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# Design, development and testing of tillage cart with cultivator and hook patella attachments

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■ **ABSTRACT :** In order to improve the utilization of human and animal energy and to popularize the organic and animal farming for sustainable rural development through making animal farming more pleasant and comfortable, a prototype implement named Animal Drawn Tillage Cart (ADTC) was designed, developed and tested with two suitable attachments *i.e.* cultivator, and hook patella. The above attachments tested for preparation of seed bed with collecting and removing clocked debris by sitting on the cart. The unit was developed at the Faculty of Agricultural Engineering, IGKVV, (CG) during year 2005. Both the attachments were tested in the inceptisol soil at different moisture (18 to 24%, db) and depth level (5 to 10 cm). Performance parameters with animal fatigue were observed. The draft and field capacity increased with the depth and number of tines, respectively. Average draft with the three tined cultivator and 11 tined hook patella were recorded 85 and 80 kg, field capacity about 0.9 and 1.0 ha/day, field efficiency 64 and 72 %, cost of operation 323 and 321 Rs./ha, respectively. In 4 hr continuously working the animal shown fatigue level (score 19) while operator reported negligible fatigue. The control lever functioned well and the unclogging of whole debris by pressing the foot lever and lowering/raising of implement achieved promptly through operating levers by sitting position. Additional saving of Rs412/ha in cost of operation was recorded over traditional local ploughing (Rs 734/ha), beside saving in time by 13.5 % AND SAVING IN ENERGY BY 163 mj/HA. The fabrication cost of animal drawn tillage cart (ADTC) with cultivator and hook patella attachments was found to be Rs. 8000/per set.

■ **KEY WORDS :** Tilage cart, Cultivator, Hook patella

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In present era of mechanization the importance of animal farming is being realized for organic farming and sustainable production and rural development. As draught animals are an important source of power and energy for crop production in India (Verma and Verma, 1987). The scope of animal farming seems bright under Indian conditions because size of land holding of Indian farmer is in reducing trend and cost of fuels and chemical fertilizer is increasing rapidly. Adoption of organic farming becoming essential for sustainable yield and profit. Draught animal power gives greater output per hp-h as compared to tractor hp-h (Srivastava and Yadav, 1987). However, the animal farming is becoming very difficult and expensive with the traditional implements. In traditional ploughing a ploughman has to walk about 60-80 km/ha behind plough which is very tedious job. Farmers demand is for riding type of implements. Therefore, an attempt was made to develop a multipurpose tillage cart. All tillage operations including collection of weeds can be done by pressing foot levers. Animal farming can be popularized again by making it more pleasant and comfortable. In riding mode, the work output of a ploughman increases. As when operator is tired; he takes irrespective of the animal fatigue. Therefore, the work output capacity of a pair of animal was quite dependent on the health and walking capacity of a ploughman.

## ■ METHODOLOGY

The major components of the tillage cart was designed using standard formula from text books (Khurmi and Gupta,1988) and later fabricated in the workshop of Faculty of Agricultural Engineering, IGKVV, Raipur (C.G.) followed by field-testing in the research fields during the year 2005.The selection of material was generally made as per IS :68,13/1973 and was brought from local market.

**Design consideration for animal drawn tillage- cart:**

The design of an animal drawn tillage cart was adopted considering functional requirement, weather protection, soil type, cultural practices, type of animals, farmers attitudes and demand and cost of implement. The tillage cart consists of a frame having provision for attachment of cultivator ,planker and other implements, a seat for operator, ground wheels and controlling levers and paddles. Design of major components and controlling arrangements are discussed under following heads.

**Design and development of a universal frame:**

The length, width and height were taken considering practical experiences in controlling animals and implements in the field. The length of the frame excluding beam was taken 1350 mm. The width of the frame was selected considering width of implement attachment and the average size of village road/path in villages for easy transportation of the cart through them. Closest distance between two bullocks and he buffalos on yoking was also considered. The width taken was 1500 mm. The height was selected considering ,height of soil working tools, ground clearance of mounted implement during transportation, height of operator seat for easy and safe riding and controlling distance of operator with the animals on the basis of the all these considerations the height of universal frame was selected 450 mm from the ground.

