UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF A LEMONGRASS HARVESTING IMPLEMENT

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APPROVAL SHEET

The project report here to entitled “Development of a lemongrass harvesting implement” prepared and submitted by Muhamad Abbqarry Bin Omar in fulfilment of the requirements for the degree of Bachelor of Agricultural and Biosystems Engineering with Honours has been examined and is recommended to be accepted.

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ABSTRACT

The demand for lemongrass in Malaysia has been on the increase, but the production from local farmers cannot be supported due to labour shortage. This study aimed at designing and developing a prototype of lemongrass harvesting implement to be used by smallholder farmers. Based on the data collected from physical properties and manual harvesting performance, a new prototype-harvesting implement was designed and fabricated. In this study, the characteristics of the lemongrass evaluated were the size, weight, rhizome and root zone, and planting distance of the lemongrass for each variety. The different varieties of lemongrass determined were *Serai Kampung, Peha Ayam,* and *Serai Gajah*. The size and the weight of the *Serai Kampung, Peha Ayam,* and *Serai Gajah* were 117.6 cm, 141.8 cm, 156.2 cm, 1.14 kg, 5.92 kg, and 4.4 kg respectively. The root zone had been determined in range 10 cm to 13 cm depth and this data were used to design the blade that could penetrate to that depth. The field efficiency of manual harvesting was 0.0038 ha/hr for *Peha Ayam,* 0.0018 ha/hr for *Serai Gajah*, and 0.0025 ha/hr for *Serai Kampung*. Evaluation of mechanical harvesting would cover the design analysis, field performance of mechanical harvesting, and draft estimation. The draft estimation from this study was 1.06kN on the sandy loam soil with coarse type soils, the speed of the tractor was10 km/hr with a machine width of 73.6 cm. In conclusion, the lemongrass harvesting implement was able to do the harvesting process in the field.

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ABSTRAK

Permintaan serai di Malaysia semakin meningkat, tetapi produksi daripada petani tempatan tidak dapat menampungnya kerana kekurangan pekerja. Kajian ini bertujuan untuk mereka bentuk sebuah prototaip mesin penuai serai untuk digunakan oleh petani. Data yang diperolehi daripada ciri fizikal dan prestasi menuai secara manual telah digunakan dalam membentuk mesin penuai tersebut. Dalam kajian ini, ciri-ciri serai yang di uji ialah saiz, berat, zon rhizome, zon akar, dan jarak tanaman pada setiap jenis serai. Pelbagai jenis serai telah di tentukan iaitu Serai Kampung, Peha Ayam, dan Serai Gajah. Saiz dan berat Serai Kampung, Peha Ayam, dan Serai Gajah ialah 117.6 cm, 141.8 cm, 156.2 cm, 1.14 kg, 5.92 kg, dan 4.4 kg. Kedalaman zon akar telah ditentukan diantara 10 cm hingga 13 cm, data ini digunakan dalam membentuk mata pisau yang mampu menembusi kedalaman tersebut. Kecekapan ladang menuai secara manual ialah 0.0038 ha/jam daripada Peha Ayam, 0.0018 ha/jam daripada Serai Gajah, dan 0.0025 ha/jam daripada Serai Kampung. Penilaian penuaian secara mekanisasi akan merujuk kepada analisis reka bentuk, prestasi ladang oleh penuai mekanisasi dan menganggar nilai draft. Kajian ini telah menganggar nilai draft sebanyak 1.06kN pada jenis tanah loam berpasir dengan keadaan jenis halus, kelajuan traktor 10 km/jam dengan lebar mesin 73.6 cm. Kesimpulannya mesin penuai serai berupaya untuk melakukan proses penuaian di ladang.

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CHAPTER 1
INTRODUCTION

1.1 Background

Lemongrass is a type of edible grass and a tropical perennial plant that crops aromatic oil. The name lemongrass is derived from the typical lemon-like odor of the essential oil present in the shoot. Lemongrass also is known as *Cymbopogon Citratus*. It can grow up to 1 m high and leaves can reach a size of 40cm x 1cm.

In Malaysia, this plant is not a new thing for local people, this plant regularly was used in cooking by them. Lemongrass also was used to produce traditional medicine and was also used as pesticide control in local agricultural practice. This practice makes a high demand for lemongrass plants.

In Malaysia, most of the planter of lemongrass are cultivated on a small scale because of limited worker nowadays. Not only have that, but the process of manual harvesting lemongrass also need a lot of energy for the worker because they need to pull out all the plants from the soil one by one.

Lemongrass harvester is very helpful for the farmer but to own the implement is very costly for a smallholder farmer. In this project, we decided to design and test an implement powered by the PTO mechanism. This project was expected to allow smallholder farmers to maximize their harvesting process without spending a lot and only enough with one worker.

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1.2 Problem Statement

Lemongrass is a fast-growing crop type in Malaysia. The lemongrass planting will give the big profit for the smallholder farmer in range 6 to 9 months, the time for the lemongrass was ready to be harvested. It is hard for a farmer to plant the crop because not enough labour to handle this planting process. Most of the farmers were elderly, with age above 55 years old.

The planting practice of the lemongrass is very challenging and it requires high energy demand for a veteran farmer to plant this crop. Then, the local practice of the farming was done in the rural area, it hard to design the implement for the large tractor. It also gives a challenge to the big tractor operator to work on the limited space in the rural area.

The lemongrass harvesting process is a very crucial part because this crop is easy to dry out after it is removed from the soil. This process is time consuming for the farmers to work on. This makes the process of harvesting a very critical process to own the lemongrass

It needs to do the harvesting process at the exact time, so the worker needs to harvest the lemongrass as fast as possible from the soil to keep their production in good quality after harvest. This allows the smallholder farmers only limited time to produce a good quality of lemongrass in the harvesting process.

Nowadays, lemongrass harvester will help the farmer to do the harvesting process. To work on the limited space, the implementation needs to be designed for a small scale that can be attached to a mini tractor. This technology is still in development stage in Malaysia agriculture practice. The recent lemongrass implement

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is very costly for the farmers to own. This makes the smallholder farmers choose manual harvesting rather than use the lemongrass-harvesting implement.

1.3 Objectives

This study aimed at designing and developing a prototype of lemongrass harvesting implement to be used by smallholder farmers. The specific objectives were as follows:

- To determine the physical properties of lemongrass
- To evaluate the performance of manual harvesting
- To evaluate performance of mechanical harvesting

1.4 Scope and limitations

1. The data presented in this thesis were collected only in Lenggeng, Negeri Sembilan.
2. The design of the implement was only suitable on the soft soil type condition.
3. The lemongrass harvesting implement would work efficiently under well prepared soil.
4. The size of the implement was designed to be attached to a mini tractor.

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CHAPTER 2

LITERATURE REVIEW

2.1 Taxonomy and origin of lemongrass

Lemongrass usually known as fragrant grass that produces evaporative oils, this crop is *Cymbopogon* species and it belongs to the family *Graminae (Poaceae)*. These species had been counted to incorporate around 140 species and a few assortments. In Africa, more than 52 have been counted, 45 species in India, six in South Africa, and the same amount of species in Australia. In Europe, four species that had been counted and two in North America and the rest of the species in South Asia. The antiqued Latin called this species as *Citratus*, which means lemon-scented leaves (Bekele, 2017).

It has two distinct species of lemongrass, most of it an enduring herb in India and were cultivated in the topics and subtopics. *Cymbopogon flexuosus (DC) Stapf* was known as East Indian lemongrass or the other names are Cochin or Malabar Grass. This crop is a tufted robust perennial grass and 2 m height. Linear and lanceolate type of leaves. Other species are edible lemongrass is *Cymbopogon Citratus (DC) Stap*f also known as West Indian lemongrass or American lemongrass it is a stemless perennial grass with numerous stiff tillers arising from the short rhizomatous rootstock. This plant was planted to produce oil since 1888 in India.

Most of the Malaysia lemongrass species are *Cymbopogon Citratus* also known as a densely tufted perennial herb. This crop can reach 1 m to 1.5 m of height. The flowering panicles are rarely formed; inflorescence is 30-60 cm long nodding; the partial inflorescence is paired racemes of spikelet subtended by a spathe (Ross, 2005).

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2.2 Planted Area in Malaysia

In Malaysia, the practice of planting lemongrass is very popular in Negeri Sembilan. The most popular planting area in Negeri Sembilan has been in Beranang, Negeri Sembilan. This area has become one of the larger producers of lemongrass in Malaysia (Bernama, 2019). A local people around Beranang did this crop planting practice. A total of the farmer had been involved in this planting crop around 500 people were practice in the small-scale area, this will give the total extensive planting area around 283 hectares to 324 hectares for commercial purpose (Bernama, 2019).

2.3 Economic value of the lemongrass in Malaysia

This crop is very popular among the local consumers because it has a different application in daily life. This gives the lemongrass are a very demanding crop for the local consumer. The lemongrass also had been exported to Thailand and Singapore. In the local market price, the lemongrass can reach RM 11 per 4 kg, in a total of 0.4 hectares if lemongrass area, the profit gain from the farmer can reach from RM 7000 to RM 8000 (Bernama, 2019).

2.4 Variety of lemongrass in Malaysia

Malaysia have several verities that are being planted commercially and the most comment varieties are *Serai Kampung* and *Serai Jamil*. These varieties have their own specialty and method to be used. This variety have different characteristics in terms of physical and chemical properties. In terms of physical properties, Serai Jamil has the biggest size compared to other verities, which is Serai kampong, (Amirah,

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2019). While, in term of chemical properties, Serai Kampung has a strong odor and good smell compared with Serail Jamil verities (Amirah, 2019).

2.5 Planting of lemongrass

Lemongrass is very active in local agricultural practice in small scale industries. This is because the edible lemongrass is the fast-growing type of crop. This crop requires little maintenance, can be planted in most types of soil except very clayey and under waterlogged conditions but the best condition for planting this crop is on sandy loam soil with a high content of organic matter. This crop is well adapted with a tropical climate and needs an evenly distributed rainfall throughout the growth period. The optimum of monthly rainfall that is suitable for this plant is 260 mm to 300mm and the optimum growth of lemongrass is needed full of sunlight (Globinmed, 2018).

Lemongrass needs proper land preparation for good control of weeds and crop establishment. If necessary, Ground Magnesium Limestone (GML) was applied 2 weeks before plowing to increase the pH to 5–6. The soil requirement for planting the lemongrass need pH between 5.0 to 8.4 (Amirah, 2019).

Planting spacing for local agriculture practice in Malaysia is usually 0.6 cm x 20.6 cm. This spacing will give the 20000 clumps of lemongrass in the area of 1 hectare (Harress, 2017). In this area of lemongrass plantation, for 20000 clumps of the

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lemongrass, it will produce 25 ton to 30 tans of lemongrass that can be placed in the market (Harres, 2017).

Figure 1. Planting Distance of the lemongrass (MyAgri, 2017)

Based on figure 1 the planting distance shows that the big tractor cannot be used to work on this distance. The average value for the working width of the standard tractor on the farm was 1.9 m (Louth, 2020).

2.5 Crop care practice of lemongrass in Malaysia

The local practice of lemongrass of this crop is to plant and leave. The lemongrass can sustain the hot weather or drought season (Harress, 2017). Even though the lemongrass can sustain at extreme condition, it needs to be watered two times per day for the early stages (Harress, 2017) To gain the healthy and quality yield of the lemongrass, the farmers need to do intensive care on the early stage of planting the lemongrass. At the early stage, the fertilization process needs to be done twice in the month by using NPK fertilizer with a ratio of 15:15:15 in 40 gram per clump of lemongrass (Harress, 2017). In the early stage of growing the lemongrass,

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the weeding process is needed to increase the rate of lemongrass growth. This will avoid the lemongrass from any competition with another plant (Harress, 2017).

2.6 Harvesting of lemongrass

Lemongrass can be harvested after 6 to 9 months after planting. During the peak developing season this crop would be able to be harvested as often as possible (DOA of South Africa, 2012).

In local agriculture practice, harvesting the lemongrass only cuts the needed parts for their consumption in daily life. This makes the harvesting of lemongrass to be done multiple times in a day or a week after it achieved maturity. This crop does not have any season to be matured. This crop can be harvested any time after it had been matured.

This crop can be harvested by hand or machinery. The small farmer will choose to harvest by hand because of the area for their planting are small and not necessary to use a machine. Manual harvesting is not recommended for industry-level because manual harvesting the lemongrass would take a long time.

This study tried to compare the efficiency of harvesting the lemongrass by manual handling and mechanical harvester.

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2.6.1 Manual harvesting

Figure 2. The Farmer digging out the lemongrass (Harizamrry, 2009)

In terms of commercial manual harvesting, the lemongrass needs to be pulled out from the leaf until the root. The farmer needs to dig out the clump of lemongrass one by one. This is why commercial harvesting takes a longer time to fully harvest the lemongrass. They also need to be cautious when digging out the lemongrass to avoid damaging the rhizome part on the lemongrass. To dig the lemongrass, they need to use the hoe before they pull out the lemongrass by hand and dig for 10 cm to pull out the roots (Harress, 2017). After that, a farmer will cut the leafy part of that crop.

Next, the root of lemongrass needs to cut out, the root does not have any use in cooking either for the herb. Completing this process make the lemongrass a successful harvest. The worker will repeat this process until the harvesting process is completed. They will collect all the lemongrass and they will tie up into bunch before selling to the market.

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2.6.2 Mechanical harvesting

Mostly for the mechanical harvesting method, the farmer will use a tractor and implement it to do the specific work. This method was used for a large scale area. A tractor is very useful in modern agricultural practice. By using a tractor will make the productivity per agricultural worker increase. Quality of field operation will improve, soil environment for seed germination and plant growth will become better (Liljedahl, 1989).

The application of tractor for field operation also needs to consider the best specification of the tractor. In the management of field operations, the farmer needs to determine the best tractor to operate at their field area. Spending on tractor operation needs to be optimum with the operating of the tractor on the field. To determine the suitability of the tractor infield, the farmer needs to know the field performance and the field efficiency of the tractor based on the farmer planting area.

Figure 3. Harvesting process of potato by harvesting implement (Wheeltractor 2015)

The harvesting process by tractor operation will be helped from the harvesting implement like Figure 3. Every crop had a specific harvester. The harvester can be

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cutting or digging process. This harvester will be attached to the tractor either in front or behind of tractor. In lemongrass planting, the suitable type of harvester in lemongrass, it harvesting process is the digging process. The digging process was needed to reach the root zone of the crop. The lemongrass harvester does not exist yet for commercial. This implement still in the development process. The separating process of lemongrass is needed, the separating process soil and the roots of lemongrass by using a shaking mechanism can break the soil from the root.

In Malaysia agriculture practice in lemongrass planting, mostly in small scale areas for the small farmer because lemongrass is not the main crop for Malaysia. Using a tractor is not very suitable for small farmer operations and in terms of the crop distance. The demand for the implementation of lemongrass harvester was high because of the farmer's lack of workers. They need this to implement to improve their time consumption in the harvesting process.

2.7 Root digger concept in carrot harvesting

Lemongrass is small scale crop and it is a root crop, to harvest this crop, the crop needs to be pulled out with the root. Designing the harvester for this crop was based on the concept from root digger of carrot. This implement has the same operation to harvest the lemongrass. Root digger was used to harvest the root crop like potato, onion, carrot, etc.

After China, the first runner upcountry the largest producer of vegetables is India. In the years 2010 – 2011, India have contributed 14% in world vegetable production (Narender, 2012). The main focus is carrot planting in India. The carrot

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harvester had consisted of two major components; a soil separation unit and the digging unit. The V-shaped blade is used for digging unit with length and width 350mm and thickness of 15mm at 25º rake angle and 20º angle of soil separator (Shirwal, Mani, Sirohi, & Kumar, 2015). The concept of the harvesting implement is shown at Figure 4.

Figure 4. The carrot harvesting implement using V-shaped blade (Yucheng Agrimachinery 2017)

In the soil separation unit, the spacing between the rods of the web was kept as 5 cm, width, and length of the soil separator were 700 mm, respectively. This harvester was evaluated its performance by different levels of rake angle, soil separator length, and angle of soil separator. The research shows that when the carrot harvester was operated at a speed 3.8 km/h the harvesting percentage was 97.8%, the carrot damage percentage of 4.6%, soil separation index of 0.21, the power requirement of 5.18 kW, and field capacity of 0.21 ha/h (Sunil, Indra, Sirohi, and Ardash, 2015).

