stress contour in the banana plant using Nylon-6 as the tie material

## 3.18 Conclusion and Future work

The PANS as discussed herein is formed from a careful study of the strength and stability characteristics of typical flexi plants such as banana plants herein after flexi plants are referred to but not limited to banana plant. Experimental investigation of banana plant stem revealed the following properties: Young's modulus 4 to 25MPa, Flexure strength 0.5 to 1MPa and Poisson's ratio, 0.05.

From the numerical analysis using FEA software on a banana plant with a tie, it is clear that the stress developed in the banana plant is much lower than the stress at failure when there are no ties. Thus, the banana plant will be able to withstand high magnitude wind loads if it is tied properly around its periphery.

The pattern and strength of the towing system are decided based on the experimental result of the mechanical properties of banana plants, tensile strength of banana fibre ties and explored possibilities practical implementation of the towing system in the fields. The capability of the proposed towing system to prevent any sort of failure of banana plants or flexi tress is justified. This kind of an arrangement not only prevents uprooting of the plants but avoids any chance of flexural or buckling failure by adjusting the fruit bunch load, wind forces and self-weight of plants via the tension in the steel hooks. Preferably, the PANS would comprise of a connection from the primary support to the banana plants which are planted 0.9 m to 1.5 m apart. The PANS could connect a minimum of four adjacent banana plants. The flexible connection member connected to the banana plant can be adjusted as per requirement so that it would not cause any damage to the banana plants. The PANS is effective once the banana plant grow to a specific height or the age of the plants reaching 3 to 5 months, approximately.

The following are the salient advantages of the present disclosure:

- The PANS is a connected system and hence provides modular functionality.
- The PANS has simple looping design and the flexible connecting member is made of eco-friendly and user-friendly material and hence reusable, easily bio-degradable, cost-efficient and durable.

- The steel hooks in the Anchorage System (AS) can be used to tie single or many banana plants.
- The PANS use looping of the flexible connecting members and hence avoid any wear and tear of the plant.
- The PANS provides better performance in comparison to other such techniques.
- In PANS, any number of ropes can be tied to any position of the adjustable (diameter) tying member around the circumference of the banana plant.

In light of the above-mentioned advantages, the PANS results into a whole new employability. In future different varieties of Banana Plants, various flexi-trees, under different soil conditions and varying wind force can be analysed.

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# Procedure II

## Design and Development of a Model Knowledge Based System for Diagnosing Diseases in Banana Plants, after verification of the knowledge

*M B Santosh Kumar, Renumol V G, B Kannan, "Design and Development of a Knowledge Based System for Diagnosing Diseases in Banana Plants", 1st International Conference on Latest Advances in Machine learning and DAta Science", Advances in Intelligent Systems and Computing, Springer, (Accepted).*

Chapter 4

# DESIGN AND DEVELOPMENT OF A MODEL KNOWLEDGE BASED SYSTEM FOR DIAGNOSING DISEASES IN BANANA PLANTS

Contents



## 4.1 Introduction

The knowledge received from the agricultural experts and the expert farmers have to be verified before being used by the farmers. In this study banana farmers are focused and it is usually difficult to identify and treat various diseases in Banana Plants (BP) because it demands a wide spectrum of knowledge. Moreover this knowledge is tacit and not readily available to farmers. This situation motivated the authors to design and develop a technology-assisted Knowledge Base (KB) system for farmers. As a preliminary step towards building a KB, a set of images of diseases in BP were taken from the manual prepared by Vegetable and Fruit Promotion Council Keralam (VFPCK). These sets of images were used to collect data from agricultural experts and

experienced farmers on various diseases of BP, their symptoms and remedies. The data was collected from the participants by conducting semi-structured interview and then analyzed to design the KB system. Since the diagnosis of diseases was a subjective process, the inter-rater reliability check was done on the data, using Cohen's Kappa method and found reliable. Then using this data, a KB system has been designed and developed as a mobile application named as 'Ban-Dis'. An initial usability study has been conducted among a few farmers and their feedback has been recorded. The KB system would be more beneficial as indicated by the farmers if the interface were in regional language.

## 4.2 Expert System

An Expert System is an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require human expertise for their solution. The knowledge necessary to perform at such a level plus the inference procedures used can be thought of as a model of the expertise of the best practitioners in the field. Expert system is designed to simulate the problem-solving behavior of a human who is an expert in a domain or discipline. An expert system is normally composed of a knowledge base (information, heuristics, etc.), inference engine (analyzes the knowledge base), and the end user interface (accepting inputs, generating outputs) [1]. The path that leads to the development of expert systems is different from

that of conventional programming techniques. The concepts for expert system development come from the subject domain of artificial intelligence (AI), and require a departure from conventional computing practices and programming techniques. A conventional program consists of an algorithmic process to reach a specific result. An AI program is made up of a knowledge base and a procedure to infer an answer. One of the most powerful attributes of expert system is the ability to explain reasoning. Since, the system remembers its logical chain of reasoning, a user may ask for an explanation of a recommendation and the system will display the factors it considered in providing a particular recommendation [2].

Banana plant was supposed to be originated from South-East Asia and has been cultivated for more than ten thousand years [3]. The first traces were found to be in Papua New Guinea [4], which date back to seven thousand BC. This belongs to monocotyledon class and musaceae family. Natural Banana crops have been produced with lot of nutritional qualities for human [5]. As time passed by, the varieties of banana have been moved due to human migration, initially from South-East Asia and Papua New Guinea towards Indian subcontinent [6]. A survey of various Expert Systems in agriculture shown in the Table.4.1 below.

**Table 4.1:** Details of Expert System

| Sl No | Name of ES | Subject/ Crop | Year | Details ES |
|---|---|---|---|---|
| 1 | POMME | Apple | 1985 | The system provides advice regarding specific pest management, treatment of winter injuries, drought control and general pesticide selection[7] |
| 2 | COMAX | Cotton | 1986 | Comax determines the best strategy for irrigating, applying fertilizer, and applying defoliants and cotton boll openers.[8] |
| 3 | Expert | Cotton | 1986 | Management recommendations [8] |
| 4 | GOSSYM | Farm | 1988 | Gossym simulates the growth and development of the entire cotton plant on an organ. [9] |
| 5 | PLANT/DSS | Soyabean | 1990 | Diagnosis of diseases [10] |
| 6 | The PENN | Apple | 1992 | Pest management and chemical [11] |
| 7 | CALEX | Agriculture | 1992 | This shell provides for efficient data entry and management and permits the integration of information from a variety of sources to develop crop management guidelines. [12] |
| 8 | Rice Crop Doctor | Rice | 1995 | To diagnose pests and diseases for rice crop management [13] |
| 9 | SOYPEST | Soyabean | 2002 | To solve the farmer's queries related to pest diagnosis and management [14]. |
| 10 | Agriculture Land Suitability Evaluator (ALSE) | | 2013 | Land suitability for different crops in tropical and sub tropical region [15] |
| 11 | AGREX | Paddy, Fruits and Vegetables | 2014 | To give timely and correct advice to the farmers about fertilizer application crop protection, irrigation scheduling, diagnosis of diseases Harvest and technology [16] |
| 12 | A trait based approach to explain weed species response to agriculture practices in a simulation with a crazing system model. | Weed growth monitoring | 2014 | Uses a cropping system model to evaluate the potential impacts of modified agriculture practices. Ex ante on weeds. [17] |
| 13 | Define eco-efficient crop rotation using life cycle assessment of crop combination | Crop rotation, Nitrogen Fertilizers | 2015 | Nitrogen Management is a key device for the environmental impacts. [18] |
| 14 | Development of rice cultivation management ES based of fess | Rice Cultivation | 2016 | Development of AES which can provide for producing quantitative analyze of rice cultivation process managing methods [19] |
| 15 | Expert based model building to quantify risk factors in a combined agriculture – agriculture system | Integrated Farming | 2017 | Production of crops revolved around soil and water quantity [20] |

The production cycle for a normal banana plant is approximately 9 to 12 months depending on the climatic zones. The bunch of the banana plants depend on the flowering and cutting time. The difference in size of the plants depends on the area of production and altitude of the plantation [21]. The genetic diversity of the banana plants is mainly due to the combination of natural reproduction and human selection.

In 2013, the world banana production was around 220 million tonnes, of which 40% were cooking banana varieties and 60% were dessert banana varieties. A survey on world banana production was conducted by Lescot T. and Charles S. and their finding are shown in Fig.4.1.

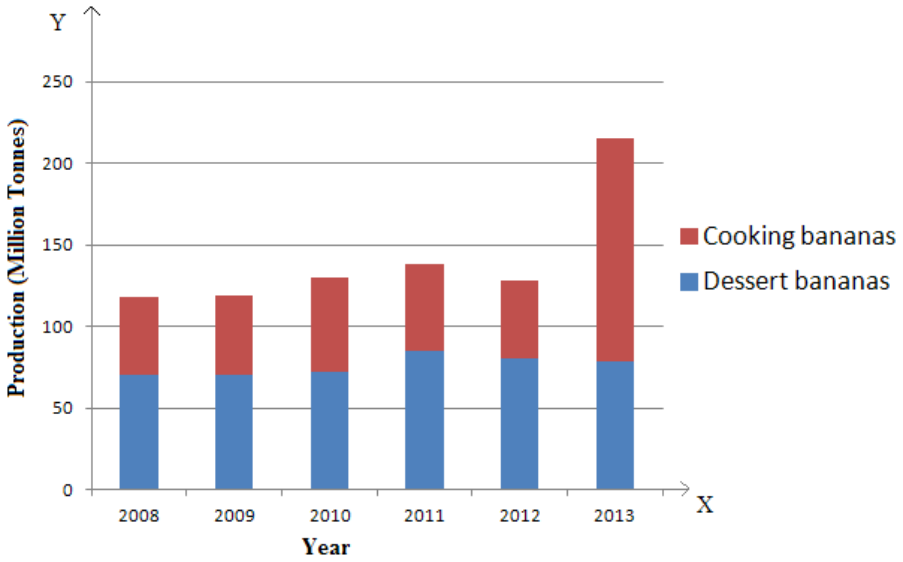



**Fig. 4.1:** World banana production in million tonnes [22]

The banana cultivators are nowadays present across the globe. The main production zones are located in Asia which represents approximately 45% of the world volume followed by Africa (about 25%) and the remaining in the South and Central America. From the Table 4.2 given below, it is observed that India is the largest producer of banana [23].

**Table 4.2:** Top 10 countries in banana production (dessert and cooking) in tonnes as on 2013 [21]

| | **Dessert bananas (Tonnes)** | **Cooking bananas (Tonnes)** | **Total production (Tonnes)** |
|---|---|---|---|
| **World total** | **78860773** | **54831192** | **133691995** |
| India | 17075000 | 10500000 | 27575000 |
| China | 11506238 | 569000 | 12075238 |
| Uganda | 500000 | 8426308 | 8926308 |
| Philippines | 5790091 | 2855658 | 8645749 |
| Brazil | 6402622 | 490000 | 6892622 |
| Ecuador | 6145527 | 594212 | 6739739 |
| Colombia | 2587625 | 2817740 | 5405365 |
| Indonesia | 3289115 | 2070000 | 5359115 |
| Rwanda | 250000 | 3013462 | 3263462 |
| Nigeria | 315000 | 2907000 | 3222000 |

## 4.3. Losses in BP due to diseases

Lot of diseases that affect banana plants exists. A study conducted by Vegetable and Fruit Promotion Council Keralam (VFPCK) identified

19 common diseases affecting BP [24]. The most harmful is the fungus-induced disease namely Sigatoka and Banana Wilt [25]. The diseases appear in the form of black streaks which destroys the leaves. Banana Wilt or Panama disease is caused mainly by soil and root fungus. This fungus normally remains in the soil for more than 30 years. Pests such as Nematodes or Black Banana Weevil disrupt the plant growth and topple it down. There are bacterial diseases such as Moko disease that is spread through the soil, plantation tools or by other insects. There are viral diseases such as Mosaic or Bunchy Top which cause, losses to both commercial and village plantation. Thus there is a need for identifying the various diseases affecting the banana plants and come up with a remedial measure depending on the symptoms of the diseases. However, farmers find it difficult to diagnose and take remedial measures to protect their BP in time.

Banana ranks fourth as the world's most important starch crop after cassava and sweet potatoes since its yields of carbohydrates per unit area are very high. It is the fourth most widely-grown food crop after rice, wheat and maize [26]. It is an important staple food in many Asian countries including India. Unfortunately, banana production has been on the decline nowadays. This can be attributed to a number of factors such as poor crop production and management practices, pests, diseases, declining soil fertility etc. [27].

Overall, pests and diseases pose a serious threat to banana production. Some banana cultivators have been severely damaged by a wide range of pests and diseases, resulting in heavy yield losses. The important and widespread diseases include black and yellow Sigatoka leaf spots, cigar end rot, banana bunchy top virus disease, and post-harvest diseases. Banana thrips, nematodes and the banana weevil are among the most important pests of banana in most banana growing regions. Yield losses in highlands are mainly due to weevil [28]. To a great extent it is the ability of the farmers to identify pests and diseases affecting bananas. Normally Farmers are empowered to check the occurrence of the pests and diagnose the diseases at the initial stage itself so that the spread of the pests and disease to the crop can be avoided [29]. However, banana farmers usually find it difficult to identify and treat various diseases in Banana Plants (BP) because it demands a wide spectrum of knowledge. Moreover this knowledge is tacit and not readily available to farmers. These situations motivated to design and develop a technology-assisted Knowledge Base (KB) system for farmers.

Kerala Agricultural University website [30] and various other portals have come up with different methods [31] to protect the banana plants. But the farmers in the field located in remote areas do not get access to such training which is normally conducted at the centres situated in the town limits. The knowledge imparted to these farmers by the agricultural experts may not be completely understood by the

farmers. There also exists a lot of traditional knowledge [32] to identify and rectify various BP diseases. However due to change in the climatic conditions there are chances for the traditional remedies not to work properly in banana plant cultivation.

## 4.4 Design and development of the Knowledge Based System

There were different Small Agricultural Groups (SAGs) in every panchayath of every districts of Kerala (a state in India). These SAGs consist of 4 to 14 farmers, which are headed by an SAG leader. These SAG leaders get training on various precautionary steps to be taken when the agricultural products get infected with various diseases. The training to the SAG leaders is mainly given by the Vegetable and Fruit Promotion Council Keralam (VFPCK), Central Plantation Crops Research Institute (CPCRI), Agricultural Experts etc. from government and non-government organizations.

Thus the need for the development of some technology-assisted tool is very relevant and need of the hour. The availability and accessibility of the tool is considered for designing and developing it. The farmers who have no access to the computers or ipads should also get access to this tool. Hence it has been decided to develop an Android App which can be accessed through their Smartphone. The architecture of the application is given in Fig.4.2. There are three major components - The Graphical User Interface (GUI), the Inference Engine [33] and the Knowledge Base (KB). The inference engine builds up an expert

reasoning model to infer the new information by combining, the matter-of-fact stored in working memory with instructions.

