CHAPTER I

INTRODUCTION

Agriculture is a practice of cultivating the soil, producing crops for livelihood and commercial purpose. Over 70 per cent of rural households depends on agriculture and allied sectors and it accounted for 17 per cent of GDP in Indian economy in 2013-14. Nowadays agriculture sector results in tremendous increase in crop production due to emerging technologies and techniques. However 15 per cent of the produce is being wasted in the site of production, mainly due to improper crop management from seedbed preparation to harvesting period. These can be mitigated to an extent by developing suitable harvesters for each crop there by saving time, money and labour.

To the India economy the major share from agriculture sector is contributed from tropical crops, vegetables, cereals, and spices. Of these tropical crops, spices contributes about 30 per cent of the production. Tropical crops are important food crops after the cereals. Though most of the tropical crops are *Dietary* fibres, used for nutritional and medicinal purpose. Banana is one among them which are rich in Potassium and Manganese, and a very good source of Vitamin C.

1.1 IMPORTANCE OF BANANA CULTIVATION

Banana (*Musa paradisiaca*) is a large perennial which produces succeeding generation of crop with leaf sheaths that form trunk like pseudo stem. The first cycle after planting is called the plant crop. The ratoon is the sucker (also called the follower) succeeding the harvested plant. The second cycle is called the first ratoon crop. The third cycle is the second ratoon crop, and so on. A pit size of 45 x 45 x 45cm is normally required for banana cultivation (Shanmughavelu, *et al.* 1992). The soil should have good drainage, adequate fertility and moisture. Deep, rich loamy and clay loam soil with pH between 6 -7.5 is most preferred for banana cultivation. Banana is nutritional goldmine, high in Vitamin B6. Banana is the

Second most important fruit crop in India next to mango. It has year round availability, affordability, varietal range, and taste, nutritive and medicinal values.

1.2 AREA, PRODUCTION AND PRODUCTIVITY OF BANANA IN INDIA

Banana cultivation is one of the most popular agricultural practices in India, about 8,46,000 ha of land under cultivation with total production of 29.124 million tonnes. In Kerala 59.100 ha of land under banana cultivation with an average productivity of 9.79 t ha $^{-}$1(Indian Horticulture database – 2014) which are usually seasonal in nature. Fertile soil is important for its cultivation, so it is best grown in volcanic and alluvial soils. The fruit can be cultivated in the temperature range between 10°C and 40°C, and high humidity conditions. Yield is higher when the temperature is above 24° C. In India, it is widely grown in the states of Maharashtra, Gujarat, Tamil Nadu, Assam, Kerala, Karnataka, West Bengal, Orissa, Madhya Pradesh and Andhra Pradesh. There are many varieties of bananas grown in kerala like Robusta, Dwarf Cavendish, Poovan, Nendran, Karpooravalli, Khadali etc.

Banana can be planted throughout the year except in severe winter and during heavy rains when the soil remains wet. The ideal time (October-November) of planting is after the monsoon season, every year. There are three methods of planting the banana crop viz., pit method, furrow method, and trench method. The recommended spacing for it 2.5 x 2.5, 2.0 x 2.0, 2.5 x 2.0 m respectively. After planting the crop is ready to harvest after 11-12 months. Sucker is the seed material for raising next generation in banana. After harvesting, uprooting of mother corm and its suckers without damage wss very essential for obtaining good quality planting material.

About 70 per cent of farmers are using suckers as the planting material while the rest 30 per cent of the farmers are using tissue culture seedlings. After the harvesting of the crop immediate clearing of land is the main difficulty faced by banana farmers as less time is available between harvest and fresh planting of banana field.

In conventional method of uprooting, banana suckers are uprooted by using sharp hatchets and spades. The sword suckers should be dugout and separated from the mother plant. Uprooting the mother plant and suckers, clearing the land etc. are done manually which are highly labour intensive and more time consuming field operation. The present practice of uprooting takes a lot of time and energy. In preliminary investigation of study on banana harvesting by manually we came to know that one man labour can uproot about 15-20 clumps (Mother plant and suckers) per day.

Plate 1.1 Conventional method of uprooting of banana suckers

In 2013, a banana uprooting machine was developed as an attachment to a tractor at KCAET, Tavanur. It was operated by the hydraulic system of a tractor. It consisted of a single hydraulic cylinder with one control valve. There were several problems associated with the construction especially with respect to the uprooting mechanism, undue exertion forces the sucker getting damaged and hence excess fuel, hydraulic oil consumption and more slippage of the tractor during the uprooting of the suckers. In view of the above factors, a research programme was undertaken with the following objectives:

1. To determine the physical and mechanical properties of soil, sucker and its clump
2. To modify the tractor operated KAU banana sucker uprooting machine
3. To evaluate its field performance and workout cost economics

CHAPTER II

REVIEW OF LITERATURE

This is a chapter gives comprehensive review of research work done by many research workers, scientists, students and which includes previous works on physical and mechanical properties of soil, design of machineries and equipment's for uprooting the vegetables, shrubs, and trees and field tested in different countries. Also it includes various literature about cultivation practices and propagation of banana and plantain.

2.1 SOIL MECHANICAL PROPERTIES

Steven and Omi (1985) stated that compaction of soil effects the soil properties viz., moisture content, soil strength, texture, the effects on seedling growth. Study states that penetrometer resistance decreased as moisture content (at the time of compaction) of sandy loam increased and in unsaturated sandy soil, bulk density increased as applied load (range 60 to 360 kPa) increased. Water content on compaction also affected by soil texture. Sandy clays may compacted to 1.7 to 2.1 g/cm^3 at only 8 to 15 per cent moisture, clays to 1.5 to 1.7 g/cm^3 at 20 to 30 per cent moisture (Froehlich 1973). Seedling establishment was generally > 75 per cent on a sandy loam, regardless of compaction intensity (1.2, 1.4, 1.6, and 1.8 g/cm^3); on a silt loam, only soil compacted to 1.8 g/cm^3 significantly reduced seedling establishment (Zisa et al. 1980). Length of primary root penetration of Pseudotem declined to 71 to 87 per cent as bulk density increased from 1.38 to 1.76 g/cm^3 (Heilman 1981). Study resolved that compaction can detrimentally affect soil physical characteristics, resulting in poor tree growth

Brandelik and Hiibner (1996) developed electromagnetic measurement techniques of soil moisture. He used three different sensors, which enriched the accuracy of exiting measurement device and extend the range applications. The first one was in-situ sensor, which evaluated soil moisture profile down to 2.5 m with a vertical resolution of 3 cm and an accuracy of 1.5 unconditional volumetric water content. The second sensor measured accurately the water content in the surface layer of the soil. Third sensor was a moisture sensitive cable. It used the technique of time domain reflectometry and frequency domain reflectometry.

According to Jahn and Hamburg (2002) frequently use a cone penetrometer and the Cone Index (CI) to characterize soil strength in agronomic study of soil. He used the traction models that utilize CI as the measure of surface soil strength. Tractor mounted versions that reduce manual labour requirements. General use of Cone Index was enhanced by the existence of a standard (ASAE S313.2) addressing the physical and operational aspects of cone penetrometers and the calculation of the CI, making comparisons from different studies practical. He concluded that cone penetrometers had limitations as a means of characterizing soil strength. The easily measured parameter (cone index), represented by the force to push a cone into the soil divided by the cross sectional area of the cone.

Reddy (2002) conducted experiment on engineering properties of soils based on laboratory testing. The test was conducted to determine the physical and mechanical properties of soils like moisture content a lab experiments for the mechanical properties of the soil like moisture content, bulk density and grain size analysis (sieve and hydrometer analysis methods). He termed that water content is the ratio, expressed as a percentage, of the mass of “pore” or “free” water in a given mass of soil to the mass of the dry soil solids. (ASTM D 2216 - standard test method for laboratory determination of water content). The bulk density is the ratio of mass of moist soil to the volume of the soil sample, and the dry density is the ratio of the mass of the dry soil to the volume the soil sample. And grain size analysis as the mechanical or sieve analysis is performed to determine the distribution of the coarser, larger-sized particles, and the hydrometer method is used to determine the distribution of the finer particles.

The cone index of a soil was the degree of its strength had been revealed to be affected by its water content and bulk density (Agodzo and Adama, 2003; Vaz *et al.* 2001) and was usually measured in kilo-Pascal (kPa). According to USDA (1999), penetration resistance (Cone Index) depends intensely on the soil water content: the drier the soil, the greater the resistance to penetration. Therefore, the water content of the soil should be noted when taking a measurement of cone index.

Study states that water content of the soil is an important property that controls its behavior of implement. As a quantitative measure of wetness of a soil mass, water content affects the level of compaction of soil during the tillage, which is indicated by its bulk density (Agodzo and Adama, 2003).

Morris (2006) measured some low-cost soil moisture monitoring tools and methods, including new generation of sophisticated and user-friendly electronic device and explained the process of water detention by soil.

Thompson *et al.* (2007) determined lower limit values for irrigation management using continuously monitored data from volumetric soil water content (SWC) sensors. Four indices were derived from SWC data. Indices were calculated for 0-20 and 20-40 cm soil depth in four drying cycles applied to melon and to autumn and spring tomato crops. In each cycle, there were well watered and un watered irrigation treatments.

In this study the Measurement of soil moisture content by gravimetric method. The criterion for a dry soil sample is the soil sample that has been dried to constant weight in oven at temperature between 100 – 110^0 C (105^0 C is typical). It appears that this temperature range has been based on water boiling temperature and does not consider the soil physical and chemical characteristics (Angelis, D. 2007)

Latteorre *et al.* (2013) conducted an experiment by NSQE method to estimate soil hydraulic properties viz., sorptivity (S) and hydraulic conductivity (K) from full-time cumulative infiltration curves. A total of 264 infiltration measurements performed with a 10 cm diameter disc under different soil conditions. They found out that the NSQE method had significant effect on accurate estimate of the soil hydraulic properties in a transient water flow.

2.2 BANANA CULTIVATION

Robinson and Nel (1986) conducted a study in the subtropical banana-growing areas of South Africa, and identified that there is a pronounced and consistent tendency for fruit to be oversupplied in the spring (September-November) and undersupplied in the autumn (March May). Under identical soil, planting material and general management conditions, a crop-timing trial with ‘Williams' banana was established at Burgershall Research Station, Eastern Transvaal, to compare the effects of planting date (September, December, March), time of first sucker selection (5 and 10 months after planting) and density (1666 and 1250 plants ha−1) on yield and harvest season over 3 crop cycles.

Robinson and Nel (1990) conducted a desuckering experiment with cultivar ‘Williams' banana was established at Burgershall Research Station in the subtropicalm Eastern Transvaal. Unwanted suckers were excised when they attained a height of 300 (control), 500 or 800 mm, leaving one suckers per mat as the ratoon follower. A fourth 7 treatment entailed desuckering at a height of 300 mm. In the plant crop there was no significant reduction of bunch mass or yield per annum due to desuckering at 800-mm height. However the selected first (R1) and second (R2) ratoon followers which were competing with large unwanted suckers produced smaller bunches, an extended cycle time and lower yield per annum. In the R1 and R2 cycles, the yield reductions with 500 mm desuckering were 8.3 and 9.1%, whereas for 800-mm desuckering yield was reduced by 16.9 and 17.5%, respectively. The presence of a large nursery sucker in addition to the follower decreased yield by 7.9 and 12.6%, respectively. Leaf area on an 800-mm sucker was 39 times greater than for a 300-mm sucker. Early desuckering of small suckers is recommended to improve yields and reduce labour costs.

Shanmughavelu *et al.* (1992) described different aspects of production technology of banana crop for different varities in South India.

Eckstein and Robinson (1999) conducted a study on Banana tissue culture plants (cv. Dwarf Cavendish) at Burgershall Research Station, South Africa, to demonstrate the influence of the mother plant on sucker growth, development and photosynthesis. Removing the leaf canopy and newly-emerged bunch from the mother plant, at sucker selection stage, doubled total dry mass and leaf area of the ratoon sucker six months later, and related with suckers attached to normal, unpruned mother plants. This decrease in sucker growth after severing was associated with lesser photosynthesis and transpiration in the severed suckers, compared with levels in attached suckers. However, removal from the mother plant of a newly-emerged bunch, which normally accounts for more than 30% of total plant dry matter at harvest, is acceptable for increasing sucker production in banana nurseries

Mathew (2000) conducted an experiment to study the effect of cutting height of parent pseudo stem and its relationship with the number of suckers, followers connected non-severed and severed with the mother plant on foliar and soil nutrient status of first ratoon crop in banana. In his experiment concentration of N, P and K of leaf was found considerably higher by retaining major parts of the parent 9 pseudo stem above corm level. Separating of suckers, followers considerably decreased the leaf N status at both shooting and harvesting stages. Nitrogen content was proportionately higher with the increasing extent of retaining the other plant. Higher concentration of leaf P and K was observed with retention of single connected/non severed sucker with half cut mother plant over the parent plant cut at corm level. Soil nutrient status mainly total N and available P in the upper soil layer 0– 25 cm depth increased extensively with retaining of untopped mother plant.

Nelson (2000) conducted a study on field performance of in-vitro propagated banana plants was compared with that of the sucker-derived plants. In his study vitro-propagated plants established and grow faster, taller and bigger than the conventional sucker-derived plants. In this experiment, the in vitro-propagated plants had many intact roots and a bulk of vermiculite around their roots but the sucker-derived plants had many damaged roots at the time of planting. In addition, in vitro-propagated plants started growth earlier and grew faster permitting them to intercept more light for photosynthesis than the sucker-derived plants. This may explain the higher yield in the in vitro propagated plants. He conclude that in vitro-propagated banana performs better in terms of growth and yield than the sucker-derived plants under field conditions.

Smith *et al.* (2001) conducted a study on suckering behaviour of micro propagated bananas is important not only in terms of commercial management but also to gain further appreciation of the physiological mechanisms involved in sucker development. Field studies showed that plants of micro propagated banana produced significantly more suckers than plants grown from conventional planting material. However, when bits were established in containers in a glasshouse and 10 grown under the same conditions as micro propagated plants, the differences became less distinct. Plants derived from bits that had been established directly in the field always lagged behind plants grown from the other two sources. The most significant difference between micro propagated plants and those grown from containerized bits was greater leaf area and dry weight of suckers from the micro propagated plants. He reported that suckers with large leaf areas were categorized as water suckers. These differences may be related to root density and point of sucker origin on the rhizome and supports the need to desuckering the early flush of new suckers on young micro propagated plants.

Mello *et al.* (2002) carried a work to define adequate spacing for the development and yield of 'Comprida Verdadeira' plantain in the South Rain Forest Region of Pernambuco State, Brazil. Experimental design of randomized blokes with three treatments, composed of three distinct spacing (3.0 x 2.0 m, 2.5 x 2.0 m and 2.0 x 2.0 m), and three replicates were utilized. The characteristics evaluated were: plant height, pseudostem circumference, numbers of suckers and leaves emitted, days from planting to inflorescence emission and harvest, bunch and hands weights, numbers of fruits and hands per bunch, fruit length and diameter, and skin thickness. Different distances had no effect on first cycle productivity. However, 3.0 x 2.0 m and 2.5 x 2.0 m spacing increased yield of bunch weight, and fruits showed the best physical characteristics.

Elainapshara and Sathiamoorthy (2003) conducted an investigation on the effect of planting density and spacing on growth and yield of banana cv. Nendran (AAB) revealed that the increase in planting densities significantly increased the pseudo stem height and reduced the pseudo stem girth. While total crop duration increased with higher plant population, the actual days to fruit maturity decreased. Decreasing trend of individual bunch weight with increase in plant population was evident. The longer crop 11 life and lower individual bunch weight were compensated by the total yields, as there was 80.39% increase over control in the densest planting.

Blomme *et al.* (2004) conducted a study on Effect of Nematodes on Root and Shoot Growth of in Vitro-propagated and Sword Sucker-derived Plants of Six banana crop.The study was carried out at the International Institute of Tropical Agriculture High Rainfall station at Onne in southeastern Nigeria in an ultisol soil. This study evaluated the effect of infection by a mixture of nematode species on the root system size and shoot growth of six Musa genotypes. The Musa genotypes were the triploid (AAA-group) dessertbanana cvs Yangambi and Gros Michel, the triploid plantain CVS Agbagba and Obino l'Ewai and two IITA improved tetraploid plantain hybrids TMPx 548-9 and TMPx 5511-2. Results showed that during vegetative growth, shoot growth of infected plants was less than that of non-infected plants. At flower emergence, a severe reduction in root system size (as much as 75%) was associated with moderate (in most cases less than 20%) reduction in corm and shoot growth characteristics.

Alagumani *et al.* (2005) evaluated economic analysis of tissue- cultured banana and sucker propagated banana through studying their costs and returns. The factors influencing the costs of their production have been identified and resource-use efficiency has been studied. The study has been conducted in the Theni district of Tamilnadu using personal interview method. Probity model has been engaged to find out the factor influencing the assumption of tissue culture. The study has revealed that tissue cultured banana is more profitable to farmers than sucker-propagated banana. The resource could be utilized efficiently in TCB, gross income and bunch weight is the major factors that effecting the adoption of TCB. Also the risk is lower in TCB than in SPB. The study has suggested that farmers should be encouraged to adopt TCB to get higher yield and profits

Oluwafemi (2013) investigated the Influence of number of sucker per plant on the growth, yield and yield components of Plantain (Musa sp). The results shows that tallest plants were observed in the plantain plants with more than three suckers (multiple sucker) while the shortest was recorded in either the zero or one sucker plant. With obtained results he concluded that, zero or one sucker plants result in increased yield and yield components with shorter and thicker plants.

Mahdi *et al.* (2014) study conducted on the influence of three selective levels of sucker pruning namely (mother + 2 followers, mother + 3 followers and mother + 4 followers) on growth and yield of the banana compared to the traditional farmer practice. The results revealed that a significant reduction in growth and yield parameters of banana plant with increase in number of suckers left with the mother plant.

Shaikh et al. (2015) conducted a field experiment at the Banana Research Station, Jalgaon during 2009-2013 to determine the proper time of keeping follower as a ratoon crop in plant crop system that would maximize the yield of commercially grown banana cv. Grand Naine. Treatments applied by keeping followers after 7, 8, 9,10,11,12 and 13 months after planting of plant crop. Result showed that, the treatment of keeping follower 10 months after planting of plant crop was found better in respect to growth and yield of banana.

2.3 PLANT UPROOTERS AND SOIL DIGGERS

William & Wichita (1940) developed a machine for uprooting trees and bushes in front of the tractor and without disturbing the surrounding vegetation or grass growing on the surface of the soil. This is especially beneficial for use in removing small bushes and trees from arid land, while conserving the growth of grass there on after removal of the shrubs.

Harvard (1977) developed a machine for sorting out the roots of a tree from the earth. It uproot the attached roots of the tree and transports it to the other location. The designation of the machine is “treeballer”. It wraps the root structure, which resemble as a ball. It is simple and less costly to manufacture as compared with known, similar machines.

Berthollet (1980) developed a machine for cutting shrubs and plants from the soil and for lifting them with their root intact to deposit them upon the ground or in a previously formed hole for planting. It is a tractor mounted machine, provided with a spade or lade which can be drawn downwardly below the shrub by forward movement of the tractor and then rotated through 360◦ to free the root ball from the surrounding soil. The support also carries an arm which engages the root neck, stalk, trunk or stem of the shrub to hold and displace it independently of the blade carrying structure.

Frankel (2003) studies a kinematics & dynamics of backhoe. In his study describes that kinematic and dynamic relationships between the cylinder forces and succeeding motions of the backhoes four degrees of freedom, specifically the swing, boom, stick, and bucket links. The geometric transformations between joint angles and cylinder positions are derived, and both forward and reverse displacement analyses are solved. Finally, he anticipated the digging trajectory, and the reverse kinematic equations are used for simulation.

