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Development of power operated paddy seeder for dry and wet seeding

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Abstract
Rice is one of the most important crops in India with a total area of 44 Mha and a production of 110 million tonnes. The major constraints in manually transplanted paddy cultivation are non-availability of labour on time, especially during peak periods of sowing and need of large quantity of water. Mechanical transplanter could not be made widely popular because of higher cost, poor traction and sinkage. Direct seeded rice is becoming popular in India due to severe shortage of water and labour and almost comparable yield. There is no single machine available for direct seeding of rice in both dry and wet condition.
It is a single wheel, 8-row riding type machine fitted with a 2.94 kW single cylinder, air cooled diesel engine which powers the forward movement of the driving wheel and rotary motion of metering mechanism. The drive wheel receives power through V-belt, cone clutch and gear box. Gear box for ground wheel comprises three sets of spur gear. The input shaft of gear rotates at speed of 1300 rpm and then according to shifting of gear lever it is reduces up to 185 rpm. A universal shaft from the gear box provides power to the sets of bevel and spur gear box and from then power is transmit to input shaft of gear box of metering mechanism as 468 rpm and then finally reduces up to 20.51 rpm to the cup type metering mechanism through chain sprocket assembly mounted over the float. The performance evaluation of a power operated paddy seeder was done with the pre-germinated paddy seed and dry seed under laboratory and field test.
Engine of paddy seeder 2.43kW (4 hp) revolves at speed of 2600 rpm which reduces as 90 rpm to the metering shaft and 21 rpm to the driving wheel through reduction unit. The fuel consumption varied between 2.57 to 2.83 l/ha with an average of 2.68 l/ha in dry seeding condition and 2.78 to 2.98 l/ha with an average of 2.83 l/ha in wet condition. The effective field capacity of machine is 0.23-0.25 ha/h. The field efficiency of paddy seeder in dry condition was 77.67 % and in wet condition it is 71.88 %.

Keywords: Power operated paddy seeder, metering mechanism, power transmission

Introduction

Directed seeded rice plays an important role in satisfying the rice grain requirement of the people of the world. Transplanting of rice seedlings being a high labour intensive and expensive operation needs to be by direct seeding which could reduce labour needs by more than 20 per cent in terms of working hours. For line sowing many designs of manual drum seeder & bullock drawn drum seeder have been fabricated but pulling capacity them on puddle fields involves drudgeries problem and is classified as heavy work. Direct dry seeding is one of the best methods under rain fed field condition. In the rainy season friable field conditions, soil is available for limited period. If rains continue the soil becomes saturated. Under such conventional seed drill becomes difficult to operate due to clogging and chocking of furrow openers. Therefore it is necessary a machine which can be operated in both dry and wet field conditions. The developed the power operated paddy seeder unit could be useful in eliminating drudgery in transplanting or pulling of manual drum seeder besides other advantages of pre-germinated line seeding. Sahoo *et al.* (1994) [11] developed a six row power tiller operated pre-germinated paddy seeder and results showed that the effective field capacity of the seeder was 0.168 and 0.114 ha/ h for 99 and 253 mm hard pan depths respectively. The row to row spacing was 200 mm and hill to hill spacing was 99.5 mm with 3-5 seeds per hill. Cup type seed metering discs of 8 mm diameter and 6 mm depth were designed so as to pick up 3-5 seeds per hill. The capacity of the hopper was 40 kg. The cost of operation of the seeder was observed Rs. 173 per hectare.

The seed rate was set at 75 to 85 kg/ha for three varieties, super fine, fine and coarse grain. Krishnaiah (1999) [6] reported that the Directorate of Rice Research, Hyderabad India, developed an 8-row modified seeder in 1997-98. The cost of seeder was about Rs. 2000 and weight was only 12 kg. A single drum with 8-rows of holes was mounted on two wheels at the ends. The seed rate was adjustable to 50-75 kg/ha. Two workers were used for operating the machine in the field. The seeds were soaked for 24 hours and incubated for 24 hours before they were sown in the field. Mathankar *et al.* (2006) [7] developed a self-propelled rice ridge seeder for pre-germinated seeding for wet field condition at Central Institute of Agricultural Engineering Bhopal. They reported that, the yield crop was 5.3 t/ha and it was comparable to manual transplanting 5.7 t/ha and manual drum seeder 5.1 t/ha and it was higher than manual broadcasting 4.4 t/ha. Sharma and Reddy (2006) [12] developed a self-propelled 10-row paddy seeder at CIAE Bhopal and reported that the effective the field capacity of the seeder was 0.25 ha/h. The seeder has a working width of 2.0 m row length. For each row there was a seed hopper, a drum type metering device. The row to row spacing was 200 mm and hill to hill spacing was 100 mm with 4-6 seeds per hill. The capacity of the seed box was 30 kg. The cost of operation of the seeder was observed Rs. 500/ha.

Material and Methods

Assumptions made in design of Paddy Seeder were

1. The Power operated paddy seeder should be worked in both dry as well as wet field condition. The design should be so simple for interchangeability that with limited time and tools it can be modified for dry or wet sowing.
2. The seed rate of power operated paddy seeder can be change from 15 to 25 kg/ha.
3. The number of seeds requires 2 to 3 seeds per drop.
4. The distance between plant to plant maintains as 20 cm, 15 cm and 10 cm depends on number of cups in the per plants of metering device. Paddy Seeder consists of a 2.9 kW 2600 rpm 4-stroke diesel engine, a centre driven transmission box with bevel gear, gear box, metering mechanism.

Design of Power Operated Paddy Seeder for Dry and Wet Field Conditions

Based on agronomic requirement of paddy and assumption made, the power operated paddy seeder for dry and wet field condition was developed by designing the individual components. The conceptual design of the machine is shown in Fig. 3.1. The designs of various components are described below.

