DEVELOPMENT AND TESTING OF DYNAMOMETER ATTACHMENT BETWEEN THE LOADING CART AND THE TRACTOR

ABSTRACT

Farm Power is an essential input in agriculture for timely field operations for operating different types of farm implements. During last 55 years the average farm power availability in India has increased from about 0.30 kW/ha in 1961 to about 2.24 kW/ha in 2017. The source of farm power includes human, animal, tractors, power tillers, diesel engine and electric motor. Information about the availability of these power sources under time-series is very essential in planning and prediction level of farm mechanization. For increasing productivity of dry land agriculture which constitute about 66% of the cultivated area in India, timeliness in farm operations is essential especially for seedbed preparation and sowing operations for establishing good crop stand in deficient/ receding soil moisture content. Tractor power on farm will continue to be an absolute necessity for increased agricultural production. Efficient performance of the tractor–implement system includes selection of the implements that neither overload nor fail to use adequate power available from the source. This emphasizes the importance of proper matching of power available from the source with that utilized by the implement, particularly for tillage operations where the nature of work is hard. The satisfactory performance of the tractor-implement system is dependent upon the stability of the operation, power of the engine and traction developed. An attachment was developed to attach the spring dynamometer of capacity 2000 kg between the tractor and the loading cart. The developed frame was tested with two spring dynamometer of capacity 2000 kg each and the maximum spring deflection was measured. The maximum spring deflection were measured as 31 and 26 mm, respectively for old and new spring dynamometer of the same capacity of 2000 kg each.

***Key words*: Dynamometer; Draft; Traction; Slip; Tractive power; Farm power**

Introduction

Unlike industry where men machines and materials are brought under one roof, the agriculture requires men, machinery and material being moved to field and various unit operations performed timely, with required precision, that gives desired productivity in a manner it does not cause drudgery and health hazards to the workers. In this context availability of appropriate farm power sources are required. Traditionally human and draft animals ~~met~~meet this need. Draft ability of draft animals has been studied. Bullocks ~~and he~~and buffaloes pull about 10% of their body weight, camels about 18% of the bodyweight and donkeys about 34%. However, for the current level of intensity of farming, required levels of productivity, with a work environment ~~required~~required, ~~can not~~cannot be met by animate sources alone. As a ~~result~~result, electro-mechanical sources supplement and substitute animate sources. For stationery operations like operation of irrigation pump, power thresher, a chaff cutter and grinder engines and motors are in use. ~~Where as~~Whereas for tractive field operations there are tractors and power tillers run by diesel engines mounted on them.

Farm Power is an essential input in agriculture for timely field operations for operating different types of farm equipment and for stationary jobs like operating irrigation equipment, threshers/ shellers/ cleaners/ graders and other post harvest equipment. During last 55 years the average farm power availability in India has increased from about 0.30 kW/ha in 1961 to about 2.24 kW/ha in 2017 (Mehta *et al.*, 2019).

It is visualized that the additional requirement of food grains in future will be met, to a great extent, from Indo-Gangetic plains where the demand of tractors, power tillers and other machinery will continue to increase in future also. For increasing productivity of dry land agriculture which constitute about 66% of the cultivated area in India, timeliness in farm operations is essential especially for seedbed preparation and sowing operations for establishing good crop stand in deficient/ receding soil moisture content.

Mechanization in Indian agriculture started with the establishment of the Central Tractor Organization (CTO) mainly for land reclamation and development, mechanical cultivation and reduction of sanccharum spontanium. The increased use of farm machines has found expression in the phenomenal expansion of cropped area and cropping intensity and the country’s agricultural production on all fronts. The programmes of farm mechanization have resulted in adoption of farm machinery such as tractors, power tillers, combine harvesters, irrigation equipment, plant protection equipment, threshers, improved implements and hand tools.

Tractor power on farm will continue to be an absolute necessity for increased agricultural production. The ability of the tractor to develop drawbar pull depends on many factors, such as the physical capability of the tractor, soil conditions, operating conditions, type of hitch mechanism and type of implement in use. Efficient performance of the tractor–implement system includes selection of the implements that neither overload nor fail to use adequate power available from the source. This emphasizes the importance of proper matching of power available from the source with that utilized by the implement, particularly for tillage operations where the nature of work is hard. The satisfactory performance of the tractor-implement system is dependent upon the stability of the operation, power of the engine and traction developed.

