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RESEARCH ARTICLE
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DESIGN, FABRICATION, AND PERFORMANCE EVALUATION OF MANUALLY OPERATED FOUR ROW RICE SEEDER

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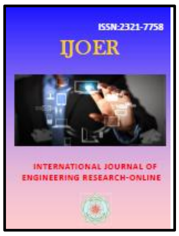

ABSTRACT

In Ethiopia, among the targeted commodities that have received due emphasis in promotion of agricultural production, rice is one which is considered as the “Millennium Crop” expected to contribute in ensuring food security in the country. Hence, its production has increased in the last few years. Despite the increase, there are still many problems that are not solved in the production system, among which planting technique seems the first. The farmers still used traditional methods to broadcast the seed on the field, which is labour intensive, time consuming and cause high decline in the yield due to suboptimum plant population. Therefore, in order to overcome the problems encountered with traditional way of broadcasting the seed on the farm and maintain the optimum plant density; there was efforts have made to design and fabricate suitable planting machine for rice cultivators. So that after the design mission was completed, the prototype fabrication, and the performance evaluation of the seeder work were conducted at Melkassa Agricultural Research center. Before conducting the field experiment the machine was tested in the laboratory, the result shows that the seeder was good with the combination of 25% drum fill ratio and 1m/s forward speed. Then depends on this, the field experiment was evaluated in comparison with Manual planting technique in rows. The parameters used for comparison were seed rate, seed spacing, planting time, and plant population. The test was designed in RCBD with three replications, and 10m x 8m plot size was used. The test results (table 1 and table 2) revealed that the two techniques were significantly different at the level of significance $p<0.05$ and LSD, 5% test. It was found that *melkassa seeder* was better than manual method in all parameters except plant density. The first parameter was seed rate, it required 65kg per ha for *melkassa seeder* while 106.8kg per ha required for manual method. This implies that *melkassa seeder* reduces the requirement of the seed by 41.8kgs. The second parameter was seed spacing, it was found that 1.8967cm for manual method while 2.2633cm for *melkassa seeder*. In terms of labour-requirement, it was found that 18.40hr per ha required for manual method while 4.30hr per ha for *melkassa seeder*. The last one was plant population; it also found that 49.067seedling per m^2 for manual method and 44.061seedling per m^2 for *melkassa seeder*.

Key Word: Design, Fabrication, Rice Seeder, Performance evaluation

1. Introduction

1.1. *Background and Justifications:* Rice cultivation is a recent phenomenon in Ethiopia. Efforts to introduction of rice had probably been started in Ethiopia when the wild rice (*O. longistaminata*) was observed in the swampy and waterlogged areas of Fogera and GambellaPlains[9]. According to the report of *MoARD* (2010), the potential rice production area in Ethiopia is estimated to be about 30 million hectares, of which more than 5 million ha is highly suitable. There is an increasing trend in both area and production of the crop[23, *14, 9*]. Currently, Amhara, SNNP, Oromiya, Somali, Gambella, BenuShangulGumuz, Tigray and Afar regions are rice producing regions in Ethiopia [14]. The amount of area under rice cultivation in Ethiopia is low as compared to the potential. Along with the increased level of production, there is increased volume of rice import. For the year 2008 and 2009, the government of Ethiopia imported 25,667 and 30,082 tons of rice respectively. It is assumed that if rice production continues to increase, the country will be able to substitute imports and will export in the near future [14]. Generally, rice has great potential and can play a critical role in contributing to food and nutritional security, income generation, poverty alleviation and socio economic growth of Ethiopia.

Farmers in different regions of Ethiopia have shown keen interest for rice productions and are frequently requesting for improved technologies. Considering the importance and potential of the crop, it has been recognized by the Government as "the new millennium crop of Ethiopia" to attain food security. However, the production, productivity and expansion of rice has been constrained by lack of pre-harvest, post-harvest and processing technologies, and lack of awareness on its utilization were among the major constraints of rice production in Ethiopia[24].

Although, with this immense potential, the rice farming practice in Ethiopia is dominantly traditional with overwhelming participation of small-scale producers with small farm size. Similarly, the status of mechanization in rice production for different steps such as soil tillage, planting, harvesting, and threshing is very few. Almost all of the farm operations are performed with bare hand or using rudimentary hand tools and traditional animal drawn implements [14]. From those the major mechanization problems, it was mentioned that planting method is one; this is because of lack of suitable rice seeder or planter. Farmers normally use hand-broadcasting method for planting rice seed on the field. It is obvious that the traditional method of planting cannot be uniformly distributing the seed and maintains the optimum plant density in the field. As a result, low efficiency and high cost are being incurred. It was examined that seeding of rice by mechanical means could be given optimum plant population and achieve high field capacity compared to traditional hand broadcasting methods. Furthermore when the pattern became uniform in rows it becomes easy to cultivate and the rows create opportunity to use inter-row cultivator.

Many researchers have reported that direct sowing of paddy using drum seeder has resulted in lower cost of production and higher yield as compared to manual transplanting and broadcasting method [2, 3, 20]. Despite it, such kind of planting machine has the following limitations; the first problem was as the grains get continuously discharged from the drum through the orifices, the percent fill of the drum decreases; this leads to non-linear variation in the flow rate of grains; this again affect uniformity of plants, hence affects crop yield. And the second problem was the seeds drops continue while turning at the head of the field, hence improved seed may be wasted. Third it needed frequently refilling, and difficult to inspect the amount of seeds available inside the drum. Even if the machine has those limitations, it is difficult to get and use such kind of machine for Ethiopian farmers because of economic issue as well as unavailability of the machine itself in the country. Therefore, it needs to design suitable rice seeder from locally available material by considering the above limitations.

Hence, in this paper effort was made to solve problems observed in traditional rice planting method through design and fabrication of techno-economically compatible manually operated four row rice seeder.

1.2. Objectives

1.2.1. General objective

- To design, fabricate and performance evaluation of manually operated four row rice Seeder for row drilling.

1.2.2. Specific objectives

- To find the necessary physical properties of rice seeds related to rice seeder
- To design and fabricate manually operated seeder for rice seed
- To evaluate the performance of the seeder

2. Literature review

Direct seeding of rice refers to the process of establishing a rice crop from seeds sown in the field rather than by transplanting seedlings from the nursery. There are three principal methods of direct seeding of rice (DSR): dry seeding (sowing dry seeds into dry soil), wet seeding (sowing pre-germinated seeds on wet puddle soils), and water seeding (seeds sown into standing water). Dry seeding has been the principal method of rice establishment since the 1950s in developing countries [16].

