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Development and evaluation of a multipurpose tool bar for mini tractor suitable for the cropping pattern of middle Gujarat region

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■ **ABSTRACT :** A mini tractor drawn multipurpose tillage tool has been developed by Anand Agricultural University suitable for seed bed preparation at wapsa conditions under sandy loam soil of middle Gujarat Agro-climatic zone in a single operation. The implement consisting of iron ploughs for tillage and clod crusher for breaking clods which is useful for preparation of seed bed in a single pass with a saving of about 20% in the cost of the operation as compared to the cultivator. Therefore, it is recommended for farmers of the region to prepare the seedbed by using the developed implement.

■ **KEY WORDS :** Mini tractor, Multipurpose, Tillage tool, Clod crusher

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Kumar and Manian (1986) worked on combination tillage tool for the primary and secondary tillage operation simultaneously. Due to simultaneous combination of tillage operations 10 h/ha of tractor operation can be reduced by combination of tillage tool as compared to conventional field preparation. Thierstein and Bansal (1988) worked on the animal-drawn wheeled tool carrier which was a multipurpose machine.

Sharma *et al.* (2001) carried out study on the tractor drawn ridger-seeder and modified in to multipurpose tractor drawn seeding machine. Chandegara (2003) developed a bullock drawn multipurpose implement for tillage, sowing, interculturing arid digging operations in sandy loam deep soils of middle Gujarat Agro-climatic Zone-Ill. During the field testing, cost of cultivation was Rs.2063.88/ha for local implements, while for the multipurpose implement it was Rs. 1471.17/ha. Thus, multipurpose implement saved, Rs.592.711ha in addition to time and 52. 19 % lower investment over traditional implement. The hourly cost of a pair of bullock was Rs.39.62.

Gebregziabher *et al.* (2006) worked with development of animal drawn tillage tools. With the recent development in farm technologies and mathematical modelling techniques supported by computer based simulations, new methodologies in research are available to improve animal traction tillage implements. When adopted, these methodologies could significantly assist in optimising the implement designs and operational conditions aiming at minimum draught requirement and best soil manipulation performance.

Karthikeyan *et al.* (2009) studied various traditional tools used for agricultural operations by the farmers of Tamil Nadu. Pacharne *et al.* (2009) developed a tractor drawn V blade harrow which consisted of a mild steel frame and a V shape blade fitted to the frame. The blade

was strong and made up of high carbon steel. Due to its V shape its penetration in soil was easy which required 35 or more hp tractor. Study was conducted over 20 ha area with following results 0.46 ha/hr effective field capacity, 95% field efficiency and 416.00 Rs./ha cost of operation. Mohammadhossein *et al*. (2012) concluded that intensive tillage practice requires multiplication of energy input in an agricultural production system. Energy requirement for seedbed preparation are important objectives of sustainable farming. The reduce tillage operation also known as conservation tillage operation require lesser energy efficiency for sustainable agriculture.

Nayak and Verma (2012) tested multi purpose tool (MPT) for ease in control of animal, sharp turning, adjustment, and comfort to the animal as well as operator. The performance of MPT was found satisfactory using universal frame, lifting mechanism and tool attachments as compared to the ploughing.

Objectives :

– To design a multipurpose tillage implement for mini-tractor.

– To fabricate the tillage implement.

– To evaluate the performance of the developed multipurpose tillage implement.

METHODOLOGY

Design consideration:

A mini tractor drown multipurpose tillage implement was designed and fabricated in workshop, Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Anand Agricultural University, Godhra. Various components of the tillage tool were fabricated and details are given below:

Selection of soil working tool :

A survey was conducted to find out the existing tillage tools at farmers' field. It has been observed that small and marginal farmers are using bullock drown iron plough (as shown in Fig. A and B) for most of the tillage as well as sowing operation. In another survey, the availability of the iron plough was accessed in local market of Panchmahal, Dahod, SabarKantha and Gandhinagar regions. The available iron plough was selected as soil working tillage tool. Five bullock drawn iron ploughs were procured from the market and modified to assemble on the tillage tools. Soil working tool was modified by welding the bracket of mild steel flat (10 cm × 10 cm × 10 mm). It can be assembled to the front of frame with using of U clamp. By clamping the plough in the front of the frame provide extra support of the frme and load is not transferred to the U clamp only.