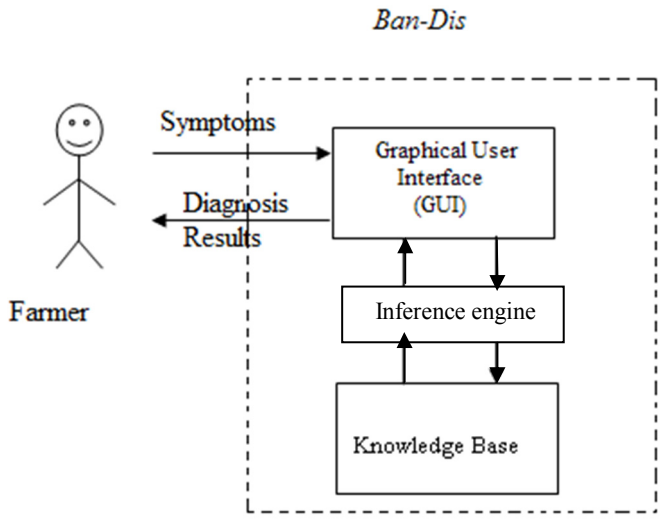



**Fig. 4.2:** Architecture of Mobile App

The GUI was designed as a simple window, where farmers can select the symptoms as input to the system. Accordingly the system will display the name of the disease. Then the farmer can click the 'remedy' button to get the solution steps. In order to develop the knowledge base part, a semi-structured interview was conducted among agricultural experts and experienced farmers. Their knowledge on BP diseases, related symptoms and remedies has been collected. This data was used to build a Knowledge Base.

It was decided to delegate one of the authors for conducting the interview. Authors identified a set of experienced farmers and agricultural experts as participants for the semi-structured interview. Before going to the field for data collection, the interviewer conducted a

study on various diseases in BP and their symptoms by referring the existing literatures [34] [35] [36] [37]. This awareness helped the interviewer to conduct the interview effectively. A set of interview questions were prepared to collect data on various diseases from the agricultural experts and experienced farmers. The quality and reliability of the data collected to a great extent depends on how effectively the data collecting procedures was conducted. Hence the following measures were taken to increase the quality of the data collected:

- Properly explaining the main objective of the interview to the participants and the importance of giving correct answers.
- Casual way of collecting the data without revealing the details of the participants.
- Keeping the data collected confidentially and using the data for academic and research purpose only.
- Allowing the participants to express will-fully and sincerely without any compulsion.

The interviewer collected images of 19 diseases of banana plant from a manual published by Vegetable and Fruit Promotion Council Keralam (VFPCK) [24]. All the nineteen diseases which indicated the most prominent diseases in BP were numbered and arranged sequentially. A data sheet with the 19 images of the diseases as shown in the Table 4.3 is given to the participants.

**Table 4.3:** Format for collecting data from participants

| Sl No | Image of diseases | Name of diseases | Symptom of diseases | Remedial Measures |
|---|---|---|---|---|
| 1 |  | <Filled during interview> | <Filled during interview> | <Filled during interview> |
| 2 |  | …….. | …….. | …….. |
| | | …….. | …….. | …….. |
| | | …….. | …….. | …….. |
| | | …….. | …….. | …….. |
| | …….. | | | |
| | …….. | | | |
| | …….. | …….. | …….. | …….. |
| 19 |  | …….. | …….. | …….. |

During the data collection, the interviewer showed the data sheet to the participants and prompted them to identify the diseases. The interviewer also asked to suggest the common symptoms for each disease and the remedies. It was a semi-structured interview, so the interviewer interfered in between to collect more information while conducting the interview. The entire conversation was recorded as audio files.

The data were collected from two districts of Kerala namely Kochi and Trichur, since these two districts were easily accessible and closer to the location of the researchers. It took around two hours for interviewing each participant. Feedbacks from a total of five participants were collected, of which two were agricultural experts (AE) from the VFPCK and the other three were experienced farmers (EF). The details of the participants are shown in Table 4.4.

**Table 4.4**: Details of Participants

| Participant | Age | Qualification | Experience in years |
|---|---|---|---|
| 1(AE1) | 47 | Post Graduate | 10 |
| 2(AE2) | 38 | Post Graduate | 7 |
| 3(EF1) | 65 | $10^{th}$ grade | 22 |
| 4(EF2) | 62 | $10^{th}$ grade | 20 |
| 5(EF3) | 58 | $8^{th}$ grade | 18 |

When the data has been analyzed, it was noticed that the participants identified most of the diseases identically, but in few cases, the same image has been identified as different diseases by the participants. Moreover, the farmers' knowledge about the diseases was comparatively lesser than experts. They could not identify all the diseases and they were ignorant on their symptoms and remedies. This indicates that the farmers are not much knowledgeable about the diseases in banana plants. Table 4.5 shows the difference in the names suggested by the agricultural experts and experienced farmers after observing the image.

**Table 4.5.** Name of the diseases suggested by Agricultural experts and Experienced Farmers by observing the image

| Sl No | Image | Name of the diseases identified by | | | | |
|---|---|---|---|---|---|---|
| | | AE1 | AE2 | EF1 | EF2 | EF3 |
| 1 |  | MANAVANDU (Cosmopolites sordidus) | MANAVANDU | MANAVANDU | MANAVANDU | VELLA KOOMP |
| 2 |  | THADA THURAPPAN (Odoiporus longicollis) | PINDI PUZHU | THADATHURAPPAN | PINDI PUZHU | CHELLU |
| 3 |  | VAZHA PEEN (Pentalonia nigronervosa) | VAZHA PEEN | VAZHA PEEN | VAZHA PEEN | Not Commented (NC) |
| 4 |  | ILATHEENI PUZHUKKAL | PUZHU | PATTALA PUZHU | PUZHU | NC |

Table 4.5 continued

| | | | | | | |
|---|---|---|---|---|---|---|
| 5A |  | NIMA VIRA (Radopholus similis) | NEMATODE (NIMA VIRA) | NC | NIMA VIRA | NIMA VIRA |
| B |  | VERUMEELI MOOTTA (Geococcus spp) | NC | NC | NC | NC |
| 6 |  | MANDARI VELLICHA | MANDARI NC | MANDARI NC | MANDARI (MITES) NC | MANDARI NC |
| 7 |  | KURUNAMBU (Banana bunchy top virus) | KOOMBADAPPU | KOOMBADAPPU | NC | NC |
| 8 |  | COCCANE VIRUS (Banana bract mosaic virus) | COCCANE | COCCANE VIRUS | COCCANE | COCCANE |

Table 4.5 continued

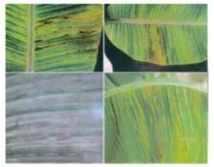
| | | | | | | |
|---|---|---|---|---|---|---|
| 9 |  | MOSAIC ROGAM (Cucumber mosaic virus) | MOSAIC ROGAM | MOSAIC ROGAM | NC | NC |
| 10 |  | STREAK ROGAM | STREAK ROGAM | NC | STREAK ROGAM | STREAK ROGAM |
| 11 |  | PANAMA VATTAM | PANAMA VATTAM | NC | PANAMA VATTAM | PANAMA VATTAM |
| 12 |  | ELAPPULLI ROGAM | SIGATO LEAF | ELAPPULLI ROGAM | ELAPPULLI ROGAM | ELAPPULLI ROGAM |
| 13 |  | KADACHEEYAL | MANAM AZHUKAL (KOOMBU CHEEYAL) | NC | KADACHEEYAL | KADACHEEYAL |

Table 4.5 continued

| | | | | | | |
|---|---|---|---|---|---|---|
| 14 |  | CIGAR END ROT | CIGAR END ROT | CIGAR END ROT | CIGAR END ROT | CIGAR END ROT (CHUND POLLAL) |
| 15 |  | BORON DEFICIENCY | BORON DEFICIENCY | BORON DEFICIENCY | BORON DEFICIENCY | BORON DEFICIENCY |
| 16 |  | POTTASSIUM DEFFICIENCY | POTTASSIUM DEFFICIENCY | NC | POTTASSIUM DEFFICIENCY | NC |
| 17 |  | CALCIUM DEFFICIENCY | CALCIUM DEFFICIENCY | NC | NC | NC |

Table 4.5 continued

| | | | | | | |
|---|---|---|---|---|---|---|
| 18 |  | MAGNESIUM DEFFICIENCY | NC | NC | MAGNESIUM DEFFICIENCY | |
| 19 |  | VELLAKOOMBU AND VAZHAPPANI | KOOMBADACHIL AND VAZHAPANI | KOOMBU VELUTH THALLAL AND VAZHAPPANI | NC | NC |

In this study data was taken from two agricultural experts and three experienced farmers. These participants identified the diseases, symptoms and suggested remedial measures independently. Since this is a subjective process, the interviewer decided to calculate the inter-rater reliability using Cohen's Kappa method [38]. The answers from the participants were coded as shown in Table 4.6. The entry '1' indicates mutual agreement and '2' indicates disagreement.

**Table 4.6**: Coded feedback from the participants which is given as input to SPSS tool

| | **Name of Disease** | | | | | **Symptoms** | | | | | **Remedies** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **AE 1** | **AE 2** | **EF 1** | **EF 2** | **EF 3** | **AE 1** | **AE 2** | **EF 1** | **EF 2** | **EF 3** | **AE 1** | **AE 2** | **EF 1** | **EF 2** | **EF 3** |
| **1** | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **2** | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 |
| **3** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **4** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **5** | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **6** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **7** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **8** | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **9** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| **10** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 |
| **11** | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 |
| **12** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **13** | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **14** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **15** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **16** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **17** | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 2 |
| **18** | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 2 | 1 | 2 |
| **19** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |

The above table was fed to the Statistical Package for Social Sciences (SPSS) tool and the Table 4.7 indicates the values of Cohen's Kappa for three categories namely:

- Expert 1 Vs Expert 2
- Farmer 1 Vs Farmer 2
- Expert 1 Vs Farmer 1

**Table 4.7:** Coefficient of inter-rater reliability (Cohen's Kappa) between the participants

| Sl. No. | Category | K value for Diseases | K value for Symptoms | K value for Remedies |
|---|---|---|---|---|
| 1 | Expert 1 Vs Expert 2 | 0.826 | 0.732 | 0.776 |
| 2 | Farmer 1 Vs Farmer 2 | 0.872 | 0.890 | 0.895 |
| 3 | Expert 1 Vs Farmer 1 | 0.578 | 0.537 | 0.587 |

The values of inter-rater reliability, Cohen's Kappa (*K*) between Expert1 and Expert2 with reference to the name of diseases, symptoms and remedial measures were found to be greater than 0.7, which indicates that the results are reliable. Also the *K* values for Farmer1 Vs Farmer2 were greater than 0.7, which again indicates that the values are reliable. Whereas the Cohen's Kappa value for Expert1 Vs Farmer1 was less (<0.7) when compared to the other two values which indicates that there is a mismatch in the knowledge level between farmers and experts in this area. Thus this study reveals that the knowledge of the agricultural experts from VFPCK is more reliable than the experienced farmers. Thus the knowledge base was built mainly using the data collected from agricultural experts. A set of rules are incorporated in the knowledge base normally IF…THEN. In Agri Knowledge Management System select the category if it is fruits or

vegetables. If fruits, then banana, jackfruit, grapes… If banana is selected, check for the symptoms for the diseases in leaf. For example, if the leaf color is yellow, the disease will be panama wilt. Similarly symptoms for 19 diseases are identified and the rule based system is designed. An android-based mobile app named as 'Ban-Dis' has been developed using this knowledge base. Using this application, banana farmers can identify the diseases and come up with the required remedial measures based on the type of symptoms exhibited. When farmers enter the symptoms of the diseases, the tool provides the accurate analysis of the diseases along with some images and pops up the desired remedies. The app can be downloaded from the web-link http://nss.cusat.ac.in/goorganic/home.php. This can be installed in any Android mobile. A website is also available at http://indianrupeeservices.in/diseases/.

An initial usability study has been conducted among a few farmers and their feedback has been recorded. The study results are promising and warrant further enhancements to the systems. The KB system would be more beneficial as indicated by the farmers if the interface were in regional language. They also suggested incorporating different input modes such as audio, text, image etc.

## 4.5 Conclusion and Future Work

Banana farmers usually face problems in diagnosing and solving diseases in BP. Hence the study focused to build a knowledge-based

system to help farmers. The data, to build the required knowledge base for the system, was collected from agricultural experts and experienced farmers. The reliability of the collected data was found out by using Cohen's Kappa inter-rater reliability. An Android App named as 'Ban-Dis' was designed and developed by using this reliable knowledge. With the help of this app, farmers can easily diagnose the disease and get remedial measures. An initial usability study has been conducted among a few farmers and their feedbacks are encouraging and warrant further enhancements to the system. Some of the future modifications to the system can be done by incorporating regional languages, user-input in multimodality etc. The same system can be used for some other crops by replacing the knowledge in the knowledge base accordingly.

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Procedure III

## A Model Knowledge Based System for Exchanging Agricultural Knowledge

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Chapter 5

# A MODEL KNOWLEDGE BASED SYSTEM FOR EXCHANGING AGRICULTURAL KNOWLEDGE

Contents



## 5.1 Introduction

It is highly essential to preserve traditional agricultural methods which have been followed by farmers for decades. By using Modern technology we tried to extend the possibility of preserving these kinds of knowledge. Knowledge based systems is used for preserving and exchanging knowledge for various applications. This chapter focus on development of a model of knowledge based system for exchanging traditional agricultural knowledge. Apart from the conventional

knowledge type, agricultural knowledge based system should have a capacity to keep knowledge which are in multimedia format. The proposed model aims to fulfill these objectives by incorporating knowledge of such types for effective knowledge preservation and exchange. The model constructed is based on the study conducted on two different banana farm fields in different geographical locations of Kerala.

## 5.2 Need for such a model

The objective is to study the transfer of agricultural knowledge from an inter-agricultural farm point of view i.e., mainly transfer of knowledge between farmers in one location to another location. Argote et al; 2003 has expressed his view that knowledge can be transferred from one organization to another [1].

Agri-knowledge exchange is considered as an interactive process in which the knowledge is collected, stored and transferred from one location with the help of technology to another location. Many models were proposed by Bozeman et al; 20015 [2]. Knowledge transfer is the process to impart the success and goal achieved in one location to another. Transferring Technology is a process oriented interface between two entities, which can be shared and used mutually as indicated by Argote and Ingram; [3]. Lot of effort is involved in imparting such knowledge, where the knowledge used in one location is not suitable in

another. Hence the main objective is to increase the utility and productivity of agriculture by using the knowledge which is inherited by the farmers from different locations.

## 5.3 Related work

There is a need for the dissemination of agricultural information through the usage of information technology to bring about a marginal change in the field of agriculture and the rural development in terms of usage of technology, reduced cost, high storage capacity etc.[4][5][6][7]. Initially information technology systems in agriculture have a limited impact to date, but increasing pressures on agriculture and recent technological developments have created a situation for radical change. Multimedia teaching and learning aids can also be used in the field of agriculture to impart various knowledge [8]. With the advent of ICT the technology and communication have improved a lot even among the farmers [9].