Design of frame

Frame was subjected to torsion and bending due to induced draft. Eight furrow openers were arranged on tool frame for dry seeding. Design was based on the stresses produced in the frame. Let the working width of furrow was top width 40 mm, lower width 25 mm and 35 mm deep and shape of furrow is trapezoid.

$$\text{Cross section of furrow opener (A)} = \left(\frac{a+b}{2}\right) \times h. \quad (1)$$

Where,
a = top width of furrow opener
b = lower width of furrow opener
h = cutting depth of furrow opener

$$A = \left(\frac{40+25}{2}\right) \times 35$$

$$A = 11.375 \text{ cm}^2$$

The value of the actual average soil resistance is calculated by the following formula. (Varshney *et al.*, 2004)

$$F_x = A \times P_k \ldots \quad (2)$$

Where,
A = Cross section of furrow
P_k = Specific soil resistance for the heavy soil

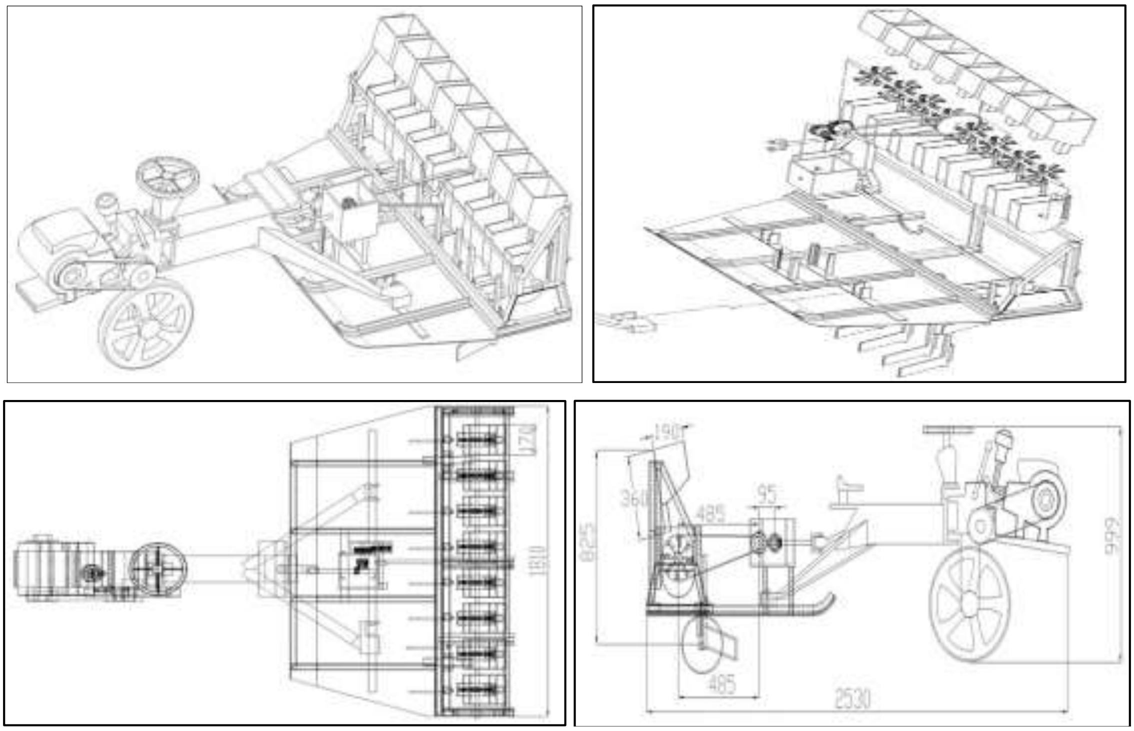

Fig 1: Conceptual design of power operated rice planter for dry and wet land

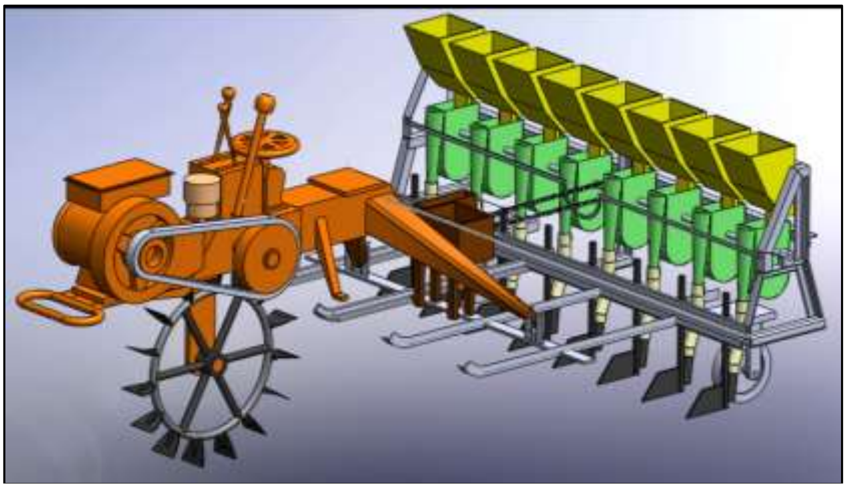

Fig 2: Conceptual design view of power operated paddy seeder for dry seeding

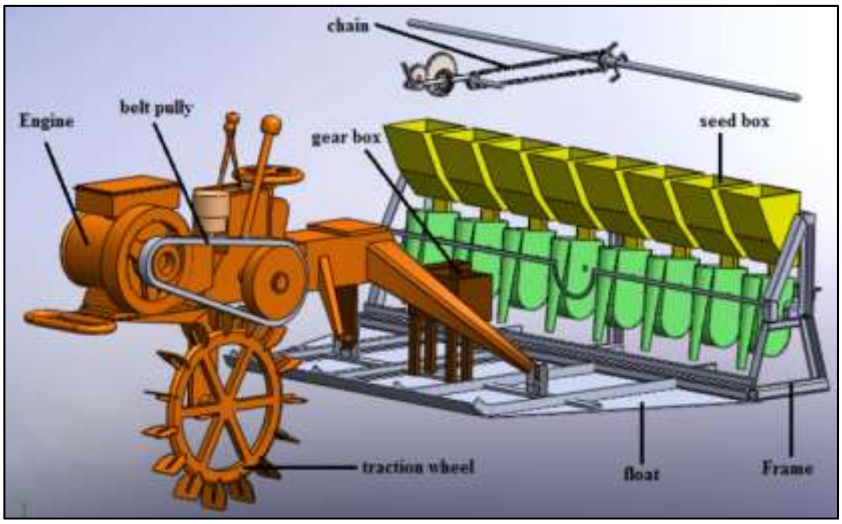

Fig 3: Conceptual design view of power operated paddy seeder for wet seeding

Specific soil resistance P when sowing to a depth of 15 cm under different soils are: (Varshney *et al*., 2004)

Light soil : 0.12 kg/cm^2
Medium soil : 0.15 kg/cm^2
Heavy soil : 0.20 kg/cm^2

Therefore, F_x = 11.375 × 0.20 = 2.275 kg

The soil resistance is assumed to be 3 to 5 times higher than actual average soil resistance (F_x)

Draft at the tip of tine

(D_t) = Fx × (3 to 5 times) kg … (3)

D_t = 2.275 × 4 = 9.1 kgf

Total draft = 9.1 × 9.81
= 89.271 N

Eight furrow openers are to be arranged in a single bar. The design was based on the total stress produced in the bar.

Draft per furrow opener = 89.271 N
Total draft = 89.271 × 8
= 714.168 N
= 714.168 × (F.O.S)
= 714.168×4(F.O.S for MS=4; Khurmi& Gupta, 2005)