Current farming economics reinforce the importance of efficient farm tractor operation. In draft or drawbar work, costs are minimized when a tractor is operated near its maximum tractive efficiency. Adjusting a tractor to operate at maximum tractive efficiency requires the optimization of tractor weight, weight location, tire pressures and the adjusting of ground speed for the operating load and soil conditions.

Methods of Loading Tractors

The principle of loading a tractor or an animal is basically the same. In ~~all the~~all cases, the ground drive wheels of a vehicle are braked to various amounts to vary the force required to pull the vehicle.

Loading Cart

Loading cart is a device which is used to load the tractor or any tractive power units during tractive performance evaluation. Different methods of loading the power source’s tractive effort are shown in Fig. 1.

Kibalama et al. (1995) developed a loading cart with two tyres fitted on a rear axle. It consists three shafts- rear shaft, intermediate shaft and final drive shaft. Loading was achieved by using band brake on the final drive shaft. It was developed for testing the animal performance in the field.

Prasanna et al. (1998) developed a hydraulic loading cart for testing self-propelled machines of capacity less than 7.5 kW by using the double shoe internal expanding brake system employed in front wheels of ambassador car. The loading cart consisted of a ~~heavy duty~~heavy-duty axle with a pair of supporting spoked wheels coupled with brake system components at each end, dynamometer frame, axle loading arrangement and single point hitch system. Instruments like dynamometer, spring balance and pressure gauge were also provided to measure respectively the tractive effort, brake lever force and hydraulic pressure in fluid lines.

Datta et al. (1998) determined the tractive effort developed by a 4.5 kW ~~Lambardini~~Lombardini diesel engine driven self-propelled machine by using a hydraulic loading cart. The machine was tested with two types of wheels, namely the spoked cage wheels and the pneumatic wheels (6×12, 6PR) commonly used in power tillers on mur~~o~~ram road and compact agricultural surfaces. It was observed that at 20% slip, the machine fitted with pneumatic wheels can develop a maximum tractive effort of 542.08 and 233.38 N respectively on mu~~o~~rram road and compact agricultural surface, and for cage wheels this was 264.14 and 121.37 N at a normal axle load of 695.04 N.