Kuśmierczyk and Szlagowski (2008) evaluated the automated excavation process analysis for given trajectory and soil parameters. In this study the test rig were conducted, consisting of excavator, ditch with soil and computer system. The excavator – Warynski K-111 with bucket capacity of 0,1 m3 is placed 3m over the ground. In front of excavator’s support, the ditch is positioned. There is a soil prepared according to developed methodology inside the ditch. The results shows that ditch capacity was 17m3. Soil inside the ditch which weights around 28 tonnes.

Vladeanu and Vladeanu (2011) conducted an experiment on the control of the bucket position at the hydraulic excavators with backhoe attachment. In this experiment they have used the sensors for positioning the bucket for digging. Sensors which indicate the bucket position and regulator which emits command signals in the view of the obtaining of the desired trajectory of the bucket and laser transmitter generates a reference plane towards which the bucket position is established with the aid of the laser sensors mounted on the working equipment. They had concluded that increasing in precision of the execution of the digging works with excavators with a bucket is assured and also an increase in productivity.

Patel and Prajapati (2012) study conducted on then evaluation of bucket capacity, digging force calculations and static force analysis of mini hydraulic backhoe excavator. He Calculated method of bucket capacity and digging forces required to dig the soil or to uproot the trees. This technique provides the prediction of digging forces and can be applied for autonomous operation of excavation task the evaluated digging forces can be used as boundary condition and loading conditions to carry out finite element analysis of the backhoe mechanism for strength and stress analysis. The area of bucket is 66836 mm^2 and bucket heaped capacity was calculated using formula,

$$V_h = V_S + V_e$$

The bucket struck capacity (V_s) was 0.2072 M^3 and excess material capacity (V_e) for an angle of repose 1:1 is 0.00709 m^3 from these two values the bucket heaped capacity (V_h) obtained was 0.028 m^3

Patel and Prajapati (2012) evaluation of Resistive Force using Principle of Soil Mechanics for Mini Hydraulic Backhoe Excavator. The study emphasize on graphical representation of the relations between excavation force and different parameters like soil density, soil tyne friction angle, soil cohesion, internal friction angle and depth of tool. In this study they have utilized a model of soil-tool interaction that predicts resistive forces experienced at the tool during digging. This paper evaluates the digging force based on fixed bucket size of 300 mm length × 300 mm width × 300 mm depth and the minimum digging depth up to 1.5 m. Rated capacity of bucket is calculated was 0.028 m3 and total resistive force experienced using soil-tool interaction was 39203.5 N.

Aswathi *et al.* (2013) developed and tested a banana sucker uprooting machine as an attachment to a tractor to uproot the soil-banana sucker clumps. The machine was tested at the instructional farm, KCAET, Tavanur. It is reported that the machine could uproot 180 banana clumps in six hours. The field capacity of machine was 0.19 ha h^{-1} and they have opioned that the cost of uprooting can be reduced to three fourth compared to conventional method.

Babu and Venu (2013) reported the design optimization of excavator bucket using Finite Element Method. The main aim was to improve excavator bucket life by optimizing the design and design parameters and excavator bucket model will be generated acoording to SAE and modelling was carried out in FEM software and load calculations will be done to utilize the load value in FEM software. From the structural analysis results obtained for displacement, stress and strain of FEA using ANSYS software they have concluded that the optimized design of bucket will give 300% improvement in life, strengthen ribs are going to get damaged , periodically ribs have to be replaced to protect the bucket.

Bende and Awate (2013) design, modeling and analysis of excavator arm. In this study they have designed an arm and bucket using CAD-CAE systems and calculated capacity of bucket and analysis using FEA. The capacity and load acting on bucket was 40.964 and 568.62 N.

Mishra and Dewangan. (2013) study conducted on optimization of component of excavator bucket. In this study they have focused to analyze the force calculation of excavator bucket and calculation of excavator bucket capacity, which are failing under the given operating conditions. During operation of excavator at different positions the stresses induced in the bucket.

Sohrab and Gandhi (2014) reported the traditional method of uprooting of banana suckers after harvest. He initiated the usage of spade, pick-axe and crow-bar for uprooting and subsequent land clearing.

Mahesh (2015) evaluated method for bucket capacity and digging forces required to dig. His method provides the prediction of digging forces and can be applied for autonomous operation of excavation task. He stated that bucket capacity is a measure of the maximum volume of the material that can be accommodated inside the bucket of the backhoe excavator. Bucket capacity can be either measured in struck capacity or heaped capacity. The struck capacity directly measured from the 3D model. The bucket capacity for the proposed 3D backhoe bucket model obtained was 0.028 m3.

Manisha and. Zaveri (2015) Design and Analysis of an Excavator Bucket and they had conducted study on the stresses developed at the tip of excavator bucket teeth. Percentage error between stress analytical result and stress ANSYS result are calculated. Design an excavator bucket by using CREO parametric software and analysis is done by ANSYS 13.0 software. The stress at the tip of teeth of an Excavator bucket obtained was 96. 39 MPA and stress due to shearing of rivet was 157.67 MPA by analytically. Percentage error between analytical result and Ansys result obtained 14.69 % and 5.82 %.

Sagar and Pranay (2015) experiment conducted on comparative study of factors affecting productivity and cycle time of different excavators and their bucket size. In this study, they have focuses on study of actual productivity against the theoretical productivity to demonstrate the loss of productivity. Cycle times can be one of the more puzzling aspects of open -pit excavation. The experiment was carried out for two sites. They have used capacity of bucket 0.5 cum and efficiency considered was 75%.

Shanmukheswar and Ananth (2015) designed excavator bucket teeth with different cross section using solid works software. They had designed the bucket tooth based on the material selection and its shape and sizes. The size of the tooth was 300 mm x 300 mm x 300 mm and material selected based on strength to weight ratio, abrasion resistance and impact strength of the material. Also they have proposed soil-tool interaction model that predicts resistive forces experienced at the bucket teeth during digging. The material used was steel for square-cross section of teeth and minimum and maximum stress values obtained was 3.5967e006 N/mm^2 (MPa) and 0.045264 2 N/mm^2 (MPa) and for triangular cross section of teeth the minimum and maximum stress values obtained was of 0.888399 N/m^2 (MPa) and 51193.1 N/m^2 (MPa) for travel speed of 0.277 m/sec. Observing cross section results of triangular and rectangular section, they got less stress values for steel when compared with the grey cast iron, Titanium Boride and Titanium

Xiaoping and Xiaoping (2015) structural Analysis and Optimized Design of Working Device for Backhoe Hydraulic Excavator. The structural analysis carried for working devices viz., arm, and bucker using the VB programmed software called self-compiled structural analysis software (SSAS) and these reliability of SSAS was verified through comparing result to ANSYS simulation. The result shows that: the weight is eliminated by 1.33% which is approximately 38.3 Kg of arm.and they concluded that research provides a new way for structural design and optimization of working device, which is significant to design original excavator with better quality.

Kumar and Alam (2016) study conducted on the deformation analysis of the bucket teeth wear. The tooth material for excavator bucket were taken as of AISI 1040 standard. The maximum stress generated is calculated using von-misses stress theory He reported that maximum stress is at the fixed point while the rate of deformation is maximum at the tip of the teeth. The abrasive nature of soil is one of the reason of tip wear and head of tooth is the most critical point and so it could be conclude that high strength steel will be adequate because of the extreme loads.

Lomate *et al*. (2016) investigated on Design and Shape Optimization of Excavator Bucket. They have stated that bucket capacity is a measure of the maximum volume of the material that can be accommodated inside the bucket.

Bucket capacity can be either measured in struck capacity or heaped capacity. The study focused on an analysis and optimization Bucket of chassis model was done in ANSYS 15.0 Workbench. The Model of Bucket is analyzed under 4 different loading conditions to find out the bucket distortion, and bucket distortion is compared with regular bucket. It is observed that the stresses in 1.8 cum design when analyzed for 1/3 offset and for full offset are lesser than 1.9 cum of bucket capacity.

Nishane et al (2016) conducted a modeling and static analysis of backhoe excavator bucket. They have suggested to use finite element analysis (FEA) as a tool for static analysis of backhoe excavator bucket for existing and optimized excavator bucket and used CAD modelling for creation, modification of the bucket. The maximum stress point and deformation and method to minimize it with increasing the life of backhoe excavator bucket was explained by finding the mechanical properties viz. Youngs modules, poisons ratio, density for existing models of bucket. The results shows that Maximum and Minimum deformation of 2.677and 0 mm respectively. The equivalent stress 191.1 MPa and shear stress of 67.3 MPa and life of bucket obtained was 22760 min.

George and Sivasubramaniam (2017) reported the anxieties created at the tip of excavator basin teeth and rate blunder between stress explanatory outcome and stress ANSYS result are determined. The results shows that the worry at the Tip of teeth of an excavator pail is assumed 96. 39 MPA and worry because of shearing of bolt is computed 157.67 MPA by logically. The worry at the tip of the teeth is computed 112.98 MPA and worry because of shearing of bolt 167.42 is ascertained. Rate mistake between scientific outcome and ANSYS result are 14.69 % and 5.82 %.

Sekhar and kumar (2017) investigated the stresses developed at the tip of excavator bucket teeth at different inclinations of teeth such as 250,300,350,400,450 was carried out on three types of materials such as stainless steel, AISI-1045 and TI carbide and the action of various stress and strains on the excavator bucket at various loads. The results shows that maximum and minimum shear stress for stainless steel, AISI-1045 and TI carbide was 39.349 and 39.062, 39.815 and 42.197, 39.493 and 39.308 respectively.

2.4 MEASUREMENT OF HYDRAULIC SYSTEM AND HYDRAULIC FLOW RATES

Hemami *et al.* (1999) conducted the some experimental force analysis for automation of excavation by a backhoe. The experimental work consists of the measurement of the ram forces during a number of excavation tasks on the same soil and the automating the excavation function of an excavator is a complex control problem, because of the nature of the interaction between the cutting tool and the medium and the many parameters that are involved in the process. Results of experimental measurements of the excavation forces are presented. These forces cannot be measured directly on the bucket, but the kinematic and dynamic relations can serve for this purpose.

Sakaida *et al.* (2006) conducted experiment on the Analysis of Excavator Operation by Skilful Operator. In experiment they have used backhoe (SK05, KOBELCO) model described the experiment for extracting operator's skill for controlling unmanned hydraulic excavator. They have compare the operation of skilful with non-skilful operator. The skilful operator operates the arm widely about 100 (cm) on the average, meanwhile the non-skilful operator operates narrowly about 40(cm) on the average. excavation length of the skilful operator's is about 290 (cm) meanwhile non-skilful operator's length is about 200 (cm) and excavation depth of the skilful operator is about 75(cm), meanwhile non-skilful operator's depth is about 90 (cm). From these results, they have revealed that skilful operator realizes unified trajectories of the bucket with quick moving and this causes the efficient performance.

International standard (2007) Test method for measuring breakout forces and lift capacity to maximum lift height. ISO 14397 specifies a test method for measuring the breakout forces and lift capacity to maximum lift height of wheeled or crawler. According to the ISO 14397-2:2007(E) hydraulic circuit working pressure applied to the specific hydraulic lifting circuit by the hydraulic pump and lift capacity to maximum height ⟨bucket application⟩ mass, in kilograms, which can be lifted from the ground to maximum height using the lift cylinder or cylinders at hydraulic circuit working pressure, with the bucket positioned to hold the maximum load, and with the resultant force acting vertically through the centroid of the rated bucket volume as specified in ISO 7546.

Jaroslaw and Jan (2008) study conducted on an automated excavation process analysis for given trajectory and soil parameters. Study shows the relation between excavating force and tool angle of attack and optimization of the bucket path. Test rig, consisting of excavator, ditch with soil and computer system. The excavator – Warynski K-111 model were used with bucket capacity of 0.1 m3 is placed 3m over the ground on specially designed support. Ditch capacity is approximately 17m3. Soil inside the ditch witch weights around 28 tons. The backhoe excavator works under control of computer system, which is based on OS-9 operating system.

Dunn (2010) study conducted on applications of pneumatics and hydraulics in tractor and performance characteristics two way direction valve and fluid flow measurements. His study shows that hydraulic systems are high pressure systems and pneumatic systems are low pressure systems.

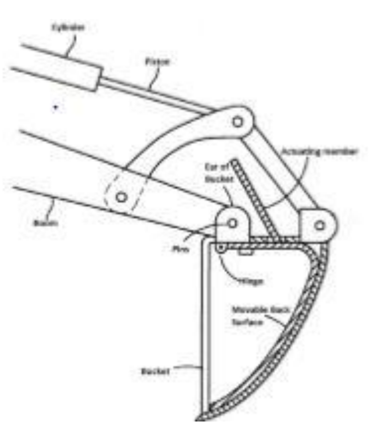
Vladeanu, and Vladeanu (2011) conducted experiment on control of the bucket position at the hydraulic excavators with backhoe attachment. In this study Correlations between the angles of position of the boom, the arm and the bucket mentioned. Excavator equipment three angle transducers are mounted. Three transducer which indicates the relative angular displacement between the boom and rotation platform, boom and arm, arm and bucket, signals transmitted by the position sensors of the boom and arm and the bucket. The results shows the depth of penetration of bucket was 0.40m and with a radius of 2.90 m.

Jagadeesha (2012) explained the concept of Control components in Hydraulic system and use of different directional control valves, pressure valves and flow control valve in hydraulic system.

According to the lei *et al.* (2012) properties of hydraulic system decided high efficiency, security as well as stability under the different working condition. Beginning with the simulation analysis on hydraulic system of hydraulic lifting appliance under different working conditions. This study analyzed a certain hydraulic system through which design reference can be offered for optimizing hydraulic system properties via hydraulic system force and change of torque .the results indicated that on the basis of AMESIM software, the breaking and change characteristics of hydraulic system under each working condition were worked out by taking the advantage of the simulation analysis.

Battiato *et al.* (2013) conducted a study on the mechanical approach to top soil damage due to slip of tractor tyres. In this study condition along the soil tyre contact surface which lead to top soil cutting were analyzed with a soil tyre interaction model and discussed traction test with a MFWD tractor on an agricultural silt loam soil. The longitudinal top soil shear stress along the soil tyre contact approach the soil strength. The longitudinal top soil shear displacement was measured for slip of ranging between 5 to 48%.these slip value were indicated as indicative line in tillage operation in order to avoid the top soil damage

Pande *et al.* (2013) conducted a research design and analysis of clogged soil ejecting mechanism in long-reach excavator bucket. He suggests a spring-plunger mechanism connected to soil ejecting plate which is assembled in the bucket itself. The mechanism works with the curling and uncurling operation of the bucket. Ejecting plate is connected with plunger and spring. Bracket in the bucket is provided for resting of spring and pusher is welded on tipping link of arm about which bucket rotates during curling and uncurling operation. This pusher forces the plunger head during the unloading operation of bucket (see figure 2). Force applied by pusher should be greater enough so as to rotate plate. When pusher applies force on plunger head, spring of plunger compresses and ejecting plate rotates about the hinged rod. Due to this, end of ejecting plate will go on shearing the soil attached to bucket. And so, all the mud will be removed.



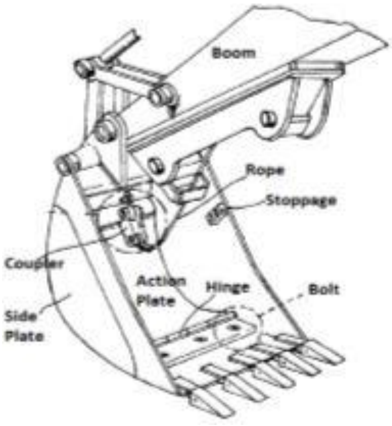


Fig.1Working mechanism Fig.2 Self-cleaning mechanism

He suggest that with implementing this mechanism in the existing buckets will definitely reduce their jerking to significant level. Also the efficiency and life of bucket will increase to great extent.

Zu and Rui (2013) research carried on the whole stability of WZ 30-25 backhoe loader. A virtual prototype of WZ 30-25 hydraulic backhoe loader is established by using parameterization modelling and analysis function of ADAMS software. In his experiment specification of components were bucket cylinder diameter is 90mm, piston rod diameter 45mm, diameter of arm cylinder and boom cylinder is 100mm, piston diameter is 50mm, working pressure of hydraulic system is 17.5 Mpa. Using an ADAMS software in the 20 s three backhoe working equipment cylinder co-ordinate work.

Borghi *et al* (2014) studied alternative hydraulic architecture for agricultural tractors in comparison with the traditional systems. The analysis was performed with the reference to the hydraulic circuit and the operating condition of the circuit architecture uses independent meeting valves and electronically controlled variable pumps and involved different control strategies. They had demonstrated that considerable energy saving was achieved using the alternative architectures.

Felix *et al.* (2016) study conducted on eco-approach to optimize fuel efficiency (kg/l) and productivity (m^3/h) of a hydraulic excavator. The study examined for the two variables engine speed and bucket cut depth to determine their effect on productivity and fuel efficiency of hydraulic excavator. The results shows that the combination of various engine speed settings and bucket cut depth can increase productivity by 30%. It has been found that BCD and RPM settings can affect fuel efficiency and productivity of operation of a hydraulic excavator. Highest RPM settings will achieve highest productivity, conversely low RPM settings do not necessarily consume least fuel to complete the same task. The results also scientifically proved that that half-filled bucket (50% BCD) can have a maximum effect of 30% improvement on productivity (m^3/h), 24% saving on fuel efficiency (kg/l).

Gajda *et al*. (2016) study conducted on Analysis of the kinematic characteristic of the test stand for various steering systems for the hydraulic driven working attachment. The test stand was designed on the basis of excavator for tractors, model 260 from John Deere. In this study test stand which permits one to test various steering systems for the hydraulic driven working attachment were explained. Micro-controller ATmega 32 was used as a supervisory system of the mechanical arm. The arm is driven by four hydraulic actuators, where each is connected with a 5/2 valve, whole system is supplied by a hydraulic pump with an overflow valve, which can be adjusted at 6 bar pressure. Preliminary study shows that this solution grant only a 0.5 s delay of the signal on the valve. The test stand shows the close representation of the real working attachment manipulation conditions as well as the ability to connect various steering systems to it were the main design criterions.

Roeber *et al*. (2016) conducted an experiment to measure the tractor hydraulic flow and pressure measurement using hydraulic power acquisition system. The tractor used in this study had a rated engine speed of 2700rpm and high idle speed of 2900 rpm, so both the speeds chosen for high flow rate test. The engine for low rate include 1200 rpm which was assumed to be transmitted speed, 1500 rpm representing half throttle position and 2100 rpm representing at a full throttle valve. The hydraulic test aperture capable for measuring tractor hydraulic flow and pressure measured device could be installed on the rare of the tractor to provide a hydraulic power consumption at different hydraulic orientations. The measure system installed allowed hydraulic line from the tractor hydraulic remote parts to be attached to the flow meter and pressure sensors at the multiple angle of $0^{o,}$ $45^{o,}$ and 90^{o}. to test the effect of tube ben configuration on pressure and flow rate measurement acquiring on agricultural tractors connected with in-line device under test (DUT) and a bench hydraulic pressure and flow rate measurements. The test were conducted at typical engine speed other than the governor maximum speed. The results showed that the DUT pressure was higher than the bench pressure as anticipated due to the pressure drop across the hydraulic fittings.

2.5 FIELD TESTING

Iqbal *et al.* (1994) conducted a study on draft requirement of selected primary and secondary tillage implements in a field at an operating speed of 2.5 km. h^{-1} in silt clay loam at 13.2% moisture content. The experiment results indicated that the draft required by cultivator, chiesel plough and sub soiler increased linearly with the increase in depth of operation. Maximum power consumed was found with the chiesel ploughing, during which an excess of 40% more power was consumed. In this study, draft measurement was made by installing a dynamometer between the two tractors. The implement was pulled through the soil at varying depths with a constant speed of 2.5 km h^{-1}. The depth of operation was varied from 5 cm to 45 cm with the successive step increase of 5 cm. The actual drawbar pull of the implement was determined by subtracting the amount of pull required by the front tractor in pulling the rear tractor without engaging the implement from the total drawbar pull exerted by the front tractor when the implement was engaged.

