

Full Length Research Paper

Design and development of a power tiller operated seed-cum-ferti till-drill machine

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The adoption of power tiller is slowly increasing in India. However, suitable conservation seed cum fertilizer drill is to be evolved. Therefore, in order to minimize the soil moisture loss and turnaround time and energy loss during seed bed preparation and seeding operations, a seeding attachment was designed and developed for riding type of power tiller at Faculty of Agricultural Engineering, IGKV, Raipur, India. The main design considerations were to place seed and fertilizer with tractive type of tines while rotatilling the field with rotary tiller. The roto tiller need not to remove as it developed back thrust and increased pulling capacity of power tiller, which was revealed by work done and fuel consumption of power tiller with and without developed machine attachment. Thus seeding and tilling accomplished in single pass with conserving energy and in situ soil moisture. It saved operational time and cost of operation. The developed machine consisted a seed cum fertilizer box, four fluted feed rollers, four rigid tines mounted on toolbar with reversible shovels, ground wheel and adjusting devices. Fabrication cost of the machine was worked out about Rs. 6000.00 per unit and its total weight was about 32 kg. All the components of machine worked satisfactory.

Key words: Power tillers, design, development, seed-cum-ferti drill, riding type.

INTRODUCTION

In view of soil compaction, soil health and sustainable agricultural production, the power tiller and animal farming systems seems better scope than the tractor farming. Nowadays use of animal is found difficult for seed bed preparation and proper placement of seed and fertilizer. Farmers too show-least interest in animal farming due to laborious walking-tillage-seeding system and costly maintenance (Varshney, 1995).

In conventional system first seed bed is prepared

thereafter 2 to 3 days, seeding is done in dry seed bed because by the time field residual moisture is lost which affect plant emergence. Therefore, in order to conserve the field-moisture time and energy in preparation of seed bed and seeding, these operations can be done simultaneously. Keeping above points in view, a power tiller operated, conservation till drill machine was planned to be designed and developed with suitable furrow openers.

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Table 1. Description of the developed machine.

S/No.	Name of components	Material used	Size, mm
1	Seed box	MS sheet	180 X 170 X 680
2	Fertilizer box	MS sheet	100 X 100 X 560
3	Tyne, (4 nos.)	Flat iron	40 x 8 x 340
4	Reversible shovel, (4 nos.)	Flat iron	30 x 5 x 160
5	Tool bar, (1 no.)	Angle iron	35 x 35 x 5 x 720
6	Seed Metering fluted roller, (4 nos.)	Aluminum alloy	Standard
7	Braces, (8 nos.)	Flat iron 32x5	Variable size
8	Ground wheel, (1 no.)	Forged MS flat iron	Flat size 25 x 3 Dia. = 360
9	Seed metering shaft, (1 no.)	MS bar	Dia. = 15.88, L = 960
10	Fertilizer Shaft, (1 no.)	MS bar	Dia. = 15.88, L = 720
11	Sprockets, (3 nos.)	Cast iron	14 teeth, 19 teeth

MATERIALS AND METHODS

As per of aim of study, a desired type of seed cum fertilizer drill machine was designed and developed to suit with the *SHRACHI* power tiller, model: SF 15 DI. Engine S 1100 N, 4 -stroke Diesel Engine (Horizontal Type), manufactured /supplied by M/S Bengal Tools, Pvt. Ltd. Calcutta.

Design considerations

- (i) Easiness of seeding attachment.
- (ii) To accommodate in available space between rotary tiller and riding seat (Varshney et al., 2004)
- (iii) Details of major components of the machine are shown in Table 1 and detail-design is next described.

Seed and fertilizer box

The seed and fertilizer box of 2 mm MS sheet was designed for about 16 kg wheat seed and 14 kg paddy and for 10 kg DAP/IFFCO granular fertilizer capacity. Considering density of seed and fertilizer and working capacity of power tiller, the size of box is about 0.021 m³.

Tines

Four rigid tines, made of MS flat size 40 x 5 mm were mounted on a tool bar for seeding at a varying spacing of 18 to 22 cm suiting to wheat and paddy. Reversible narrow shovels mounted on each tine. Design methodology, materials and methods used for the study for individual components are next described.