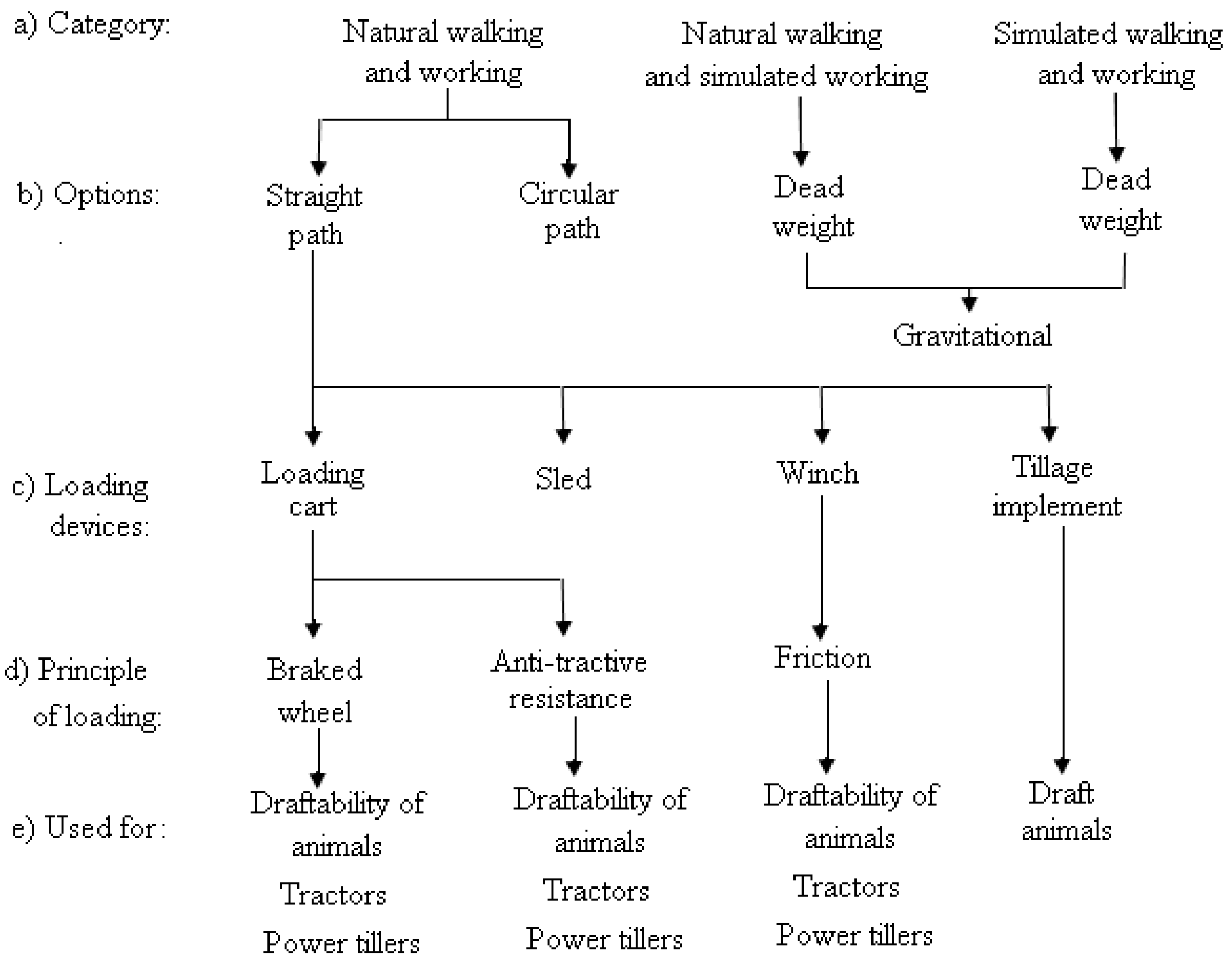

Fig. 1 Different methods of loading the power sources

Draft Measurement

To match the tractors and implements, one must know the pull the tractors can develop and the draft requirement of the implements. The models available to predict tractive performance of tractors and draft requirements of implements are described in Zoz and Grisso (2003) and ASABE Standard D497.5, respectively.

Grisso et al. (1992) ~~were~~ demonstrated the tractor performance trends using lotus templates. Comparison of bias ply versus radial ply tires, dual versus single tires, and the influence of travel speed, tire size, ballast distribution, soil condition, ~~two wheel~~two-wheel drive (2WD) and ~~four wheel~~four-wheel drive/mechanical front wheel drive (4WD/MFWD) tractors was shown. An alternative calculation mode can be used to determine the required weight to obtain a desired performance. This mode was used with an optimizing ballast scheme to predict the optimum wheel slip and maximum tractor efficiency for each comparison.

Godwin et al. (1993) ~~were~~ designed a dynamometer to measure the forces and moments acting on a tillage implement for use both in a soil bin and in the field. The instrument is able to measure the three orthogonal forces acting on the implement and the three moments acting about the orthogonal axes, up to a maximum force of 100 kN and a maximum moment of 100 kNm.

Glancey et al. (1995) ~~were~~ developed a new approach to predict draft requirements of agricultural implements using a standard tillage tool. The standard tillage tool acts as an analog device and characterizes the dynamic soil conditions. This approach was verified using three different implements (subsoiler, moldboard plow and chisel plow) and two different analog tillage tools.

Maswaure and McKyes (1997) ~~were -~~ conducted a field experiment to observed the effects of the geometric parameters of flat tillage tools on their draft, cutting efficiency and loosening of a moist clay soil. The test tool variables included rake angles to the horizontal of 30, 60 and 90^0, widths of 75 and 150 mm and depths of operation of ~~100, 150 and 200 mm.~~100-, 150- and 200-mm. measurements were taken of draft, disturbed soil cross sectional profiles and the initial area of soil disturbed by the tools. The resulting draft requirement increased with width, depth and rake angle of the tool.

Janobi and Suhaibani (1998) ~~were~~ measured the draft of major primary tillage implements operating on sandy loam soil. Implements included three chisel plows of different shanks, an offset disk harrow and a mould board plow. The effects of speed and depth upon the draft measurements were investigated. A significant increase in draft was observed for all the implements with an increase in depth.

The Alberta Farm Machinery Research Centre (2001) ~~has~~ developed a simple instrumentation system and test procedure to measure power delivery parameters on farm tractors during field operation. The system does not measure standard tractive ~~efficiency, but~~efficiency but instead measures an alternative or substitute called power delivery efficiency. With this system an operator can measure the effect of changes made to a tractor to improve traction efficiency.