The field capacity of a farm machine was the rate at which it performs its primary function, i.e., the number of hectares that can be worked per hour or the number of tonnes of cassava that could be harvested per hour. Measurements estimates of machine capacities were used to schedule field operations, power units, and labour, and to estimate machine operating costs. The most common measure of field capacity for agricultural machines was expressed in hectares covered per hour of operation (Hanna, 2001).

Macmillan (2002) defined wheel-slip as the proportional measure by which the actual travel speed of the wheel falls short of (or exceeds) the "theoretical" speed and in terms of measurement and presentation of tractor performance, slip is the single most important, dependent parameter.

Anonymous (2005) explained a test procedure for measuring the soil shear strength in fine-grained clayey soil using a miniature vane shear. The torque measured using the equation,

$$T = \frac{\Delta}{B}$$

$$\tau = \Delta \times R$$

T = Torque in lbf·ft (N·m),

B = Slope of calibration curve in °/N·m), and

Δ = Deflection in degrees

R = Constant

$\tau =$ shear strength (N-M)

Alsuhaibani *et al.* (2006) developed an instrumentation system and mounted on an MF 3090 tractor to measure the various performance parameters of the tractor and attached implements. System was used for the formation of a database of draft requirements, tillage depth, fuel consumption, engine speed, and fluid temperatures. The wheel torque and weight transducers measures the torque and forces acting on the wheels, whereas the other transducer was used to measure the vertical and the horizontal forces on mounted implements. They have developed general regression equation to predict draft of the implements as.

$$UD = \beta 0 + \beta 1 * D + \beta 2 * D2 + \beta 3 * S + \beta 4 * S2 + \beta 5 * D * S$$

Whereas: UD = Unit draft, N/mm or N/tool

D = Tillage depth, cm

S = Travel speed, km/h

β0, 1, 2,3,4,5 = Regression coefficient

Anonymous (2007) test was performed to find shear strength of clay soil. Vane shear test apparatus was used for measurement of shear strength of cohesive soils. The shear strength was found was 0.3 kg/cm2.

Anbazhagan (2009) study conducted on strength and compressibility testing on soils at a given site. The torque (T) value obtained was 3.53 D^3Cu. The torque was measured using the equation, C_u undrained shear strength

$$T = \frac{\pi D^2 H}{2}\left[1 + \frac{D}{3H}\right] C_u$$

According to Grisso *et al*. (2010) farmers might consider several ways to evaluation and reduce fuel consumption but the first step is to determine how much fuel is being used for a particular field operation and compare it to average usage. This measurement can be completed by filling the fuel tank of the tractor before and after a field operation, noting the number of hectares covered.

Depending on the type of fuel and the amount of time a tractor or machine was used, fuel and lubricant costs will usually characterise at least 16 per cent to over 45 per cent of the total machine costs. With reference to the above statement, Grisso (2010) emphasized on the fact that fuel consumption plays a significant role in the selection and management of tractors and equipment.

Andrea *et al.* (2013) analysed a soil-tyre interaction model and discussed the traction tests with a MFWD tractor when operating with silt loam calcaric fluvisol. The longitudinal top soil shear displacement was measured for the slip ranging between 5% and 48%. From the results they concluded that the slip value was the most indicative limit in zero-tillage.

CHAPTER III

MATERIALS AND METHODS

In this chapter, site selection and package of practices of banana cultivation viz. planting, harvesting, land clearing after harvest and uprooting the suckers are briefly explained. Methods followed to determine the physical and mechanical properties of soil are also explained in detail. The modification of the banana sucker uprooting machine was carried out by incorporating additional hydraulic cylinder with suitable control valve to operate in the fields. The field tests were conducted at various soil types by using different types and number of the tynes. The results were analysed using OP-STAT online software. Cost economics was evaluated and compared with the conventional uprooting method.

3.1 SITE SELECTION AND LAND PREPARATION

An Area of 0.025 ha was selected in the Instructional Farm, KCAET, Tavanur. The land was cleared and prepared by ploughing with tractor drawn MB plough followed by two harrowing with a 32-blade rotavator. The pits were dugout using tractor drawn post hole digger having 60 cm diameter at a depth of 60 cm.

3.2 PACKAGE OF PRACTICES ON BANANA CULTIVATION

The banana was cultivated in the study area as per the Package of Practices, Kerala Agriculture University.

3.2.1 Selection of suckers

One month old good quality seedlings of tissue culture sword suckers (Plate 3.1) were selected from the healthy clumps of Nandan variety. The pseudostems were at the lengths of 15 to 20 cm from corm. The rhizomes were applied with cow dung solution, ash and sun dried for about 3 to 4 days and placed in a shade for about 15 days before planting (Nambiar, *et al*. 1979)

Plate. 3.1 Selected suckers for planting

3.2.2 Planting of the suckers

The suckers were placed in the centre of the pit with 10-15 cm of the pseudo stem above the soil surface. Spacing is affected by the growth habits of the plant and the fertility of soil. The spacing of 2.5 x 2.5 m was maintained while planting the banana suckers. After planting the pits were filled with top soil mixed with 5-10 kg of FYM per plant.

3.2.3 Irrigation

The furrow irrigation system was adopted for applying water to the crop. In this system the water consumption was about 4-5 litres per plants at 3 days interval during summer season and 8-10 litres per plant in 7 days of interval during winter season. The land should have good drainage system to prevent from the water logging. During the first ratooning of crop the water requirement per plant will be high due to the emergence of side suckers. Hence, additional supply of 4-5 litres of water per plant was necessary during these growth stages.

3.2.4 Mulching and earthing up

Mulching and earthing up operations were carried out with the help of labourers by covering the top soil of pit with dry leaves and paddy straw which in turn helped in conserving the soil moisture and to control the weed growth. Earthing up helped to provide support to the plant and to propagate the root system. It was also helped to avoid the water logging problems and facilitated good drainage.

3.2.5 Fertilizers application

NPK fertilizer was applied at ratio of 40:65:60 gram per plant after one month of planting and in second month 30:50:60 gram per plant was applied. Proper irrigation has to be given immediately after fertilizers application. After four months, third dose of NPK was applied at the ratio of 30:00:60.

3.2.6 Ratooning

Excess plants are to be removed from the mother corm for the healthy growth of the plant. It was carried out by cutting one or two suckers after the emergence of bunch. At the time of harvest of the first crop, the left over suckers will become ready for the next ratoon cropping.

3.3 LAND CLEARING

After harvesting of the banana crop the land has to be cleared for next planting. This was normally carried out with the help of manual labours. In this study, a modified tractor operated banana sucker uprooting machine was developed for land clearing. The machine attached with bucket fitted with tynes will penetrate in to the soil at a depth of 60 cm and lifts the clump. This facilitates easy clearing of land after harvesting of banana.

3.4 PHYSICAL AND MECHANICAL PROPERTIES OF THE SOIL.

The physical and mechanical properties that affect the modification and testing of the banana sucker uprooting machine were studied. The four properties, *viz*, moisture content, bulk density, shear strength and soil texture, which were directly related to the modification of banana sucker uprooting machine were determined in the present study. Soil samples from different locations of the experimental plot were collected in containers to determine the above mentioned properties of the soil. The tests were conducted in the Soil and Water Laboratory at KCAET, Tavanur.

3.4.1 Moisture content

Moisture content (W) is the ratio of the weight of water to the weight of the solids. The moisture content of the sample in per cent dry basis was determined by using the equation.

$$MC\,(\%) = \frac{Wi - Wd}{Wi} \times 100 \qquad \ldots (3.1)$$

Where,

W_i is initial weight of the soil, g

W_d is dry weight of the soil, g

It is expressed in percentage and is found out by oven dry method. Soil samples of six different locations were collected from the banana field of study area at depths of 0-20 cm, 20-40 cm, 40-60 cm and 60-80 cm. The soil samples of 50 g each were collected in different containers and placed in a hot electric oven under controlled temperature of 105°C for a time period of 24 hours (Angelis, 2007). The weight before and after drying were found out using an electronic weighing balance having a sensitivity of 0.01g. The determination of soil moisture content helped to find out water requirement.

The in-situ soil moisture content were also recorded before uprooting the suckers using digital soil moisture meter (model – BST-SM400) having resolution of 0.1% and accuracy ± (5% + 5d) F.S. @ 23 ± 5. The moisture meter was inserted in a soil at a depth of 10- 15 cm for about 30 seconds. The percentage of moisture content of the soil was displayed in the display board and was recorded. The moisture content of the soil after harvest decides the easiness of uprooting the soil-sucker composite.

Plate 3.2 Digital moisture meter

3.4.2 Bulk density

The compactness of the soil is determined by bulk density. The bulk density was found out by using the equation,

$$\rho = \left(\frac{\mathbf{M}}{\mathbf{V}}\right) \qquad \ldots (3.2)$$

Where,

ρ – Bulk density, g cm^{-3}

M – Mass of the soil, g

V – Volume of the soil, cm^3

Initially volume of a cylinder (cm^3) was determined by measuring the internal diameter (10cm) and height of core cutter (12.5cm) and empty core cutter was weighed.

A small area of (30 X 30 cm^2) of the soil to be tested in banana field was exposed and surface was levelled. A cylindrical core cutter was pressed into the soil mass using the rammer with dolley placed over the top of the core cutter. Pressing was stopped when the dolley protrudes about 15mm above the soil surface. Surrounding soil of core cutter was removed, and it was taken out. Top and bottom surface of the core cutter was carefully trimmed using a straight edge. Core cutter filled with the soil was removed and weighed. Bulk density of soil was measured by using equation (3.2).

3.4.3 Texture

The soil compactness also depends on its texture. It affects the digging efficacy of the uprooting machine. Soil texture was determined by using sieve analysis method. The sieve sizes selected were respectively as 2mm, 1mm, 600micron, 425micron, 300micron, 212micron, 150micron, and 75micron. The seives were arranged according to the standard sieve sizes, the large sieve kept at top and small seive kept with pan at the bottom and lid at top. The soil sample of 1.0 kg was taken on the top sieve. All the seives were fitted on seive shaking machine and shaking was made for 10 minutes. The soil retained on each sieve was weighed and recorded.

3.4.4 Shear strength

Shear strength of soil is a maximum resistance offered by the soil to shearing stresses (Awadhal and Singh 1985). The Shear strength was found out by using the (Anon., 2007) equation,

$$S = \frac{T}{\pi\left(\frac{D^2H}{2} + \frac{D^3}{6}\right)} \qquad \ldots\ (3.4)$$

Where,

S = Shear strength in kgf/cm^2

T = Torque in kgf.cm

D = Overall diameter of vane in cm

H = Height of the vane in cm

If, H = 2D the equation reduces to

$$S = \frac{3\ T}{11\ D^3} \qquad \ldots\ (3.5)$$

The in-situ measurement of shear strength of soil was done using a vane shear test apparatus (Make – AIMIL (CIVIL)) arrangement is as shown in (Plate

3.3). Bore hole was dugout at a depths of 30, 60, and 90 cm. Casing was extends up to the depths, casing was secured it so that it does not move during the test. Torque applicator was fixed on the stand with the help of spikes. The vane size of 37.5 mm diameter was selected for laterite soil conditions and it was connected to the vane rod having same female thread and vane was lowered to the above required depths. The vane was pushed downward with a moderate steady force up to a depth of 50mm below the bottom of the bore hole and allowed for 5 minutes after the insertion of the vane. The initial dial gauge reading was set to the zero and gear handle was turned so that the vane was rotated at the rate of 0.1^{o} per second, this in turn help to get a uniform rate of 12 turns per minute. Vane was rotated completely ten times to disturb the soil. Torque indicator dial gauge reading was noted at half minute interval and rotation of vane was continued until the reading drops appreciable from the maximum.

Plate 3.3 In-situ shear strength apparatus

3.5 PHYSICAL AND MECHANICAL PROPERTIES OF SUCKERS

The physical and mechanical properties of the sucker are important in designing of bucket with tynes for uprooting the banana suckers. The bucket for uprooting the soil-sucker clump were fabricated according to the size, shape and length of the banana suckers. The major design condition for uprooting the suckers is that it should not be damaged while uprooting. The physical and mechanical properties of the suckers viz., size and shape, number of the suckers per plant, weight and hardness were found out using standard test procedure. The samples were taken from the six different banana plants and observations of these properties were recorded.

3.5.1 Size

The size of the banana sucker is an important parameter in designing the bucket with tynes for uprooting the soil-sucker composite. The size was determined for six samples. Length and width of the suckers were directly measured with the help of the measuring scale. The average maximum and minimum values of length and width of the suckers were determined.

3.5.2 Shape

The shape of the suckers is another important parameter which effects the design of the bucket for uprooting the suckers. The shape of the sucker was determined by graphical method. Six samples of suckers were taken and each sucker was wrapped with a graph paper. Unwrapped the paper and the shape was marked using a marker pen.

3.5.3 Number of suckers

The number of the suckers per plant was noted to determine the capacity of the bucket and uplift force required to uproot the soil-sucker clump.

3.5.4. Weight of the suckers

Weight of the suckers directly effected the lifting capacity of the soil-sucker clump during uprooting. The weight of the sucker was measured by an electronic weighing balance (Model No - AET 30 and Accuracy - 1g). The weight of the suckers in a clump determines the maximum amount of material that can be accommodated in the bucket.

3.5.5 Hardness

Hardness of a material is defined as its resistance to fracture when stressed or the amount of energy that a material can absorb before damaging. While uprooting the suckers with the machine, there is every chance of getting damage to the suckers. Hardness of sucker is an indicator of good quality of the pseudo stem which can be used as planting material.

Hardness was determined using TAHDI texture analyser of stable micro system (Plate 3.3). The instrument has a microprocessor regulated texture analysis system interfaced with a personal computer. The instrument consists of two separate modules; the test-bed and the control console (keyboard). Both are linked by a cable which route low voltage signal and power through it. The texture analyser measures time, distance and force and hence provide a three-dimensional product analysis. A sample of banana sucker was kept on the flat platform of the instrument and was subjected to double compression by a cylindrical probe with 5 mm diameter. The test was conducted at a post speed of 10 mm s^{-1} and distance of 10 mm using 50 kg load cells. The sample was allowed for a double compression of 40 per cent with trigger force of 0.05 kg during which various textural parameters were determined. From the force deformation curve, the hardness (peak force), and toughness (area under the curve) were determined. The instrument was calibrated at various test speeds, return distance and contact force. Thus the instrument was calibrated for each parameter before the analysis.

Plate 3.4 Texture analysis of the sucker

3.6 STUDY OF THE TRACTOR OPERATED BANANA SUCKER UPROOTING MACHINE

A banana sucker uprooting machine as an attachment to the tractor (Plate 3.4) was developed and field tested at KCAET, Tavanur. It consisted of a gib-crane fitted with a tyne, one double acting cylinder, directional control valve and connected by means of two hydraulic hoses. The machine was attached with separate hydraulic system having pump output of 25.7 lps and lifting capacity of 1500 kgf. The tractor with 45 hp was used as prime mover for operating the banana sucker uprooting machine. The machine was used to uproot the banana suckers and helped in clearing the land after harvest of the crop. The main problem identified with this machine was that it do not have provision to penetrate into soil to a depth of more than 60 cm. Also the suckers during the uprooting were found out damaged. Undue exertion forces and hence more hydraulic oil consumption were resulted while uprooting with the tractor system. With these factors in view an attempt was made to resolve the above said problems in the study and the KAU banana sucker uprooting machine was modified and field tested.

Plate 3.5 KAU Banana sucker uprooting machine

3.7 MODIFICATION OF KAU BANANA SUCKER UPROOTING MACHINE

Based on literature review and field studies, the following theoretical design considerations have been considered and discussed under following sub-sections.

i. Modification considerations of banana sucker uprooter
ii. Fabrication of functional components banana sucker uprooter

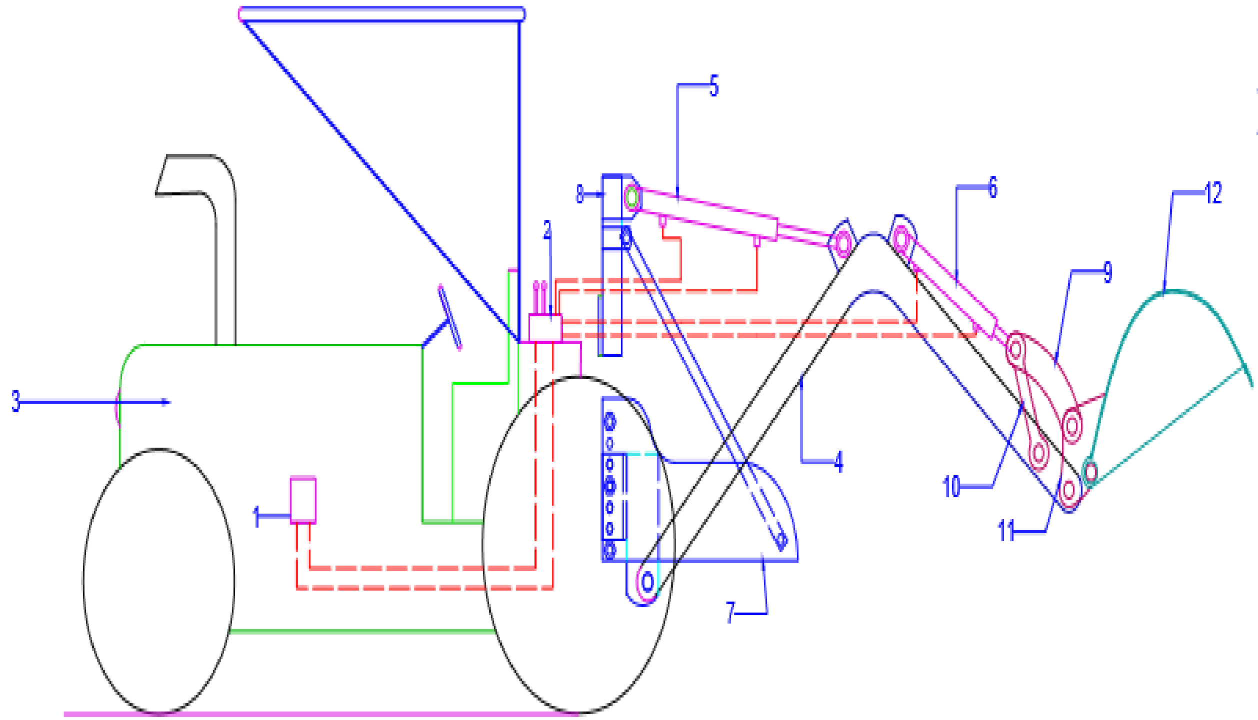
3.7.1 Considerations for the modification

The following requirements were visualised for the modification of tractor operated banana sucker uprooting machine. The modified uprooting machine was operated with separate hydraulic units in addition to the existing tractor hydraulics. The machine should have a bucket with tynes for easy uprooting of suckers.

i. It should dugout the clump to uproot the suckers
ii. It should lead to the reduction in drudgery and tedium associated with the manual uprooting
iii. The modification should ensures reduction on damage to the suckers and availability of good planting material
iv. It should consume less fuel and hydraulic oil
v. The machine should uproot all varieties of the banana crop
vi. The total power requirement should not exceed the power available from currently available 55 hp tractor.
vii. The machine shall be simple in operation, the cost of the machine shall be affordable to farmers at cheaper price and ease to manufacture at minimum cost.

