



DEVELOPMENT OF A HAND- PUSH WEEDER FOR CUTTING WEEDS

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ABSTRACT

A hand-push weeder was designed, fabricated and evaluated for household use and peasant farmers in order to mechanize cutting process and minimize the higher aggressive nature of weeds contrasted with harvests posing major danger to crop production, the invasion on soils is very high particularly during the raining seasons when soil moisture is high and plant development conditions are ideal. The major components of the weeder are the weeding drum and frame made of mild steel, adjustable handle made of galvanized steel, transmission system made up of belt and pulley mechanism, two wheels both at the front and rear. The highest weeding efficiency of 93.496% and field capacity of 0.055 ha/hr were obtained based on some parameters that influence mechanized weeding (soil condition, age of weed, number of weed, and optimum speed of the weeding machine been 1800rpm). The production cost of the weeder is \$185 and it is powered by a 3 hp gasoline engine

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1.0 INTRODUCTION

Weeds are wild plants that meddle with harvest plant development (Jiken, 2016). Weeding activity is one of the significant intercultural culturing tasks which control undesirable plants between the columns which expend more manures and decrease the harvest yield (Singh *et al.*, 2015). Controlling weed is one of the major issues looked by the farmers. Of the extreme losses brought about by invasions, weeds have a significant effect of (30%) (Mahilang *et al.*, 2017). It is impossible to obtain good yield from crops without adequate weed control (Olaoye *et al.*, 2011).

Weed removal has progressed from a system totally based on the physical efforts of humans using animals, mechanical implements, and chemicals and to some extent biological methods. Weeds reduce the productivity, increase the cost of cleaning and overall adversely affect the value of the land and thereby affecting the farmer's energy, time or money (Amrita, 2018). Thirty-three percent (33%) cost of development is spent on weeding alone when completed with the physical work. The convoluted task of weeding is generally performed physically with the utilization of customary hand tools in upstanding bowing stance, prompting back

agony for majority of workers (Raut *et al.*, 2013).

Weeds accounts for about 50-70% reduction in yield particularly in the humid tropics where heavy rainfall significantly interrupt work on the farms in the season (Olaoye *et al.*, 2012).

The situation necessitates the introduction of an appropriate machine for effective weeding control. Mechanical weeding is preferred to chemical weeding because herbicide application is generally expensive, hazardous and selective. Besides, mechanical weeding keeps the soil surface loose by producing soil mulch which results in better aeration and moisture conservation. Mechanical control not only eradicates weed between rows, but also softens superficial soil and enhances aeration of soil thus preferred among other methods which include hand pulling, hoe and sickle, biological, solarization, cultural, thermal method. Hand weeding is overwhelming and hurts workers who are mostly women (Mohammad, 2011).

Following this period comes the efforts of the innovators including Nigerians toward the development of a mechanical weeder with Odigbo and Ahmed leading the start in Nigeria in 1979 to develop a ridge profile weeder, Oni in 1985 and Ademosun in 1991 developed reciprocating weeder with weeding efficiency of 80%, field capacity of 0.0255 and in 2006, Olukunle and Oguntunde designed a row crop weeder which has the weeding efficiency of 90% been the highest among other locally made weeders done before this weeder. Adeleke (2005) developed a row crop weeder with a weeding efficiency of 90% and field capacity of 0.075. Olaoye and Adekanye

(2013) developed a rotary power weeder with operating speed of 0.847 m/s, field capacity of 0.068 and weeding efficiency of 73%.

However, the adoption levels of present available weeders are low which result in low level of weeding operation. This is possibly due to higher cost of the weeder, weeding efficiency and field capacity of the weeder. It is necessary to design a light weight, cost effective and high efficiency weeder which can be able to work under low land conditions where weeds grow easily, and management of this weeds are very costly and required more labour. The objective of this research was to develop a Hand- Push Weeder for cutting weeds for household use and peasant farmers.