Fig. A : Selected soil working tool

Fig. B : Selected soil working tool (Iron plough)

Design of frame :

The frame was developed using square sectional sections (50mm x 50mm x 5mm). The selection of the square section was carried out by assuming the average of 200 kgf force acting on each iron plough.

Square hollow section :

H (Outer width) = 50mm, h (Inner width) = 40mm

and c (thickness) = 5 mm

$$\text{Moment of inertia (I)} = \frac{(H^4 - h^4)}{12}$$

$$\text{Moment of inertia (I)} = \frac{(5^4 - 4^4)}{12}$$

$$\text{Moment of inertia (I)} = 30.75 \text{ cm}^4$$

$$\text{Section modulus} = \frac{1}{c} = \frac{30.75}{5} = 61.5 \text{ cm}^3$$

$$\text{Radius of gyration} = \sqrt{\frac{H^2 + h^2}{12}} = \sqrt{\frac{5^2 + 4^2}{12}} = 1.8 \text{ cm}$$

Hollow square section (50 mm × 50 mm × 5 mm) was found to have sufficient strength to bear load more than 1000 kgf and two supports were also provided to further increase strength of the frame. In the range of 200 kgf force each on five different places on the frame were considered to act. Maximum load on each point of the frame was observed and it was found less than 200 kgf during the testing in the field condition by employing single tillage tool. The sides of the frame were kept 10 cm longer to assemble clod crusher. The hitching system was also fabricated on the frame at central portion. The centre to centre distance of the lower hitching points was 45 cm and the vertical distance between top hitching point and the line of lower hitching points was kept 45 cm. The hitching system was developed by using the hollow square section as used in the frame. At each of the hitching points two mild steel flats (12.5 cm x 5 cm x 1.2 cm) with 20 mm hole at centre were welded for easy and quick assembling or disassembling of the tillage tool.

Fig. C : Frame

Design of clod crusher :

A clod breaker behind the soil working tool was provided to break the clods and to develop the seed bed having fine tilth. The clod crusher was developed using used mild steel pipe (with 230 mm diameter and 135 cm length) and eight rows of triangular projections (13 number in each row).The clod crusher was hinged at lower ends of the frame with the help of suitable links. On outer periphery of the pipe, triangular shaped mild steel pegs. The pegs were developed by using diagonally bended (40 mm x 40 mmx2 mm) square mild steel pieces. Each peg was welded at 10 cm centre to centre distance in a row and at inter row distance of 9 cm. A mild steel (50 mm diameter) pipe with 5 mm thickness was used as axle rod which holds the clod breaker pipe at both the ends. The clod crusher was connected with the main frame with the help of two side sockets (arms). The sockets of 50 cm length (40x40x5 mm square section) were fabricated with 56 mm dia. pipe of 10 cm length to facilitate holding and easy rotation of the axle of the clod crusher at both the ends.

Fig. D : Clod crusher

The mass of the clod crusher was found as 58 kg and which was further increased by filling concrete of 5-10 mm size in the hollow cylinder through a hole on one side of the circular portion. The total mass was increased upto 100 kg, which was found suitable for crushing/breaking soil clods.

Thus, the good proto type of multipurpose tillage implement was fabricated and performance evaluation was done in field condition.