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CHAPTER 3

METHODOLOGY

In this study, all the parameters were needed to consider in designing the lemongrass-harvesting implement. This parameter had its specification that was needed for lemongrass-harvesting implement could work well in the field and became the most efficient equipment to harvest the lemongrass compared to the manual harvesting method. The lemongrass harvesting implement was a digging typed implement because of the manual method to harvest the lemongrass was digging up the whole bunch of the crop out from the soil, from this digging typed implement were the best choice to be part of designing the harvesting implement.

The next step was to consider the performance of the lemongrass-harvesting implement. Several things that had been considered were the fuel efficiency of the implement where it may affect the cost of fuel consumption, then how fast will the implement works in an area, and how efficient could the implement will be working when it was in the field. Besides, the draft also needs to be considered, as it was one of the most important aspects of showing the force needed in pulling the implement. All of this field performance aspect needs to be considered and determined to develop a machine that could perform well in real use

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3.1 Flowchart of Methodology

The flowchart shows the flow of this study from the beginning until it reaches the end. These things will show the action taken if an error in this study occurs. The flowchart was created, based on the objective of this study.

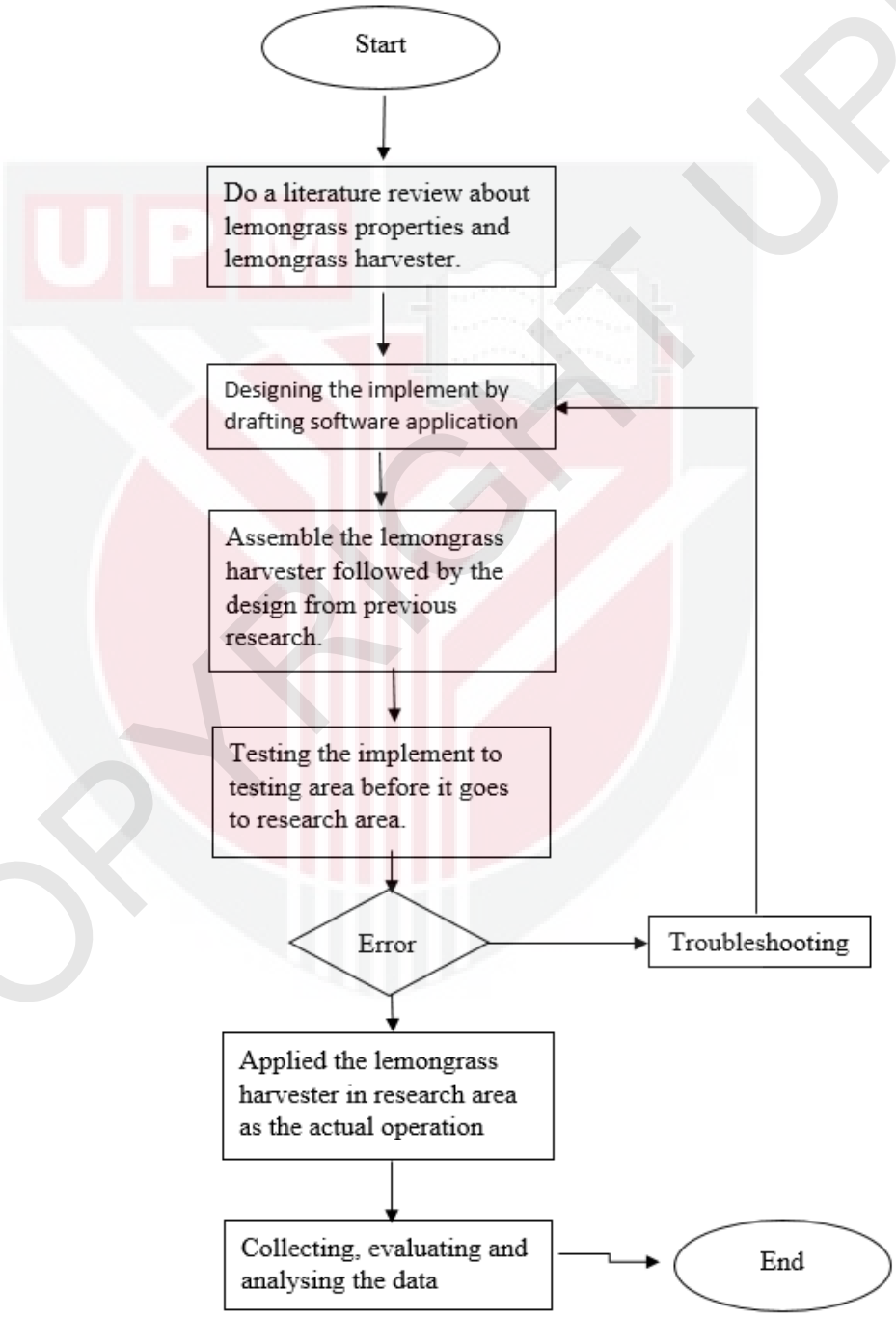

Figure 5. The flow of study in developing the harvesting implement

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3.2 Crop characteristics

When designing this implement, understanding of crop behavior was very important because the lemongrass had several varieties that were planted in local farmers practiced. The characteristic of the lemongrass that needs to be evaluated was the size of the lemongrass, weight of lemongrass, tuber zone, and planting distance of the lemongrass for each variety. The behavior was needed to make the implement work well with the lemongrass during harvesting. This will be done in the field data collection.

3.1.1 Location of field testing

Location for this studied at Lenggeng, Negeri Sembilan. In this research, the size of the planting area that was used for lemongrass planting had been determined for each variety. The planting density was determined in the planting field area using a formula as stated below.

$$Plant\ population = \frac{Area\ of\ the\ planting\ area}{Planting\ distance}$$

Equation 1

Field evaluation of lemongrass harvester had been tested on the plot of lemongrass, each type of evaluation in manual and mechanical method had been done in the same area.

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Figure 6. 1 acre of planting area of Peha Ayam

Figure 6, shows the field area that evaluation of manual harvesting had been tested, the plant population in this area was 5000 clump of lemongrass.

3.1.2 Physical properties of lemongrass

Finding and determined the physical properties of the lemongrass had given a big idea in designing the lemongrass-harvesting implement. Three different varieties had been determined in the local farmer planting area. The varieties of the lemongrass in Lenggeng area were, *Peha Ayam*, *Serai Gajah*, and *Serai Kampung*. The physical properties of all varieties of lemongrass had been recorded.

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Figure 7. The harvested of Serai Kampung

Figure 7 shows the serai kampung after it was harvested, it had been clean and ready to be placed in the local market. It had thin rhizome characteristics and had a strong odor compared to the other varieties.

From the result of the physical properties of each variety, could be used to determine the root zone of the lemongrass, and then it could be, determine the percent height of the rhizome part in lemongrass. The weight of lemongrass was used to determine the amount of load that lemongrass had been produced. The load had been calculated by using the formula below.

$$Load\ of\ lemongrass\ (N) = Mass\ of\ lemongrass\ \times gravitional\ force$$

Equation 2

3.3 Evaluation of manual harvesting

The manual harvesting was evaluated, to determine the field capacity of the farmer work on the harvesting process at their planting area. This result was needed to be a benchmark for the lemongrass-harvesting implement when working in the field.

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Figure 8. Evaluating the harvesting process that were done by a farmer

Figure 8, shows the evaluation of the manual harvesting method that was done by a farmer. The evaluated process was done to determine the time consumed for harvested one clump of lemongrass. The process had been repeated five-times, all 5 samples were taken randomly on the field planting area.

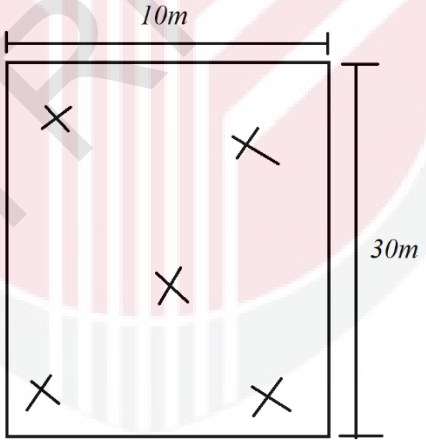

Figure 9. Pattern of choosing the sample for manual harvesting

Figure 9 shows, the point of collecting the chosen sample for the *Serai Gajah* variety. This method had been repeated with other varieties to evaluate their field capacity.

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3.4 Design concept of lemongrass harvesting implement

The design concept of the harvesting implement was the draft design. This concept was used to determine the function that was needed to make the implement could do a harvesting process.

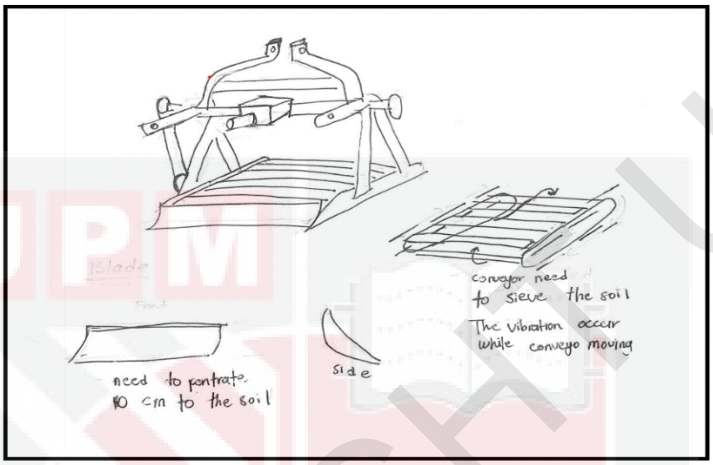

Figure 10. The draft of the design concept of harvesting implement

Figure 10 shows an image of drafting the implementation in the designing process. The idea of mechanization of this process focused on the blade, which needs to dig out the lemongrass. The blade needs to be able to penetrate the soil until it reached the root zone. Then, the conveyor part was designed to do a sieving process by vibration, it would separate the soil from the root of the lemongrass.

3.5 Design analysis of lemongrass harvesting implement.

Designing the implement was followed by the properties of the lemongrass. The working of implement was inspired by the disk plough and carrot-harvesting implement. It will be attached to the back of the tractor and was powered by PTO from the tractor. It will be dragged by the tractor to dig out the lemongrass from the soil.

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The working width of the implement was done on one row based on the planting distance of lemongrass. The digging angle range between 25˚ to 30˚ based on the carrot harvesting implement concept. All of the manual field performance aspects were needed to build a machine that could perform well in real used.

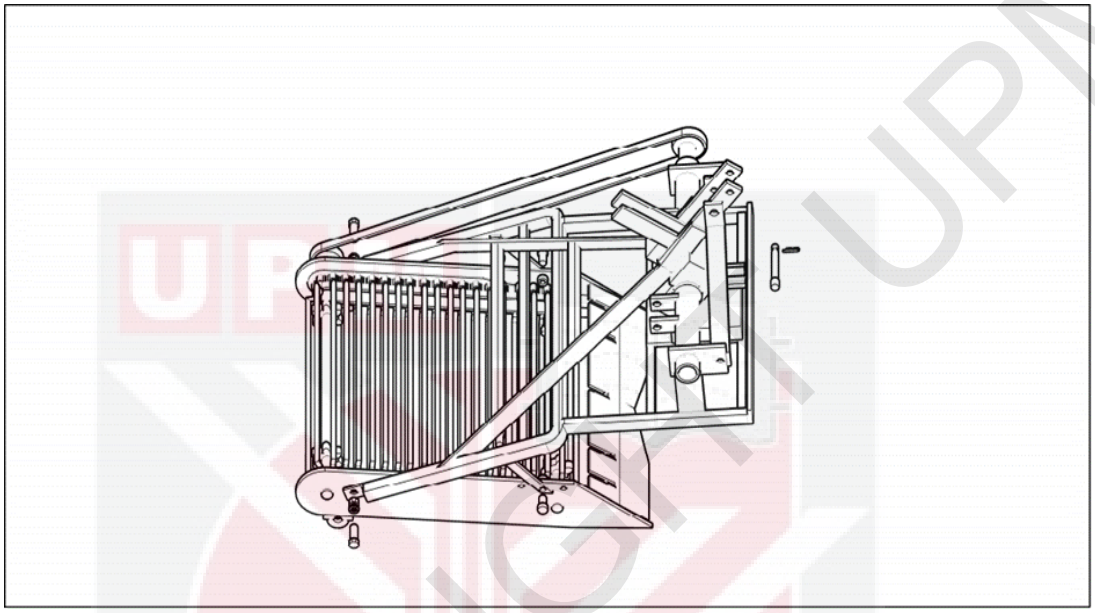

Figure 11. The design of harvesting implement

The maximum of the rotation that could be supported was 540 rpm. This implement will be dragged by a tractor and the conveyor was used as a separator to separate the lemongrass and soil.

3.5.1 Gearbox Analysis

In this project, the implement needs the power to move the conveyor, which means that the gearbox was needed to link the implement to the tractor by using a PTO. PTO was the rotation energy typed from the horsepower engine from the tractor. The gearbox was also known as the box containing the gear, it will alter the torque and

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speed from the PTO of the tractor. In the world, the PTO has two different types of speed only. The PTO speed has 540 rpm and 1000 rpm only. The value shows that the PTO maximum speed for the tractor. The more the value of PTO speed, it shows the greatest horsepower required of the tractor to support that speed.

In designing the implement, 540 rpm was chosen to work with this implement. It was because most of the tractors in Malaysia use the 540 rpm type only. This implement was also not necessary to get 540 rpm to work in the field.

Figure 12 Gearbox of the harvesting implement

The gearbox that was combined with the tractor was the used part of the old cultivator implement from Makmal Kejuruteraan Kertanian, UPM. This gearbox was modified because the rotation from this gearbox was clockwise. For this project, the gearbox need to rotate in anti-clockwise direction. This gearbox also had some specific function that was taken to be chosen for this project. The function of this gearbox not only changed the direction of the rotation, but it also used as a reducer of the PTO speed. The gear ratio for this gearbox was 1:2. From this, we could know the maximum speed that was produced from this gearbox.

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The ratio of gear

Driven: Driven

$1 : 2 = x : \ 540\ rpm$

$$\frac{1}{2} = \frac{x}{540\ rpm}$$

$x = 540\ rpm \ \div 2$

$x = 270\ rpm$

3.5.2 Pulley Analysis

Figure 13 Pulley used to transfer power from gearbox to conveyor

The pulley used to transfer the rotation from the gearbox to the conveyor chain. In this project, using the pulley system is better than using chain and gear because the maintenance of the gear and chain is overpriced rather than using pulley and belt. This project makes the pulley easier to change if the belt is already worn out.

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Using the pulley makes it easier to determine the rotation on the conveyor because the rotation of conveyor chain speed was 1:1 with output rotation pulley speed. In this project, the pulley will reduce the speed from the gearbox, which means the speed of the conveyor was slower from the gearbox, the radius of the driver was smaller than the driven. This makes the speed of the pulley to reduce. The radius of the driver pulley was 5 cm and the driven pulley was 10 cm. To find the max rotation speed of the chain conveyor, it could be determined by the pulley ratio. It stated like above, the ratio of the driven pulley was 1:1 with the speed of the conveyor; the power transmitted from the gearbox, the speed of the output gearbox also 1:1 with the input pulley. The ratio of driver pulley was 1:2. Form the calculation of gearbox ratio, the output speed of the gearbox was 270 rpm.

