DESIGN AND DEVELOPEMNT OF A MULTIPURPOSE TOOL CARRIER FOR HOMESTEAD AGRICULTURE

By

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"DESIGN AND DEVELOPMENT OF A MULTIPURPOSE TOOL CARRIER FOR HOMESTEAD AGRICULTURE"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Place: Tavanur

Date: 07/08/2019

ARYA K.T.

(2017-18-006)

CERTIFICATE

Certified that this thesis entitled **"DESIGN AND DEVELOPMENT OF A MULTIPURPOSE TOOL CARRIER FOR HOMESTEAD AGRICULTURE"** is a bonafide record of research work done independently by Ms. Arya K.T. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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LIST OF SYMBOLS AND ABBREVATIONS

et al.	: And others
etc.	: Etcetera
db	:Dry basis
FAO	: Food and Agriculture Organization of the United Nations
GI	: Galvanized Iron
KAU	: Kerala Agricultural University
KCAET	: Kelappaji College of Agricultural Engineering and Technology
min	: Minute
MPTC	: Multipurpose tool carrier
MS	: Mild steel
n.d	: no date
No.	: Number
TNAU	: Tamil Nadu Agricultural University
wb	: Wet Basis

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Introduction

CHAPTER I

INTRODUCTION

Agricultural systems can be divided into industrialised agriculture and sustainable agriculture. Industrial agriculture mainly focuses on the production of crops which can be promoted for sale. In sustainable agriculture, practices are done to meet the desired needs of a small family often called homestead agriculture. The purpose of sustainable agriculture is to protect natural biodiversity, enhance crop production and increase the prosperity of a family through homestead agriculture.

Kerala, a tropical state in South India, is an example of a region with a dynamic history of land-use change that has not been particularly well-renowned. Agricultural practices in large fields were declining habitually due to the scarcity of land holdings and growing demand for houses in Kerala. Kerala has got high population density and the size of small farm holdings in Kerala ranges from 0.02 to 1 ha (Nair and Krishnankutty, 1984). All these necessitated cultivation in homesteads and a revival of homestead agriculture in Kerala. As the land scarcity is the major barrier for farmers, they are enforced to do cultivation in the available area. Homestead is defined as an operational farm unit in which a number of crops are grown with livestock, poultry or fish production mainly for the purpose of satisfying the farmer's basic needs (John, 2014).

Homestead agriculture can be regarded as cultivation around the immediate surroundings of a house and is considered as the oldest land-use activity which has evolved through generations. It is different from other commercial cultivation practices as it is mainly dependent on family labour, paying more attention to women in the family. Major crops grown in homesteads of Kerala are rice, coconut, banana, pepper, vegetables, nutmeg, areca, etc.

One of the most important causes for the decreased rate of productivity in small farms including homesteads is the lack of suitable machinery that caters to and suits the requirements of these small-scale farms. For this reason, many small farms are regarded as unproductive and ineffective. Since the common practice is mixed farming of the available area, the mechanisation issues in homestead agriculture are much more complicated compared to commercial agriculture. As conventional methods of farming depending largely on human labour are practiced in homesteads, the requirements of mechanisation are much diverse. Common operations in homestead agriculture are land preparation, sowing, planting, intercultural operations, plant protection, and harvesting.

As the crop diversity and cropping pattern in homesteads are diverse, it requires different types of hand tools which can be manually operated or powered. As animal power is no longer a power source in the homesteads of Kerala, powered tools are the need of the hour as manual operations involve hard physical labour and drudgery. Drudgery involved in farming operations is likely to decrease the efficiency of human power and that in turn affects productivity. This is one important reason which drives away the young generation from agriculture. Appropriate mechanisation is essential to sustain the interest of small farmers and to increase their productivity.

Mechanisation is the most important intervention required in the system to make homestead agriculture more attractive to the young generation. As the number of members in a family has come down, additional human labour is required for many operations. Shortages of labour and high labour wages are the factors which strongly propel mechanisation. At the same time, several factors such as the size of the farm holding, investing capacity of a farmer and the technical know-how of the people will restrict the adoption of mechanisation. Even though it is necessary to mechanise homestead agriculture there are limitations as the area is limited to a few acres of land, and the farmers are not wealthy enough to purchase costly machines.

Hence it is highly relevant to evolve a technically and economically feasible mechanisation strategy for homesteads.

The present scenario in homestead agriculture warrants an affordable and versatile power operated multipurpose tool carrier. The multipurpose tool carrier is a scientific term used to indicate a multipurpose tool frame that provides the link between the implement and the power source (Bansal and Thierstein, 1982). As a multipurpose unit, tool carriers are designed to be used with a number of implements. The unit is conceived to work in a way similar to a multipurpose tractor which facilitates quick changing of implements on the toolbar according to operational requirements. Knowledge about different operations involved and different tools used for the operations in the homesteads can facilitate the design and development of different tools.

Mechanisation of the homestead agriculture in Kerala is in its juvenile stage. Even though power tillers were expected to cater the needs of small scale and homestead farmers in Kerala seldom own power tillers. The main reason is that the farmers are not satisfied with the versatility and ease of operation, especially in undulating fields. Presently engine operated brush cutters are probably the widely used powered aid in homestead agriculture. Among them, backpack engine operated brush cutters are comparatively cheaper and much versatile. The development of a multipurpose tool carrier powered by the engine of such a brush cutter was expected to avoid the requirement of different implements and power sources for different operations and hence offered much utility and cost saving over traditional implements. Such a machine was envisaged as farmer friendly and women-friendly as it could easily be operated and handled. Hence the development of a multipurpose tool carrier for homestead agriculture, powered by a back-pack brush cutter engine was highly relevant in the present context. The specific objectives laid down for the present study were:

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1. To design and develop a multipurpose tool carrier with provision for different attachments

2. To develop matching attachments for the multipurpose tool carrier

3. To evaluate the performance of the developed multipurpose tool carrier system

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Sustainable production of commodities in the available area is currently a trend in agriculture. Enhancing production in small holder agriculture, especially in homesteads, warrants proper mechanical aids and implements. Multipurpose tool carriers cater this requirement and is regarded as a suitable option for reducing human drudgery for different farming situations. Review of the researches carried out on homestead agriculture and the efforts to develop multipurpose tool carriers by different workers are described in this chapter.

2.1 HOMESTEAD AGRICULTURE

Kerala can be introduced as the home for homestead farming where a farmer cultivates an array of crops including coconut in and around their home. The basic building blocks for farming systems are the farm-household system, characterized by a specific livelihood pattern allied with particular resources, crops, trees, livestock, fish and or off-farm activities which are frequently interdependent (John, 2014).

2.1.1 Characteristics of homestead agriculture

Fernandes and Nair (1986) conducted a study for evaluating the structure and function of tropical home gardens. They defined home garden as a land use system where multipurpose trees and shrubs are managed in intimate association with annual and perennial agricultural crops along with and livestock within the compounds of individual households. The average size of the home garden unit was less than 0.5 ha. According to them, some of the main characteristics which disallowed the improvement of home gardens were structural complexity, species diversity, multiple output nature and unevenness of farm land.

Thus, a homestead could be defined as an operational farm unit in which a number of field crops, as well as tree crops, were grown with livestock, poultry and fish production units primarily for the purpose of fulfilling the farmer's basic needs (Nair and Sreedharan, 1986).

Homestead cultivation is different from other commercial modes of cultivation as it concentrates only on the near surroundings of the home and produces all types of food items using mainly organic manures provided by livestock whose milk and meat provide rich nutritional security to the households. Commercial cultivation primarily focuses on market demand and is generally done on land away from their homes (Ali, 2005).

Tang (2011) conducted an investigation to study the structure, functions, and contribution of home gardens to rural household's income generation. The methodology adopted was Rapid Rural Appraisal (RRA) in which techniques such as personal observation, key informant interview and focus group discussion along with household questionnaire survey were used. In terms of inputs and outputs per unit area, it was found that there were higher input and output in smaller home gardens compared to larger ones. Homegardens in the study area had the potential to get better livelihoods notably if farmers took essential steps to make production further sustainable.

Another definition stated that, a functional and self-sustaining farm unit which consists of a conglomeration of crops and multipurpose trees, planted arbitrarily, with or without animals, poultry, apiculture, owned and primarily managed by the residence farm family, with the objectives of satisfying the basic family needs such as food, fuel, timber and producing marketable surplus for the purchase of non-producible items (John, 2014).

Fox *et al.* (2017) researched on the agricultural land use changes in Kerala and India using a combination of remote sensing, quantitative surveys and semi-structured interviews. They found that plantations were replacing home gardens, whose extent was unpredictable. The study revealed the general decline in the importance of home gardens. The decreased rate of production and diversity of crops for average Kerala households were evident. Average home garden size ranged from 0.19 ha in Thamarssery to 0.67 ha in Vengapally, with a mean across all panchayats of 0.34 ha. In general, home gardens were smaller in densely populated panchayats, which tend to be closer to the coast and larger in less populated areas, usually closer to the mountains. They had interviewed 115 farmers, out of this 52 % and 28% relied on farming as their primary and secondary sources of income, respectively, whereas 20% used their home gardens for only personal use.

2.1.2 Constraints of homestead agriculture and mechanisation

Peyre *et al.* (2006) reported that fifty percent of the home gardens still displayed traditional features whereas 33% incorporated modern practices. Home gardens were managed by a farming family and mostly all farming operations were done by the family members with or without seeking help from hired workers. In cultivating rice, generally women did transplanting, harvesting and winnowing operations. Men did the operations which required higher effort such as land preparation, transportation etc. For vegetable cultivation, men were seen handling the burdensome works like plowing, fertilizer and pesticides applications and marketing. Women perform weeding and harvesting. Majority of tree crops were harvested by men while post-harvest operations were done by women.

The extend of mechanisation in homesteads were nominal as evidenced by the studies conducted by Pandey *et al.* (2007). The tools used usually included a spade, pickaxe, axe and locally-made cutting blades.

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Priya (2011) conducted a study for finding the status of homestead based agro-biodiversity through surveying farmers. She reported that most important constraint faced by farmers in homestead based agro-biodiversity conservation was the unavailability of labour and high cost of labour.

Helen and Baby (2013) conducted analysis of sixty farmers from three agro-ecological situations of Palakkad district of Kerala for assessing the existing situation in coconut based homestead farming. They found that there existed a crisis in maintaining the age old traditional integrated farming system in coconut based homesteads. Farmers preferred to follow management practices in which the labour requirement was less in homestead cultivation.

Regina *et al.* (2013) determined constraints and determinants in the adoption of mechanisation in rice cultivation in Kerala. They collected data from rice farmers through focused group discussion and informal interviews. The questionnaire contained a list of 15 constraints divided into 3 categories viz. socio economical, technological and bio-physical. Farmers were asked to score them from 1-10 based on the importance of the constraints. They revealed the major constraint was the small holding size that prevents the farmer from individual possession of machines. Meanwhile, availability of machines in the *padasekharam* could manage the important constraint.

Lavanya (2014) conducted a study on the impact of mechanization of bengalgram cultivation in Prakasam district of Andra Pradesh. Based on farm size farmers were divided into three groups like small, medium and large farmers. A pretested schedule was used to collect the necessary information from the farmers through survey method. Major constraints found out were the lack of suitable harvester, small farms, poor farmers, high cost of machinery and delay in the supply of subsidized machinery.

Begum *et al.* (2015) conducted a baseline survey with a pre-structured questionnaire in terms of demographic, socioeconomic status, agricultural practices in and around their home and women participation in the farming activities in order to assess the importance of integrated farming.

Sharma *et al.* (2015) assessed the importance of improved farm tools in order to reduce the drudgery of women workers. They did a comparative study among traditional garden tools and improved farm tools by conducting trials with women worker. The results showed that the use of selected improved tools such as garden rack, circular blade weeder, and hand fork were economically viable and superior in terms of reducing drudgery over traditional old tools.

Andrews and Kennan (2016) in their study to estimate status and land usage under homestead cultivation in Kerala found that homestead farming was not done in an organised way due to the crisis of labour availability in farmland. The households preferred to grow a perennial crop which needed less care and labour.

Agricultural mechanization led to an increase in the productivity of farm labour due to higher cropping intensity and thus it increased the profitability. Additionally, mechanization provides timeliness of operation, a better quality of work and more efficient utilization of crop inputs (Verma, n.d).

Jaslam *et al.* (2017) studied land utilization and current status of homesteads in Kerala and found that farmers depending on farming alone were found in distress due to low and fluctuating income. It was found that selected homesteads were following coconut based cropping system along with tubers, commercial crops, spices and condiments, stimulants, fruits, vegetables, livestock and poultry. In the majority of homesteads, farm activities were carried out by family labour along with hired labour. Moreover, a significant contribution was observed from the part of women in the homesteads. It was concluded that increased population and low per capita availability of lands had necessitated better management practices in home gardens and the micro-development models make a way for success in homestead farming. Thus it was fairly evident that use of appropriate mechanical aids has a big role in sustaining the homestead cultivation in Kerala.

2.2 MULTIPURPOSE TOOL CARRIER SYSTEMS

An animal-drawn multipurpose tool carrier is a multi-purpose frame that provided the link between the implement and the power source. It had been in being for at least 25 years. Tool carriers were designed to provide the advantages of improved implements which could be used along with animal-power-or mechanical power source in different farming systems. They were operating like tractors whose implements can be changed easily to suit the operational requirements. Timeliness, quality of operations and efficiency in the utilization of animal power were the factors that made wheeled tool carriers economically and technically viable in agricultural farming (Bansal and Thierstein, 1982).

Chauhan (2006) ergonomically designed and developed a multipurpose hand tool carrier along with attachments like seed-cum fertilizer drill, cycle wheel hand hoe and rolling-type crust breaker for farmers belonging to small and marginal land holding categories. When tested for performing different operations such as sowing, crust breaking, hoeing and weeding, it was revealed that cycle wheel hoe had improved performance with higher range of weeding efficiency compared to manual weeding.

In order to utilize draught animal power efficiently and to increase the working efficiency, an animal-drawn pneumatic wheeled multipurpose tool (MPT) frame was developed by Tiwari *et al.* (2009). The tool frame consisted of a rectangular shaped frame, pneumatic wheels with screw jacks, an operator's seat, handle and beam. Different implements could be attached with the tool frame with the help of quick fixing type U clamps. Developed MPT frame could be used for the operations such as tillage, seeding, fertilisation and weeding in a timely and precise manner. Moreover, it could be further used as a cart to provide transportation. When the performance of MPT frame was compared with traditional practices, it was found that the draft requirement of MPT was within the draft capacity of animals. It was also seen that an increase in the command area was observed in tillage and sowing operation by MPT frame over the traditional implement system.

Chadegara (2009) developed a multipurpose bullock drawn implement for sandy loam soil. It was indented to be used as a cultivator, seed drill, inter-culturing unit, and a groundnut digger. Performance of the multipurpose implement was evaluated for ploughing, sowing, bed shaping, inter-row cultivation and groundnut digging on the basis of draft requirement, actual field capacity, field efficiency and travel speed of the bullock. From the economic analysis, it was revealed that the multipurpose bullock drawn implement provided an effective low-cost alternative machinery system, especially when high initial investment in machinery like tractor was a major constraint in the adoption of the improved mechanisation technologies.