3.7.2 Development of a tractor operated banana sucker uprooting machine

The tractor operated uprooting machine was modified with the optimized levels of machine and crop variables. It consisted of a prime mover, gib-crane, swinging links, bucket, tynes, hydraulic cylinders, directional control valve, high pressure flexible hose pipes, hydraulic pump and supporting frame. The different components of the machine were fabricated / procured having adequate strength and dimensions separately. The one end of the gib-crane is fitted with a bucket with tynes. The other end of the gib-crane is pivoted at the supporting frame. The bucket with tynes were hinged by using swinging links. A two-in-one control valve controls the flow of hydraulic fluid from pump to the double acting hydraulic cylinders of stroke length 60 cm. Flexible hose pipes were used as conduits for hydraulic fluid flow from control valve to two hydraulic cylinders. Arm cylinder was used for lowering and lifting of gib-crane and bucket cylinder was used to penetrate bucket tynes at an angle of 60^0 into the soil. It is achieved by lowering and lifting the bucket. Separate hose connection was also provided through which the fluid flow directly from hydraulic pump to the two-in-one control valve without passing through hydraulic system of tractor. One set of square blades with sharp edges were fixed to the bucket for easy penetration in to soil. The overall length of the machine was 336.0 cm and width was 53.0 mm. Each components with specifications are presented in Appendix-I



SL NO	DESCRIPTION
1	HYDRAULIC PUMP
2	HYDRAULIC CONTROL VALVE
3	PRIME MOVER(TRACTOR)
4	ARM(GIB-CRANE)
5	ARM CYLINDER
6	BUCKET CYLINDER
7	SUPPORT FOR TRAILED HITCH
8	SUPPORT FOR HYDRAULIC ACTUTOR
9	INTERMEDIATE LINK
10	IDLER LINK
11	FIXED LINK
12	BUCKET

Fig 3.1 Modified tractor operated KAU banana sucker uprooting machine

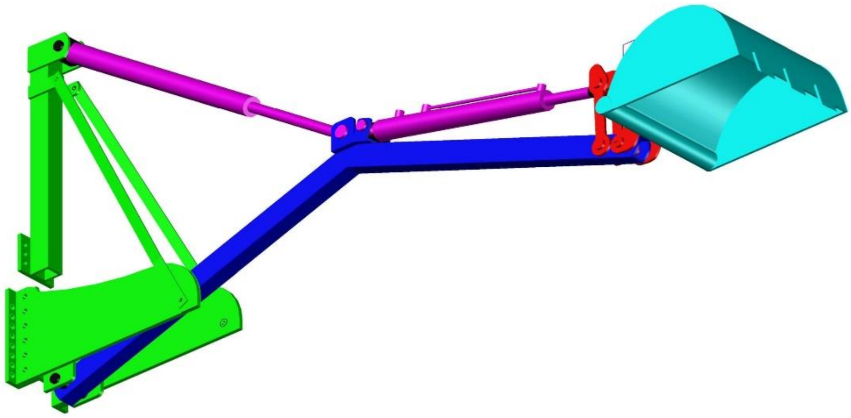


Fig 3.2 3D model of the modified banana sucker uprooting machine

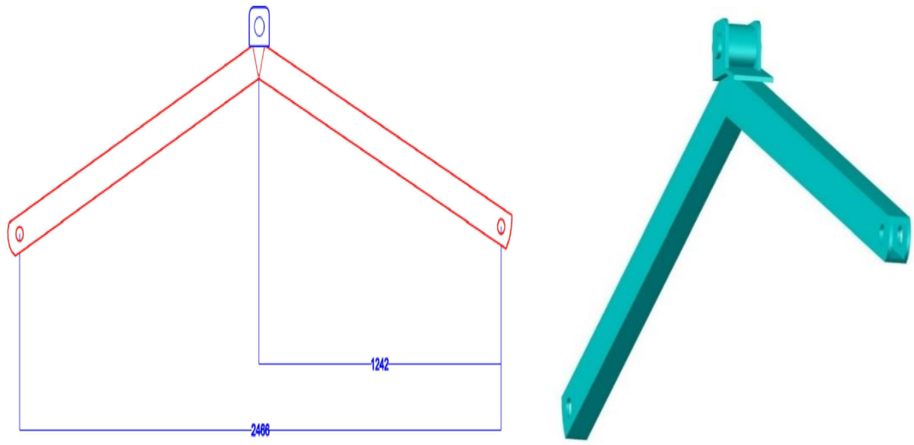
3.7.2.1 Prime mover

The capacity to meet the power requirement for digging and traction is taken into consideration for the selection of the prime mover. The total weight of the gib-crane assembly and the weight due to soil-sucker composite comes around 350 to 400 kg. In order to operate with this attachment a tractor having a sufficient hydraulic lifting capacity was needed. Hence, the tractor engine of the John Deere 5310 tractor having heavy duty adjustable global axle with 55 hp and 2400 rpm was selected as the prime mover. The specifications of the tractor is given in the Appendix I

3.7.2.2 Gib-crane

Gib-crane (Fig. 3.3) is the major part of the banana sucker uprooting machine to which the bucket was attached with the help of swinging links. It was made up of mild steel. It was curved in shape with 2.46 m length, 1.5 m height and

10.0 cm width. The lowering and lifting action of the gib-crane was obtained through the arm hydraulic cylinder. it facilitated easy uprooting of banana suckers.

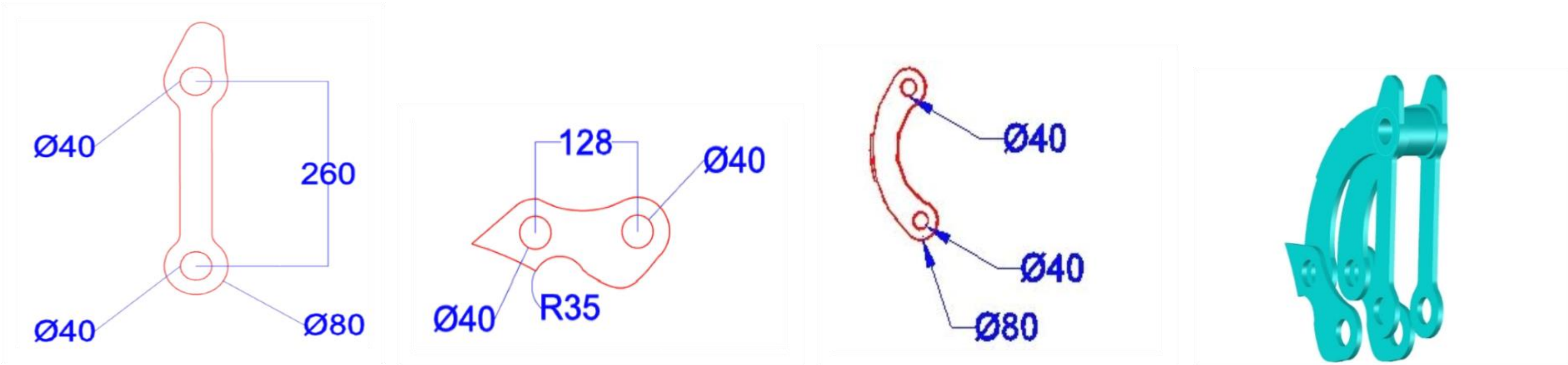


(a) 2-D drawing of gib-crane **(b) 3D model of the gib-crane**

Fig. 3.3 Gib-crane

3.7.2.3 Swinging links

Swinging links (Fig. 3.4(d)) support the bucket during digging and uprooting operations with the help of bucket hydraulic cylinder. Swinging links (5 Nos.) were fabricated using 4 mm MS plate. Of the five links, two are intermediate links (Fig.3.4(c)), two are idler links (Fig.3.4 (a)) and a fixed link (Fig.3.4 (b)). One end of the intermediate links are connected to the fixed link through pin joint and other end connected to the idler links with the help of hitch pin. Idler links are connected between intermediate links attached to the gib-crane and fixed link attached to the bucket.

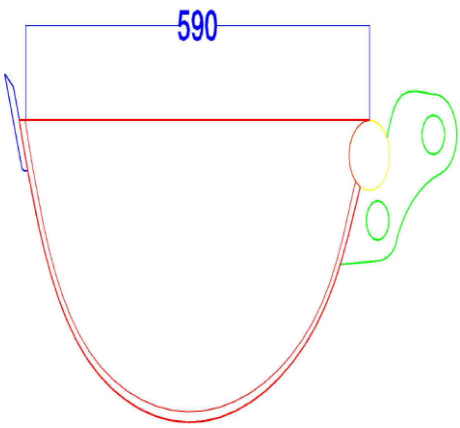


(a) Idler link **(b) Fixed link** (c) **Intermediate link** **(d) 3D model of swinging links**

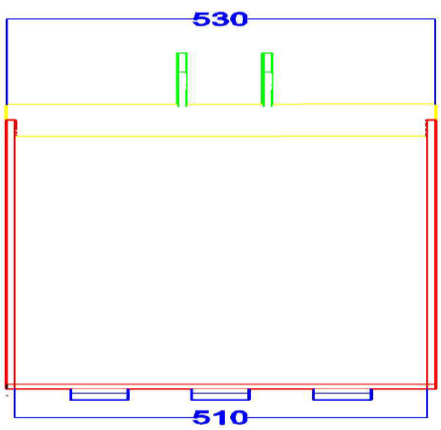
Fig 3.4 Swinging links

3.7.2.4 Bucket

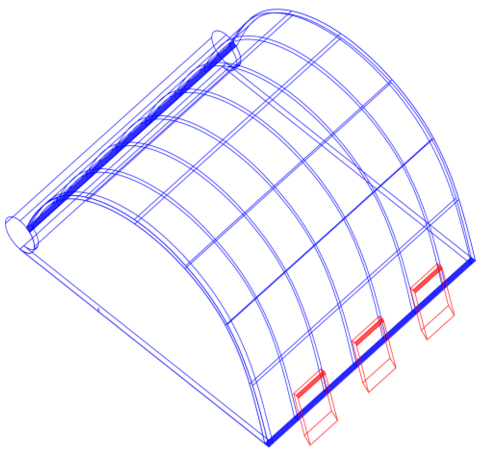
Due to the action of hydraulic bucket cylinder, the bucket (Fig.3.5) attached to the end of the gib-crane penetrates in to the soil with the help of sharp edge tynes. On the reverse action of the cylinder, the bucket recedes and uproot soil-sucker clump without damage. Bucket was made up of 8 mm MS steel. It is having an inner width of 51.0 cm, outer width of 53.0 cm and curvature depth of 60 cm.



(a) Side view



(b) Front view

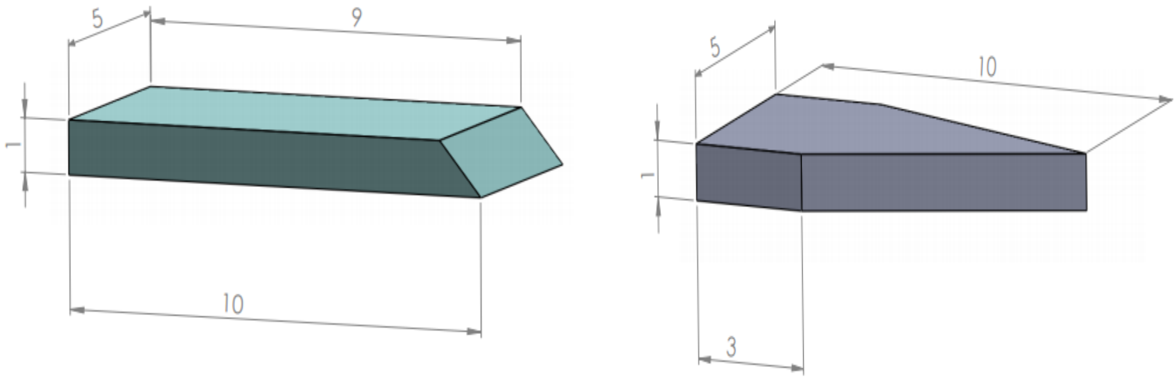


(c) Isometric view

Fig 3.5 Bucket

3.7.2.5 Tynes

The tynes (Fig. 3.6) facilitate easy penetration of the bucket in to the soil. Two types of tynes were fabricated and tested. These were fixed to the tip of the bucket with the help of nut and bolt. Two types of tynes viz., rectangular (Fig. 3.6 (a) and triangular tynes (Fig. 3.6 (b) with sharp edges were fabricated with 8 mm MS plate. The size of tynes are respectively as100 x 50 x 10 mm for rectangular type and 100 x 50 x 10 mm for triangular type. These tynes were fixed to the bucket at a distance of 10.0 cm interval, leaving 5.0 cm on each side.



(a) Rectangular tyne **(b) Triangular tyne**

Fig. 3.6 Tynes

3.7.2.6 Hydraulic cylinders

Two Hydraulic cylinders were used in this study. Arm hydraulic cylinder and bucket hydraulic cylinder. Arm cylinder facilitated the movement of lowering and lifting the gib-crane and bucket hydraulic cylinder facilitated the penetration of the bucket in to the soil and uprooting the soil-sucker clump.

3.7.2.6.1 Arm hydraulic cylinder

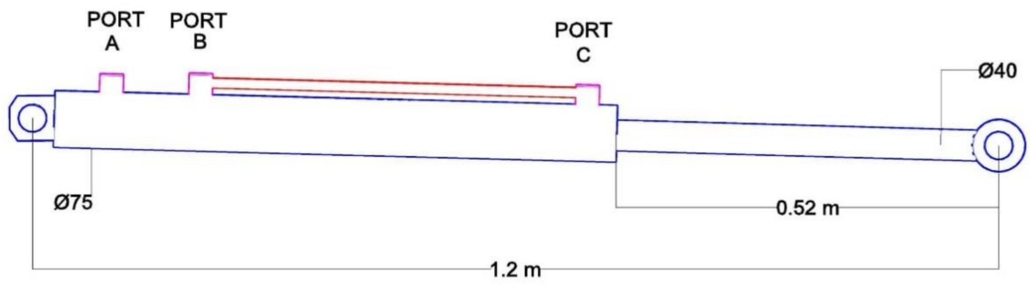
Arm hydraulic cylinder is a double acting hydraulic cylinder (also called as linear hydraulic actuator) is used to give a unidirectional force through a unidirectional stroke. The arm cylinder having a 75 mm diameter and 600 mm stroke length. The major parts of a hydraulic cylinder include cylinder barrel, cap, head, piston, and piston rod. The arm cylinder is connected between the support stand and gib-crane (arm). It facilitated the movement of lifting and lowering the gib-crane. The cylinder gets power from the pressurized hydraulic fluid. It consists of cylinder barrel, in which piston connected to the piston rod which moves back and forth. The hose pipes are fixed to the ports present on the cylinder. Through these pipes the fluid flow takes place from control valve to the hydraulic cylinder. By doing this, the stoke extension and retraction takes place. During the stoke extension the arm cylinder lowers the gib-crane. To extend the cylinder further the fluid flow is again sent to the blank-end port as the fluid from the rod-end port returns to the reservoir. To retract the cylinder, the pump flow is sent to the rod-end port and the fluid from the blank-end port returns to the tank.

3.7.2.6.2 Bucket hydraulic cylinder

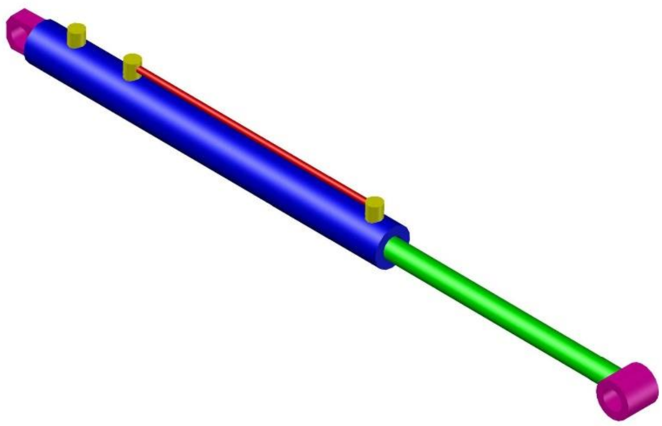
Bucket hydraulic cylinder is also a double acting hydraulic cylinder which provide motion in a straight line. The function of this hydraulic cylinder is to convert hydraulic power into linear mechanical force or motion. The cylinder is fixed to the gib-crane (arm) and the bucket. The bucket cylinder having a diameter of 75 mm and stroke length of 60 cm. Through the inlet and outlet ports of the cylinder the hydraulic fluid enters the cylinders. When fluid flow is sent to the blank-end port, the forward stroke takes place as the fluid from the rod-end port returns to the reservoir, during this period bucket tynes penetrated in to the soil and uproot the soil-sucker clump with the help of swing links. When the fluid flow is sent to the rod-end port revers the stroke during this period and the bucket lifts the soil-sucker clump and leave the clump on the ground surface.

The Fig.3.7 (a) shows the details of the hydraulic cylinder. It has three ports viz. Port A is a pressure line port, port B is a return line port and port C is additional port on the cylinder. The fluid from pump enter through port A with high pressure by operating the control valve. Due to this cylinder rod extrudes which helps in penetration of bucket and cause the uprooting operations. The port B is closed during the extension stroke. The return of fluid to the pump takes place through port B. During this time port A will be closed with the help of spring inside the cylinder.

During this the retraction stroke of the cylinder rod will takes place. The turf guard supreme plus 50 hydraulic oil was used. The design calculations of hydraulic cylinder as given in appendix XVI.



(a) Dimensions of hydraulic cylinder



(b) 3D view of hydraulic cylinder

Fig. 3.7 Hydraulic cylinder

3.7.2.7 Direction control valve

These valves are also called as on-off valves because they allow the fluid flow in only in one direction (Jagadeesha 2012). A directional control valve Plate 3.5 is a device which controls the flow of fluid from the hydraulic pump to hydraulic cylinder. These valves are the primary devices used to sequence the motion of equipment. The valve is generally specified by number of positions and number of ways (ports). But in this case a two-in-one directional control valve with 4 ports was used. The control valve consisted of two levers, one lever operates arm cylinder and other operate bucket cylinder. It is having an inlet port and outlet port. The hydraulic fluid from pump is passes through a main line and enter in to the inlet port of the control valve. When the control lever is pushed to forward the fluid will pass through outlet with high pressure, which cause the extension of the arm cylinder. It will facilitate the lowering of gib-crane. When control lever-1 pushed backward the hydraulic arm cylinder retracts backward which helps in lifting the gib-crane upward. When the control lever-2 is operate the bucket cylinder, when the lever pushed forward the bucket cylinder get extended and facilitate the bucket to penetrate in to the soil and uproot the soil-sucker clump. When the lever pushed backward the bucket cylinder retracts and helps in lifting of soil-sucker clump from the pit.