Design of seed and fertilizer box

In literature, the box capacity for different type of manually, animal and tractor drawn seed drills are available but not for power tiller (Varshney et al., 2004). Therefore, as per design consideration of seed and fertilizer box, the dimensions were decided. The box was made from MS sheet rectangular in shape and shown in Figure 2. Horizontally, the seed cum fertilizer box was located between rototiller and riding seat behind the hood of rotary tiller. Vertically, the box height was limited by upper main transmission gear-lever, rotary transmission gear-lever and handles. Finally the size of seed box was determined as:

$$L \times W \times H = 680 \times 180 \times 170 \text{ mm}^3$$

$$= 0.02081 \text{ cubic meter}$$

$$\text{The size of fertilizer box, } L \times W \times H = 560 \times 100 \times 100 \text{ mm}^3$$

$$= 0.0056 \text{ cum.}$$

$$\text{And the theoretical capacity of seed box} = 0.2081 \text{ cum} \times 800 \text{ kg}$$

$$/ \text{cum} = 16.640 \text{ kg for wheat and for Paddy grain } 12.5 \text{ kg.}$$

Seeding capacity

The seeding capacity of the developed machine, with paddy and wheat seed is worked out based on actual observations as given below:

$$\text{Theoretical capacity (ha/h), } C = \frac{W \times S}{10}$$

Where, W = working width, m = 4 x 0.20 = 0.80 m, S = speed, kmph (1.45 - 3.0 km/h)

Thus, the designed box size for seed capacity is found satisfactory. Therefore, the net designed seed box capacity of 16 kg wheat would be sufficient for about 2 working hours.

Design of tool bar

A tool bar of square section, made by joining two angle iron was designed and fabricated for mounting of tractive tynes. The tool bar was made of square section of 40 x 40 x 5 mm joining two MS angle iron of size 35 x 35 x 5 mm and its length was kept 720 mm as shown in Figure 3. The short design calculation for forces and strength was calculated and the dimension of tool bar was determined using standard formulas.

Design calculation

In order to select the size of material requiring for tool bar, The following assumptions are made.

(i) Number of tines = 4

(ii) Maximum depth of operation, cm = 15

(iii) Width of furrow opener, cm = 3

(iv) Maximum ground clearance of tool bar and height of tines, cm = 34

(v) Center to center distance between two tines, cm = 20

$$\text{Area of furrow cross section} = \text{width} \times \text{depth} = 3 \times 15 = 45 \text{ cm}^2$$

Therefore, the draft requirement for each tine = $45 \text{ cm}^2 \times 0.6 \text{ kg/cm}^2 = 27 \text{ kg}$. (Assuming draftability of sandy clay soil in friable moisture condition = $0.6 \text{ kg}_f/\text{cm}^2$)

The tool bar is subjected to torsion and bending moment due to induced draft.

The tool bar consist with four tines in one row.

Hence,

$$\text{Total Draft} = 27 \times 4 = 108 \text{ kg}_f = 108 \times 9.8 = 1058.4 \text{ N}$$

The design was calculated based on maximum load. Maximum load was calculated considering factor of safety equal to four for agricultural machines (Paul, 2003; Verma, 2005) as follows:

$$\text{Total draft} = 1058.4 \times 4 = 4233.6 \text{ N}$$

$$\text{Torque on the tool bar by each tine} = \text{Draft} \times \text{ground clearance} \\ = 27 \times 0.34 = 9.18 \text{ kg}_f\text{-m} = 89.96 \text{ N-m}$$

$$\text{Total torque on the tool bar with 4- tines} = 89.96 \times 4 = 359.84 \text{ N-m}$$

In addition to torque on the tool bar, bending moment would also be produce. The tool bar was considered as simple supported beam on the fram. The maximum bending moment:

$$BM_{\max} = \frac{wl}{4} \quad (1)$$

Where, w = Total weight / force on the fram, l = Total length of tool bar, cm

$$BM_{\max} = \frac{4233.6 \times 72}{4}$$

$$= 762.048 \text{ N-m}$$

Equivalent torque ue to torision and bending moment was calculated as:

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

$$= \sqrt{762.048^2 + 359.84^2}$$

$$= 842.73 \text{ N-m}$$

The maximum shear stress developed on the tool bar was obtained by using torsional formula as:

$$f_s / R = T / J \quad (3)$$

Where, f_s = Shear stress at any section, R = Distance of the section from neutral axis = $d / 2$, T = Equivalent torque, J = Polar moment of inertia.