**Design and development of ground wheel:**

*Diameter of wheel:*

The diameter of transportation / ground wheel, which are made to facilitate transportation and to operate rotavator and seed-drill etc. was selected about 800 mm, considering the following parameters.

Average height of local animal = 105 cm and working vertical load on animal neck = 20-30 kg.

Load on animal cart (weight of operator, 60-75 kg + weight of axle and frame = 85 kg + vertical components of tillage forces, 30 kg) = 190 kg

Sinkage of ground wheel = 10 cm

Minimum ground clearance in wet land (30 cm)

*Rim thickness:*

The thickness of the rim was calculated by using the following formula (Pandaya and Shah, 1997).

The thickness of rim, $\mathbf{t = PD/2f}$ (1)

where,

P = soil reaction, kg/cm$^2$ = W/A = load/ contact area

T = thickness of rim, cm, D = diameter of rim

F = tensile stress (360 kg/cm$^2$) and contact area

A = rim width x distance between two consecutive spokes

*Design of hub:*

The hub of the transportation wheel is most important and centrally attached component. It gives support to the spokes and shaft. The diameter of the hub was calculated using the following formula (Pandaya and Shah, 1997).

The outer diameter of the hub, $d_1$ = 1.5 d + 25 mm = 1.5 x 22 + 25 = 58 mm. Standard size selected = 60 mm

where, d= diameter of the shaft = 22 mm

The length of hub, L = $\pi$d/2 = 34.54 mm $\approx$ 35 mm.

*Design of spokes:*

The third most important component of the ground wheel was considered to spokes which maintained the rim in circular position against the soil resistance, operator weight and the jerk exerted by the soil working tools. The diameter and number of the spokes were calculated as below (Paul, 2003).

$$\text{Bending moment (M)} = W.C_t(D/2 - d/2) \quad (2)$$

where,

W = total load = 190 kg x 9.806 = 1863 N

$C_t$ = coefficient of traction, = 11.14 x $10^{-4}$

D = diameter of wheel rim, = 800 mm

$d_1$ = outer diameter of hub = 58 mm say, 60 mm

$f_s$ = allowable stress of the material, kg/cm$^2$ and so

Bending moment (M) = 1863 x 11.14 x $10^{-4}$ (800/2 – 60/2) = 767.89 N-mm also

$$M = f_s \times Z = f_s \times \pi \times d^3/32 \quad (3)$$

and $d^3$ = (M x32)/ $f_s$ x $\pi$ = 308.83 mm$^3$

d = 6.76 mm .

On the safety point of view and availability of material in the market, the spokes were made of m.s rod of 10 mm diameter and number of spokes.

n = 2.1 $(D/100)^{1/2}$ = 5.93 $\approx$ 6 numbers

where,

D = diameter of wheel rim, mm

N = number of spokes

Considering the transportation problem in future, 10 numbers of spokes at $36^0$ were used, to make the ground wheel adequate strong.

**Development of split axle for sharp turning:**

In existing riding types of implements, major problem faced during tunings, therefore to achieve sharp turning at the corners of the field, the axle was made in two parts as shown in Fig.A.

The one end of the each shaft was supported on ball bearing within a hollow pipe (axle 75 mm diameters) and other end was fitted with transportation wheels. Shaft was