### 5.3.1 Entities involved in knowledge transfer

Riesman; 2005 [10] have suggested that there are three main categories of actors who are involved in knowledge transfer mainly the suppliers, research centers and consultants. In our study many activities are involved in the process of knowledge transfer from the Initial Location (IL)/Source location to the sink/ destination. In between these two entities Initial Location and sink is the intermediaries. For example:

for a knowledge transfer from the Initial location to the sink, many intermediaries like SAG (small agricultural group), VFPCK (Vegetable and Fruit Promotion Council Keralam) officials, Agricultural experts, experienced farmers and many others were involved. Many a times, opinion of the agricultural experts from Agricultural Universities were also obtained and also the innovative ideas/concepts adopted or proposed by the farmers are also identified. Chesbrough [11] proposed an internet technology and open source software for this purpose and recorded with the consent of the farmers. Farmers have problem in communicating the knowledge they have acquired either traditionally or through their experience. Amesse ad cohendert [12], has pointed out this very clearly stating that the emitting capacity from an initial location depends on the technological, organizational and cultural skills .Difficulty was faced in acquiring the knowledge from farmers due to different terminology used by farmers in different parts of the Kerala State itself. Although CPCRI (Central Plantation Crops Research Institute) gives training to the farmers, the farmers lack communication skills to express and understand the content of the training. The farmers come up with lot of innovative ideas and techniques, but there is no tool to check the authenticity of these. Autio et al [13], has mentioned about the technological capabilities like the technical capacity, managing technical system and the ability to get adapted to the specific needs of the recipient .The farmers in different parts of the state of Kerala were

either following farming techniques inherited from their ancestors or through trainings from VFPCK/CPCRI. Crossan et al [14], has suggested that the performance of the individuals, knowledge acquisition and knowledge transfer can be enhanced if there is a proper routine for performing it. This study tried to focus on these aspects.

### 5.3.2 Barriers in Knowledge Transfer Process

Farmers face lot of barriers while transferring knowledge, due to lack of confidence in what they are expressing and the terminology used for different farming processes. Dougherty & Hardy [15], suggests that there are a lot of barriers involved in the knowledge exchange process like trust, communication and the distance between the source and sink.

So normally while acquiring the knowledge from farmers, we have to trust in what they express and convey. Multimedia recordings were done with the consent of the farmers, so as to ensure the originality of the knowledge and build trust. Amesse and Cohedet [16] has pointed out that trust can be established if there is a strong reciprocity between the initial location and the destination.

Farmer's prior knowledge about the various new techniques of preserving and cultivation of plants (banana) helps to recall the techniques they have inherited from their ancestors and use the knowledge appropriately. Most of the farmers were very positive to impart the knowledge when they were conveyed that this study was for

research purpose and for the betterment of the farmers at other location and vice-versa. Cohen & Levinthal [17] has correctly pointed out that the absorptive capacity is actually the result of knowledge accumulation process and the ability to innovate.

Cummins and Teng [18], has remarked that as a relational factor of interest, distance between parties i.e. the source and the destination is very important. The geographical distance for transferring knowledge is not a problem. The knowledge acquired from one location can be conveyed to farmers at another location. The multimedia (audio/ video) helps the famers at remote site to view and analyse the knowledge used by the farmers at different locations.

The farmers at sink/ destinations who propose to use such knowledge normally believe and trust the knowledge they get for reference through the website. Inkpen [19], has defined 'trust' as that reflects the belief that the words or promise of a partner is reliable and the partner fulfils it. To establish a strong trust between the Initial Location (IL) and sink/destination it is essential to give a feedback from the farmers who are using the knowledge for their agricultural purpose. We found from the field that most of the farmers were motivated and very enthusiastic if such applications are available within their reach. Davenport and Prusak [20], correctly indicated that the reputations of the source is reflected in the perception of the willingness to share knowledge.

If farmers from different locations express their ideas and help to acquire and transfer the knowledge they possess, then such a system will be very effective and useful for the farmers and the farming community. Hansen [21], has indicated that the relationship plays a prominent role in improving the processing capacity of data and this allows effective flow of knowledge. Similarly in our case a centralized server will help to store and retrieve the information acquired by the farmer. According to Van Wijk et. al [22], a central location creates a mediating position and allows exchange of knowledge. The awareness of relevant knowledge from Initial Location can be transferred to sink/ destination and vice versa, if there is a proper connectivity between the various technologies used by the farmers at different locations and controlled by a central location as mentioned by Tsai [23].

## 5.4 The Knowledge Base

The knowledge base is normally updated with new knowledge added either from the expert farmers or from the agriculture expert. The knowledge obtained from the farmers is tacit, which requires proper documentation so as to be stored in the Knowledge Base (KB). According to Uzzi [24], the empirical studies have indicated that tacit knowledge can more easily be transferred between organizations within a network than to new organization. Normally the Tacit knowledge of the farmers is more or less the same in a particular location for example:

it is same within the same Small Agricultural Groups (SAG). Galbrith [25] suggested that if the distance between the organizations is high, then slower and less effective will be the technology/knowledge transfer. But if the distance between the farmers is increased then the transfer of knowledge becomes less effective. Consider an example; the Knowledge used for protecting banana plant from heat in one location is not the same in another location, but the Multimedia (audio/video) demonstration makes it very effective to convey the actual knowledge.

If the Initial Location and the destination can understand and disseminate the same knowledge, then we can assume that the knowledge transferred is effective and useful. Now Non government Organizations (NGO) and other government bodies responsible for agriculture upliftment are given training so as to unify the knowledge used by farmers.

## 5.5 Intermediaries

Intermediaries are the third party actually involved in the process of technology/ transfer of knowledge and assume the role of facilitator between Initial Location and the sink/destination. The type of intermediaries depends on various factors, like the services provided, researchers, the area of cultivation, agri-consultants and so on. The intermediaries range from individuals to consultants and cater different areas of specialization according to Landry et al [26].

In this research, the intermediary include both government and non-government agencies, science and technology parks, research centers, science and technology departments etc. which helps to transfer the acquired knowledge from the farmers. Gilsing et al [27], points out that many private and public organizations are involved in the liaison work for the knowledge transfer. The knowledge abstracted from the farmers are gathered and effectively communicated to the knowledge base. Thus the role of intermediaries is very important for bridging the gap between the Initial Location and the sink.

## 5.6 Knowledge Transferring Process

Knowledge transferring process is 'epistemological'. Knowledge attained from the farmers regarding the farming techniques/diseases of plants can be transferred using various channels/mechanisms which are effective and efficient. For example: mobile apps, websites etc can be used to capture a picture and upload to the server. Therefore different types of technology and knowledge as indicted by Szulanski [28], is required to transfer knowledge from the Initial Location to sink. Even different types of technologies (Multimedia) can be integrated to such a system.

The traditional knowledge acquired according to Howells [29], can be either tacit (which can be expressed and transferable) or explicit (which can be documented and thus easier to get transferred). When we

discuss about technology transfer, it is not only a physical artifact but also gaining of knowledge by any individual and how well it can be used. Polanyi [30] expressed that tacit knowledge is non-verbalized, intuitive and unarticulated and very difficult to formalize and communicate. Tacit knowledge obtained from farmers is difficult to encode and transfer. This to a great extent depends on the farmer's characteristics and their policies of farming prevailing in that region. Such knowledge is very difficult to replicate as well. But in explicit knowledge, the farmers have made a note of the knowledge available by attending the seminars and conferences and they have proper documentation of such knowledge. Nonka [31] articulated that these two types of knowledge are mutually dependant on each other and together they reinforce the quality of knowledge transferred. The tacit knowledge which the farmer expresses helps to determine and interpret explicit knowledge.

## 5.7 Proposed Model for Knowledge Transfer

Many models are proposed by various researches to express an overview about knowledge transfer. Davenport & Prusak, Cummings & Teny [32] argues that tacit knowledge; experience of personals and skill of individuals represent a kind of knowledge with high degree of viscosity whereas from documents it is thin. Normally the knowledge transfer is from an Initial Location (IL) to sink (destination), by using

various technologies. In the study, the knowledge transfer is possible from sink/destination to Initial Location as well. For example: Knowledge transfer from one farm land to another farm land at a distant place and vice- versa.

### 5.7.1 Model Architecture

The fig.5.1 below indicates the model for agricultural knowledge transfer. The arrows indicate the flow of knowledge transfer from one part to another. The knowledge is transferred using different channel and different media (Multimedia).The design is done based on the feedback from AE/ Agricultural scientists /EF etc.

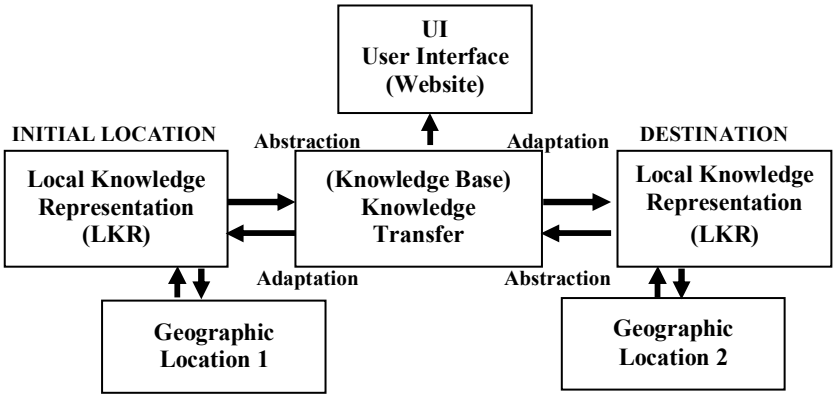


**Fig. 5.1:** Agriculture Knowledge Transfer Model (AKTM)

### 5.7.2 Initial Location and sink/destination

Malik [33] explains about a 'broadcasting model', where there is a sender, recipient and the message. Similarly knowledge transfer

originates from the Initial Location and imparting of knowledge to the sink/destination in our study**.** In this model as shown in the fig.5.1 above, the arrow is bidirectional; knowledge can be transferred from initial location to sink/destination and vice-versa. Currently there is no proper intermediary to transfer the traditional /tacit knowledge of one farmer to other. Liyanage [34] has proposed a model with two main actors, the source which shares the knowledge and the receiver which acquires it.

Kumar and Ganesh [35] have pointed out that when technology/ knowledge is transferred, their properties and characteristics will also be transferred. The knowledge or experience of the farmer from one site is transferred to other location, with the help of audio/image/video clippings (Multimedia).

The knowledge is transferred from the Initial Location to the destination with the help of the intermediaries. The audio/video files are stored in the database of the website developed. Farmers at the destination can browse the website and get the new knowledge. Chi, Tailan [36] has pointed out that such exchange structure between firms involves a lot of cost problems. Genuinely captured audio/ video /image is retained and transferred to the website without any tampering of the data with the help of various intermediaries. Hargadon and Sutton [37]

have correctly indicated that the intermediaries are agents which are involved in the process of knowledge / technology exchange.

## 5.8 Model evaluation

Data were collected by using the questionnaire, direct interviews and telephonic talk with the farmers. The tacit /experienced knowledge is thus collected and transferred from one farmer site to another. Liyanage et al [38], expressed different modes like social, external and internal aspects which influence the knowledge transfer. To a great extent the success of such process depends on the degree of implementing successfully the knowledge acquired from the remote site [39].

## 5.9 Case Study

A case study on how to protect the BP from the sunlight is discussed in this section. The knowledge from the farmers was collected from two locations. A study on the availability of various knowledge (traditional/non-traditional) was conducted by interacting with farmers across the state of Kerala. There existed different knowledge in different locations. But the knowledge known in one location is completely ignorant in another location. In this case study two knowledge were considered, which is elaborated below. The knowledge transfer phase depends on time as mentioned by Szulanski [40]. Depending on the need and the initiation, transfer of knowledge normally takes place. The various phases considered in this knowledge transfer model include

(i) **Initial phase:** in this phase the initial set up for acquiring the knowledge from the farmers, experts and identifying the various transfer methodologies, should be identified. In our case researcher identified farmers from two districts as mentioned earlier. For example: The farmer was identified and with their permission, the knowledge was acquired (Multimedia-audio/ video files) on how to cut the Banana bunch from a tall Banana Plant.

(ii) **Local knowledge representation:** the knowledge acquired from the farmers has to be represented locally. The knowledge attained from the Geographical location-1 can be tacit or explicit knowledge, or it can be both.

(iii) **Abstraction:** in this process, the essential ideas of a technology are extracted and stored in the knowledge base. This knowledge is transferred to the destination and in the adaptation phase, ideas are implemented adapting to the environment in the destination. For example:

**Case-I** A video cam/mobile phone was used to record the knowledge about how to cut the banana bunch from a tall banana plant. Here a plastic strip was used to hold the banana in position by tying it to an arecanut/coconut tree. While cutting the banana bunch, the strip was used to pull the banana bunch close to the ground and using a knife the stem connecting the bunch fruit was cut. Here the knowledge about how to cut the banana from a tall banana plant is demonstrated and the

knowledge is gathered. Such abstracted knowledge can be transferred to a new location.

(a) Identifying the BP

(b) identifying the Bunch

(c) Pulling the bunch and cutting

(d) Banana bunch cut

**Fig. 5.2:** Process involved in cutting of banana bunch from tall BP

**Case-II** Similarly, audio/video on how to protect the banana saplings from severe heat was recorded from Banana Research Station Kannara. They used the coconut leaves for providing the necessary shade as well

heat to the saplings. Thus protecting the saplings. This process was recorded and stored in the knowledge base. Abstracted knowledge can be assessed in the destination location (http://indianrupeeservices.in/agri/ ).

(a) BP sapling

(b) Coconut leaf preparation

(c) Coconut leaf protecting BP

(d) BP saplings protected in the farm

**Fig. 5.3:** BP sapling and the process of protecting it from severe sunlight

(iv) **Transfer:** once the Knowledge is acquired, it was shown and discussed with the farmers and stored in the Knowledge Base (KB). Proper planning was taken to avoid any problems. One of the main problems was communicating with the farmers and to

explain the banana bunch cutting process in a simple manner. Then it was stored in the database and transferred to the destination.

(v) **Adaptation:** in the adaptation process, only the necessary knowledge from the knowledge base is extracted as per the requirement of the farmer at the destination/sink. All the knowledge abstracted may not be used in the sink/destination due to the difference in the geographical conditions, climatic conditions; types of soil used and so on. Here the ideas are implemented adapting to the environment at the destination. For example: the banana bunch cutting process at the sink/destination can use bamboo/wood log for supporting and pulling the banana bunch down. Similarly, in the case of protecting the banana saplings at the sink/destination, they can use the adapted knowledge i.e. the requirement of the limited sunlight for the saplings. For this they can use the organic/plastic net sheets, so that the adapted knowledge can be used at the destination.

(vi) **Integration and Retrieval:** Once the Knowledge acquired is shown to the farmers at the sink/ destination, and if they understands the knowledge and able to perform the task based on the audio/video (multimedia) files stored in the knowledge base, then the assumption can be made that the knowledge transfer is successful and proper integration and retrieval of the knowledge took place.

But if the receiving end farmer, have problem in identifying the Knowledge (audio/video files), then the knowledge transfer becomes a failure. The image/knowledge acquired from one location is hoisted on the website (http://indianrupeeservices.in/agri/index.php) as shown in figure 5.4-5.5 and the farmers can have a view of the knowledge transferred. If the multimedia file is able to express the knowledge acquired then the process can be said to be effective.