Munde *et al.* (2009) tested an animal-drawn groundnut digger developed in Marathwada Agricultural University as a matching tool to a multipurpose tool carrier. Test results were then compared with groundnut digger developed by CIAE Bhopal and local designes. Performance of developed digger was found to be better than the other two diggers.

Veerangouda *et al.* (2011) developed and evaluated a multipurpose tool carrier operated with power tiller for different operations like tilling and harrowing. It is found that the multipurpose tool carrier helped in reducing drudgery in the field and also carried out the operations timely. The tool carrier was operated at an average working speed of 2.0 km per hour for tilling operation and 2.2 km per hour for harrowing with the average depths of operation of 5.15 cm and 4.0 cm for tilling and harrowing respectively. The average drafts were found to be 70.0 kg and 60.0 kg with filed efficiencies 66.66% and 69.88% for tilling and harrowing respectively. The cost of operation was observed to be Rs.201.20 per hectare for harrowing operation.

Kumar and Verma (2012) evaluated the performance of an animal-drawn multipurpose tool carrier for tillage and biasi operations. Ploughing and other intercultural operations were done with the developed MPT in wet soil condition as well as in sandy loam soil. The field test for finding its power utilization, speed of operation and field capacity while doing both ploughing and biasi operations revealed that the average field capacity found in the primary tillage operation and biasi operation as 0.0985 and 0.112 ha h^{-1}.

Gautam *et al.* (2013) developed an animal-drawn multipurpose tool carrier (MPTC) suitable for non-descript breed of bullocks. MPTC was developed to prepare seedbeds in dry as well as wet soil conditions and to perform various other agricultural operations. The machine consisted of a tool frame, tynes, furrow openers, hitching system and a depth control system. Design of different components of the machine was done keeping in view of the draft capacity of local bullocks. Provision for adjusting row to row distance according to crops requirements in different operations was provided. Performance of the multipurpose tool carrier was evaluated for secondary tillage, sowing, and weeding operation. Observation of pull, operating time and turning time in each bed were recorded for all operations. The field performance of multipurpose tool carrier was compared on the basis of draft requirement, actual field capacity, field efficiency and travel speed of the bullock. It was observed that the use of MPTC was much economical than the traditional implements. The fabrication cost of MPTC with attachments such as cultivator with shovel and seed -drill was about Rs.7800.00.

Achuta *et al.* (2016) worked on three different concepts for developing multipurpose agricultural equipment. Out of which the first concept was included a cubic shaped frame in which sprayer, sowing tool, fertilizer pipes and an inter cultivator were assembled in a bulky manner. Second concept was dealt with a single frame in which all the implements could attach. As the third concept, he proposed that means of a single frame and single attachment to bicycle results in a reduction in space, cost and also helps in local transportation. By comparing all the concepts it revealed that the third concept was economically feasible to undertaken different operations.

Takur (2016) developed a low-cost multipurpose tool carrier as an attachment to power tiller along with matching tools like M.B. plough, shovel, sweep and horizontal blade was fabricated and tested in the field. The developed carrier along with its attachments was evaluated for field efficiency, unit draft, power requirement, energy requirement, performance index, fuel consumption, field capacity, soil pulverization and cone index at different moisture content. The speed of operation was kept uniform and additional weights were added according to the desired depth of operation. The difficulty in operation due to clogging was solved by using zigzag tynes. From the field evaluation, it was found that M.B. plough was suitable as a primary tillage tool while shovel was found to be an effective soil cutting tool for secondary tillage operation. The horizontal blade could be used effectively for leveling. It was reported that tool carrier was found to be suitable for year-round use as different tools could be attached with only a slight effort.

Ramya *et al.* (2016) tested animal-drawn multipurpose tool carriers for tillage implements to determine the energy expenditure of the operation. They compared two models of multipurpose tool carrier developed by ICRISAT, Hyderabad and MPUAT Udaipur. It was shown that all models needed 1.5 h work-rest schedule for tillage operation. ICRISAT model had the highest performance and least energy expenditure.

Annasaheb (2017) concluded that the developed animal-drawn multipurpose tool carrier could be used as planter, sprayer and inter cultivator. The result showed that implement performed better in the field especially for sowing with a seed covering device and spraying with a theoretical field capacity of 0.189 ha hr^{-1} and field efficiency of 88% respectively.

Kiran *et al.* (2017) developed multipurpose equipment in order to utilize it for different operations such as tilling, fertilizer application, sowing and weed removal operations. It was revealed that according to operational requirement, different tools could be easily rearranged since they were attached to the equipment with the help of fasteners.

Singh (2017) developed a multipurpose tool frame powered by tractor for different attachments needed in sugarcane cultivation. Furrow opening, herbicide spraying, earthing up and intercultural operations were mainly focused. From the performance evaluation, the use of multipurpose tool frame in intercultural operation and fertilizer spraying was found to be more economical compared to manual weeding and spraying.

Mandloi *et al.* (2017) developed a multipurpose toolbar which was drawn by a mini tractor of 15 hp. It was tested in the field with different tool combinations viz. combination of iron plough and clod crusher as well as clod crusher and planker. From the performance evaluation, it was found that developed multi toolbar with clod crusher for breaking clods was suitable for seedbed preparation in a single pass with a saving of about 20% in cost of operation as compared to cultivator.

Kamaraj *et al.* (2017) reporteded that basic concepts of selection of different attachments as well as their adjustments such as depth, width and spacing adjustments were easily possible when they were mounted on a basic frame. Tools could be separated from the system to make transportation easily.

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2.3 SMALL ENGINE OPERATED WEEDERS

At the lower end farmers with very small land holding use manual weeding methods. Power weeders are self-propelled walking type machines used for weeding agricultural fields. A petrol engine or diesel engine powered weeding machines make use of weeding blades. The major role of weeding blades is to cut or uproot the weeds and to bury both the weeds and soil during operations. These machines consist of a reduction gearbox, clutch and power transmission system for their smooth operation.

Rangasamy *et al.* (1993) developed and evaluated the performance of a power weeder and compared it with the conventional method of manual weeding with a hoe and manually operated dry land weeder. The field capacity of weeder was 0.04ha h^{-1} with a weeding efficiency of 93% and a performance index of 453. The cost of operation per hectare with the power weeder amounted to be Rs.250/- as against Rs.490/- by dry land weeder and Rs.720/- by manual weeding with a hoe. Saving in time was 93% while saving on cost was 65%.

Pitoyo *et al.* (2000) developed a power weeder for mechanical control of weeds in the rice field. The machine was driven by a two-stroke engine of 2 hp (6500 rpm) with a performance of 15 h ha^{-1} capacity at traveling speed 1.8 km h^{-1}. The mass of the machine was 24.5 kg.

Pannu *et al.* (2002) evaluated a self-propelled, diesel engine operated power weeder of 3.8 hp (2600 rpm). This weeder was found to be suitable for weeding in wider row crops like maize, cotton, sugarcane, etc. The moisture content of the soil at the time of evaluation was 17-18%, the depth of operation ranged from 4-7 cm and the weeding efficiency was obtained as 88%.

Victor *et al.* (2003) designed, developed and fabricated a rotary power weeder for wetland paddy with the help of 0.5 hp petrol engine. Belt and pulley as well as chain and sprocket were used for power transmission from engine to traction wheel

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and the rotary unit which is equipped with four L-shaped standard blades for cutting. Two big traction wheels were used for the smooth operation and a gauge wheel was provided for depth adjustment. The field capacity of the machine varied between 0.04-0.06 ha h^{-1} with a field efficiency of 71% and weeding efficiency of 90.5%.

Olukunle and Oguntunde (2006) designed and fabricated a row crop weeder and it was tested in different types of grass fields. The design was based on the principle of weed stem failure due to shear and soil-root failure due to impact and abrasion. It was found that it could be used as a weeder as well as mower for a variety of grasses. It worked as mower when the cutting height was between 2 cm and 4 cm and worked as a weeder at cutting heights between 2 cm and 1 cm above the ground level. The force required to uproot some weeds were determined by pulling a thread attached to the weed through a spring balance and recording the force at the point of weed removal. The weeding efficiency of 94.80% to 97.5% was observed at forward speeds of 0.25 to 0.5 m s^{-1}. The field capacity of 0.0504 ha $h^{-1}$was observed at a higher speed of 0.5m s^{-1}.

Manuwa *et al.* (2009) designed and developed a power weeder with a working width of 0.24m for weeding in row crop. Effective field capacity, fuel consumption and field efficiency of the machine were 0.53 ha h^{-1}, 0.7 l h^{-1}, and 95%, respectively.

Hoque *et al.* (2010) also designed and evaluated a power weeder for row crop which was fabricated with locally available materials and spare parts. An additional gearbox was fitted in order to get backward and forward motion of the weeder and a dog clutch aided easy turning. From the evaluation, it was found that power weeder saved 90% of weeding cost and labour requirement in comparison to manual weeding.

Olaoye and Adekanye (2011) stated that the motion of the weeding disc at any point on the surface of a rotary tiller travels through a trochoidal or cycloidal path depending on the distance of the point from the rotor axis (radius). During operation, the motion of the rotor of a rotary tiller was generated by a combination of the machine's forward motion, the rotors rotational motion of the tines on the disc and the distance of rotational axis to the point of interest (rotor radius).

Olaoye *et al.* (2012) developed and evaluated a rotary power weeder to reduce the drudgery and ensure a comfortable posture of the operator with the components such as frame, rotary hoe (disc), tines, power unit and transmission units. The results of field performance evaluation showed that field capacity and weeding efficiency of the rotary power weeder were 0.0712 ha h^{-1} and 73% respectively.

Hegazy *et al.* (2014) developed an economical mechanical power weeder that could be used as inter and intra-row weeding and it was evaluated in triple hybrid 314 variety of maize. Power weeder consisted of an engine, blade assembly and transmission system. Modified vertical blades were mounted on a circular rotating element which got their drive from the transmission system. Depth of operation, the effect of forward speed, moisture content of the soil, weeding index, plant damage, effective field capacity and field efficiency were taken into consideration for testing. The three levels of moisture contents chosen were 7.73, 12.28 and 16.18% and the depth of operation were in the ranges of 0 to 20 mm and 20 to 40 mm. The forward speeds were 1.8, 2.1 and 2.4 km h^{-1}respectively. The minimum value of fuel consumption was 0.546 l h^{-1} and the field efficiency was 89.88%.

Kamal and Oladipo (2014) developed a manually operated ridge profile rotary weeder with two rotary hoes each weeding one-half of adjacent ridges. The inclination of the rotary hoes to the ridge profile was adjustable according to the angle of repose of the ridge. The weeder was designed for a row spacing of 750 – 900 mm and was not limited by crop height. Preliminary tests carried out showed that the weeder was effective for control of young weeds.

Manjunatha *et al.* (2014) reported that the developed a low cost sprocket weeder using inexpensive bicycle parts which could be operated by farmers or unskilled laborers. The weeding efficiency of the sprocket weeder was found to be 94.5% which could work up to 4 cm depth. No plant damage occurred during weeding operation and the field capacity was found to be 0.032 ha h^{-1}.

As mechanical weed control on ridges was very difficult. Sabaji *et al.* (2014) developed and evaluated a power weeder for potato crops grown in ridges. The main components of weeder were cutting blades and rotor shaft. Three types of blades like C-type, L-type and F-types blades were used and C-type blades were found to be more suitable at a gang speed of 200 rpm at 15.26% soil moisture content. The weeding efficiency, plant damage and field capacity were 91.37%, 2.66%, and 0.086 ha h^{-1}, respectively. As compared to manual weeding, ridge profile power weeder showed 92.97% saving in time of weeding.

Kumar *et al.* (2017) developed and evaluated a power weeder for wet and dry land. Field capacity, plant damage, weeding efficiency and fuel consumption were evaluated. The field performance analysis revealed that weeding efficiencies to be 76.40% and 69.65% with plant damage of 11.10 and 8.34% in dry and wetlands. It was also found that power weeder had the higher values of field capacity, Plant damage and weeding efficiency in the dry land compared to wetland.

Sahu and Goel (2017) developed a power weeder for dry sawn and wet sown paddy powered by petrol engine of 1.33 kW with a speed reduction of 34:1. It was tested in the field by changing its blades such as C-type blades, L-type blades and hatched blades. The highest weeding efficiency was obtained with hatched type blade in wet land and in dry land.

Chakravarthy *et al.* (2018) developed a knapsack sprayer engine operated paddy weeder which consisted of a 0.81 kW petrol engine and a float system. Power

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transmission from engine to weeder blades were provided through a flexible shaft. Weeder blades were rotated at 200 rpm. The cutting blades moved with a forward speed of 2.48 km h^{-1} and provided a depth of operation ranging from 3 to 4.5 cm. Weeding efficiency of the developed weeder was found to be 80.8% with a fuel consumption of 0.55 *l* h^{-1}.

To overcome these problems of crops with closely spaced rows a portable knapsack power weeder powered with a two-stroke 1.25 kW petrol engine was developed with a width of cut of 25 cm. The main working components of power weeder were flexible drive shaft, worm gearbox, rotor shaft, flanges and blades. The " L" type blade was selected with length, width and thickness of 130 mm, 30 mm and 5 mm, respectively. The developed weeder worked up to 5 cm depth with a field capacity of 0.025 ha h^{-1}. Higher weeding efficiency up to 89.30% was obtained. The plant damage was 2.4% and the fuel consumption was observed to be 0.76 *l* h^{-1} (Devojee *et al.*, 2018).

Kumar *et al.* (2018) conducted a study to evaluate the performance of power weeder, wheel hoe and star weeder. Three weeders were initially evaluated in the dry land planted with maize. Actual field capacities of power weeder, wheel hoe and star weeder were 0.0494 ha h^{-1}, 0.022 ha h^{-1}, 0.021 ha h^{-1} respectively. Performance parameters such as field efficiency, weeding efficiency and field capacity were found to be more for power weeder than wheel hoe and star weeder.

Rakesh *et al.* (2018) modified a power weeder for paddy and tested in the field after 20 and 45 days of sowing to compare the performance with the traditional manual weeding and manual operated Ambika weeder. It was found that the modified weeder was more appropriate than Ambika weeder since it had weeding efficiency of 74.22% and 86% at 20 and 45 DAS and less cost of operation per ha of Rs.928/- than Ambika weeder.

Sirmour and Verma (2018) designed a power weeder for rice, which could be operated in a single row. From the design point of view, power source, cutting blades and shaft were the significant components of single row power weeder. The average working speed of operation was found as 2.45 km hr^{-1}. The average fuel consumption of power weeder was found as 0.55 *l* hr^{-1} and the maximum field capacity was found as 0.054 ha hr^{-1}. The working width of the developed machine was adjustable between 140 mm to 250 mm. The weeding efficiency was observed as 88.62%.

2.4 ROTARY TILLAGE OPERATIONS USING LOW POWER ENGINE

Kushwaha (2002) developed a weeder and it was used as a secondary tillage tool. Maximum depth of operation was found to be 7-8 cm. Power weeder was field operated as secondary tillage implement in soil having a dry bulk density of 1.31 g cm^{-2}. Field capacity and theoretical field capacity for this operation were found to be 0.21 and 0.27 ha h^{-1} and field performance index was calculated to be 77.78%.

Sakamoto (2007) reported the development of an electric powered tiller for house gardening. Tiller was composed of a driving shaft which is being powered by a 125 W DC motor. Motor drives the wheel in different rotations. The rotor of the tiller rotating at 200-400 rpm was connected to a 400W DC motor.