Traditionally, rice is cultivated with the transplanting pattern, consisting of raising nurseries, picking seedlings up and transplanting, which cost a large number of manpower and financial resources. In the past two decades, the planting pattern is gradually and partially replaced by direct seeding (DS) in many developed countries [5*, 13, 12, 1, 16]*. So is the case with China, and the area of direct seeding rice is rapidly increasing. DS cultivation provides rice, in particular at the seedling stage, with a completely different growth environment from that in transplanting cultivation. It has been reported that the direct seeding rice showed favorable changes for high yield formation in comparison with the transplanting rice, including earlier seedling emergence [16] stronger root activity, higher seed setting rate and greater biomass production at the early stage [13*, 12*].

Huge water inputs, labour costs and labour requirements for TPR have reduced profit margins. In recent years, there has been a shift from TPR to DSR cultivation in several countries of Southeast Asia. This shift was principally brought about by the expensive labour component for transplanting due to an acute farmlabour shortage, which also delayed rice sowing. Low wages and adequate water favour transplanting, whereas high wages and low water availability suit DSR[16]. TPR has high labour demands for uprooting nursery seedlings, puddling fields and transplanting seedlings into fields. The adoption of a direct-seeded method by using drum type seeder for lowland and highland rice culture would significantly decrease costs of rice production [8].

DSR is a major opportunity to change production practices to attain optimal plant density and high water productivity in water scarce areas. The advantages of the TPR include increased nutrientavailability (e.g. iron, zinc, phosphorus) and weed Suppression [19]. With respect to yield, both direct seeding (viz. wet, dry or water seeding) and transplanting had similar results [11]. In Southeast Asia, DSR is more often adopted in the dry season than in the wet season probably due to better water control; but dry-season rice accounts for less than one-quarter of rice production in this region. At present, 23% of rice is direct-seeded globally [7]. In the United States, Australia and Europe, rice is planted into either a dry-seeded or water-seeded system. In Australia, for instance, most rice is aerially sown in water [17], while in rain feddry lands and wetlands sub Saharan Africa, rice seeds are broadcast, drilled, or dibbled in prepared dry-to-moist soil. All three methods are equally effective when the optimum seed rate of 50–80 kg/ ha is used[22]. In drilled and dibbled rice fields, effective weed control is possible with inter-row cultivation. Similarly like others African countries; here in Ethiopia also rice farmers have many challenges related to input, agronomy, pre-and-post harvest mechanization, market, utilization, investment and human and institutional capacity [14]. The national rice R&D strategy(NRRDSE) prioritized rice production inputs constraints, from those constraints one which prioritized as the fourth major constraints was related with the poor access and use of pre-harvest techniques and

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equipment's. Especially, in areas of wet soil moisture condition this causes both land preparation and cultivation work to be much drudgery (table 1). And also the method and date of planting taking into consideration the rainfall patterns, soil type, and seed rate were reported as a fourth, a fifth and a sixth constraints respectively (table 2).

Table1. Prioritized rice production inputs constraints

Constraints	Rank
Access to improved varieties	1
Access and use of post-harvest equipment	2
Access and use of pesticides	3
Access and use of pre-harvest equipment	4
Financial shortage	5
Labour shortage during pick farm operation season	6
Access and use of chemical fertilizer	7

Source: MoARD, 2010, National Rice R&D Strategy

Table 2. Prioritized constraints of rice agronomy

Constraints	Rank
Weed and weed control method	1
Insect disease and birds and their control methods	2
Poor land preparation technique	3
Method and date of planting	4
Seed rate	5
Type, rate and date of fertilizer application	6

Source: MoARD, 2010, National Rice R&D Strategy

Therefore, there is a need for Proper rice seeder for direct seeding rice seed. Because it is one of the important factors which ameliorate not only the input related constraints but also the agronomic constraints by giving optimum plant population in rows; provide opportunity to use mechanical weeder, and hence improve crop yield and yield components.

However, there were many factors should be considered in order to develop such machine; factors including crop and machine parameters influence the performance of a seed metering device for such planter; variables like rotational speed and diameter of the seed outlet (i.e. holes) of the metering device, as well as the type of variety have a major impact on the machine performance.

Many researchers have been conducted to study the performance of different rice seed metering units. *Raheman and Singh* (2004) developed a manual drawn multi-crop drum seeder for dry land with considering the effects of hole size, hole space and forward speed on the value of seed rate, uniformity of metering, band width and missing seed dropped for wheat and mustard seeds. *Sivakumar et al.* (2005) studied some parameters affecting performance of the drum seeder to determine the appropriate shape of the drum. The study of drum seeders, the commonly used device for direct seeding of pre-germinated paddy seed, showed that the uniformity of seed distribution in this type of seeder not only depends on the amount of seed in drum space but also depends to paddy variety, so that there are many difficult to operate the seeder for paddy with awns.

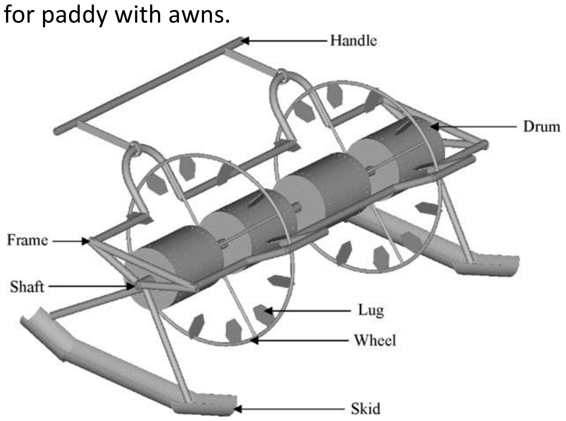

Fig. 2 Eight-row manually drawn drum type IRRI seeder

It has been also observed that the flow rate of paddy rice seeds through the orifices on the circumference of drum is not uniform during operation leading to variation in seed spacing and seed rate [15]. The size of orifice, spacing between the orifices on the drum, percent fill of drum and speed of operation significantly affected the flow rate of seeds through the orifices A non-linear increase in seed rate with decrease in the percent fill of drum has been observed [*21*].

3. Materials and Methods

3.1. Description of Experimental sites

The fabrication of the machine and its performance test were conducted at *Melkassa*research center. It is found around 117km east of *Addis Abeba*. It is located at an altitude of 1466m above sea level and lies on the geographical coordinates of 8° 24' 0" N, 39° 20' 0" E Latitude and Longitude respectively. It has a highly variable rainfall that ranges between 500 and 800 mm annually.

3.2. Materials used for experiments

The materials used for the experiment were sticky belt (made by oil soaked paper (1X4 m^2)) long, small plastic bags, weight balance (0.1gm accuracy), measurement tape (with millimeter graduation) and stop watch instruments, 50kg of paddy seed and 100kg fertilizer were employed during the field and laboratory experiments.