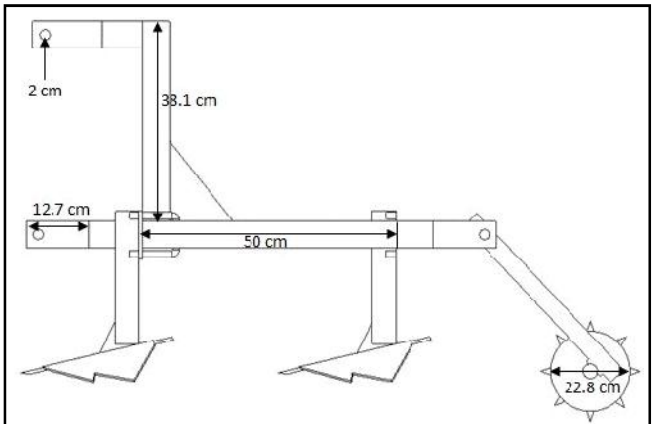

Fig. E : Schematic diagram showing side view of multipurpose tillage implement

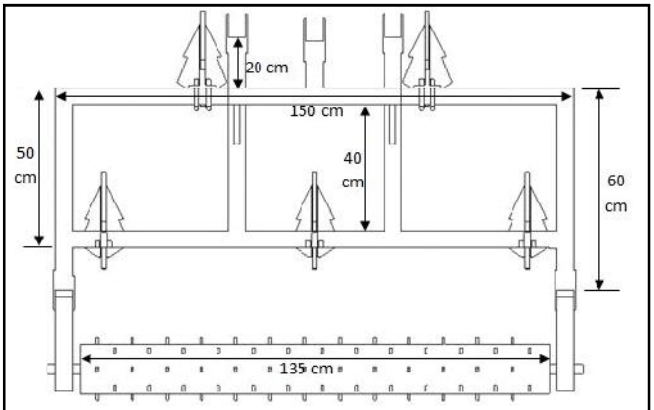

Fig. F : Schematic diagram showing top view of multipurpose tillage implement

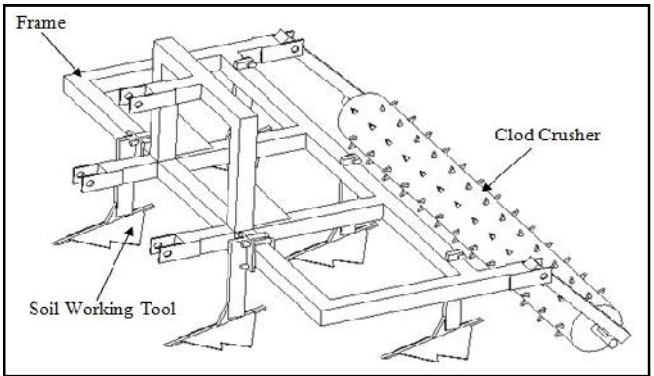

Fig. G : Schematic diagram showing isometric view of multipurpose tillage implement

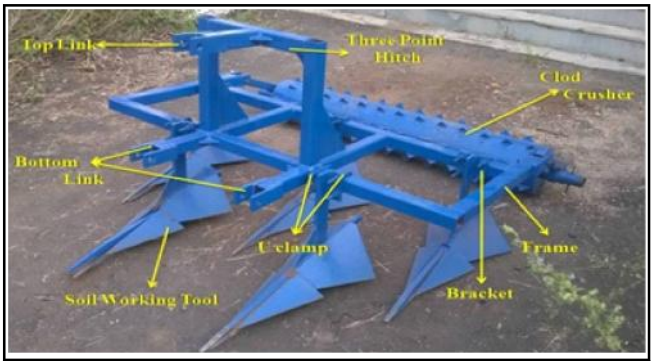

Fig. H : Multipurpose tillage implement with clod crusher

■ RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Performance study of the tillage implements :

The performance of mini tractor drawn multipurpose tillage implements was evaluated in sandy loam soil of middle Gujarat region. The experimental site is located in middle Gujarat Agro-climatic Zone of Gujarat State. All the parameters of the tractor-implement performance were measured and recorded in line with the recommendations of RNAM (Regional National for Agricultural Machinery) test codes and procedures for farm machinery technical series (1995). A 15 hp Mahindra Yuvraj tractor was used to operate the implement.

The matching implements for seed bed preparation used were multipurpose tillage implement, cultivator, M.B. plough in combination. In a trial the prototype was extensively tested in the field conditions and draw backs and operational problems were observed. It was observed that share bars of the iron ploughs got loosen frequently, bending of the tynes of the plough and breaking of the shoe body of the plough were also observed. Sometimes the tractor got stopped due to higher depth of operation.