Sahay *et al.* (2009) conducted a comparative study on non-oscillating and oscillating tillage implement powered by power tiller. The oscillatory tillage implements having 25 cm tool width and non-oscillatory implement was used for tillage in dry land field conditions. Ploughing depth of 15.3 cm was achieved using prototype oscillatory tillage implement while only 7.4 cm depth of operation was achieved in the non-oscillatory mode of operation. The volume of soil handled per unit time, fuel consumption and tillage performance index were higher with oscillatory tillage implement compared to non-oscillating implement.

Mandloi *et al.* (2011) fabricated a low-cost shrub cutting machine with an engine of power 1.1 kW in which a rotary saw type blade was used to cut the shrubs. Through transmission mechanism, horizontal rotation of engine output shaft was converted into vertical rotation by bevel geared transmission case.

Shinde *et al.* (2011) stated that tillage tool with different geometry designed to perform a particular tillage operation by rotary or sweep action would have more influence on the soil physical properties such as soil structure, texture, moisture, resistance and cone index.

Naque *et al.* (2013) developed a power-operated tiller cum weeder powered by a 1.5 hp four stroke petrol starts kerosene run engine. It was mainly composed of cutting blades made of EN-8 material, body frame, gear assembly and ground wheel for guiding the direction of the machine according to operator and field condition.

Mandal *et al.* (2014) found that cone index of a soil engaging tool will increase with an increase of penetration forces and soil had its own optimized moisture content at which the strength will be very less.

Takur *et al.* (2018) reported that the power requirement for operating tillage tools was directly proportional to the depth as well as moisture content of the soil.

2.5 BRUSH CUTTER AND ITS DIFFERENT ATTACHMENTS

Langton *et al.* (2006) studied the design of a brush cutter blade and its integration into a semi-mechanized harvesting system. The aims for the project were, to design a blade that could be attached to a brush cutter to cut sugarcane and, to integrate the brush cutter into an economically and ergonomically sound sugarcane harvesting system. The developed harvester called the Illovo sugarcane harvester was accessed for performance, efficiency, economics and blade durability. Results showed that there was less stress and strain on the operator's back when using this system compared to manual harvesting.

Bora and Hansen (2007) modified a brush cutter into a rice harvester. Original cutter blade was replaced by a 25 cm diameter circular saw blade provided with a metal plate and rubber guard in order to guide the stalk to the left side. The overall weight of the machine was found to be 9.2 kg which could be easily bought by the farmers.

Handaka and Pitoyo (2011) modified a grass cutter into a small rice harvester. They replaced the cutter blade with a rotary blade and changed in to a harvester. It required 18-20 hours for operating one ha.

Bikash *et al.* (2016) conducted a performance evaluation of brush cutter attached crop harvester. It consisted of a circular saw blade and windrowing system. The study revealed that the capacity of crop cutter was 2.23 times higher than manual harvesting for wheat and 2.44 times higher for rice depending on the operator's skill, variety and harvesting condition.

Prasad *et al.* (2016) developed a pineapple harvester as an attachment for a backpack brush cutter. The prototype was tested and it was reported that the fuel consumption per ha is 70 *l*.

Bagesar *et al.* (2018) conducted a study to modify a crop cutter operated by an AC motor of power 1 hp. It was reported that crop cutter could be used for harvesting fodder crops without effort and efficiently.

2.6 AUGER FOR DIGGING PITS

As per reported by Preman (1996), Kathirvel *et al.* (1990) developed an auger digger as an attachment to power tiller of 8-10 hp. It consisted of a spiral auger operated by rack and pinion arrangement to move the auger up and down with the help of a hand wheel. It was found that the auger could dig 30-45 pits of size 22.5 cm in diameter and 45 cm depth in one hour.

As reported by Preman (1996), a power-operated portable tree hole digger developed by Kumar *et al.* (1990) had an engine 1.7 hp with speed reduction unit, frame, auger bits and a bevel gearbox assembly as its main components. The tests revealed that the digger could make a pit of 15 cm diameter and 25 cm depth.

Roberts (n.d.) studied the design considerations of screw conveyors and stated that the screw must be immersed into the feed material at least to the level of the lower end of the casing since it is being closed, otherwise the conveyor will not elevate the bulk material. It was found that screw conveyors of large diameter attain their maximum output at lower speeds than conveyors of smaller diameter. In the case of the horizontal conveyor, the helix angle of the path was independent of the screw speed. The helix angle was given by:

$$\alpha_e = \tan^{-1}\left[\left(\frac{p}{\pi D}\right)\left(\frac{\mathrm{Ro}}{\mathrm{Re}}\right)\right] \;\ldots\ldots\ldots\ldots(1)$$

Where p = pitch D = 2 Ro = screw flight diameter, Ro = outside radius of screw flight, R_i = inner radius of shaft and R_e was given as:

$$\mathrm{Re} = 2/3\;[(R^3_o - R^3_i)/\,(R^2_o - R^2_i)]\ldots\ldots\ldots\ldots\ldots(2)$$

Zareiforoush (2010) described the volumetric efficiency of horizontal screw conveyor such that:

$$\eta_v = \frac{Qa}{Qt}\ldots\ldots\ldots\ldots\ldots(3)$$

Where Q_a was the actual volumetric capacity and Q_t is the theoretical volumetric capacity given by:

$$Q_t = \pi/4(d_{sf}^2 - d_{ss}^2)\, l_p\, n \ldots\ldots\ldots\ldots(4)$$

Where d_{sf} was screw flight diameter, d_{ss} was screw shaft diameter, l_p the pitch length and n was the rotational speed.

Longchen *et al.* (2014) conducted a study on auger drilling technology and the results indicated that the bit inner diameter was determined by target sampling mass and the density of drilling objects. Outer diameters of the bit and the helical blades were determined by the required power and torque for auger driller's restart from its state buried. Moreover, bit height is the only parameter which affected the core recovery than drilling procedure.

Rajkumar *et al.* (2014) developed a post hole digger machine attached to the PTO output of 4 w Kamco tractor in order to make pits for planting coconut trees, rubber plant, sugar cane, etc. Blade length and diameter were 1300 mm and 250 mm respectively.

Wangyuan *et al.* (2016) reported that a positive correlation could be generated among the power consumption and feed rate with respect to digging depth. As the digging depth increased there was a decrease in power consumption and at 200 mm depth power consumption was maximum.

2.7 USE OF GARRETT'S RANKING TECHNIQUE TO PRIORITIES CONSTRAINTS

Sedaghat (2011) used Garrett's ranking method to find the constraints in production and marketing of pistachio. The major aim of the study was to suggest the best way to reduce the constrains and thus help the farmers.

Christy (2014) analysed the major constraints to control clinical bovine mastitis problems in dairy farms through Garrett's Ranking method. High treatment costs, shortage of labour and difficulty in diagnosis were the top three constraints ranked by the farmers in the study area.

Zalkuwi *et al.* (2015) used the Garrett's ranking method to analyse the factors affecting the sorghum cultivation in India and Nigeria. The major advantage of this Garrett's ranking method was of the constraints based on their importance from the respondent's point of view. The study concluded that inadequate agriculture credit, extension support and research, high input cost, shortage of input and variation in rainfall availability were the major constraints faced by the sorghum farmers in India.

Balaganesh (2016) adopted Garrett's ranking techniques for identifying the major constraints faced by the farmers in adoption of precision farming in banana. The results showed that the inadequate resource and technical expertise were the major constraints in the adoption of precision farming. High input cost, high installation cost of drip and fertigation system and the instability in price were also the major economic issues faced by the banana farmers.

Dhanavandan (2016) applied Garrett's ranking technique to find the user preferences of using e-sources among the faculties of higher educational institution in Dindigul district of Tamilnadu. From the Garrett's scores it was found that E-journel were most preferred followed by E- thesis and dissertation.

Nirmala *et al.* (2016) employed Garret's ranking method to measure gap in rice yield on small farms and to find out factors contributing the gap. The results revealed that, shortage of labour, lack of remunerative cost, pest infestation, diseases, and unavailability of fertilisers were the major constraints in the field.

Kumar *et al.* (2017) employed Garrett's ranking technique in order to identify the constraints in indigenious dairy farming. The study revealed that lack of knowledge about improved dairy farming was ranked as a major constraint by majority of respondents. Low milk productivity was ranked as second constraint.

Materials and Methods

CHAPTER III
MATERIALS AND METHODS

This investigation was aimed at developing a multipurpose tool carrier for mechanisation of homestead agriculture. An attempt was conducted to develop diverse tools compatible with the intended multipurpose tool carrier for various identified operations. Developed tools were tested to assess their performance. This chapter deals with the methodology adopted for the above investigations.

3.1 GENERAL SURVEY OF HOMESTEADS

For the design of a multipurpose tool carrier with compatible tools for homestead agriculture, it was important to conduct a survey among the homestead farmers with landholding ranging from 0.02 ha to 1 ha in order to identify the constraints faced in the adoption of mechanisation. A basic survey form (Appendix A) for collection of details on their farming practices, crop characteristics and extent of mechanisation presently adopted was prepared. For the purpose, three districts in central zone viz. Malappuram, Thrissur and Palakkad were selected. From each districts, 3 sets of farmers having small, medium and large homesteads were surveyed.

In order to identify the significant factors which prevent farmers from adopting mechanical technology for homestead cultivation, Garrett's ranking technique (Dhanavandan, 2016) was adopted to analyse the data collected in the survey.

3.1.1 Determination of constraints by Garrett's ranking method

The general constraints faced by farmers in the adoption of mechanisation in homesteads were identified by the interviews conducted along with the survey.

Garrett's ranking method was then used to evaluate them and farmers were asked to assign the rank for each factor/constraint. The outcome of the ranking was then converted in to score values with the formula (5).

$$\text{Per cent position} = 100 \times \frac{\text{Rij - 0.5}}{\text{Nj}} \qquad ....(5)$$

Where,

R_{ij}: Rank given for the i^{th} factor by the j^{th} operator

N_j: Number of factors ranked by the j^{th} operator

The scores corresponding to the estimated per cent position was found out from Garrett's table. The scores of each individual factor were added up to get the total values of scores from which the mean value of the scores was calculated. The factor having the highest mean value was considered to be the most important factor/constraint.

The given ranks were then converted into percentages using the above method (Appendix B).

3.2 SOIL PHYSICAL PROPERTIES AND CROP CHARACTERISTICS

The methodologies for determination of different soil physical properties and crop characteristics to be considered for the development of the multipurpose tool carrier for homestead agriculture are discussed in this section.

3.2.1 Soil properties

Multipurpose tool carrier with different attachments was field tested after the fabrication. The relevant soil properties which are expected to influence the

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performance of the machine were identified to be moisture content, bulk density and cone index.

3.2.1.1 Moisture content

The moisture content of the soil on dry basis was determined using the oven drying method. Soil samples were collected from each test field in a weighed sample box and kept in the oven at 105^0C for 24 hours. The initial and final weights of the samples were measured using an electronic weighing balance having a sensitivity of 0.01g.

$$\text{Moisture content (db)} = \frac{[M_1 - M_2]}{M_2} \quad \ldots\ldots(6)$$

Where,

M_1 = Initial weight of the soil, g
M_2 = Final weight of the dried soil, g

3.2.1.2 Dry bulk density

Bulk density is defined as the mass of the soil per unit volume. It was estimated by the core cutter method shown in Fig. 3.1. The core sampler consisted of a hollow cylinder of 10 cm in diameter and 13 cm in height with a total volume of 1021.012 cm^3. A 2.5 cm dolly was driven in the cleaned surface of the soil before and after the operation with the help of a rammer. Then the cutter was dug out from the ground and then the soil core was kept in the oven for 24 hours after trimming the excess soil from the cutter. The dried soil was weighed to calculate the bulk density by dividing the mass with its volume.

Figure 3.1 Measurement of bulk density by core cutter method

3.2.1.3 Cone index

Cone index is an indication of soil strength and expressed as force per square centimeter required for a cone of the standard base area to penetrate into the soil in different depths. A cone penetrometer shown in Fig. 3.2 was used to measure cone index. It consisted of a dial gauge and a cone at the bottom with a cone angle 30^0 and base area of 6.45 cm^2. As the cone was pushed into the soil the force required for the penetration of the cone into the soil was indicated on the dial gauge.

$$\text{Cone index} = \frac{F+W}{A} \qquad \text{......(7)}$$

Where,

F = Applied force, kg_f

W = Weight of the cone penetrometer, kg_f

A = Base area of the cone, cm^2

Figure 3.2 Measurement of Cone index

3.2.2 Crop characteristics

Crop characters which are likely to influence the working of the machine were considered in the design of the tool carrier.

3.2.2.1 Crop spacing

Crop spacing was identified as an important factor that influences the total width of the multipurpose tool carrier. It was measured using a standard measuring tape.

3.2.2.2 Crop height

Crop height was the limiting factor in the development of tools for intercultivation, as the ground clearance of the machine should be compatible with the crop height. It was measured prior to weeding operations using a standard metric scale shown in Fig. 3.3.

Figure 3.3 Measurement of crop height

3.3 DESIGN OF MULTIPURPOSE TOOL CARRIER FRAME (MPTC)

The multipurpose tool carrier is a technical term used to indicate a multipurpose tool frame that provides the link between different implements and a power source (Bansal and Thierstein, 1982). A basic frame along with a power source which could be fitted with different tools as per the requirement was the envisaged system.

3.3.1 Design consideration for the multipurpose tool carrier

i. The total power requirement for different attachments of the multipurpose tool carrier should not exceed the power availability of a 1.5 kW (2 hp) back pack brush cutter engine.
ii. Functional requirements of the multipurpose tool carrier should match with the available torque and available rpm.
iii. The multipurpose tool carrier should match with the required farm operations envisaged in homestead agriculture.
iv. Selection of material for the fabrication should be based on market availability.

v. The tool carrier should be simple in construction which could be manufactured at low cost.
vi. Handle height and hand grip of the machine should be acceptable with respect to the recommended ergonomic standards.
vii. Easy adjustability of the tool carrier for different tools needed for different operations should be ensured.
viii. Safety and operator's comfort should be an important consideration.
ix. Affordability of the machine by homestead farmers.

3.3.2 Prime mover

The multipurpose tool carrier was expected to be an affordable mechanical aid for homestead agriculture. In this case, the prime mover selected should be economical and should be affordable to the farmers. Hence it was decided to select a low cost back pack brush cutter as the basic unit (Fig. 3.5). The back pack brush cutter engine shown in Fig.3.4 was selected as the prime mover for the multipurpose tool carrier. The details of the selected brush cutter are given in Table 3.1.

Figure 3.4 Engine of back pack type brush cutter

Figure 3.5 Back pack type brush cutter

Table 3.1 Details of brush cutter engine

Model	CG437(A)
Engine	Single cylinder two-stroke petrol engine
Displacement	31 cc
Engine Power	1.5 kW
Speed	9340 rpm
Weight	4.70 kg

3.3.3 Development of tool carrier frame

Multipurpose tool carrier frame with provision to attach the brush cutter engine required an additional gear reduction unit and supporting frame with handle. Then tool was conceptually designed (Figure 3.6) with a provision to attach required tools according to the purpose. A rigid shaft was selected to transmit power from engine to gear reduction unit.