2.0 MATERIALS AND METHODS

2.1. Machine Description and Working Principle

The weeder consists of the weeding drum, blade, frame, wheel, petrol engine, fuel chamber cover, belt and pulley, bearings, operator guard, handle, nut, washer, bolt, shaft and front wheel. The weeding drum as the main cutting tool, circular in shape and its connected to the shaft which has sharp spaces provided within the drum. It provides a chance to eliminate clogging on the cutting material which make it preferable than arranging a tine on a rod been welded to a circular plate connected to the shaft. Therefore, the metal selected is strong enough to sustain the prevailing forces, as well as to support the load of the implement. The weeding drum spaces are sharpening at the lower end so it can penetrate the soil at a proper angle and get a desired depth during weeding. The weeding drum is welded to the shaft which passed

through the center of the frame, the shaft is then supported by two ball bearings to prevent it from shaking and vibration. The weeder has two wheels both at the front and the back, the front wheels serve as stability and the two at the rear has a steering capacity which make it easy to maneuver at ease during operation. The rear wheels are connected in a such a way that it controls the cutting depth of the cutting weeding drum. The frame is fabricated to carry the weight of the machine and gives support and rigidity. The handle is one of the most unique parts of the weeder in respect to other weeders through which the machine is control by the operator are mild steel welded to the base of the frame behind the rear wheels having galvanized steel on it with it adjusting port. It is fabricated from the galvanized iron pipe having a circular cross section with thickness 1mm inserted with its adjustment in

a mild steel of a square cross section with thickness 2.0 mm. The overall length of the handle is 400 mm. A belt is connected to the pulley of the engine which is 3.0 Hp gasoline engine that powered the machine, which in turn connected to the shaft on which the weeding drum is welded to transmit power which will be used for useful work. The machine is powered by a 3 Hp three – phase electric motor and has production cost of \$185 with the construction materials being locally available at affordable costs. The exploded view of the weeder is presented in Figure 1.

2.2. Design Considerations and Calculation Procedures

2.2.1. Design considerations

All the design parameters are taken into consideration which make the machine to

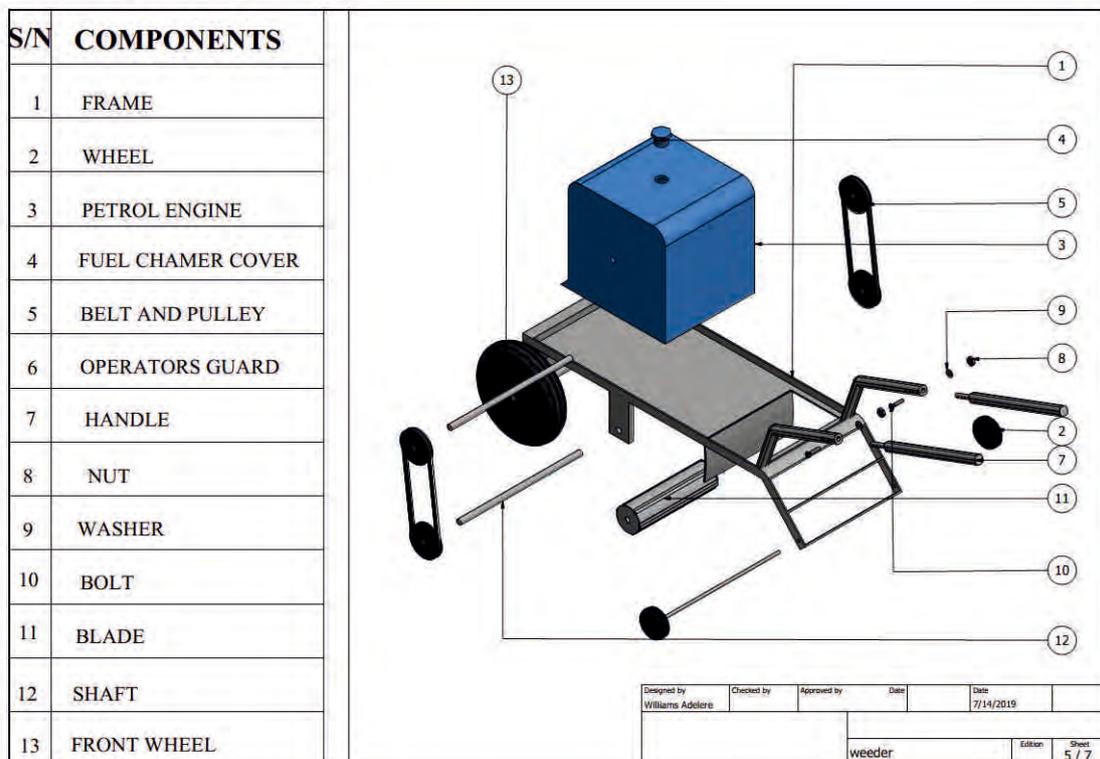


Figure 1: Exploded view of the weeder showing the component parts

have high efficiency, easy to operate by operators and adoptable for peasant farmer. The design considerations of the machine considered include simplicity without sacrificing workability and efficiency. It should be made from available standard parts and materials, reduction in labour efforts and drudgery encounter by using manual method of weeding and saves time of operation, reasonable space and weight requirement to allow moving it to the site, easy to operate by providing an adjustable handle that will enable operators of different height to operate it without posing back ache, low cost so that it can be easily purchased and repairable by farmer, cutting and uprooting of weed easily, safety, light weight of machine, overcome man power scarcity, saves time and cost, easiness in fabrication are taken into account for its design procedure. The operation and adjustment were made simple so that a village artisan can fabricate, repair the weeder and farmer can operate the weeder easily.