3.3. Physical properties of paddy seeds

The seeds were cleaned manually to remove all foreign matter such as dust, dirt, stones and chaff. To determine the size of the seeds, 50 sample seeds were randomly selected and their linear dimensions namely length (L), width (W) and thickness (T) were measured using a digital vernier caliper to an accuracy of 0.02 mm. The 1000 seeds mass was measured by an electronic digital balance to an accuracy of 0.0001g.

3.4. Description and Design of the required prototype

Manually operated four row drum seeder was designed, as the name indicated, the drums used as a metering mechanism, and it has four rows, two on each drum. The drums have holes around the circumference; hence the seeds drop by gravity when the holes of the drum reach the bottom position. The ground wheel and the two seed drum metering mechanism were assembled on the shaft; therefore, they have the same angular rotation with the ground wheel. Paddy stored in the upper main hopper and partially stored inside the drum. The upper hopper used as a feeder; it continuously feeds the drum through the connected plastic pipes. A long beam handle was provided by which the implement could be pulled or pushed by one operator. The chain attached at the bottom of the rear end of the machine provided covering of the paddy seed. The drum holes covered by a curve structure assembled under it while negotiating turn at the head land, the operator can close the drum holes by pushing the close lever arm on the handle and can control seed wastage. Due to the provision of the drum holes, this machine was suited for row planting of different crops, such as wheat, barley, soybean, sorghum etc. However, for this design it was considered rice seed or paddy only.

Fig3. The fabricated prototype of *melkassa*seeders'

In order to start the design, the following assumed values (i.e. speed of operation 1 – 3km/hr, machine weight 12kg, wheel diameter 60cm), rice agronomist recommendations (i.e. seed rate; it should be in the range of 50 – 80kg/ha, row to row distance given 20cm, plant to plant distance should be 2 – 3cm, and measured values (i.e. bulk density of paddy 689kg/m^3, angle of repose 36^0) were considered.

At first, wheel revolution and machine weight on wheel would be calculated as follows:

- Peripheral distance = πD = 1.89m,
- As wheel covers 1.89m/rev, at 1m/s it covers $\frac{1\text{m/s}}{1.89\text{m /rev}}$, therefore, wheel revolution, N_w became 0.53rev/sec or 31.8rev/min,

- Since the machine has one wheel, Machine weight, M_{wt} on wheel equals the machine weight itself, m_{wt} = 117.72N,

3.4.1. Power developed by the operator

According to Campell et al. (1990) the power of useful work done by human being is given by:

HP = 0.35 – 0.092logt … (eq.1)

Where,

HP = horse power developed during time t

t = time in minutes

Now, for 6 – 8 hours continues work the power developed by the operator would be

HP = 0.35 – 0.092Log (360min or 480) = 0.115 - 0.103hp, let's take the average of the ranges; it becomes = 0.109hp. Therefore, according to him the power of useful work done developed by an average human worker becomes 0.109hp

In order to change this power in to force we can use the following formula:

$$HP = \frac{\text{push (kgf)x speed } (\frac{m}{s})}{75} \ldots \text{(eq.2)}$$

Let the operating speed of the machine be 1m/s, therefore by rearranging equation 2 we can get

$$\text{Push (kgf)} = \frac{HP \times 75}{\text{Speed } (\frac{m}{s})} \ldots \text{(eq.3)}$$

$$= \frac{0.109 \times 75}{1\frac{m}{s}} = 8.175\text{kgf}$$

Hence, force developed by an average human worker = 8.175kgf

3.4.2. Force required maneuvering the machine, F_f

Force required operating the row seeder was calculated with the following formula:

$F_f = (C_R + i)m_{wt}$… (eq.4)

Where C_R = Rolling resistance

m_{wt} = machine weight = 12kg = 117.72N

i= maximum gradient of the ground, let 1%

The rolling resistance can be found by using the following formula:

$$C_R = \sqrt{\frac{Z}{Dw}} \ldots \text{(eq.5)}$$

Where, Z = maximum of the wheel that gets in to soil, assume = 5cm

Therefore, substituting eq. 5 in to eq. 4 we can get the following:

$$F_f = \sqrt{\frac{Z}{Dw}} + i)m_{wt} \ldots \text{(eq.6)}$$

$$F_f = (\sqrt{\frac{5}{60}} + 0.01)117.72N = 35.2N = 3.52kgf$$

Since, the force demand of the machine was less than that of the operator developed (i.e. 3.52kgf < 8.175kgf), this result prove that the machine was easily operable by one person.

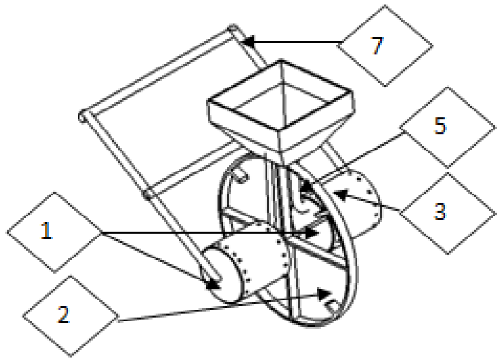

Fig 4. An isometric view of the assembled product of the designed *melkassa* seeder, and its part, 1 Drum side cover plates, 2 Lugs, 3 Drums, with holes around, 4 Ground wheel, 5 Feeder hoses, 6 Seed hopper, 7 handle.

3.4.3. The torque produced by the driving wheel, T_w

For determine wheel analysis and for shaft analysis the torque produced by the driving wheel, T_w is one of the necessary data. Therefore, it was calculated using the following formula:

$T_w = F_f \times D_W/2$ … (eq.7)

Where, T_w = torque produced by the driving wheel

F_f = Force required maneuvering the machine, F_f

D_w = diameter of the wheel, 0.6m

Therefore, substituting the values in eq. 7 we can get; Tw = 35.2N X 0.3m = 10.56N.m

3.4.4. Power required driving the planter, P

The operability of the machine by one-person determined in equation 7; here also it can be expressed in terms of power, so that it was calculated using the following equation:

$P_m = T_w N_W$ … (eq.8)

Where, N_W = wheel revolution, N_w is in rad/sec,

$P_m = 10.56N.m \times (0.53 \times 2\pi) = 35.17$ watt.

Since 1kw equals 741hp, it became

$$= \frac{0.03517}{0.741} = 0.047hp$$

Therefore, Po of operator much greater than Pm demand of the machine, so again this shows us it is safe to operate by one person(i.e. 0.109hp of the operator produced greater than 0.047hp of the power required by the machine, so we can conclude that it is easy to operate).

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3.4.5. Design of the seed metering mechanism.