Plate 3.6 Two in one direction control valve

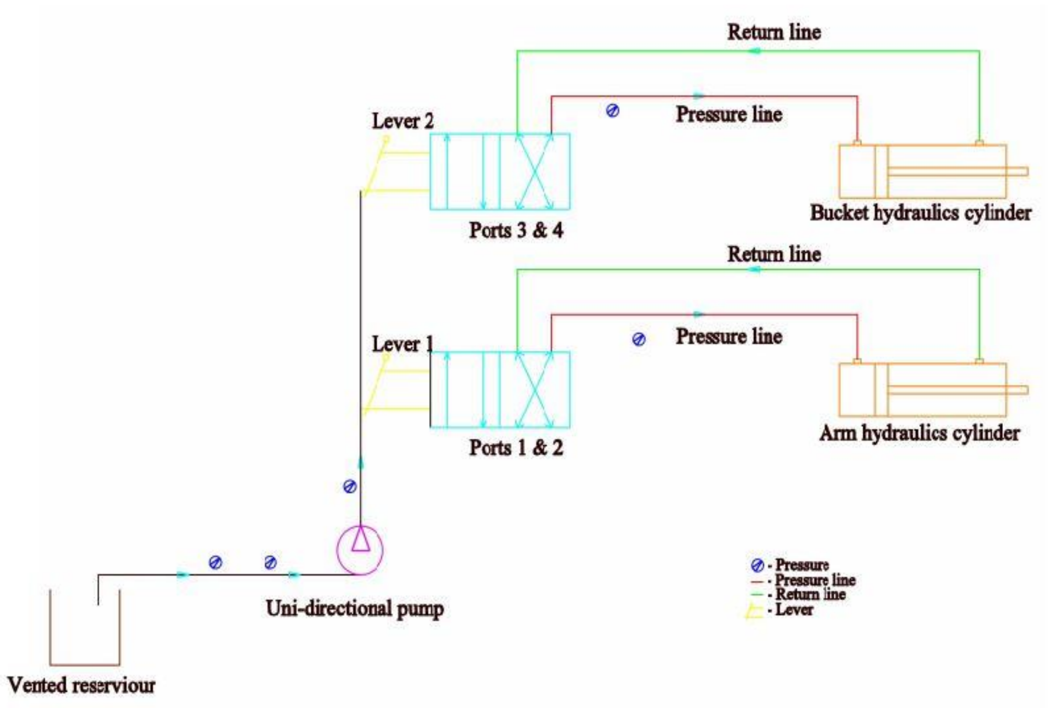
3.7.2.8 Hydraulic hose

Separate hydraulic hoses were used to connect hydraulic pump to the two double acting cylinders through the ports of cylinder. Hose pipes having length of 1.5 m and inner and outside diameters of 9 mm 23 .3 mm were used.

3.7.2.9 Supporting frame

The three point linkage bracket of the tractor was dismantled and a support frame for the gib-crane and the hydraulic cylinder attachment was fixed with the help of hexagonal bolts. A separate trailer hitching unit was fabricated with 16 mm MS plate which has the provision to fix the pin horizontally. The gib-crane was supported by this unit, through a pivoted joint. It allowed the free movement of gib-crane in a circular manner.

3.7.2.10 Hydraulic flow of tractor operated KAU banana sucker uprooting machine



(Hydraulic power graphic symbols - ISO 1219-1:2012)

Fig. 3.8 Schematic diagram of hydraulic circuit

3.8 FIELD TESTING

The field test was conducted with the modified tractor operated banana sucker uprooting machine at the instructional farm, K.C.A.E.T, Tavanur. The field trails were carried out for different soil, crop and machine parameters in consideration. The results obtained at field conditions are tabulated and statistically analysed. Similarly field trials were carried out at BRS Kannara where in the soil was of clay type.

Plate. 3.7 Field testing at IF, KCAET, Tavanur

3.8.1 Working

By operating the directional control valve, the bucket tynes penetrated into the soil at a depth of 60 cm and at an angle of 65°, the suckers found lying in the soil at a depth of 40-50 cm. The uprooted suckers passed over the inclined bucket were then unloaded on the surface of soil by moving the tractor forward. Thus the soil-sucker clump was lifted up easily and hence the uprooting became easier and faster.

3.9 SELECTION OF VARIABLES

The various parameters affecting the uprooting of suckers were selected by considering the operational constraints in the field. The performance of the machine was tested for four machine parameters viz., size and shape of the tynes, number of tynes, angle of penetration and draft. The size and shape of tyne were selected as 100 x 70 x 5 mm for rectangular type and 100 x 70 x 5 mm for triangular tyne. The number of tynes were varied with 3 and 4 numbers. The angle of cutting blade was fixed as 65 degrees. These parameters were optimized to achieve the most suitable size and shape of tynes and angle of penetration of the bucket for uprooting in two different soils types viz. clay and laterite soil.

Table 3.1 Factors selected for the experiment

Soil type	Size of tyne, mm	Shape of tyne	Number of tynes
Clay	100 x 70 x 5	Rectangular	3
Laterite		Triangular	4
Replications		**3**	

Total number of treatments = 2 x 1x 2 x 2 = 8

3.9.1 Size and shape of tynes

The size and shape of tynes affect the draft of the implement. The independent parameters selected for the study include two types of shapes namely rectangular and triangular tynes and spacing between blades as 10 cm. Size of both tynes selected for the study was 100 x 70 x 5 mm.

3.9.2 Number of tynes

The 3 and 4 number of rectangular and triangular tynes (100 x 70 x 10 mm) used for the uprooting bucket. Each tyne was fixed at an equal distance of 10 cm apart along its width of bucket. It penetrates and breaks the hard pan of soil which in turn helped easy uprooting of the banana suckers. The trials was carried out with 3 and 4 number of tynes.

3.9.3 Angle of penetration

The angle at which the bucket with tyne penetrate in to a soil while uprooting of the suckers was observed. The angle of penetration of during the field test was the same for two types of the soils. But the tyne angle selected was different for two types of soils for easy penetration and increase the efficiency of the uprooting machine.

3.10 PERFORMANCE EVALUATION

The performance evaluation of the banana sucker uprooting machine was conducted for the draft required to uproot the soil-suckers composite, time of uprooting, number of suckers per clump, depth of penetration and percentage of damage with respect to various independent parameters. The tests were carried out separately for clay and laterite soils.

3.10.1 Draft

An experimental set up as shown in Plate. 3.8 was used to determine the load and draft while uprooting the suckers machine. S-Beam load cell was used to find out the draft under tension or compression. The S-type load cell dynamometer was attached at the front of the tractor on which the implement was mounted. Another supplementary tractor was used to pull the implement mounted tractor through the S-type load cell dynamometer. The supplementary tractor pulled the implement mounted tractor with the latter tractor in neutral gear but with implement in the operating position. The pull was recorded in the indicator of load cell dynamometer. The draft in the measured distance was noted directly. On the same field, the draft in the same distance was noted with the implement in lifted position, i.e at zero load. The difference gave the draft of the implement.

Plate 3.8 Draft measurement of the modified uprooting machine

3.10.2 Time for uprooting

The time taken to uproot the banana suckers with respect to soil type, shape and number of tynes was observed by using a stop watch. The results were statistically analysed using OP - STAT online software

3.10.3 Depth of penetration

Depth of penetration affects the draft of machine. Also it effects the damage of suckers. The depth of penetration will varies according to the type and moisture content of soil. The root zone depth of different varieties of banana viz. Kunnan, Nendran, Robosta was respectively as 40, 60 and 80 cm.

3.10.4 Percentage of damage

The damage of banana suckers due to the cutting of suckers by the bucket tynes or bruising during uprooting. The accuracy of sucker's damage shall be minimum for getting good quality suckers. The total number of sucker's available (h^{-1}) were also determined. The percentage of damage of suckers in each soil-sucker clump after uprooting was calculated using equation.

$$\text{Damage (\%)} = \frac{\text{Number of damaged suckers per plant}}{\text{Total number of sukers per plant}} \qquad \ldots (3.5)$$

The results were analysed statistically using OP-STAT online software

3.10.5 Fuel consumption

A separate portable fuel tank was fitted on the tractor. Tank was filled with fuel to its full capacity before field test. The test trails were conducted and the quantity of fuel used to top-up the fuel tank was then recorded. The fuel consumption was expressed in $l.hr^{-1}$.

3.10.6 Wheel slippage

The wheel slippage was computed in percentage and calculated by using formula,

$$\text{Wheel slippage (\%)} = \frac{N_1 - N_2}{N_1} \times 100 \qquad \ldots (3.6)$$

Where,

N_1 = No. of rotation of rear wheel of tractor at load condition.

N_2 = No. of rotation of rear wheel of tractor at no load condition.

3.10.7 Number of suckers

The number of suckers uprooted per clump was observed was 5-7 and it was recorded. The observations were analysed statistically, with respect to soil type, size and shape of tynes

3.10.8 Effective field capacity

In the course of field tests, effective field capacity was calculated for clay soil and laterite soils. Productive time event *viz,* Penetrating the bucket into soil and uprooting the suckers, and non-productive time event viz., turning losses were recorded. However in calculating the effective field capacity (ha h^{-1}), the time consumed for effective work and the time losses were recorded.

$$M = \frac{A}{T_p + T_n} \qquad \ldots (3.7)$$

Where,

M = Effective field capacity, ha h^{-1}

A = Area covered, ha

T_p = Productive time, hr

T_n = Non-productive time, hr

3.10.9 Field efficiency

Field efficiency (E_f) is expressed as percentage and is calculated using the equation,

$$\text{Field efficiency} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \times 100 \qquad \ldots (3.8)$$

$$E_f = \frac{W_e \times V_e \times T_p}{W_t \times V_t \times (T_p + T_n)} \times 100$$

Where,

W_e = Effective working width, m

W_t = Theoretical working width, m

V_e = Effective operating speed, m s^{-1}

V_t = Theoretical operating speed, m s^{-1}

T_p = Productive time, s

Tn = Non-productive time, s

3.11 STATISTICAL ANALYSIS

The data obtained were statistically analysed by 3 Factorial Completely Randomized Design (FCRD) using OP-STAT online Software. The analysis of variance (ANOVA) and mean table for different parameters were tabulated and the level of significance was reported.

3.12 COST OF OPERATION

Based on the material used and labour requirement for the fabrication of the banana sucker uprooting machine and the cost of operation were calculated. The saving in cost in the field operation with banana sucker uprooting machine was worked out in comparison with the conventional method of uprooting.

Manual harvesting was carried out using tools like the spade, sharp hatches etc. The capacity of the manual labourers for the harvesting (man-hours/ha) was determined by recording total time (minutes) taken to uproot one soil-sucker clump and fixed cost and variable cost of the tractor unit was calculated.

CHAPTER IV
RESULTS AND DISCUSSION

This chapter deals with the details of the field experiments carried out to estimate the performance and economics of the modified tractor operated KAU banana sucker uprooting machine. The following sections give the details of the physical and mechanical properties of soil and suckers and field performance of banana sucker uprooting machine. The results are summarized along with cost economics and are presented.

4.1 PHYSICAL AND MECHANICAL PROPERTIES OF SOIL

Physical properties of the as the moisture content, texture and bulk density and the most influential mechanical property viz... Shear strength which influence the performance of the banana sucker uprooting machine were determined.

4.1.1 Moisture content

Moisture content was determined as percentage by weight, by oven dry method. Soil samples from six different locations in the study area at specified intervals were determined using the equation as explained in sec. 3.4.1. The average moisture content was found out as 13 per cent. The recorded values and its calculations are given in Appendix II. Moisture content of the soil affect the penetration resistance of bucket tynes. It was observed that, as the moisture of the soil increases the penetration resistance of the bucket tynes decreases.

4.1.2 Bulk density

The bulk density of the soil in the experimental field was measured by core cutter method. The average bulk density of the soil was found to be 1.602 g cm^{-3}. The observations are given in Appendix III. The maximum capacity of bucket was determined according to bulk density of soil.

4.1.3 Texture

It is measured of soil sample passing through each sieve by standard sieve size analysis. The percentage retained in each sieve was found to be 99.99 %. The observations were recorded and the cumulative per cent retained and total percentage pass calculations are given in Appendix IV. Texture of the soil affected the performance of the machine. If the soil was clayey, the penetration of the bucket tynes was difficult. But in the laterite soil the penetration of the bucket tynes was easy and requires less force to uprooting the soil-sucker clump.

4.1.3. Shear strength

Shear strength of soil at depths of 30, 60, and 90cm was measured to find the strength of soil when shear stress is applied during the penetrating of bucket in to the soil. The shear strength was determined by in-situ vane shear test apparatus using the equation as explained in sec. 3.4.3. The average shear strength (S) at depths of 30, 60, and 90cm of the soil from the experimental plot was found as 0.577 kg cm^2. The calculations of shear strength obtained at different levels of depth as mentioned in Appendix V.

4.2 PHYSICAL AND MECHANICAL PROPERTIES OF SUCKERS

Physical properties of the suckers viz., size and shape, number of suckers per plant, and weight and a mechanical property viz., the hardness were found out using standard test procedure. These properties are important in designing the bucket with tynes for uprooting the banana suckers and to determine the behavior of the machine for uprooting the soil-sucker clump.

Table 4.1 Physical characteristics of the sucker and soil-sucker composite

Sl No	Parameters	Inference
1	Shape	Conical, Spherical
2	Length of rhizome, mm	457.7

3	Weight of rhizome, kg	3.03
4	No. of suckers per clump	5-7
5	Area of soil-rhizome composite, m^2	0.25 X 0.25
6	Weight of soil-rhizome composite, kg	140 - 160

4.2.1 Size

The size of sucker was determined using measuring scale. The maximum and minimum length and width of sucker were measured and the values are given in Appendix VI. The average maximum length of the sucker was 45.7 cm and the average maximum width was 15.6 cm (plate 4.1).

Plate 4.1 Size of the sucker

4.2.2 Shape

Shape of a sucker was an important parameter which lead to increase in damage percentage of suckers and effected the design of the bucket tyne. The shape of banana sucker variety ‘Nandran’ was almost oblong as shown in (Plate 4.2).

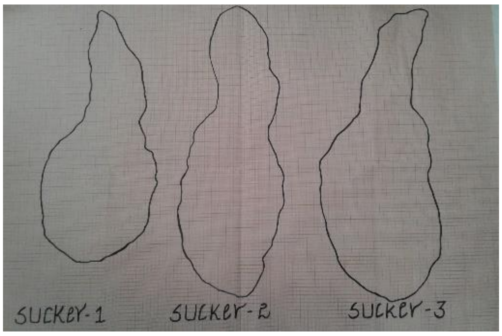


Plate 4.2 Shape of the suckers

4.2.3 Number of suckers per clump

Increase in the number of banana suckers per plant lead to an increased in load requirements while uprooting the soil-sucker composite. The number of the suckers per plant were observed and recorded. The average number of suckers found in the variety ‘Nandran’ was six. There were six number of suckers found in each plant were recorded and shown in Appendix VII.

4.2.4 Weight

The weight of the suckers was measured by using an electronic weighing machine. Weight of the suckers directly effects the lifting capacity of the soil-sucker clump during uprooting. The total load to be lifted by thr tracor was hence found out. The average weight of the sucker and soil-sucker clump are given in the Appendix VIII. The average weight of a sucker and soil-sucker clump obtained was 3.03 kg and 142.5 kg respectively.

4.2.5 Hardness

Hardness of a material is its resistance to fracture when stressed or the amount of energy that a material can absorb before damaging and was found out by calculating the area underneath the stress strain curve. Hardness of sucker is an indicator of the quality of the suckers to resist against the compression load. The maximum and minimum hardness obtained were as respectively 46.242 and 9.583 N (Plate 4.3). The results are given in Appendix IX.

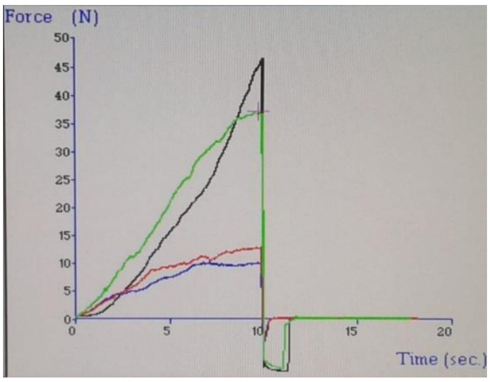


Plate 4.3 Textural profile of banana suckers

4.3 MODIFICATION OF THE KAU BANANA SUCKER UPROOTING MACHINE

The KAU tractor operated banana sucker uprooting machine was modified and field tested as explained in section 3.5.1. The uprooting unit was fabricated as explained in section 3.4.

The uprooting machine was modified to work in various types of soil. The machine performed several operations viz., opens the pit adjacent to the soil-sucker composite, penetrates into soil at an angle of 65^0 to a depth of 75 cm, uproot the soil- sucker clump of an average weight 140-160 kg in laterite soil and 55-60 kg in clay soil and thus helps to clear the land after the harvesting.

Provisions were made to move the bucket for lifting and lowering with the help of directional control valve and hydraulic cylinders. Depth of penetration of bucket tynes into the soil varied according to the type of soil, shape and number of tynes. The specifications of the modified tractor operated banana sucker uprooting machine is given in Table 4.2

Table 4.2 Specifications of the modified tractor operated banana sucker uprooting machine

Sl. No.	Particulars	Values
1	Over all dimensions	
	Length × width × height, mm	3360 × 600 × 1400
2	Specifications of tractor	
	i. Make and model	John Deere 5310
	ii. Power source, hp	55
3	Type of implement	Attached
4	Number of tynes	3 and 4
5	Tyne spacing, mm	100 (Adjustable)
6	Nominal width of cut, mm	600
8	Depth of penetration, mm	40 (min)
9	Supportive frame	
	Dimensions	

	i. Length x width	1400 x 60cm
	ii. Fixing bolts	6
	iii. Hinge-pin	1
10	Bucket tynes	
	a) Rectangular tyne	
	i. Shape	Rectangular
	ii. Number	3 and 4
	b) Triangular tyne	
	i. Shape	Triangular
	ii. Number	3 and 4
11	Boom (gib-crane)	
	i. Length x width	2400 x 150
12	Hydraulic cylinders	
	i. Number	2
	ii. Type of cylinder	Double acting cylinder
	iii. Oil type	Turf guard supreme 50 grade oil
13	Swinging links	
	Types of links	3
	i. Idler link ii. Intermediate link iii. Fixed link	2 2 2
14	Flexible hose pipes	4
15	Direction control valve	1
16	Weight of unit	235 kg

4.4 PERFORMANCE EVALUATION OF BANANA SUCKER UPROOTING MACHINE

The field performance of banana sucker uprooting machine was evaluated at KCAET, Tavanur and BRS Kannara for two types of soils during February 2017. The field testing of the up rooter was conducted for time of operation, depth of penetration, number of suckers per clump, weight of soil sucker-clump, and percentage of damage with respect to clay and laterite soils, with rectangular and triangular 3 and 4 number of tynes. The field testing and evaluation of banana sucker uprooting machine was conducted as discussed in sec 3.6...

The effect due to shape and number of tynes with respect to the changes time of uprooting, depth of penetration and percentage of damage. As the number of tynes increases the time of uprooting and percentage of damage is reduced and depth of penetration was increased. Variation in the above parameters with respect to changes in the shape of the tynes and number of tynes in two different soils were given in Table 4.11. The results obtained under various level of parameters were statistically analyzed. The results are described separately for rectangular and triangular shape 3 and 4 number of tynes in both clay and laterite soils.

Table 4.3 Variation in the parameters with respect to changes in the shape of the tynes and number of tynes in two different soils.

Sl. No.	Experiment runs	Time of uprooting (s)	Depth of uprooting, cm	Number of suckers per plant	Percentage of damage, %	Weight of soil-sucker clump, (kg)
1	C R_3	225	47.66	3	33.33	138.1
2	L R_3	180	44	8	25	140.3
3	C R_4	131	57.6	4	28.5	143.7
4	L R_4	105	62.3	8	12.5	151.2
5	C T_3	158	50.3	3	14.28	140.3
6	L T_3	119	55	8	12.5	146.3
7	C T_4	108	65.6	3	14.28	143.6
8	L T_4	88	71.0	8	0	157.6

C and L = Type of soils (clay and laterite)

R and T = Shape of tynes (Rectangular and Triangular)

3 and 4 = Number of tynes

4.6 FIELD PERFORMANCE TESTS

4.6.1 Draft

The draft developed by tractor for operating the banana sucker uprooting machine was measured by using S-type load cell dynamometer as mentioned in section 3.9.4. Load was applied by pulling with supplement tractor. Digital indicator connected to the load cell through appropriate cable. The average draft developed by the tractor attached banana sucker uprooting machine at the working test selected for uprooting operation in the soil was 811 kg for banana sucker uprooting during the experiments. On comparing this noted value with the calibration table of the instrument (S-type load cell), the total force required was found out as 7953.19 N Hence, it was found that the machine meets the force requirements for uprooting the soil-rhizome composite.