2.3 Design Calculations

2.3.1 Belt transmission

2.3.1.1 Design for pulley and belt

The velocity ratio of the pulley and belt of the rotating shaft was calculated using equation 1 as reported by Khurmi and Gupta (2005); Nakara (1982).

$$\frac{N1}{N2} = \frac{D2}{D1} \quad (1)$$

where N1 is the speed of the driver (selected speed of the shaft) = 900 rpm, D1 is the diameter of the driver pulley =70 mm, D2 is the diameter of the shaft pulley =120 mm, N2

is the Speed of shaft (selected Speed of the motor) = 1800 rpm.

Therefore, 1 = 3.4 is the velocity ratio of the pulley and belt of the rotating shaft

2.3.1.2 Determination of the belt speed

The speed of belt of the weeder was determined using equation 2 as reported by Khurmi and Gupta (2005).

$$\text{Belt speed} = V = \frac{\pi D1}{60} * N1 \quad (2)$$

$$V = \frac{3.142 * 0.07 * 1800}{60}$$

Where V is the belt speed, π is 3.142, D1 is the diameter of the driver pulley =70 mm, V= 6.6 m/s.

Belt speed of 6.6 m/s is required.

2.3.1.3 Determination of the pulley speed

Pulley speed was calculated using equation 1 as reported by Khurmi and Gupta (2005); Nakara (1982).

where N1 is the speed of the driver = 1800 rpm, D1 is the diameter of the driver pulley =70 mm, D2 is the diameter of the shaft pulley =120 mm, N2 is the speed of the pulley = 1050 rpm.

Therefore, pulley speed of 1050 rpm is required

2.3.1.4 Determination of the length of belt

The length of belt of the weeder was determined using equation 3 as reported by Khurmi and Gupta (2004).

$$L = 2C + \frac{\pi}{2}(D_2 - D_1) + \frac{(D_2 + D_1)^2}{4C} \quad (3)$$

Where L is the total length of the belt, C is the distance between the centres of two pulleys, D₂ is the diameter of larger pulley and D₁ is the

diameter of smaller pulley.

2.3.2.1 Determination of the torsional moment

The torsional moment (M_t) of the belt was calculated using equation 4 as reported by Adetola *et al.* (2012)

$$M_t = \frac{D_2}{2} (T_1 - T_2) \quad (4)$$

Where, M_t is the torsional moment, D_2 is the diameter of driven pulley, T_1 is the tension at the tight side, T_2 is the tension at the slack side, $D_2 = 120\text{mm} = 0.12\text{m}$, $T_1 = 396.21\text{N}$, $T_2 = 80.86\text{N}$

$$M_t = \frac{0.12}{2} (396.21 - 80.86)$$

$$M_t = 18.92\text{N}$$

2.3.2.2 Determination of shaft diameter

The shaft diameter of the machine was determined using equation 5 as reported by Bhandari (2010) and 1.5 was used as the factor of safety to determine the shaft diameter.

$$d_s^3 = \frac{16}{\pi S_s} \sqrt{(k_t M_t)^2 + (k_b M_b)^2} \quad (5)$$

$$d_s^3 = \frac{16}{\pi \times 56 \times 10^6}$$

$$\sqrt{(1.5 \times 145.01)^2 + (1.0 \times 18.92)^2}$$

$$d_s^3 = \frac{16}{131.96 \times 10^6} \sqrt{47670.74}$$

$$d_s^3 = \frac{16 \times 218.33}{131.96 \times 10^6} ; d_s^3 = 2.65 \times 10^{-6}\text{m}$$

$$d_s = \sqrt[3]{2.65 \times 10^{-6}}$$

$$d_s = 0.0138\text{m} = 13.8\text{mm}$$

Taking into consideration the factor of safety

of 1.5. The diameter of the weeding shaft = $13.80\text{mm} \times 1.5 = 20.70\text{mm}$.