Metering mechanism is the heart of seed sowing machine and its function is to distribute seeds uniformly at the desired application rates. Here the drum was used as metering mechanisms (fig 5)

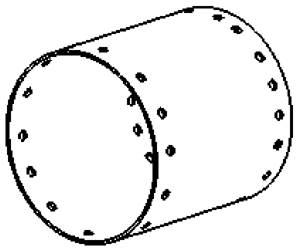

Fig .5The seed metering drum having holes around it's' circumference

However, the function of the hopper was used as a feeder; it feeds the drum continuously, then the drum metered the seeds (Fig 6).

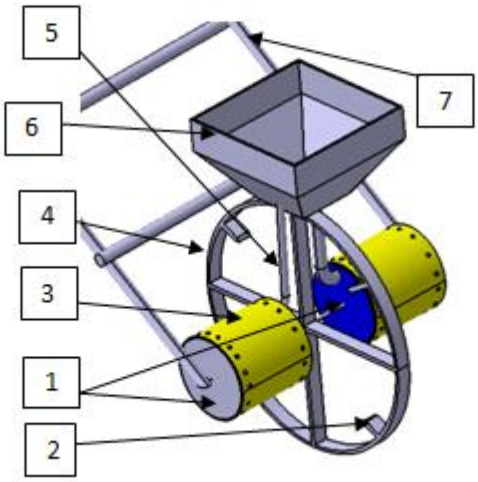

Fig .6 an isometric view of the assembled components of the design of *melkassa* seeder. The components are: 1 Drum side cover plates, 2 Lugs, 3 Drums, with holes around, 4 Ground wheel, 5 Feeder hoses, 6 Seed hopper, 7 handle.

This machine was designed for planting rice grain or paddy rice seed, in order to sow it in rows; as it mentioned above, the drum was used as a metering device. Hence, the number of the holes on each drum should be calculated, so it was determined using the following formula:

$n = \frac{\pi D}{Ix}$... (eq.9)

Where, n = number of holes on the drum

D = diameter of the drum, it takes 20cm

X = required seed to seed spacing, it takes 2cm

I= ratio of wheel to drum rotation, 1: 1

Therefore, substituting the values in eq. 9 we found that;

$n = \frac{\pi \text{ x } 20\text{cm}}{2}$ = 31.42 = take 32holes

The size of the hole is determined depends on the value of the average geometrical mean of the rice grain, their length(l), width(w), and thickness(t) of 50 seeds were taken. Their average geometrical mean calculated using the following equation, it result became 2.95mm, for the design we took 6mm.

dg = $\sqrt[3]{l * w * t}$... (eq.10)

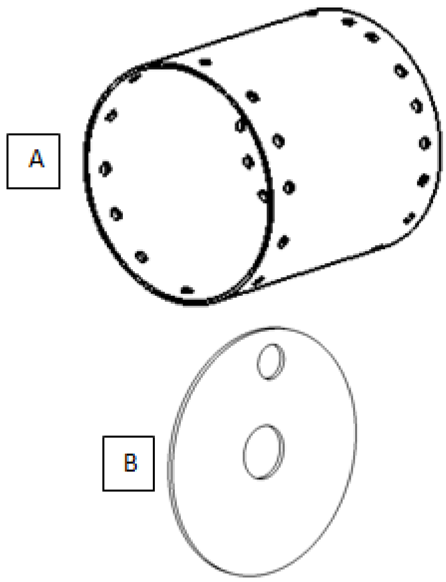

Fig .7 Isometric view of the designed seed drum, A and drum side cover, B for *melkassa* seeder

As you see in fig 6 and fig 7b, there are two side cover plates on the side of each drum, their function were seal or cover the opened drum sides. However, from the left drum the right side cover plate and from the right drum the left side cover plate used as not only side cover but also take paddy seed through the feeder hose which is running down from the upper hopper and let the seed to the drum; therefore, it maintain the percent fill ratio of the drum, and unlike the other two side cover plate they are stationary.

Due to the drum was partially used as seed storage; the weight of the seed of the drum should be included in calculation, so we know that;

$m_{sd} = \rho v$ ... (eq.11)

Where, m_{sd} = mass of the seed inside the drum, kg

v = volume of the drum, m^3

ρ = bulk density of the seed, kg per m^3

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The volume of the drum can be calculated as using equation 12;

$v = \pi r^2 h_d$… (eq.12)

Where, r = radius of the drum, m

h_d = height or length of the drum, m

so, entering the values we found the volume of the drum;

$v = \pi \times 0.1^2 \times 0.2 = 0.0063m^3$

Therefore, substituting the values of eq. 12 in to equation 11 we found the mass of the seeds in the drum;

$m_{sd} = \rho v = 596kg/m^3 \times 0.0063m^3 = 3.76kg$, for the design it assumed 4kg

3.4.6. Design of the seed box or feeder box

It is better to assume a trapezoidal shape of seed box is used in the machine due to consideration of free flow of seeds from the hopper bottom. Also the following parameters were considered for the design of the box; Angle of repose = 36^0, Bulk density of rice seeds = $689kg/m^3$ there where mentioned above.

Then theoretically the Volume of seed box was calculated by the following formula:

$V_b = 1.1V_s$ … (eq.13)

Where, V_b = volume of seed box, cm^3

V_s = volume of seed, cm^3

Here we found the volume of seed V_s, using equation 14 below

$Vs = \frac{Ws}{\gamma s}\gamma_s$

… (eq.14)

Where, W_s = weight of seed in the box, 6000g

γ_s = bulk density of seed, $0.689g/cm^3$

Therefore, substituting the above mentioned values in equation 13 we found that;

$V_b = 1.1\frac{Ws}{\gamma s} = 1.1\frac{6000\,g}{0.689 g/cm3} = 8{,}708.3cm^3 \approx 8709cm^3$

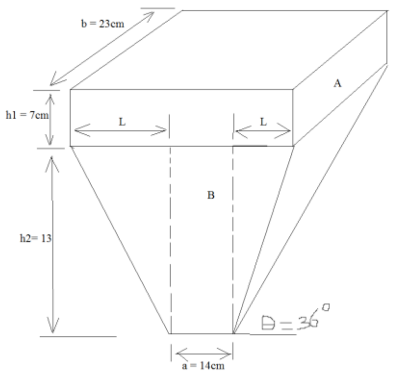

Fig.8 Details of seed box of the *melkassa*seeder

We can get the practical dimensions by trial and error methods. Hence, here also it was assumed that the box has a square in size at the top whose sides are equal to b = 23cm, l a= 14cm, b= 23cm, h_1 = 7cm, h_2 = 13cm

Now, from above fig 8, we can calculate the length L

2L = 23cm -14cm = 9cm

L = 4.5cm

Therefore, using the above dimensions of seed box assumptions, its volume is calculated by equation 15, it is the combination of the upper square box volume, V_A and the lower box, V_B.