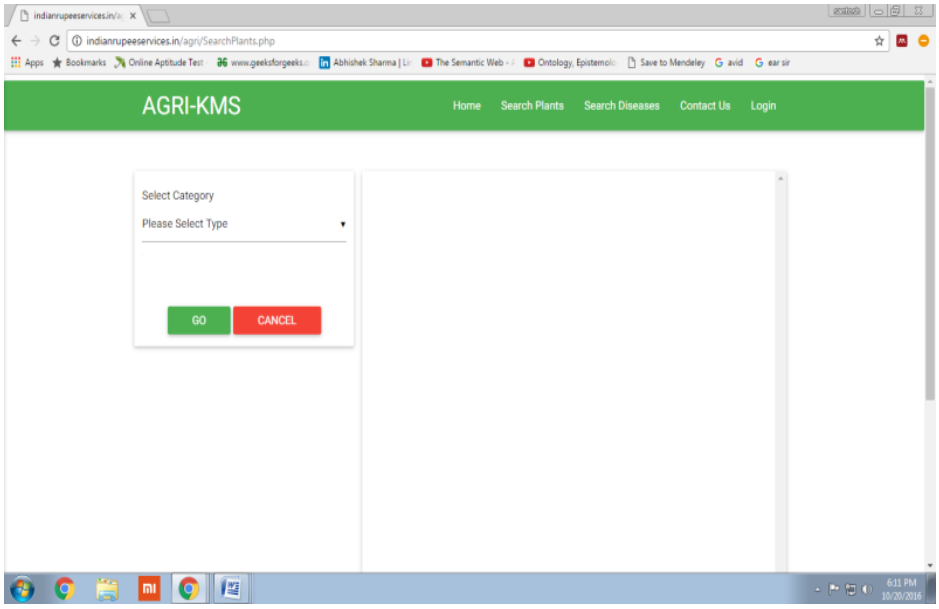


**Fig. 5.4:** Knowledge management website-home page

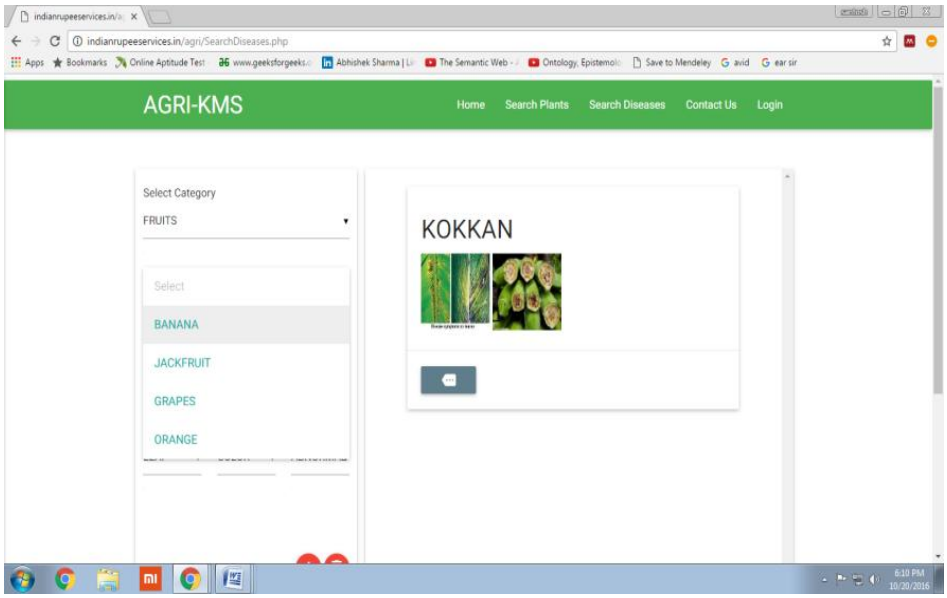


**Fig. 5.5:** Knowledge management website-knowledge acquiring page

Since the video and audio descriptions are available it is easy for the farmers at sink/destination to implement the knowledge acquired. The success of such transfer of knowledge from one location to another mainly depends on the content and context of the knowledge abstracted from the initial location and how it is adapted in the sink/destination. Rule based systems are designed to represent the knowledge. Aryote [41], Ferdows[42], Kingsley[43], has pointed out that the best approach for such knowledge exchange can be done by transfer of manuals, documents, seminars, workshops and so on.

## 5.10 Conclusion and Future work

Positive and negative aspects of Agricultural Knowledge Transfer exist. The use of technology, modern tools (Multimedia-audio/video capture), Government and non government Organizations, Agri-clinics and research centers opens a wider scope for the farmers to transfer knowledge from any remote location to another location and vice-versa. Factors like technology, technological skills, geographical location, cultural and social factors etc. influence the knowledge of the farmers. Thus in this study the transfer of knowledge from one location to another was incorporated using the technology. Similarly any knowledge from any source can be acquired, stored and adapted as per the requirements of the destination.

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# Procedure IV

## A Smart Phone Based System for Agricultural Product Procurement and Distribution

*M B Santosh Kumar, B Kannan, "Smart Phone based System for Agriculture Product Procurement and Distribution", International Journal of Computer Applications (Accepted).*

## Development of a Model Recommender System for Agriculture (ARS) Using Apriori Algorithm

*M B Santosh Kumar, B Kannan, "Development of a Model Recommender System for Agriculture using Apriori Algorithm", International Conference on Cognitive Informatics & Soft Computing (CISC-2017) held at Vignana Bharati Institute of Technology, Hyderabad during 20-21 Dec 2017. (Accepted).*

Chapter 6

# A SMART PHONE BASED SYSTEM FOR AGRICULTURAL PRODUCT PROCUREMENT AND DISTRIBUTION

Contents



## 6.1 Introduction

In this chapter we investigate the strategies required for efficient distribution of Agriculture products using ICT. Distribution and marketing of agriculture product is a problem faced by both customers and farmers. Exploration of the nature of agriculture information and its uniqueness, by using an internet based and mobile based distribution system is implemented. Different web portals for agriculture like ICAR, IARIs was a part of the study for designing, developing and implementing in CUSAT [1]. ISP (Internet services providers) provides a range of services including voice messaging, data and fixed land line

communication. Mobile communication helps to increase agricultural productivity and efficiency which ultimately improves the living standards of the rural farmers. Standardization of various communication equipments is not clear yet; still lots of companies are trying to solve this problem [2][3][4][5]6].

## 6.2 Need for ICT Agriculture in Kerala

The Information and Communication Technology (ICT) is defined as the tools and processes to access, store, retrieve, organize, manipulate, produce, present and exchange information by electronic and other automated means [7]. The ICT's can be openly understood as the technologies to make easier the communication, processing and transmission of communication by the electronic means. And it contains a group of technologies such as radio, telephone, modern technologies like mobile phone, multimedia, internet, satellite based communication system etc. The Task Force on India as Knowledge Super Power (2001) reported the essential of developing the capacity to generate, absorb, disseminate and protect the knowledge and maximize it as a powerful tool for the societal transformation [8]. Towards a knowledge revolution in rural India, there is a need for greater stress on harnessing the power of ICTs for increase agricultural competitiveness. The information provided should be demand driven and applicable to the day-to-day life of the rural mass [9].

Richardson (1996) categorized five main areas of ICTs support to agricultural and rural development. They are; Economic development of farmers, Community development, Research and education, Small and medium enterprise development and Media networks [10].

ICT in agricultural development have some applications, in a country like India they are; Providing online information on different aspects of agriculture, Global Information System and Remote sensing, Expert Systems in Agriculture (Decision Support Systems), e-procurement, e-commerce, e-governance, Online courses in agriculture and allied sectors, Question answer services, Tele education, Mobile based services for farmers, Development of databases, Rural networking and Community radios for information dissemination [11].

Majority of the industrialized countries could afford to implement ICT (information & Communication Technology) solutions into agriculture. Kerala started introducing ICT in agriculture very recently. Different parts of Kerala have different farming characteristics. For example, in the cultivation of Banana (Nendran) several difficulties were faced by the farmers like: [12]

1) Geographic difference:

   One of the most challenging aspects is the different characteristics of the land and soil across Kerala.

2) Traditional Vs Modern equipments :

In Kerala there isn't any specification for using traditional/non-traditional equipments in agriculture.

3) Need for an ICT based solution for the distribution of agriculture products.

4) Farmers often faced difficulties to get a market for the product and are forced to sell the product at a very low price through the middleman.

5) Customers do not have direct access to the farmer's product. And hence has to buy the product at inflated price from the shops.

6) Globalization:
Some of the Banana (Nendran) product are of high quality and has high demand in the global market. But the varieties of banana (Nendran) coming from Tamil Nadu and other states creates a problem for Kerala agriculture (Banana) farmers.

## 6.3 Farmers and Technology

A smart vegetable and fruit distribution system was designed and implemented successfully with the help of technology in CUSAT. The farmers, the employees and students of the University community were able to freely access this facility through the 'Go Organic' website. This facility can be extended to the general public. To implement this some of the technologies used were: [13]

1) Web portal:

The use of different specific-applications for ordering "safe to eat" vegetables from the agri farmers required a high-speed network allowing exchange of information between the employees of CUSAT and the farmers.

2) Farmer access:

The farmers were given access to the website by giving them a username and password. The farmers were able to get the details of the order from the CUSAT employees and students through this website.

3) Mobile android app:

To make the distribution channel more effective and efficient, an Android mobile app 'Go Organic' was designed and developed. The website and the mobile app was developed in consultation with the agriculture farmers, VFPCK (vegetable and fruit promotion council) Kerala and the employees of CUSAT. This app can be freely downloaded from the website (http://nss.cusat.ac.in/goorganic/app.php ).

## 6.4 Integrated Vegetable Distribution System (IVDS) Model description

The main challenges which the farmers face differ and depend on various reasons. The main objective was to solve some of their problem

and to create a new business model and platform "Go Organic– distribution system". The initiative of this project is to produce commercialization by adapting and using ICT [12][13][14][15][16]17].

To create this innovative integrated vegetable distribution system model (IVDS) following entities were involved

1) Agri farmers:

Farmers are the main information providers in developing the IVDS model. The information provided by agri farmers are very vital and helped in developing the IVDS model. The fig.6.1 shows the architecture of IVDS model

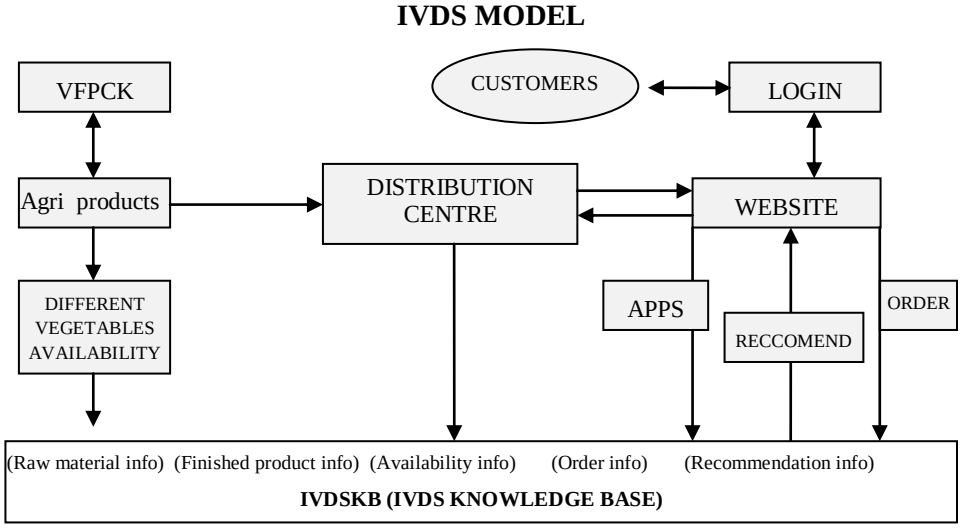


**Fig. 6.1:** Architecture of IVDS model

2) End users:

Although we considered that the farmers are the main beneficiaries, but still middlemen are getting the most benefit. The 'Go Organic' system is basically for the end users to interact in a user friendly manner, directly with the farmers.

3) CUSAT distribution centre:

The distribution centre is the place where the farmers bring their products in packed forms and are distributed to the customers.

4) IVDSKB:

Two databases were created. One for the farmers' product database and the other for customer database. The knowledge base system proposes to recommend the availability and the usage pattern of the end users and thus help farmers to make their produce as per the requirements of the customer.

5) APPS:

An app based on Android is designed and developed. This can be freely downloaded by customers for ordering their vegetables and check the availability of the various vegetables / agri products [18].

## 6.5 Interface design

Items are displayed on the website/smart phones. Users can login and then input their requirements and priority for the ordering of agri products through the Android app.

The User Interface (UI) is designed in such a way that any layman can choose the required quantity and make their order accordingly. The website for ordering various agri products is shown in the fig.6.2-6.5 given below:

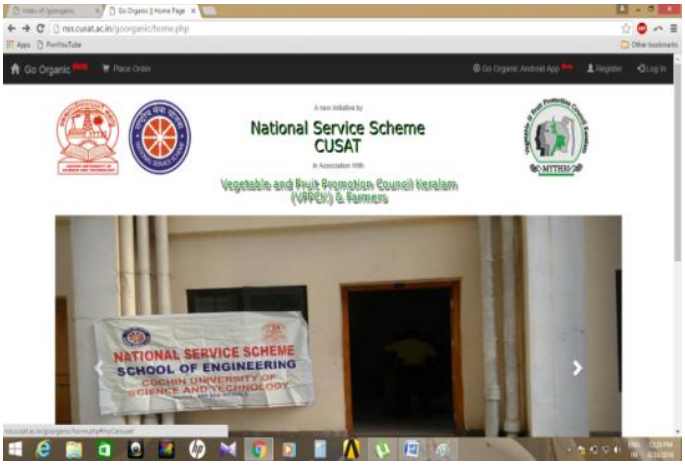


**Fig. 6.2:** Home page for GoOrganic

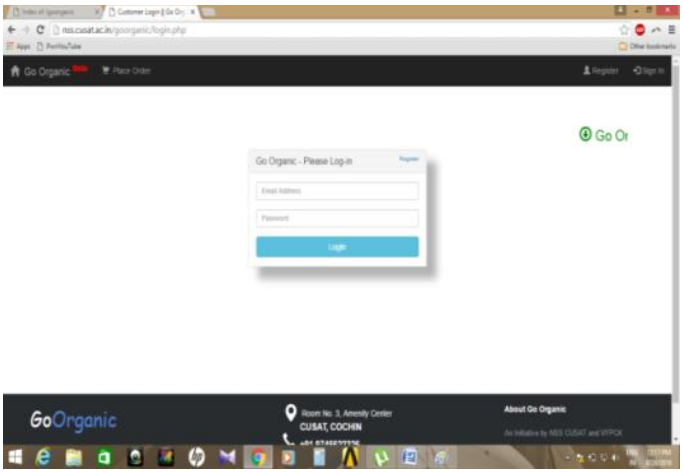


**Fig. 6.3:** Login Page for GoOrganic

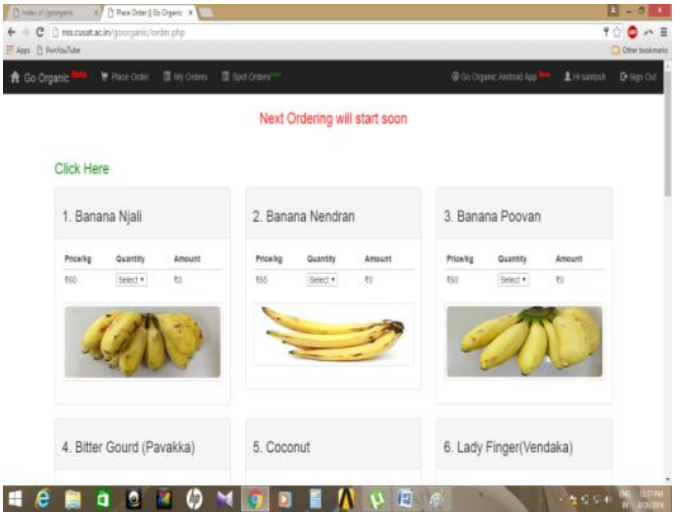


**Fig. 6.4:** Product display page for GoOrganic

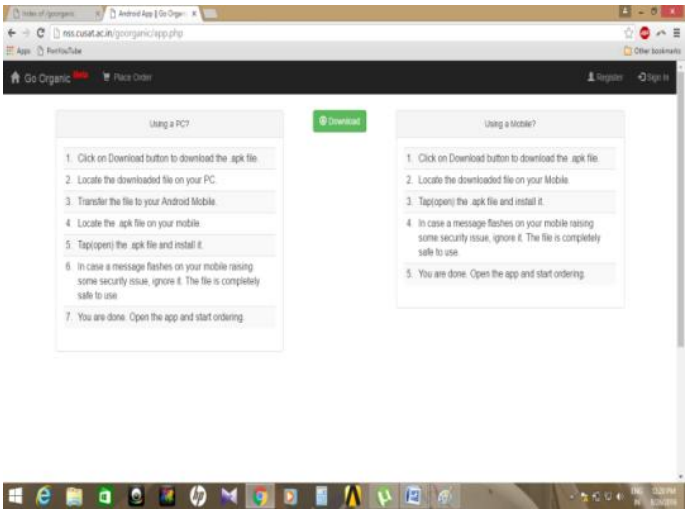


**Fig. 6.5:** Android app download page

## 6.6 Conclusion and Future work

Most of the farmers are facing lot of difficulties regarding their farming business mainly due to the weather condition, price fluctuation and constant financial disparity.