= 2856.672 N (291.2 kg)

Torque on the square bar = draft x ground clearance

Ground clearance = 40 cm =0.4 m
Torque on the square bar = 2856.672 × 0.40
= 1142.66 N-m

In addition to the torque, bending moment would also be produced. The bar was considered as simple supported beam on the frame in between the eight furrow openers.

The maximum bending moment

$$M = \frac{WI}{4} \ldots \quad (4)$$

Where,

W= Total draft, N
= Total weight on frame
= 2856.672 N
I = Total length of frame
= 170 cm

$$M = \frac{2856.672 \times 1.70}{4}$$

M = 1214.09 N-m

Equivalent torque due to torsion and bending moment

$$T_e = \sqrt{M^2 + T^2} \ldots. \quad (5)$$

Where,

T_e= Equivalent torque, N-m

M = Max. Bending moment, N-m
T = Torque on the bar, N-m

$$T_e = \left(\sqrt[2]{\{1214.09^2 + 1142.66^2\}}\right)$$

T_e = 1667.24 N-m = 16995.31 kg-cm

The maximum shear stress developed at the center of the tool frame was obtained by well-known relationship

$$\frac{f}{R} = \frac{T}{I} \quad \ldots \quad (6)$$

Where,
F = shear stress at any section
R = Distance of the section from neutral axis
T = Torque produced
I = Polar moment of inertia ($d^4/9.6$)

The maximum working stress for squaresection of M.S. steel is 3500 kg/cm^2 (Sharma, 2008) [12]. For square section having each side may assuming d.

I = $d^4/9.6$ Here f is 3500 kg/cm^2
(3500 x 2)/d = 16995.31 × 9.6 /d^4
d^3 = 16995.31 x 9.6/3500 x 2
d = 2.856 cm
d = 28.56 mm
d = taken the width of section 30 mm

Therefore considering availability of the square bar section 30 x 30 x 5 mm was selected.
For supporting seed boxes and metering devices an MS angle iron was used with dimensions of 30 x 30 x 05 mm and for float and power transmission unit MS flat bar type supporting frame was used with dimension 20 x 04 mm. the whole dimension of frame as 1130x1700x910 mm.The isometric view of the main frame is shown in the Fig. 4