Considering each side of measured d mm and factor of safety 2 – 4 (we selected maximum safety of factor = 4) and ultimate stress of selected material, $F_e = 360 \text{ N/mm}^2$ (Verma, 2005).

$$\text{Design stress} = \frac{\text{Ultimate stress}}{\text{Factor of safety}} \quad (4)$$

$$= \frac{360}{4}$$

$$= 90 \text{ N/mm}^2$$

Maximum working stress of 360 N/mm^2 act at the center of toolbar. J is calculated by using formula as:

$$J = d^4 / 4 \quad (5)$$

Where, d = width of section

On substituting above values in the Equation (3), we get:

$$\frac{90}{d/2} = \frac{842730}{d^4/4}$$

$$d = 35.5 \text{ mm} \approx 36 \text{ mm}$$

Therefore, equivalent size of tool bar of 40 mm, depending availability of material, was considered safe for the machine. The detailed diagram is shown in Figure 3.

Furrow openers

The design considerations for the furrow opener were that they should be of self cleaning nature, easily un-clogging type and narrow shape to minimize draft requirement.

Design procedure of the tine

The height of tine ie ground clearance was taken as 340 mm which was calculated as:

(1) Maximum working depth in tilled soil = 150 mm

(2) Free length (to avoid clogging by tool bar) = 190 mm

Width and thickness

The width and thickness of the tine was calculated as follows. A reversible shovel was fitted with tine as cutting tool. The tine was made of mild steel plate having carbon content from 0.15 to 0.25 per cent (Verma, 2005) of size 40 x 10 mm. Width of reversible shovel was 30 mm, with 5.0 mm thickness and was made of MS sheet.

The furrow cross sectional area = $150 \times 30 = 4500 \text{ mm}^2$

The soil resistance = 0.0060 kg/mm^2

Soil resistance exerted at the tip of each furrow opener /tine = 264.6 N

Ground clearance of tine = 340 mm

The bending moment = draft x distance

= $264.6 \times 340 = 89964 \text{ N/mm}^2$

Bending stress:

$$F = \frac{MC}{I} \quad (6)$$

Where, f = Bending stress, N/m^2 , C = Distance from neutral axis to the point at which strain is determined, m.

The sectional modulus from the neutral axis is computed by using formula:

$$Z = \frac{I}{C} \quad (7)$$

From the Equations 6 and 7, we get:

$$Z = \frac{M}{f} \quad (8)$$

Taking bending stress equal to 49.05 N/mm^2 (Sachin, 2000; Verma, 2005).

$$Z = \frac{89964.0}{49.05}$$

$$= 1834.13 \text{ mm}^2$$

Table 2. Summarize data on designed, developed and tested machine.

S/No.	Crop	Wheat (Kanchan)
1	Fuel consumption, l/h	1.04
2	Effective working width, m	0.80
3	Moisture content, %	18.0
4	Theoretical field capacity, ha/h	0.13
5	Effective field capacity, ha/h	0.11
6	Field efficiency, %	84.61
7	Wheel slip of power tiller, %	8.00
8	Operational speed, km/h	1.67
9	Cost of operation, Rs/ha	1413.00
10	Energy requirement. MJ/ha	657.94

Table 3. Comparative study of standard and design blade/tyne.