Pulley ratio

Driven : Driver

$1 : 2 = x : \ 270\ rpm$

$$\frac{1}{2} = \frac{x}{270\ rpm}$$

$x = 270\ rpm\ \div 2$

$x = 135\ rpm$

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3.5.3 Conveyor Analysis

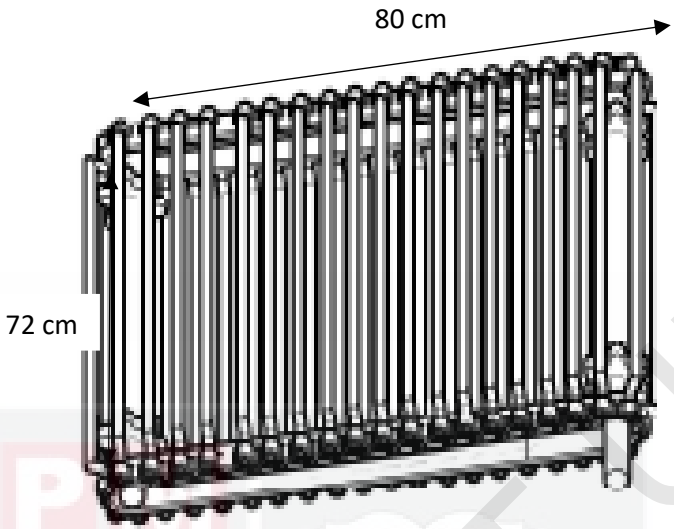

Figure 14 Chain Conveyor

In this implement, the chain conveyor was needed. This conveyor had several functions while working in the harvesting process. The first function of the conveyor was the common use of the delivery process of the material. This conveyor was brought the lemongrass from the blade into the backed of the conveyor. The second function of this conveyor was cleaning. It will do a cleaning process of the lemongrass, it was also known as a separator. It will separate the lemongrass from the soil due to vibration. The lemongrass will clean from the soil when it reaches the behind of the implement.

This conveyor was set up to vibrate while it rotating to make the separation process could occur. To make the conveyor vibrate, the chain needs to be loose, but if not too loose, the chain would be off-tracked from the gear. When it loses it makes

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the chain vibrate naturally while rotating. This natural vibrate will occur at high rpm. If the rpm of the conveyor was slow, the vibration cannot occur.

When the cleaning process occurs, the soil will separate from the lemongrass. The soil will break down in between the gap of the conveyor. The gap between the conveyors had a specific length. When it is too wide, it cannot hold the lemongrass on the conveyor. The gap width between the conveyor rods in this design was 3 cm. This gap allows the soil only to pass through due to gravitational force. In this study, the type of soil for lemongrass was very crumbled which makes it easy to separate from the root due to the vibrational force.

In the calculation of the pulley ratio, the speed of the conveyor chain was 1:1 with output pulley. The speed of the conveyor was 135 rpm. The power from the PTO of the tractor was reduced 4 times slower. The max speed of the conveyor was not fast to make the lemongrass thrown away from the conveyor. In the observation, the natural vibration occurred when the speed of the conveyor was more than 100 rpm. If lowered than that the vibration cannot be produced and the conveyor would stay rigid following the rotation of the gear.

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3.5.4 Blade analysis

Figure 15 Blade of the lemongrass-harvesting implement

The blade was a part to the digging work during the harvesting process. This blade will penetrate the soil until it reaches the root-zone of the lemongrass. The depth of the penetration to reach the root-zone, the blade needs to penetrate through the soil in the range of 10cm – 15cm. This model of the blade was designed for the bounded land of bris soil typed. This blade could work on the flat ground, if the blade was used in the uneven ground, the blade will break an effect directly to the body implement.

The shape of the blade was slightly curved, this design will make sure the lemongrass will be lifted to enter the conveyor area. The curve model of the blade also will slightly reduce the draft of the soil; because of the angle of the blade that touches the soil decreases. At the side of the blade had a small metal plate, it functions to block the soil when the digging process was thrown out beside the blade. This makes sure the lemongrass was lifted from the blade.

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The working width of this blade was followed from the result data of the inter-row of the lemongrass. In the fieldwork, the value of the inter-row of the lemongrass was 2 feet. The inter-row of the lemongrass had been determined; the suitable working wide for the blade was 29 inches, SI unit value of working wide of this blade was 73.6 cm. From the analysis, the implementation was suitable to work on one row at one time. The blade could be adjustable in terms of suitability of the depth of the blade to penetrate.

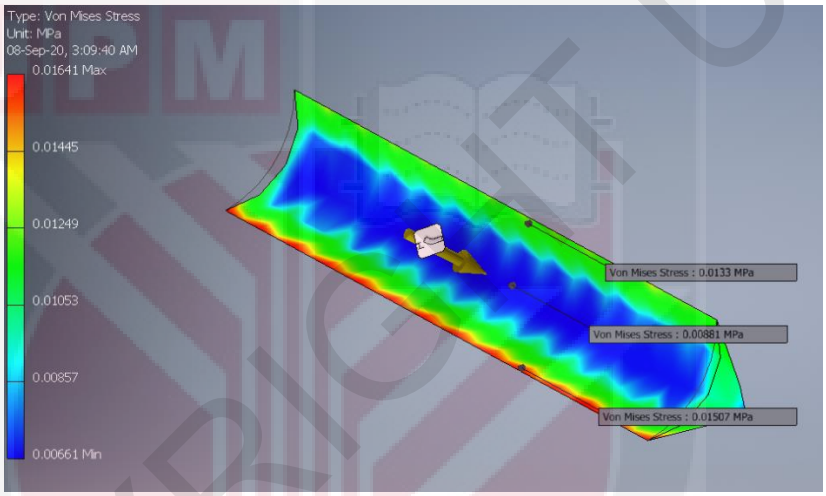

Figure 16. Blade stress test simulation

Figure 16, the simulation of the stress from von misses stressed predicted that the inside surface could endure the draft from the soil. 1.06 kN of the load had been applied to the red, the result had been shown as in Figure 16. The red area shows that the edge of the blade will break easily, in term endurance, this design of the blade will support the draft from the soil.

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3.5.5 Body Frame Analysis

The body frame was the structure of the implement to make the working part could be attached to the tractor and make it the implement could work well during the harvesting process. The body frame had its specification on the size of the material. In the body, frames had several parts with their function in this lemongrass-harvesting implement. The first part was the main body frame the second part was the supporting frame and adjustable frame.

3.5.5.1 Main Body Part

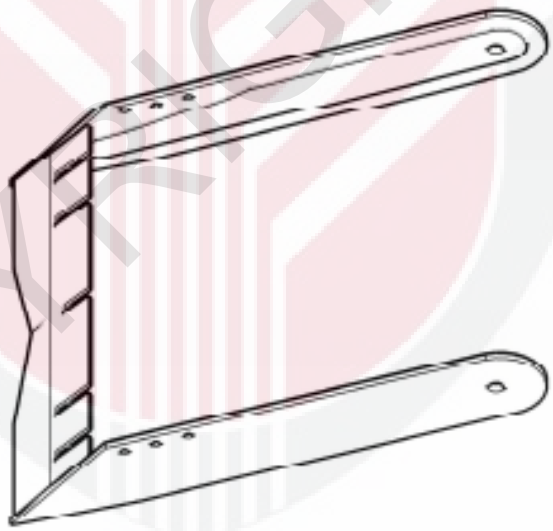

Figure 17 Main Body Frame

In designing this project, the main body frame was the base structure for the implement that make the place for the working part. The front body was placed for the blade in this harvesting implement to do the digging process for the lemongrass. The conveyor covered was to give structure to the conveyor and protect the conveyor

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from the foreign objected entered while harvesting process. This conveyor covered also protects the harvesting material from the thrown side when the cleaning and separating process occurs.

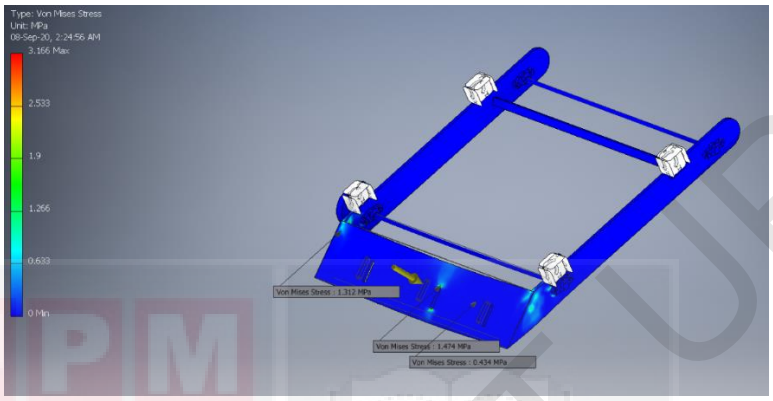

Figure 18. Simulation of Stress Test by Using Von Mises Stress analysis

By using a simulation of Von Mises Stressed analysis, by applying 1.06 kN of load that considers the mass of the estimated draft of soil, it shows that the critical pointed at the side of the frame, but it still could handle the stress.

The mainframe body thickness was 2 cm because 2 cm thickness of mild steel was very appropriate to give a solid structure of the implement. Two cm of the thickness of this mild steel also easier to get from the industry sector.

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3.5.5.2 Supporting Frame

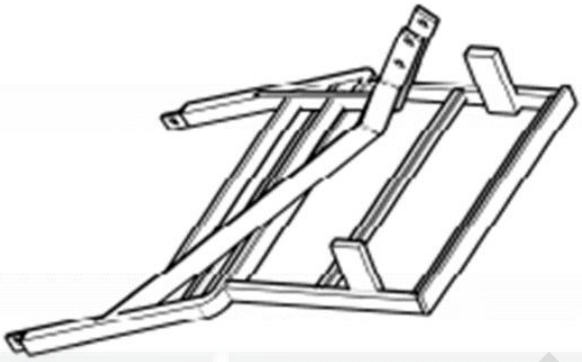

Figure 19 Supporting Frame

The second part of the main body frame analysis was the supporting part. The material of this beamed was mild steel. In this part, it consists of several structures beamed that give a supporting structure to the main body frame in this implement. The supporting frame had several functions in this lemongrass-harvesting implement. The first function for this part was the common structure-function, which was, give support for the implement. It will handle stresses occurring during the harvesting process. When the digging implement penetrate the soil to dig up the lemongrass, the draft will occur. The draft force of the digging type implement was larger, and this supporting frame will handle the stress from the draft force of the soil very well.

The second function of this supporting frame was to do the attachment job on the tractor. The supporting will be linked by using a 3-point linkage for the tractor. The range opening of the lowered pinned of this lemongrass-harvesting implement was determined; a range of opening of the lowered link will follow it from the tractor. The range of the opening lowered pinned of the implement was 65 cm. The thickness of this supporting frame was 1cm only. This beamed was easy to bend to make it

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easier to shape the structure from the proposed design. In this design, the supporting frame has not required a heavy metal. It because the support will not give a huge load that could make the main body in a stressed condition. The 1 cm thickness of solid steel was not easy to breakdown; this thickness could resist this implement harvesting duty.

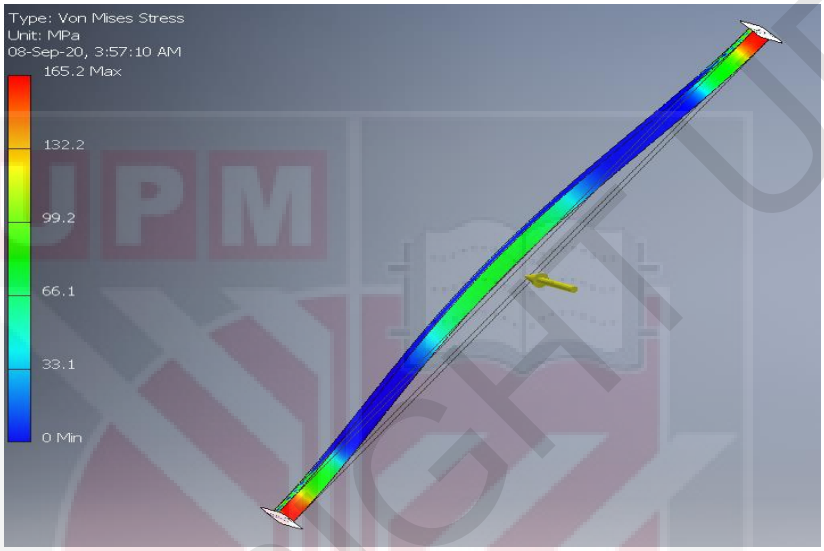

Figure 20. Simulation of the strength test of 1 cm beam

Figure 20 shows a simulation of a single beamed with a thickness of 1 cm. The load had been applied to the beamed was 1060 n. The result shows that bending will occur on the beam but it was very sturdy and hard to break. This test had been proving that this beamed was very suitable to be used in the design.

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3.5.5.3 Adjustable Frame

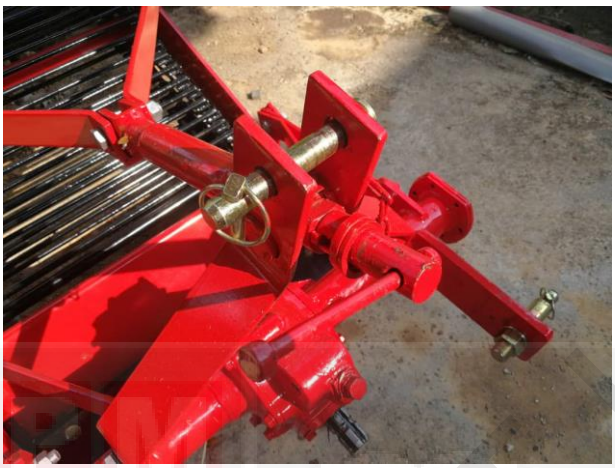

Figure 21 Adjustable of the angle body frame

The last part of the main body frame of the lemongrass-harvesting implement analysis was the adjustable part of the body frame. In this part, the adjustable was the function to control the structure of the body frame. This adjustable part of this frame body had several locations on this harvesting implement. Each type of adjustable mechanism had its function.

The first part of the adjustable mechanism was the linear actuator; this adjuster was a used part also. It was already attached on the gearbox before the modification, from this situation give an idea for the designing, the implement that could make the angle of the body frame could be adjustable. It could create a linear motion in a straight line from the circular motion. The type of this linear actuator was a screw typed, it the simple mechanism that could control the linear motioned of the shaft. The function of this actuator on this harvesting implement used to adjust the implement angle. The maximum angle of this implement was 65˚ and the minimum of the angle of this implementation could be achieved was 30˚.

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Figure 22 Adjustable blade length

The second location of the adjustable part was located on the blade part. On this part, the blade could be adjusted to make it long or short. The adjustment of the blade could be adjusting in 5.1 cm only. This adjustment in this design to make the blade of this implement could work in any type of soil. If the soil was easy to penetrate, the blade could make it short reduce the draft form the soil. If the implement needs to work on an undisturbed soil, it makes the surface of soil harder to penetrate, longer the blade of the implement could penetrate the soil and increase the depth of penetration of soil to reached the root zone of the lemongrass. It only uses bolt and nut to adjust the length of the blade. This means this part needs human help to adjust the blade. The operator work easier due to the suitability of their own land farm soil factor.

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Figure 23 Conveyor chain adjuster

The last location of the adjustable part in the lemongrass-harvesting implement was the conveyor chain adjuster; Figure 23 shows the physical appearances of the adjuster, it consists of a small nut and screw. The mechanism of this part was attached to the bearing of the conveyor shaft.

It functions to control the conveyor chain tightness. In this design, the conveyor needs a little looseness to make it vibrate for the cleaning process of separating the soil from the lemongrass. This adjustable mechanism could be adjusting the conveyor chain followed to the suitability of the implement condition. The adjustment of this mechanism was smaller in this design; by using the smaller bolt and nut could make a little adjustment for chain conveyor, it also makes the accuracy of the setting higher.

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3.5.6 Feeding chute of the lemongrass harvesting implement

The feeding chute was the area of the lemongrass from the soil that will be entered to be lifted and were sent to the conveyor part. This area needs to be determined to make sure the harvested lemongrass could be entered into the implement. To determine the suitable size of feeding chute, it could be done by finding the mean average of the height of the lemongrass at the field-testing.

Figure 24 Feeding chute of lemongrass harvesting implement

This was an area where the lemongrass will enter with the soil when the harvesting process. From Figure 24 the area of the entrance occurs because of the gearbox and gearbox shaft at the front of the harvesting implement, forming the area. This area was fixed and cannot be adjusted. If the entrance of the area were too small, the lemongrass cannot be entered, it will be stuck to the gearbox. When this happens it will make the soil will rollover because the lemongrass had been blocked and soil will be stuck to. This will make the harvesting process worse and the crop will damage. If the feeding chute was large enough, the process of digging the lemongrass becomes easier. This feeding chute will be tested in the field-testing either it suitable or not.