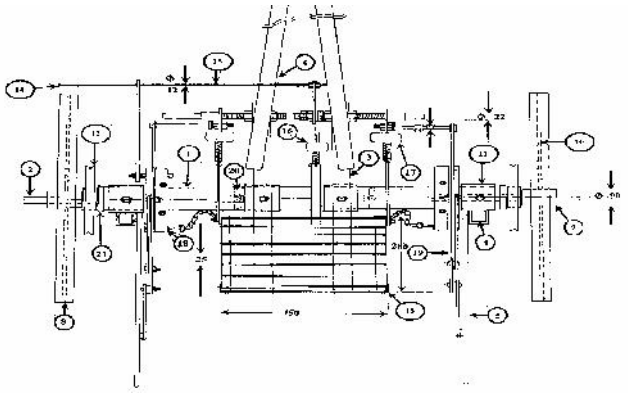



**Fig. A : Top view of Animal Drawn Tillage Cart**

made of circular rod (32 mm dia) and taking length of shaft = 100 cm (splitted in two pieces of 50 cm each). The design of shaft was carried out considering imposed load of 50 - 60% of total weight of the machine (Sengar and Singh, 2002) and using the design equation as,

$$\frac{M}{F} = \frac{f}{y} \qquad (4)$$

Can be written as

$$M = \frac{I}{y} f$$

Also M = f z

where

M = bending moment

= Load imposed (W) x Length of shaft (L)

= 103 x 50 % x 50 = 2575 kg. cm

f = allowable stress of the material, kg / cm²

= 1000 kg / cm² (permissible)

z = section modulus= $\frac{\pi d^3}{32}$

d = diameter of shaft, cm

$$M = \frac{f \pi d^3}{32} \text{ or}$$

$$d^3 = \frac{32 M}{\pi f} = \frac{32 \times 2575}{3.14 \times 1000} = 26.24$$

$$d = \sqrt[3]{26.24} = 2.97 \text{ cm}$$

**Development of braking system :**

Generally in animal drawn implements brake is not required due to being very slow moving in nature. But braking pad for one wheel was provided to facilitate sharp turning and control of animals. During tillage operation, the bullocks are mostly trained for taking turn on the left hand side of the operator. Therefore, the brake pad was provided for left hand wheels only and controlling paddle was provided near leg of operator.

**Development of foot operated lever for unclogging of debris and raising implement :**

The foot operated lever was designed and developed for lowering and raising the attached implements with minimum effort. Raising of implements during turning and for unclogging of debris and also to keep the raised position of implement during transportation and crossing bunda. Therefore, two foot levers near both sides of the operator's leg were provided through which the implement could be raised up to desired height.

**Adjusting arrangements:**

The developed tillage cart has been developed for multi tillage operations and transportation purposes, therefore, necessary arrangements for quick adjustment of wheel track and depth of operation were provided.

*Depth :*

The depth of furrow, in reference to the transportation wheels could be adjusted with the help of linkage made on the tool bar, named as height adjuster. Tool bar adjuster can be fixed by tightening the nut-bolt manually.

*Penetration angle:*

The angle of penetration of the soil working tools need to be changed as per the soil conditions in the field. This too be adjusted.

**Design and development of suitable cultivator and hook patella attachments :**

Cultivator is very important and multipurpose implement. It was developed to till and prepare the field as primary and secondary tillage. It was made in rectangular shape of tool frame with provision for attaching three-to-five curved tines in two rows of tool bar as shown in Fig. B. The tool bar was made of square pipe 45 x 45 x 5 mm. Design was carried with following assumptions.

– Depth of cutting = 8-10 cm

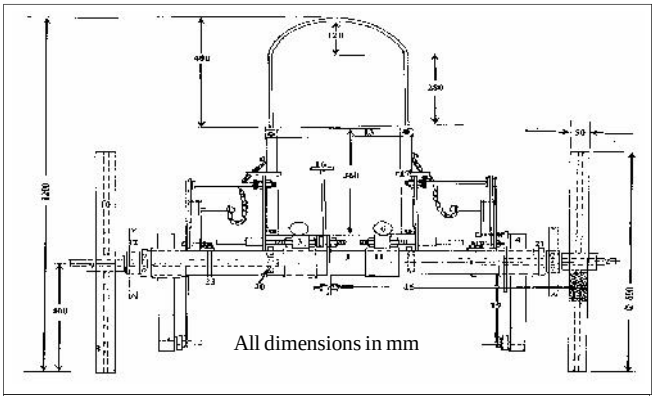



**Fig. B : Front view of Animal Drawn Tillage Cart**

- Width of furrow opener = 15 cm
- Ground clearance = 25 cm
- Number of tines = 3 to 5
- Adjustable spacing of tines = 15-30 cm
- Soil resistance = 0.4 kg/cm$^2$ (39200 N/m$^2$)
- Soil type = Sandy loam soil

The height of the tine (Ground clearance) was taken as 25 cm, considering the working depth in ploughed soil = 15 cm + free length (clearance to avoid clogging) = 10 cm.