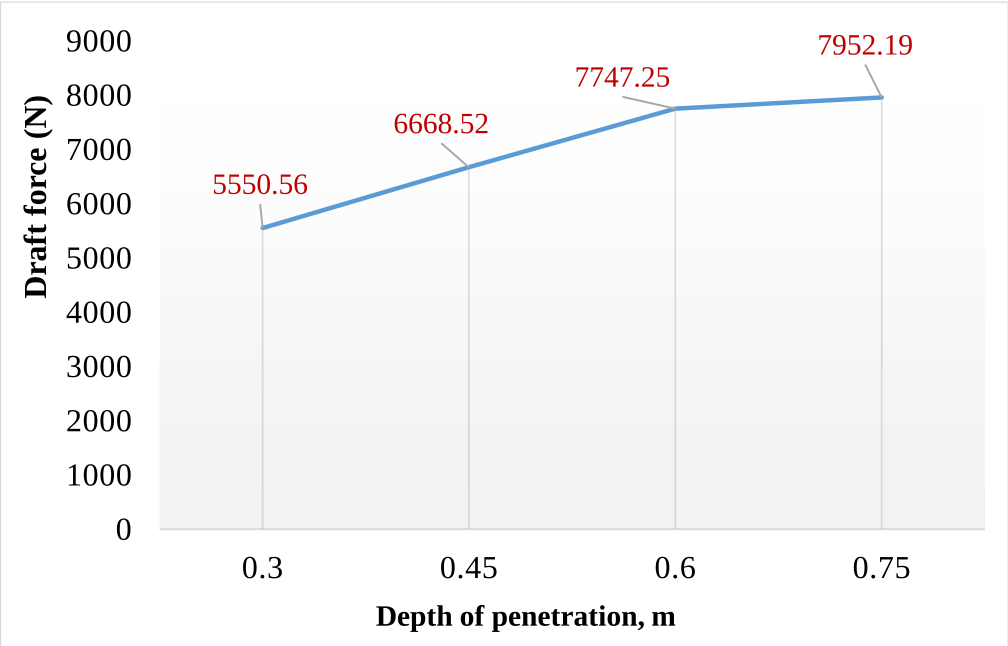


Fig. 4.1 Force required at various depths of penetration

Fig 4.1 shows the machine draft due to the operation when the bucket was penetrated in to the soil at various depths. When the bucket was penetrated into soil at a depth of 0.30 m the draft due to horizontal pull to uproot the soil-sucker clump was 5.55 KN. At the maximum depth of penetration of 0.75 m the draft was 7.95

KN. As the depth of penetration of the bucket increases, the draft due to pull for uprooting the soil–sucker clump also increases. This may be due to cohesive nature of the soil. An increasing response in specific draft was observed with an increase in tillage depth and speed for all the implements tested in the field (Al-Janobi and Al-Suhaibani, 1998). The biggest changes were mostly due to the result of changing operating depth of the implement. Draft required at various levels of depth as given in Appendix X.

4.6.2 Time taken to uproot banana soil-sucker rhizome clump

The analysis of variance for the time taken to uproot the soil- sucker clump with respect to soil type, shape of tynes, and number of tynes is given in Table 4.4. From the results it was inferred that the interaction effect due to number of tynes and shape of the tyne is significant, and also the effect due to number of tynes is significant.

It was also observed that the effect of interaction of factor means of bed soil type, number of tynes, shape of the tynes was highly significant, but the interaction of factor means of number of tynes and soil type were not significant and also interaction of factor means of soil type and shape of the tynes were not significant The three factor interaction, namely the influence due to bed width, number of tynes and height of bed were significant. It was inferred that there were differential effect soil type, shape of the tynes, number of tynes at 5 per cent level of significance. The effect due to the treatment combinations of shape of the tynes and number of the tynes was high differential response. The three factor interaction was significant, showing that there was differential response among the three selected variables namely soil type, shape of tynes, and number of tynes

Table 4.4 Analysis of variance of time taken to uproot the banana suckers

Source of variance	DF	SS	MS	F	
Soil type (A)	1	6,402.66	6,402.667	39.110	*
Shape of tynes (B)	1	23,437.5	23,437.50	143.166	*

Soil type x shape of tynes (A x B)	1	541.500	541.500	3.308	NS
No. of tynes (C)	1	10,500.1	10,500.16	64.139	*
Soil type X No. of tynes (A x C)	1	48.167	48.167	0.294	NS
No. of tynes x Shape of tynes (B x C)	1	2,904.00	2,904.000	17.739	*
A x B x C	1	-0.000	-0.000	-0.000	**
Error	16	2,619.33	163.708		
Total	23	46,453.3			

* Significant at 5% level   ** Highly significant at 1% level   NS- Not significant

4.6.2.1 Interaction of factor means for time of uprooting

Time taken to uproot soil-sucker clump with respect to the soil type, shape of the tynes, and number of the tynes was different when field tested with the uprooting machine as given in the (Table 4.5). It is observed that the minimum time taken to uproot the soil-sucker clump in clay soil using 3 number triangular tynes was 158 sec. The maximum time taken with rectangular 3 tynes was 225 sec. But for same soil type minimum time taken was 108 sec, to uproot soil-sucker clump using 4 number of triangular tynes. The maximum time taken was 131 sec when 4 number rectangular tynes was used.

Table 4.5 Interaction of soil type, shape and number of tynes on time taken to uproot soil-sucker clump.

Shape of tynes	Soil type			
	Clay soil		Laterite soil	
	Number of tynes			
	3	4	3	4
Rectangular tynes	225^{a}	131^{c}	108^{b}	105^{c}
Triangular tynes	158^{b}	108^{d}	119^{a}	88^{d}

SED = 10.447   CD = 22.149

Similarly in laterite soil it was observed that the maximum time taken to uproot the soil-sucker clump using 3 number of triangular tynes was 119 sec. The minimum time taken was 108 sec using 3 number of rectangular. It is also observed that the minimum time taken to uproot the soil-sucker clump using 4 number triangular tynes was 88 sec for the same soil. The maximum time taken was 105sec when 3 number of rectangular tynes was used.

The time taken for uprooting the soil-sucker clump was found to be less in both the soils using 4 number of triangular tynes. Operating with 4 number of triangular tyne the uprooting was found to be optimal for both the soil conditions rather than 3 and 4 number of rectangular tynes and 3 number of triangular tynes. If the number of tynes was increased to 4 the triangular shape tyne was found to be ideal. If number of tynes is 3, there might be an effect of load on tynes with respect to different soil conditions. This might be due to the fact that as the number of tynes was decreased the load on tyne will be increased and ultimately the speed of operation was decreased and hence more time was taken to uproot the soil sucker clump in the selected soil conditions.

4.6.3 Depth of penetration

The analysis of variance for the depth of penetration of bucket tynes with respect to soil type, shape and number of tynes is given in Table 4.6. From the results it was inferred that the interaction effect due to soil type and shape of the tynes is not significant and also the effect due to soil type is not significant.

It was also observed that the effect due to the shape of the tyne is significant and the effect due to the number of the tynes was highly significant but the interaction of factor mean soil type and number of tynes is not signicant and also the interaction due to shape of tyne and number of tynes is not significance. The three factor interaction, namely the influence due to soil type, shape and number of tynes were not significant. The three factor interaction was not significant, showing that there was no differential response among the three selected variables namely soil type, shape and number of tynes.

Table 4.6 Analysis of variance of depth of penetration of bucket tynes w.r.t respect to the soil type, shape and number of tynes.

Source of variance	DF	SS	MS	F	
Soil type (A)	1	45.37	45.37	3.372	NS
Shape of tynes (B)	1	1,335.0	1,335.0	99.198	*
Soil type x shape of tynes (A X B)	1	30.37	30.37	2.257	NS
No. of tynes (C)	1	345.0	345.0	25.638	**
Soil type x No of tynes (A X C)	1	30.3	30.3	2.257	NS
Shape of tynes x No. of tynes (B X C)	1	3.37	3.37	0.251	NS
A X B X C	1	22.0	22.0	1.638	NS
Error	16	215.3	13.45		
Total	23	2,026.9			

* Significant at 5% level ** Highly significant NS- Not significant

4.6.3.1 Interaction of factor means for depth of penetration

Depth of penetration of bucket with respect to the soil type, shape and number of the tynes was different when field tested with the machine as given in the (Table 4.7). The depth of penetration varies in different soil due to the high compactness of soil. When field tested in clay soils, the minimum depth of penetration of 47.6cm was observed when operated with 3 number rectangular tynes and maximum depth of penetration of 50.3cm was observed when operated with triangular tynes. But for same soil type, the minimum depth of penetration of 57.6cm was observed when operated with 4 number rectangular tynes and maximum depth of penetration of 65.6cm was observed when operated with 4 number triangular 4 tynes.

Table 4.7 Interaction of factor of mean soil type, shape and number of tynes on depth of penetration of bucket tyne

Shape of tynes	Soil type			
	Clay soil		Laterite soil	
	Number of tynes			
	3	4	3	4
Rectangular tynes	47.6[d]	57.6[b]	44[d]	62.3[b]
Triangular tynes	50.3[c]	65.6[a]	55[c]	71.0[a]

SED=2.995 CD=3.175

Similarly in laterite soil it was observed that the minimum depth of penetration of 44cm was observed when operated with 3 number rectangular tynes and maximum depth of penetration of 55cm was observed when operated with 3 number triangular 3 tynes. But for same soil type, the minimum depth of penetration of 62.3cm was observed when operated with 4 number rectangular tynes and maximum depth of penetration of 71cm was observed when operated with 4 number triangular tynes.

The depth of penetration of bucket in to the soil to uproot the soil-sucker clump was found to be minimum in both the soils using 3 number triangular tynes and maximum when used with 4 tynes. When operated with 4 number triangular tynes the uprooting was found to be optimum for both the soil conditions for better uprooting of soil-sucker clump rather than rectangular and 3 number triangular tynes. If the number of tynes was increased 3 to 4, the triangular shape tyne was found to be the best. If number of tynes was 3 there might be the effect of less force acting on the soil to penetrate the bucket tyne. This might be due to the fact that the number of tynes is decreased, the force acting on the soil will be decreased and ultimately leads to more damage of the suckers due to less penetration.

4.6.4 Percentage of damage of suckers

The analysis of variance of percentage of damage that occurred while uprooting the soil-sucker clump using three factor of interactions soil type, shape and number of tynes is given in Table 4.8. The results revealed that the effects due to interaction of soil type and shape of tynes were not significant. The effects due to soil type and number of tynes were not significant and also effects due to shape and number of tynes were not significant. While the response due to the three factor interaction of the above said parameters are significant at 5% level. Hence it was inferred that there were differential effects on the percentage of the damage with respect to the selected variables and its interactions.

Table 4.8 Analysis of variance on damage percentage of suckers w.r.t soil type, shape and number of tynes.

Source of variance	DF	SS	MS	F	
Soil type (A)	1	0.167	0.167	0.400	NS
Shape of tynes (B)	1	0.667	0.667	1.600	NS
Soil type X shape of tynes (A X B)	1	0.000	0.000	0.000	NS
No. of tynes (C)	1	0.167	0.167	0.400	NS
Soil type X No of tynes (A X C)	1	0.167	0.167	0.400	NS
Shape of tynes X No. of tynes (B X C)	1	0.000	0.000	0.000	NS
A X B X C	1	-	-	-	*
		0.000	0.000	0.000	
Error	16	6.667	0.417		
Total	23	7.833			

* Significant at 5% level NS- Not significant

4.6.4.1 Interaction of factor means for percentage of damage

Interaction of factor means for percentage of damage of individual plants occurred during uprooting of banana soil-sucker clump for clay and laterite soil with 3 and 4 number of rectangular and triangular tynes is represented in Table 4.9.

From the results, it was observed that the minimum damage of 14.2 % was occurred when uprooted the soil-sucker clump with 3 number triangular tynes and maximum damage of 33.3% was occurred when uprooted with 3 number rectangular tynes in clay soil. Also, a minimum damage of 14% was occurred when uprooted with 4 number triangular tynes and maximum damage of 28.5% was occurred when uprooted with 4 number rectangular tynes in same soil.

Table 4.9 Interaction of soil type, shape and number of tynes on percentage of damage

Shape of tynes	Soil type			
	Clay soil		Laterite soil	
	Number of tynes			
	3	4	3	4
Rectangular tynes	33.3^{a}	28.5^{a}	25^{a}	12.5^{a}
Triangular tynes	14.2^{b}	14.2^{b}	12.5^{b}	0^{b}

SED=0.527 CD=1.117

Similarly in laterite soil it is observed that the minimum damage of 12.5 % occurred when uprooted the soil-sucker clump with 3 number triangular tynes and maximum damage of 25% was occurred when uprooted with 3 number of rectangular tynes and no damage was occurred when uprooted with 4 number triangular tynes and maximum damage of 12.5% was occurred when uprooted with 4 number rectangular tynes.

From the results it is concluded that a minimum damage of 0% to 14.2% was observed with 4 and 3 number of rectangular tynes. But a maximum damage of 12.5 to 33.3 per cent was occurred when 4 and 3 number of rectangular tynes were operated. 3 and 4 number of triangular tynes was found to be optimum for both the soil conditions for better uprooting soil-sucker clump with less percentage of damage. Operating with rectangular tynes were difficult. This may be due to fact that the triangular tynes has, to open less area of soil, which resulted easy uprooting with less or no percentage of damage.

4.6.5 Weight of soil-sucker clump uprooted

The analysis of variance for the weight of soil-sucker uprooted clump w.r.t soil type, shape and number of tynes is given in Table 4.10. From the results it was inferred that the interaction effect due to soil type and shape of the tyne is highly significant and also the effect due to soil type and shape of tynes is significant.

It was also observed that the effect of interaction of factor means of soil type and number of tynes is highly significant and interaction of factor of mean of shape of tynes and number of tynes is not significance. The three factor interaction, namely the influence soil type, shape and number of tynes were not significant. It was inferred that there were differential effect due to soil type, shape and number of tynes at five percent level of significance. The effect due to the treatment combinations of soil type and shape of the tynes and soil type and number of tynes was with high differential response. The three factor interaction was not significant, showing that there was no differential response among the three selected variables namely soil type, shape and number of tynes.

Table 4.10 Analysis of variance of weight of soil-sucker clump w.r.t the soil type, shape and number of tynes

SV	DF	SS	MS	F	
Soil type (A)	1	330.04	330.04	75.12	*
Shape of tynes (B)	1	361.92	361.92	82.38	*
Soil type X shape of tynes (A X B)	1	68.00	68.00	15.48	**
No. of tynes (C)	1	77.76	77.76	17.70	*
Soil type X No. of tynes (A X C)	1	39.49	39.49	8.98	**
Shape of tynes X No. of tynes (B X C)	1	1.40	1.40	0.31	NS
Int A X B X C	1	2.55	2.55	0.58	NS
Error	16	70.28	4.39		

Total	23	951.46

* Significant at 5% level   **highly significant at 1% level   NS- not significant

4.6.5.1 Interaction of factor means for weight of damage

Interaction of factor means for amount weight of soil-sucker clump obtained during uprooting of banana soil-sucker clump for clay and laterite soil with 3 and 4 number of rectangular and triangular tynes is presented in Table 4.11. From the results, it is observed that the minimum weight of 138.16 kg was obtained when uprooted the soil-sucker clump with 3 number of rectangular tynes and maximum weight of 140.33 kg was obtained when uprooted with 3 number triangular tynes and minimum weight of 143.60 kg was obtained when uprooted the soil-sucker clump with 4 number triangular tynes. A maximum weight of 143.70 kg was obtained when uprooted with 4 number rectangular tynes. The maximum weight was obtained when uprooted with 4 number triangular tynes was optimum. This was due to the fact that more depth of penetration of tynes in to the soil leads to the maximum amount of soil-sucker clump to be uprooted by the bucket.

Table 4.11 Interaction of soil type, shape and number of tynes on weight of soil-sucker clump

Shape of tynes	Soil type			
	Clay soil		Laterite soil	
	Number of tynes			
	3	4	3	4
Rectangular tynes	138.16^{b}	143.70^{cd}	140.30^{b}	151.26^{d}
Triangular tynes	140.33^{a}	143.60^{dc}	146.30^{a}	157.60^{c}

SED =1.210   CD= 2.566

For laterite soil, it was observed that the minimum weight of 140.30 kg was obtained when uprooted the clump with 3 number rectangular tynes and maximum weight of 146.30 kg was obtained when uprooted with 3 number triangular tynes and minimum weight of 151.26 kg was obtained when uprooted with 4 number rectangular tynes and maximum weight of 157.60 kg was obtained when uprooted with 4 number triangular tynes, which was considered as the optimum level. Also, it was inferred that the 4 number of triangular tynes was form suitable for uprooting of the soil sucker clump.

4.7 COMPARISON OF PERFORMANCE OF THE MODIFIED BANANA SUCKER UPROOTING MACHINE

Banana sucker uprooting machine was compared with respect to time, depth, percentage of damage and weight separately with 3 and 4 number of rectangular and triangular tynes. The observations were separately recorded for various parameters. The results are illustrated with respect to time, depth, percentage of damage and weight of soil-sucker clump.

4.7.1 Time

The performance on time taken to uproot the soil-sucker clump in clay and laterite soils with 3 and 4 numbers of rectangular and triangular tynes fitted to the bucket is shown in Fig 4.2. It is obvious that the time taken to uproot soil-sucker clump in clay soil was the highest when operated with 3 number rectangular tynes, whereas minimum time taken was with the 4 number triangular tynes. Accordingly, the time taken to uproot in laterite soil was maximum with 3 number of rectangular tynes and minimum was with the 4 numbers of triangular 4 tynes.

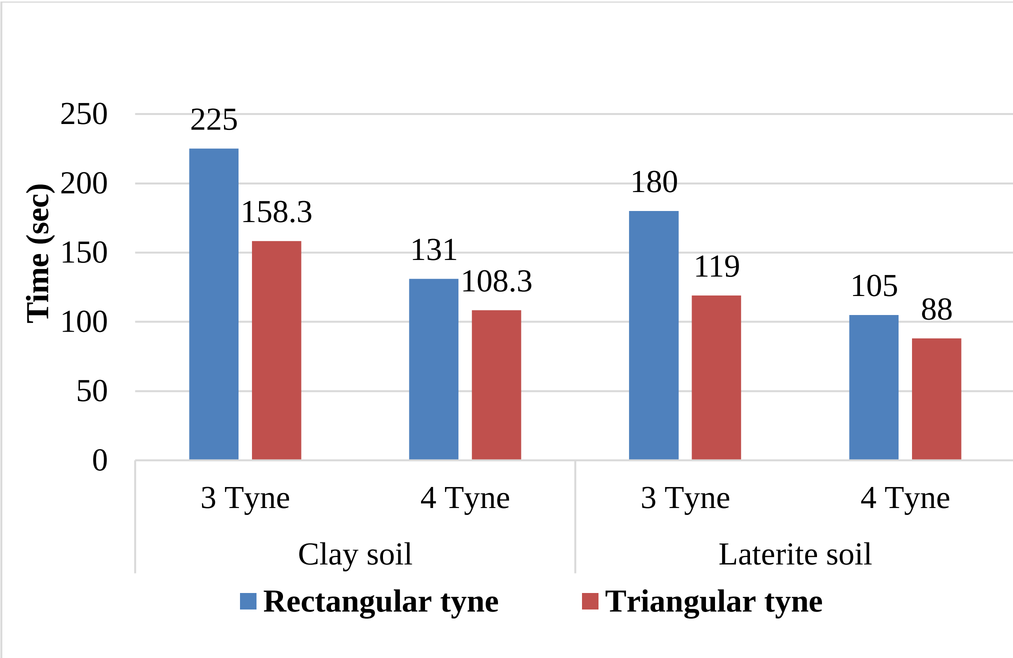


Fig. 4.2 Time taken (sec) to uproot the soil-sucker clump with respect to soil type, shape of tynes and number of tyne

4.7.2 Depth of penetration

The performance on depth of penetration of the tynes into the soil to uproot the soil-sucker clump in clay and laterite soils with 3 and 4 number of rectangular and triangular tynes is shown in Fig 4.3. Depth of penetration of the tynes into the soil to uproot the soil-sucker clump in clay soil was minimum when operated with 3 number rectangular tynes, but more depth of penetration was obtained when operated with 4 number triangular tynes. Similarly depth of penetration of tynes into soil to uproot the soil-sucker clump in laterite soil was minimum when uprooted with the 3 number rectangular tynes, whereas more depth of penetration was observed when uprooted with 4 number triangular tynes.