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3.5.7 Safety precaution design analysis

The designing the implement, a safety part need to be considered when designing the implement, it because of the implement need to handle by human help, if the implement malfunction without any safety precaution part that could be caused the human injury, that implements were very dangerous to use on the field. No operator was willing to work with the implement. This design only had several parts that were very dangerous that could be caused by accidents due to the mishandling of the implement. Not only that but this design also had a safety announcement to remind the operator of capable of this implement. If the usage of this implement exceeds their capacity limit could be caused by the failure of the implement. Figure 25 is the one part of the safety precaution in this design.

Figure 25 Pulley cover

Figure 25 shows the physical figure of the pulley cover. Its function is to cover the pulley from causing the injury to the operator when the pulley was rotating during harvesting, it also could be avoided damaging the crop at the other row. This cover was not a permanent part, it could be opened to doing a maintenance process on the pulley system. It was made from the bendable stainless steel and mash frame. This part

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was very light and not directly give the body frame when the implement doing the harvesting process.

Figure 26 Safety label

In Figure 26, it shows one of the safety labels that were stuck on the frame of the lemongrass-harvesting implement. This label gives reminder for the operator when handling this implement. The function of this label also tells the capability of the implement. The label in Figure 26 shows the gearbox capability in this implement. If the output rpm of the tractor exceeds 540 rpm, the gearbox will be damaged. This label is very important to keep this implement could stay longer to work on the field. The location of the label needs to be placed at the suitable location, to make the operator easier to saw and read. The label also needs to be an understandable context for the operator to understand the aim of the label. This was one of the methods of sustainability of this harvesting implement.

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3.6 Fabrication

Figure 27 Fabrication implement at EMDEK SDN BHD

The lemongrass-harvesting implement was sent *to EMDEK SDN BHD* to fabricate. They will determine the cost of the material. The list of the material will be followed as listed in the design material by our request. This fabrication also had some modifications and changes of the part due to lack of material requested, to make the lemongrass-harvesting implement working well. The fabrication of this implement took 20 days to finish.

3.7 Proposed the field evaluation for lemongrass harvester

The field evaluation will focus on lemongrass harvesting implement with a tractor. The parameter that needed to be evaluated was the field capacity of the tractor and field efficiency of the tractor. This parameter would show the effectiveness of the implementation to work on the harvesting process of lemongrass. The result would

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show the percent increase of efficiency in fieldwork on the harvesting process compared to the manual harvesting method.

3.7.1 Using tractor

In tractor operations, the lemongrass harvester would be attached to the tractor. The parameter that would be evaluated was the time operation of tractor per total area, time-consuming that the tractor was needed to complete the harvesting per area. This would determine the field capacity of harvesting lemongrass by using the lemongrass-harvesting implement. The speed of the tractor would be taken, to determine the slippage of the tractor when attaching the implement while working in the field. The fuel consumption would be taken for tractor operation, to determine the cost of fuel consumption while working for harvesting by using the tractor. Then observe the implement if it was not working like expectation and to record any failure that occurred during the field-testing.

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3.8 Determination the Field performance

As usual, the field performance of the tractor was calculated in terms of quantity per hour, and the performance was stated as total land operation total operating time. Common units that farmers used to determine their total area of planting area in hectares and acres. In this study, the unit to determine the land area was in hectares. The hectare was basically in 10 000 square meters which means it 100-meter length by 100-meter width.

The rate of field machine performance was determined by finding the field capacity in terms of land area per hour. The theoretical field capacity could be calculated if the speed of travel and effective width of the stripped for the machine was known as:

$$TC = \frac{SW}{C} \qquad \textit{Equation 5}$$

This equation shows the rate at which it will cover land if operated continuously for one hour. In actual field conditions, to determine the measure of a machineability were used Effective Field Capacity. It can be determined by calculating using this formula:

$$EFC = \frac{A}{T} \qquad \textit{Equation 6}$$

This equation shows the rate at which it will cover land if operated continuously for one hour. In actual field conditions, to determine the measurement of a machineability were used effective field capacity. It could be determined by calculating using this formula:

$$EC = \frac{EFC}{TC} \qquad \textit{Equation 7}$$

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Traction of the tractor and walking tractor need to be determined to evaluate the losses of the tractor due to the interaction of tire and soil. This parameter was called slippage. This could be calculated by using this equation:

$$Slippage = \frac{Vt - Va}{Va} \qquad \textit{Equation 8}$$

The equations mention that Vt was the velocity of a tractor on a hard surface and Va was the velocity of a tractor on the field.

3.9 Determination the fuel efficiency

Fuel efficiency was one of the parameters that need to be considered to evaluate the performance of the tractor. Getting a field efficiency needs to be considered in finding fuel consumption and fuel economy. Finding fuel consumption in terms of distance travel could follow this equation:

$$Fuel\ consumption = \frac{Amount\ of\ fuel\ used, L}{Distance\ travel, m} \qquad \textit{Equation 9}$$

The unit for fuel consumption was in liters. The value of the fuel usage when the operation of the tractor was the same value of the diesel was used to complete the harvesting operation by the unit. The distance travel was the distance of the tractor to complete the harvesting operation by unit km. The fuel consumption also could be determined in terms of unit area. It would be calculated as which means fuel consumption was the fuel usage that covers a certain area.

Fuel could be measured by the amount of fuel usage with the operation of time. Determination the fuel consumption of lemongrass harvesting implement with tractor

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would be taken from the operation on the field. The fuel tank for both tractors would be filled until its full capacity. After that, this tractor would be operating at the same time for each type of a tractor. After that, the fuel tank would be filled back 0.5 L by using a measuring cylinder until it is full on each type of the tractor. This would be repeated to be the next operation. The average fuel consumption would be divided into total time operation. The result of the calculation would show in liter per minute.

Fuel economy was the parameter that shows how far the distance travels in 1 liter of fuel usage. From this parameter, the farmer could determine the price of the fuel by finding the distance travel. The equation of the fuel economy could be shown as:

$$Fuel\ economy = \frac{Distance\ travel,m}{Volume\ of\ fuel\ used,L} \qquad \textit{Equation 10}$$

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3.10 Draft Estimation

The draft was one of the most important things to estimate the power needed to conduct the implementation well. Most of the draft estimation and calculation that had been made was summarized in ASABE Standard D497. 6 and the standard uses a simplified draft prediction equation proposed by Harrigan and Rotz (1995). The standard formula for draft prediction was:

$$D = Fi\ [A+B \times S + C \times S^2]\ WT$$

Equation 11

- D is implement draft, N
- F is a dimensionless soil texture adjustment parameter
- i = 1 for fine, 2 for medium and 3 for coarse textured soils
- A, B and C are machine-specific parameters
- S is field speed, km/h
- W is machine width, m or number of rows or tools
- T is tillage depth, cm for major tools, or equals one for minor tillage tools and seeding implements.

By using Equation 11, the value of draft estimation was 1060 N or to be simple, it was 1.06 kN. The draft estimation value had been applied on the soil depth at 10 cm. The typed of soil at field testing was sandy loam soil. The texture of this soil was coarse soils. The speed of tractor on the field testing was 10 km/hr with machine width 73.6 cm.

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CHAPTER 4
RESULT & DISCUSSION

In this chapter, the result from the experiment and testing in this studied was discussed further. The discussion described the result of the physical properties of the several verities of the lemongrass in the field. The properties of the lemongrass discussion will include the biomass of the lemongrass. Then, the effective field capacity of the manual harvesting method of lemongrass would be described to shows the result of this studied. This result would be used to give the idea and to be used to design the lemongrass-harvesting implement that would be attached to the tractor, the implement would be used for the harvesting process of the lemongrass more effectively.

This chapter also will describe the mechanical harvesting process of the field-testing result. It was tested to see the effects of this lemongrass harvesting work in the field. After the field testing, the implementation was not working like the expectation. Comparison of the mechanical evaluation with manual evaluation cannot be achieved. The reason for this will be described more in the mechanical harvesting process section.

This unexpected outcome from the mechanical testing will describe the new proposed design. The modification of the design will be followed based on the mechanical result to improved the implementation. The improvement to make the implement could work well on the field and could be used for the small farmer.

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4.1 Physical Properties of the lemongrass

The physical properties of the lemongrass data in this studied very important, need to be used for designing the lemongrass-harvesting implement. It was also used to determine the suitability of the implement could work efficiently on the field. This study will cover three main varieties in the context of the data of physical properties and the biomass of the lemongrass. This, three main varieties usually were very popular variety among the smallholder farmer and were planted by them to be commercialized used. This statement was confirmed by the once smallholder farmer of lemongrass at Lenggeng, Negeri Sembilan.

4.1.1 Lemongrass Variety, *Serai Peha Ayam*

Table 1. Length of Clump, Peha Ayam variety

Length of Lemongrass	Min.	Max.	Avg
Overall (cm)	139	145	141.8
Roots (cm)	10	15	12.6
Rhizome (cm)	36	43	39.4
Leaf (cm)	87	92	89.8

The variety of *Serai Peha Ayam* is the most popular variety of lemongrass among the farmer, this variety always was used to be planted as their commercial crop for lemongrass. Five samples of the lemongrass were taken randomly in a one-acre area of lemongrass. Table 1, shows the maximum size of the lemongrass can go up to 145 cm and the minimum size of the lemongrass was 139 cm. Then, the average overall size of the lemongrass from this sample was 141.8cm height. The roots of the

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lemongrass are fibrous type, based on table 1, the maximum depth of the root it can go to 15 cm. The minimum length of the root of this sample was 10 cm. The average of this root depth was 12.6 cm. The rhizome part of the lemongrass also known as the edible part can be obtained at 43 cm, the maximum length of that part, based on table 1. The minimum for the rhizome length in this sample was 36 cm. It will give the average of the rhizome length for this variety was 39.4 cm. The leaf part, the longest part of the lemongrass's physical properties. The minimum length of the leaf on this variety was 87 cm. The maximum length for the leaf part was 92 cm, the result shows the average value of the leaf part was 89.8 cm.

Table 2. Biomass of Peha Ayam

Biomass of Lemongrass	**Min.**	**Max.**	**Avg**
Stalk (pcs)	59	65	61.6
Overall (kg)	5.5	6.2	5.92
Roots (kg)	0.9	1.2	1.08
Rhizome (kg)	2.9	3.2	3.08
Leaf (kg)	1.6	2.1	1.79

The biomass of the lemongrass is to determine the total mass of every part in this variety. The total weight of this variety for minimum weight was 59 kg; the maximum weight for this variety based on table 2 was 65 kg. This makes the average weight this variety was 61.6 kg. The range of the weight of the roots for *Peha Ayam* variety was 5.5 kg to 6.2 kg. The average value of the weight of roots was 5.92 kg. The most weight of all the parts is the rhizome part, the weight of this part in the range of 2.9 kg to 3.2 kg per clump. The average weight that was harvested was 3.08 kg per clump. The leaf of lemongrass also needs to be weighed to determine the total mass of the leaf in one clump. The range of the leaf weight of *Peha Ayam* in one clump around

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1.6 kg to 2.1 kg. The average value of the weight of the leaf for this variety was 1.79 kg. Then, *Peha Ayam* lemongrass can produce 59 to 65 pieces of the stalk in one clump of the lemongrass. The average value of stalk in one clump of lemongrass was 61.6 pieces.

This data can be shown as percentage value, which makes it easy to understand. The data of the length and weight in percent are shown in Table 3.

Table 3. Average percent of one clump of Peha Ayam lemongrass

Percent in one clump	**Roots**	**Rhizome**	**Leaf**
Length	9 %	28 %	63 %
Weight	18 %	52 %	30 %

Table 3 shows that the *Peha Ayam* variety has 63% length of the leaf with only 30 % of the total weight of one clump lemongrass. The rhizome is one of the parts that contain the highest percent of the weight with 52% from the total weight of the clump but it sizes only 28% from the total length of the length clump. The last part is the roots part with a length of 9% from the total length of the length clump. This 9% percent is the average length of their root zone for *Peha Ayam* variety with 18% of weight from the total weight of the clump.

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4.1.2 Lemongrass Variety, *Serai Gajah*

Table 4. Length of Clump, Serai Gajah variety

Length of Lemongrass	Min.	Max.	Avg
Overall (cm)	150	161	156.2
Roots (cm)	10	12	11
Rhizome (cm)	33	38	36
Leaf (cm)	101	116	109.2

The next variety of lemongrass was *Serai Gajah*. *Serai Gajah* was the taller variety among the sample. Based on Table 4, five clumps of the sample were taken from the planting area. This lemongrass can be grown at the range of 150 cm to 161 cm tall. The average growth length of this species in the planting area only 156.2 cm. The root can grow from 10 cm until 12 cm long. The average root length of this species was 11 cm long. The rhizome part, which is the edible part of lemongrass, it was big and long enough from 33 cm to 38 cm long. Mostly harvested rhizome length on an average of 36 cm. The result shows that the leaf for this variety is long enough more than 1m. The leaf was long from 101cm to 116 cm long. The average length of this leaf was 109.2cm. This root zone of this variety was 11 cm. The digger needs to penetrate the soil from 10 cm to 12 cm long.

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Table 5. Biomass of Serai Gajah

Biomass of Lemongrass	Min.	Max.	Avg
Stalk (pcs)	36	46	39.8
Overall (kg)	4	5	4.4
Roots (kg)	0.5	0.6	0.54
Rhizome (kg)	1.9	2.4	2.08
Leaf (kg)	1.5	2.1	1.78

Based on the result in Table 5 it has shown the biomass of the *Serai Gajah* variety. The mass of this variety can reach from 4kg to 5 kg. The average mass it can grow will reach 4.4 kg. The mass of roots growing in the range of 0.5 kg to 0.6 kg. The average weight of *Serai Gajah* can reach 0.54kg. The edible part of the lemongrass, which is the rhizome part, was mass from 1.9 kg minimum and 2.4 kg maximum it can reach. The average mass value for this variety can reach was 2.08 kg. The weight leaf of *Serai Gajah* can go to 1.5kg per clump for minimum and can go to 2.1 kg per clump for maximum weight. The average mass of the leaves was 1.78 kg per clump. In this variety, it can produce 36 pieces to 46 pieces of the lemongrass stalk in one clump. The average stalk of one clump can produce was around 39.8 pieces of the lemongrass stalk.

Table 6. Average percent of one clump of Serai Gajah lemongrass

Percent in one clump	Roots	Rhizome	Leaf
Length	7 %	23 %	70 %
Weight	12 %	47 %	41 %

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The results from Table 6 show that the roots have 7% with weight 12% from their overall length and mass of the clump. Because the roots are a very small size and very light because the fibrous root is not heavy. The rhizome part for the *Serai Gajah* variety shows that 23% of the length of the clump is the rhizome part. The weight of the rhizome part shows 47% of the total weight of the clump of lemongrass. This part is very heavy because this part area very thick and solid compared to leaves and roots. The leaf of this species can reach 70% of the total length of the lemongrass. The weight of the leaf is 41% from the total weight of the clump of the *Serai Gajah*.

4.1.3 Lemongrass Variety, *Serai Kampung*

Serai Kampung is the most common variety that was used for cooking in Malaysia. This variety was easy to get and to grow this variety easier. The size of the clump is the smallest compares to the other variety. The data had been shown in Table 7.

Table 7. Length of Clump, Serai Kampung variety

Length of Lemongrass	**Min.**	**Max.**	**Avg**
Overall (cm)	111	125	117.6
Roots (cm)	20	26	23.4
Rhizome (cm)	30	36	32.6
Leaf (cm)	56	69	61.6

The *Serai Kampung* can grow around 111 cm and 125 cm. This variety shows that it can grow in average at 117.6 cm length. The root length of this variety can reach 20 cm until 26 cm. it shows that the average of the length of the roots in one clump is 23.4 cm long. The rhizome part was between 30 cm to 36 cm. long and the average

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size of the rhizome part in one clump was 32.6 cm. The leaf part is the longest, the leaf *Serai Kampung* can reach up to 56 cm until 69 cm long. The average of the length's leaf was 61.6 cm.