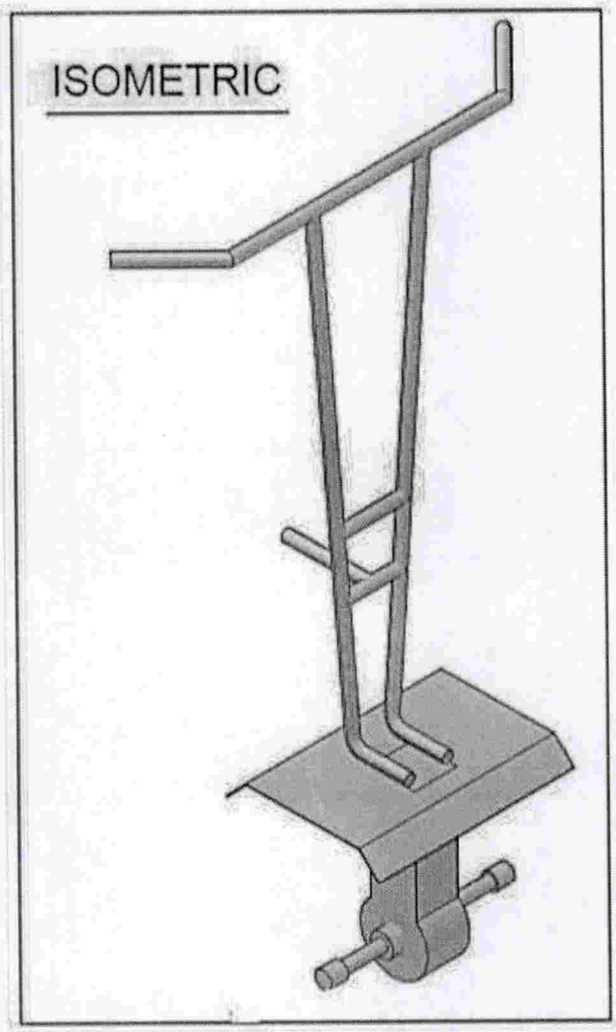

Figure 3.6 Conceptual design of the multipurpose tool frame

3.3.3.1 Selection of power transmission system

Brush cutter engine rpm was in the range of 9000 rpm which is too high for operation of any soil working attachment. As this high rpm was not compatible with the required operations, a gear reduction unit was selected which could convert the high engine rpm in to the required range. A suitable transmission shaft was designed for the purpose of power transmission from engine to gear reduction unit.

3.3.3. 2 Selection of configuration for supporting frame with handle

A suitable configuration of supporting frames with a handle in order to attach the prime mover and different tools were designed. Handle length and grip dimensions were designed in consideration of operator's comfort.

3.4 DEVELOPMENT OF DIFFERENT ATTACHMENTS

The different operations considered necessary in the homestead agriculture were identified through survey. Based on the survey and according to the power availability with multipurpose tool carrier, different attachments that would be compatible to the MPTC were identified.

3.4.1 Development of vegetable weeding attachment to the multipurpose tool carrier

A suitable weeding attachment for weeding of vegetable garden was identified according to the soil condition and depth of operation required.

3.4.1.1 Weeding rotor

Based on the power availability, crop height at the time of weeding and relevant soil physical properties a rotor configuration was selected.

3.4.1.2 Transportation wheel

In order to transport the MPTC with different attachments into the field, a transport wheel was required to be fabricated and fitted.

3.4.2 Development of paddy weeding attachment to the multipurpose tool carrier

The conceptual design of attachment for paddy weeding was based on the Japanese type power weeder. The design consisted of two weeding rotors, power transmission shafts, guards and a float.

3.4.2.1 Weeding rotor

A finger type rotor configuration was selected so as to enable wetland paddy weeding. For the selection of dimensions of the rotor for weeding operation, the diameter of the rotor and the number of blades required were adopted from Japanese design power paddy weeder, which was already reported successful (AICRP on FIM, 2017). This configuration was further analysed for its compatibility with the tool carrier system with respect to the engine power and crop height during weeding.

3.4.2.2 Power transmission shaft

Two hollow shafts were designed for extending the shaft from the gear reduction unit to both sides for the attachment of rotors.

3.4.2.3 Guards

Suitable guards were required to protect the crop plants and were designed and fabricated for the paddy weeding attachment. Operator's safety was also another concern in the design. The material of construction selected was plastic as the weight should be in the permissible ranges. PVC sheets with sufficient strength and GI pipe were selected for fabrication of the frame for supporting the guards. A skid was also required to be attached centrally so that the weeder is supported in the inner space between the two middle rows of paddy. A short handle was also required to be provided at the front for easy handling.

3.4.3 Development of surface pulveriser cum two-row vegetable weeding attachment to the multipurpose tool carrier

In row crop vegetable fields weeding operation was considered to be a problematic operation. The farmers felt that the mechanical weeders available in the market could damage the crops during weeding. In order to enable the weeding operation at the early stage of growth, a suitable weeder rotor was selected and fabricated. The basic configuration was adopted so as to enable two-row weeding.

3.4.3.1 Design procedure for weeding rotor

As per the requirement of operation, power availability and plant height, a helical rotor configuration to facilitate two-row weeding along with mild soil earthing up was designed. Diameter and number of helical blades were fixed based on the row crop spacing.

The basic configuration adopted for the weeding rotors blades were helical in shape as shown in Fig. 3.7. The design was adopted so as to enable shallow operation to uproot the young weeds emerging in the inner spaces of two adjacent rows. Mild earthing up was also advantageous and hence two rotors were aligned so that the soil will be moved laterally towards the base of the crop plant.

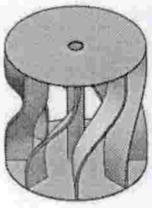

Figure 3.7 Weeding rotor configuration

3.4.4 Development procedure of coconut basin listing attachment

A suitable attachment for carrying basin listing operation for coconut tree was designed based on the power availability of the backpack brush cutter engine.

3.4.4.1 Fabrication procedure of basin listing attachment

Basin listing is the method of forming a basin in order to conserve the moisture and to reduce the soil erosion. Conventionally coconut basin was made by manual operation using spades. The soil is removed from the basin of the coconut tree and forms a wide basin of diameter 4 m (KAU, 2016).

By considering the ease of operation and adjustability a horizontal auger tool was selected as the basin listing attachment. Length, pitch and diameter of the auger were selected based on the power availability. The conceptual design of the horizontal auger is shown in Fig. 3.8.

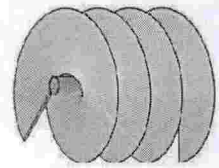

Figure 3.8 Conceptual design of horizontal auger as a basin listing tool

3.4.5 Development of earth auger

Earth auger was developed for the purpose of digging pits for fixing supports for banana as well as for various other purposes such as planting of saplings. By considering the diameter requirement for the selected purposes and power availability, the auger bit was designed.

Earth auger supporting frame with suitable handle was designed in such a way that a single person can operate the auger by supporting it in his hands.

3.4.5.2 Gear reduction unit for auger

As compared to the recommended standard rpm of earth augers, rpm of brush cutter engine was higher. Hence a reduction gear unit was selected to reduce the engine rpm to the required range for auger.

3.5 PERFORMANCE EVALUATION OF MULTIPURPOSE TOOL CARRIER WITH DIFFERENT ATTACHMENTS

Multipurpose tool carrier along with different attachments was field tested with respect to different machine parameters and to assess the performance of the various attachments.

3.5.1 Lab testing of the machine

Lab testing included the determination of overall dimensions, operational width and weight of machine. These were determined for each of the attachments.

3.5.2 Speed of operation

Speed of operation was calculated by observing the actual time taken to travel a measured distance and converting it into the unit of kilometers per hour. Three trials were carried out to find out the average speed of operation. Speed could be found out using the formula:

$$\text{Speed of operation, km h}^{-1} = \frac{Distance\ traveled,\ km}{time,\ h} \quad \ldots\ldots(8)$$

3.5.3 Determination of speed of the rotors

The rotational speed of the rotors fitted on the shaft driven by the prime mover was measured by a DT 1236L laser type tachometer. This tachometer could be used as a contact type as well as non-contact type to measure rpm of rotating shaft. The built-in laser for non-contact measurement provided accurate measurement up to a distance 2 m away from the target. The measurement was carried out by attaching a reflector on one of the rotating blades.

3.5.4 Time of operation

Time taken to do the particular operation was measured using a stopwatch.

3.5.5 Effective field capacity

Effective field capacity is defined as the actual average rate of coverage by the machine, based upon the total field time. It is a function of the rated width of the machine, the percentage of rated width actually utilized, speed of the travel and the amount of field time lost during the operation. Effective field capacity is expressed in hectare per hour.

$$\text{Effective field capacitya, ha h}^{-1} = \frac{Area\ covered,\ ha}{Total\ time\ is\ taken,\ h} \text{.......(9)}$$

3.5.6 Field efficiency

Field efficiency is defined as the ratio of actual field capacity to the theoretical field capacity and is expressed in percentage. Theoretical field capacity is the function of the width of operation and speed of operation and it is given below.

$$\text{Theoretical Field capacity, ha h}^{-1} = \frac{S \times W}{10} \quad \text{......(10)}$$

Where,

S = Speed of operation, km h^{-1}

W = Total width of the machine, m

3.5.7 Fuel consumption

Fuel consumption is defined as the rate at which an engine uses fuel, expressed in litre per hour. It was measured by the top fill method. The fuel tank was filled to full capacity before the testing at the leveled surface. After completion of the test operation, the amount of fuel required to top fill again is the fuel consumption for the test duration.

3.5.8 Depth of operation

Depth of operation has vital importance in the weeding operation as well as tillage operations. Depth of operation was measured using a metric scale.

3.5.9 Weeding efficiency

It is defined as the ratio between the number of weeds removed by power weeder to the number of weeds present in a unit area and is expressed in percentage. The sampling was done by quadrant method, by random selection of spots by a square quadrant of 1 square meter. It was found out using the formula:

$$\text{Weeding efficiency (per cent)} = \frac{W1-W2}{W1} \times 100 \qquad \text{....(11)}$$

Where,

W_1 = Number of weeds counted before operation per square meter

W_2 = Number of weeds counted after operation per square meter

3.5.10 Plant damage

It is the ratio of the number of plants damaged after an operation in a unit area to the number of plants present before the operation in the same unit area. It is expressed in percentage.

$$R = \frac{q}{p} \times 100 \qquad \text{......(12)}$$

Where ,

R = Plant damaged, %

p = Total number of plants per unit area before operation

q = Total number of plants damaged per unit area after operation

3.5.11 Performance evaluation of vegetable garden weeder

Vegetable weeder was tested in the field at different soil moisture conditions. It was tested for different parameters viz. depth of operation, speed of operation, field efficiency, fuel consumption and weeding efficiency using the methodologies described in previous sections.

3.5.12 Performance evaluation of paddy weeder

Paddy weeder was tested in the field after 30 days of transplanting the paddy crop. Prior to field testing the machine was tested in the laboratory to measure its overall dimensions and weight.

3.5.13 Performance evaluation of surface pulveriser cum two-row vegetable weeder

The machine was tested in a field in which chili crops were planted in an area of 0.028 ha at a spacing of 50 x 50 cm. Performance indices were measured as same as that of vegetable weeder described in section 3.5.

3.5.14 Performance evaluation of coconut basin lister

It was tested in the laboratory as well as coconut farm in the Instructional farm of KCAET, Tavanur .

3.5.14.1 Helix angle of horizontal auger

In the case of the horizontal conveyor, the helix angle of the path is independent of the screw speed. The helix angle is given by (Roberts, n.d.):

$$\alpha_e = \tan^{-1}[(\frac{p}{\pi D})(\frac{Ro}{Re})] \quad ....(13)$$

Where,

p	=	pitch, cm
D	=	2 Ro = screw flight diameter,
Ro	=	outside radius of screw flight,
R_i	=	inner radius of shaft

R_e is given as,

$$Re = 2/3\ [(R^3_o - R^3_i)/ (R^2_o - R^2_i) \quad ....(14)$$

3.5.14.2 Volume of soil displaced

Volume of soil displaced (m^3/h) by the auger can be measured by the formula,

Volume of soil displaced per hour = Length of auger, m × Speed of operation, m h^{-1}× Depth of operation, m

3.5.14.3 Capacity of basin lister

The capacity of the basin lister was calculated by counting the basin made per hour. Lister was operated and the time taken to completely form the basin of required diameter was noted down. From this the capacity was worked out.

3.5.14.4 Basin diameter

Basin diameter was measured using a standard measuring tape after the operation. Five trials were carried out in order to find the average basin diameter.

3.5.15 Performance evaluation of earth auger

Earth auger was tested in the field to determine pit dimensions and capacity. They are explained in the following sections.

3.5.15.1 Pit dimensions

The diameter and depth of pits made by the auger was measured using a metric scale. Ten successive pits were made and the average values of the pits were obtained.

3.5.15.2 Capacity of auger

The capacity of the auger can be expressed as the number of pits dugout per unit time. It was found out by operating the auger to dig ten pits and note down the time required.

3.5.16 Cost economics

Cost economics of the developed multipurpose tool carrier was found out. Fixed cost and the variable cost were found out by following the procedure given in IS: 9164-1979, which deals with the estimation of cost of farm machinery operation.

Cost of operation of each attachment along with multipurpose tool carrier was found out based on the field capacity calculated for each attachment.

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

A detailed account of the results of the investigations carried out to assess the constraints of mechanisation in homestead agriculture as well as the outcome of the design, development and evaluation of the multipurpose tool carrier with different attachments is illustrated in this chapter.

4.1 MECHANISATION OF HOMESTEADS AND PRIORITISATION OF CONSTRAINTS

In the survey conducted among homestead farmers, it was found that majority of the farmers were following the conventional method of farming. They were not much familiar with mechanised farming and the availability of low-cost machines except brush cutters. The information obtained in the interview revealed that the following operations require priority in mechanisation:

I. Among intercultural operation, weeding operation for various crops including paddy, vegetables and banana requires intensive labour and conventional manual operation is uneconomical.

II. Land preparations like shallow tilling and earthing up for vegetable cultivation.

III. Earth auger for digging small pits especially for providing supports for banana.

IV. Basin listing in homestead coconut gardens.

This general survey among homestead farmers was helpful in gathering information on various aspects of mechanisation requirement in homesteads. The constraints were identified using Garrett's ranking method.

4.1.1 Constraints in mechanisation of homestead agriculture

Garrett's Rank for each factor to identify the critical constraints faced by the farmers is shown in Table 4.1. The entire procedure followed to find the rank is given in Appendix B. The high cost of machines was found to be the most critical constraint that prevented the farmer to adopt mechanisation in homesteads. Lack of small machines for a specific operation, difficulty in operation of the machine, lack of awareness on machines and high operational cost were ranked 2nd, 3rd, 4th and 5th by the farmers, respectively. Farmers seem to be not much concerned about the quality of the machine, indicated by the lowest rank (8th) among various parameters.