Type of blade/tyne	Field capacity (ha/h)	Fuel consumption (l/ha)	Field efficiency (%)	Mean mass diameter of clod (mm)	Earth work (ton/l fuel)
Standard blade, C	0.055	20.71	82	20.58	27.53
Standard blade, L	0.054	21.75	81	19.55	30.65
Design tyne	0.056	21.55	78	31.97	40.57
CD	0.150	0.91	2.00	3.22	8.34

Section modulus of the furrow openers, the ratio between the thickness to width ($t : b$) can be taken from 1 : 3 to 1 : 4. (Sharma and Mukesh, 2008):

So, $t : b = 1 : 4$

$$Z = \frac{t \times b^2}{6} \quad (9)$$

$$1834.13 = \frac{t \times (4t)^2}{6} = \frac{16(t)^3}{6}$$

$$t = 8.82 \text{ mm}$$

Considering the factor of safety, availability of material of standard size, the thickness of tine was taken 10 mm. Therefore, width of the tine = $4.0 \times 10 = 40 \text{ mm}$

Therefore, the narrow reversible shovel types openers were selected as shown in Figure 4. In order to overcome the problem of trash and clod collection, between the adjacent tines, the furrow openers were placed behind the rotary blades on the frame. So, that a narrow shallow slot could be tilled by the rotary blades for placing seed in direct conservation drilling.

Seed metering mechanism

Simple fluted rollers were used for the metering of seeds and orifice types arrangement made for the fertilizer. The simple knob mechanism is used to meter the desired quantities of seed. The detailed diagram and figure of the fluted roller is shown in Figure 5.

Ground wheel and other parts

The ground wheel was made of MS flat iron of size $25 \times 3 \text{ mm}$ and the ring was made of 360 mm diameter, with steel pegs of length 70 mm. The pegs were made of $25 \times 3 \text{ mm}$ size. Total numbers

of pegs were taken 12 on the periphery. The numbers of spokes were 6, made of iron rod of size 9.5 mm. The detailed diagram and figure of the ground wheel is shown in Figure 6. The diameter was designed for minimum rolling resistance and easy operation of the ground wheel. So, the clods and stubbles height should not be more than one third of its diameter. Considering 15 cm height of stubbles/ clods, the diameter of ground wheel was designed for 45 cm and thus the tip to tips of peg, the diameter was taken = 50 cm.

Working principle

The power is transmitted to ground wheel to metering shaft of seed and fertilizer without hindrance in the rotary tilling. During seeding, the tractive tines of seed cum fertilizer drill, place seeds and fertilizer behind rotary tiller instantaneously and perform tilling cum seeding operation in a single pass, conserving field moisture. The fabrication cost of the machine was found about Rs 6000.00. The machine was easily attached and detached and can be adjusted for different crops.

RESULTS AND DISCUSSION

The detailed view and design diagram of the developed machine is shown in Figure 1. As per design considerations the machine components were designed and fabricated successfully. During the field testing, the developed machine gave satisfactory results. Summarized data on designed, developed and tested machine are given in Table 2. The table revealed that the cost of sowing was worked to be Rs 1413.00 per ha and energy requirement was found to be 658 MJ/ha. Comparative study of standard blade and design tyne are given in Table 3. The maximum earth work was found in



Figure 1. View of developed machine.