Academic and farmer based research initiative have solved different issues which ultimately affect the farmer. In this system, the middlemen were completely avoided while supplying the products to the distribution centre. Better price for the products were ensured and safe to eat vegetable, fruits and its allied products were distributed through this 'Go Organic' website. This system was designed focusing on the customers of CUSAT. Such a system can be extended to general public so that public can get a good product for a good price without any middleman in between. Thus the farmers will get a good price for their products and the customers also will be getting the products for cheaper rates. VFPCK and Government organizations will take care of the quality of the products and the technology developed as a part of the research can be used for the implementation of such a distribution system.

Plans are initiated to develop the knowledge base system for IVDS model so that proper recommendation can be given automatically to the farmers as per the buying behavior of the customers. This initiative has helped farmers to interact with the customers directly without any middleman intervention. Therefore a recommender system should be

designed and developed to help the farmers to make the cultivation of agri products without any wastage and increase in the profit. A knowledge base can be designed and made available online for different varieties of products in the future.

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Chapter 7

# DEVELOPMENT OF A MODEL RECOMMENDER SYSTEM FOR AGRICULTURE (ARS) USING APRIORI ALGORITHM

Contents



## 7.1 Introduction

The state of Kerala is tagged as one of the agricultural hubs for many food crops like rice, coconut, banana etc. due to the advantages in climatic conditions. But improper planning of the production of items ultimately will lead to a huge loss to the farmers. So a proper prediction and recommendation of items is required. RS are software tools that provide suggestion for Items to be of use to the customers and farmers [1] [2] [3]. A RS normally focus on a specific type of Items, in this study

focus is on vegetables and fruits and its allied products such as chili powder, rice powder, banana chips, jackfruit halwa etc.

By analyzing the buying behavior of the Items purchased by the customer, the RS was designed. Using the system, farmers will get information about what all items to be cultivated for the next seasons by analyzing the interaction with the customers/users through the web interface. For example Amazon employs a RS to personalize each customer trading through the online store [4]. Most of the RS are personalized, since the buying behavior of one person differs from another, also there exists non-personalized RS [5].

In personal recommender system (PRS), a recommendation has a priority based on the list of items purchased which has a ranking as well. In the process of ranking, most suitable items are predicted using RS. To complete such tasks, customer's preferences, which are explicitly expressed, in the form of implicit ratings of the Items are important for the design of RS. Navigation to a particular Item was considered as an implicit sign by the RS [6].

The decisions made by other customers play a prominent role in making the recommendation by the individuals for the purchase of the items [1] [7]. For example people rely on the reviews of the movie that film critics have made before watching the movie, similar condition were checked in the purchase of Agri items.

## 7.2 Review of Related Work

RS has evolved as a prominent and independent research area by mid-1990's [1] [7] [8] [9]. The terminology, RS indicates systems that normally filter information. Various recommendations based on the end customer needs and preferences were obtained. Normally Recommender System is used for applications that suggest products or services or identification of the items best required for placing the next order. One of the important task is to give proper prediction of the items which can be viewed or purchased and thus generate the recommendation [10]. Different types of problems arise to make the correct prediction of the items. A proper ranking of the items was done using apriori algorithm [11].

Semantic web based architecture are available to generate agricultural recommendations, using spatial data and agricultural knowledge bases [12]. 'GO-ORGANIC' is the name of the RS which can be accessed by the customers or farmers by logging in with a username and password. The result of the query related to any items will be displayed on the website and in the Android App [13]. Customers can also have access to the various items of interest if given a plethora of interest online [14].

Based on the interest of the customers say for example their long term and short term preference for various items can be found out by rating, tagging and using some other metrics. Thus combining all these together a set of personalized record can be generated [15].

In content based systems, prediction for a new item depends on the similarity of the items which were rated with a high percentage [16]. Consider Collaborative filtering, here the recommendations is be done by considering the preferences of previous users ordering items of same interests [17]. Different approaches and algorithms of data filtering and recommendations exist [18]. Increasing the production of various crops considering the climatic condition, soil fertility etc. is an important task. There are systems that formulate, simulate and evaluate a genetic algorithm based model to maximize crop yields and retain soil-fertility [19].The predictive accuracy of various methods can be compared using a set of representative problem domains [20].

## 7.3 Methodology

The Recommender System works mainly according to the recommending techniques; collaborative filtering and content based filtering. In Collaborative filtering, the recommendations are made by considering the preferences of previous customers having same interests. In content based systems, prediction for a new item depends on the similarity of the items which were rated with a high percentage. The first and arguably most influential algorithm for efficient association rule discovery is Apriori [21], which was considered while designing the model. The active customers have some agreement with the customers in the past, then the recommendation will have more relevance and of more interest to the active user [22].

'GO-ORGANIC' is a website to place an order and collect Items, hence can be considered as a model of E-commerce. A need for filtering the whole range of available alternatives to make the recommendations is necessary. It was found that choices of the items were good, but too much choice is not good [23]. RS generate recommendation with the help of customer data, various types of Knowledge, the available item and historical data about the transactions with reference to the database. The customer can browse through the RS and accept or reject Items; hence an implicit or explicit feedback is received. All the transactions are stored in the recommender data base can be used for generating new recommendations during the next ordering of the Items [23].

The RS developed utilizes item and customer based approaches. In item based approach many of the products ordered by the customers remain more or less the same. Similar items helps in building neighborhoods based on appreciations of customers [24]. Later the system generates recommendations based on the items, customer would prefer. In customer based approach customers plays a prominent role. Customers ordering the same items are grouped together. Recommendations are made based on the evaluation of the items they have ordered. A hybrid system which combines both content based and collaborative filtering methods are considered in this model. Fig.7.1 depicts the model architecture of the Agriculture Recommender System (ARS).

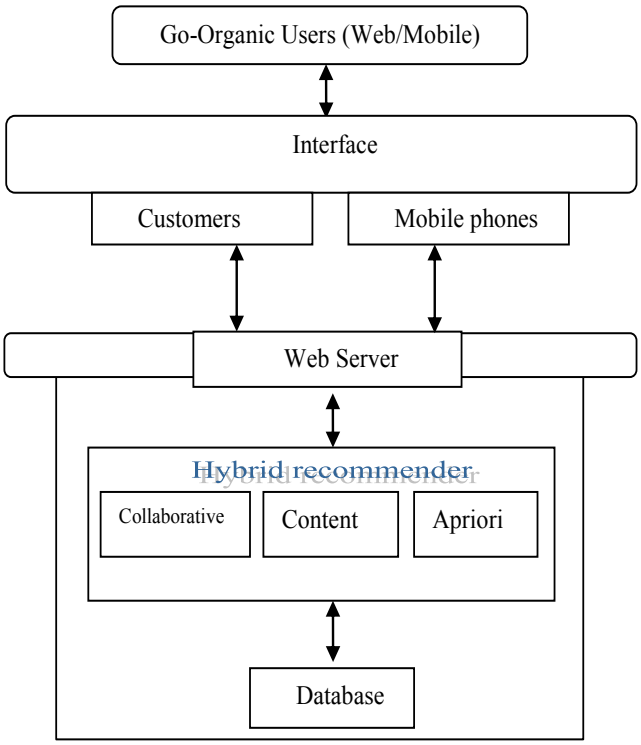


**Fig. 7.1:** Model architecture of ARS

The system was developed as a web based graphical user interface (GUI) and as a mobile app. The entire requests made by the customers are running on a web server. All the inputs were stored in the database and hybrid system which can make approximate recommendations in the form of prediction of purchase of various items were designed. The web clients were developed using PHP and database - SQL server running 24x7 and is organized in client-server architecture.

Considering all the items ordered by each customer, the cumulative of the same item by all the customers helps to predict the usage of a particular item at a particular season of the year. Thus such a system will help to make a prediction of the consumption of various products by the customers. Thus the farmers can make the production of vegetables and fruits based on the prediction and recommendation of the Recommender System.

Association rules are "if-then rules" with two measures which quantify the support and confidence of the rule for a given data set is considered in the study. A hybrid web based Recommender System model based on association rule mining algorithm were designed and implemented. India touted to be an agricultural country still using traditional ways of recommendations in agricultural sector. Presently the knowledge and recommendations are passed through interaction between farmers and experts. The recommendations will be different from different experts. Our system helps the customers to get the information and recommendations based on their need and preferences. This helps to reduce the gap between technology, customers and farmers. The customers and farmers can access products through the website 'http://nss.cusat.ac.in/goorganic/login.php'. An android based mobile application is also developed and the App can be downloaded from 'http://nss.cusat.ac.in/goorganic/downloads/Green-RS.apk'

## 7.4 Design and Implementation of an Agricultural Recommender System (ARS) *"Rec-Veg"*

Recommender System was modeled based on Association Rule Mining as depicted below.

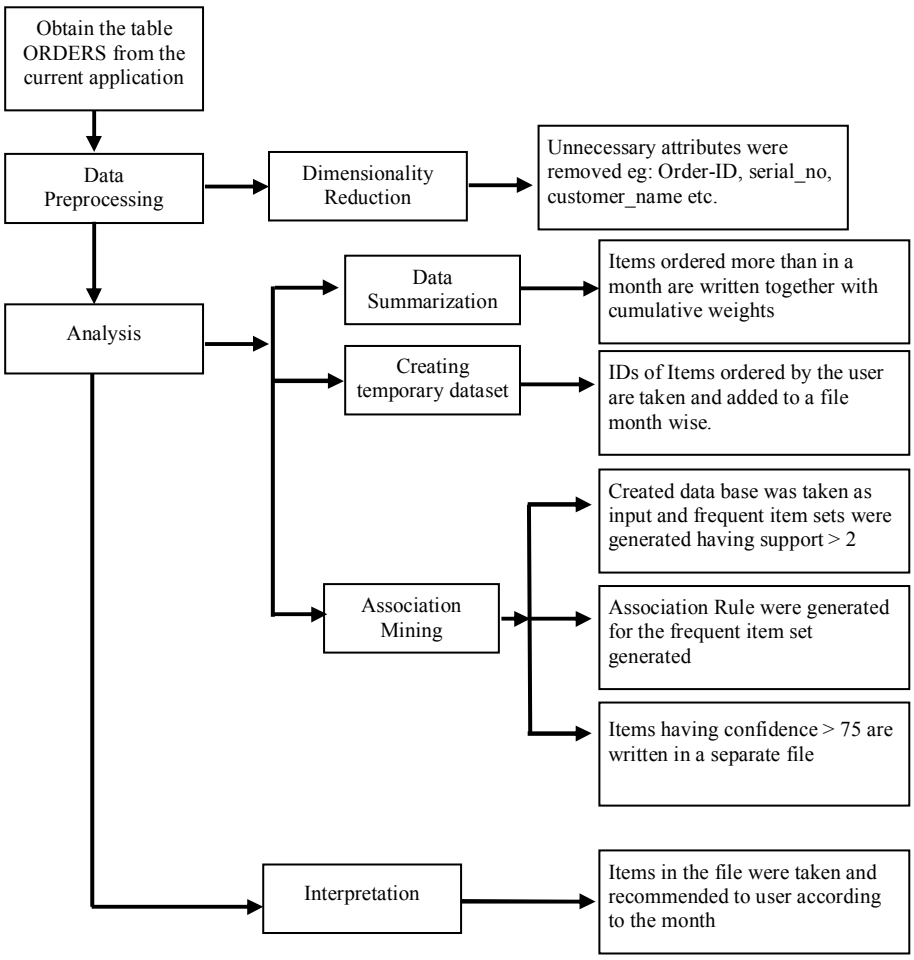


**Fig. 7.2:** Diagrammatic representation of Design and Implementation of ARS

*"Rec-Veg"* is the name given to this Agriculture Recommender System. Dimensionality reduction was done by removing unwanted columns like, serial-number; Order Id, customer email-ID etc. Column sets used from the available table were: User-ID (mobile number), Item ID, Purchased quantity of items, Order date.

Apriori Algorithm was used to analyze the data based on Frequent Item Sets generated. Then association rules were generated, and items included in rules with minimum confidence 75%, were stored as recommended products by using the formula given below.

Association rules: X->Y & Y->X.

If item set is X, Y then confidence is:

$$conf(X \rightarrow Y) = \frac{Supp(X \cup Y)}{Supp(X)}$$

It means probbility of buying. $Y$ if user bought $X$

If item set is $X, Y, Z$.

Then, Association rules formed would be

$$XY \rightarrow Z, XZ \rightarrow Y$$

$$Z \rightarrow XY, Y \rightarrow XZ \text{ etc.}$$

And confidence would be calculated as,

$$conf(XY \rightarrow Z) = Supp(XY \cup Z) \Big/ Supp(XY)$$

Analysis phase consists of a) Data summarization: - here, the items ordered more than once in a month were considered along with cumulative weights. b) Creating temporary data set: - IDs of item ordered by the customers were taken and added to file, month wise. c) Association rule mining: - the created data base was taken as input and item set (frequent) were generated having support > 2. Association rules were generated for the frequent item set generated. Items in the rule having confidence >75 were written in a separate file. d) Interpretation: - items in the file were taken randomly and recommended to customer according to the month.

### 7.4.1 ARS Model –Tables

Four tables were designed initially. Table 7.1 indicates customer details; Table 7.2 indicates various Items, Table 7.3 indicates the order placed by the customer and Table 7.4 indicates the list of ordered items. The mobile numbers were used as the unique ID which acts as the primary key for the table. The sample size of the customers for the ARS model design constituted around 350.

Transactional data related to each customer was extracted from the available customer database and record was made for the amount of each item purchased month wise. Transactional data refers to the columns which includes order date, item-id and purchased quantity etc. present in 'Order' table of the database which contains all the orders made for a

period of eight months (May-December). Separate Graphs were made for each item, based on its sale during the same period.