Table 4.1 Garrett's ranks of identified constraints

Constraints	Garrett's rank
High cost of machine	1
Lack of suitable machineries for specific operation	2
Difficulty in operation of machines	3
Lack of awareness on machines	4
High operational cost	5
High cost of repair and maintenance	6
Lack of repair and maintenance facilities	7
Low quality of machine	8

Garrett's Rank obtained for each constraint represents priority as conceived by homestead farmers of the region. It was evident that high cost of existing machines like power tillers was the most critical constraint that prevented the farmer to adopt mechanisation even in medium homesteads. Lack of small machines for specific operations like weeding and inter culture was also posing difficulty of farmers. As the fuel prices were high the farmers seemed to be concerned on the operational cost which had a major dependency on the cost of fuel. The farmers were also worried about the technical knowhow of the machines as most machines required frequent repairs and maintenance. Even educated farmers were not confident in using machines themselves and the hired labourers, often those migrated from other states were mostly illiterate and unskilled. Hence training facilities for farmers in using small machines need to be strengthened.

4.2 DEVELOPMENT OF MULTIPURPOSE TOOL CARRIER (MPTC)

The multipurpose tool carrier designed and fabricated as per the conceptual design (section 3.3.3) consisted of a prime mover, gear reduction unit and a supporting frame with handle.

4.2.1 Basic tool carrier frame with handle

The tool carrier frame was made up of 2.54 cm diameter GI pipe and a 5 mm thick MS plate as shown in the Fig. 4.1. Brush cutter engine was mounted on the tool frame.

Length of the handle was 98 cm with a hand grip of 15 cm length. Along with the frame, another member was provided as an aid for attaching supporting tools viz. transporting wheels, depth adjusting attachment and float. This member was fabricated with a GI pipe of 2.5 cm diameter and 30 cm length.

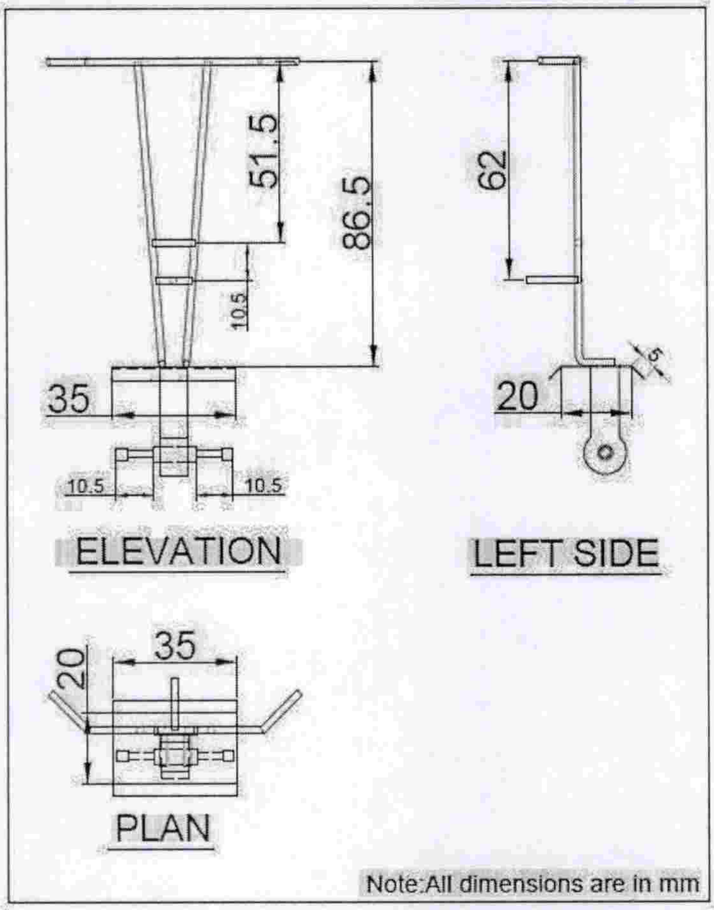

Figure 4.1 Basic frame of multipurpose tool carrier

4.2.2 Gear reduction unit

A gear reduction unit was provided with a reduction ratio of 40:1. Two horizontal drive shafts on both sides of the gear reduction unit were provided, to which different tools could be attached according to the required operation. A gear reduction unit available in the market was used for the purpose and was fitted to the tool carrier.

Figure 4.2 Power transmission gear box

4.2.3 Transmission shaft

Power was transmitted through a rigid shaft (Fig.4.5) of 14.5 cm length from brush cutter engine to gear reduction unit. One end of the shaft had a square cross-section of side 5 mm and the other end had a circular cross-section of diameter 7 mm. The rigid shaft (Fig. 4.4) was inserted into a hollow shaft whose dimensions are shown in Fig. 4.3.

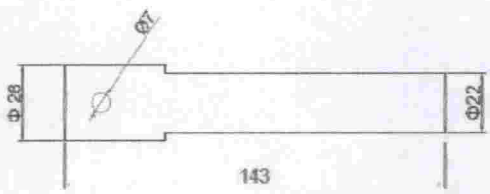

Figure 4.3 Hollow shaft

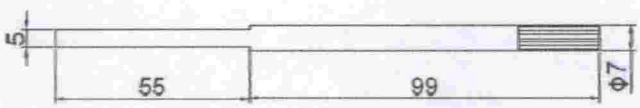

Figure 4.4 Rigid shaft

Figure 4.5 Power transmission shaft with hollow casing

Figure 4.6 Engine mounted multipurpose tool carrier frame fitted with gear reduction unit

A view of the engine mounted multipurpose tool carrier frame fitted with gear reduction unit is shown in Fig. 4.6.

4.3 DEVELOPMENT OF DIFFERENT ATTACHMENTS

Different attachments viz. vegetable weeder, paddy weeder, surface pulveriser cum two-row vegetable weeder, coconut basin lister and an earth auger were developed for the MPTC.

4.3.1 Development of vegetable weeding attachment to the multipurpose tool carrier

The system consisted of a rotary weeding assembly and transportation wheels fitted to the tool carrier frame. A compatible rotor assembly available in the market was selected. Weeder assembly is shown in Fig. 4.9.

4.3.1.1 Weeding rotor

Weeding rotor consisted of two sets of blades attached to the gear reduction unit. Each rotor had a diameter of 15 cm as shown in Fig. 4.7. Total width of the assembly was measured as 40 cm.

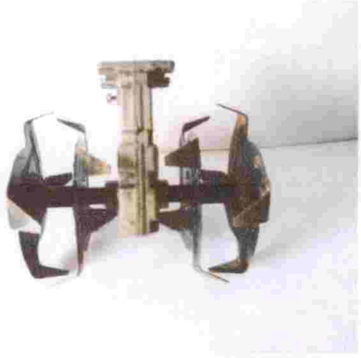

Figure 4.7 Weeding rotor with gear reduction unit

4.3.1.2 Transportation wheel assembly

Transport wheel assembly consisted of two wheels made of MS rods of 4 mm diameter and spaced 30 cm apart. Wheels were fitted on a GI shaft of 2.5 cm diameter and 30 cm length as shown in Fig. 4.8. A provision was given for adjusting the length of the member on which the wheel and axles were mounted. By changing the height of the axle from ground depth of operation could be adjusted within a range of 2 to 4 cm.

Figure 4.8 Transportation wheels

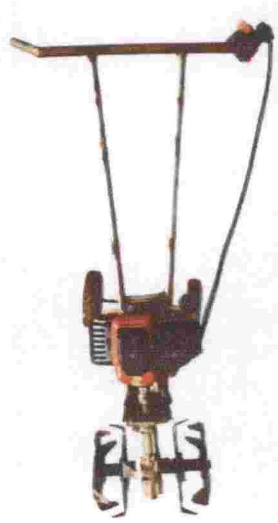

Figure 4.9 Vegetable weeder attachment assembled with MPTC

4.3.2 Development of paddy weeding attachment to the multipurpose tool carrier

A paddy weeding attachment to enable wet land weeding was developed for the multipurpose tool carrier powered by the back pack brush cutter engine as shown in Fig.4.14. Weeding attachment was developed based on the padyy row spacing of 30 cm.

4.3.2.1 Weeding rotor

Self propelled three row paddy weeder available in the market and recommended by KAU (KAU, 2016) had finger type rotors fixed in a cylindrical manner. As this configuration was a proven one, the same rotor configuration was adopted for the paddy weeding attachment. This was suitable for paddy transplanted at row spacing of 30 cm and up to an age of 30-45 days after transplanting (Fig.4.10). The rotors were attached to the shafts with a provision to adjust the spacing between rotors in accordance with the row to row spacing of the crops.

4.3.2.2 Power transmission shaft

In order to extend the shaft from the gear reduction unit, two hollow shafts were fabricated as shown in Fig. 4.11. The internal diameter was the same as that of the existing shaft from the gear reduction unit and the outer diameter was increased by 2 mm for attaching the weeding rotors. Two hollow shafts each of length 34 cm with 2.4 cm outer diameter and 2 cm internal diameter were fabricated and attached to the shaft from gear reduction unit. Power was transmitted from the gear reduction unit to the rotor through these hollow shafts.

Figure 4.10 Rotor of paddy weeding attachment

Figure 4.11 Shafts for power transmission

4.3.2.3 Guards

The plastic guards shown in Fig. 4.12 were fabricated from PVC sheets. Guards of 22 x 29 cm were cut and fixed to the frame made of GI square pipe provided at the front so as to restrict the plants from getting entangled by the rotor of the weeder. A skid of 24.5 cm length was attached at the rear end of the machine for supporting it during the operation. Once the machine reached the end of a row, it needed to be lifted for shifting to the next row. A handle made of GI pipe of 2.5 cm diameter was welded on the guard frame.

Figure 4.12 Plastic guards fixed with GI frame

Figure 4.13 Weeding rotor with guards attached to MPTC Frame

Figure 4.14 Paddy weeder fitted on MPTC

4.3.3 Development of surface pulveriser cum two-row vegetable weeding attachment to the multipurpose tool carrier

For the purpose of weeding cum earthing up of row crop vegetables at early stages, a helical blade attachment was fabricated as shown in Fig.4.17. This helical rotor was intended for two-row weeding with simultaneous soil displacement onto the base of the young plants.

4.3.3.1 Design and fabrication of weeding rotor

The rotor was designed in a helical shape so as to enable two-row weeding cum earthing up operation. It was made up of 2 mm thick GI sheet. Two circular discs of 20 cm diameter were cut from the GI sheet and it was then welded to a pipe of 2.5 cm diameter and 20 cm length. Eight rectangular sheets of width 4 cm and 20 cm length were drawn into helical shape as shown in Fig. 4.16. It was then inserted into the grooves made in the disc.

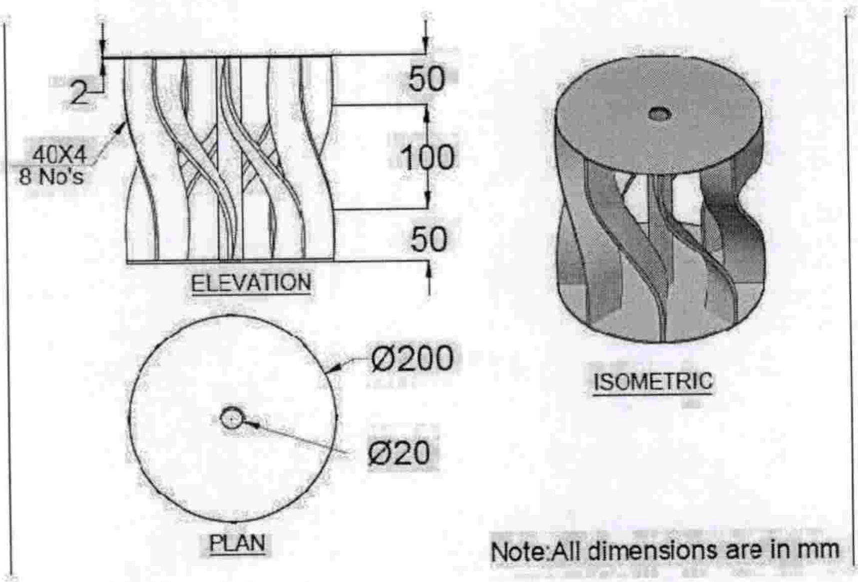

Figure 4.15 Design of helical blade

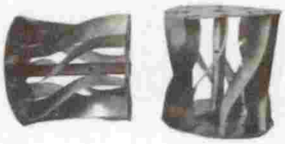

Figure 4.16 Helical blade rotors

Figure 4.17 Helical blade rotor attached to MPTC

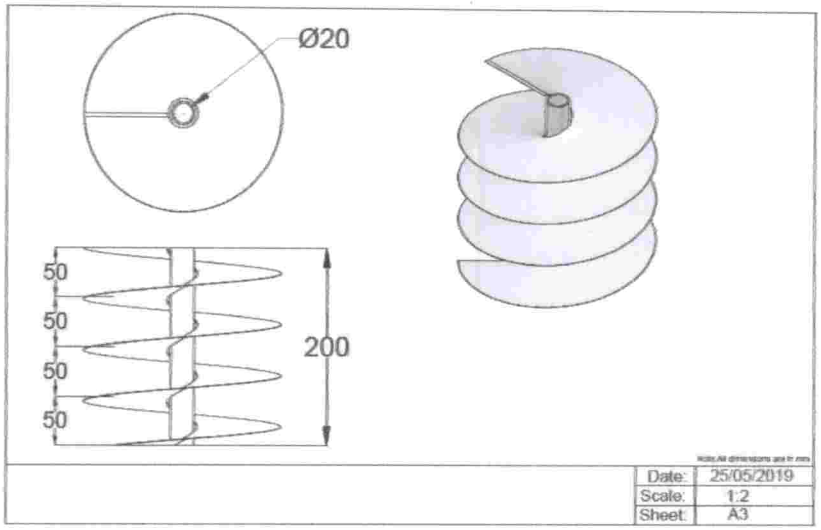

Figure 4.18 Design of auger

4.3.4 Development of coconut basin listing attachment to the multipurpose tool carrier

A horizontal auger system along with accessories was designed and fabricated as an attachment for multipurpose tool carrier as shown in Fig. 4.20.

4.3.4.1 Design and fabrication of basin listing attachment

Two horizontal augers shown in Fig.4.19 were fabricated using a GI sheet of thickness 2 mm. The overall dimensions of the auger were 20 cm (length) X 20 cm (diameter) with a pitch of 5 cm. The two augers were attached to the MPTC in such a way that both the augers will throw the soil in the same direction.

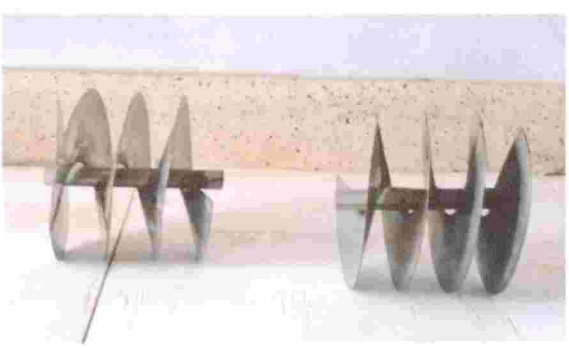

Figure 4.19 Horizontal auger

Figure 4.20 Horizontal auger attached to MPTC along with accessories

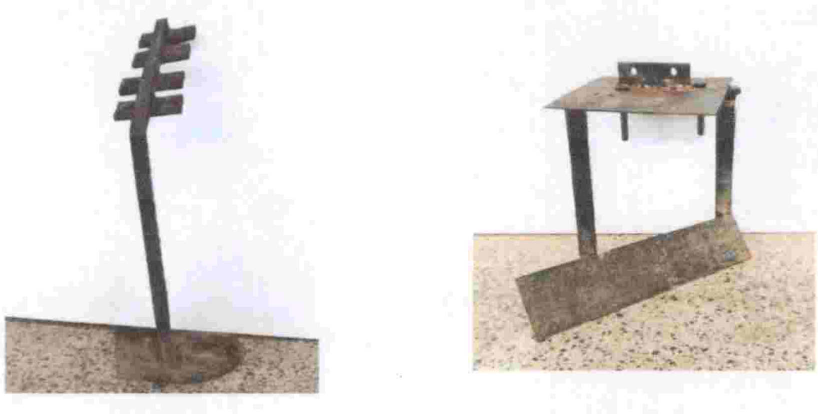

Figure 4.21 Horizontal auger accessories

4.3.5 Development of earth auger attachment for digging pits

Earth auger consisted of an auger bit, a gear unit and a supporting handle. It was indented for digging pits to fix support poles for banana as it was an identified requirement of farmers in the survey. As per the requirement an auger bit and a suitable gear reduction unit were selected.