Table 8. Biomass of Serai Kampung

Biomass of Lemongrass	**Min.**	**Max.**	**Avg**
Stalk (pcs)	40.00	60.00	51.40
Overall (kg)	1.00	1.30	1.14
Roots (kg)	0.10	0.30	0.19
Rhizome (kg)	0.67	0.90	0.82
Leaf (kg)	0.10	0.15	0.13

Based on the result in Table 8 it shows the biomass of the *Serai Kampung* variety. The mass of this variety can reach from 1kg to 1.3 kg. The average mass it can grow will reach at 1.14 kg. The mass of roots growing in the range of 0.1 kg to 0.3 kg. The average weight of *Serai Kampung* can reach 0.0.19kg. The edible part of the lemongrass, which is the rhizome part, was mass from 0.67 kg minimum and 0.9 kg maximum it can reach. The average mass value for this variety can reach was 0.82 kg. The weight leaf of *Serai Kampung* can go to 0.1 kg per clump for minimum and can go to 0.15 kg per clump for maximum weight. The average mass of the leaves was 0.13 kg per clump. In this variety, it can produce 40 pieces to 60 pieces of the lemongrass stalk in one clump. The average stalk of one clump can produce is around 51.4 pieces of the lemongrass stalk.

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Table 9. Average percent of one clump of Serai Kampung lemongrass

Percent in one clump	Roots	Rhizome	Leaf
Length	20 %	28 %	52 %
Weight	17 %	72 %	11 %

Table 9 shows the result of the average percent of one clump in length and the weight of the *Serai Kampung* variety. The *Serai Kampung* variety has 52% length of the leaf with only 11 % of the total weight of one clump lemongrass. The rhizome is one of the parts that content with the highest percent of the weight with 72 % from the total weight of the clump but it size only 28% from the total length of the length clump. The last part is the roots part with a length of 20% from the total length of the clump. This 20 % percent is the average length of their root zone for *Serai Kampung* variety with 17% of weight from the total weight of clump.

4.2 Evaluation of manual harvesting process field testing result

The evaluation of manual harvesting was evaluated. This evaluation will be comparing manual harvesting with mechanical harvesting in terms of field performance and working efficiency. It will be tested on each variety.

The process to determine the field capacity of the lemongrass, need to find the size of the planting area of lemongrass and time consuming of the worker to complete the harvesting process of the lemongrass in the planting area. To get the completing time of the harvesting process in the area, need to determine the population of the lemongrass in the planting area. After that, find the average time needed for workers to complete harvesting for one clump of lemongrass. The result of each field capacity was recorded like below.

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4.2.1 Peha Ayam

Table 10. The evaluation of the lemongrass (Peha Ayam)

Population of the lemongrass (clump)	5000
Avg. time needed for harvesting one clump (s)	76.4
Time taken to complete harvest in area (hr)	106.1
Total planting area (ha)	0.4047
Field capacity of harvesting lemongrass (ha/hr)	0.0038

The variety of *Peha Ayam* was planted on the field with an area of 0.4047 ha. The plant population of in this area contain 5000 clump of lemongrass with crop distance 0.9 m by 0.9 m. Harvesting one clump of lemongrass average time takes 76.4 s, the work of cleaning the soil from the root by shaking the clump also include in the average time harvesting process. This given the field capacity of the manual harvesting for *Peha Ayam* was 0.0038 ha/hr, which means the worker, can cover in harvesting the lemongrass for one hour.

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4.2.2 Serai Gajah

Table 11. The evaluation of lemongrass (Serai Gajah)

Population of the lemongrass (clump)	850
Avg. time needed for harvesting one clump (s)	71.6
Time taken to complete harvest in area (hr)	16.9
Total planting area (ha)	0.03
Field capacity of harvesting lemongrass (ha/hr)	0.0018

The variety of *Serai Gajah* was planted on the field with an area of 0.03 ha. The plant population of in this area contain 850 clump of lemongrass with crop distance 0.6 m by 0.6 m. Harvesting one clump of lemongrass average time takes 71.6 s, the work of cleaning the soil from the root by shaking the clump also include in the average time harvesting process. This given the field capacity of the manual harvesting for *Serai Gajah* was 0.0018 ha/hr, which means the worker, can cover in harvesting the lemongrass for one hour.

4.2.3 Serai Kampung

Table 12. The evaluation of lemongrass (Serai Kampung)

Population of the lemongrass (clump)	600
Avg. time needed for harvesting one clump (s)	52.6
Time taken to complete harvest in area (hr)	8.7
Total planting area (ha)	0.022
Field capacity of harvesting lemongrass (ha/hr)	0.0025

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The variety of *Serai Kampung* was planted on the field with an area of 0.022 ha. The plant population of in this area contain 600 clump of lemongrass with crop distance 0.6 m by 0.6 m. Harvesting one clump of lemongrass average time takes 52.6 s, the work of cleaning the soil from the root by shaking the clump also includes in average time harvesting process. This given the field capacity of the manual harvesting for *Serai Kampung* was 0.0025 ha/hr, which means the worker, can cover in harvesting the lemongrass for one hour.

4.3 Evaluation of mechanical harvesting process field testing result

The evaluation of the mechanical harvesting process could not be done in terms of field performance and fuel efficiency because the implementation was not working as expected. The implementation failure came from several factors while doing the testing. The factors had been listed down to be used to redesign the harvesting implement to make it work on the field effectively based on the observation of field-testing. The factors that caused the implement failure during testing were the soil factor and the failure from the implement.

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4.3.1 Soil factor

In this discussion, the soil factor gave a big impact on the implementation of failure while field-testing because the soil in the testing area was not suitable for this implement since the field area was not well prepared.

4.3.1.1 Unploughed soil

The soil from the testing area was not ploughed. This means the soil was very compact and hard, even though it was a sandy loam soil type. It made the soil were hard to penetrate, even the blade can penetrate the soil, the draft of soil very high compared to the ploughed soil. The ploughed soil would make the soil become fine texture of the soil, and would help the process of the digging become easier. It also would help the separation process of the soil from the root of lemongrass more efficient. The design of this implement work well and suitable for the ploughed soil type only. The commercial planting activities would do well with land management before planting the crop.

4.3.1.2 Levelling soil of field testing area

The other reason for the soil factor causing the harvesting implement failure during the field-testing was the soil surface. On the testing area, the soil surface was not level and had a small pit on the lemongrass planting area.

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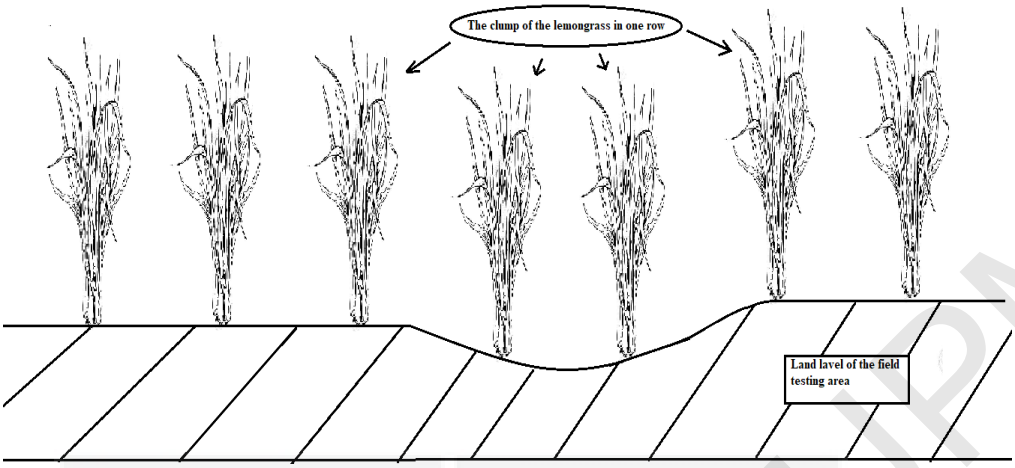

Figure 28 Illustration of the pit in the row of lemongrass on field testing area

Figure 28, shows the illustration of the condition of the soil level at field-testing, it had a small pit in the row of the lemongrass. The blade of the harvesting implement would destroy the rhizomes of the lemongrass that was planted on the pit surface. The destroyed lemongrass would be stuck at the feeding chute causing the next lemongrass unable to move to the conveyor causing a mess at the feeding chute of the implement. This pit could also cause the shock on the implement because the draft at a high level drastically increased. The reason this occurred because of no good preparation of land management before planting the crop. This implements was not suitable to work on unlevelled soil. Land preparation before planting the lemongrass is required to solve this problem.

The last factor from the soil was the soil type. This machine could work well in the sandy loam soil because it was designed to work on this soil type. The study stated that this crop could be grown at any type of soil, but this crop can grow effectively on the sandy loam type soil. According to the smallholder farmers at Lenggeng, he stated that some planting areas of lemongrass at Lenggeng were not sandy loam soil. He also stated that this machine could not operate at a different type

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of soil other than sandy loam type. This shows the weakness of this implement in terms of suitability working in the different types of soil. This weakness can be overcome with the redesign of this harvesting implement.

4.3.2 Implement Factor

The implement factor also gives a reason for the failure in field-testing. This causing the implement cannot work in the field, it is because of the implement design had some unsuitable parts that used in this study. Some parts were not functioning on the implement and it can be replaced with other parts to improve their functionality. In this section, this discussion will describe the failure that occurred caused by the implement, describing the detail at certain implement part causing the failure and improving the design for this harvesting implement.

4.3.2.1 The blade

The blade is an important part to do a digging job for this lemongrass-harvesting implement. This blade will penetrate the soil to lift the lemongrass. The field-testing shows that the blade was not able to penetrate the soil, like the concept study. This is because the concept study only shows the ideal condition of the soil and this implement can work in that condition. The angle of the blade was not very effective causing the blade to fail to penetrate the soil. The digging of the blade was not depth enough to pull out the lemongrass from the soil.

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4.3.2.2 The adjuster

The adjuster that was attached in this experiment did not have any functionality for this harvesting implement. The adjuster part that caused a problem in this section was the linear actuator. The part could control the angle of the implement body frame. The main reason for attaching this adjuster was to study the most suitable angle for this implement. Reducing the length of the adjuster, the angle of the implement from the ground level would increase, while increasing the length adjuster, the angle of the implement body frame would decrease. The adjuster was not agronomic and hard to be used while the implement attached to the tractor. This made the testing the suitable angle quite hard because when in use, the adjuster stuck to the upper link of the tractor, to adjust the angel it needed to open the upper link to turn the adjuster.

4.3.2.3 Stopper

The stopper was used in this design to become a stopper of the frame to keep in their position. It functioned in to maintain their angle of body frame. The problem that happened in this part was the stopper failed to maintain the body frame. The body frame became unstable cannot maintain their position; made the frame could not do the digging process. This occured because of the stopper had broken because the size of the stopper could not hold the stress force while digging process. The investigation showed that the size of the stopper was too small and could be seen by a naked eye, the stopper was not strong enough and easy to brake. The second reason for the failure to occur on the stopper was the welding was not good enough.

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The welding was too thin at certain parts to make that part easy to break. The stopper was a very important part to make the body frame in a good position, because the digging process need the rigid body of the frame to make the blade easy to break the soil.

4.3.2.4 Hinge factor

The hinge functions as to make the frame body turn into the setting position. The hinge was used in the design to allow the movement of the angle of the body frame; it would allow the movement from the linear actuator to set the frame body angel. The hinge consisted of bolt and nut only. Hinge also functioned to lock and connect the part into another part. The problem that occured in the hinge was that it could not hold the position of the body. The hinge allowed the body to move. In this harvesting implement, the supporting frame was too much of a hinge. That made the body move freely. This occurred because the stopper was not functioning well. It made the body move freely even the screw had been too tight. The force from the digging operation made the frame move out and the hinge would make the body frame move away to the direction of the reaction force.

4.3.2.5 Feeding chute

The feeding chute is the area where the lemongrass would enter after the digging process to move to the conveyor. The feeding chute of this implement was fixed and couldnot be adjusted. The area can be seen in figure 11. The problem with this occuring was too small. It made the lemongrass difficult to move to the conveyor area. It occured because of the lemongrass was stuck on the gearbox shaft and pull out

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the lemongrass away from the feeding chute. It stuck because the leaves of lemongrass were too thick when it stuck together, this caused the lemongrass was blocked to enter the feeding chute. When the lemongrass was pulled away, the next lemongrass also would stick. Then it would repeat to the next lemongrass. The worst failure of this was the soil that was dug out would roll over with the lemongrass. The lemongrass was harmful; the harvesting of lemongrass could not be done.

4.4 Proposed a new design

After field-testing, the prototype of the lemongrass harvesting implement was not enough to do the harvesting process and needed to be improved in terms of designing the implement. It is because the failure of the implementation mostly occured because of the weakness of the implementation. On the field-testing, the result gives an indication part in the implementation causing the failure in the harvesting process. The part that caused this has been discussed in the previous section. The new design was based on improving and upgrade the efficiency of the lemongrass harvesting implement. It also had some parts that were removed in this implement, because it was not very practical to be used in this implement. The new design was drawn by Autodesk Inventor application.

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Figure 29 The New Design of Harvesting Implement

The lemongrass-harvesting implement was redesigned to improve the performance and make it work well in the field. Figure 16, shows that the new design that was improved in term of functionality and the weakness from the old design. The implement working width was still the same as the old design version. This design also needs power from PTO with 540 rpm for the maximum rated speed for this implement. The changes that occurred from the old design only on several parts.

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4.4.1 The Blade

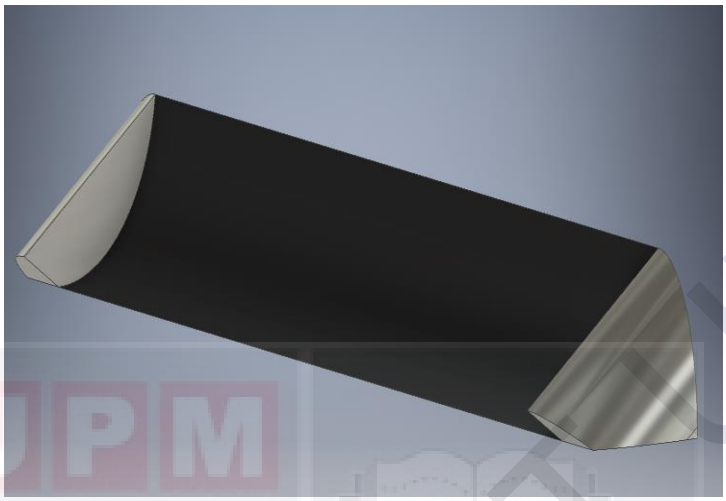

Figure 30 The Blade

The blade for this implement needed to be upgraded to increase the efficiency of digging the soil. The problem on the blade was not enough depth into the soil. In this design, the length of the blade had been increased to 2 cm. The penetration angle of this blade was set to 25˚ to 30˚ This was enough to reach the root zone of the lemongrass, which made it easier to pull out the lemongrass from the soil. The curve of the blade was still the same as the old pattern from the previous design. In this design, the improvement in term of functionality, the blade guard at the side of the blade from the previous design like figure 5, it functions to block the soil from thrown out from the side of the implement. This new blade design, the guard at the side of the blade were changed to another design to improve their functionality and add other functions while doing the harvesting process. The guard is also known as a tight end, which was changed from the flat pattern to curve design.

The function of that curve was to create a path by pushing away the next crop out from the path of working implement without damaging the crop. The surface of the curve tight end was made smooth, the suitable material for construct this part was

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a stainless steel plate because the stainless steel plate easier to bend and it has a smooth surface. It also gives marking to the soil to make the operator that driving the tractor can saw the previous path for lining the implement at the next harvesting path.

4.4.2 The Hinge and The stopper

The old pattern of the previous design of the hinge and the stopper made the implement become in the worst condition. The old design made the body frame could not stay in the position setting. The new design for the hinge and the stopper was no longer needed, this part was removed from the new design. This means the body frame would not be able to move, it would stay on the position permanently. This made the adjustment of the angle of the body frame no longer functioning. The angle adjuster still on the design if the adjuster were needed for future purposes. The harvesting implement needed the angle to make the digging process. The angle was designed below 45˚, to reduce the draft and hard to lift the lemongrass to enter the conveyor area trough feeding chute. Even the angle was too high causing the feeding chute to become small.