**Table 7.1:** Customer

| customer_id (primary key) | Mobile (unique) | first_name | last_name | email_id | password |
|---|---|---|---|---|---|

**Table 7.2:** Items

| item_id(primary) | item_name | item_price |
|---|---|---|

**Table 7.3:** Order

| order_id (primarykey) | mobile | order_time | order_status | payment_status | total |
|---|---|---|---|---|---|

**Table 7.4:** Ordered items

| Id (primary key) | order_id | item_id | item_name | item_quantity | item_price |
|---|---|---|---|---|---|

After forming required number of tables and eliminating the item sets having support less than the minimum support i.e. 2, the association rules were applied on the final set. For example taking the dataset of items purchased for eight months, which is shown below.

*(Repeated items mean that many times the item is purchased in that month).*

| |
|---|
| May-3, 7, 9, 10, 1, 3, 8, 1, 3, 6, 7, 10, |
| June-2, 3, 6, 11, 12, 2, 12, 14, 3, 4, 6, 9, 10, 11, 2, 4, 6, 11, |
| 12, 14, |
| July-2, 3, 6, 12, 14, 1, 2, 3, 6, 12, 4, 6, 10, 1, 2, 3, 4, 6, |
| 8,10,12,14, |
| Aug-1, 2, 6, 12, 3, 5, 14, 15, 1, 2, 3, 4, 5, 6, 12, 14, |
| Sep-1, 2, 12, 14, 15, |
| Oct-1, 2, 4, 6, 7, 12, 14, 15, |
| Nov-2, 4, 6, 11, 12, 14, 15, 1, 2, 6, 7, 12, 15, 1, 8, 1, 2, 6, |
| 7, 12, |

So support of each item was stored in table 7.5

**Table 7.5:** Item vs Support

| Item no. | Support |
|---|---|
| **1** | **11** |
| **2** | **13** |
| **3** | **10** |
| **4** | **7** |
| **5** | **2** |
| **6** | **14** |
| **7** | **5** |
| **8** | **3** |
| **9** | **2** |
| **10** | **5** |
| **11** | **4** |
| **12** | **13** |
| **13** | **0** |
| **14** | **9** |
| **15** | **5** |

Taking minimum support=2, and eliminating the rows with support value less than 2, a new table 7.6 was obtained as shown below.

**Table 7.6:** Item vs Support with minimum support = 2

| Item No. | Support |
|---|---|
| **1** | **11** |
| **2** | **13** |
| **3** | **10** |
| **4** | **7** |
| **5** | **2** |
| **6** | **14** |
| **7** | **5** |
| **8** | **3** |
| **9** | **2** |
| **10** | **5** |
| **11** | **4** |
| **12** | **13** |
| **14** | **9** |
| **15** | **5** |

(Item no. 13 was eliminated).

Now, two items present in the updated table 7.6 were paired and the support of both of them appearing at same time was obtained and stored in a new table 7.7 as shown below.

**Table 7.7:** Item vs Support with minimum support > 2

| Item no. | Support |
|---|---|
| **1,2** | **8** |
| **1,3** | **6** |
| . | . |
| . | . |
| **1,11** | **1** |
| . | . |
| . | . |
| . | . |
| **3,10** | **5** |
| . | . |
| . | . |
| . | . |
| . | . |
| . | . |
| **14,15** | **4** |

A similar approach as above was applied and the item sets having support less than 2 were removed from the table to form another new table. The same process of grouping the items was applied till there was no group present with support less than the minimum support. After forming the final item set table, association rules were applied and confidence was calculated.

Now Items with confidence more than 75% were noted in a separate file and recommended to the customers. Recommendations are shown to the customers based on their previous purchases they have made. User Interface was designed for the customers where they can view the recommended items along with the items they want to purchase. Amount of items to be produced by farmers will be based on the sales graph made for each month and recommendations made for each customer which is depicted below.

### 7.4.2 Graphs

The graphs below indicate the consumption of various types of agricultural products. Figure 7.3 indicates the consumption of Yam, with x-axis indicating the quantity of consumption in kilogram (kg), figure 7.4 indicating the consumption of water melon, figure 1.5 indicates the consumption of turmeric powder and figure 7.6 indicates the consumption of tapioca. Similarly graphs can be drawn for all the items.

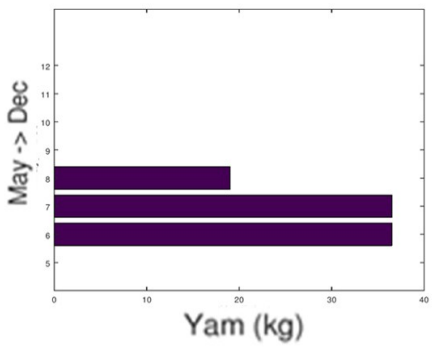


**Fig. 7.3:** Consumption of Yam

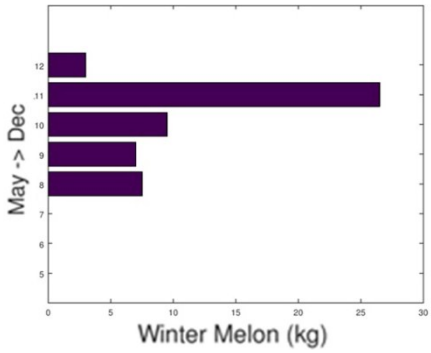


**Fig. 7.4:** Consumption of water melon

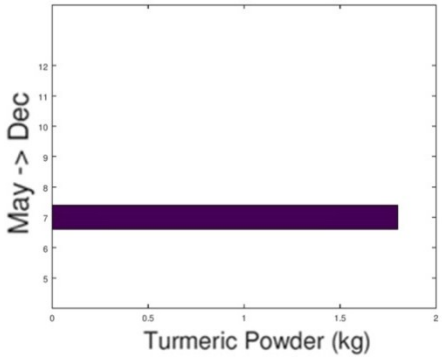


**Fig. 7.5:** Consumption of turmeric powder

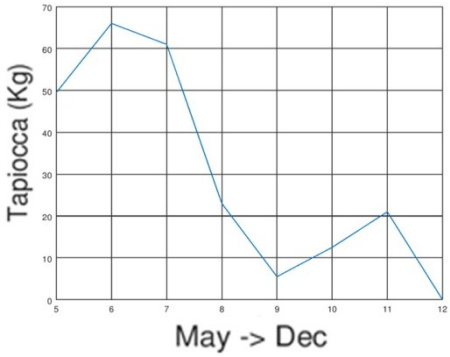


**Fig.7.6:** Consumption of tapioca

## 7.5 Results and Discussion

The recommender system used in Go-Organic recommends products to the users based on two things:

### 7.5.1 Purchases made by the user in the past

The recommender system is based on the transactions made in the previous year. The database contains information about every transaction. Each transaction has several products related to it and every product in the database is distinguished by a unique id. Now to give the recommendations following steps were followed: All the transactions of the specified month of a single user were taken and association rules were generated according to Association Rule Mining which also contains product ids. Whenever customer makes a purchase in that month, the product ids were matched with the generated association rules. Whenever the purchasing pattern of any of the association rules matches, the corresponding products present in the association rule were recommended. In case, the purchasing patterns did

not match a single association rules then recommendations were made by matching them with multiple association rules. These recommendations were different for every user; i.e.; according to the taste of the user. This is significant for the existing users who have some transaction history to make their purchases more interactive.

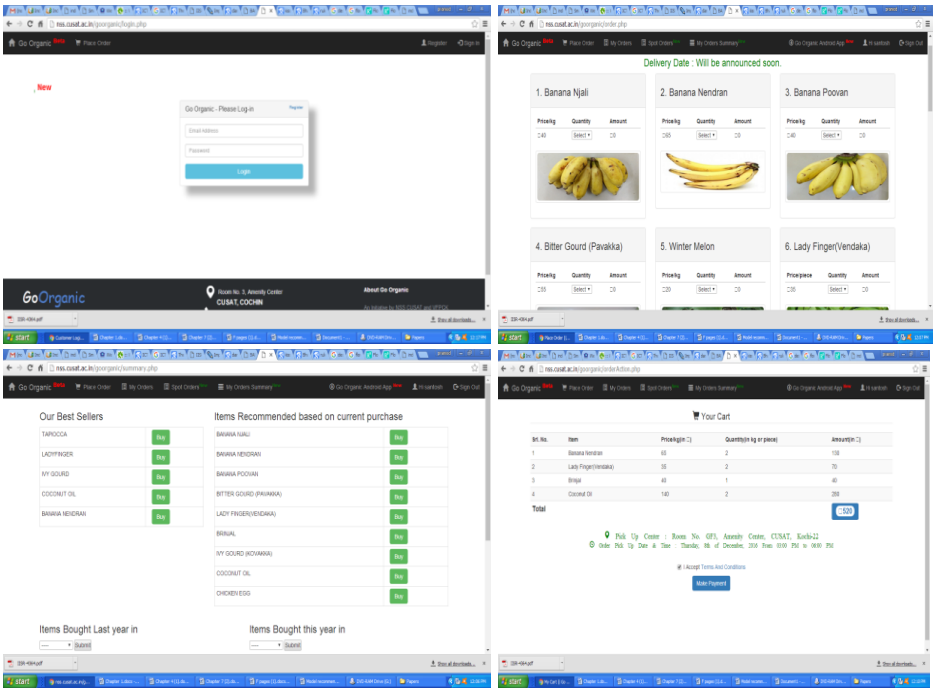


**Fig. 7.7:** Screenshots of actual execution of Recommender System using sample inputs

### 7.5.2 The bestselling products

Most of the products sold from the previous year were recommended to the customers. The amount for each product in the previous year was

calculated and the top five products ranked on the basis of the amount were taken as the most sold products and recommended to the user. These recommendations remained same for every user. This is significant for the new users who don't have a purchasing history.

## 7.6 Conclusion and Future work

A recommender system model for predicting and recommending the consumption of various agricultural items was designed and developed using apriori algorithm. The system developed was able to make the predictions and recommendation on the basis of the customer's consumption and their peer's recommendation of the items. The model ARS can make prediction of items consumed by all the customers, so that the farmers can produce the items according to their choice. Thus the cumulative prediction can help the farmers to plan and make the cultivation of the Agriproducts (Items) for any season, so that there will not be any wastage of the items produced by the farmers. Thus the system developed, helped the customers to recommend more items than the predicted one. Similarly different types of products can be predicted and recommended using recommender systems.

As a part of the future study, the various stages of the banana diseases in the locality can be identified. In future, the system will have additional features to add additional symptoms and provision for farmers to ask questions. As a part of the future study, Vernacular language support system will be designed and developed.

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# Chapter 8

# CONCLUSION

The research conducted was interdisciplinary. Consultation was done with various departments like Ship, Civil, Mechanical, PSRT etc. for data collection, conducting experiment and Data analysis. Farmers can be benefited by feeling the pulse of the market, and they can start planning the farming strategy. Farmers can eradicate the role of middle man in sales and marketing thus increase their profits. Customers can get farm fresh organic and safe to eat vegetables which are very cost effective, directly from the farmers.

Through experiment, various procedures to analyze the physical and mechanical properties of banana plant were studied. Using Ansys software the banana plant model was designed to develop a Portable Agriculture Network System (PANS). The various knowledge collected from the agriculture experts and experienced farmers were tested for reliability using Cohen's Kappa. The reliable knowledge can be abstracted, stored, transferred, and adapted as per the requirement, from one location to another. Smartphone based integrated vegetable distribution system

(IVDS) was designed, developed and implemented successfully to prove that using technology even the farmers can do business and attain maximum profit without middlemen intervention.

Various websites and mobile apps were designed and developed to help the farmers to sell their products effectively. A model Recommender System for Agriculture (ARS) was designed, developed and implemented to understand the buying behavior of customers. With the help of this model farmers can plan and predict the quantity of production for the subsequent year so that there is no any loss in the agricultural products. Therefore it is suggested that the Government and Non-Government policy makers take into consideration all the above said factors while framing the agricultural policies for the upliftment of farming community.

This research is not the end but the opening of doors to various areas of research in the area of agriculture and technology.

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# APPENDICES

# Appendix I

## Expert-1

A sample response sheet from the expert-1(VFPCK)

| Sl No: | Name of disease | Symptoms | Remedy |
|---|---|---|---|
| 1 | MANAVANDU (Cosmopolites sordidus) | • Vazha kannu contain Black mark<br>• Severe 2 months no growth | • Kannu clean & keep<br>• Chemical endosulphan<br>• Ekalex water soluble<br>• Use chemical |
| 2 | THADATHURAPPAN (Odoiporus longicollis) | • Attack before 5 months<br>• Hole sharp tip<br>• 3 months life span | • 3-4 months real care<br>• Cut vazha & put near plant so that weeds won't come<br>• Clean and keep without the weed<br>• Put clay on the stem<br>• Use vaippin kuru in rainy season |
| 3 | VAZHA PEEN (Pentalonia nigronervosa) | • Kannil ninnu neeru ootti kudikkum.<br>• Coccan virus disease is being spread by this<br>• Koombu adakkum | • Use Veppin pinnakku, due to its smell it won't come<br>• Use Mithrakumil with water |
| 4 | ILATHEENI PUZHUKKAL | • Small worms eat the leaves<br>• Large holes seen in leaves | • Use any chemicals containing vaippu. |
| 5A | NIMA VIRA (Radopholus similis) | • No growth<br>• Black lines are seen | • Keep clean<br>• Check on the root<br>• Don't take from the plot,check the sucker also.<br>• Any doubts don't do. |
| 5B | VERUMEELI MOOTTA (Geococcus spp) | • Seen Like rice powder sprayed on the root and suck juice. | • Put vaippin pinnakku in the pit before planting<br>• Use 50% hot water with 50% normal water. |

| | | | |
|---|---|---|---|
| 6 | MANDARI<br><br><br><br><br>Vellicha | • Small pest drench juice from leaves.<br>• Within one week leaf burn<br><br><br><br><br>• White pooppal in leaves. | • Wet Sulphur,10-15 grams in water put under the leaves.<br>• OBRON chemical can be used(costly)<br>• Remove the affected leaves and destroy using fire<br>• Wet the leaves at 7AM every morning<br>• Use chemicals containing vaippu |
| 7 | KURUNAMBU<br>(Banana bunchy top virus) | • Virus spread by vazha pen<br>• Affect vazha kannu<br>• 99% plants get affected if it is planted near. | • Cut the plants and destroy using fire to kill the virus<br>• Do not keep the affected plants |
| 8 | COCCANE VIRUS<br>(Banana bract mosaic virus) | • Affects 3-4 months before bunching<br>• Vazha kannu contain maroon colour<br>• Leaves seen in 2 sides only | • Cut and burn the plants to destroy the virus<br>• Use vaippu pinnakku<br>• |
| 9 | MOSAIC ROGAM<br>(Cucumber mosaic virus) | • Vazha pen spread the virus in 2-3 month old plants<br>• Leaf gets hard and yellow waves are seen on the leaves. | • Use 1Kg of vaippu pinnakku per plant.<br>• Use verticilium ,Mitrakumil etc<br>• Use chemicals containing Vaippu. |
| 10 | STREAK ROGAM | • Virus is affected by the help of Verumili mootta<br>• Yellow lines on leaves.<br>• Midrib turns violet colour<br>• Vazha stem cheeyunnu.<br>• Bunch becomes small | • Select successor<br>• Use Verticilium to control |
| 11 | PANAMA VATTAM | • Pola polichil<br>• High water content<br>• Yellowish color on leaves | • Use kummayam<br>• If severe use Carbondasim 2gm/L |
| 12 | ELAPPULLI ROGAM | • Like mandarin full leaves dried and destroyed<br>• Bunch ripe much before<br>• From one leaf or bunch it spreads all over. | • Cut and burn<br>• Use Preodomonas |

| | | | |
|---|---|---|---|
| 13 | KADACHEEYAL | • Kada filled with bacteria<br>• Water spread marks are seen<br>• Sponge like stem<br>• When touch the stem will fall. | • Use 4gm/L Copperoxy chloride once daily<br>• Do regular visit to the field |
| 14 | CIGAR EN ROT | • Fruit tip get black | • Cover bunches with dry leaves.<br>• Wet well in summer season<br>• Spray the bunch with 4gm/L pseudomonas.<br>• Use fish,amino acid. |
| 15 | BORON DEFICIENCY | • Leaf curliing<br>• Inhibition of root and flower formation. | • Mix 20gm Borax with soil<br>• Mix 1gm boric acid and 3gm urea/L and spray |
| 16 | POTTASSIUM DEFFICIENCY | • Older leaves exhibit orange-yellow chlorosis with brown patches | • Use manures of potassium as directed. |
| 17 | CALCIUM DEFFICIENCY | • Tight white leaves<br>• No height to leaves | • Use 50gm kummayam per plant. |
| 18 | MAGNESIUM DEFFICIENCY | • Yellowish and green pattern on leaves<br>• Irregular shape<br>• Leaf bend<br>• Thin stem<br>• Unhealthy | • 2gms/L Magnessium sulphate to leaves |
| 19 | VELLAKOOMBU AND VAZHAPPANI | • Water will ooze from stem<br>• Smell<br>• Only affects individually due to imbalance between N & K | • Use Urea , Ammonia<br>• Use manures containing N and P and K. |