A shaft diameter of 22mm is then selected for the weeding machine.

2.3.3 Determination of power required to drive the machine.

The total power required of the weeding machine was determined using equations 6 and 7 as reported by Khurmi and Gupta (2004).

$$T = \frac{P}{2\pi N} \quad (6)$$

$$P = T \times 2\pi N$$

$$F = T/R \quad (7)$$

$$P = T \times 2\pi N$$

$$P = 2 \times 3.142 \times 1800 \times 0.368 \quad \text{Case 1,}$$

$$N = 1800$$

$$P = 2 \times 3.142 \times 900 \times 0.368 \quad \text{Case 2,}$$

$$N = 900$$

$$P \text{ for case 1} = 4162.52\text{W} = 4.1 \text{ kW}$$

$$P \text{ for case 2} = 2081.26\text{W} = 2.08 \text{ kW}$$

Conversion from Watt to Horsepower (746W = 1 HP)

$$4163\text{W} = 5.58 \text{ Hp}$$

$$2081\text{W} = 2.79 \text{ Hp}$$

Thus, an engine of 3.0 Hp can power the machine at a speed of 900 rpm and 5.5Hp at a speed of 1800 rpm and run effectively with less crop damage.

2.3.4 Determination of weeding efficiency

The weeding efficiency was calculated using equation 8 as reported by Nkakini *et al.* (2010).

$$\text{Weeding efficiency} = \frac{\text{number of weeded weeds} \times 100}{\text{number of total weed.}} \quad (8)$$

2.3.5 Determination of field capacity

The field capacity of the weeder was calculated using equation 9 as reported by Olaoye and Adekanye (2011).

$$FC = \frac{A \times 3600}{10000 \times T} \quad (9)$$

Where FC is the field capacity, A is the area covered, T is the time taken to weed the area

2.4 Material Selection and Fabrication of the Machines Components

In the design of any machine, material selection is a major controlling factor. The materials chosen should be suitable for the conditions of operation and service of the machine. Selection of metal must be such that it can be formed into desired shape, it is based

on ductility characteristics of the metal. The forming of metal is usually done by cold working that means forming is done at room temperature. Factors contributing to the choice of materials for the production of the machine includes; corrosion resistance, coefficient of friction, commercial availability, costs of materials, ease of maintenance, ease of manufacture, fabrication techniques, effect of fabrication on the mechanical properties and corrosion resistance of the materials, creep strength, fatigue strength. Table 1 shows the selected materials used with the justification for the selection made which were the best and suitable material out of the available options considering the mechanical property of the materials, cost and availability of the materials. The autographic of the weeder, dimensioned diagram of the weeder and isometric view diagram of the weeder are

Table 1: Highlights of the Suitable Materials, the Selected Materials and Justification for Selection.

S/N	Name of components	Suitable materials	Selected materials	The justification for selected material
1	Shaft	Medium carbon, galvanized steel	Medium carbon steel	The cost, high machinability and availability
2	Prime mover	Diesel engine, petrol engine, electric motor.	Petrol engine	Availability, cost, weight on the frame and power required.
3	Pulley	High carbon steel, cast iron, mild steel	Mild steel	The strength to withstand stress of high speed
4	Belt	Leather, rubber	Rubber	Easy operation and safety of operator.
5	Handle	Galvanized steel, High carbon, mild steel.	Galvanized steel	Machinability and light weight.
6	Frame	High carbon steel, mild steel	Mild steel	Ruggedness and prevent rust.
7	Bearing	Pillow bearing, ball bearing, bush bearing	Ball bearing	Ease of operation and aid easy transmission of motion.
8	Drum	Mild steel, high carbon steel	Mild steel	Prevent rusting, machinability.
9	Disc	Mild steel, high carbon steel	High carbon steel	Availability and ruggedness
10	Wheel	Steel track, rubber, metal	Rubber	Availability, balancing, good support.

presented in Appendix A, B and C respectively.

3. RESULTS AND DISCUSSION OF THE MACHINE TESTING.

The weeding machine was designed, developed, fabricated and assembled at the department of Agricultural and Environmental Engineering workshop Obaekere, Federal University of Technology Akure. The weeding machine was designed to be powered by 3HP gasoline engine following the calculation for the power required to drive the weeder with a minimum breakdown. The efficiency of the weeder was 93.496% on the field while the field capacity was calculated as 0.055 ha/hr) which is better compare with the weeding efficiency of some existing weeders earlier presented. The total cost of the machine was estimated to be \$185 which make it affordable for the low-income farmers. The machine was designed to have an adjustable handle to settle the hitch of different operators of varying height (Ademosun, 1991; Olukunle and Oguntunde, 2006; Adeleke, 2005; Olaoye and Adekanye, 2013).