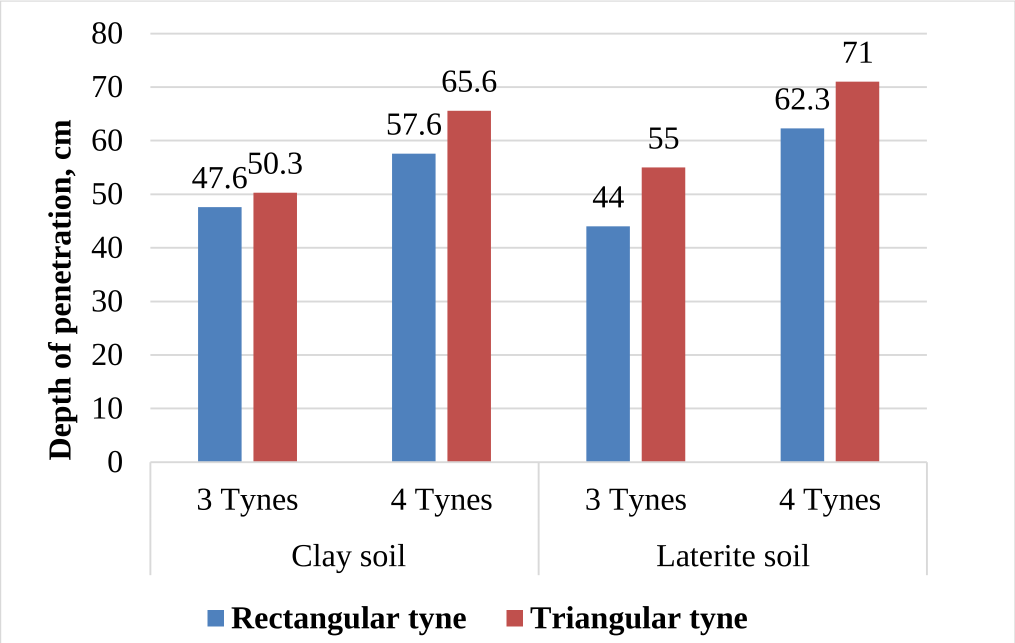


Fig. 4.3 Depth of penetration of tynes (cm) w.r.t to soil type, shape and number of tynes

4.7.3 Percentage of damage

Performance on the damage of suckers occurred while uprooting of soil-sucker clump for clay and laterite soils with 3 and 4 number of rectangular and triangular tynes is shown in Fig 4.4. From the results, it is observed that a minimum damage of 14.2 per cent was occurred when operated with 3 number of triangular tynes and maximum damage of 33.3 per cent was occurred when uprooted with 3 number rectangular tynes in clay soil and a minimum damage of 14 per cent occurred when uprooted with 4 number triangular tynes. A maximum damage of 28.5 per cent was occurred when uprooted with 4 number rectangular tynes in same soil.

Similarly in laterite soil it was observed that the minimum damage of 12.5 per cent was occurred when uprooted the of soil-sucker clump with 3 number of triangular tynes and a maximum damage of 25 per cent was occurred when uprooted with 3 number rectangular tynes and no damage was occurred when uprooted with

4 number triangular tynes. Maximum damage of 12.5 per cent was occurred when uprooted with 4 number rectangular tynes.

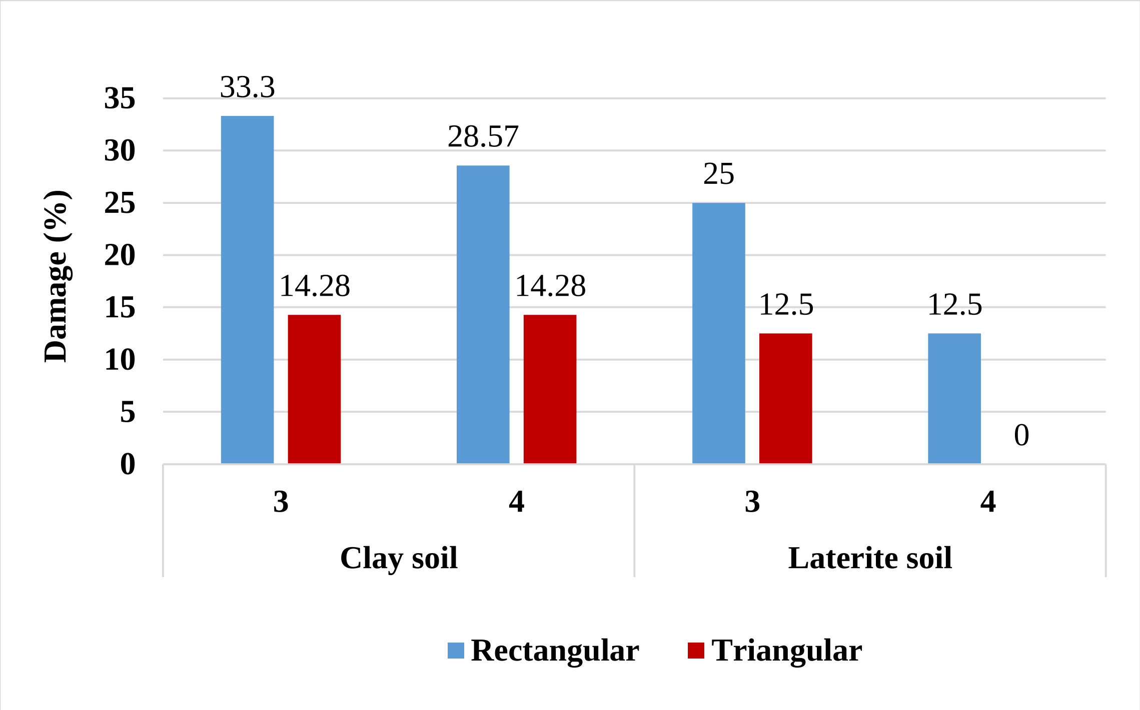


Fig. 4.4 Damage of sucker w.r.t to soil type, shape and number of tynes

4.7.4 Weight of soil-sucker clump uprooted

The maximum and minimum weight of soil-sucker clump was obtained by changing the shape and the number of the tynes in clay and laterite soils is shown in Fig 4.5. In clay soil the maximum weight of soil-sucker clump was 140.33 kg and a minimum was 138.16 kg when uprooted with 3 number of triangular and rectangular tynes. A maximum weight of 143.7 kg and a minimum weight of 143.6 kg were obtained by used with 4 number of rectangular and triangular tynes. Similarly a maximum weight of 146.3 kg and a minimum weight of 140.3 kg were obtained when uprooted with 3 number of triangular and rectangular tynes. A maximum weight of 157.6 kg and minimum weight of 151.2 kg were obtained when uprooted with 4 number triangular and rectangular tynes in laterite soils.

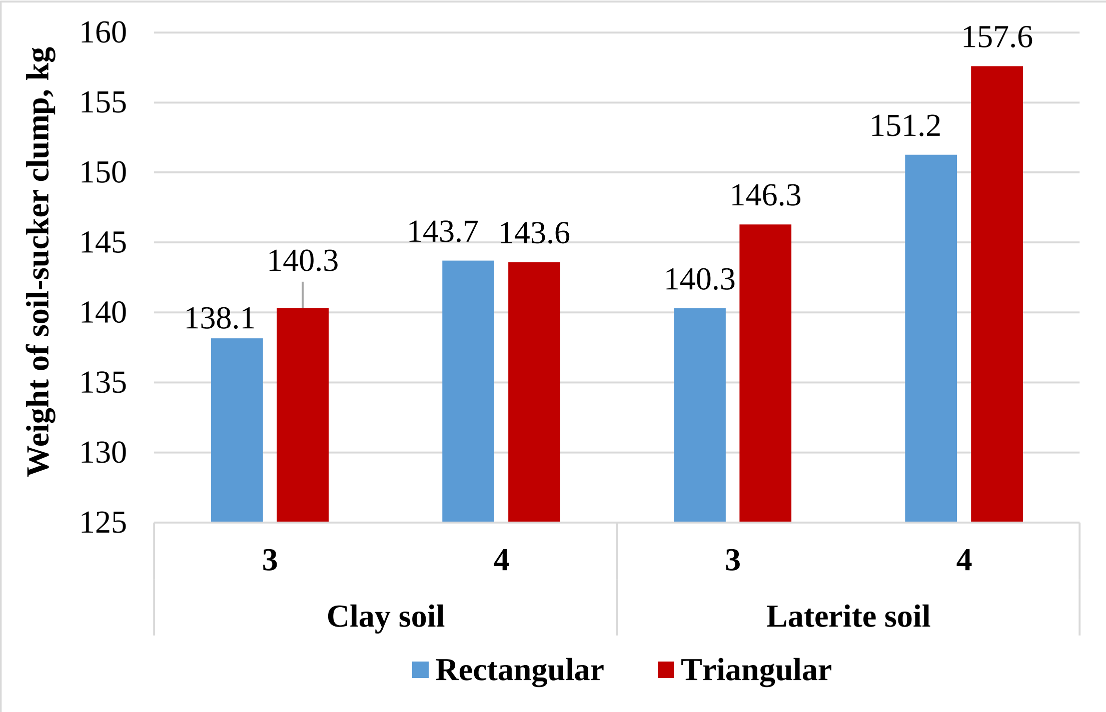


Fig. 4.5 Weight of soil-sucker clump w.r.t soil type, shape and number of tynes

4.7.5 Wheel slip

The wheel slip during uprooting of soil sucker rhizome was measured as described in section 3.10.6. The wheel slip measured was 8.0 per cent which is within the recommended range of slip.

4.7.6 Fuel consumption

The fuel consumption was measured by the procedure as described in the section 3.10.4. The uprooting machine was operated in an area of 0.025 ha. The time and fuel consumption for the test area was measured. The fuel consumption obtained was 4.1 *l* ha^{-1}.

4.8 FIELD EFFICIENCY

Field efficiency of modified banana sucker uprooting machine is the ratio of actual field capacity to the theoretical field capacity. It was observed that the total time taken to uproot an area 0.025 ha in clay soil was 1.8 h. Hence the actual field capacity was 1.875 x 10^{-3} ha.h^{-1} and theoretical field capacity was 2.5 x 10^{-3} ha h^{-1}. The field efficiency was obtained as 75%. Where in the laterite soil the time taken to uproot an area 0.025 ha was 1.5 h. The actual field capacity obtained was 3 x 10^{-3} ha $h^{-1}$and theoretical field capacity was soil was 3.75 x 10^{-3} ha h^{-1}. Then the field efficiency was 80 per cent. Calculations of field capacity and field efficiency of modified tractor operated banana sucker uprooting machine is given in Appendix XI.

4.9. COST ECONOMICS

The cost economics of the modified tractor operated banana sucker uprooting machine is given in appendix XII. The cost of banana sucker uprooting machine was Rs.39, 992/-, whereas cost of uprooting with the machine is Rs. 22,930 $ha^{-1.}$ In conventional methods, uprooting was carried by digging out the soil-sucker composite by employing a labour using a sharp hatchets and spades the sword suckers should be dugout and separated from the mother plant. It was found that a man could uproot only 15-20 soil-rhizomes per day. About 480 man hours required to uproot soil-sucker clump per hectare. At the present wage rate of Rs 600 per day. It is estimated that an amount of Rs.48000 ha^{-1} is required for uprooting of banana clumps after harvest. Hence the savings over conventional method is Rs 25,070 per hectare. The cost and time saved over manual uprooting was about 52.22% and 93.06% respectively. The benefit-cost ratio of the modified uprooting machine was 1.09:1

CHAPTER V

SUMMARY AND CONCLUSIONS

Banana (*Musa paradisiaca*) is a large perennials which produces succeeding generation of crop with leaf sheaths that form trunk like pseudo stem. Sucker is the planting material used for cultivation of banana. After harvesting, the banana bunch uprooting of mother corm and its suckers without damage is very essential for obtaining good quality planting material. After the harvesting of the crop immediate clearing of land is the main difficulty faced by banana farmers as less time is available between harvest and fresh planting of banana in the field.

In conventional method of uprooting, banana suckers are uprooted manually by using sharp hatchets and spades. Uprooting the mother plant and suckers, clearing the land etc. are highly labour intensive and more time consuming operations which requires proper handling to avoid cuts, breakage, bruises and injuries. The present practice of uprooting takes a lot of time and energy. In preliminary investigation of uprooting of banana suckers manual method it is understood that one man labour can uproot only15-20 clumps per day.

To overcome these problems and decrease the cost of uprooting of banana suckers, an uprooting machine as an attachment to a tractor was developed at KCAET, Tavanur. It was operated by the hydraulic system of a tractor, which consisted of a double hydraulic cylinder with a control valve. There were several problems associated with the construction especially with respect to the uprooting mechanism, undue exertion of forces on the suckers which inturn damaged the suckers and hence high fuel and hydraulic oil consumption. Also, more slippage of the wheels of the tractor during uprooting of the suckers. With these factors in view, an attempt was made to resolve the above said problems and to decrease the cost of uprooting the suckers and to increase the field efficiency, a modified tractor operated KAU banana sucker uprooting machine was developed and test has been conducted.

An Area of 0.025 ha was selected in the Instructional Farm, KCAET, Tavanur as the study area. The laterite soil having moisture content of 13 per cent. The physical and mechanical properties of the soil have an effect directly or indirectly at the soil-machine interface as well as the growth of the crop. The major three physical properties of soil *viz.*, moisture content, bulk density and soil texture and the most influential mechanical property of soil viz., shear strength were determined using standard test procedures. Soil samples of six different locations were collected from the banana field of study area at depths of 0-20, 20-40, 40-60 and 60-80 cm at the time of planting and also in-situ soil moisture contents at the time of uprooting was observed and recorded.

After the harvesting of crop, the field was ready for conducting the testing with the machine.

The physical and mechanical properties of the suckers *viz*., size, shape, weight and hardness were found out using standard test procedures. The hardness of the sucker was measured determined using texture analyzer. The KAU banana uprooter was developed as an attachment to a tractor was studied in detail. The modified tractor operated KAU banana sucker uprooting machine was developed for uprooting and land clearing. The uprooter was operated by a hydraulic system of a tractor. The total weight of the gib-crane assembly and the weight due to soil-sucker composite comes around 350 to 400 kg. In order to operate with this attachment a tractor having a sufficient hydraulic lifting capacity was needed. Hence, the tractor engine of the John Deere 5310 tractor with 55 hp selected as the prime mover. Two types of tynes were fabricated and tested to increase the efficiency of the digging and uprooting of banana soil-sucker. It takes most of the soil resistance during operation. The tynes will penetrate at an angle of 65^o with the vertical. Two double acting hydraulic cylinders were used to convert hydraulic power into linear mechanical force or motion.

The field testing was conducted for uprooting the banana soil-sucker in two types of soils viz., laterite soil at IF, KCAET Tavanur and clay soil at BRS Kannara. Trials were conducted to evaluate the performance uprooter with 3 and 4 numbers of rectangular and triangular shape tynes. The uprooting was carried out for each of the treatment combinations. Three replications were carried out to each treatment. Hence total number of experiments was eight. Observations were statistically analyzed using three factor ANOVA using OP-STAT online software. The experiments were laid out according to Factorial Commonly Randomized Design (FCRD).

Draft measurement was carried out with the uprooting machine using with S- type load, cell attached between the two tractors. The total force required was found out as 7.95 KN. Hence, it was found that the selected tractor was ideal to operate with the machine.

Performance analysis of the modified banana sucker uprooting machine was compared with respect to time, depth of penetration, percentage of damage of suckers and weight of soil-sucker clump uprooted separately with 3 and 4 number of rectangular and triangular. The observations were separately recorded for clay and laterite soil.

The performance on the time taken to uproot. It was found out as the maximum with 3 number of rectangular tynes, whereas minimum time taken was with 4 number of triangular tynes in both clay and laterite soils. The maximum time taken with rectangular 3 tynes was 225 sec. But for same soil type minimum time taken was 108 sec, to uproot soil-sucker clump using 4 number of triangular tynes.

The performance on depth of penetration of the tynes in to soil to uproot the soil-sucker clump in clay soil was the minimum with 3 number rectangular tynes, whereas more depth of penetration was observed with 4 number triangular tynes. When field tested in clay soils, the minimum depth of penetration of 47.6cm was observed when operated with 3 number rectangular tynes and maximum depth of penetration of 65.6cm was observed when operated with 4 number triangular 4 tynes. Similarly in laterite soil it was observed that the minimum depth of penetration of 44cm was observed when operated with 3 number rectangular tynes and maximum depth of penetration of 71cm was observed when operated with 4 number triangular tynes.

Performance on the damage of suckers occurred while uprooting of soil-sucker clump in clay was maximum damage of 33.3 per cent was occurred when uprooted with 3 number rectangular tynes and a minimum damage of 14 per cent occurred when uprooted with 4 number triangular tynes. Similarly in laterite soil it was observed that the minimum damage of 12.5 per cent was occurred when uprooted the of soil-sucker clump with 3 number of triangular tynes and a maximum damage of 25 per cent was occurred when uprooted with 3 number rectangular tynes and no damage was occurred when uprooted with 4 number triangular tynes.

The maximum weight of soil-sucker clump in clay soil was 140.33 kg and a minimum was 138.16 kg when uprooted with 3 number of triangular and rectangular tynes. A maximum weight of 143.7 kg and a minimum weight of 143.6 kg were obtained by using with 4 number of rectangular and triangular tynes. Similarly a maximum weight of 146.3 kg and a minimum weight of 140.3 kg were obtained when uprooted with 3 number of triangular and rectangular tynes. A maximum weight of 157.6 kg and minimum weight of 151.2 kg were obtained when uprooted with 4 number triangular and rectangular tynes in laterite soils

Thus it is concluded that the minimum time taken and maximum depth of penetration in clay soil were 108 sec and 65.6 cm respectively, when uprooted with 4 number triangular tynes. Though the percentage of damage (14.28%) was lower than with 3 and 4 number rectangular tynes, the weight of soil-sucker clump was also maximum when uprooted with 4 number triangular tynes compared to 3 number of tynes. Hence it is suggested that the best uprooting of soil-sucker clump is with 4 number triangular tynes angular tyne bucket for clay soil conditions and for laterite soil condition. It is concluded that the minimum time taken and maximum depth of penetration in clay soil were 88 sec and 71 cm respectively, when uprooted with triangular shape 4-tynes. The weight of soil-sucker clump was also maximum when uprooted with 4 number triangular tynes compared to 3 number tynes. Hence the triangular shape 4-tyne bucket is the best for uprooting of soil-sucker clump. The uprooter can be further modified for horizontal movement of gib-crane along with the different shapes of bucket and number of tynes for minimum time of uprooting.

Field efficiency of modified banana sucker uprooting machine is the ratio of actual field capacity to the theoretical field capacity. It was observed that the total time taken to uproot an area 0.025 ha in clay soil was 1.8 h. Hence the actual field capacity was 1.875 x 10^{-3} ha.h^{-1} and theoretical field capacity was 2.5 x 10^{-3} ha h^{-1}. The field efficiency was obtained as 75%. Where in the laterite soil the time taken to uproot an area 0.025 ha was 1.5 h. The actual field capacity obtained was 3 x 10^{-3} ha $h^{-1}$and theoretical field capacity was soil was 3.75 x 10^{-3} ha h^{-1}. Then the field efficiency was 80 per cent.