$V_b = V_A + V_B$ … (eq.15)

Where, V_b = volume of seed box

V_A = volume of section-A of box

V_B = volume of section-B of box

Then the volume of V_A and V_B can be calculated using equation 16 and equation 17 respectively;

$V_A = bxbxh_1$… (eq.16)

$V_A = 23cm \times 23cm \times 7cm = 3703cm^3$

$V_B = \frac{1}{2}(a + a + L + L)\, h_2 \times b$ … (eq.17)

$V_B = \frac{1}{2}(2a + 2L)\, h_2 \times b$

$V_B = \frac{1}{2}\{(2x14) + (2x4.5)\}\, 13x\, 23 = 5,\, 531.5cm^3$

Hence, adding the results of V_A (eq.16) and V_B (eq.17) in to eq.15

$V_b = V_A + V_B$

$V_b = 3{,}703 + 5{,}531.5 = 9,\, 234.5cm^3$

Since the designed volume of seed box is $9{,}234.5cm^3$, which is higher than the theoretical volume ($8709cm^3$) found by equation 13. Therefore, the designed dimensions of the box are correct.

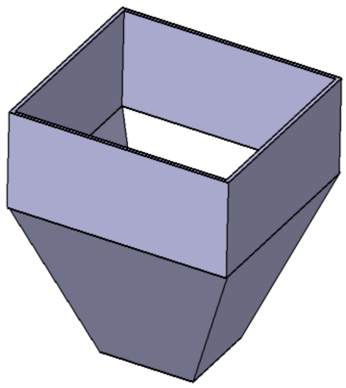

Fig.9 An isometric view solid work of the designed seed box for *melkassa* seeder.

3.4.7. Shaft design and analysis

The shaft that the seed drum rotates on must be visualized against forces, torques, and bending moments that are created in the shaft during operation. In process of transmitting power from ground wheel to rotating drum directly, at a given rotational speed, the shaft is inherently subjected to a torsional moment, or torque. Thus, torsional shear stress is developed in the shaft. Also, a shaft usually carries power-transmitting component which is bearings, and the load from seed box and drum, which exert a force on the shaft in the transverse direction (perpendicular to its axis). These transverse forces cause bending moments to be developed in the shaft, requiring analysis of the stress due to bending. In fact, in these shafts must be analyzed for combined stress because of the simultaneous occurrence of shear stresses and normal stresses due to bending.

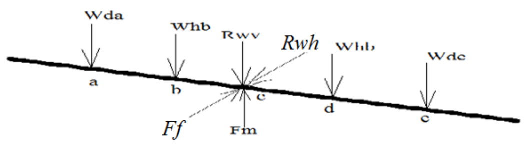

Fig 10. Free body diagram of the shaft subjected to different forces in xyz plane

Where,

F_m = the ground reaction due to the sum of machine weight, and weight of seeds carried by the machine itself. F_m = 12kg + 10kg = 22kg or 215.82N

F_f= force driving the wheel, equals 35.2N, we found it by eq.6

R_{wh} = wheel reaction at c in the horizontal direction.

R_{wv}= wheel reaction at c in the vertical direction.

W_{da} = weight of seed drum including the seed at full load at point a.

W_{hb} = weight of seed hopper including the seed at full load at point b.

W_{hd} = weight of seed hopper including the seed at full load at point d.

W_{de} = weight of seed drum including the seed at full load at point e.

Here in order to find those forces acted on the shaft and depend of the value of those forces; we determined the optimum diameter of the shaft, so we follow the following steps:

Step 1. Finding the load exerted on the shaft

The load exerted on the shaft comes from the seed box and from the seed drums. Therefore, the weight comes from the drums can be calculated as follows, (since the two drums are equal in volume it was assumed that they contain equal mass of seeds 4kg, which was found by equation 11).

W_{da} = W_{de} = [seed weight at full load + drum weight] … (eq.18)

= (4kg + 0.5kg) x 9.81 = 44.145N

And the weight that comes from the seed box also can be calculated using the following formula; (since the seed box stands on the shaft with two foot, the load should be divided in to two). It was designed in the above to store 6kg rice seed.

W_{hb} = W_{hd}= 0.5[seed weight at full load + hopper weight] … (eq.19)

= 1/2 (6kg + 5kg) x 9.81 = 53.96N

Step 2. Forces exerted on the shaft in the vertical direction (yz)

The second step was finding the forces exerted in the vertical direction on the shaft, so it was showed below in fig 11

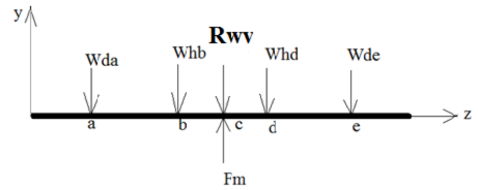

Fig 11. Free body diagram of the shaft subjected to forces exerted in vertical direction

Considering Summation of forces, that is $\sum F$ **= 0,** we can get the following:

$F_m – R_{wv} – W_{da} – W_{hb} – W_{hd} - W_{de} = 0$ … (eq.20)

From the equation 20 the only unknown is R_{wv}, it can be rearranged in to eq.21 below

$– R_{wv} = W_{da} + W_{hb} + W_{hd} + W_{de} - F_m$… (eq.21)

= 44.15 + 53.96 + 53.96 + 44.15 - 215.82 = 19.6N

R_{wv}= -19.6N, (this result shows that the assumed direction is correct), so reducing this value, i.e. $\sum Fc$ = $F_m + R_{wv}$ = 196.22N (net upward force at point c)

So the free body diagram in the yz plane looks like as follows;

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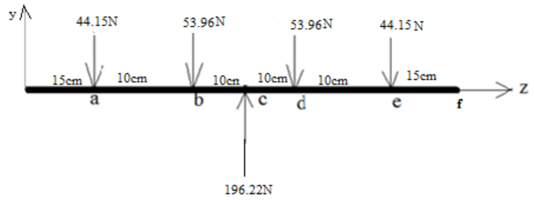

Fig a

The Shear diagram on the yz plane look like Fig b, when considered it from point f

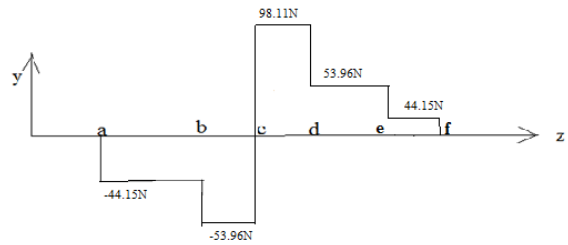

Fig b

The bending moment diagram on the yz plane, when finding from point e, look like;