The body of the iron ploughs were modified by shortening the length of the ploughs and welding the tyne at the centre of the plough in spite of the rear end (to eliminate cantilever action of the plough which consume enormous energy and resulted in to reshaping and bending of the iron plough). Iron ploughs were assembled to main frame with U clamp. The length of the plough was reduced from 70 cm to 50 cm. Thus, a compact tillage tools using modified iron ploughs was developed and during the extensive operation of the tillage operation no wear and tear and loosening of the share was observed. The tillage implement with modified iron ploughs became compact and sturdy and has been working satisfactorily. Proper blasting at front of the mini tractor was carried out for proper balancing of the tractor-implement assembly. In a feeler trial it was observed that front blasting of 100 kg mass for the mini tractor provided better stability and working efficiency of the tillage operation.

Fig. 1 : Existing iron plough and modified iron plough

Fig. 2 : Fabricated proto type multi tillage implement with modified iron ploughs

Total cost of construction of the tillage tool with iron ploughs and clod crusher was estimated as Rs. 9777.95 or say Rs. 9778/-

After modification in the iron plough the performance study was carried out. The newly developed multipurpose tillage implement with iron ploughs as tillage implements was tested in the field with clod crusher as well as with wooden planker in separately and cultivator as control. Field Efficiency and soil disturbance has been reported as two major factors in determining the performance of tillage implements (Bukhari *et al.*,1988). The field capacity of a machine is a function of its width, speed, efficiency of operation and soil parameter. The size of the testing plot was kept 20 m × 20 m.The data pertaining to soil moisture content, bulk density, operating speed, travel reduction, draft, fuel consumption, field capacity, energy requirement, soil volume disturbed, soil pulverization and drawbar power were observed as per standard methods and the observed data were analyzed.

The mean data on soil moisture content and bulk density of the soil mass before tillage operations at 0 - 20 cm depth were 14.18 (%) and 1.31 g/cc, respectively.

The performance of mini tractor drawn multi purpose tillage tool with iron ploughs was operated along with (a) clod crusher and (b) wooden planker. The data pertaining to soil moisture content, bulk density, operating speed, travel reduction, draft, fuel consumption, field capacity, energy requirement, soil volume disturbed, soil

Table 1 : Cost of fabrication of tillage tool with iron ploughs

Sr. No.	Name of parts	Material and specifications	Dimension	Total quantity used	Total weight	Rate, Rs./unit	Total cost, Rs.
1.	Frame	Square section	5 cm x 5 cm	659 cm	37.65 kg	47/ kg	1770
2.	Hitch points	M. S. Flate	5 cm x 1.2 cm	127 cm	4 kg	40/ kg	160
3.	Soil working tool	Soil working tool	65cm x 30 cm	5 no.	50 kg	72/ kg	3600
			30 cm				
4.	Soil working tool	U Clamp	5cm x 5cm	10 nos	4 kg	90/ kg	360
5.	and frame	Paint		1/2 lit		270/ lit	135
6.		red oxide		1/2 lit		185/ lit	92.5
7.		Primer		0.5 lit		90/ lit	45
Total cost of material (Rs.)							6163.50
Fabrication charges (30 % of the material cost)							1849.05
Total cost of the tillage machine (Rs.)							8012.55

Table 2 : Cost of fabrication of the clod crusher

Sr. No.	Name of parts	Material	Dimensions	Total quantity used (kg)	Total weight	Rate Rs./unit	Total cost (Rs.)
1.	Clod crusher	Square section	40 mm x 40 mm x 5 mm	100 cm	7 kg	47/ kg	329
2.	Clod crusher	Pipe	230 mm	135 cm		70/ ft	315
3.	Clod crusher	Pipe	56 mm	20 cm		70/ ft	47
4.	Clod crusher	Pipe	50 mm	170 cm		70/ ft	397
5.	Clod crusher	Square piece	4 cm x 4 cm	104 nos	3 kg	90/ kg	270
6.	Total cost of material (Rs.)						1358
Fabrication charges (30 % of the material cost)							407.4
Total cost of the clod crusher (Rs.)							1765.4

