Design of Rotary Assisted Broad Bed Former-cum-Seeder for Vertisols

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Abstract

A tractor operated rotary assisted broad bed former-cum-seeder was designed and developed at ICAR-Central Institute of Agricultural Engineering, Bhopal, India. The basic aim of this development was to performed rotary tillage followed by broad bed formation, sowing and reshaping of bed by using dumbbell shape re-shaper. Performance of developed machine was evaluated and compared with flatbed sowing for soybean and wheat crops at ten randomly selected farmer's field in vertisols. The field capacity and fuel consumption of developed machine were found as 0.32 ha/h and 15 L/ha respectively. The grain yield under broad bed seeded soybean was found 0.96 t/ha, however, conventionally sown soybean yielded 0.71 t/ha. Thus, the yield gain in soybean crop under broad bed technology was found 35.95%. The yield of broad bed and conventionally sown wheat, were found 4.99 and 4.15 t/ha, respectively. Therefore, grain yield increased by 20% in wheat crop due to the sowing with developed machine under broad bed condition. This machine saved 17.3% cost of operation as compared to the traditional flatbed sowing.

Keywords: Broad bed former, Vertisols, Rolling type bed shaper and Seeder.

Introduction

Vertisols are potentially productive soils within the dry semi-arid regions of central India. These soils have high water holding capacity, low water infiltration, high incidence of inundation, accelerated runoff and soil erosion during high rainfall year and drought stress during the low rainfall year. Consequently, crop yields on vertisols using traditional systems of management are low (Lal, 1995). Vertisols of the central part of the country have a fairly high potential for crop production when improved soil and water conservation practices are adopted. The improved technique with engineering interventions to drain excess water can help to increase the productivity of vertisols and allow farmers to harness the maximum crop productivity.

Broad bed and furrow (BBF) crop production system has been developed as a measure for water conservation in vertisol, to deal with waterlogging and improving soil structure. BBF technique requires less quantity of water by crops. It drains out the excess amount of water automatically which is not possible on flat beds. Ghani et al. (2007) has found 36% water saving for broad beds, about 10 % for narrow beds and grain yield increase of about 6% for wheat crop, 33% of maize crop. Thus, constructing broad beds and furrows has been a new idea which draws soil from the furrows on either side of the bed and thrown on top of the bed. It involves making beds of height 150 to 300 mm (Gupta and Undadi, 1994) and width of 1.7 to 2.0 m alternatively to allow drainage of excess water (Astatke et al., 2002).

Wheat has traditionally been planted on flat beds either by drilling closed spaced rows 100-300 mm apart or broadcasting and then incorporating it by means of shallow tillage operation (Sayre and Moreno-Ramos, 1997). Sowing on broad beds has improved yield, increased fertilizer and irrigation use efficiency, reduced weed incidence, facilitate better field management by providing passage to mobility in cropped field and save seed, fertilizer and irrigation water (Mandal et al., 2013; Rao et al., 2015; Shrivastava et al., 2017). Also, broad bed seeded crops cope up with excess and continuous rainfall conditions. The objective of the present study was to investigate the sowing of soybean and wheat crops on broad bed and compared to the conventional method of sowing on flat surface at farmers field. Thus in view of climate worthiness of the bed seeding system, rotary assisted broad bed former-cum-seeder has been designed and developed by ICAR-CIAE, Bhopal. Rolling type bed shaping system enables reshaper to make better quality beds even in poor tilled soil. The paper presents details of the developed machine and its performance results compared to the commercial bed planter and flatbed method of sowing for soybean and wheat crops.

Materials and Methods

Design Consideration

Design of the rotary assisted bed former cum seeder mainly consist of design of seed box, design of fertilizer box, design of ridger bottom, design of frame and design of bed shaper cum ground wheel. Technical specifications of the developed rotary assisted broad bed former-cum-seeder are shown in **Table 1**.