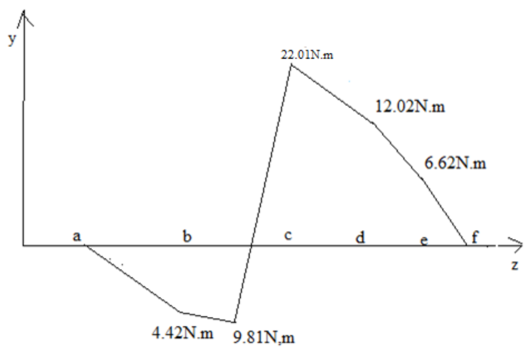

Fig c

From the above analysis we found that the maximum bending moment occurs at point c, with a magnitude of 22.01N.m

Step 3. Forces exerted on the shaft in the horizontal direction (xz plane)

The third step was finding the horizontal forces exerted on the shaft, the free body diagram looks like;

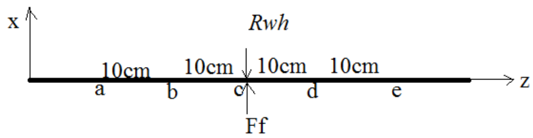

Fig 12 free body diagram of the shaft subjected to forces exerted on the horizontal direction

Considering Summation of forces, $\sum F = 0$, we found equation 22 below;

$F_f - R_{wh} = 0$ ... (eq.22)

From equation 22 we found that $F_f = R_{wh} = 35.2N$, (F_f was found by eq.6 above)

Hence, all forces in the horizontal direction become zero; we conclude that there is no shear stress as well as bending moment.

Step 4. Determining the maximum bending moment

So here the next step was finding the resultant of the vertical and the horizontal moments found in step 2 and step 3, respectively. Therefore, for this we can use the following formula:

$M_{max} = \sqrt{(M_H^2 + M_V^2)}$ ... (eq.23)

$M_a = \sqrt{(0^2 + 4.42^2)} = 4.42N.m$

$M_b = \sqrt{(0^2 + 9.81^2)} = 9.81N.m$

$M_c = \sqrt{(0^2 + 26.25^2)} = 22.01N.m$

$M_d = \sqrt{(0^2 + 12.02^2)} = 12.02N.m$

$M_e = \sqrt{(0^2 + 6.62^2)} = 6.62N.m$

Therefore, from the results of equation 23 at each point a, b, c, d, and e we found that the maximum bending moment occur at point c

Step 5. The torque on the shaft

The power transmitted from the driving wheel to the shaft with 1:1 ratio, i.e. directly, hence torque produced at the wheel and the shaft are equal, 10.56N.m or we can also calculate using the following formula:

$P = T_1N_1 = T_2N_2$ ... (eq.24)

Where, p = power transmitted

T_1 = torque produced at the wheel, equals 10.56N.m (which was found by eq.7 above)

T_2 = torque produced at the shaft, which is equal, 10.56N.m

N_1 = angular rotation of the driving wheel, =31.8rev/min (taken from the initial mentioned parameters above)

N_2 = angular rotation of the shaft, 31.8rev/min (because of 1:1)

Step 6. Diameter of the shaft

The final step for shaft analysis was determining the diameter of the shaft which was considered through the above steps. Therefore, we can find it from the following equation;

$\tau_{max} = \frac{0.5\delta a}{FS} = \frac{16}{\pi d3}\sqrt{((c_m M_{max})^2 + (c_t T)^2)}$ ... (eq.25)

Where, τ_{max}= allowable stress, 150MPa

F_s = factor of safety, 3 in agricultural machinery

$c_m = 1.5$, $c_{t=1}$

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T = torque on the shaft, 10.56N.m (eq.24)
M_{max}= the maximum bending moment, 22.01N.m (eq.23)
By rearranging equation 25, we found that;
$d^3 = \frac{32FS}{\pi\delta a}\sqrt{((c_m M_{max})^2 + (c_t T)^2)}$ … (eq.26)
$= \frac{32x3}{\pi x 150000000}\sqrt{((1.5x22.01)^2 + (10.56x1)^2)}$ = 0.0192m = 1.92cm

The shaft of the planter at least it would be 1.92cm in diameter in order to overcome the above mentioned or assumed forces.

3.4.8. Wheel design and analysis

In start to design the wheel of the planter let assume that the stress occur on the wheel is pure torsion. The wheel of the planter is made from 3mm sheet metal (stainless steel) whose shear strength τ_{max} , 80Mpa, 4 stainless steel bars 6mm thick are used to strengthen the wheel therefore, formula to be used are that estimates the Shear amount in welded closed thin wall, t<<<d: Fig 13 below;

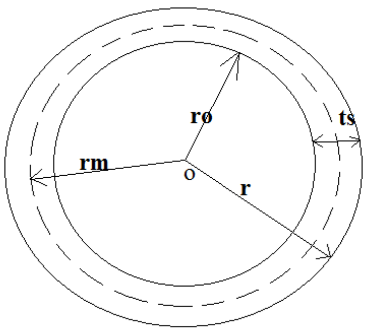

Fig 13. Detail free sketch of the wheel

We can calculate the shear amount on the wheel,
$\tau_w = \frac{T}{2Amts}$… (eq.27)
Where, τ_w= shear stress on the wheel
T= torque produced=10.56N.m (eq.24)
A_m =the area calculated based on the medium length line
r = the outer radius of the wheel=0.3m
t_s = the thickness of the wall=3mm
r_o = the inner radius of the wheel 2.997cm
r_m = radius of the medium of the wheel,m
From equation 28 we can find A_m
$A_m = \pi r_m^2$… (eq.28)
$= \pi(r - \frac{ts}{2})^2 = \pi(0.03 - 0.0015)^2 = 0.0026m^2$
Hence, $\tau_w = \frac{10.56}{2x0.0026x0.003}$ = 676.92kpa

Comparing this shear stress with the maximum allowable shear stress of the metal, τ_w<<<τmax, tells us the wheel is safe. Also the comparison can be done by calculating the maximum allowable torque amount that the wheel can handle without failure. To do that, τ_{max} , 80Mpa of material has to be used,
By rearranging equation 27, we found;
$\tau max = \frac{Tmax}{2Amts}$
$T_{MAX} = 2A_m t_s \tau_{max}$ … (eq.29)
= 2x0.0026x0.003x80Mpa = 1.23KN.m(maximum allowable torque on the wheel)

So the wheel is safe from failure the torque produced on the wheel (i.e 10.56N.m) is much less than that of allowable, i.e. T_w<<<T_{max}. Since, the torque produced by the wheel is too small, it is logically to assume that the angle of twist produced by the applied torque is negligible.