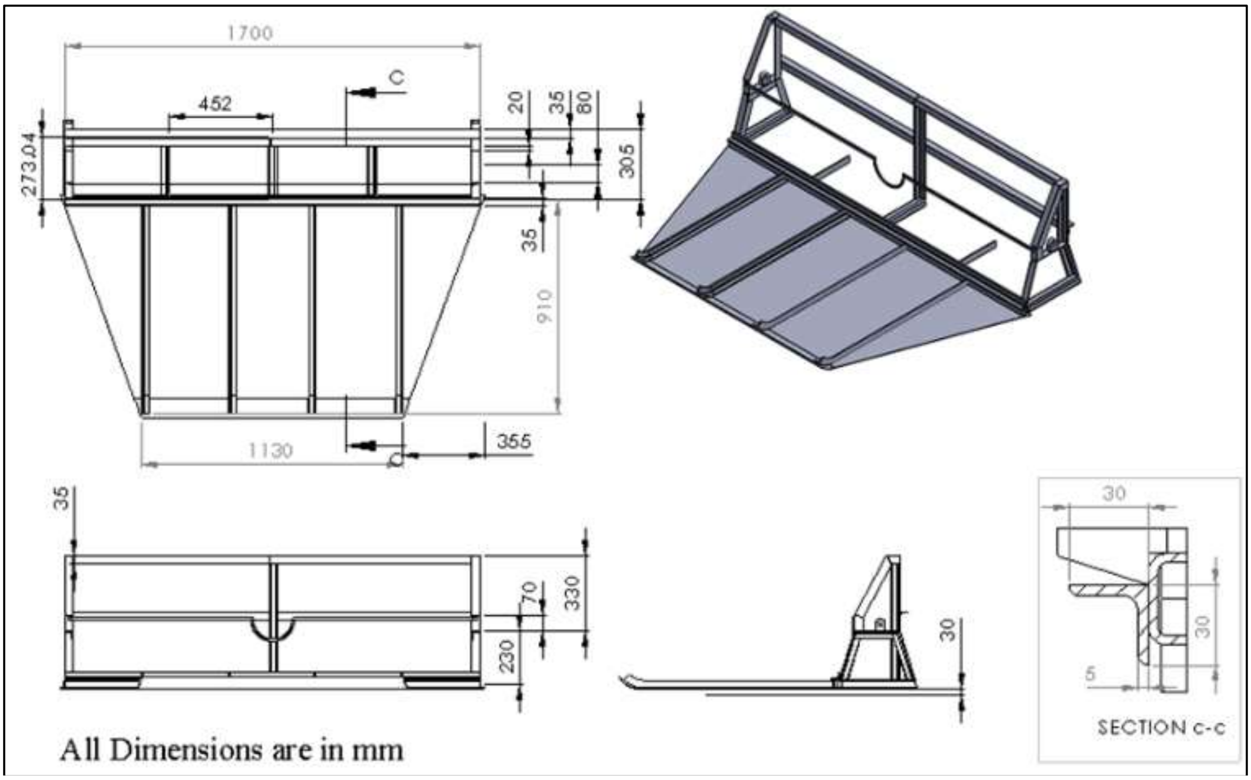

Fig 4: Isometric view of frame

Design of seed box
The cross section of the seed box may be trapezoidal, rectangular, triangular or cylindrical; in this work trapezoidal shape was considered for seed box. It was made out of MS sheet. The bottom was kept inclined from the horizontal. The dimension of seed box was 195 x 180 x 240 mm.

Capacity of seed box
Box capacity is calculated based on the quantity of the material to be filled in the box at a given bulk density, Varshney *et al.* (2004).

$$V = \frac{Q}{\rho} \quad \ldots. \quad (7)$$

Where,
V = volume of box, m^3
ρ = bulk density of material, kg/m^3
Q = box capacity, kg

Design of metering device
The design methods were adopted as given by Sharma and Mukesh (2010) [12] for seed metering mechanism. MS material is used for fabrication of metering device which circular in shape with diameter of 485 mm. The diameter of cup of the metering device was 12 mm. The shaft of diameter of 30 mm is used for revolving metering mechanism of power operated paddy seeder.
Assumptions seed rate: 15 kg/ha
Spacing : 20 cm x 15 cm
B. Calculation for dimension of cup
No. of seeds per ha: 10000000/20 x15 =333333.33
Amount of seeds to fall in each drop: 1500/333333.33 = 0.045 gm
Average length of the paddy = 9.29 mm

Diameter of cup (Taking 25 % additional length for sprouted paddy: 11.14 mm

No of seeds per ha: $\frac{100000000}{20\times15}$ = 333333.33

Amount of seeds to fall in each drop: $\frac{15000}{333333.33}$ = 0.045gm

In dry seeding condition:
Thousand grain weight: 26 gm

No. of seeds in each drop: $\frac{0.045}{0.026}$ = 2

In wet seeding condition:
Thousand grain weight: 38 gm

No. of seeds in each drop: $\frac{0.045}{0.038}$ =Average length of the paddy: 9.29 mm