3.1 The Weeding Efficiency and the Field Capacity of the Weeder

The field test result in Table 2 shows that the weed on the field of 3 cm depth were removed from the soil, cut and marched. It performs an operation of minimum tillage as well, as it engages the soil during operation which also pulverize the soil and can function as a harrow. Five different spots having no weed of height less than 2cm were selected within the departmental workshop at Obaekere to

ensure human error is avoided during the manual counting of the weed. At each spot, the weeds were counted thoroughly by using tiny rope to tie it one after another until a certain number is reached (Table 2) while the small weed that is not much is consider insignificant due to the infinitesimal number of it and yet, the weeder still remove them all because the tines attached to the weeding drum was designed to get in contact with the soil to pulverize it and as well act as a machine for minimal tillage.

The weeding efficiency of the machine was 93.496% (Table 3) and the field capacity was 0.0554 ha/hr which made it more preferred to some locally developed weeders presented earlier or that have been in existence because of its effectiveness except for the cases of a Row crop weeder developed by (Manuwa *et al.*, 2009) with weeding efficiency and field capacity of 95% and 0.053 ha/hr respectively and Mechanical weeder developed by Olukunle (2010) with weeding efficiency and field capacity of 94% and 0.18 respectively. But taking into consideration the total cost of the machine which is far affordable and yet still perform high in comparison with the two weeders that have weeding efficiency higher than it but more expensive, the weeder can then be considered preferable. Going globally, in respect to other weeders, the weeder performance is at equivalent with a power. Weeder developed by (Keshavalu *et al.*, 2017) which happen to be the best among others with a weeding efficiency and field capacity of 93.72% and 0.15 ha/hr respectively.

The counted number of the weeds were used to calculate and achieve the weeding efficiency of the machine and the results presented in

Table 2: Sample of weeded weeds and unremoved weed which were collected on the field.

Sample	Number of Weeded weeds	Unremoved weeds count	Total number of weeds
Sample 1	922	84	1006
Sample 2	990	98	1088
Sample 3	889	52	941
Sample 4	1009	103	1032
Sample 5	901	72	973

Figure 1. Nature of the weed was considered in that; the weeder was designed to uproot completely any weed with a root depth of 3 cm maximum and then cut any weed with a root depth longer than that. Secondly, weed of obnoxious nature or area with densely populated strong weed would be brutally wounded such that it won't survive withering off. The topography of the land was considered. It can perform excellently well on a plain land, undulating area and sloppy ground with the help of good wheel design and that of the front tyres which are big, having grip to aid friction and with the help of the operator himself to control the speed and in avoiding somersaulting in case of sloppy

terrain. Climatic condition was also considered in the design of the machine. It was tested during the dry season but in both wet and dry land. The weeding drum was designed to prevent clogging of both the soil and the weed on it. However, in case of raining season, the weeding drum was designed to cut at an inclination angle of 45° and run at a high speed that reduce clogging.

4.0 CONCLUSIONS

4.1 Conclusions

It can be concluded base on the performance test carried out on the weeding machine in five randomly selected portion on a field that the

Table 3: The efficiency of the machine at different places/samples

Sample	Efficiency %	Average weeding efficiency %
Sample 1	91.65	
Sample 2	90.99	(91.65+90.99+94.77+97.77+92.60)/5
Sample 3	94.77	=93.496
Sample 4	97.77	
Sample 5	92.60	