The cost of banana sucker uprooting machine was Rs.39, 992/-, whereas cost of uprooting with the machine is Rs. 22,930 ha^{-1}. It was found that a man could uproot only 15-20 soil-rhizomes per day. About 480 man hours required to uproot soil-sucker clump per hectare. At the present wage rate of Rs 600 per day. It is estimated that an amount of Rs.48000 ha^{-1} is required for uprooting of banana clumps after harvest. Hence the savings over conventional method is Rs 25,070 per hectare. The cost and time saved over manual uprooting was about 52.22% and 93.06% respectively. The benefit-cost ratio of the modified uprooting machine was 1.09:1.

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Appendix I

Specifications of tractor

Sl. No.	Particulars	Description
1	Specifications of tractor	
	iii. Make and model	John Deere 5310
	iv. Power source, hp (KW)	Engine:64 hp [47.7 kW] PTO (claimed):55 hp [41.0 kW] PTO (tested): 58.63 hp [43.7 kW]
2	Engine	John Deere 2.9L 3-cyl diesel
3	Transmission	9 Forward + 3 Reverse, Collar shift / 12 Forward + 12 Reverse PR transmission with Top shaft Synchromesh
4	Hydraulics	
	Type: Pressure: Valves: Pump flow: Total flow: Steering flow: Steering press. Lifting Capacity 3 Point Linkage	Open center 2855 psi [196.9 bar] 5 11.4 gpm [43.1 lpm] 18.2 gpm [68.9 lpm] 6.8 gpm [25.7 lpm] 1955 psi [134.8 bar] 1800 kgf at lower link ends Category II
5	Fuel tank capacity	
	ROPS Fuel: Cab Fuel:	18 gal [68.1 L] 23 gal [87.1 L]
6	Overall dimensions	
I.	Total Weight	2110 kg
II.	Wheel Base	2050 mm

III.	Overall Length	3535 mm
IV.	Overall Width	1850 mm
V.	Ground Clearance	435 mm
VI.	Turning Radius with Brakes	3150 mm

Appendix II

Determination of moisture content

Sl.no	weight of container (w_1)	weight of container + wet soil (w_2)	Weight of container + dry soil (w_3)	Moisture content $\left(\frac{w_2 - w_3}{w_3 - w_1}\right)$	Moisture content (%)
1	25.26	61.95	57.50	0.13	13.00
2	28.93	69.48	64.50	0.14	14.00
3	34.28	79.64	74.00	0.14	14.00
4	27.15	67.00	61.78	0.15	15.00
5	27.31	57.00	54.00	0.11	11.00
6	32.00	63.50	60.34	0.11	11.00

Sample calculations:

Mass of container, m_1 (g) = 22.26

Mass of container + wet soil, m_2 (g) = 61.95

Mass of container + dry soil, m_3 (g) = 57.50

Moisture content, % = $[(m_2-m_3) / (m_3-m_1)] \times 100$

= (61.95- 57.50) / (57.50-22.26)

=4.45/32.24

=0.13 x 100

Moisture content (%) = 13.00

Appendix III

Determination of bulk density

Mass of core cutter(g)	**Mass of core cutter + wet soil,(g)**	**Mass of wet soil (g)**	**Height of core cutter (cm)**	**Internal diameter (cm)**	**Volume (cm^3)**	**Bulk density (g/cm^3)**
984	2556	1572	12.5	10	981.25	1.66
984	2506	1522	12.5	10	981.25	1.61
984	2702	1718	12.5	10	981.25	1.82
984	2681	1697	12.5	10	981.25	1.80
984	2684	1700	12.5	10	981.25	1.80
984	2664	1680	12.5	10	981.25	1.78
984	2577	1593	12.5	10	981.25	1.69

Sample calculations:

Mass of core cutter, g = 984

Mass of core cutter + wet soil, g = 2556

Mass of wet soil, g = 1572

Height of core cutter, cm = 12.5

Internal diameter, cm = 10

Volume, cm^3 = 981.2

Bulk density, g/cm^3 = Mass/ volume

= 1.602

Appendix IV

Soil texture

Seive size	Weight retained in each seive (g)	Per cent retained in each sieve	Cummulative per cent retained	Total percentage pass
2mm	367	36.7	54.5	45.5
1mm	178.8	17.8	72.3	27.7
600micron	57	5.7	78	22
425 micron	110	11	89	11
300 micron	85	8.5	97.5	2.5
212micron	73.5	7.35	104.8	4.8
150micron	63.3	6.33	111.1	11.1
75micron	49	4.9	116.8	11.6
Pan	16.5	1.65	117.7	11.7
Total	1000	99.99		

Appendix V

Shear strength determination

Height of vane cm	Diameter of vane cm	Torque dial gauge reading kg-cm	Shear strength kgf-cm^2
		450	0.935
10	5	250	0.552
		110	o.245

Appendix VI

Size of banana suckers

Number	length (cm)	width (cm)
Sample 1	60	13
Sample 2	55	13.6
Sample 3	54	12.7
Sample 4	72	14
Sample 5	54	12
Sample 6	45.7	15.6

Appendix VII

Number of suckers per plant

Sl.no	Samples	Number of suckers
1	Plant 1	6
2	Plant 2	5
3	Plant 3	6
4	Plant 4	7
5	Plant 5	5
6	Plant 6	5
7	Plant 7	7

Appendix VIII

Weight of the suckers and soil-sucker clump

Sl. No	Sample	Weight of the suckers (kg)	Weight of soil-sucker clump (kg)
1	Sample 1	3.32	142.5
2	Sample 2	2.87	145
3	Sample 3	2.7	148.5

4	Sample 4	3.1	138.2
5	Sample 5	3.4	151.6
6	Sample 6	2.8	147.7

Appendix IX

Hardness of the suckers

Sl. No	Sample	Trials	Time (sec)	Force (N)
1	A	T_1	10	17.412
		T_2	10	13.113
		T_3	10	21.494
		T_4	10	13.106
2	B	T_1	10	16.220
		T_2	10	14.330
		T_3	10	14.855
		T_4	10	15.534
3	C	T_1	10	46.242
		T_2	10	9.983
		T_3	10	36.816
		T_4	10	36.816

Appendix X

Force required at various depths of penetration

Sl..No	**Depth of penetration (ft.)**	**Load cell reading (kgf)**	**Force required (N)**
1	0.3 m	566	5550.56
2	0.45 m	680	6668.52
3	0.6 m	790	7747.25
4	0.75 feet	811	7953.19

APPENDIX XI

Field capacity and field efficiency

$$\text{Theoretical field capacity} = \frac{\text{Width of operation (m)} \times \text{Travel speed (km hr}^{-1}\text{)}}{10}$$

$$\text{Effective field capacity ha h}^{-1} = \frac{\text{Area covered ha}^{-1}}{\text{Productive time, h} + \text{Non - productive time, h}}$$

$$\text{Field efficiency} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \times 100$$

a) For clay soil

Total area 15 x 15 m = 225 m^2

Spacing between plant to plant and row to row = 2.5 x 2.5 m

Total number of plants = $\frac{225}{2.5 \text{ x } 2.5}$ = 36 plants

Width of uprooting was 0.5 m per plant neglecting the other area

So, for 36 plants total operating length is = 36 x 2.5

= 90

Total area of uprooting = Operating length x width of operation

= 90 x 0.5

= 45 m^2

Uprooting time per plant = 3 min

Total time for 36 plants = 108 min

= 1.8 h

= 80 h ha^{-1}

Travel speed (km h^{-1}) = $\frac{90}{1.8}$

= 50 m h^{-1}.

= 0.05 km h^{-1}

Theoretical field capacity = $\frac{0.5 \times 0.05}{10}$

= 2.5 x10^{-3} ha h^{-1}

$$\text{Effective field capacity ha h}^{-1} = \frac{\text{Area covered ha}^{-1}}{\text{Productive time, h + Non - productive time, h}}$$

$$\text{Effective field capacity ha h}^{-1} = \frac{45}{2.4 \text{ x } 10000}$$

$= 1.875 \text{ x } 10^{-3}$ ha h^{-1}

$$\text{Field efficiency(\%)} = \frac{1.87 \text{ x } 10^{-3}}{2.5 \text{ x } 10^{-3}} \times 100$$

= 75.00%

b) For laterite soil

$$\text{Theoretical field capacity} = \frac{0.5 \times 0.075}{10}$$

$= 3.75 \text{ x } 10^{-3}$ ha h^{-1}

$$\text{Effective field capacity ha h}^{-1} = \frac{45}{1.5 \text{ x } 10000}$$

$= 3 \text{ x } 10^{-3}$ ha h^{-1}

$$\text{Field efficiency} = \frac{3 \text{ x } 10^{-3}}{3.75 \text{ x } 10^{-3}} \times 100$$

= 80 %

APPENDIX XII

Estimation of cost of the uprooter

Sl. No.	Material	Qty, nos	Specification	Length, m	Total weight, kg	Rate Rs/kg	App Cost, Rs.
I.	**Supporting frame**						
1.	MS plate	1	12 mm	1.2	15.5	100	1550
2.	MS rod	2	2”	2	8.3	85	705
II	**Gib-crane**						
1.	MS plate	2	12 mm	1.6	31	100	3100
2.	MS plate	2	8 mm	1.6	18.5	80	1480

3.	Lower hitch pins	2	-	0.3	-		480
III	**Swinging links**						
1.	MS Flat	1	8 mm	0.5	8		640
IV	**Bucket**						
1.	MS plate	1	12 mm	1	9.2	100	920
2.	MS rod	1	2”	0.5	5.5	85	467
V	**Bucket tynes**						
1.	MS plate	1	12 mm	0.10	6	100	600
VI	**Main items**						
1.	Hydraulic cylinder	2	2” dia, 60cm stroke length	0.60	-		14000
2.	Control valve	1	-	-	-		3000
3.	Hydraulic pipes	4	10 mm (Dia.)	-	-		1600
4.	Pipe Fittings	8	-	-	-		750
5.	Shaft, I- pad, bushes, brass sleeves	4, 2, 12,8	-	-			850
6.	Hydraulic oil	5 litres					2500
VII	**Others**						
1.	Nut and bolts(kg)	6	-	-	-		350
2.	Welding rods	-	-	-	-		250
Total cost			**33242**				
Fabrication cost			**6750**				
Total cost of uprooter			**39992**				

Cost of operation of modified KAU banana sucker uprooting machine.

1. **Tractor**

Cost of tractor, C = Rs. 6, 00,000

Expected life, L = 10 years

Salvage value, S = 10% of C = Rs. 60,000

Annual operating hours, H = 1000 hrs

Annual interest or interest on Investment, I = 10%

i. Fixed cost

a) $\text{Depreciation} = \frac{C - S}{L \times H}$

Where,

C = Total cost of machine

S = Salvage value 10% of C

H = Annual use in hours

$$\text{Depreciation} = \frac{600000 - 60000}{10 \times 1000}$$

= Rs. 54.00 h^{-1}

b) $\text{Interest} = \frac{C + S}{2} \times \frac{i}{H}$

Where,

i = % rate of interest per year

$$\text{Interest} = \frac{600000 + 60000}{2 \times 1000} \times \frac{10}{100}$$

=Rs. 27.5 h^{-1}

c) Housing cost (1% of the initial cost of tractor)

$$= \frac{600000}{1000} \times \frac{1}{100}$$

= Rs. 6 h^{-1}

d) Insurance and taxes (2% of the initial cost of tractor)

$$= \frac{600000}{1000} \times \frac{2}{100}$$

= 12 h^{-1}

Total fixed cost = a + b+ c + d = Rs. 99.5 h^{-1}

ii. Variable cost

a) Average diesel consumption = 3.5 lit h^{-1}

Fuel cost (3.5×Rs. 64.5 lit^{-1}) = Rs. 224 lit^{-1}

b) Lubricant oil cost (30% of fuel cost)

$$= 264.45 \times \frac{30}{100}$$

= Rs. 81.33 h^{-1}

c) Repair and maintenance cost (10% of initial cost)

$$= \frac{600000}{1000} \times \frac{10}{100}$$

= Rs. 60 h^{-1}

d) Operator wages (Rs. 800 per day of 5 hours)

$$= \frac{800}{5} = 160\ h^{-1}$$

Total variable cost = a + b+ c + d = Rs. 525.33 h^{-1}

Total operating cost of tractor = Fixed cost + Variable cost

= 87.5 + 467.28

= Rs. 624.83 h^{-1}

2. Banana sucker uprooting machine

Cost of uprooter, C	= Rs. 39,992
Expected life, L	= 10 years
Salvage value, S	= 10% of C = Rs. 3992.2
Annual operating hours, H	= 200 hrs
Annual interest, i	= 10%

i. Fixed cost

a) $\text{Depreciation} = \frac{C - S}{L \times H}$

Where,

C = Total cost of uprooter

S = Salvage value 10% of C

H = Annual use in hours

$$\text{Depreciation} = \frac{39992 - 3999.2}{10 \times 200}$$

= Rs. 17.9 h^{-1}

b) $\text{Interest} = \frac{C + S}{2} \times \frac{i}{H}$

Where,

i = % rate of interest per year

$$\text{Interest} = \frac{39992 + 3999.2}{2 \times 200} \times \frac{10}{100}$$

=Rs. 8.99 h^{-1}

c) Housing cost (1% of the initial cost of tractor)

$$= \frac{39992}{200} \times \frac{1}{100}$$

= Rs. 1.99 h^{-1}

Total fixed cost = a + b+ c = Rs. 28.8 h^{-1}

ii. Variable cost

a) Repair and maintenance cost (5% of initial cost)

$$= \frac{39992}{200} \times \frac{5}{100}$$

= Rs. 9.99 h^{-1}

Total variable cost = Rs. 9.99 h^{-1}

Total operating cost of uprooter = Fixed cost + Variable cost

= 28.8 h^{-1}+ 9.99 h^{-1}

= Rs. 38.79 h^{-1}

Total operating cost of tractor and uprooter = Tractor cost + uprooter cost

= 624.83 h^{-1} + 38.79 h^{-1}

= Rs. 662.79 h^{-1}

Theoretical field capacity of uprooter = 0.0375

Actual field capacity of uprooter = 0.003

Field efficiency of uprooting machine = 80 %

Time required to cover 1 ha, h $= \frac{1}{AFC}$

$= \frac{1}{0.003}$

= 33.3 h ha^{-1}

Cost of operation of uprooting machine = 33.3 × 662.79 = Rs. 22,930 ha^{-1}

APPENDIX XIII

Cost of uprooting by conventional method (manual uprooting)

Labour requirement = 480 man h ha^{-1}

Cost of uprooting Rs. 600 per labour = $\frac{480}{6} \times 600$

= Rs. 48,000 ha^{-1}

Cost saved over manual uprooting = 48000 - 22,930

= 25,070 ha^{-1}

Cost saved over manual uprooting (%) = $\frac{25070}{48000} \times 100$ = 52.22%

Time saved over manual uprooting = 480 – 33.3

= 446.7 h ha^{-1}

Time saved over manual uprooting (%) = $\frac{446.7}{480} \times 100$ = 93.06%

3. Benefit-cost-ratio

Benefit cost per hectare **=** Cost of manual uprooting - Cost of machine uprooting

= Rs. 48000 - 22,930

= Rs. 25070

Therefore,

$$\text{Benefit cost ratio} = \frac{\text{Benefit cost}}{\text{Cost of machine uprooting}}$$

$$\text{Benefit cost ratio} = \frac{25070}{22930} = 1.09$$

APPENDIX XVI

Hydraulic cylinder calculations

(a) Cylinder blind end area

Diameter of cylinder = 7.5 cm

Radius = 3.75

Area = π x R^2

= 3.14 x 14.06

= 44.15 cm^2

(b) Cylinder rod end area

Diameter of cylinder = 7.79 cm

Diameter of rod = 3.98 cm

Radius of rod = 1.98

Area = π x R^2

= 3.14 x 0.60

= 11.61 cm^2

Cylinder rod end area = Blind end area – Rod area

= 44.15 – 11.61

= 32.54 cm^2

(c) Cylinder output force

Diameter of cylinder = 7.5

Operating at 200.72 kgf cm^{-2}

Pressure x cylinder area = 200.7 x 44.15

= 8860.9 N

Required pull force with 7.5 cm diameter cylinder and 3.98 diameter of rod operating at 200.72 kgf cm^{-2}

Cylinder rod end area = 32.12 cm^2

Pressure = 200.72 kgf cm^{-2}

Pressure x cylinder area = 200.7 x 32.12

= 63240.3 N

(d) Fluid pressure required to lift load

Pressure needed to develop 63240 N of push force from 7.5 cm diameter cylinder

Newton of force = 63240.3

Cylinder blind area = 43.74 cm^2

Force needed = 63240/ 43.74

= 1445.1 N cm^{-2}

Pressure needed to develop 63240.3 N of push force from 7.5 cm diameter cylinder which has 4.0 cm diameter rod.

Newton of force = 63240.3 N

Cylinder rod end area = 32.12

Force needed = 63240.3 ÷ 32.12

= 1968.45 N cm^{-2}

= 196845 N. m^{-2}

ABSTRACT

Banana (*Musa* paradisiaca) is a large perennials rhizome crops widely cultivated in India. These crops provide excellent opportunities in raising the income of farmers. Sucker is the planting material used for the cultivation of the banana. After the banana bunch harvesting, uprooting of mother corm and its suckers without damage is very essential for obtaining good quality planting material for banana cultivation and clearing of land is the main difficulty faced by banana farmers as less time is available between harvest and fresh planting of banana field. Uprooting the mother plant and suckers, clearing the land etc. are highly labour intensive in banana cultivation. As the entire State faces an acute shortage of labour, the development of suitable equipment for uprooting the banana clump is necessary. The present practice of uprooting was carried by digging out the soil-sucker composite by employing a labour using a sharp hatchets and spades the sword suckers should be dugout and separated from the mother plant. Uprooting takes lot of time and energy. In the University farms, one man labour uproots 15-20 clumps per day. At the present wage rate of Rs.600 per man, an amount of Rs.48000 per acre is required for uprooting of banana clumps after harvest. The presently available mechanical banana uprooting device faces problems of excess fuel consumption, more time taken to uproot, high percentage of damage to suckers etc., hence, a study was undertaken to modify the hydraulic operated banana sucker uprooting machine that was developed at KCAET, Tavanur. The machine was modified and field tested. The physical and mechanical properties of banana rhizomes namely, size, shape, and weight were found out using standard test procedures. Based on the effective root zone area and unit draft of the soil, the total draft force required to lift the clump was calculated. A john deer 5310 tractor 41.5 KW (55 hp) was used as a prime mover. The machine (attachment) consists of a gib crane fitted with bucket with tyne at its lower end.

The field performance of the machine was conducted for uprooting the banana soil-sucker in two types of soils, laterite soil at KCAET, Tavanur and clay soil at BRS Kannara. Trials were conducted to evaluate the performance of uprooter

with 3 and 4 number of rectangular and triangular shape tynes. The uprooting was carried out for each of the treatment combinations. Performance analysis of the modified banana sucker uprooting machine was compared with respect to time, depth of penetration, percentage of damage of suckers and weight of soil-sucker clump separately with rectangular and triangular 3 and 4 number of tynes. The observations were separately recorded for clay soil and laterite soil. It was found that irrespective of the soil type, triangular shape with 4 number of tynes recorded lesser time for uprooting, higher depth of penetration, and lower percentage of damage while uprooting.

Field efficiency of modified banana sucker uprooting was observed that the total time taken to uproot an area 0.0025 ha in clay soil was 1.8 h. The field efficiency obtained was 75%. The total time taken to uproot an area 0.0025 ha in laterite soil was 1.5 h and field efficiency is 80%.

Cost of uprooting by using uprooting machine is Rs. 22,930 ha^{-1}. The cost and time saved over manual uprooting was about 52.22% and 93.06%.