Drilling Unit: Five row drilling unit was used for fertilizer and seed placement on broad bed. Main components of the drilling unit were seed box, fertilizer box, fluted roller metering mechanism, frame, rate controller, furrow opener and seed and fertilizer tubes. The frame was made of mild steel square box of 50 × 50 × 5 mm. Length and width of the frame were 2000 and 700 mm. The frame was fabricated having three members i.e. front, middle and rear. Rotary unit was mounted on front member. The middle member of frame was used to stagger the three tynes and two ridgers. While the rest of the tynes and bed shaper unit were attached to the rear member. The frame of seed drill is subjected to both torsion and bending moment due to the horizontal and vertical force acting on the tynes. Tynes were bolted to the frame with the help of clamp to provide easy adjustment of tynes to meet the suitable spacing. Seed and fertilizer box was mounted on the main frame. They were made of mild steel sheet. It was designed for the seed rate of 100 kg/ha. Two seed rate controllers were fitted on the box for seed and fertilizer, separately.

Design of Seed Box: Among the seed used for owing by the seed drill, Wheat has the maximum seed rate 70-100 kg/ha. Therefore the seed drill may be designed for the seed application rate of 100 kg per ha. The effective field capacity of machine was calculated by following formula:

Effective field capacity of drill = $(W \times S) / 10 \times \eta$

Where, W is the working width of the machine (m), S is the operating speed of the machine (km/h) and η is the field efficiency (%).

The effective field capacity of seed drill was calculated as 0.42 ha/h considering the speed of operation of 4 km/h and field efficiency of 70%. The design of the seed box with capacity was calculated on the basis of refilling of seed requirement after 1 hour.

Therefore, the weight of seed to be used in 2 h = seed rate (kg/ha) × area covered /h × time = 100 × 0.42 × 1 = 42 kg

Now, volume of seed box = Weight of seed / Bulk density of seed = 42 / 800 = 0.052 m^3

Consider spillage losses of 10%. Therefore, total volume of seed drill is calculated as:

Volume of seed box (Vs) = 0.052

Table 1 Technical specification of rotary assisted bed former cum seeder

Particulars	Description
Dimension of machine	1760 × 2600 × 1160 mm (Length × Width × Height)
Number of furrow opener	5
Type of furrow opener	Shovel type
Seed metering mechanism	Sliding fluted roller type
Weight of machine	550 kg
Number of ridger	2
Width of furrow	80 mm
Dimension of bed	Top width: 1200 mm and bed height: 200 mm
Row to Row spacing	Adjustable
Plant to Plant spacing	Adjustable
Fertilizer attachment	Sliding fluted roller type with metering mechanism
Metering unit drive	Drive to the metering unit is provided from rear mounted two rolling dump bell with spring loaded chain
Ground Wheel	Two 517 mm diameter spiked roller with spring to maintain contact with ground.
Hitching	3 point linkage is provided
Shaper	Rolling dump bell is provided for seed covering
Power Transmission	Chain and sprockets
Required tractor power (hp)	With rotavator: 60-70 hp (44.74-52.2 kW) Without rotavator: 40 hp (29.83 kW)

+ 0.0052 = 0.058 m^3

According to geometry of seed box, let the seed box is of trapezoidal section, total seed box was divided into two sections. The volume of seed box (Vs) is given by:

$(Vs) = [(a + b) / 2] \times h \times l_b$

Where, Vs is the volume of seed box having trapezoidal section, a is the bottom width of seed box, b is the top width of seed box, h is the height of seed box and lb is the length of seed box

Then, $(Vs)_1 = [(0.186 + 0.190) / 2] \times 0.106 \times 1.596 = 0.031$ m^3

$(Vs)_2 = [(0.190 + 0.160) / 2] \times 0.100 \times 1.596 = 0.027$ m^3

Total volume of seed box = 0.031 + 0.027 = 0.058 m^3

The thickness of seed box (t_s) is given by:

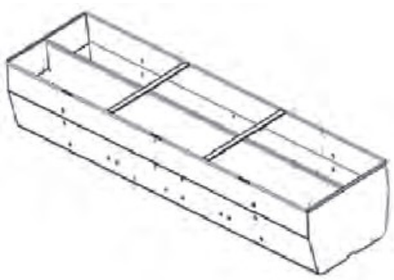
$t_s = \sqrt[3]{(3 \times \rho \times a^2 \times h^2) / (4 \times a \times b_s)}$

Where, t_s is thickness of seed box (cm), ρ is the bulk density (kg/cm^3), a is the bottom width of seed box (cm), h is the height of seed box (cm), bs is the bending stress in kg/cm^2 (1000 kg/cm^2), Therefore, $t_s = \sqrt[3]{(3 \times 0.008 \times 16^2 \times 10^2) / (4 \times 16 \times 1000)} = 0.132$ cm

The thickness of seed box was calculated as 1.32 mm (say 1.5 mm).