3.4.8.1. Wheel width design

The width of the wheel specified for the design is 10cm (0.10). Now in the following calculation the maximum pressure created due to the contact of the wheel and the ground is analyzed, and then compared with the minimum pressure of the ground measured using cone-penetrometer reading.

During the analyzes, if P_{max}<P_{min} it would be considered that the chosen width of the wheel is safe because it means that the wheel rotates over the surface of the ground without parts of it sinks in to the soil. while, if P_{max}>P_{min}, the length or width of the wheel should be increased to some level to avoid sinking of the wheel in to the soil. In order to calculate it we use the following relation; as dipping of the wheel in to soil increases draft requirement can be calculated using the following formula:

$b = \sqrt{[\frac{2F}{\pi l}\frac{[(1-y1^2)/I1 + (1-y2^2)/I2]}{^1/_{d1}+^1/_{d2}}]}$ … (eq.30)

Where, y_1 = Poisson ratio of steel =0.3
y_2 =Poisson of sandy soil = 0.25-0.4
I_1= young modulus of elasticity of steel=200Gpa
I_2=young modulus of elasticity of sandy of soil, (10-50Mpma (loose to compact, for this case select loose one)

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b=half length of the narrow rectangular area of contact of the wheel and the ground.

d_1 = diameter of the wheel, 0.6m

d_2 = diameter of the contact surface, ∞

p_{min} = The minimum pressure of the ground obtained at 17% moisture content of the soil, 328.31 Kpa

Solving for b

$$b = \sqrt{\left[\frac{2x117.72}{\pi x 0.1}\frac{[(1-0.3^2)/200\ x10^9 + (1-0.4^2)/\ 10x10^6]}{{}^1/_{0.6}+{}^1/_{\infty}}\right]} = 5.013x10^{-3}$$

Now we can determine P_{max} with the following formula:

$p_{max} = \frac{2F}{\pi bl}$ ... (eq.31)

Where,

F = the force exerted by the wheel, 117.72N

l=Width of the wheel or length of contact of with the ground, 10cm

p_{max}= the maximum pressure exerted on the wheel

p_{min} = The minimum pressure of the ground obtained at 17% moisture content of the soil, 328.31 Kpa (taken from cone penetrometer reading)

Therefore, substituting the result of equation 30 and the values mentioned in to equation 31 we found the result that;

$p_{max} = \frac{2x117.72}{\pi x 0.15 x 5.013x10^{-3}}$ = 99.66kpa

Since Pmax<Pmin, the selected length of the width of the wheel is safe and the wheel will rotate, over the surface of the ground without dipping in to soil.

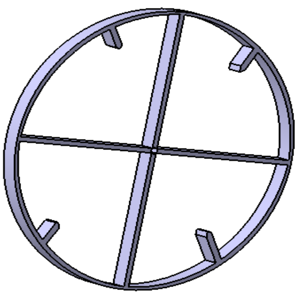

Fig 14.An isometric view of the designed wheel.

3.5. Designing of handle of the planter

In order to design this there was selected simply 25mm mild steel outside diameter conduit pipe. Then the length of handle is calculated based on the standing elbow height of female operators, it will be 1m, the distance of the wheel center from the operator, it will be 1.15m (*D.N.Sharma, S.Mukesh, 2010*); therefore, we can calculate the angle of inclination Ө with the horizontal. Fig 15

tan Ө = $\frac{opposite\ \ side}{adjecent\ \ side}$... (eq.32)

Ө = 31.3^0

We can find the lenth of the right side handle from sine law

Sin Ө = = $\frac{opposite\ \ side}{hypotene\ ss,L}$... (eq.33)

L = $\frac{opposite\ \ side}{\sin\ Ө}$ = $\frac{0.7M}{\sin\ 31.3}$ = 1.35m,

It multiplied by 2 for two sides, then it becomes = 2.7m. Adding the width, it is 0.7m, therefore, it becomes 3.3m conduit pipe was used to construct the handle. See Fig 15

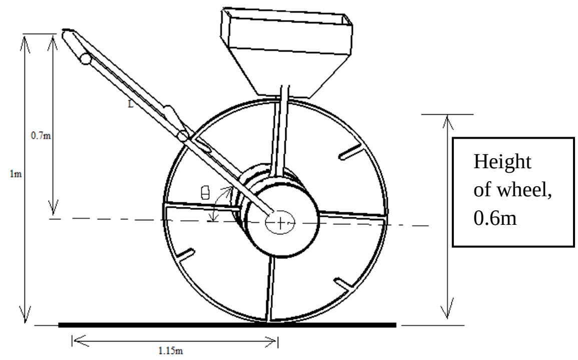

Fig 15 handle of the designed YP planter

3.7. Methods used to test the performance of the seeder

Manually operated four row rice seeder was tested in comparison with hand planting method. The experiments were arranged in a randomized complete block design (RCBD) with three replications. The plot area was 10m × 8m. The variety used for the test was NERICA-1. Fertilizer was applied equally to all the treatments according to the standard recommendations. Data were recorded about plant population, seed rate, seed spacing, planting time or labour requirement, 1000-grain weight, and germination rate before and after planting. All data were subjected to ANOVA using the SAS8.0 statistical software for windows and comparisons between the treatments were considered significantly different at level of *P* <0.05 by the LSD test, 5%

4. Results and discussions

4.1. Laboratory test result and its discussions

Before directly conducted the test, the machine was subjected to laboratory test in order

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to compromise the forward speed and the recommended seed space and seed rate. *G.V. Prasanna Kumar, BrijeshSrivastava, D.S. Nagesh*(2009) examined and recommended that the optimum drum configuration was one with 36 orifices of 6mm diameter on its circumference. The necessary initial percent fill of drum was about 53%. The optimum forward speed of operation should be 4.6 – 6.9 km/hr. And *kunninka Naklang, Shu Fukai, Kesorn Nathabut*, (1996) recommended that the distance between the seed or hill should be 2 – 3cm and row to row spacing was should be 20cm.WARDA (2002) reported that the optimum seed rate should be between 50-80kg per ha. Also *Kunninka Naklang, Shu Fukai, Kesorn Nathabut,* (1996) examined that for direct seeding upland and upland conditions the rate should be up to 63kg per ha. By consideration of this recommended value the machine was tested in the laboratory on stick belt with three different forward speeds such as 1m/s, 1.60m/s and 1.92m/s (table 3).

In order to get some of the physical properties of the seed, 50 sample seeds were randomly taken and their length, width and thickness were measured. Their average geometrical mean became 2.95mm; the 1000 seeds mass of the rice seeds became 19.432g; the bulk density became 689 kg/m3. All the readings were taken and determined at the moisture levels of 12 %(w.b.)