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Figure 31 The supporting frame

Figure 31 shows that all the screws on the supporting frame were removed from this design. Joining all the parts in this frame was used the full welding method. The entire join would be stuck together and become stronger to hold the stress compared using the hinge and stopper. This made the position of the body frame fully locked and could not be move anymore.

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4.4.3 The Feeding chute

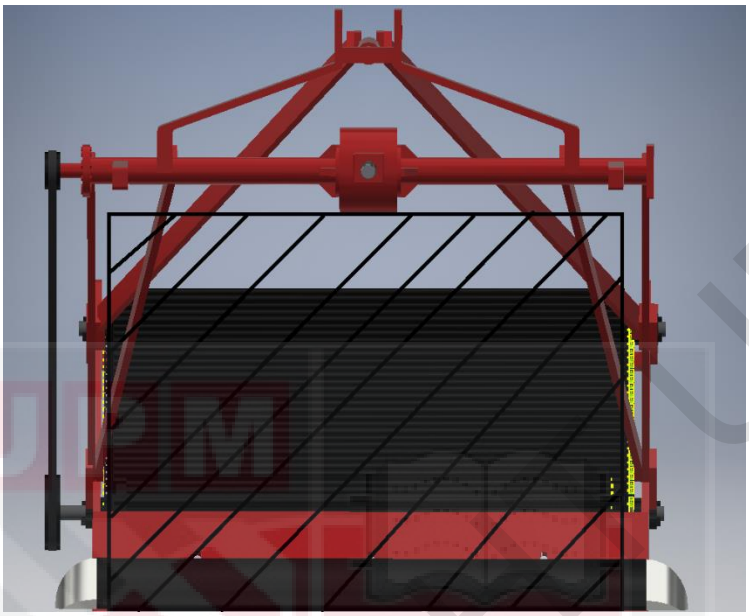

Figure 32 The feeding chute of new design

The feeding chute was very important in this implement to be the harvesting implement because the feeding chute would allow the crop to enter the conveyor part after the digging up the crop. In the previous design, the feeding chute was too small for the lemongrass to enter into the implement. The area of the previous design is shown in Figure 24. The failure that caused during the field-testing makes the lemongrass and the soil rollover because the area was not enough to make the lemongrass enter the implement. In the new design, the feeding chute had been expanded to follow the size of the lemongrass height. The height of this entering was 60 cm from the below gearbox to the blade and the width of the feeding chute followed the working side of the blade measurement. The new feeding chute of this design was shown at below.

$$The\ Feeding\ Chute\ Area = Height\ \times Length$$
$$= 60\ cm\ \times\ 73.6\ cm$$
$$= 4416\ cm^2$$

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CHAPTER 5

CONCLUSION

In this study, it can be concluded that in designing the lemongrass harvesting implement need to consider the physical properties of the crop for different varieties, because different varieties will give the different situation on-field performance. The information from this study will give the best design concept idea for designing the implement. All functionality of the implement can be followed based on the information on the physical properties of the lemongrass.

The small farmers around Lenggeng, Negeri Sembilan, Malaysia planted 3 different varieties in their field. The different variety of the lemongrass had different usage, functionality, and different market to be distributed. The variety was found around Lenggeng farmer, the most variety of lemongrass planted was *Peha Ayam*, most of them planted this variety in large-scale area. The variety most popular among the consumer for cooking was *Serai Kampung* because it had a strong odor to make the cooking smell more delicious. The large variety among three verities in this study was *Serai Gajah* variety with an average height of the lemongrass as 156.2 cm. It has long left and big size of rhizome but the odor of this variety is not much.

This study had determined the suitable root zone for the digging process in lemongrass harvesting. The result shows the variety of *Peha Ayam* had a 12.6 cm depth average, while *Serai Gajah* was 11 cm, the average value of root length, for S*erai Kampung* had 23.4 cm long, the deepest of the root zone. The suitable digging depth for this implement to penetrate the soil was 10cm to 13 cm into the soil. If the blade penetrate deeper the draft will increase. The suitable shape of the digger needed to be slightly curved to reduce the stress force of the blade to reduce the draft force.

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The manual evaluation result showed that the range of field capacity was done by workers from 0.0018 ha/hr to 0.0038 ha/hr. The result showed that the hardest variety to harvest was *Serai Gajah*. It took 0.0018 ha in harvesting the lemongrass for one hour only. The longest time to harvest was the *Peha Ayam* variety, it tooks 76.4s to complete the harvesting process for one clump. Estimation of doing harvesting and cleaning process by using harvesting implement could be done around 10s to 20s for one clump of lemongrass. It showed that using the harvesting implement was more efficient.

The field evaluation of manual and mechanical had been recorded. However, the result showed that the mechanical method could not be evaluated because of several factors mainly due to the implement and soil. Therefore, the field evaluation of this implement could not be performed. The initial design was modified and improve into a new design. The implement were not suitable to work on undisturbed and undulating type of soil.

To make this harvesting implement more efficient, the new design had been developed, by improving the functionality of the design. The changes in the part occur in the designing process. It can be concluded that the new design would solve the problem that happened in the previous design. It considered the parts that failed to function in field-testing.

In summary, the determination of the physical properties and manual harvesting of the lemongrass had been achieved successfully. The mechanical evaluation method on the field testing shows the unexpected result due to the limitation of field testing. the designing the new harvesting implement for the small farmer in

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lemongrass planting could improve their efficiency of the harvesting process and help them to maximize their fieldwork in the harvesting process.

5.1 Recommendation

After working in this study, several suggestions and recommendation can be stated for helping the future researchers to continue and develop this project. The recommendations are as follow:

1. Focus on the blade design to get the blade that can do a digging process more efficiently.
2. Create the own field testing near UPM to make it easier to manage and do field testing.
3. Improve in the soil factor analysis to get the proper draft estimation to be used in designing the lemongrass harvesting implement.

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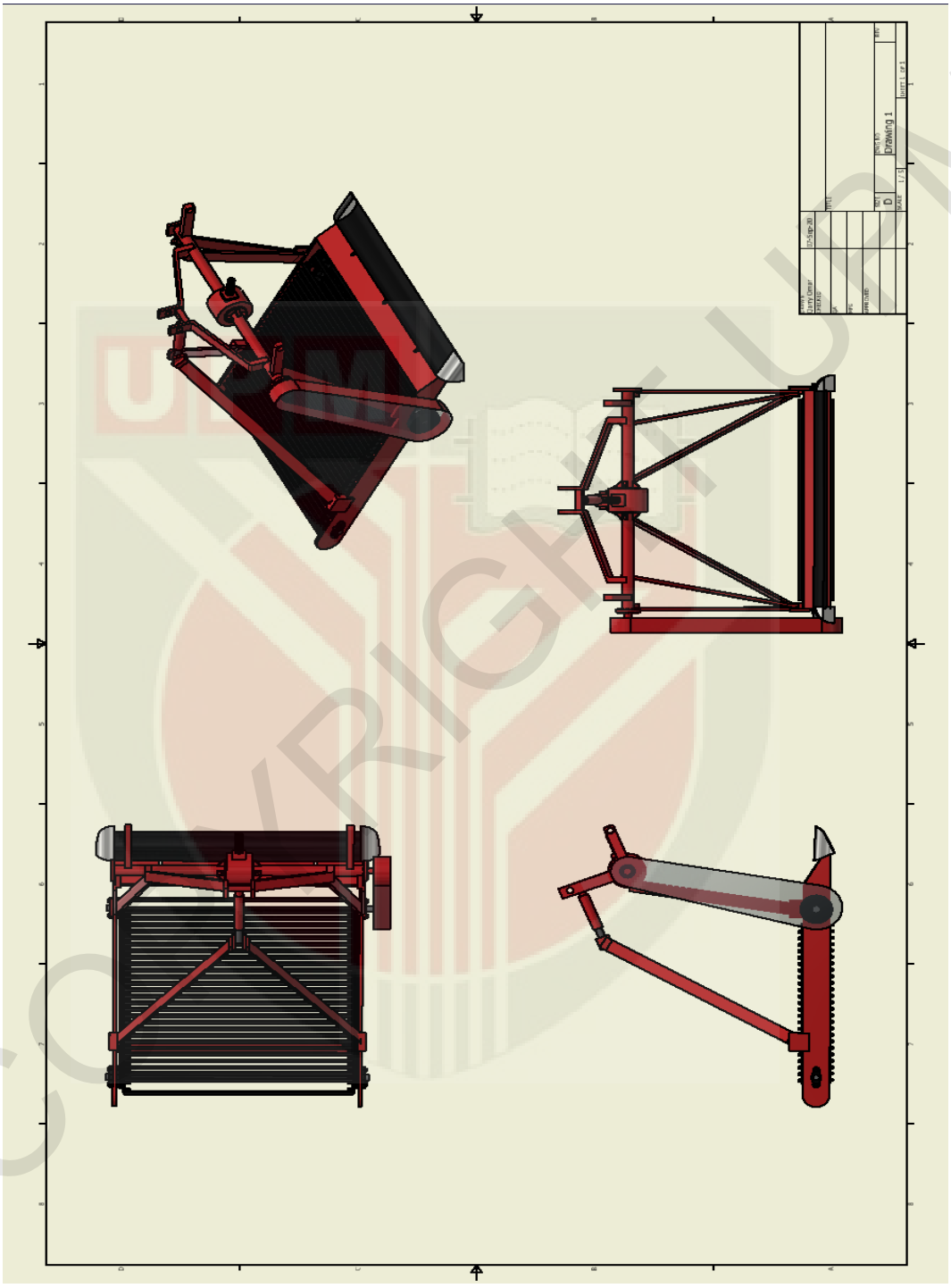
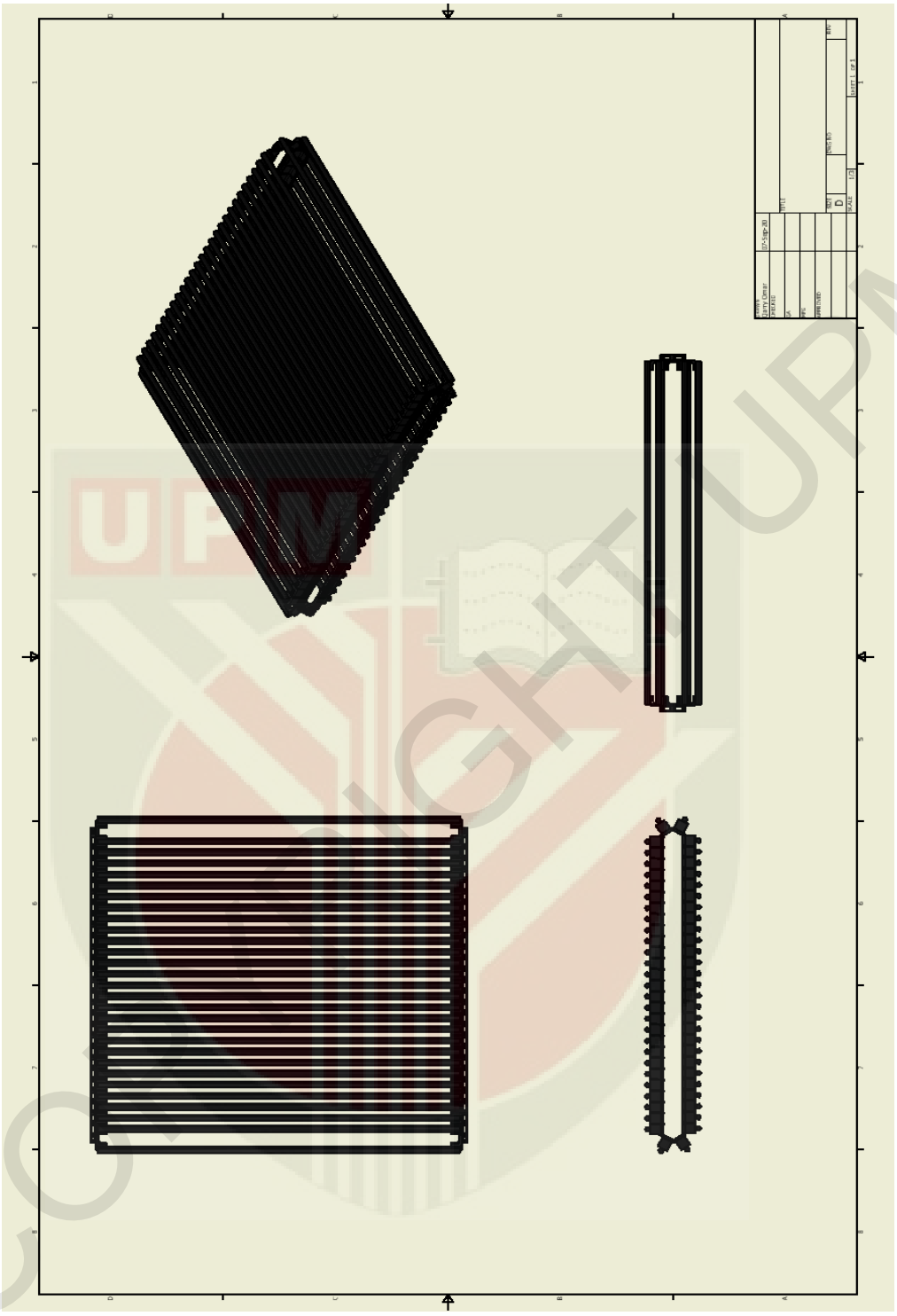
APPENDIX A

New Design of Lemongrass Harvesting Implement



Chain Conveyor



Lower Body Frame

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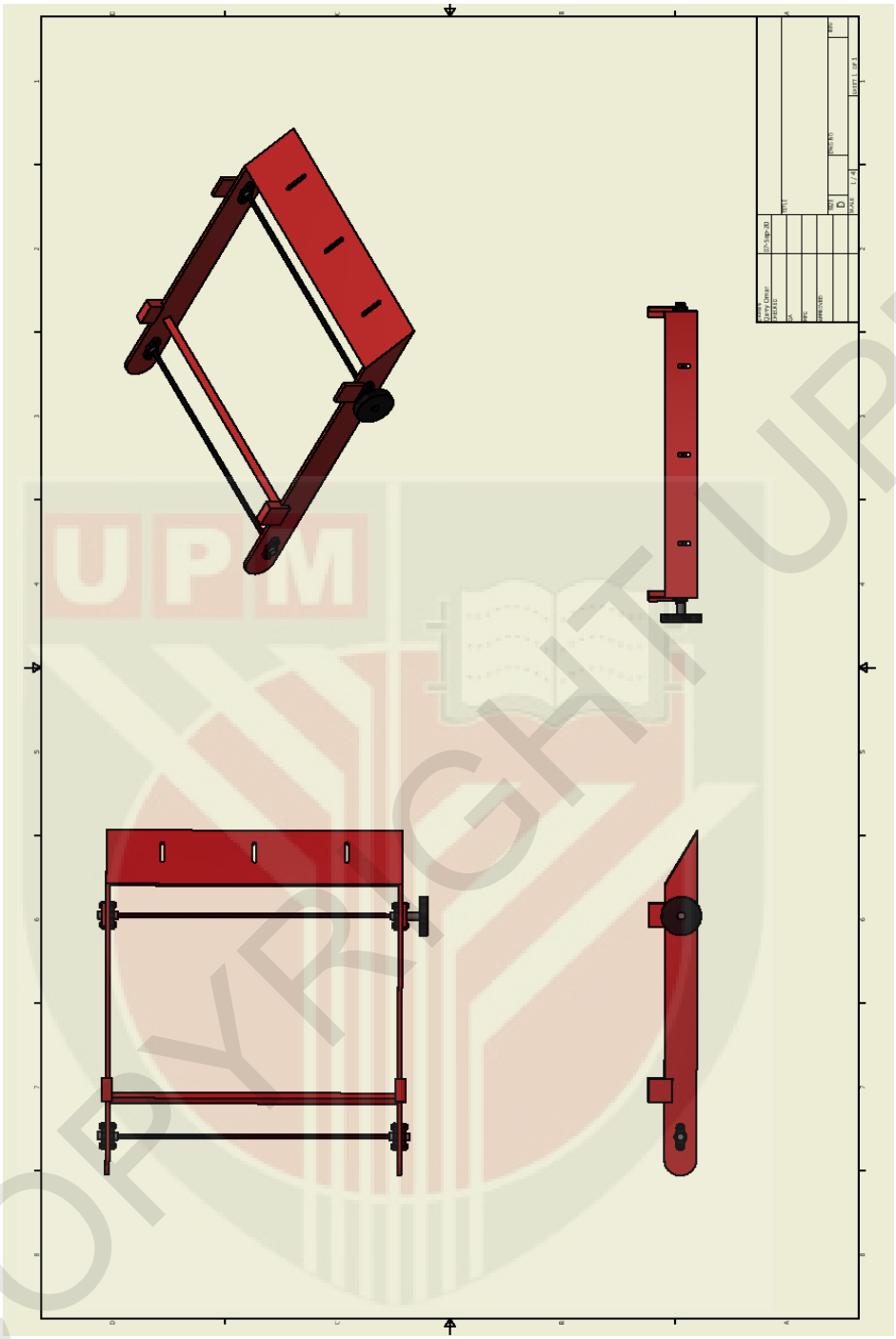