**Expert-2**

A sample response sheet from the expert-2(VFPCK)

| Sl No: | Name of disease | Symptoms | Remedies |
|---|---|---|---|
| 1 | MANAVANDU<br>(Cosmopolites sordidus) | • Lower portion lay off<br>• Vazha azhuki pokunnu<br>• No strength<br>• Spread in 3-4 months | • Cut and fire affected plants<br>• Use cowdung mixes with charcoal powder<br>• Use PHYTLANE |
| 2 | THADATHURAPPAN<br>(Odoiporus longicollis) | • Side wall break<br>• Plant become pale<br>• Black slender | • Cut and fire<br>• Use PHYTLANE<br>• Use Strephocyclene |
| 3 | VAZHA PEEN<br>(Pentalonia nigronervosa) | • Black spots<br>• Drink all juice from stem and leaf bottom | • Use Strephocyclene<br>• Use vaippenna |
| 4 | ILATHEENI PUZHUKKAL | • Small holes below leaf | • Use acalyx |
| 5A<br><br><br>5B | NIMA VIRA<br>(Radopholus similis)<br><br>VERUMEELI MOOTTA (Geococcus spp) | • Red cube strap in root | • Use 2g/L vaippin pinnakku<br>• Use Strephocyclene |
| 6 | MANDARI<br>Vellicha | • Small | • SULTAF<br>• ASATAF |
| 7 | KURUNAMBU<br>(Banana bunchy top virus) | • Virus affect | • Cut and fire |
| 8 | COCCANE VIRUS<br>(Banana bract mosaic virus) | • No fruit<br>• Leaf not healthy | • Cut and fire |

| | | | |
|---|---|---|---|
| 9 | MOSAIC ROGAM<br>(Cucumber mosaic virus) | • Side leaves round up folded. | • Use lime |
| 10 | STREAK ROGAM | • Small insects<br>• Stripes are seen | • Use Borax<br>• Use lime |
| 11 | PANAMA VATTAM | • Side leaves down<br>• Hang down or break | • Use Strephocyclene 2.5gm/L |
| 12 | ELAPPULLI ROGAM | • leaves dried and destroyed | • Use Boron<br>• Use lime |
| 13 | KADACHEEYAL | • Yellowish leaf break<br>• Decreases strength | • Use bleaching powder<br>• Use pseudomonas |
| 14 | CIGAR EN ROT | • Not commented (NC) | • Use lime and Borax |
| 15 | BORON DEFICIENCY | • Not commented (NC) | • Not commented (NC) |
| 16 | POTTASSIUM DEFFICIENCY | • Leaf edge dry | • Put more pottassium |
| 17 | CALCIUM<br>DEFFICIENCY | • Yellow leaves | • Use lime |
| 18 | MAGNESIUM DEFFICIENCY | • Not commented (NC) | • Use magnesium sulphate |
| 19 | VELLAKOOMBU AND VAZHAPPANI | • Koombu adayunnu | • Use less Nitrogen and less Urea |

**Farmer-1**

A sample response sheet from the expert-3(farmer-1)

| Serial No: | Name of disease | Symptoms | Remedies |
|---|---|---|---|
| 1 | MANAVANDU<br>(Cosmopolites sordidus) | • Leaf yellow<br>• Gel will come from below | • Use lime for 45 days |
| 2 | THADATHURAPPAN<br>(Odoiporus longicollis) | • Leaf yellow<br>• Gel coming<br>• Above sharp | • Use pseudomonas<br>• Use soap |
| 3 | VAZHA PEEN<br>(Pentalonia nigronervosa) | • Small peen<br>• Leaf yellow | • Use pseudomonas<br>• Use streptocycline |
| 4 | ILATHEENI PUZHUKKAL | • Eat leaves<br>• Holes on leaves<br>• Comes rarely | • Use chemical acalex<br>• Use chemical chloropyrofox |
| 5A<br><br><br>5B | NIMA VIRA<br>(Radopholus similis)<br><br>VERUMEELI MOOTTA (Geococcus spp) | • Not commented (NC) | • Not commented (NC) |
| 6 | MANDARI<br><br>Vellicha | • Leaf black | • Use aryaveppu<br>• Use garlic<br>• Use OBRON , TILT… |
| 7 | KURUNAMBU<br>(Banana bunchy top virus) | • No height | • Not commented (NC) |
| 8 | COCCANE VIRUS<br>(Banana bract mosaic virus) | • Not commented (NC) | • Not commented (NC) |

| | | | |
|---|---|---|---|
| 9 | MOSAIC ROGAM<br>(Cucumber mosaic virus) | • Not commented (NC) | • Not commented (NC) |
| 10 | STREAK ROGAM | • Not commented (NC) | • Not commented (NC) |
| 11 | PANAMA VATTAM | • Not commented (NC) | • Use lime |
| 12 | ELAPPULLI ROGAM | • Yellowish leaves | • Use pseudomonas<br>• Use OBRON |
| 13 | KADACHEEYAL | • NC | • NC |
| 14 | CIGAR EN ROT | • NC<br>• | • Use fish (saradine ) amino acid for 40 days |
| 15 | BORON DEFICIENCY | • Leaves unfold | • Use BORAX<br>• Use kappalandi pinnakku in 1 cup water |
| 16 | POTTASSIUM DEFFICIENCY | • NC | • Use manures of K |
| 17 | CALCIUM<br>DEFFICIENCY | • NC | • Use lime |
| 18 | MAGNESIUM DEFFICIENCY | • NC | • NC |
| 19 | VELLAKOOMBU AND VAZHAPPANI | • Excess water and factomfose causes this Use pseudomonas | • NC |

**Farmer-2**

A sample response sheet from the expert-4(farmer-2)

| Sl No | Name of disease | Symptoms | Remedies |
|---|---|---|---|
| 1 | MANAVANDU<br>(Cosmopolites sordidus) | • Small holes seen<br>• Gel will come from STEM<br>• Weak stem | • Vaccination<br>• Spray pesticides |
| 2 | THADATHURAPPAN<br>(Odoiporus longicollis) | • Gel coming | • Avoid pesticide<br>• Use soap |
| 3 | VAZHA PEEN (Pentalonia nigronervosa) | • NC | • NC |
| 4 | ILATHEENI PUZHUKKAL | • Eat leaves<br>• Holes on leaves<br>• Comes rarely | • Daily care<br>• Use chemical chloropyrofox |
| 5A<br>5B | NIMA VIRA (Radopholus similis)<br>VERUMEELI MOOTTA (Geococcus spp) | • NC | • NC |
| 6 | MANDARI<br>Vellicha | • Leaf yellowish or black | • Usewet Sulphur<br>• Use OBRON |
| 7 | KURUNAMBU (Banana bunchy top virus) | • NC | • NC |
| 8 | COCCANE VIRUS (Banana bract mosaic virus) | • NC | • Borax powder |
| 9 | MOSAIC ROGAM (Cucumber mosaic virus) | • NC | • NC |
| 10 | STREAK ROGAM | • Small leaves | • NC |
| 11 | PANAMA VATTAM | | • Use lime |
| 12 | ELAPPULLI ROGAM | • Marks like eyes on leaf<br>• Yellowish leaves | • Cut and fire |
| 13 | KADACHEEYAL | • Occurs in rainy season due to excess water<br>• Weak and if touch breaks down | • Remove it<br>• Avoid water flooding in plot |
| 14 | CIGAR EN ROT | • NC | • Use fish<br>• Use soap |
| 15 | BORON DEFICIENCY | • Leaves rolled<br>• Small leaves | • Use BORAX<br>• Use urea |
| 16 | POTTASSIUM DEFFICIENCY | • Leaf edges brown | • Use potassium sulphate |
| 17 | CALCIUM DEFFICIENCY | • NC | • NC |
| 18 | MAGNESIUM DEFFICIENCY | • NC | • NC |
| 19 | VELLAKOOMBU AND VAZHAPPANI | • NC | • NC |

**Farmer-3**

A sample response sheet from the expert-5&6(farmer-3&4)

| Serial No: | Name of disease | Symptoms | Remedies |
|---|---|---|---|
| 1 | MANAVANDU (Cosmopolites sordidus) | • NC | • NC |
| 2 | THADATHURAPPAN (Odoiporus longicollis) | • Gel coming<br>• Patta cheeyal visible after 5 months | • Use furidan spray<br>• Use soap |
| 3 | VAZHA PEEN (Pentalonia nigronervosa) | • NC | NC |
| 4 | ILATHEENI PUZHUKKAL | • NC | • Remove |
| 5A<br>5B | NIMA VIRA (Radopholus similis)<br>VERUMEELI MOOTTA (Geococcus spp) | • Leaf drying | • Use Diluted dispan 2.5ml/L |
| 6 | MANDARI<br>Vellicha | • Leaf drying | • Use TILT one week |
| 7 | KURUNAMBU (Banana bunchy top virus) | • Plant becomes dwarf | • Cut and fire |
| 8 | COCCANE VIRUS (Banana bract mosaic virus) | • Maroon color spreds | • Remove root<br>• Cut and fire |
| 9 | MOSAIC ROGAM (Cucumber mosaic virus) | • NC | • Use Boron |
| 10 | STREAK ROGAM | • NC | • Use lime |
| 11 | PANAMA VATTAM | • Vazha cheeyunnu<br>• Root full loss | • Use lime<br>• Use bleaching powder |
| 12 | ELAPPULLI ROGAM | • Yellowish leaves | • Cut and fire<br>• Use lime |
| 13 | KADACHEEYAL | • NC | • Use lime |
| 14 | CIGAR EN ROT | • NC | • Use lime at root |
| 15 | BORON DEFICIENCY | • Leaves rolled | • Use BORAX on leaves |
| 16 | POTTASSIUM DEFFICIENCY | • Leaf edges dry | • Use potassium sulphate |
| 17 | CALCIUM DEFFICIENCY | • NC | • NC |
| 18 | MAGNESIUM DEFFICIENCY | • NC | • Use magnesium carbonate |
| 19 | VELLAKOOMBU AND VAZHAPPANI | • NC | • Cut and remove |

# Appendix-2

Department of Polymer Science & Rubber Technology
പോളിമർ റബ്ബർ ശാസ്ത്ര സാങ്കേതിക വിഭാഗം
Cochin University of Science & Technology
കൊച്ചി ശാസ്ത്ര സാങ്കേതിക സർവ്വകലാശാല

Professor & Head

Ref: 160506

21.05.2016

Dr. Santhoshkumar M.B
School of Engineering
CUSAT
Kochi-22

**Test Result**

Sample Particulars: Flexible Translucent Plastic String

| Testing Parameter | Result |
|---|---|
| Material (Polymer) | Nylon - 6 |
| Tensile Strength (MPa) | >223 |

HEAD OF THE DEPARTMENT

Kochi, Kerala, India, Pin 682 022, Tel: 0484 2575723, Fax: 0484 2577747, E-mail: hodpsrt@cusat.ac.in, hodpsrt@gmail.com

# Appendix-3

Phone : 0484 - 2556187
DIVISION OF CIVIL ENGINEERING
SCHOOL OF ENGINEERING
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY
KOCHI - 682 022
Grams: CUSAT Cochin-22, Telex: 885-5019 CU IN

Ref. No. SOE/CE/699/2016-17 Date: 03.10.2016

From

Head

To

M.B. Santhoshkumar
Assistant Professor
SOE, CUSAT.

Sir,

Sub : Testing of Plantain Stem samples

Ref. : Letter No. Nil; dated : 07.09.2016

With reference to the letter cited above, we are giving below the test results of Banana tree samples brought to this laboratory.