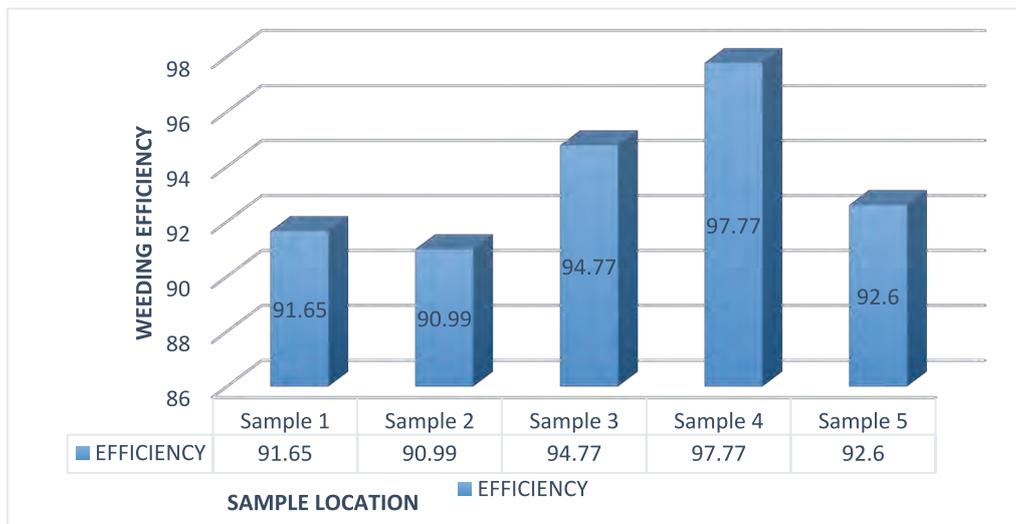


Figure 1: A graphical representation of the Weeder efficiency on a different field location.

developed and fabricated motorized weeder will surely enable the peasant farmer embrace farm mechanization since crop protection operation, which involve weeding is a major threat on them as it is laborious, causes food losses and consume time. The efficiency of the machine was 93.496 %. Weeding operation done by the weeder does not only remove or uproot the weed but also keep the soil surface loose thereby enhancing soil water relationship for crop growth by increasing water intake capacity and better soil aeration. The cutting mechanism which consists of a weeding drum has a higher efficiency as it doesn't wear out easily and withstand a strong weed than tines welded on a plate.

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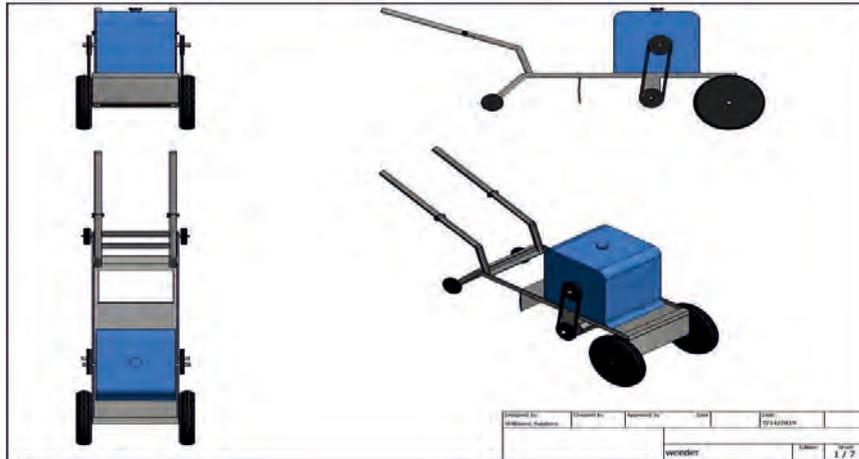
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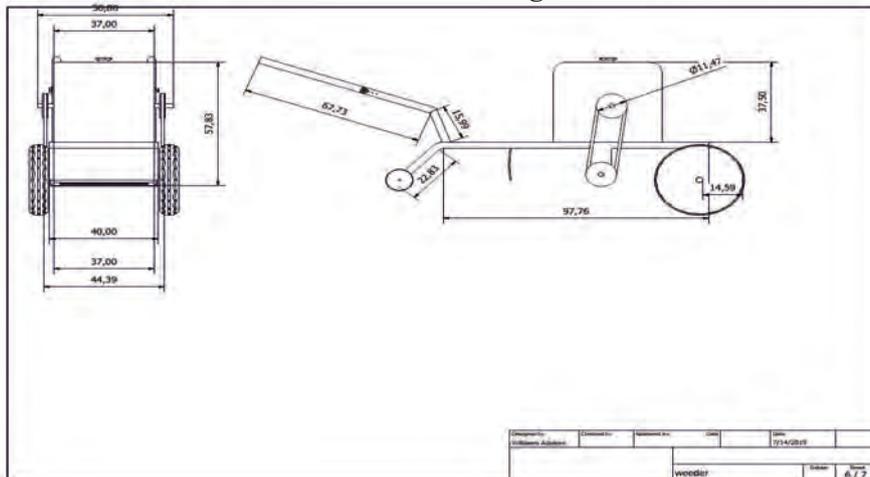
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APPENDIX A: Autographic of the Weeder



APPENDIX B: Dimensioned Diagram of the Weeder



Appendix C: Isometric View Diagram of The Weeder