Design of Fertilizer Box: Design of fertilizer box was same as the seed box. All the designing parameter considered for fertilizer box was similar to the design of seed box. The volume of fertilizer box is 0.058 m^3. Therefore, the total volume of seed and fertilizer box was calculated as 0.11 m^3. The drawing of the seed and fertilizer box is shown in **Fig. 1**.

Fig. 1 Drawing of seed and fertilizer box



Ridger Unit: The ridger unit consisted of mainly shank, shovel, and adjustable wings (**Fig. 2**). It was designed for handling the volume of 1200 mm width of soil. The shank was made of MS flat. The dimension of shank was 650 × 50 × 25 mm. The shovel was attached to the shank so the overall length of tyne from tip of shovel to the upper end of shank was 675 mm. The lower portion of the shank was curved with radius of curvature of 150 mm. It consisted of two holes of 12 mm diameter at its bottom for mounting shovel. Commercially available reversible shovel of 250 × 50 mm was used. It was made from medium carbon steel. Width and length of shovel were 50 mm and 250 mm, respectively. The leading edge of the opener was a sharp-pointed triangle. The boot wedge and rake angle were 45° and 40°, respectively. The shovel was attached to shank with nut and bolt for easy replacement. Two ridgers were used in the developed machine. Wings of the ridger have provision to change the width of furrow according to bed size and shape in the range of 200-400 mm.

Design of Ridger Bottom: the ridger bottom was made by joining the two wings to the shank. Calculations for designing the ridger bottom ares given below. The draft on ridger bottom shank (D_f) calculated by following formula:

$D_f = K \times w \times d$

Where, D_f is draft on ridger bottom (kN), k is specific soil resistance (kPa), w is the width of furrow opener (mm), d is the depth of sowing (mm). The furrow slice cut by the furrow bottom was in trapezoidal shape. Assuming the specific soil resistance of 39.2 kPa for vertisol soil, the draft of ridger bottom was calculated as:

$D_f = 39.2 \times (600 + 300) / 2 \times 150 = 2.7$ kN

Now, for mild steel tynes factor of safety can be taken as 1. So, the design draft of furrow opener would be 2.70 kN.

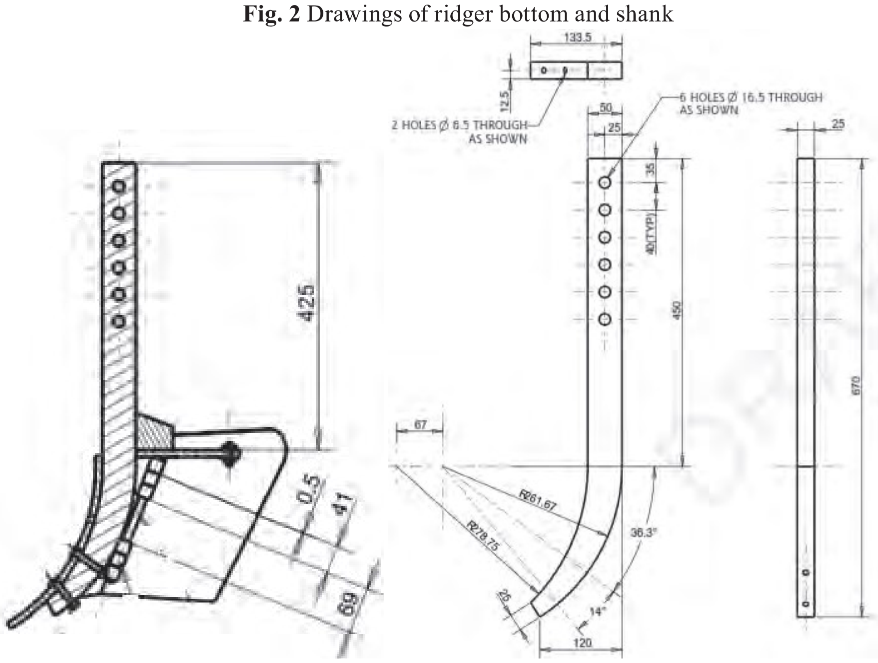
Considering the ridger bottom tyne as a cantilever beam of 500 mm size fixed to the frame at one end the maximum bending moment in the tyne is given by