Narang et al. (2005) evaluated an 8.95 kW tractor for draft and drawbar power on tilled land. Empirical equations were developed to correlate the relationship between draft and wheel slip, drawbar power and wheel slip and drawbar power and fuel consumption. The values of draft, drawbar power and specific fuel consumption were calculated at 25% wheel slip. The draft values at engine speed of 1500 rpm were 748 and 735 N in second low and third low gears under slightly loose soil conditions.

Kim et al. (2005) ~~has~~ analyzed the improvement of agricultural tractor performance using the data from 926 diesel tractors tested at Nebraska Tractor Test Laboratory from 1959 through 2002. The performance analysis included the specific volumetric fuel consumption, power per unit weight, traction coefficient, maximum torque rise and sound level. They were evaluated based on the PTO power level and chassis type of tractor.

Sahu and Raheman (2006) ~~were~~ developed a methodology to predict the draft requirements of combination tillage implements in any soil and operating conditions. This methodology required the draft requirements of individual tillage implements in undisturbed soil condition and draft utilization ratio of the rear passive set of combination tillage implement.

Grisso et al. (2007) ~~were~~ developed and demonstrate the use of a spreadsheet for matching tractors and implements. The spreadsheet was based on the Brixius Model and ASABE Standard D497.5 to predict tractor performance and implement draft, respectively. The results show that the spreadsheet can be used effectively to match implements with tractors or vice versa.

Materials and Methods

The frame for dynamometer attachment in between the loading cart and the tractor was designed and developed with the considerations of the dimensions of the spring dynamometer of maximum capacity 2000 kg. The fabrication of the frame was done at Department of Agricultural and Food Engineering, Indian Institute of Technology, Kharagpur. The frame consists of fulcrum (drawbar side and implement side), C-shape plate, MS Flat (under tension and bending) and stopper. The dimensions of the spring dynamometer and the schematic diagram of the frame are shown in **Fig. 2** and **Fig. 3**, respectively.

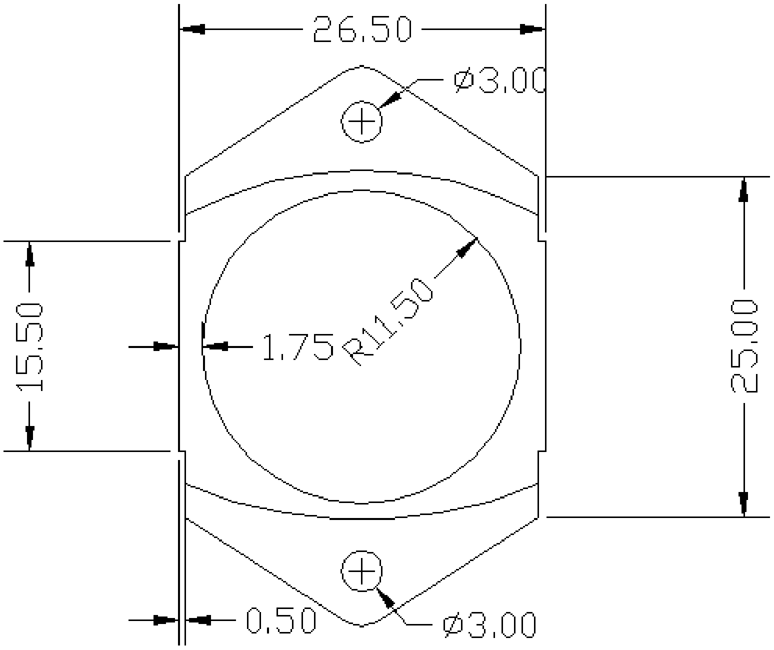

Fig. 2. Spring dynamometer (all dimensions are in cm)