Diameter of cup (Taking 25% additional length for sprouted paddy): 11.14 mm

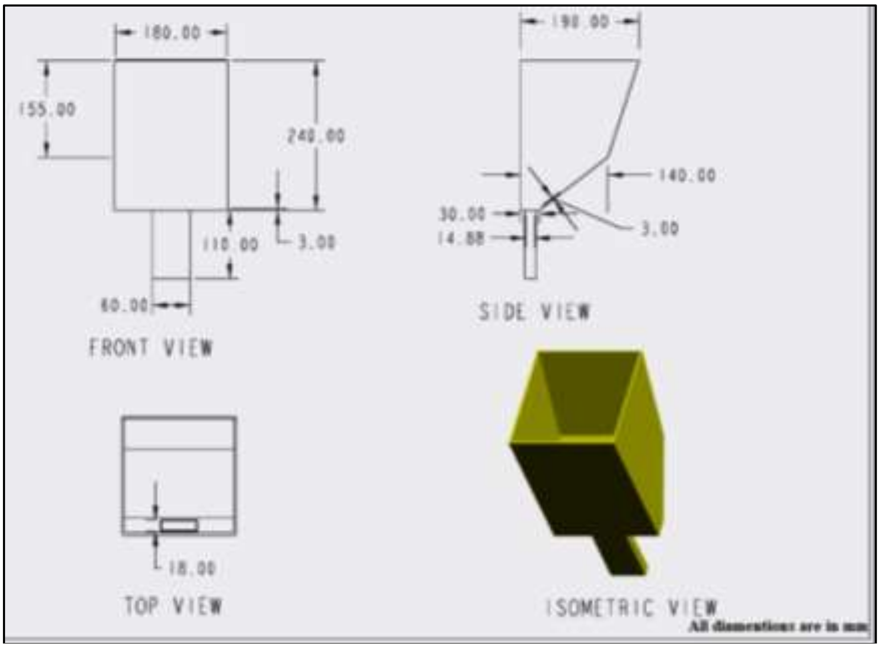

Fig 5: View of seed box

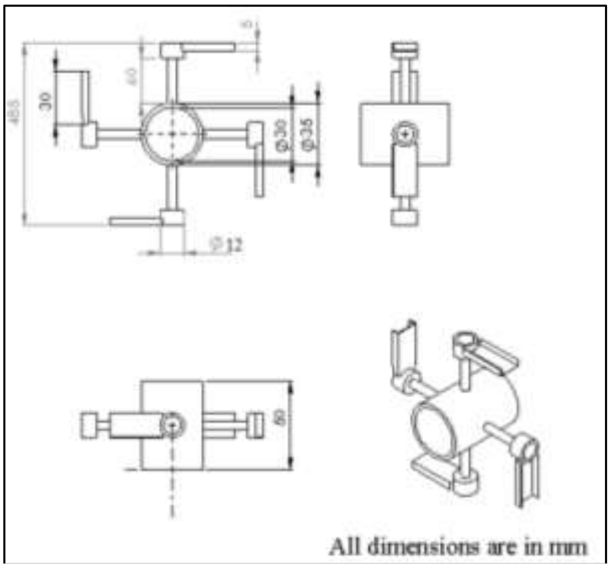

Fig 6: View of metering device

Fig 7: Developed metering device of 4, 6 and 8 number of cups

Power requirement for paddy seeder

The total power of engine was utilized for rotation of metering for placement of paddy seed into soil (mud) from seed box and to give forward motion to the machine. Initially total power requirement for seedling removal and placement was determined practically. The power required for forward motion of seeder was calculate theoretically.

Power requirement for rotation of metering device

1) Required speed of metering shaft = 90 rpm
2) Required average torque for metering shaft = 8.97 kg-m
Therefore power required for rotating the metering device unit:

$$P_r = \frac{2\pi N_g T_g}{4500} \ldots \quad (8)$$

Where,
Pr = Power required to remove seedlings from mat, hp;
Ng = Speed from gear box, rpm;
Tg = Torque at transplanting mechanism, kg-m.

$$P = \frac{2\times3.14\times90\times8.98}{4500}$$

P = 1.2 hp

Therefore the power required for rotating the metering device is 1.2 hp.

Power required for forward motion of seeder

The forward motion of seeder was achieved through the drive wheel. The drive wheel works in puddled soil offers rolling resistance, as well as tractive efforts. The engine was mounted at front side of seeder. Hence most of the weight was available on the drive wheel of the machine. The tractive effort of the drive is the summation of drawbar pull and rolling resistance of the machine.

Tractive effort = Drawbar pull + Rolling resistance ... (9)

Where,
c = Rolling resistance coefficient = 0.301
W = Weight of the machine= Assume 400 kg

Tractive effort = 73.41 + 120.40
= 193.81 kg

Torque at drive wheel shaft = Tractive effort × rolling radius of drive wheel
= 193.81 × 0.25 m
= 48.45 kg-m

Power required for forward motion= $\frac{2\pi N_d T_d}{4500}$ … (10)

Where,
N_d = Drive wheel speed, rpm

T_d= Torque at drive wheel shaft, kg-m= $\frac{2\times3.14\times21\times47.45}{4500} \approx$ 1.42 hp

Total power required for the operation of seeder = Power required for rotating the metering device + Power required for forward motion
= 1.2 + 1.42
= 2.62 hp

Considering transmission loss to 30 % and factor of safety to 10% the total power requirement of the developed paddy seeder will be = 2.62× 1.4 = 3.67≈ 3.7 hp
Diesel engine of 3.7 hp size was not available in the market. Hence next higher size engine i.e. 4 hp was selected for the seeder.

Power transmission of paddy seeder

The design of power transmission unit was sure that the power was transmitted from engine to final drive of power operated paddy seeder with minimum loss in power. Plan of power transmission unit shown in figure.

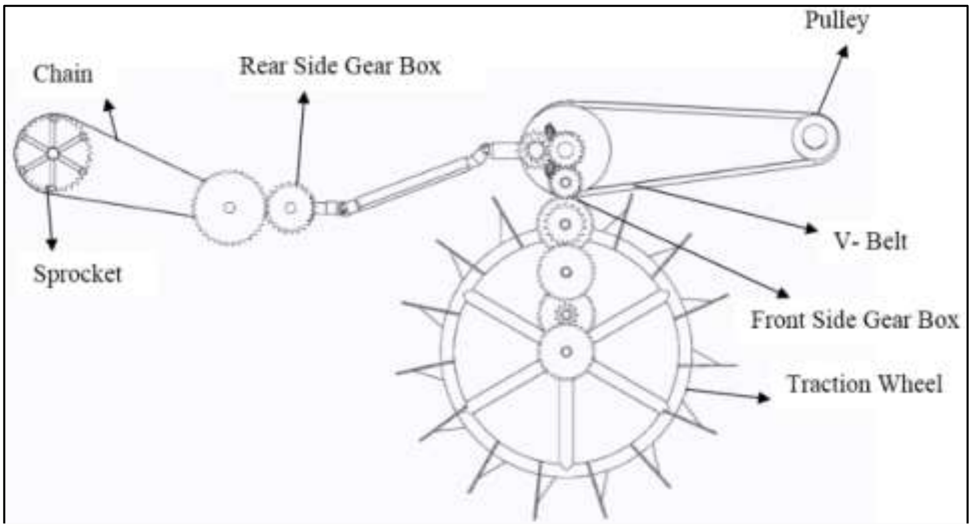

Fig 8: Layout plan of power transmission system in the power operated paddy seeder

Design of gear box

Power seeder consists of two gear boxes. One gear box was provided to give power to the ground wheel and other gear box was provided at the rear side for provided the power to the shaft to operate the metering mechanism. The power transfers from engine to gear box through universal cross shaft and finally to metering mechanism. The row to row spacing maintained by seeder was 20 cm and plant to plant spacing was 15 cm. The plant to plant spacing can be varied from 10 cm to 20 cm by changing the number of cups.