M = Design Draft (kN) × Beam span (m)

Then, M = 2.7 kN × 0.50 m = 1.35 kN-m = 1350000 N-mm

Now, section modulus of tyne Z is calculated as:

Fig. 2 Drawings of ridger bottom and shank



$\sigma_b = MC / I = M / Z$ (as $Z = I / C$)

Where, σ_b is bending stress in tyne, N/mm^2 (for mild steel 100 N / mm^2), M is bending moment in tyne (N-mm), C is distance from neutral axis to the point at which stress is calculated (mm), I is polar moment of inertia of rectangular section (mm^4) and Z is section modules of tyne (m^3).

Also, for rectangular section

$Z = t \times b^2 / 6$

The ratio between the thickness and width (t:b) is 1:2.

Therefore, $Z = t \times (2t)^2 / 6$

Also, $Z = M / \sigma_b = 1350000/100$

$13500 = 4t^3 / 6$

$t^3 = 20250$

t = 27 mm (say 25 mm)

b = 25 × 2 = 50 mm

Therefore, cross section of the tyne was 25 × 50 mm. Therefore, the mild steel flat of 25 × 50 mm was selected for the tyne of ridger seeder. The drawing of the ridger bottom is shown in **Fig. 2**.

Design of Frame: The frame was fabricated having five members to stagger the five furrow openers on seed drill. The frame of the seed drill was considered as simply supported beam with point load. The maximum banding moment was acting at the centre of the beam at point. Maximum bending moment (M) is given by:

$M = (800 \times 3p) - (1000 \times p) - (600 \times p) - (200 \times p)$, Where, p is the maximum load per tyne.

Therefore, $M = (2400 - 1000 - 600 - 200) \times 60 \times 9.8 = 352800$ N.mm

Again,

Torque produced on toolbar (T) = maximum bending moment × ground clearance × number of furrow openers

Then, $T = 60 \times 9.8 \times 350 \times 6 = 1234800$ N.mm

The equivalent torque (Te) is given by:

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

So, $T_e = \sqrt{352800^2 + 1234800^2} = 1284211$ N.mm

Again equivalent torque is given by:

$S_s / Y = T_e / I$

Or $I / Y = T_e / S_s$

And $I / Y = d^3 / 6$

Where, S_s is shear stress, Te is equivalent torque, I is moment of inertia, y is the distance from the neutral axis to the point at which stress is determined and d is size of square rod.

So, $d^3 = 1284211 / 60 \times 6$

d = 50.4 or say 50 mm

Therefore, the square box of 50 mm was used for the fabrication of frame of the machine. The drawing of frame of seed drill is shown in **Fig. 3**.

Rolling type Bed Shaper: Broad bed seeder consists of a rolling type bed shaping system which creates an intact and smooth bed with a proper height. The design of bed shaper was done for achieving the bed top width, bottom width and height of 1200, 1500 and 200 mm, respectively. The rolling type bed shaping system consisted of shaft, dumbbell shape re-shaper, levelling pipe and pegs. The shaft was made of MS rod having length and diameter of 2000 and 25 mm, respectively. One end of the shaft was connected to the sprocket of 14 teeth. It is rolling type bed shaping system which has also been used as power wheel which is a special feature of this seeder. Dumbbell shape re-shaper is also used as power source for metering device. The distance between levelling pipe and the edge of the dumbbell was kept 200 mm for making 200 mm bed height. Twelve numbers of triangular shape mild steel pegs of 25 mm width were kept for providing smooth rotation to drilling unit. Due to rolling action of bed shaper, the clods get burrowed in the bed and achieve the desired geometry of broad bed.