**Njalipoovan**

**Span : 700mm (Single point loading)**

| Load = $\frac{PRRx25000}{900}$ N | Sample No. I Peripheral Length = 418.33mm | Sample No. II Peripheral Length = 385mm | Sample No. III Peripheral Length = 482.66mm |
|---|---|---|---|
| | Deflection (mm) (PRRx0.01mm) | | |
| 0 | 0 | 0 | 0 |
| 2 | 74 | 19 | 90 |
| 4 | 140` | 270 | 156 |
| 6 | 210 | 412 | 230 |
| 8 | 289 | 600 | 293 |
| 10 | 372 | 782 | 358 |
| 12 | - | 990 | - |
| 14 | - | 1295 | - |
| 15 | 585 | 1975 | 520 |
| 16 | | - | - |

Fax: 0484-2577405, E-mail: civil@cusat.ac.in

:2:

| | | | |
|---|---|---|---|
| **20** | **815** | **-** | **-** |
| **25** | **895** | **-** | **600** |
| **30** | **1250** | **-** | **997** |
| **34** | **1880** | **-** | **-** |
| **35** | **1955** | **-** | **1006** |
| **36** | **2240** | | **-** |
| **40** | **-** | **-** | **1300** |
| **45** | **-** | **-** | **1570** |
| **50** | **-** | **-** | **1810** |
| **60** | **-** | **-** | **2030** |
| **Maximum Load** | $\frac{44 \times 25000}{902}$ | $\frac{22 \times 25000}{902}$ | $\frac{80 \times 25000}{902}$ |

## COMPRESSION TEST

**Njali - 1**

Peripheral Height : 480mm

Height : 300

| Load (PRR) | Deflection (DGR) Lateral | | | | |
|---|---|---|---|---|---|
| | 0.01 | 0.002 | 0.01 | 0.002 | 0.01 |
| 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | -3 | 3 | 0 | 35 | 49 |
| 10 | -7 | 20 | 4 | 37 | 127 |
| 15 | -16 | 98 | 18 | 50 | 212 |
| 20 | -23 | 117 | 28 | 101 | 239 |
| 25 | -28 | 134 | 36 | 170 | 260 |
| 30 | -33 | `152 | 43 | 244 | 277 |
| 35 | -39 | 182 | 51 | 302 | 297 |
| 50 | -50 | 210 | 65 | -53 | 334 |
| 60 | -55 | 225 | 75 | -15 | 357 |
| 70 | -60 | 251 | 83 | -73 | 380 |
| 80 | -65 | 277 | 90 | -36 | 406 |
| 100 | -71 | 295 | 98 | -96 | 433 |
| 110 | -72 | 304 | 103 | -68 | 470 |
| 130 | -72 | 310 | 112 | -95 | 510 |
| 150 | -72 | 325 | 118 | -45 | 555 |

**Maximum Load : 317 Div.**

## COMPRESSION TEST

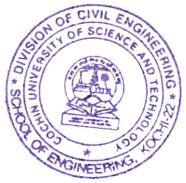
**Njali - 2**

Peripheral Height : 480mm

Height : 300

| Load (PRR) | Deflection (DGR) Lateral | | | | |
|---|---|---|---|---|---|
| | 0.01 | 0.002 | 0.01 | 0.002 | 0.01 |
| 0 | 0 | 0 | 1000 | 1000 | 0 |
| 10 | 0 | 64 | 1041 | 835 | 139 |
| 20 | 0 | 81 | 1042 | 813 | 188 |
| 30 | 21 | 102 | 984 | 788 | 222 |
| 40 | 41 | 118 | 900 | 766 | 313 |
| 50 | 45 | 123 | 874 | 758 | 355 |
| 60 | 72 | 132 | 861 | 751 | 433 |
| 70 | 94 | 135 | 854 | 749 | 481 |
| 80 | 105 | 143 | 845 | 748 | 621 |
| 90 | 105 | 160 | 845 | 742 | 760 |

**Maximum Load : 147 Div.**



## COMPRESSION TEST

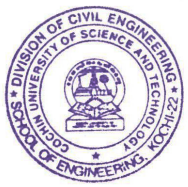
**Njali - 3**

Peripheral Height : 430mm

Height : 300

| Load (PRR) | Deflection (DGR) Lateral | | | | |
|---|---|---|---|---|---|
| | 0.01 | 0.002 | 0.01 | 0.002 | 0.01 |
| 0 | 200 | 200 | 000 | 300 | 0` |
| 10 | 142 | 213 | 89 | 288 | 190 |
| 20 | 142 | 215 | 89 | 288 | 210 |
| 30 | 142 | 222 | 89 | 281 | 240 |
| 40 | 142 | 229 | 89 | 274 | 267 |
| 50 | 142 | 237 | 92 | 266 | 283 |
| 60 | 142 | 246 | 114 | 257 | 306 |
| 70 | 142 | 254 | 131 | 248 | 327 |
| 80 | 142 | 260 | 139 | 240 | 352 |
| 90 | 142 | 287 | 162 | 234 | 369 |
| 100 | 135 | 373 | 185 | 227 | 393 |

**Maximum Load : 222 Div**



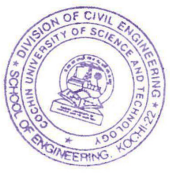
## BENDING TEST

**NENTHRAN**

Peripheral Height : (430+390+365)/ 3 = 395mm
(440+400+370)3 = 403.33mm
(430+390+350)/3 = 390.0mm

Span : 700mm

| Load (PRR) | Deflection (DGR) Lateral | | |
|---|---|---|---|
| | 0.01 | 0.01 | 0.01 |
| 0 | 0 | 0 | 0 |
| 2 | 145 | 70 | 145 |
| 4 | 280 | 149 | 295 |
| 6 | 478 | 230 | 472 |
| 8 | 678 | 328 | 680 |
| 10 | 935 | 450 | 900 |
| 12 | 1250 | 558 | 1242 |
| 14 | 1512 | 710 | 1695 |
| 16 | 2040 | 865 | 2080 |
| 18 | - | 1022 | - |
| 20 | - | 1315 | - |
| 22 | - | 1595 | - |
| 24 | - | 2150 | - |
| **Max Load** | **21Div.** | **29Div.** | **21 Div.** |



## COMPRESSION TEST

**Nentran - 1**

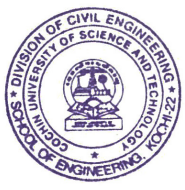
Peripheral Height : 440mm

Height : 300mm

| Load (PRR) | Deflection (DGR) Lateral | | | | Longitudinal |
|---|---|---|---|---|---|
| | 0.002 | 0.01 | 0.002 | 0.01 | 0.01 |
| 0 | 400 | 500 | 600 | 500 | 0 |
| 10 | 400 | 500 | 600 | 480 | 36 |
| 20 | 371 | 504 | 630 | 480 | 75 |
| 30 | 275 | 515 | 715 | 466 | 120 |
| 40 | 65 | 540 | 910 | 435 | - |
| 50 | 150 | 570 | 1245 | 391 | 230 |
| 60 | - | 620 | 2022 | 319 | 430 |
| 70 | - | 580 | - | 336 | 430 |

.

**Maximum Load : 135 Div**



## COMPRESSION TEST

**Nentran - 2**

Peripheral Height : 460mm

Height : 300mm

| Load (PRR) | Deflection (DGR) Lateral | | | | Longitudinal |
|---|---|---|---|---|---|
| | 0.002 | 0.01 | 0.002 | 0.01 | 0.01 |
| 0 | 200 | 500 | 500 | 500 | 100 |
| 10 | 200 | 508 | 511 | 492 | 1110 |
| 20 | 200 | 518 | 519 | 481 | 1147 |
| 30 | 200 | 523 | 519 | 475 | 1179 |
| 40 | 200 | 531 | 528 | 468 | 1210 |
| 50 | 200 | 540 | 536 | - | 1240 |
| 60 | 200 | 548 | 560 | 449 | 1279 |
| 70 | 185 | 557 | 602 | 438 | 1315 |
| 80 | 168 | 563 | 731 | 429 | 1335 |
| 90 | 140 | 572 | 775 | 420 | 1376 |
| 100 | 90 | 580 | 821 | 412 | 1410 |

.

**Maximum Load : 204 Div**

## COMPRESSION TEST

**Nentran - 3**

Peripheral Height : 450mm

Height : 300mm

| Load (PRR) | Deflection (DGR) Lateral | | | | Longitudinal |
|---|---|---|---|---|---|
| | 0.002 | 0.01 | 0.002 | 0.01 | 0.01 |
| 0 | 500 | 600 | 600 | 500 | 0 |
| 10 | 500 | 578 | 600 | 519 | 125 |
| 20 | 501 | 545 | 600 | 549 | 230 |
| 30 | 502 | 500 | 600 | 592 | 285 |
| 40 | 540 | 490 | 520 | 601 | 400 |
| 50 | 557 | 486 | 515 | 605 | 450 |
| 60 | 557 | 483 | 517 | 608 | 476 |
| 70 | 557 | 483 | 531 | 609 | 532 |
| 80 | 557 | 483 | 531 | 611 | 610 |
| 90 | 557 | 483 | 531 | 612 | 680 |
| 100 | 660 | 483 | 531 | 612 | 820 |

## COMPRESSION TEST

**Njali - 1**

Peripheral Height : 505mm

Height : 250mm

| Load (kN) | Deflection Compressometer Reading 0.002mm | Longitudinal(0,01m) |
|---|---|---|
| 0 | 0 | 400 |
| 1 | 11 | 615 |
| 2.6 | 15 | 625 |
| 3.0 | 17 | 750 |
| 4.0 | 40 | 794 |
| 5.0 | 50 | 820 |
| 6.0 | 100 | 880 |
| 7.0 | 149 | 958 |
| 8.0 | 170 | 1120 |

**.Maximum Load : 8.6kN**

## COMPRESSION TEST

**Njali - 2**

Peripheral Height : 465mm

Height : 245mm

| Load (kN) | Deflection Compressometer Reading 0.002mm | Longitudinal(0,01m) |
|---|---|---|
| 0 | 0 | 900 |
| 1 | 5 | 935 |
| 2 | 14 | 105 |
| 3 | 22 | 1097 |
| 4 | 30 | 1137 |
| 5 | 38 | 1182 |
| 6 | 51 | 1250 |
| 7 | 81 | 1350 |
| 8 | 81 | 1520 |

**.Maximum Load : 9.8kN**

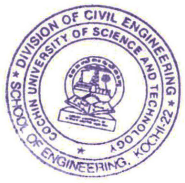
## COMPRESSION TEST

**Njali - 3**

Peripheral Height : 500mm

Height : 245mm

| Load (kN) | Deflection Compressometer Reading 0.002mm | Longitudinal(0,01m) |
|---|---|---|
| 0 | 0 | 300 |
| 1 | 1 | 500 |
| 2 | 1 | 525 |
| 3 | 1 | 590 |
| 4 | 1 | 645 |
| 5 | 1 | 700 |
| 7 | -9 | 860 |



## COMPRESSION TEST

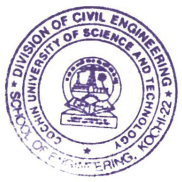
**Nentran 2**

Peripheral Height : 360mm

Height : 200mm

| Load (kN) | Deflection Compressometer Reading 0.002mm | Longitudinal(0,01m) |
|---|---|---|
| 0 | 0 | 500 |
| 4 | 1 | 540 |
| 10 | 1 | 560 |
| 20 | 1.5 | - |
| 25 | 4 | 621 |
| 32 | 4 | 653 |
| 36 | 4 | 677 |
| 45 | 5 | 724 |

**.Maximum Div. : 98**



## COMPRESSION TEST

**Nentran 3**

Peripheral Height : 340mm

Height : 200mm

| Load (kN) | Deflection Compressometer Reading 0.002mm | Longitudinal(0,01m) |
|---|---|---|
| 0 | 0 | 500 |
| 4 | 0 | 515 |
| 9 | 8 | 543 |
| 18 | 8 | 580 |
| 27 | 20 | 618 |
| 36 | 31 | 655 |
| 45 | 35 | 690 |
| 54 | 42 | 743 |
| 60 | 62 | 825 |

**.Maximum Div. : 62**

## COMPRESSION TEST

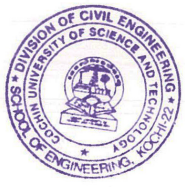
**Nentran 4**

Peripheral Height : 355mm

Height : 200mm

| Load (kN) | Deflection Compressometer Reading 0.002mm | Longitudinal(0,01m) |
|---|---|---|
| 0 | 0 | 300 |
| 4 | 0 | 327 |
| 9 | 0 | 360 |
| 18 | 6 | 409 |
| 27 | 6 | 465 |
| 36 | 6 | 550 |
| 45 | 13 | 720 |
| 54 | 13 | 830 |
| 60 | 14 | 1230 |

Faculty In charge



# Appendix-4

**Department of Polymer Science & Rubber Technology**
പോളിമർ–റബ്ബർ ശാസ്ത്ര സാങ്കേതിക വിഭാഗം
**Cochin University of Science & Technology**
കൊച്ചി ശാസ്ത്ര സാങ്കേതിക സർവ്വകലാശാല

**Professor & Head**

DPR I.18/HOD/17-18 25.08.2017

Mr. M. B. Santhosh Kumar
Dept. of Information Technology
School of Engineering
CUSAT.

Sir.

Please see the Test Results from UTM attached.

Thanking you.

Yours faithfully,

HEAD OF THE DEPARTMENT

Kochi, Kerala, India, Pin - 682 022, Tel.: 0484 2575723, Fax: 0484 2577747, Email: hodpsrt@gmail.com. Web: http://psrt.cusat.ac.in

DPR 1.18/HOD/17-18 25.08.2017

**TEST RESULT**

| **Dry** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameter | Max_Stress | Max_Strain | Break_Strain | Max_Force | Max_Disp | YP_Force | YP_Stress |
| | | | | | | 0.1 %/FS | 0.1 %/FS |
| Units | MPa | % | % | N | mm | N | MPa |
| Thread - 1 | 10.334 | 26.83 | -.- | 292.188 | 10.732 | -.- | -.- |
| 2 | 11.3729 | 32.5525 | -.- | 321.563 | 13.021 | -.- | -.- |
| 3 | 16.4438 | 40.365 | -.- | 575 | 16.146 | 565.313 | 16.1667 |
| 4 | 10.2161 | 36.7175 | -.- | 357.5 | 14.687 | -.- | -.- |
| Single thread - 1 | 17.2428 | 15.475 | -.- | 134.375 | 6.19 | -.- | -.- |
| 2 | 27.0436 | 15.645 | -.- | 227.813 | 6.258 | -.- | -.- |
| 3 | 18.6157 | 17.755 | -.- | 91.5625 | 7.102 | -.- | -.- |
| 4 | 25.9032 | 21.83 | -.- | 216.875 | 8.732 | 177.5 | 21.2003 |
| 5 | 27.8226 | 17.455 | -.- | 181.563 | 6.982 | 122.188 | 18.724 |
| **Wet** | | | | | | | |
| Parameter | Max_Stress | Max_Strain | Break_Strain | Max_Force | Max_Disp | YP_Force | YP_Stress |
| | | | | | | 0.1 %/FS | 0.1 %/FS |
| Units | MPa | % | % | N | mm | N | MPa |
| Thread -Water- 1 | 11.3027 | 52.9775 | -.- | 273.438 | 21.191 | -.- | -.- |
| 2 | 10.3751 | 28.4437 | -.- | 175.625 | 11.3775 | -.- | -.- |
| 3 | 8.13945 | 38.915 | -.- | 225.938 | 15.566 | -.- | -.- |
| 4 | 9.76287 | 48.445 | -.- | 234.063 | 19.378 | -.- | -.- |
| 5 | 5.80966 | 29.4275 | -.- | 116.25 | 11.771 | -.- | -.- |
| Single Thread - Water- 1 | 9.62117 | 21.415 | -.- | 88.125 | 8.566 | -.- | -.- |
| 2 | 9.6884 | 20.6775 | -.- | 71.25 | 8.271 | -.- | -.- |
| 3 | 9.58402 | 17.3525 | -.- | 94.0625 | 6.941 | -.- | -.- |
| 4 | 14.4977 | 13.7063 | -.- | 163.125 | 5.4825 | -.- | -.- |
| 5 | 7.48501 | 15.3725 | -.- | 97.5 | 6.149 | -.- | -.- |
| Thread -Salt- 1 | 11.1356 | 52.04 | -.- | 232.188 | 20.816 | -.- | -.- |
| 2 | 5.22526 | 21.5175 | -.- | 109.375 | 8.607 | -.- | -.- |
| 3 | 10.8705 | 56.205 | -.- | 295.938 | 22.482 | -.- | -.- |
| 4 | 8.30541 | 43.905 | -.- | 226.875 | 17.562 | -.- | -.- |
| 5 | 10.8758 | 36.1 | -.- | 220 | 14.44 | -.- | -.- |
| Single Thread - Salt- 1 | 6.64248 | 8.7575 | -.- | 78.4375 | 3.503 | -.- | -.- |
| 2 | 11.4721 | 28.915 | -.- | 140.938 | 11.566 | 111.875 | 9.10647 |
| 3 | 7.37615 | 17.345 | -.- | 81.25 | 6.938 | -.- | -.- |
| 4 | 12.2235 | 19.33 | -.- | 102.813 | 7.732 | -.- | -.- |
| 5 | 11.97 | [illegible] | -.- | 88.75 | 7.566 | -.- | -.- |

DEPARTMENT OF POLYMER SCIENCE AND RUBBER TECHNOLOGY
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY KOCHI-682 022

The Head
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Cochin University of Science and Technology
Kochi - 22

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