Design of gear box for ground wheel

Gear box comprises of three set of spur gear. The input shaft of gear box rotate at speed of 1300 rpm in which one spur gear was attached having 20 numbers of teeth. This spur gear was engaged with another spur gear having 40 numbers of teeth which rotates the counter shaft and it reduces 1300 rpm to 650 rpm. In first gear 20 number of teeth serve as driver gear which was mesh with driven gear with 70 number of teeth it reduced the speed from 650 rpm to 185 rpm. When second gear engage then 22 number of teeth of driver gear rotates along with 38 numbers of teeth with speed of 376 rpm. When third gear was engage then 24 numbers of teeth of driver gear rotates along with 22 numbers of teeth with speed of 709 rpm.

Design of gear box for metering device

Gear box for metering mechanism was placed over float it consist of assembly of bevel and spur gear. Input speed to the gear box was 867 rpm which is received by the bevel pinion having 11 numbers of teeth which was engaged with bevel gear of 16 numbers of teeth and transmitted to the spur gear having teeth 22 with the help of revolving shaft of 30 mm diameter. The speed received by this spur gear was engaged with another spur gear having 38 numbers of teeth and transmitted to the metering shaft with the help of chain sprocket mechanism. The number of teeth in pinion sprocket was 12 and number of teeth in driving sprocket was 44.

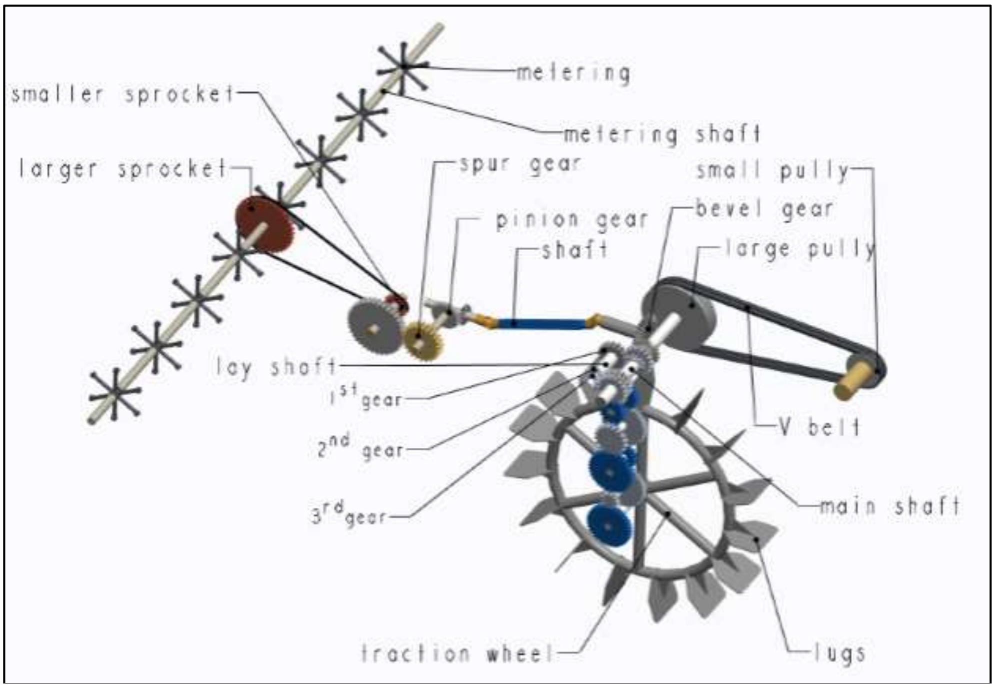

Fig 9: Power transmission system of Power operated paddy seeder

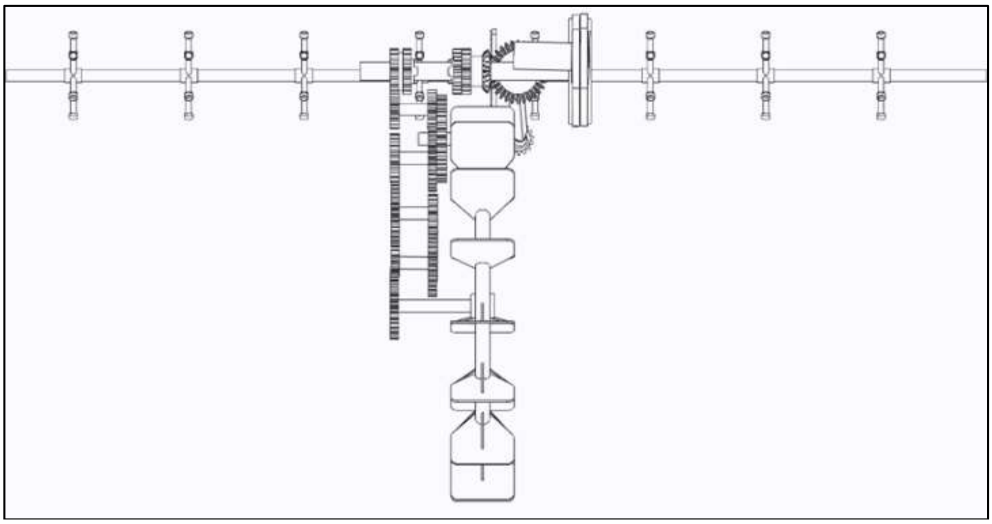

Fig 10: Top view of power transmission system of power operated paddy seeder

Selection of sprocket

The sprocket and chain were constrained to move together without slipping and ensure perfect velocity ratio. The two sprockets was select for the power operated paddy seeder.