**Width and thickness :**

A sweep type cutting tool was fitted with cultivator as cutting tool. The tines were made of mild steel flat of size 40 x 10 mm taking width of tine as 1: 4 in ratio of h: 4b. The width and thickness of the tine was also calculated by the following formula:

The width of type was considered as 1: 4 *i.e.* h: 4b

The section modulus, $$Z = \frac{b \times (4b)^2}{6} \quad (5)$$

The tines were made curved in shape and strength of tines was checked using standard formulas. Similarly the hook patella was designed for loosening of soil and collection of weeds. Removal of clogged weeds/ debris made easy. Pressing foot lever, sitting on the cart, could rise the implement.

Specification of developed animal drawn tillage cart (ADTC) and its attachments.

**Tillage cart and its frame:**

| | | |
|---|---|---|
| Overall dimension (L x W x H) mm | : | 1350 x 1800 x 1500 |
| Wheel tread, mm | : | 1100 |
| Axel pipe (length x dia), mm | : | 1100 x 80 (O.D.) |
| Shaft split type (length x dia), mm | : | 500 x 32 |
| Ground wheel (GW) dia, mm | : | 800 |
| Rim width x thickness, mm | : | 50 x 6 |
| Spokes: size, mm ø | : | 10 |
| No. of spokes | : | 10 |
| Operator's seat: base (LxW), mm | : | 450 x 280 |
| Base heights (adjustable), mm | : | 260-360 |
| Beam (V-type joint shape) length x dia mm | : | 2300 x 40 |
| Total weight, kg | : | 85 |

**Cultivator :**

| | | |
|---|---|---|
| Overall dimension (L X W X H), mm | : | 900 x 400 x 300 |
| Tines (width x thickness), mm: | | 40 x 10 |
| No. of furrow opener | : | 1-5 |
| Sweeps (width x thickness), mm | : | 100 x 3 |
| Arrangement of tines | : | Staggered in 2 rows |
| Tines: Curved shape (Radius of curvature) | : | 140 mm |
| Furrow opener type | : | V-shaped sweep |
| Penetration angle | : | $22^0$ |
| Weight, kg | : | 15-18 |

**Hook patella:**

| | | |
|---|---|---|
| Overall dimension: (L x W x H), mm | : | 900 x 400 x 200 |
| Types of hooks | : | Curve in shape. |
| Diameter of hooks, mm | : | 12 |
| Arrangement of hooks | : | Zig-Zag alternatively |
| Hook spacing | : | 75 mm |
| Penetration angle of hooks | : | $30^0$ |
| Weight, kg | : | 7.5 |

## RESULTS AND DISCUSSION

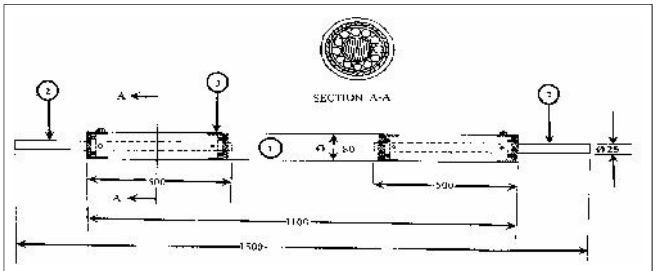
The results of the present study as well as relevant discussions have been presented under following sub heads:

**Performance of tillage cart with cultivator and hook patella attachments:**

Field plot of 0.25 ha area was prepared using each of cultivator and hook patella. Time required to cover the area, pulling force and speed was measured. The draft and efficiency of utilization of animal power was worked and presented in Table 1. Considering weight of animal pair (298 + 376 kg) and speed, the available animal power (0.75 hp) was worked out and actually utilization efficiency was calculated. The performance result of above attachments is presented under the following heads.