Table 3. Results of descriptive statistics with three forward speed in m/s, and the corresponding seed spacing in cm

Descriptive Statistics	1m/s	1.60m/s	1.92m/s
N	26	26	26
Mean	2.4577	3.6000	3.8346
SD	1.2838	1.8223	2.3823
Minimum	1.1000	1.0000	1.0000
Median	2.1500	3.0000	3.0000

From the results of the laboratory data presented in table 3 it was found that the mean seed distance for 1m/s speed was 2.46cm which fall between the ranges of recommended value, while the mean seed distance of the other two speeds became out of the range of the recommended distance. Then it also found that the uniformity of seed spacing was best (unlike recommended values) at the percent fill ratio of 25%, Hence the field experiment was conducted with settled forward speed i.e.1m/s and with 25% of the initial drum fill ratio.

4.2. Field experiment results and discussions

Table 4.Measured level of significance from the average of variance for seed rate, planting time, seed spacing, and plant population.

Parameters	df	MS	RE	F	Level of significance, $p<0.05$
Seed rate	14	0.51770	1.27	94.29	0.0000**
Planting time	56	11.5278	1.44	3.64	0.0464**
Seed spacing	56	2.01667	1.54	8.18	0.0059**
Plant density	26	187.5	3.36	10.09	0.0038**

** Means there is significant difference NS – Non significant

The results of *melkassa*seeder and manual method with the parameter used such as seed rate, planting time, seed spacing and plant density are presented on table 4 and table 5.

For the seed rate since P value of 0.0000 is less than P = 0.05, and from LSD, 5 %(table 5) it has been determined that the *melkassa*seeder and the manual method mean are significantly different from one another. From ANOVA Table 4 of seed rate the mean of manual method was found 0.8544kg and the mean of *melkassa*seeder was found 0.5178kg; which means manually planting method was taken 0.8544kg for each plot size of 10mx8m or $80m^2$ areas while *melkassa*seeder was taken around 0.5178kg for the same plot size. This implies that for manual method 106.8kg seed was needed in order to cover one hectare of land while for *melkassa*seeder needed around 65kg per ha. It was clearly found that *melkassa*seeder saved 41.8kg of seed compared with manual method. WARDA (2002) reported that the optimum seed rate should be between 50-80kg per ha. Also

Kunninka Naklang, Shu Fukai, Kesorn Nathabut, (1996) examined that for direct seeding upland and upland conditions the rate should be up to 63kg per ha. In this regard, the application rate of *melkassa*seeder was found better than manual method of planting.

Table 5 the performance of *melkassa*seeder against manual planting method.

Planting method	Parameters			
	Labour-requirement man-hr per ha	Seed rate kg per plot*	Seed spacing cm	Plant population Seedling per m^2
Manual Method	18.40	0.8544	1.8967	49.067
Melkassa Seeder	4.36	0.5178	2.2633	44.067
LSD, 5%	0.8813	0.0718	0.2567	3.235
CV(%)	13.31	10.35	23.86	9.26

The seed spacing was the second parameter and its result also determined from the above summarized ANOVA Table 4 and LSD, (5%) table 5, here we found that the p-value was 0.0099 which means it was less than p = 0.05 therefore, there is significant difference in seed spacing between the manual method and using *melkassa*seeder. It was found that 1.8967cm for manual method and 2.2633cm for *melkassa*seeder. The rice agronomist suggested that rice seed spacing (i.e. distance between seeds/hills) should be 2cm – 3cm in order to gain a higher amount of yields from a given area of land (*Kunninka Naklang, Shu Fukai, Kesorn Nathabut*, 1996). Hence, it was found that the value of distance between seeds or hills spacing for the manual method was less than from the suggested range while the value of mean seed spacing by using *melkassa* seeder was fall between this ranges. Therefore, it conclude that the better technique was using *melkassa* seeder instead of manual method; in order to minimize risk of inappropriate rice seed spacing, which was again the consequence of overplanting. Anyone obviously could understand that over planting is one of the causes of competition between seedlings or plants for nutrients and results in decline of yields.

The third parameter was used to determine the performance of the designed seeder was the time taken for planting. Its' data was recorded randomly from the trials and the data was analyzed. However, here it was analyzed against a person manually planted with the *melkassa* seeder work only within one rows. From the analysis of ANOVA Table 4, it was found that the p-value was 0.0464 which is less than p = 0.05 and also from analysis of LSD, 5% it was found that the means of the two method have a significance difference. The manual method took 13.235sec to finish 10m row while 12.311sec took to finish the same length of row using *melkassa*seeder work only with one row. This results implies that 18.4hr needed to finish one hectare of land a person work manually while 17.45hr needed by *melkassa* seeder planted with one row. If the *melkassa* seeder operated with full potential (i.e. the machine was designed for planting with four rows), it needed 4.36hr in order to complete one hectare of land. Hence the *melkassa* seeder was found four times faster than manual method of planting.

The fourth parameter was plant population, in this case the p-value became 0.0038 which was less than that of p = 0.05, hence the two means have a significance difference at level of p<0.05. It was found that 49.067seedling per m^2 for manual method and 44.067seedling per m^2 for *melkassa*seeder.

5. Conclusions and Recommendations

5.1. Conclusions

If the machine was kept operating at 1m/s forward speed and at 25% the initial fill ratio of the drum it concluded that it was better in performance comparing with a person manually planting method. The designed rice seeder (*melkassa*seeder) was found 4 times faster than manual methods in terms of time. It has also better results in saving seed; 65kg were enough to cover one ha; which is between the recommended ranges (i.e. 50 – 80kg). Similarly the plant to plant distance of *melkassa*seeder was found (2.2633cm) it falls between the ranges (i.e. 2 – 3cm). Due to the test was conducted in the dry season; although, the irrigation schemes had not properly available around the field; it was became difficult for us to control the optimum moisture requirements of the rice plant due to shortage of water. For instance, there was the significant difference between the treatments in plant population. Some of the calculated performance of the machine also presented below in table 6;

Table 6: calculated performance of YL seeder

YL seeder calculated performance			
Labour–requirement man-hr per ha	Theoretical field capacity, ha/hr	Effective field capacity, ha/hr	Field efficiency,%
4.36	0.22	0.18	82

5.2. Recommendations

- The designed seeder was better in all parameters, but it was difficult to conclude in plant density so that it has to be clarifying that the consequences of the difference in controlled moisture conditions, and the result of the yield should be included in the parameters of the future evaluation of the seeder.
- For this performance evaluation the chain that are attached at the rear end of the seeder, was used for seed covering mechanisms, but in the future it has to be replaced by seed covering structure.

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