4.3.5.1 Auger bit

Auger bit (Fig. 4.22) having 10 cm diameter and 74 cm length available in the market was selected for making pits of 10-12 cm diameter. Pitch of the auger bit was 7 cm with a helix angle of 8.88^0.

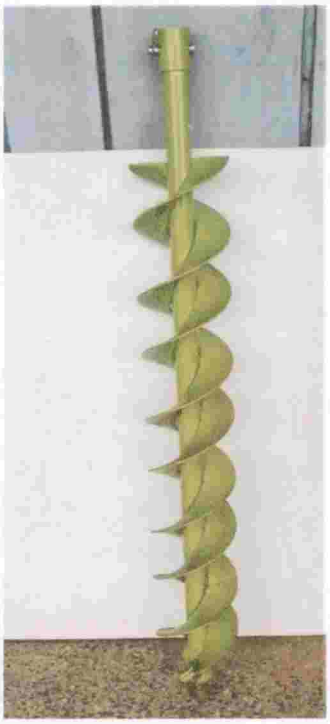

Figure 4.22 Vertical auger bit

4.3.5.2 Handle

Supporting handle (Fig. 4.24) was made up of 2.5 cm GI pipe and a 5 mm thick MS plate of size 13 cm x 20.5 cm as shown in Fig. 4.23.

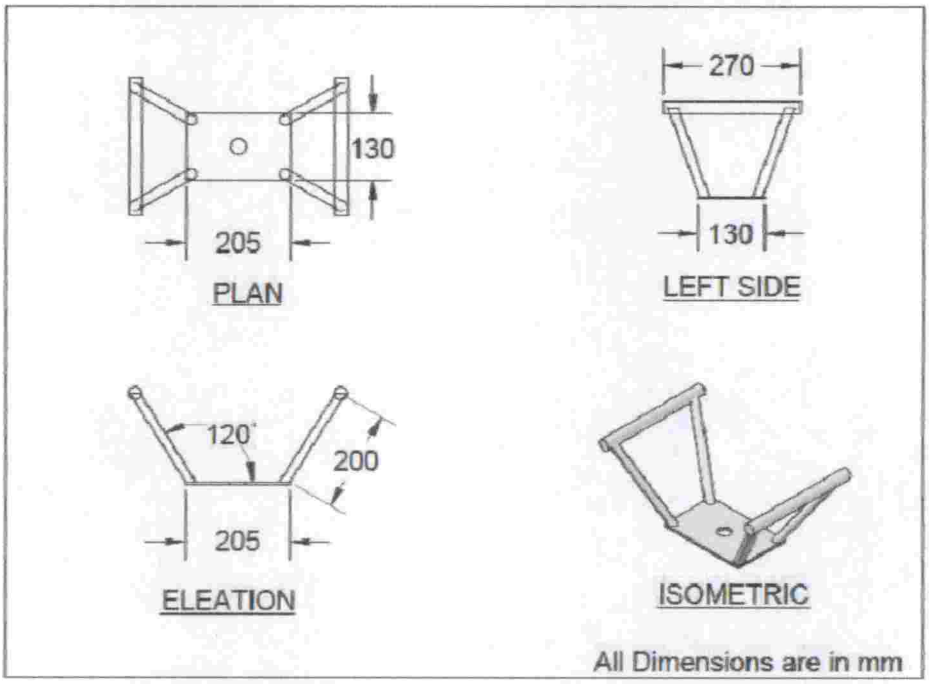

Figure 4.23 Design of supporting handle

Figure 4.24 Supporting handle for earth auger

4.3.5.2 Gear reduction unit

A separate gear reduction unit (Fig.4.25) with vertical shaft was used to reduce the engine rpm of 9340 to 255 rpm. The vertical shaft was required for attaching the auger bit with the help of suitable fixtures.

Figure 4.25 Gear reduction unit for earth auger

4.4 PERFORMANCE EVALUATION OF MULTIPURPOSE TOOL CARRIER WITH DIFFERENT ATTACHMENTS

Multipurpose tool carrier along with different attachments was tested in the field. Soil physical properties as well as machine performance indices were assessed during the test. Different tools attached to the MPTC were tested separately to find out their performance indices.

4.4.1 Soil physical properties

Soil physical properties viz. moisture content, cone index and bulk density were determined as per the method explained in sections 3.2.1.1, 3.2.1.2 and 3.2.1.3. Results obtained during field tests are discussed in the following sections.

4.4.1.1 Soil moisture content

Soil moisture contents determined by oven-dry method are given in Table C.1 of Appendix C. From the study, the preferable moisture content for the operation of multipurpose tool carrier with different attachments viz. vegetable weeder, basin listing auger attachment, earth auger and two-row vegetable weeder was found to be in the range of 10 to 30%.

4.4.1.2 Soil bulk density

Bulk density of soil determined as per the method explained in section 3.2.1.2 is given in Appendix C. Average dry bulk density before the operation was measured as 1.70 g/cm^3. Average dry bulk density after the weeding operation was found to be 1.56 g/cm^3.

4.4.1.3 Cone index

Cone index indicated the penetration resistance of the soil. The values obtained in the investigations are given in Appendix C. The average cone index of the soil when weeding attachment was tested is shown in Table 4.2.

Variation of cone index with depth is shown in Fig. 4.26. From the figure it is revealed that the cone index increased with the increase in depth indicating that soil strength is increased with increase in depth of soil (Mandal *et al.*, 2014).

Table 4.2 Average cone index at different depths

Depth (cm)	Average cone index (kg cm^{-2})
0	0
2.5	0
5	0.63
7.5	0.84
10	1.47
12.5	2.79

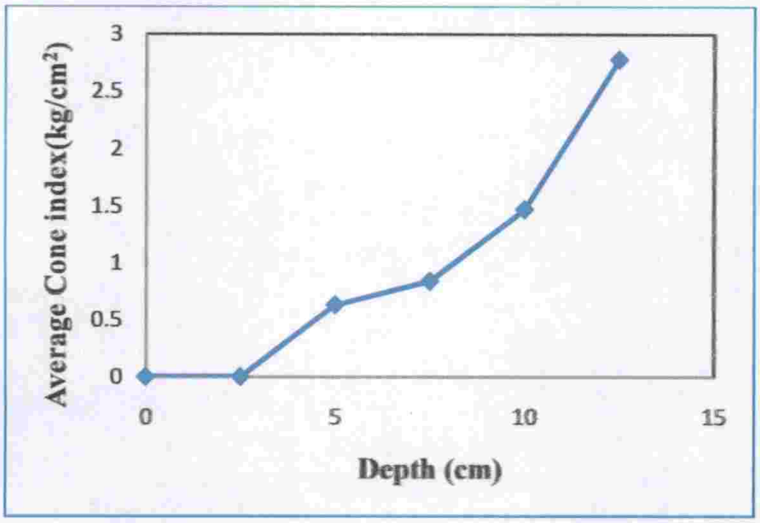

Figure 4.26 Variation of Cone index with depths

4.4.2 Laboratory testing of the rotary tillage/ weeder for vegetable garden

Operational width of weeder	= 26.5 cm
Weight of the machine	= 14.45 kg
rpm of blade	= 236.5 rpm

4.4.2.1 Performance evaluation of the rotary tillage/ weeder for vegetable garden

Vegetable garden weeder was tested in different fields F1, F2 and F3 (Fig. 4.27) at different moisture contents as given in the Table C.1 (Appendix C).

Figure 4.27 Field testing of vegetable garden weeder

4.4.2.2 Speed of operation

Speed of operation of the vegetable weeder was found out as described in section 3.5.2.

Table 4.3 Average speed of operation

Field	Moisture content,%	Average speed, km h^{-1}
F1	9.61	0.96
F2	14.9	0.75
F3	20.37	0.48

Average speed of operation at different fields of different moisture content was tabulated in Table. 4.3. Average speed of operation and moisture content were statistically analysed and it is shown in Table 4.4.

Table 4.4 Analysis of variance of speed of operation with moisture content

Source of variation	SS	df	MS	F	P-value	F crit
Between speeds	0.750	2	0.375	18.897	0.000600	4.2564*
Residuals	0.178	9	0.019			
Total	0.928	11				

*significant

From Table 4.4 it can be seen that there is a significant difference between speeds of operation with respect to moisture content.

4.4.2.3 Depth of operation

Depth of operation was measured using a metric scale after weeding operation. The average depth of operation at different moisture content of the field is given in Table 4.5.

Table 4.5 Average depth of operation

Field	Moisture content (%)	The average depth of operation, cm
F1	9.61	3.7
F2	14.9	4.5
F3	20.37	4

Data of depth of operation obtained at different moisture content was analysed statistically and it is shown in Table 4.6.

Table 4.6 Analysis of variance of depth operation with moisture content

Source of Variation	SS	df	MS	F	P-value
Depth	1.167	2	0.5833	2.33	0.153^{NS}
Residuals	2.250	9	0.2500		
Total	3.417	11			

NS -non significant

From Table 4.6 it can be seen that there is no significant difference in depth of operation with respect to moisture content. Also, it can be observed that depth of operation was not affected by the moisture content of the field. Variation of depth of operation and moisture content is shown in Fig. 4.28.

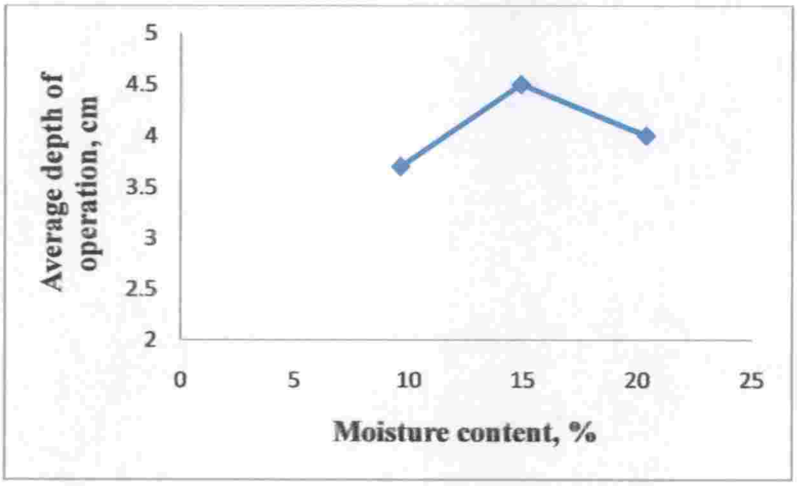

Figure 4.28 Variation of depth of operation with moisture content

4.4.2.4 Weeding efficiency

Weeding efficiency was determined as per the procedure described in section 3.5.9. Testing was conducted in different fields viz. F1, F2 and F3 of different moisture content and the calculations were appended in Table D.1 (Appendix D). Average weeding efficiency at fields F1, F2 and F3 are shown in Table 4.7.

Figure 4.29 Determination of weeding efficiency

Table 4.7 Average weeding efficiency

Field	Moisture content,%	Speed of operation, km h^{-1}	Average weeding efficiency,%
F1	9.61	0.96	90.56
F2	14.9	0.75	88.72
F3	20.37	0.48	90.18

Weeding efficiency at different moisture content was statistically analysed and the ANOVA (Table 4.8) is shown as below.

Table 4.8 Analysis of variance of weeding efficiency with moisture content

Source of Variation	SS	Df	MS	F	P-value	F crit
Between weeding efficiency	7.487391	2	3.743695	0.131539	0.87839	4.25^{NS}
Residuals	256.1448	9	28.46053			
Total	263.6322	11				

NS -non significant

From the analysis, it is found that there is no significant difference between the weeding efficiencies with respect to moisture content and thus moisture content variation did not influence the weeding efficiency of the vegetable weeder in the soil moisture range tested. Weeding efficiency of the weeder was not considerably influenced by the soil physical properties but the machine parameters were seen to. The weeding efficiency of 1.25 kW engine operated weeder developed by Devojee *et al.*, (2018) was 87.9% which was lesser than the weeder attachment in this study.

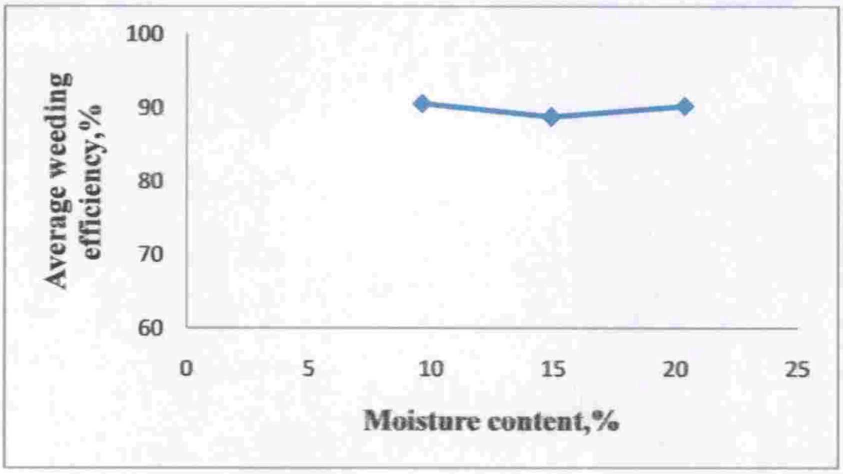

Figure 4.30 Variation of Average weeding efficiency with moisture content

The weeding efficiency and speed of operation were statistically analysed and the results are shown in Table 4.9.

Table 4.9 Analysis of variance of weeding efficiency with speed of operation

Source of Variation	SS	df	MS	F	P-value	F crit
Between speed	4.3	1	4.30	0.166	0.692	4.256^{NS}
Residuals	259.3	10	25.93			
Total	263.63221	11				

NS -non significant

From the table it can be seen that there is no significant difference between the weeding efficiencies with respect to speed of operation within the range of speeds tested.

Hence it could be inferred that the speed of operation and moisture content of the soil did not influence the weeding efficiency of the machine within the normal speeds and moisture contents usually encountered.

4.4.2.5 Plant damage

Details of plant damage occurred during the testing of the weeder at different fields of different moisture content is given in Appendix D.