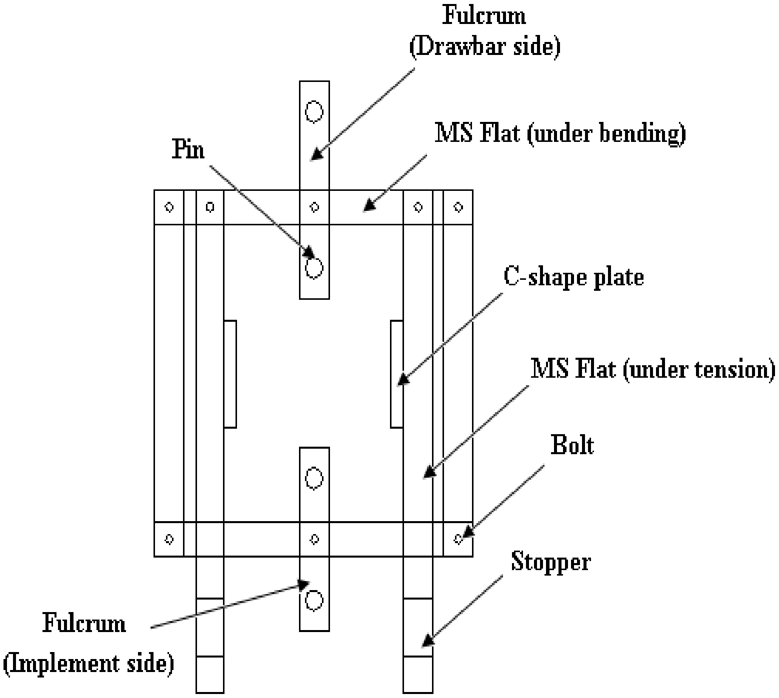

Fig. 3. Schematic diagram of the frame

Calibration of the Spring Dynamometer

Deflection of spring of the spring dynamometer of capacity 2000 kg was measured by applying the load gradually with the help of crane. The deflections of the two dynamometer of the same capacity (2000 kg) were measured one by one as shown in **Table 1**. The setup diagram of deflection measurement of the spring dynamometer is shown in **Fig. 4**.

Fig. 4. Measurement of dynamometer spring deflection

Table 1. Measurement of Dynamometer (capacity = 2000 kg) spring deflection

Dynamometer	Max load applied, kg	Max deflection, mm
1	1900	31
2	1900	26

Results and Discussions

The frame was designed and developed on the basis of maximum load capacity of the spring dynamometer and the developed frame was tested by using the same spring dynamometer of capacity 2000 kg. The stopper in the frame was designed on the basis of maximum deflection of the spring. The autocad 3D sketch and the frame attached with the spring dynamometer are shown in **Fig. 5** and **Fig. 6**, respectively. The overall dimension of the developed frame was found to be 72 x 55 cm. The detailed specifications of the developed frame are shown in **Table 2**.

Table 2. Specifications of the developed frame

Sl. No.	**parts**	**Dimensions, cm**		
		Length	**Width**	**Thickness**
1.	M.S. Flat (under tension)	62.0	5.0	0.6
2.	M.S. Flat (under bending)	55.0	5.0	0.8
3.	Fulcrum (Drawbar side)	25.0	5.0	1.6
4.	Fulcrum (Implement side)	20.0	5.0	1.6
5.	Stopper	5.0	5.0	0.8
6.	C-shape plate	16.0	3.0	6.5 (height)