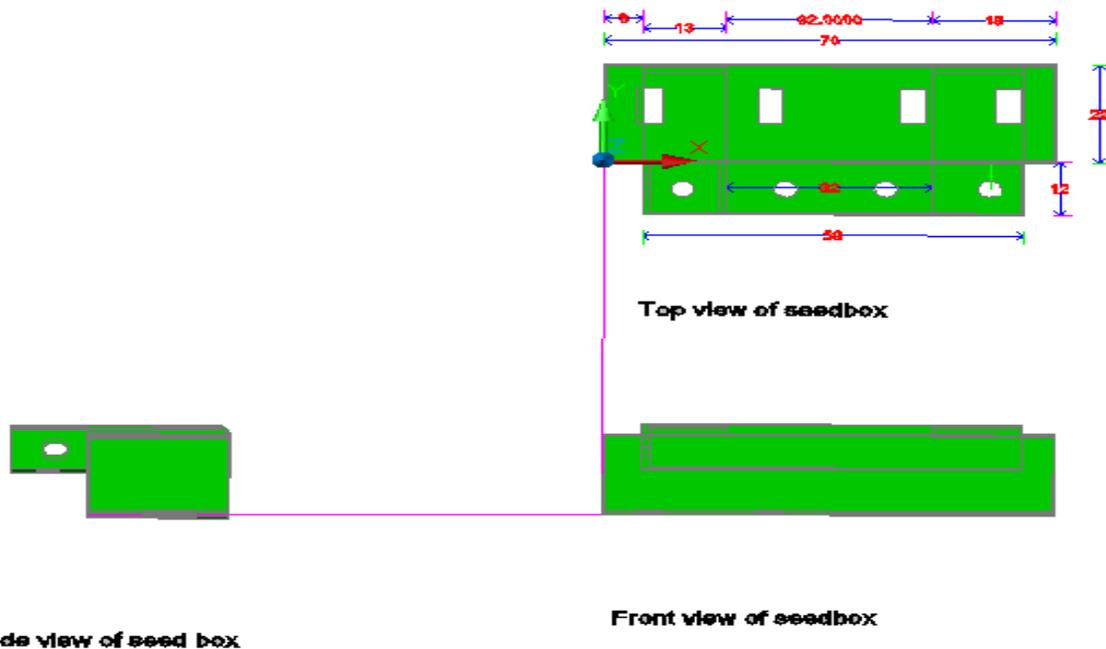


Figure 2. Views of seed and fertilizer box.



Figure 3. View of toolbar.

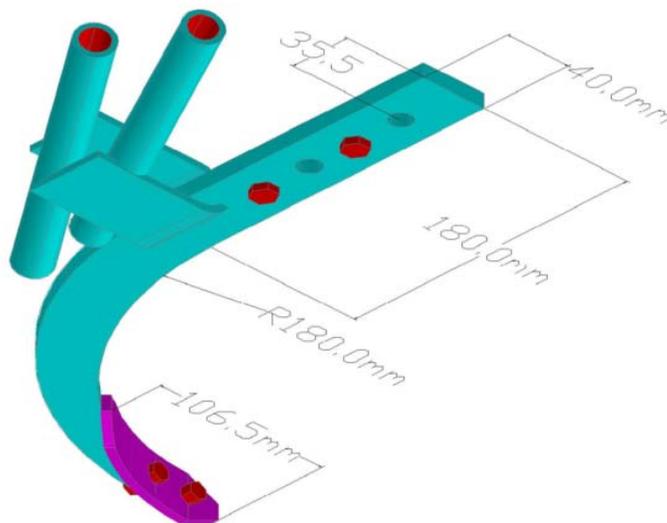


Figure 4. View of Tine with reversible shovel. d_r =Diameter of the flute, d_f =Diameter of flute and A_f =Area of cross section of flute.

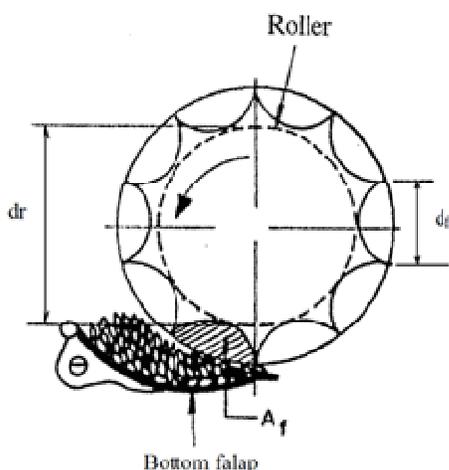


Figure 5. View of fluted roller. d_r =Diameter of the flute, d_f =Diameter of flute and A_f =Area of cross section of flute

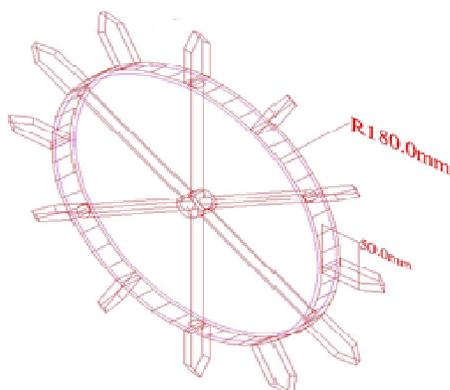


Figure 6. Ground wheel

design blade and it is significant with standard blade. However, fuel consumption was less than standard blade “L” (Kumar, 2012).

Conclusions

Field trials of developed machine have been conducted at the research field of faculty of Agricultural engineering, IGKV, Raipur. The developed machine work satisfactory.

Conflict of Interest

The authors have not declared any conflict of interest.

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