Design of Bed Shaper-cum-Ground Wheel: The design of bed shaper was done according to size of bed and as per tractor wheel base. The beds were in size of 1200 mm of top width, 1500 mm of bottom width and 200 mm height. The distance between bed to leveling pipe and edge of the shaper was kept 200 mm for making 200 mm bed height and pegs were kept 25 mm for providing smooth rotation to metering device. Due to rolling action of bed shaper the clods get burrowed in the bed which is desirable for intact shape of bed and better look. The drawing of bed shaper-cum-ground wheel is given in **Fig. 4**.

Field Testing of Developed Machine

Performance evaluation of developed machine was carried out at ten randomly selected farmer's field from *Kachhiberkheda* village in Bhopal district of Madhya Pradesh, India. The soil type was vertisols (12.6% sand, 32.7% silt and 54.7% clay) and bulk density varying from

Fig. 3 Drawing of frame of machine

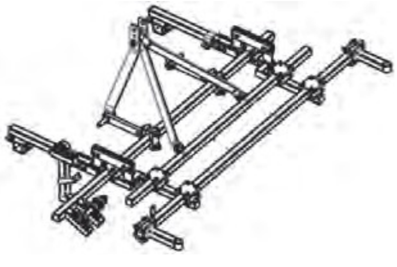
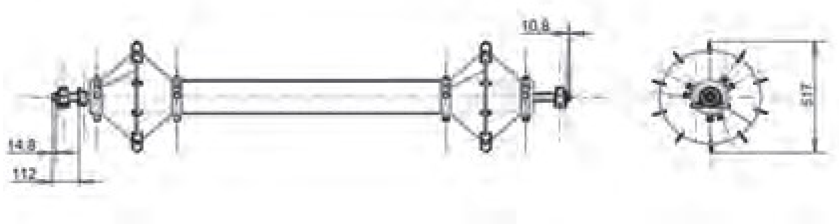


Fig. 4 Drawing of bed shaper-cum-ground wheel



1.21 to 1.25 g/cc. The experiment was designed in two blocks i.e. rotary assisted bed former-cum-seeder (M1) and flatbed sowing (M2) with ten replications. Soybean crop was sown in last week of June and harvested in the first week of October and wheat crop was sown in Mid-November and harvested in the first week of April. Soybean (80 kg/ha) and wheat (100 kg/ha) crop were sown with the developed machine on broad bed at row to row spacing of 300 and 200 mm, respectively. The shape of the bed was trapezoidal having top width and height 1200 and 150 mm, respectively. The yield of wheat was estimated at different random locations from 1 m^2 area. The difference in the grain yield, cost of cultivation, net income and benefit-cost (B:C) ratio were analyzed using random block design (RBD) at 5% level of significance ($P < 0.05$). **Fig. 5** shows the operation of developed rotary assisted bed former cum seeder in field.

Results and Discussion

Field Performance

The performance parameter of rotary assisted bed former-cum-seeder and flatbed sowing method is shown in **Table 2**. Total time required for seed bed preparation and sowing operation with rotary assisted broad bed former-cum-seeder was 2.85 h/ha. The field capacity of rotary assisted bed former-cum-seeder and flatbed sowing machine was 0.35and 0.36 ha/h at speed of operation of 3 km/h, respectively. The rotary assisted bed former-cum-seeder consumed 15 L/ha diesel for bed making and simultaneously sowing operation. This machine saved 17.3% cost of operation compared to the flat bed sowing. Rolling type bed shaping system as a power wheel is a special feature of this seeder. Due to rolling action of bed shaper, bigger size clods do not get exposed and a smooth shape of bed was formed.