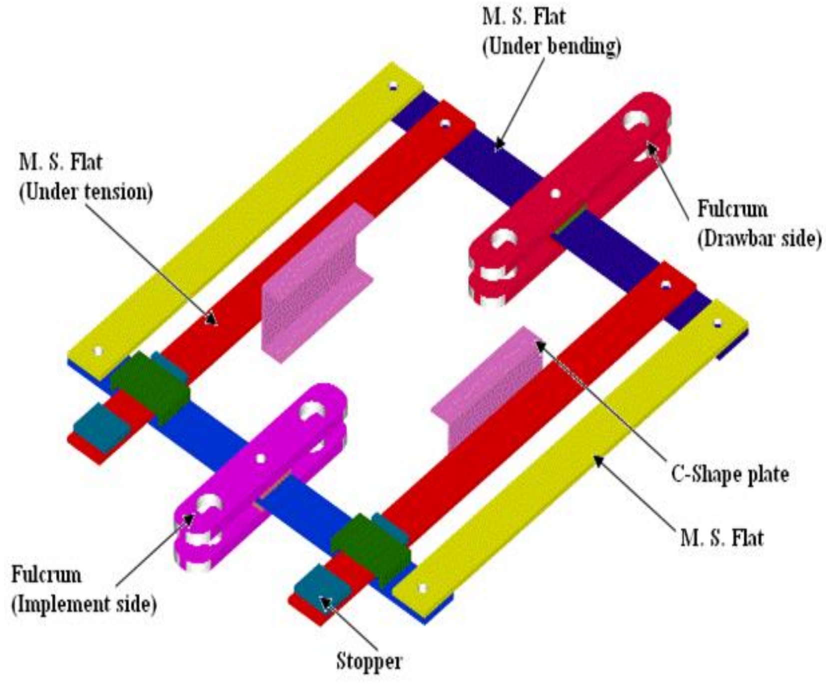

Fig. 5. 3D sketch of the developed frame

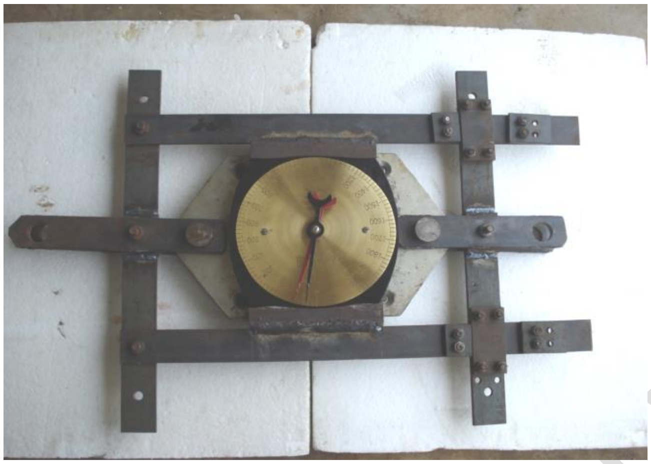

Fig. 6. Developed frame attached with the dynamometer

Testing of the developed frame

The developed frame has been tested with two spring dynamometer of capacity 2000 kg each by applying load gradually with the help of crane. The deflection of the spring of the two spring dynamometers are shown in **Table 3** and represented graphically in **Fig. 7**. The spring deflection of the two dynamometers are slightly different at the same applied load and this may be due to difference in spring stiffness or slightly difference in material properties of the springs.

Table 3. Deflection of the spring of dynamometers at different loads

Sl. No.	Load applied, kg	Spring deflection, mm	
		Dynamometer 1	Dynamometer 2
1	100	6	5
2	300	9	8
3	500	12	10
4	700	14	12
5	900	18	15
6	1100	20	17
7	1300	23	20
8	1500	26	22
9	1700	28	24
10	1900	30	27

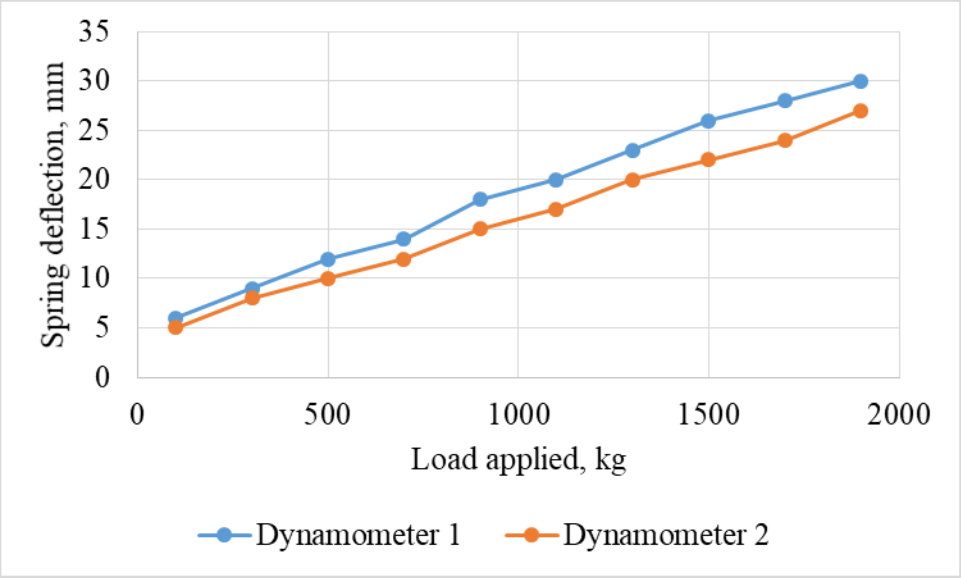

Fig. 7 Testing of developed frame with spring dynamometer

Conclusions

The developed frame was tested by using the spring dynamometer of capacity 2000 kg. The developed frame may be used to find the draft of the power source up to the maximum capacity of the dynamometer. The frame may be used for prediction of draft required to pull the self-propelled and other implements for small holder farming community. The implements can be used effectively with proper prediction of the draft requirement.

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