Fig. 3 : Multipurpose tillage implement with clod crusher and planker

Fig. 4 : Draft measurement of tillage implements

Table 3 : Performance parameters of the tillage implements

Implement	rpm	Speed (m/s)	Speed (kmph)	Width (m)	Depth of cut (m)	TFC (ha/h)	EFC (ha/h)	F.E. (%)	SDV (m^3/h)	Soil Pulver	Draft (kgf)	dbhp (hp)	Fuel (l/h)	Cost of operation (Rs/h)	Cost of operation (Rs/ha)
Iron plough	1000	0.99	3.56	1.60	0.15	0.57	0.48	84.20	739.20	11.69	235	3.10	3.15	184.19	383.73
with clod	1500	1.15	4.14	1.60	0.15	0.66	0.55	83.30	836.00	11.90	251	3.85	3.31	210.09	381.98
clusher	2000	1.29	4.64	1.60	0.15	0.74	0.61	82.40	902.80	11.98	274	4.71	3.57	234.40	384.26
Iron plough	1000	1.13	4.07	1.60	0.15	0.63	0.53	84.12	789.70	11.37	197	2.97	2.47	175.46	331.06
with planker	1500	1.16	4.18	1.60	0.15	0.71	0.58	81.69	846.80	11.65	212	3.28	2.70	190.81	328.98
	2000	1.34	4.82	1.60	0.14	0.78	0.63	80.76	894.60	11.85	230	4.11	2.90	217.92	345.90
Cultivator-I	1000	0.94	3.38	1.35	0.15	0.45	0.36	82.60	522.00	14.68	155	1.94	2.75	161.33	448.14
Pass	1500	1.21	4.36	1.35	0.14	0.58	0.43	79.10	614.90	14.87	167	2.69	3.00	173.08	402.51
	2000	1.53	5.51	1.35	0.14	0.74	0.53	81.30	747.30	14.95	172	3.51	3.23	209.04	394.42
Cultivator-II	1000	1.02	3.67	1.35	0.15	0.50	0.41	82.60	606.01	14.68	175	2.38	2.75	161.33	394.00
Pass	1500	1.23	4.43	1.35	0.15	0.58	0.43	79.10	632.10	14.87	183	3.00	3.00	173.08	402.51
	2000	1.54	5.54	1.35	0.15	0.74	0.53	81.30	773.80	14.95	196	4.02	3.23	209.04	394.42

pulverization and drawbar power and economics were analyzed. The result revealed that single pass of newly developed multi tillage implements consisting of iron ploughs with clod crusher or with wooden planker gave required tilth of seed bed in a single pass.

As per instruction of the agresco committee the detailed study of the multitillage implements after modification of the iron ploughs was carried out for the performance study of the prototype with single pass along with clod crusher and planker and cultivator as control at three different engine speeds *viz.*, 1000, 1500 and 2000 rpm.

Conclusion :

– The results of the research work revealed that newly developed mini tractor drawn multi tillage implements work satisfactorily for seed bed preparation in a single pass with use of clod crusher. In case of the operation of the tillage tool with wooden planker a huge soil mass accumulated in front of the planker which created problems for further spreading the soil mass.

– Ballasting at front of the mini tractor improves the performance of the implements as compared to the without blasting and therefore the performance study of the implements was carried out with proper blasting at the front (100 kg weight was added).

– The performance the prototype of the tillage implement was found satisfactory along with clod crusher.

– The fabrication cost of the multi tillage implements and clod crusher were estimated as Rs. 8012.55/- and 1765.4/-, respectively.

– The mean mass diameter of the soil of the seed bed prepared by the multi tillage implement in a single pass was as per the recommended range of 12-14 (Ref.). However, the soil tilth was found better in case of the planker attachment but due to accumulation of huge soil mass at the end of the operation in front of the planker spoil the operation.

– The cost of the operation of the tillage implement with the clod crusher was estimated as Rs. 382/ha which

was slightly more than the cost of operation with planker (Rs. 328.98/ha) but was almost half of the control (cultivator operation).The operation of the cultivator with single pass could not achieved the required tilth of the seed bed hence it required second operation of the cultivator which incurred doubling of the cost of operation as well as time.

– A good tillage implement has been developed which can provide good seed bed in a single pass with clod crusher for the crop of wheat and maize crop of the region of middle Gujarat with sandy loam soils. The following recommendation has been proposed for the farmers of the zone:

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