Effect of treatments on grain yield (q/ha), cost of cultivation ($/ha), net income ($/ha) and B:C ratio is presented in **Table 3**. The difference in grain yield between both the treatments was found to be significant ($P < 0.01$). Higher soybean yield was obtained in treatment M1 (0.96 t/ha) as compared to M2 (0.71 t/ha). However, broad bed shown soybean crop yielded more due to well-aerated root zone in broad bed condition. A similar

Table 2 Performance parameter of rotary assisted bed former-cum-seeder and flatbed sowing

Particulars	Rotary assisted broad bed former-cum-seeder	Flatbed sowing
Type of soil	Vertisol (12.6% sand, 32.7 silt and 54.7% clay)	Vertisol (12.6% sand, 32.7 silt and 54.7% clay)
Crop	Soybean (JS-9560) and wheat (HI-1544)	Soybean (JS-9560) and wheat (HI-1544)
Row spacing, mm	300 (for soybean) and 200 (for wheat)	300 (for soybean) and 225 (for wheat)
Seed rate, kg/ha	60 (for soybean) 80-100 (for soybean)	80-100 (for soybean) 100-120 (for wheat)
Forward speed, km/h	3	3
Width of coverage, m	1.6	1.6
No. of rows	4 (for soybean) 5 (for wheat)	5 (for soybean) 6 (for wheat)
Depth of seed placement, mm	40-60	50-70
Field capacity, ha/h	0.35	0.36
Inter row variation in field for seed, %	5.0 ± 3.5	6.5 ± 4.5
Inter row variation in field for fertilizer, %	7.4 ± 4.6	6.5 ± 5.5
Fuel consumption, L/ha	15	12.6

Fig. 5 Developed rotary assisted bed former cum seeder

Table 3 Economic analysis of soybean and wheat crop at farmer's field

Treatment	Soybean				Wheat			
	Grain yield (t/ha)	Cost of cultivation ($/ha)	Net income ($/ha)	B:C ratio	Grain yield (t/ha)	Cost of cultivation ($/ha)	Net income ($/ha)	B:C ratio
Rotary assisted bed former-cum-seeder (M1)	0.96^A	221.81^B	235.65^A	1.05^A	4.86^A	342.53^B	762.48^A	2.23^A
Flatbed Seeding (M2)	0.71^B	242.83^A	98.13^B	0.40^B	2.74^B	388.4^A	194.28^B	0.51^B
Mean	0.84	232.33	166.89	0.72	3.80	365.46	478.39	1.37
p-Value	<.0001	<.0001	<.0001	<.0001	<.0001	0.001	<.0001	<.0001
CV (%)	5.49	2.05	12.05	10.13	8.82	6.08	20.83	21.58

trend was found in wheat crop also. Higher net returns in treatment M1 for soybean crop (235.65 $/ha) was observed as compared to M2 (98.13 $/ha). The cost of cultivation in M2 was 242.83$/ha and it was higher than M1 (221.81$/ha). The B:C ratio in M1 for soybean was found higher (1.05) as compared to M2 (0.40). Lower B:C ratio in M2 was due to the high cost of cultivation and low net income per hectare. Similar trends for grain yield, cost of cultivation, net income and B:C ratio were observed for wheat cultivation also. The results of increase in yield in wheat and soybean crops under broad bed conditionin vertisol are in agreement with the study reported by Shrivastava et al., 2017 and Jat et al., 2017. This suggests that rotary assisted bed former-cum-seeder helped to increase economic benefit of the farmers adopting broad bed seeding technology.

Conclusions

The rotary assisted broad bed former-cum-seeder is useful for seeding of soybean and wheat crops on broad beds. Provision has been made for attachment of a rotavator in order to form fresh bed or perform sowing operation with reshaping of bed by using bed shaper only. The field capacity of rotary assisted bed former-cum-seeder was 0.32 ha/h at speed of 3 km/h. This machine consumed 15 L/ha fuel during operation. Field demonstration of this technology showed higher grain yield for soybean and wheat crops as compared to flatbed sowing. The higher net return was obtained with the use of rotary assisted broad bed former-cum-seeder technology. The rotary assisted broad bed former-cum-seeder helped to increase economic benefit of the farmers by suggesting them the management practices suitable for sowing under broad beds conditions.

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