Upper Body Frame with Gearbox

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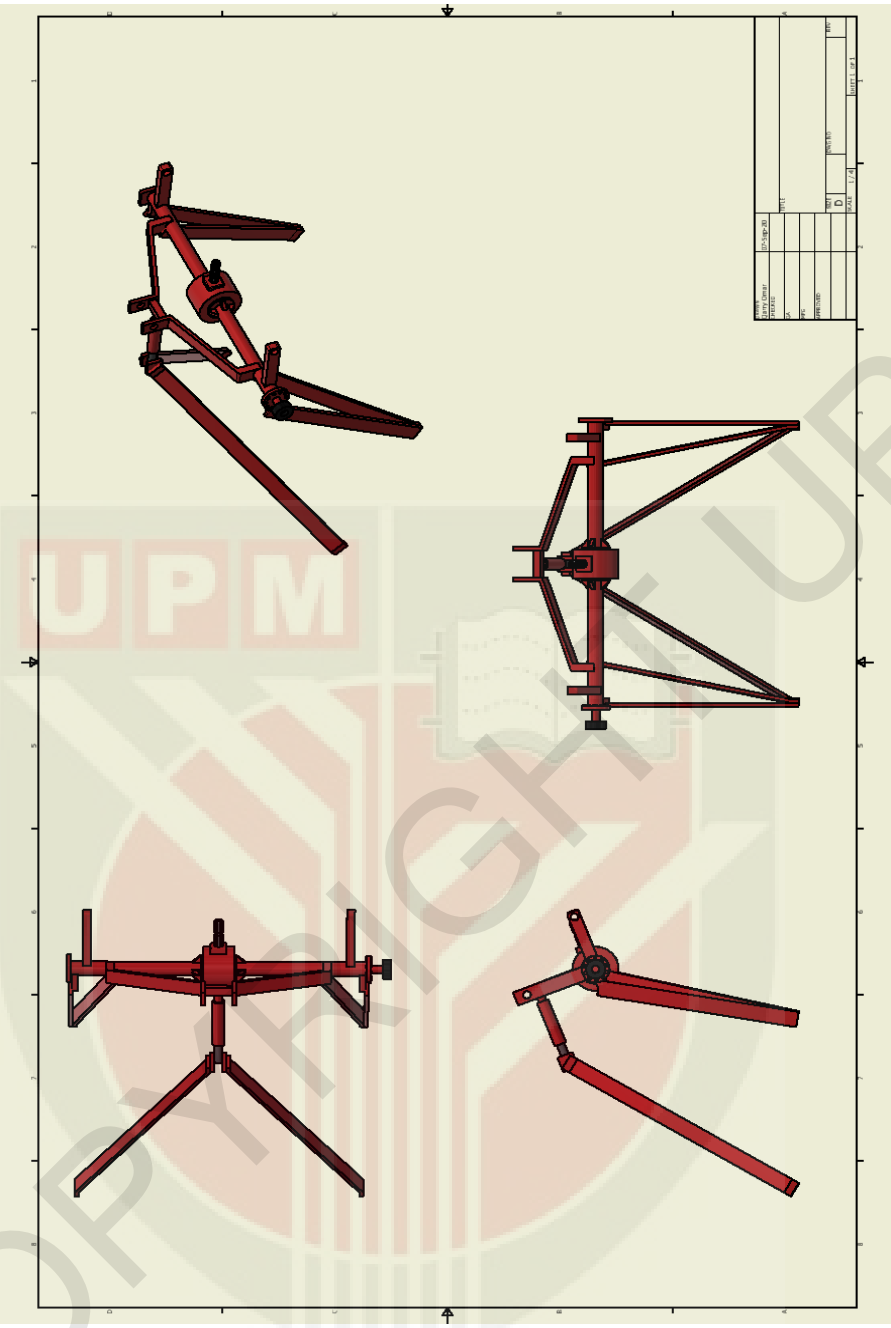

The Blade of Harvesting Implement

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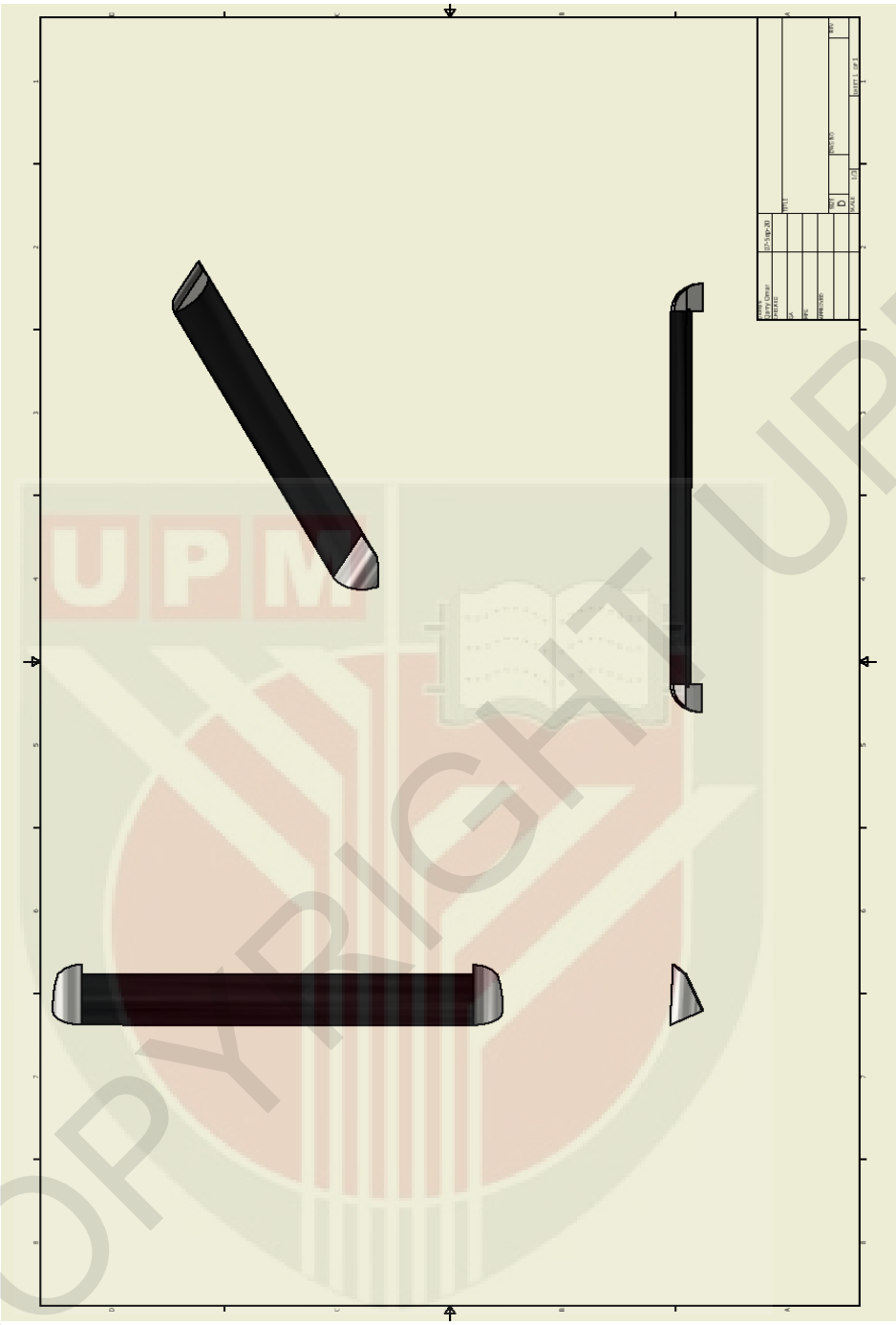

Pulley cover

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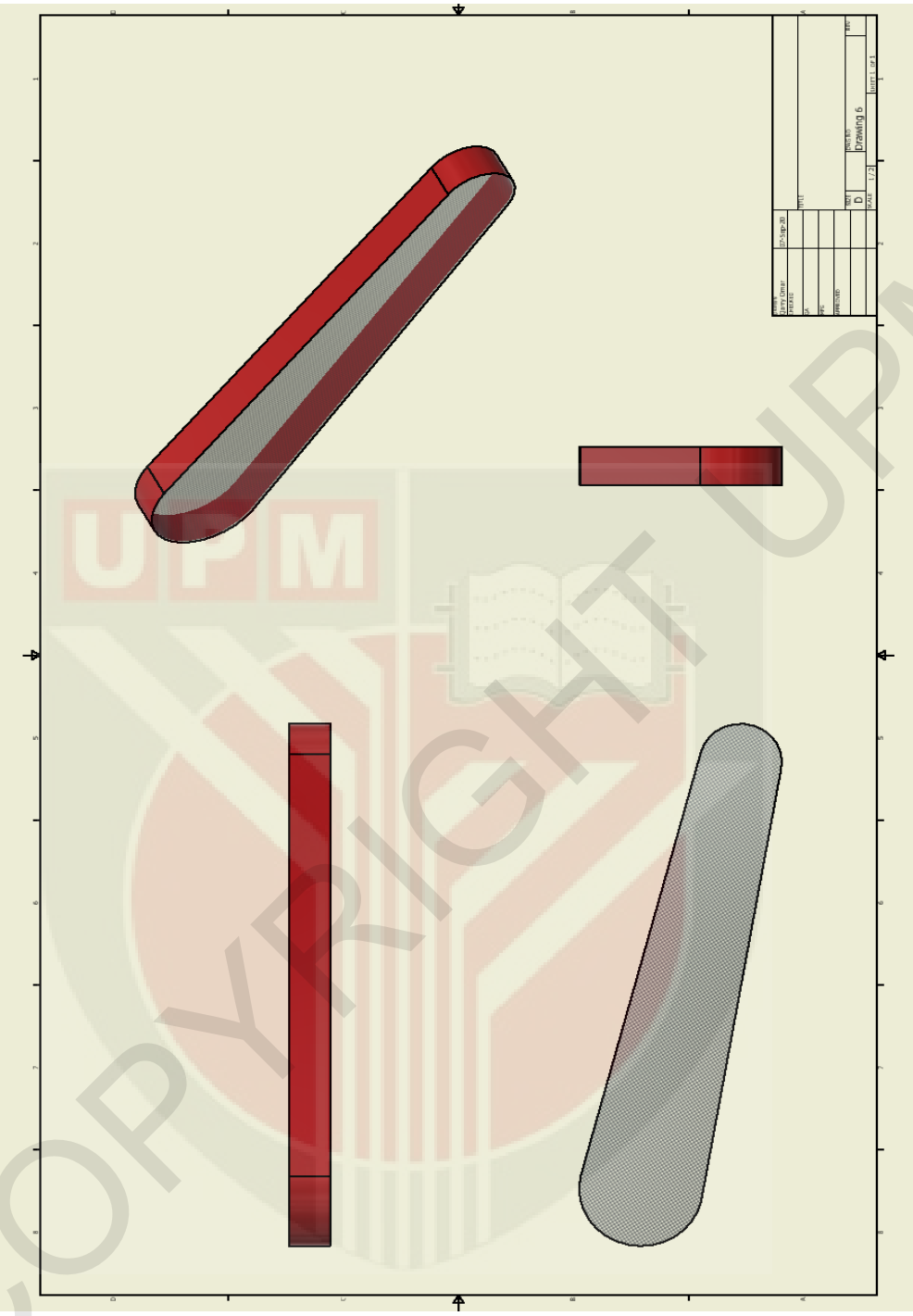

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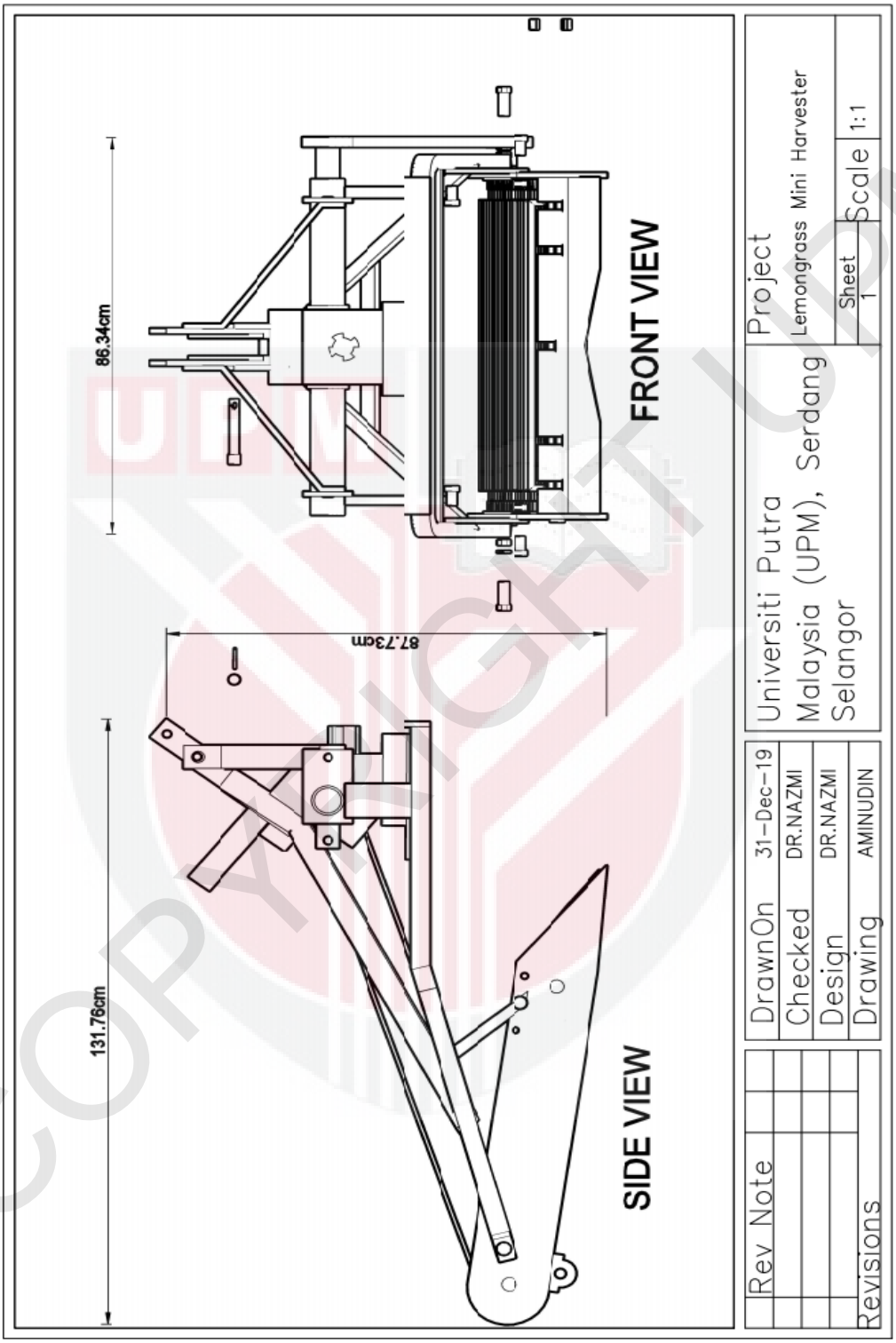
APPENDIX B