**Draft requirement with cultivator and hook patella:**

The cultivator attachment having three tines, mounted




| | | | |
|---|---|---|---|
| 1 | Pipe axle | 2 | Split shaft |
| 3 | Bearing shell | 4 | Ball bearing |

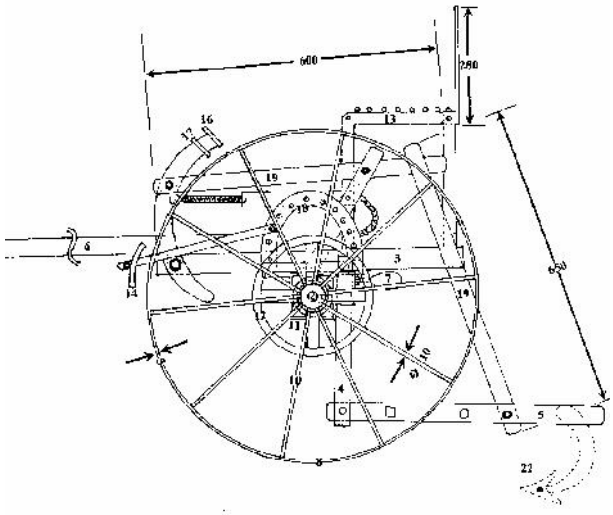
**Fig. 1 : Pipe axle with split shaft**

at spacing of 30 cm apart was operated at three levels of depths 5, 8 and 10 cm, respectively. The draft, power requirement and efficiency are presented in Table 1. The cultivator comparatively required more draft (85 kgf) than hook patella (80.7 kgf) The draft requirement increased significantly with increase in depth by 5 cm (CD 15 2.85) whereas increase in depth from 5 to 8, 10 cm (increase in depth by less than 5 cm) shown non-significant difference. Therefore, looking to the size of local animals, the depth and number of tines (3-5) may be adjusted to limit the draft. In general the tillage cart worked satisfactory with three-tined cultivator at 5-10 cm depth.

There was not much variation in animals speed during operation, with cultivator and hook patella and depth of operation. More speed was recorded with cultivator (2.18 km) than hook patella (2.06 km/h). Walking speed of animals reduced with increased in depth of operation.

**Field capacity and field efficiency :**

Actual field capacity with cultivator and hook patella were recorded of 0.126 and 0.129 ha/h, respectively. Higher field efficiency was recorded with hook patella (72.13 %) than that of cultivator (64.65 %). this was because of higher field capacity and least draft with the hook patella.




| | | |
|---|---|---|
| 1. Pipe axle | 2. Split shaft | 3. Loading frame |
| 4&7 Toolbar height adjuster | 5. Toolbar height hitching | 6. Beam to yoke |
| 8 Ground wheel | 9. Hub | 10. Wheel spokes |
| 11. Square box | 12. V belt pulley | 13. Seat |
| 14. Brake plate | 15. Brake shaft | 16. Pedal for brake |
| 17. Pedal for raising/ unclogging | 18. Lever adjuster arc | 19. Pedal arm |
| 20. Bearing | 21. Bearing cap | 22. Soil working tool |
| 23. U- bolt | | |

**Fig. 2 : Side view of Animal Drawn Tillage Cart**

**Power exertion and utilization:**

More power was exerted with cultivator (0.68hp)than with hook patella (0.62), therefore, animal power utilization was observed more with cultivator (91.5 %) than with hook patella (82.2 %).

**Time loss :**

Time loss in implement adjustment, observations and tunings were higher in the experimental plots. It was higher with cultivator (2.71 h/ha) than hook patella (2.15 h/ha).