Table 4.10 Crop plant damage during weeding

Field	Moisture content,%	Average plant damage, %
F1	9.61	4.12
F2	14.9	1.78
F3	20.37	5.80

88

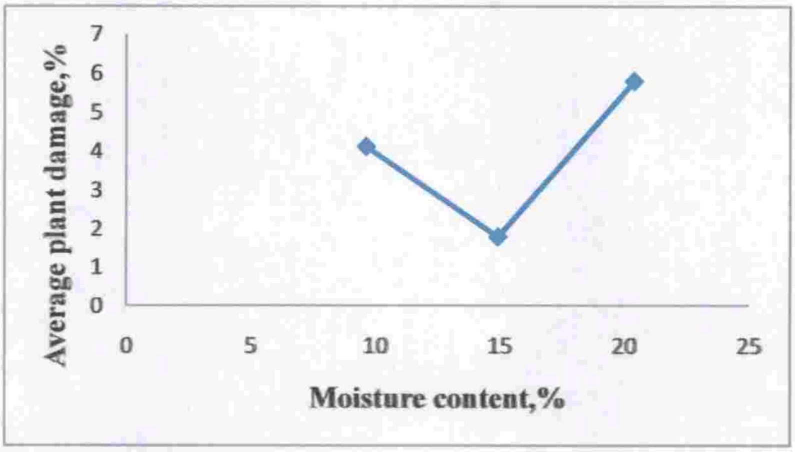

Figure 4.31 Variation of crop plant damage with moisture contents of soil

4.5.1.5 Actual field capacity

Actual field capacity of the weeder observed in fields of different moisture content is given in Table 4.11.

Table 4.11 Actual field capacity of vegetable weeder

Field	Actual field capacity, ha/h
F1	0.012
F2	0.006
F3	0.012

Maximum value of actual field capacity was found to be 0.012 ha h^{-1} and it was less than that of the power weeder for maize operated by 1.25 kW knapsack petrol engine developed by Devojee *et al.*, (2018) which was 0.023 ha h^{-1} with 2 blades and 0.029 ha h^{-1} with 6 blades. This was probably due to the higher speed of operation compared to the developed weeder in this study.

4.5.1.5 Field efficiency

Field efficiency calculations are shown in Table D.3 (Appendix D). Field efficiency at different fields is given in Table 4.12.

Table 4.12 Field efficiency of weeder

Field	Field efficiency, %
F1	49.46
F2	51.34
F3	60.84

Maximum value of field efficiency was obtained as 60.84% in field F3 since the actual filed capacity was higher in same field.

4.4.2.6 Fuel consumption

Fuel consumption was measured as per the method explained in section 3.5.7. Rotary weeder for vegetable garden weeding was operated in different fields at different moisture contents and the details of estimation of fuel consumption are given in Table D.4 (Appendix D). Table 4.13 shows the fuel consumption of the engine when the MPTC with weeder attachment is operated at different fields.

Table 4.13 Fuel consumption of weeder

Field	Fuel consumption, l h^{-1}
F1	1.26
F2	1.44
F3	1.28

90

Minimum value of fuel consumption was recorded as 1.26 l h^{-1} and maximum value was obtained as 1.44 l h^{-1}. This might be due to the high moisture content in the field F2 as compared to field F1.

4.4.3 Laboratory testing of paddy weeder

Overall width of machine	=	84 cm
rpm of rotor blades	=	226

4.4.3.1 Performance evaluation of paddy weeder

When the paddy weeding attachment was tested in the field at Pattikkad, Thrissur, it was run between the paddy crops having a row spacing of 30 cm. The plant height observed was in the range 35-45 cm.

Figure 4.32 Testing of paddy weeder

4.4.3.2 Field efficiency

Actual field capacity of the paddy weeder was determined as 0.0518 ha h^{-1} as given in Appendix D. Speed of operation was calculated as 0.936 km h^{-1} and the theoretical field capacity was calculated as 0.078 ha h^{-1} (Appendix D). Hence the field efficiency of the paddy weeder was observed to be 66.4%.

4.4.3.3 Fuel consumption

Fuel consumption was measured as per the method explained in the section 3.5.7 and it was observed to be 0.67 l h^{-1}.

4.4.3.4 Weeding efficiency

Weeding efficiency was calculated and tabulated in Table 4.14. It was observed that the paddy weeder satisfactorily removed the weeds with an average weeding efficiency of 71.09%.

Table 4.14 Weeding efficiency

Sl. No.	Number of weeds/m^2 before the operation	Number of weeds/m^2 after the operation	Weeding efficiency (per cent)
1	36	12	66.66
2	35	12	65.71
3	40	10	75
4	48	11	77

4.4.3.5 Plant damage

Plant damage was measured and shown in Table 4.15. Average plant damage was measured as 4.875%.

Table 4.15 Plant damage

Sl. No.	Number of plant/m^2 before operation	Number of damaged plant/m^2 after operation	Plant damage (per cent)
1	104	4	3.84
2	120	7	5.83
3	115	6	5.21
4	108	5	4.62

4.4.4 Performance evaluation of surface pulveriser cum two-row vegetable weeder

Two-row vegetable weeder was tested in a field having moisture content of 7.18% cultivated with chilli crop after 15 days of transplanting the seedlings. Weeding was done after 15 days of transplanting since weeder was developed for early stage weeding. Occurrence of plant damage will be less as identified at early stage (Kamal *et al.,* 2014). The plants were spaced 50 x 50 cm. Plant heights measured were within the range of 120-130 mm.

Figure 4.33 Testing of surface pulveriser cum two-row vegetable weeder

4.4.4.1 Field testing

Overall width of machine		= 54 cm
rpm of rotor blades		= 135
Speed of operation		= 1.32 km h^{-1}

4.4.4.2 Weeding efficiency

Weeding efficiency of two-row weeder was calculated and tabulated in Table 4.16. Depth of operation was measured as 4 cm.

Figure 4.34 Determination of weeding efficiency

Table 4.16 Weeding efficiency

Sl. No.	Number of weeds/m^2 before the operation	Number of weeds/m^2 after the operation	Weeding efficiency (per cent)
1	145	20	86.21
2	136	15	88.97
3	142	22	84.50
4	129	19	85.27

Average weeding efficiency = 86.23%

It was observed that when the weeder was operated at a speed of 1.31 km h^{-1}, the average weeding efficiency was 86.23%. A higher weeding efficiency of 95-97% was observed by Olukunle *et al.*, (2006) for a garden weeder when operated at a speed range of 1.5-1.8 km h^{-1}.

4.4.4.3 Plant damage

While testing in the field it was noticed that the main crop parameter which caused plant damage was plant height. The weeder was designed for simultaneous weeding in two rows and hence each rotor moved through the inter space between rows and the plants were safe as the clearance between gear reduction unit and the ground surface were sufficient. Percentage of plant damage is shown in Table 4.17. Average plant damage was found to be only 3.86%.

Table 4.17 Plant damage

Sl. No.	Number of plant/m^2 before the operation	Number of damaged plant/m^2 after the operation	Plant damage (per cent)
1	12	1	8.33
2	15	0	0
3	10	0	0
4	14	1	7.14

4.4.4.4 Fuel consumption

Fuel consumption of two-row vegetable weeder for the operation was calculated as 1.71 l h^{-1}.

4.4.4.5 Field efficiency

The details of estimation of field efficiency are given in Appendix D. It was found that the weeder had 76.92% of field efficiency on an average which was lesser compared to the field efficiency of the early stage weeder developed by Olaoye *et. al.* (2012). This is probably due to the higher actual filed capacity and theoretical filed capacity of the developed weeder.

4.4.5 Performance evaluation of coconut basin lister

Coconut basin lister was tested in coconut fields at two different moisture content viz. 15.38% and 21.15%.

Figure 4.35 Coconut basin lister in operation

4.4.5.1 Laboratory testing

Overall width of machine	= 54 cm
rpm of rotor blades	= 203
Speed of operation	= 0.155 km h^{-1}
Helix angle (Equation 13 in 3.5.14.1)	= 3.048^0

4.4.5.2 Performance indices

Performance indices of coconut basin lister at different moisture contents are shown in Table 4.18.

Table 4.18 Performance indices of basin lister

Performance indices	Moisture content %	
	15.38	21.15
Basin diameter, m	3	3
Time taken, min	2.1	4.06
Speed of operation, km h^{-1}	0.53	0.145
Fuel consumption, l h^{-1}	2.25	2.85
Volume of soil displaced, m^3 h^{-1}	31	6.264
Capacity, (basins/h)	25	14

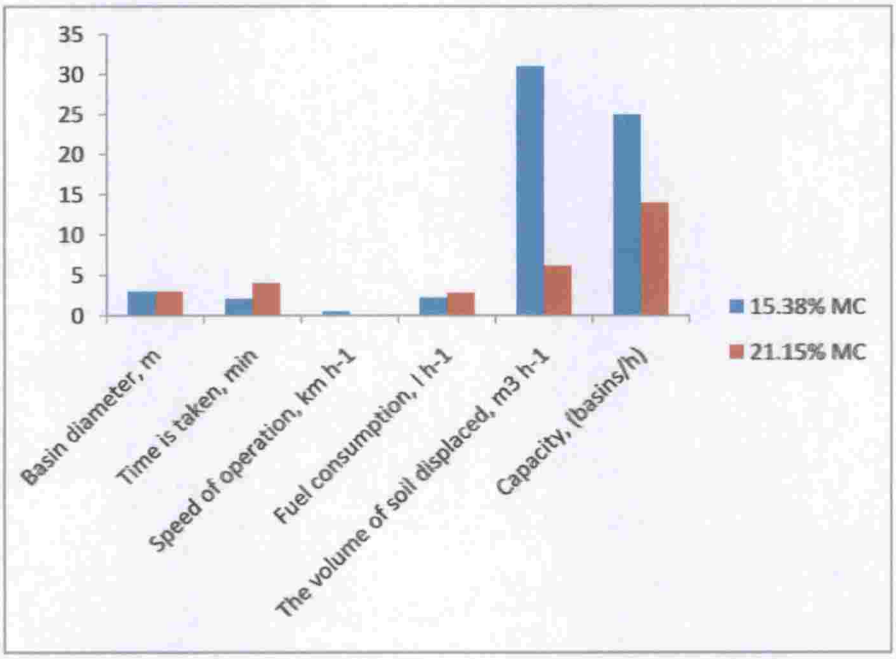

Figure 4.36 Comparison of performance indices at different moisture content

Coconut basin lister performed well in the field with moisture content 15.38% compared to the field with higher moisture content. As the moisture content increased the operational speed was found to be decrease and thus the time taken in making shallow basin of 3 m diameter was higher. This might be due to the sticking nature of soil particles as moisture increased and thus it seemed to interfere with the operation.

4.4.6 Performance evaluation of earth auger

Earth auger was field tested and operated in the field to make pits continuously. The diameter of the pit made using auger was measured as 15 cm. Average depth of hole dug was measured as 45 cm.

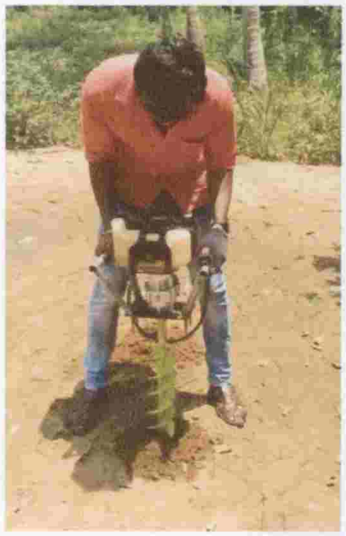

Figure 4.37 Testing of earth auger

4.4.6. 1 Fuel consumption and capacity

Fuel consumed and time taken to dig continuously 10 pits of depth 45 cm were noted down. It was found that on an average the earth auger had a fuel consumption of 1.69 *l* h^{-1} for digging pits in the soil with moisture content in the range 7-10%.

The capacity of the auger was found out by recording time taken to dig 10 pits and expressed in number of pits per hour.

Time taken for 10 pits	= 1.24 min
Capacity of auger	= 8 pits per min

4.5 COST ECONOMICS

Cost of the machine and cost of operation was found out by following the procedure given in IS: 9164-1979. Cost of construction of multipurpose tool carrier and different attachments are given in Table 4.19. Detailed estimation of constructional cost and operation cost is given in Appendix E.

Table 4.19 Cost of fabrication of MPTC and attachments

Item	Cost of construction, Rs.
Multipurpose tool carrier	13300
Rotary tiller cum weeeder attachment	6680
Paddy weeding attachment	2750
Surface pulveriser cum two- row vegetable weeder attachment	1780
Coconut basin listing attachment	2630
Earth auger	8500

Total cost of construction of multipurpose tool carrier and five different attachment was found to be Rs.35640/-.

Cost of operation per hour of different attachments along with MPTC was calculated and shown in Table 4.20.

Table.4.20 Cost of operation of MPTC with different attachments

Attachment	Cost of operation per hour, Rs.	Cost of operation, Rs.
Vegetable garden weeder	230	4220/ ha
Paddy weeder	120	2290/ ha
Surface pulveriser cum two-row vegetable weeder attachment	250	4500/ ha
Coconut basin lister	290	12/ basin
Earth auger	240	5/ 10 pits

Cost of fabrication of developed multipurpose tool carrier with five different attachments was calculated and it was then compared with prices of similar tools available in the market.

STHIL has introduced a multi tool system consisting of a multi engine and different attachments viz. cultivator blade, edge trimmer, aerator, bolo tine, pick tine, dethatcher, bristle brush and power sweeper. Many of these attachments are generally not required by homestead farmers. The attachments like "bolo tine" are difficult to be operated with the ordinary brush cutter. Total cost of the system is about Rs.55000/- whereas the developed multipurpose tool carrier with different useful attachments for the homestead farmers costs only Rs.35640/-. An earth auger is a very useful attachment which can save Rs.15000-20000 additionally. Hence, it was found that there is a 35% reduction in cost of developed MPTC as compared to the cost of tools available in the market.

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

Homestead farming is considered as the oldest land use activity and is prevalent in Kerala from the olden days. Cultivation around the immediate surroundings of a house is known as homestead agriculture. It is different from other commercial cultivation practices as it is mainly dependent on family labour, paying more attention to women in the family. One of the most important factors which threaten the sustainability of homestead agriculture is the drudgery involved in manual operations due to lack of mechanisation.

From the preliminary survey conducted among the homestead farmers, it was found that mechanisation is one among the most important interventions required in the system to make homestead agriculture more attractive, productive and profitable. It is high time to evolve a technically and economically feasible mechanisation strategy for homesteads for which an affordable and versatile power operated multipurpose tool carrier is highly relevant. Such a multipurpose unit can be used with a number of implements according to the operational requirement. This chapter summarises the major works done as a part of this study and conclusions drawn from the performance evaluation of the developed system.

Developed multipurpose tool carrier (MPTC) consisted of a tool carrier frame with handle, a prime mover and a transmission gear box with two co-axial shafts to which different attachments could be attached. A backpack brush cutter engine of 1.5 kW (2 hp) was selected as the prime mover. A transmission gear box was used to reduce the engine speed of 9340 to 230 rpm. According to the power availability and requirement of homestead farmers, different attachments to MPTC viz. vegetable garden weeder, paddy weeder, surface pulveriser cum two-row weeder, coconut basin lister and an earth auger were developed. It was then tested in the fields to evaluate its performance. In the preliminary studies, different soil properties that influenced the performance of the machine were also observed.

When the MPTC with different attachments were tested in the field, the soil moisture content was in the range of 10-30% with an average bulk density of 1.56 g/cm^3. The penetration resistance of soil at 12.5 cm depth was observed to be 2.79 kg/cm^2. Parameters such as speed of operation, depth of operation, fuel consumption, effective field capacity, field efficiency and weeding efficiency were measured and analysed.