The First Design of the Lemongrass Harvesting Implement



Three-Point Linkage

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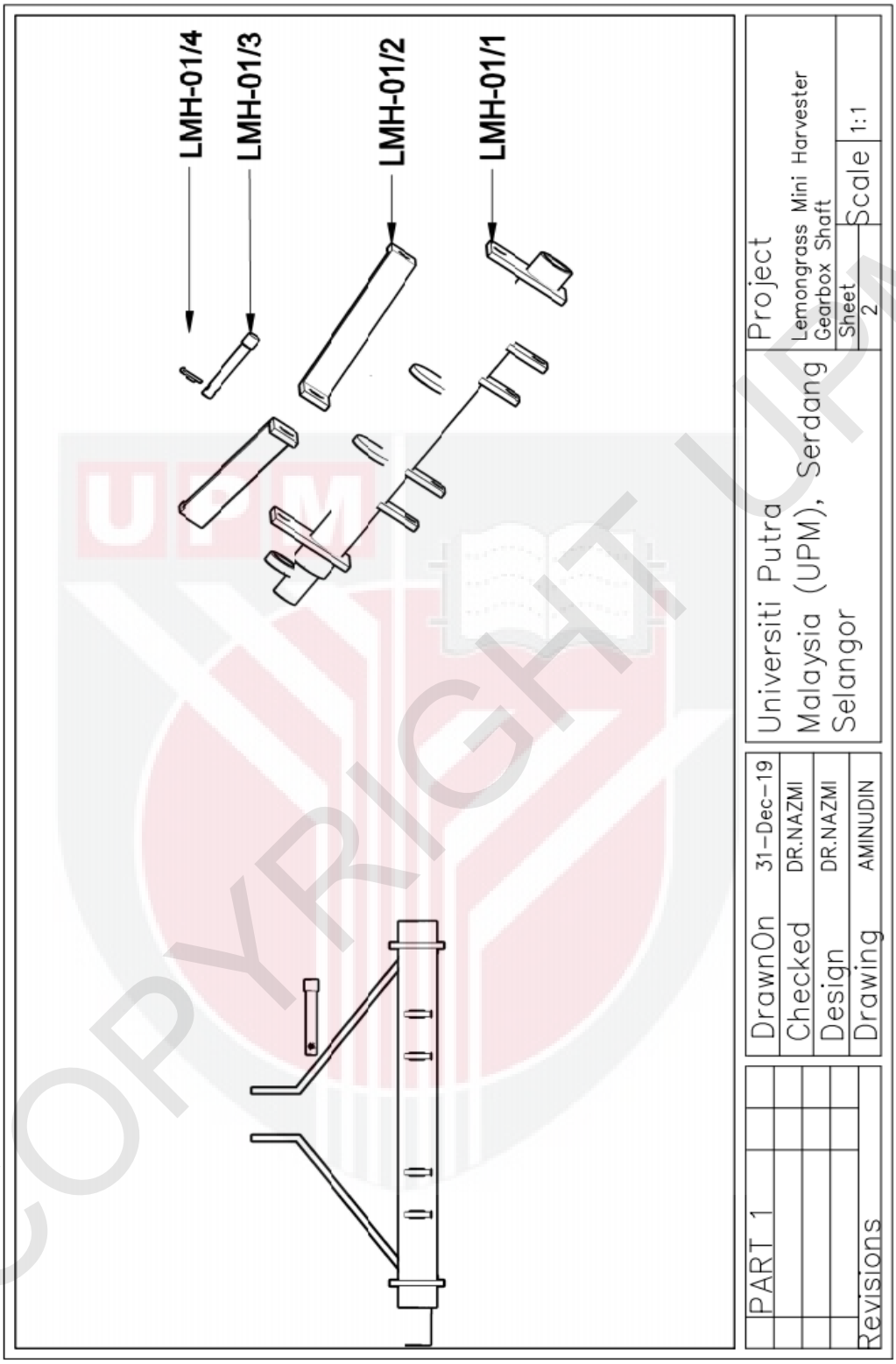

Upper Body Frame

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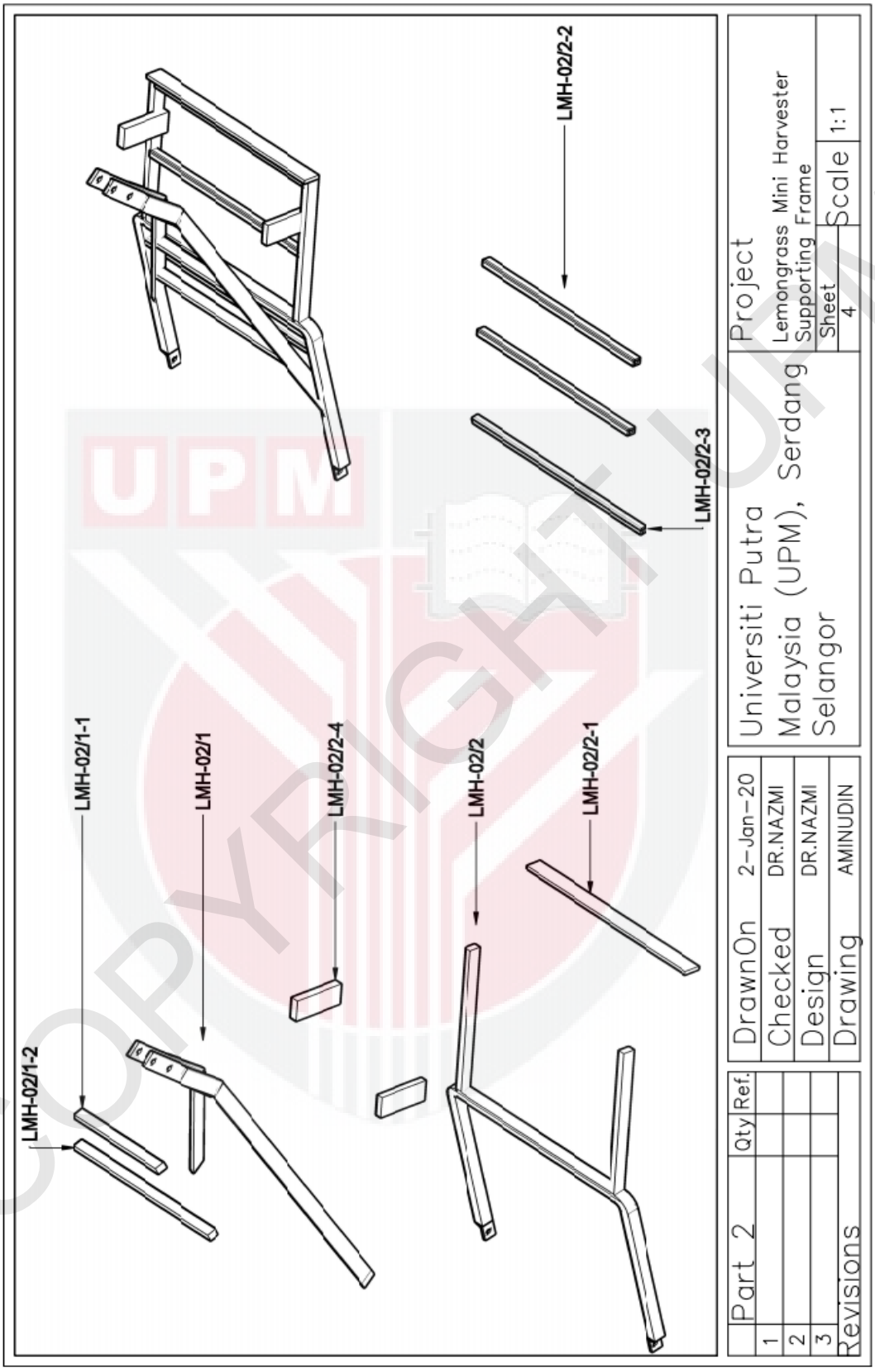

Lower Body Frame

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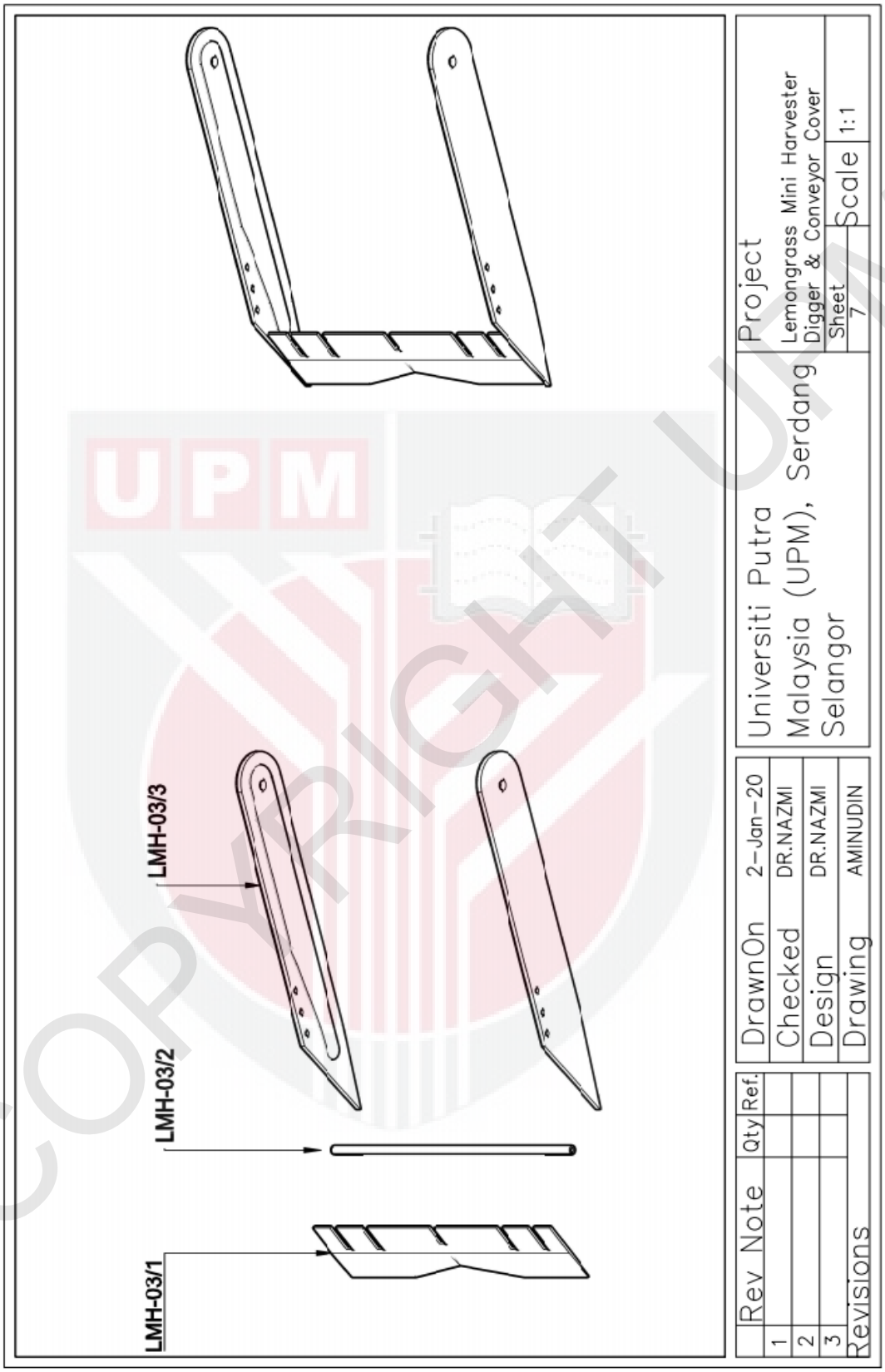

Conveyor Chain

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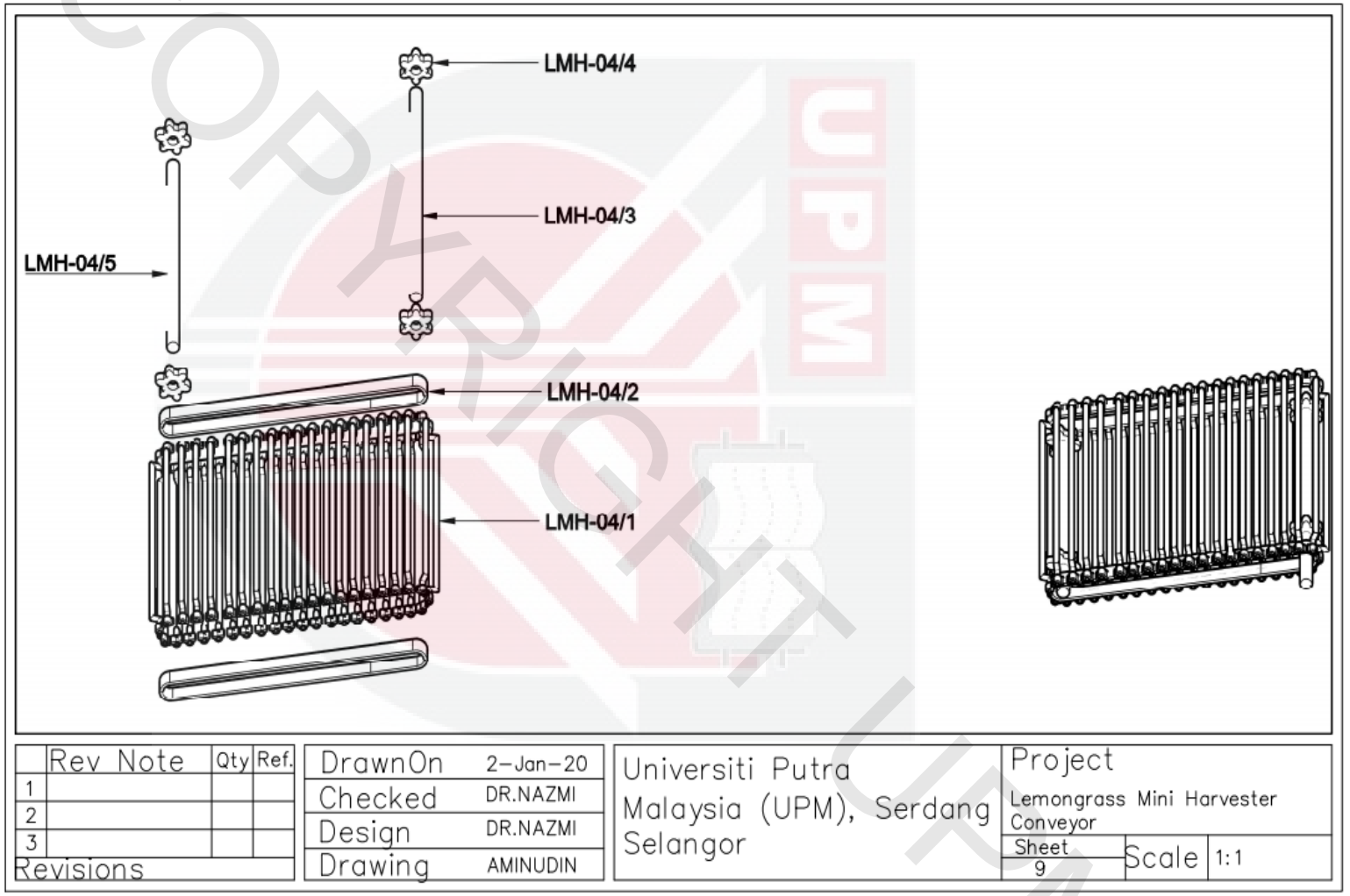

	Rev Note	Qty	Ref.
1			
2			
3			

Revisions

DrawnOn	2-Jan-20
Checked	DR.NAZMI
Design	DR.NAZMI
Drawing	AMINUDIN

Universiti Putra Malaysia (UPM), Serdang Selangor

Project: Lemongrass Mini Harvester Conveyor

Sheet 9 | Scale 1:1

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