Specifications of sprockets used in power operated paddy seeder

Number of teeth = 12 and 44 teeth

Pitch of the chain = 12.7 mm

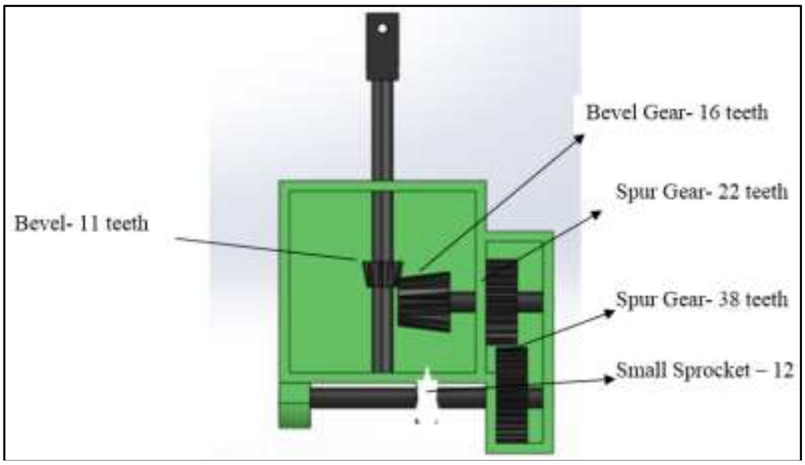

Fig 11: Gear box for metering device

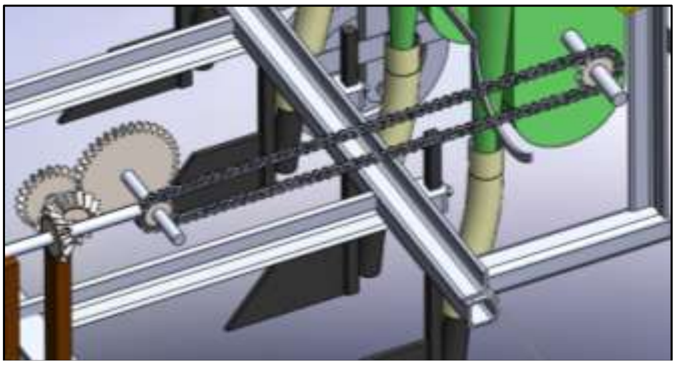

Fig 12: Layout plan of rear side of power transmission system.

Design of drive wheel

It was decided to provide one drive wheel. Drive mechanism for seeder has been designed so that one person can operate it comfortably. Considering the forward speed of seeder, as 2 km/h, diameter of wheel was determined. The calculations for determining the diameter of drive wheel was as follows:

1. Rotational speed of output shaft of gear box- 370 rpm.
2. Gear ratio of output shaft of gear box to drive wheel- 13:1.

$$\text{Hence, rotational speed of drive wheel, rpm} = \frac{\text{Speed from gear box}}{\text{Gear ratio}} \quad (11)$$

$$= \frac{370}{13} = 28.5$$

3. Let us take D as diameter of drive wheel in meter.
4. Forward motion of seeder, = π × D × Rotational speed of drive wheel

= π × D × 28.5 m/min

$$= \frac{3.14 \times D \times 28.5 \times 60}{1000} \text{ km/h}$$

5. Considering speed of the machine as 2 km/h From the above equation, $2 = \frac{3.14 \times D \times 28.5 \times 60}{1000}$

Considering 30% slippage, 2 = 5.4 x 0.7 x D Hence, D = 0.5 m Effective diameter of the lugged wheel = 0.5 m.

The design dimensions of the drive wheel are shown in the Fig. 13.

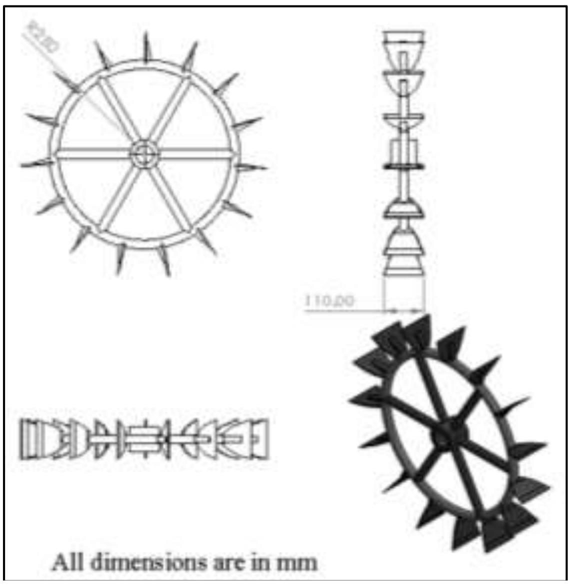

Fig 13: Traction Wheel

Development of power operated paddy seeder

Looking into the constraints there is no single machine was available for direct seeding of rice in both wet and dry filed condition. It was decided to develop power operated seeder for 8 rows that works satisfactory in both the condition with small replacement of some part of the machine. So that uniform distribution of seed in both conditions by single machine should be done since the cost of cultivation was reduced. The engine was main power source and the power was utilized for forward movement of driving wheel as well as for rotation of metering mechanism. The total power flow of the machine is as given in Fig. 14

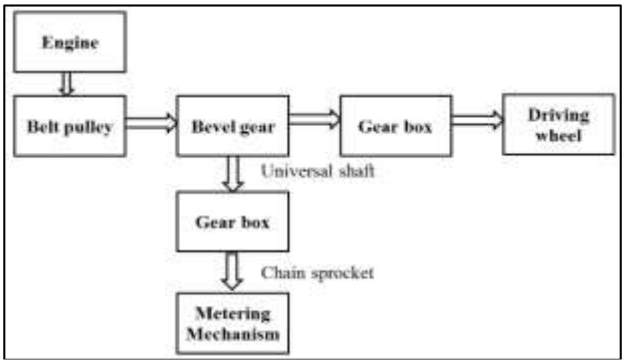

Fig 14: Total power flow of the machine

Fig 15: Developed power seeder for direct seeding of rice

Results and Discussion

Design and development of power operated paddy seeder

Based on the information obtained on soil, seed and germination parameters from the experiments, design of different seeder components were done and machine was developed with these components.