**Economy of tillage cart :**

The fabrication cost of tillage cart with two attachments (cultivator and hook patella) was around Rs. 8000/-. The suitable cultivator and hook patella were fabricated in Rs. 1320/- and Rs. 600/-, respectively. The cost of operation was worked out around 321 Rs./ha. The economy of the tillage operation with the tillage cart was also evaluated with the traditional methods of plough and data are presented in Table 2. The tillage cart was found much economical. It minimized the cost of operation and with a net saving of Rs. 411 per ha over traditional method. It also saved time and energy by 13.5 h/ha and 163 MJ/ha over traditional ploughing method.

**Quality of work :**

The quality of works was observed through the performance of cultivator and hook patella. The performance of cultivator was observed in terms of soil inversion whereas the performance of hook patella was judged through its weeds/stubbles before and after operation.

**Soil inversion with cultivator attachment :**

The soil inversion was observed to judge the quality of work with the developed tillage implements. It was observed by counting number of inverted weeds/stubbles before and after operation. Table 1 shows that soil inversion increased from 70.00 to 74.00 % with increase in depth from 5 to 10 cm, respectively. The cultivator gave better pulverization with the average soil inversion of 72.58 %.

**Weed collecting efficiency of hook patella :**

The hook patella was tested in the field which was already ploughed with the three tined cultivator. Hook patella worked satisfactory and collected debris/grass from field effectively. Table 1 shows that weed collecting efficiency increased from 85 to 89 % with increase in depth of operation from 5 to 10 cm, respectively. Weed collection was good in sallow depth of operation also, thus in order to avoid excessive draft, the hook patella can be operated at 5-8 cm depth to get satisfactory weed collecting efficiency (86-88 %).

**Conclusion:**

No breakdown or deformation in the parts of the animal drawn tillage cart was observed and all controlling levers worked properly. On the basis of the performance and results obtained from the testing with cultivator and hook patella attachments, the following conclusion could be drawn.

The designed dimensions of the shaft (32 mm diameter), wheel (diameter 800 mm), spokes (diameter 10 mm), universal frame and controlling levers were found appropriate, no deformation and breakdown were observed.

The split shaftand brake system facilitated easy control of animals and sharp turning in the field. The system minimized not only the turning time loss but also kept the farmer free from fatigue. The above system probably used first time in the bullock driven implement. With the help of foot operated levers the collected weed and debris was easily collected and removed at desired place by raising the lever.

The total cost of tillage operation was found economical (323 Rs./ha). Total weight of the developed tillage cart with cultivator and hook patella attachments was found to be 112.50 kg including 85 kg frame+ 18 kg of cultivator + 7.5 kg of hook patella. The fabrication cost of tillage cart with cultivator and hook patella was found about Rs. 8000/-.

The saving with cultivator was recorded to the tune of 64 to 69.5 as compared to local indigenous plough.

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## REFERENCES

**Khurmi, R.S. and Gupta, J.K. (1988).** *Theory of machines*. Eurasia Publishing House (Pvt.) Ltd., Ram Nagar, New Delhi (India). 1017p.

**Pandya, N.C. and Shah, C.S. (1997).** *Elements of machine design*, Thirteenth Ed. :180 pp.

**Paul, A.K. (2003).** Design development of power operated walking type weeder for vegetable. M.Tech. Thesis, Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyala, Raipur, C.G. (INDIA).

**Sengar, Mahadev and Singh, S.S. (2002).** Design and development of animal drawn seeder for rice cum green manure crops for Biasi cultivation system. M.Tech. Thesis, Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyala, Raipur, C.G. (INDIA).

**Srivastava, S.N.L. and Yadav, G.C. (1987).** Perspective planting for draught animal power for the year 2000. Procedings of the national seminar on status of animal energy utilization held at Central Institute of Agricultural Engineering, Bhopal, Jan., 24-25 : 327 pp.

**Verma, M.R. and Verma, D.N. (1987).** Status of draught animals and their utilization in eastern Uttar Pradesh.Procedings of the national seminar on status of animal energy utilization held at Central Institute of Agricultural Engineering, Bhopal Jan., 24-25:293 pp.

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