From the Garrett's ranking method, the high cost of machines was found to be a more critical constraint that restricts the farmer from adoption of mechanisation in homesteads.

- A back pack brush cutter engine operated multipurpose tool carrier was developed for homestead agriculture as a promising system to help homestead farmers in many aspects.

- Five different attachments viz. vegetable garden weeder, paddy weeder, surface pulveriser cum two-row vegetable weeder, coconut basin lister and an earth auger were developed.

- Weeding rotor of 15 cm diameter and rotating at an rpm of 236.5 was developed as an attachment for vegetable garden weeding. It could be operated at an average depth of 3-5 cm.

- Average weeding efficiency, fuel consumption and field efficiency of the weeder was found to be 90.56%, 1.44 l h^{-1} and 60.84% respectively. It was found that weeding efficiency of the weeder did not depend on the soil moisture content and speed of operation within the ranges of soil moisture content observed in the present study.

- Paddy weeding attachment had a weeding efficiency of 71.09% and it consumed 0.67 litres of petrol per hour of operation.
- Actual field capacity of paddy weeder was found to be 0.051 ha h^{-1} and the average plant damage was observed to be 4.87%.
- Surface pulveriser cum two-row weeder was used for early stage weeding of row crop vegetables. A weeding efficiency of 86.23% was seen when the average heights of plants were in the range 120-130 mm.
- Actual field capacity of weeder was 0.055 ha/h and field efficiency was found to be 76.92%. The fuel consumption (petrol) was 1.71 l h^{-1}.
- Coconut basin listing attachment consisted of two horizontal augers aligned such a way that both the augers throw soil outwards.
- On an average coconut basin lister could make 14-25 basins per hour based on soil conditions. Coconut basin lister consumed 2.85 litre of petrol per hour of operation.
- An earth auger attachment was developed to dig pits for fixing support poles for banana.
- Maximum depth of pit dug by the auger was 45 cm with a diameter of 15 cm.
- Capacity of auger was measured as 8 pits per minutes with an average fuel consumption of 1.69 liters per hour of operation.
- Cost of construction of multipurpose tool carrier was Rs.13300/-

- Total cost of construction of different attachments viz. vegetable weeder, paddy weeder, surface pulveriser cum two-row weeder and coconut basin listing were Rs.6680/-, Rs.2750/-, Rs.1780/- and Rs.2630/- respectively.

- Total cost per hour operation of multipurpose tool carrier with vegetable weeding attachment, paddy weeding attachment, surface pulveriser cum two-row weeder and coconut basin listing attachment was obtained as Rs.230/-, Rs.120/-, Rs.250/- and Rs.290/- respectively.

- Cost of operation of earth auger was found as Rs.240/- per hour and total cost of fabrication was Rs.8500/-.

It could be concluded that:

The development of a MPTC powered by the engine of a brush cutter which is commonly available in farming households was expected to avoid the requirement of different implements and power sources for different operations. Hence it offered much utility over traditional implements and significant cost saving compared to procurement of different tools to accomplish these operations.

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CHAPTER VI
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Appendices

Appendix A

General Survey Form

Design and Development of a Multipurpose Tool Carrier for Homestead Agriculture

Interview schedule

1. Name of the farmer :
2. Address of the farmer :
3. Total landholding (in acre) :
4. Crop cultivated :

Sl no.	Crop cultivated	Area of cultivation	Method of cultivation	Kind of power used for cultivation	Cost of operation

5. Farming characterization :

Sl no.	Operation	Machines/ tools used	Duration of usage	Own/hiring	Cost of operation
1	Land preparation				
2	Planting operation				
3	Intercultural operation (weeding,fertilizer application)				
4	Plant protection				
5	Harvesting & storage				

6. Extend of machine used :

Sl no.	Operation	Done by		Level of satisfaction	
		Human	Machine	Satisfied	Not satisfied

7. In what all areas you need new machines?

8. What all are the features you expect in the new machine?

9. What according to you will help in popularization of the machine?

Appendix B

Garrett's Ranking Method

(a) Fcators

HCM: High cost of machines

LRMF: Lack of repair and maintenance facilities

LQM: Low quality of machines

LAM: Lack of awareness on machines

HCRM: High cost of repair and maintenance

LSMS: Lack of suitable machineries for specific operation

HOC: High operational cost

DOM: Difficulty in operation of machines

(b) Ranks assigned by the farmers

Farmers	Ranks							
	HCM	**LRMF**	**LQM**	**LAM**	**HCRM**	**LSMS**	**HOC**	**DOM**
A	1	6	7	3	8	2	5	4
B	1	7	8	4	6	2	5	3
C	2	8	6	3	7	1	5	4
D	1	6	7	4	8	2	5	3
E	2	7	8	5	6	1	4	3
F	1	8	7	3	6	2	4	5
G	1	6	8	4	7	2	5	3
H	1	7	8	4	6	2	3	5
I	2	8	7	5	6	1	4	3

(c) Details of rank for each constraints

Factors	Ranks							
	First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth
HCM	6	3	0	0	0	0	0	0
LRMF	0	0	0	0	0	3	3	3
LQM	0	0	0	0	0	1	4	4
LAM	0	0	3	4	2	0	0	0
HCRM	0	0	0	0	0	5	2	2
LSMS	3	6	0	0	0	0	0	0
HOC	0	0	1	3	5	0	0	0
DOM	0	0	5	2	2	0	0	0

d) Percent Position

$$\text{Per cent position} = 100 \times \frac{\text{Rij - 0.5}}{\text{Nj}}$$

Rank	Percent position, %	Garret Value
First	6.25	80
Second	18.75	68
Third	31.25	60
Fourth	43.75	53
Fifth	56.25	47
Sixth	68.75	40
Seventh	81.25	33
Eighth	93.75	20

(e) Multiply each rank from section (c) with its Garret's value

Factor	I^{st} x 80	II^{nd} x 68	III^{rd} x 60	IV^{th} x 53	V^{th}x47	VI^{th}x40	VII^{th}x33	$VIII^{th}$x20	Total
HCM	480	204	0	0	0	0	0	0	684
LRMF	0	0	0	0	0	120	99	60	279
LQM	0	0	0	0	0	40	132	80	252
LAM	0	0	180	212	94	0	0	0	486
HCRM	0	0	0	0	0	200	66	40	306
LSMS	240	408	0	0	0	0	0	0	648
HOC	0	0	60	159	235	0	0	0	454
DOM	0	0	300	106	94	0	0	0	500

(f) Final Rank of constraint

Factors	Total /No. of farmers	Average score	Rank
HCM	684/9	76	1
LRMF	279/9	31	7
LQM	252/9	28	8
LAM	486/9	54	4
HCRM	306/9	34	6
LSMS	648/9	72	2
HOC	454/9	50	5
DOM	500/9	56	3

APPENDIX C

Moisture content of soil of tested fields

Table C.1 Moisture content of soil at different operation

Tool/ Operation	Initial weight of soil sample (M_1), gm	Final weight of soil sample (M_2), gm	Moisture content = MC = $\frac{[M_1 - M_2]}{M_2} \times 100$, %
Vegetable weeder	25	22.8	9.61
	26	21.6	20.37
	24.6	21.4	14.9
Auger type basin lister	24	20.8	15.38
	25.2	20.8	21.15
Earth auger	28	25.02	11.91
	22.78	21.22	7.35
Helical blade Attachment	35.8	33.4	7.18
	24.88	20.72	20.07
	25	19.5	28.20

Bulk Density of soil of the tested fields

Table C.2 Soil dry bulk density before operation

Mass of the soil, g (M)	Volume of soil, cm^3 (V)	Bulk density = M/V, g/cm^3
1766.34	1021.01	1.73
1756.48	1021.01	1.72
1702.32	1021.01	1.66
Average		1.70

Table C.3 Soil dry bulk density after operation

Mass of the soil, g (M)	Volume of soil, cm^3 (V)	Bulk density = M/V, g/cm^3
1766.34	1021.01	1.73
1568.81	1021.01	1.53
1468.2	1021.01	1.43
Average		1.56

Cone index of soil of tested fields

Table C.4 Determination of cone index

Depth (cm)	**Cone index (kg/cm^2)**			
	CI1	CI2	CI3	Mean
0	0	0	0	0
2.5	0	0	0	0
5	0	0.57	0.70	0.63
7.5	0.82	0.80	0.92	0.84
10	1.55	1.33	1.52	1.47
12.5	2.81	2.69	2.84	2.79

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Appendix D

Performance indices of vegetable weeder

Table D.1 Determination of weeding efficiency at different moisture content

Moisture content, (%)	Number of weeds per m² before operation	Number of weeds per m² after operation	Weeding efficiency, (%)	Mean weeding efficiency, (%)
9.61	268	20	92.53	90.56
	105	7	93.33	
	365	18	95.06	
	230	43	81.30	
14.9	41	5	87.80	88.72
	32	3	90.62	
	80	4	95.00	
	27	5	81.48	
20.37	245	36	85.30	90.18
	252	15	94.04	
	275	29	89.45	
	235	19	91.91	

Table D.2 Determination of plant damage at different moisture content

Moisture content, (%)	p	q	Plant damage, r = (q/p) (%)	Mean r, (%)
9.61	54	2	3.70	4.12
	59	2	3.38	
	80	4	5.00	
	68	3	4.41	
14.9	15	0	0	1.78
	14	0	0	
	16	0	0	
	14	1	7.14	
20.37	21	1	4.76	5.80
	30	2	6.66	
	18	1	5.55	
	32	2	6.25	

Table D.3 Determination of field efficiency

Moisture content,%	Actual field Capacity, ha h^{-1}	Theoretical field capacity, ha h^{-1}	Field efficiency,%
9.61	0.012	0.025	49.46
14.9	0.006	0.012	51.34
20.37	0.012	0.020	60.84

Table D.4 Determination of fuel consumption

Moisture content,%	Fuel used, l	Time, hr	Fuel consumption, l/hr
9.61	0.21	0.17	1.26
14.9	0.12	0.08	1.44
20.37	0.32	0.25	1.28

Performance indices of paddy weeder

1. Field efficiency

Theoretical field capacity $= \frac{WxS}{10}$ ha/h

= 0.84x0.936/10

= 0.078 ha/h

Field capacity $= \frac{\text{area covered (ha)}}{actual\ time\ (h)}$

= 0.01296/0.25

= 0.0518 ha/h

Field efficiency = (0.0518/0.078) x 100

= 66.4%

Performance indices of Surface plveriser cum two-row vegetable weeder

1. Field efficiency

Theoretical field capacity

$$= \frac{WxS}{10} \text{ ha/h}$$

$$= 0.54\text{x}1.32/10$$

$$= 0.0715 \text{ ha/h}$$

Field capacity

$$= \frac{\text{area covered (ha)}}{actual\ time\ (h)}$$

$$= 0.0028/0.051$$

$$= 0.055 \text{ ha/h}$$

Field efficiency

$$= (0.055/0.0715) \text{ x } 100$$

$$= 76.92\%$$

APPENDIX E

Table E.1 Estimation of cost of fabrication of machine

Sl. no	Type of implement	Material	Quantity	Cost of material (₹)	Fabrication cost (₹)	Total cost(₹)
1	Vegetable garden weeder	Gear box+ rotor	1	5000	1600	19983.16325
		Ms rod (kg)	1.75	47		
2	Paddy weeder	Plastic sheet(kg)	0.5	125	1600	16046.96
		GI pipe (m)	0.3	121.85		
		Weeding rotor	2	500		
		Ms rod (kg)	1	47		
3	Two row weeder	Ms sheet (kg)	2.7	66.95	1600	15081.67
4	Coconut basin lister	Ms sheet (kg)	2.4	66.95	2400	15932.84
		Ms flat(kg)	1.25	57		
5	Earth auger	GI pipe (m)	1.1	121.85	1600	13504.03
		Auger bit+ gearbox+ engine	1	11770		
6	Main frame	GI pipe (m)	3.26	121.85	2400	13300.91
		Gear box	1	5000		
		Prime mover	1	5000		
		Ms sheet (kg)	0.055	66.95		
		Nuts and bolts (kg)	0.5	500		

Table E.2 Cost per hour operation of different attachments

Equipment	Vegetable weeder	Paddy weeder	Two row weeder	Coconut basin lister	Earth auger
Purchase value(Rs.)	19990	16050	15080	15935	13504.03
Salvage value(Rs.)	999.5	803	754	797	675
Average purchase cost(Rs.)	10494	8426	7917	8366	7089
Life of equipment(years)	5	5	5	5	5
Average annual use(h)	240	240	240	240	240
Interest rate (%)	12	12	12	12	12
Cost of fuel per litre (Rs.)	73	73	73	73	73
Cost of oil per litre (Rs.)	200	200	200	200	200
I,Fixed cost per year(Rs.)					
Depreciation(Rs.)	3798				
Interest(Rs.)	1259	1011	950	1003	851
Housing and shelter(Rs.)	210	168	158	167	142
Total fixed cost per hour(Rs.)	22	18	17	17	16
II,Operational cost per hour(Rs.)					
Fuel cost(Rs.)	105.12				
Lubrication cost(Rs.)	8.64	0.402	10.26	13.5	10.14
Repair and maintenance cost	2.66	2.14	2.01	2.12	1.80
Operator wages(Rs.)	94	94	94	94	94
Total operating cost(Rs.)	210	101	230	273	229
Total cost per hour(Rs.)(I+II)	232	118	247	291	243

DESIGN AND DEVELOPMENT OF A MULTIPURPOSE TOOL CARRIER FOR HOMESTEAD AGRICULTURE

By

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ABSTRACT OF THESIS

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Abstract

Homesteads lack appropriate machinery that suits their diverse requirements. Homestead agriculture warranted an affordable and versatile powered multipurpose tool carrier capable of improving the efficiency of human power. Hence development of a MPTC powered by the engine of a 1.5 kW backpack brush cutter which is commonly available in farming households was under taken so as to avoid the requirement of different implements and power sources for different operations.

Main components of MPTC were support frame along with handle, transmission systems with gear reduction units which converted 9340 rpm of the engine to 226 rpm with necessary transmission shafts and transportation wheels. Tools developed as attachments to MPTC were rotary tiller/weeder for vegetable crops, paddy weeding attachment, surface pulveriser cum two-row vegetable weeder, horizontal auger for coconut basin listing and vertical auger for digging pits.

The multipurpose tool carrier with its different attachments was tested in fields with moisture contents ranging from 10 to 30%. From the field evaluation of rotary weeding attachment, it was found that the depth of cut was 3-5 cm and the average weeding efficiency was 90.07%. The fuel consumption, field efficiency, average weeding efficiency and average plant damage in the case of paddy weeder were 0.675 l h^{-1}, 66.4%, 71.09% and 4.87%, respectively. Surface pulveriser cum two-row vegetable weeder attachment for row crop vegetables gave an average weeding efficiency of 80.27% with a fuel consumption of 1.64 l h^{-1} and a field capacity of 0.024 ha h^{1}. Coconut basin lister could make 14-25 shallow basins per hour based on soil conditions. Earth auger could dig 8 pits with a maximum depth of 45 cm and 15 cm diameter. Total cost of fabrication of different attachments with MPTC was Rs.35640/-.