Main frame
Seed box
Metering device
Transmission system
Ground wheel

Main frame

The seeding mechanism was mounted on a frame at the rear side of power seeder. Main frame was designed for maintaining proper height of drop of seed during sowing. The main frame height was kept to 55.5 cm and seed pipes were provided for uniformity of seed dropped per hill. The main frame was also provide the strength of the machine components and provide stability to the machine at the time of operation in field.

Seed box

The seed box of the power seeder was made of MS sheet. The capacity of the seed box was calculated on the basis of different dimension of the seed and seeding requirement of paddy. Capacity of seed box was calculated using following expression

$$V = \frac{Q}{\rho}$$

Let,
V_a = Volume of section- A of seed box
V_b = Volume of Section- B of seed box

Volume of section A = $\frac{190+140}{2}$ x150x180=4455000 mm^3= 0.004455 m^3
Volume of section B = $\frac{140+30}{2}$ x90+180=1377000 mm^3= 0.001377
Total volume of seed box = Volume of section A + Volume of section B

= 0.004455+ 0.001377
= 0.005832 m^3

Capacity of one seed box,
$Q = V \times \rho$ = 0.005832 m^3 × 538.86 kg/m^3
Q = 3.14 kg

Capacity of eight seed box,
Q = 25.12 kg

Metering device
The design of metering systems essentially included the evaluation of cup feed metering system on the basis average seed spacing, number of seeds dropped per hill and degree of variation. The seed spacing is depends on number of cups used in metering device. The theoretical spacing of 4, 6 and 8 cups metering device was 10 cm, 15 cm and 20 cm, respectively. The number of seed drop was varies with different germination condition. The metering system was evaluated at three different filling conditions of pick up chamber with three different metering disc having 4, 6 and 8 cups at different germination conditions.

Transmission system
The power transmission from the engine of power seeder to metering disc was accomplished by different speed reduction. The power of engine is revolving at 2600 rpm which is transmitted to bevel gear through belt pulley arrangement as reduction of 2600 rpm to 1300 rpm. Gear box was comprises sets of spur and bevel gear which receives 867 rpm from the bevel arrangement through universal shaft. The gear ratio of gear box is 2.5:1 which reduces the speed of 867 rpm to 347.6 rpm and finally the metering shaft revolves at 90 rpm after the final reduction through chain sprocket with gear ratio of 3.5:1.

Ground wheel
The ground wheel is a device which receives power from the engine through several sets of gear and make possible to the forward motion of the power seeder. The peripheral speed of the ground wheel was 21 rpm with diameter of 0.5 m. Lugged type wheel was used for designing of the ground wheel which was made of cast iron because of its suitability under wet or sticky soil whereas pneumatic wheel was used in road condition.

Fig 16: Developed power seeder for dry and wet field condition

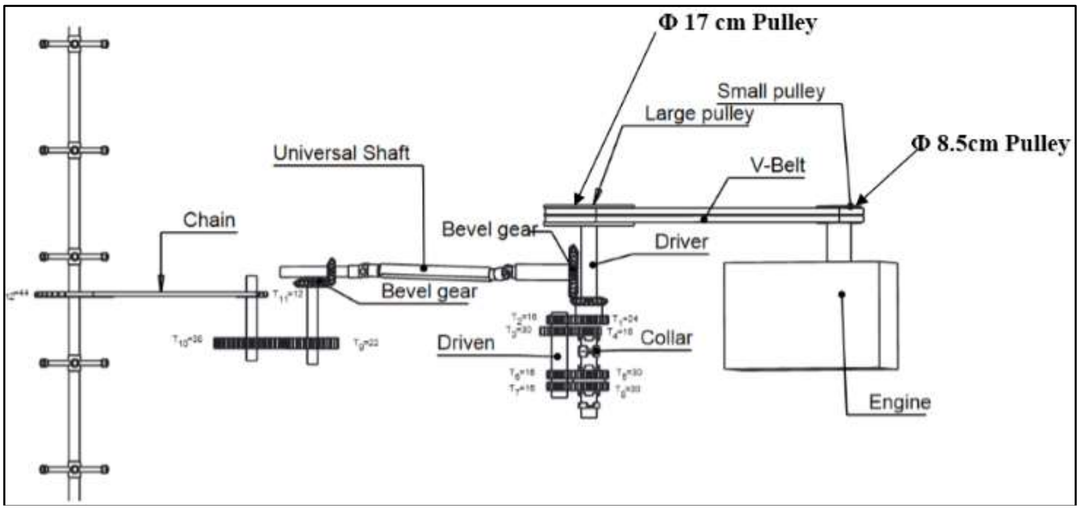

Fig 17: Power transmission system of power operated paddy seeder

Field performance test of power operated paddy seeder
The overall performance of the machine was evaluated on the basis of field capacity, field efficiency, fuel consumption and cost of operations. The actual field capacity of power operated paddy seeder during dry seeding was observed as 0.25 ha/h and during wet seeding its field capacity decreases as 0.23 ha/h. The field efficiency of paddy seeder in dry condition was 77.67 % and in wet condition it is 71.88 %

Conclusions
1. Row seeding of rice cultivation was found to be one of the best rice establishment methods under rain-fed condition. By the development of this machine farmers are able to grow rice if they fail in direct dry sowing due to continuous rains comes.
2. The field capacity of the power operated paddy seeder was found to be 0.2 ha/h.

3. The developed machine should work satisfactory in both dry and wet field condition with dry seed and pre-germinated seed respectively. All the parts should be properly covered to ensure operator safety

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